Half wave rectifier converts an a.c voltage in to a pulsating d.c voltage using only one half of the applied a.c voltage. The rectifying diode conducts during one half of the a.c cycle only. fig(a) and fig(b) shows the basic circuit and wave forms of a half wave rectifier

Operation :

Let V_i be the voltage to the primary of the transformer and given by the equation

$$V_i = V_m \sin \omega t \quad ; \quad V_m >> V_\gamma$$

where V_γ is the cut-in voltage of the diode.

→ During the positive half cycle of the input signal, the anode of the diode becomes more positive with respect to the cathode and hence diode D conducts (Forward bias). For an ideal diode the forward voltage drop is zero. So the whole input voltage will appear across the load resistance (R_L).

→ During negative half cycle of the input signal, the anode of the diode becomes negative with respect to the cathode and hence diode D doesn't conduct. (Reverse bias) For an ideal diode, the impedance offered by the diode is infinity. Hence the diode conducts no current. Hence the voltage drop across R_L is zero.

Harmonic Components of a Half wave Rectifier.

The input sinusoidal voltage ~~of~~ applied at the input of the transformer is given by

$$V_i = V_m \sin wt \longrightarrow (1)$$

The diode current or load current is given by

$$i(t) = \begin{cases} I_m \sin wt & \text{for } 0 < wt < \pi \\ 0 & \text{for } \pi < wt < 2\pi \end{cases} \longrightarrow (2)$$

Maximum or peak current through the circuit

$$I_m = \frac{V_m}{R_f + R_L} \longrightarrow (3)$$

where R_f = Forward resistance of the diode

R_L = Load resistance.

1) <u>Average current (or) DC current</u> :-

$$I_{avg} = I_{d.c} = \frac{1}{T}\int_0^T i(t)\,dt$$

$$= \frac{1}{2\pi}\int_0^{2\pi} i(t)\,dt \quad [\because T = 2\pi]$$

$$\Rightarrow I_{dc} = \frac{1}{2\pi}\left\{\int_0^{\pi} I_m \sin wt\, d(wt) + \int_{\pi}^{2\pi} 0 \cdot d(wt)\right\}$$

$$I_{dc} = \frac{I_m}{2\pi}\left[-\cos wt\right]_0^{\pi}$$

$$I_{dc} = \frac{I_m}{2\pi}\left\{-[(-1) - 1]\right\} = \frac{I_m}{\pi} = \frac{V_m}{\pi(R_f + R_L)}$$

Similarly the DC output voltage or Average voltage is given by

$$V_{d.c} = I_{d.c} \cdot R_L = \frac{I_m}{\pi} R_L = \frac{V_m}{\pi(R_f + R_L)} \cdot R_L$$

$$\therefore \boxed{V_{dc} = \frac{V_m}{\pi\left(1 + \frac{R_f}{R_L}\right)}}$$

(2) <u>RMS</u> <u>Current</u> :

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

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

$$I_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{\pi} I_m^2 \sin^2 \omega t\, d(\omega t) + \int_{\pi}^{2\pi} 0 \cdot d(\omega t)}$$

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

$$I_{rms} = \sqrt{\frac{I_m^2}{4\pi} \int_0^{\pi} d(\omega t) - \frac{I_m^2}{4\pi} \int_0^{\pi} \cancel{\frac{\cos 2\omega t}{2\omega}}\, d(\omega t)} \quad 0$$

$$I_{rms} = \sqrt{\frac{I_m^2}{4\pi} \times \pi} = \frac{I_m}{2} = \frac{V_m}{2(R_f + R_L)}$$

Similarly Rms voltage across the load is given by

$$V_{rms} = I_{rms} \cdot R_L = \frac{I_m}{2} R_L = \frac{V_m}{2(R_f + R_L)} \cdot R_L$$

$$\boxed{V_{rms} = \frac{V_m}{2\left(1 + \frac{R_f}{R_L}\right)}} \Rightarrow \text{If } R_f << R_L \text{ then } \boxed{V_{rms} = \frac{V_m}{2}}$$

(3) Rectifier efficiency (η)

Rectifier efficiency is defined as ratio of dc output power (P_{dc}) to A.c input power (P_{ac}).

Here $P_{dc} = I_{d.c}^2 R_L = \frac{I_m^2 R_L}{\pi^2}$

$P_{ac} = P_d + P_L$

P_d = Power dissipated across diode

P_L = power dissipated across load

$$P_d = I_{rms}^2 R_f = \frac{I_m^2}{4} R_f$$

$$P_L = I_{rms}^2 R_L = \frac{I_m^2}{4} R_L$$

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

$$\therefore \quad \eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{I_m^2}{\pi^2} R_L}{\frac{I_m^2}{4}(R_f + R_L)}$$

$$\eta = \frac{0.406}{\left(1 + \frac{R_f}{R_L}\right)}$$

$$\% \eta = \frac{0.406}{1 + \frac{R_f}{R_L}} \times 100 = \frac{40.6}{1 + \frac{R_f}{R_L}}$$

If $R_f << R_L$ then $\% \eta = 40.6 \%$

The maximum efficiency of a half wave rectifier is 40.6 %

4) Ripple factor (Γ) :-

The ratio of rms value of a.c component to the dc component in the output is known as ripple factor (Γ).

$$\text{Ripple factor} = \frac{\text{rms value of a.c component}}{\text{d.c value of component}}$$

$$\Gamma = \frac{V_{r,rms}}{V_{dc}}$$

$$V_{r,rms} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

$$\therefore \Gamma = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\frac{V_{rms}^2 - V_{dc}^2}{V_{dc}^2}}$$

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

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

$$\Gamma = \sqrt{\frac{\left(\frac{I_m}{2}\right)^2}{\left(\frac{I_m}{\pi}\right)^2} - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} = 1.21$$

5) Transformer utilisation factor :-

In the design of any power supply, the rating of the transformer should be determined. This can be done with a knowledge of the d.c power delivered to the load and the type of rectifying circuit used

$$TUF = \frac{\text{dc power delivered to the load}}{\text{ac rating of the transformer secondary}}$$

$$TUF = \frac{P_{dc}}{P_{ac\ rated}}$$

$$P_{dc} = I_{dc}^2 R_L \Rightarrow \left(\frac{I_m}{\pi}\right)^2 \times R_L$$

$$P_{ac\ rated} = \text{rated voltage of transformer secondary} \times I_{rms}$$

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

$$\therefore \quad TUF = \frac{\frac{I_m^2}{\pi^2} \times R_L}{\frac{I_m^2}{2\sqrt{2}} (R_f + R_L)} = \frac{0.287\ R_L}{(R_f + R_L)}$$

$$\therefore \quad TUF = \frac{0.287}{\left(1 + \frac{R_f}{R_L}\right)}$$

As $R_f << R_L$, $TUF = 0.287$.

⑥ Regulation :-

It is defined as the variation in dc voltage with change in dc load current.

It is also defined as

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

Here V_{NL} = No load voltage

V_{FL} = Full load Voltage.

Ideally Full load voltage is equal to No load voltage and hence the percentage regulation of an ideal device is zero.

(7) ~~It is defined as the~~ **Peak inverse voltage (PIV):-**

It is defined as a maximum reverse voltage that a diode can withstand without destroying the junction.

The peak inverse voltage across a diode is the peak of the Negative half cycle

For half wave rectifier PIV is V_m.

Form factor:-

$$\text{Form Factor} = \frac{\text{Rms value}}{\text{Average value}} = \frac{\frac{I_m}{2}}{\frac{I_m}{\pi}} = \frac{\pi}{2} = 1.57$$

Peak Factor:-

$$\text{Peak Factor} = \frac{\text{Peak Value}}{\text{rms Value}} = \frac{I_m}{\frac{I_m}{2}} = 2$$

Problem :

A Half wave rectifier, having a resistive load of 1000Ω, rectifies an alternating voltage of 325 V peak value and the diode has forward resistance of 100Ω. Calculate
a) peak, average and rms value of current
b) d.c power output
c) a.c input power and
d) Efficiency of the rectifier

Solution : Given data

$R_L = 1000\Omega$, $V_m = 325$ V, $r_f = 100\Omega$

a) Peak value of current $= I_m = \dfrac{V_m}{r_f + R_L}$

$$\therefore I_m = \frac{325}{100 + 1000} = 295.45 \text{ mA}$$

Average current $I_{d.c} = \dfrac{I_m}{\pi} = \dfrac{295.45 \text{ mA}}{3.14}$

$$\therefore I_{dc} = 94.046 \text{ mA}$$

RMS value of current $I_{rms} = \dfrac{I_m}{2} = \dfrac{295.45 \text{ m}}{2}$

$$\therefore I_{r.m.s} = 147.725 \text{ mA}$$

b) d.c power output, $P_{d.c} = I_{d.c}^2 \times R_L$

$$P_{d.c} = (94.046)^2 \times 1000 = 8.845 \text{ W}$$

c) A.c input power $P_{a.c} = (I_{r.m.s})^2 \times (r_f + R_L) = 24$ W

d) Efficiency of rectification $\eta = \dfrac{P_{d.c}}{P_{a.c}} = \dfrac{8.845}{24} = 36.85\%$

Problem : A half wave rectifier is used to supply 24V dc to a resistive load of 500 Ω and a diode has forward resistance of 50 Ω. Calculate the maximum value of the a.c voltage required at the input.

Solution : Given data

$V_{d.c} = 24\,V$, $R_L = 50\,\Omega$.

Average value of load current

$$I_{d.c} = \frac{V_{d.c}}{R_L} = \frac{24}{500} = 48\,mA$$

$$I_{d.c} = \frac{I_m}{\pi} \Rightarrow I_m = I_{d.c} \times \pi$$

Maximum value of load current $I_m = I_{d.c} \times \pi$

$$I_m = 48 \times 10^{-3} \times 3.14 = 150.8\,mA$$

Therefore maximum a.c voltage required at the input $V_m = I_m (r_f + R_L) = 82.94\,V$

Problem :- An a.c supply of 230 V is applied to a half wave rectifier circuit through transformer of turns ratio 5:1. Assume the diode is an ideal one. The load resistance is 300 Ω. Find

a) d.c output voltage b) PIV c) maximum and d) average values of power delivered to the load.

Solution : Given data

$V_1 = 230\,V$, $N_1 : N_2 = 5:1$, $R_L = 300\,\Omega$

a) Transformer secondary voltage

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

$$V_2 = V_1 \times \frac{N_2}{N_1} = \frac{230 \times 1}{5} = 46\ V$$

$$V_2 = V_{r.m.s} = 46\ V$$

maximum value of secondary voltage is V_m

$$V_{r.m.s} = \frac{V_m}{\sqrt{2}} \Rightarrow V_m = 46 \times \sqrt{2} = 65\ V$$

$\therefore$ d.c output voltage $V_{d.c} = \frac{V_m}{\pi} = 20.7\ V$

b) PIV of a diode is $V_m \Rightarrow V_m = 65\ V$

c) maximum value of load current

$$I_m = \frac{V_m}{R_L} = \frac{65}{300} = 0.217\ A$$

maximum value of power delivered to the load

$$P_m = I_m^2 \times R_L = (0.217)^2 \times 300 = 14.1\ W$$

d) The average value of load current

$$I_{d.c} = \frac{V_{d.c}}{R_L} = \frac{20.7}{300} = 0.069\ A$$

average value of power delivered to the Load

$$P_{d.c} = I_{d.c}^2 \times R_L = (0.069)^2 \times 300$$

$$P_{d.c} = 1.43\ W.$$

Full wave rectifier :

It converts an a.c voltage into a pulsating d.c voltage using both half cycles of the applied a.c voltage. It uses two diodes of which one conducts during one half cycle while the other diode conducts during the other half cycle of the applied a.c Voltage. Figure shows the basic circuit and waveforms of full-wave rectifier.

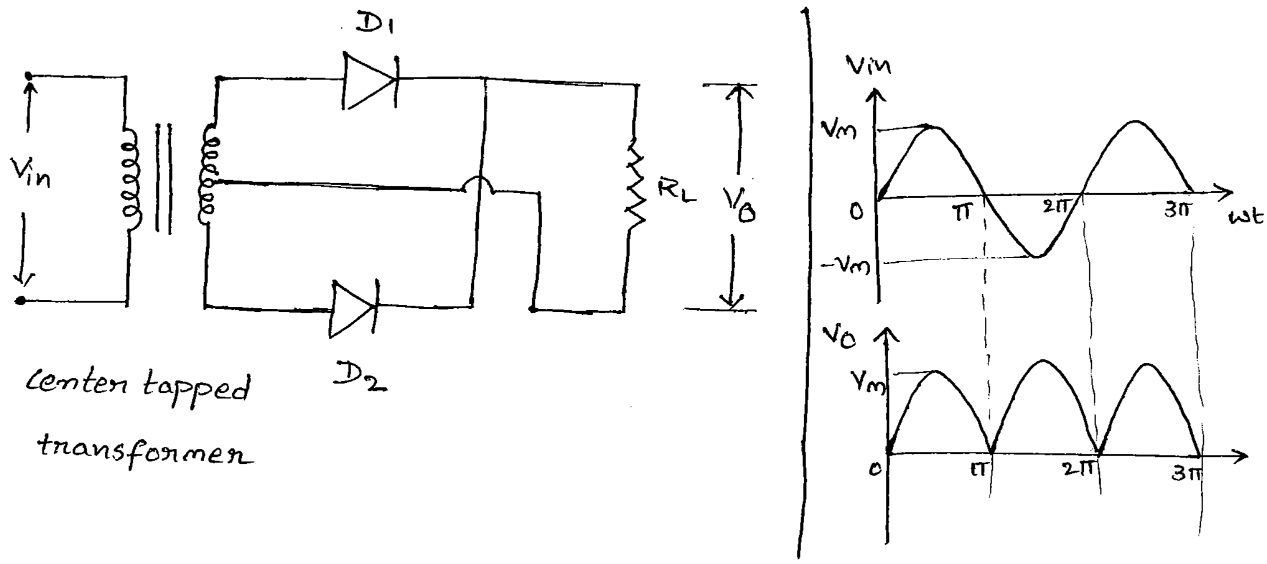
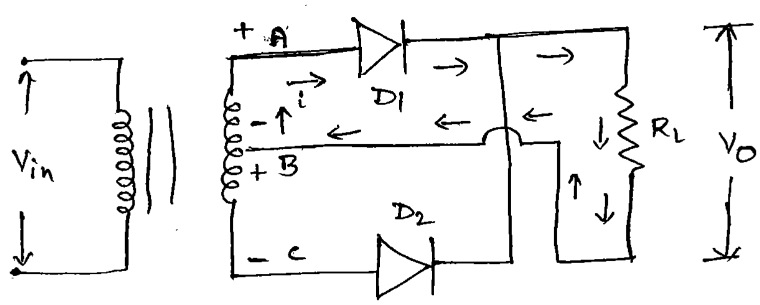


fig: Full wave rectifier

operation :

During positive half cycle

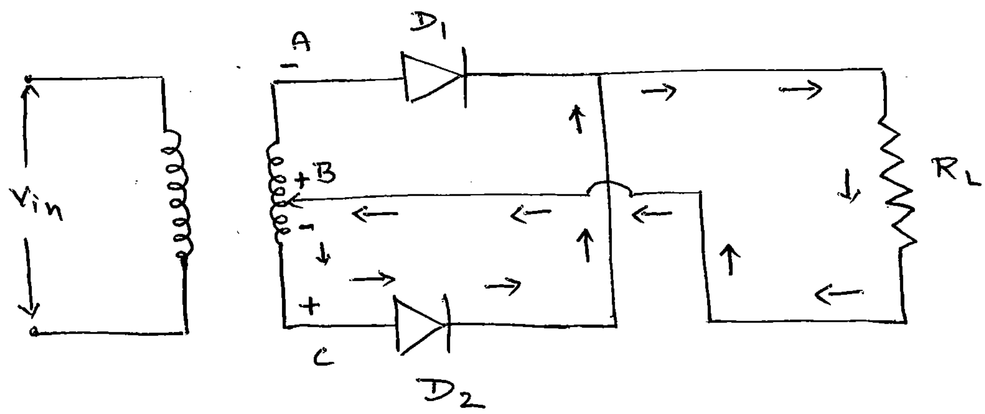


During the positive half cycle of ac input the terminal A is more positive than terminal C

So diode D_1 becomes forward biased and D_2 becomes reverse biased. Therefore diode D_1 conducts while diode D_2 doesn't conduct. The conventional current flow is shown by the path below.

$$A \rightarrow D_1 \rightarrow R_L \rightarrow B \rightarrow A.$$

During Negative Half cycle :-



During the Negative half cycle, ~~of~~ the input terminal C is more positive than A. So diode D_1 becomes reverse biased and D_2 becomes forward biased. Therefore diode D_2 conducts while D_1 doesn't conduct. The Path shown below gives the conventional current flow during Negative half cycle.

$$C \rightarrow D_2 \rightarrow R_L \rightarrow B \rightarrow C$$

Harmonic components in a fullwave rectifier circuit :

1) Average current (or) dc current :-

$$I_{dc} = \frac{1}{T} \int_0^T i(t)\, dt$$

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

$$I_{dc} = \frac{I_m}{\pi} \left[-\cos\omega t \right]_0^{\pi} = -\frac{I_m}{\pi} \left(-1-1\right)$$

$$I_{dc} = \frac{2 I_m}{\pi} = \frac{2 V_m}{\pi (R_f + R_L)} \qquad \left[\because I_m = \frac{V_m}{R_f + R_L} \right]$$

Similarly $V_{dc} = I_{dc} \times R_L = \dfrac{2 V_m}{\pi (R_f + R_L)} \cdot R_L$

$$\therefore V_{dc} = \frac{2 V_m}{\pi \left(1 + \frac{R_f}{R_L}\right)}$$

As $R_f << R_L \Rightarrow V_{dc} = \dfrac{2 V_m}{\pi}$.

2) RMS current :

$$I_{rms} = \sqrt{\frac{1}{T} \int_0^T i^2(t)\, dt}$$

$$I_{rms} = \sqrt{\frac{1}{\pi} \int_0^{\pi} I_m^2 \sin^2\omega t \; d(\omega t)}$$

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

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi} \times \pi} = \frac{I_m}{\sqrt{2}} = \frac{V_m}{\sqrt{2}\,(R_f + R_L)}$$

Similarly ~~Average~~ voltage

$$V_{rms} = I_{rms} \times R_L$$

$$V_{rms} = \frac{I_m}{\sqrt{2}} R_L = \frac{V_m R_L}{\sqrt{2}(R_f + R_L)}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}\left(1 + \frac{R_f}{R_L}\right)}$$

As $R_f << R_L \Rightarrow V_{rms} = \frac{V_m}{\sqrt{2}}$

3) Rectifier Efficiency (η) :-

$$\eta = \frac{\text{dc output power}}{\text{Ac input power}} = \frac{P_{dc}}{P_{ac}}$$

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

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

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

$$P_{dc} = \left(\frac{2 I_m}{\pi}\right)^2 \times R_L = \frac{4 I_m^2}{\pi^2} \times R_L$$

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

$$\therefore \eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{4 I_m^2}{\pi^2} \times R_L}{\frac{I_m^2}{2} \times (R_f + R_L)}$$

$$\eta = \frac{8}{\pi^2} \times \frac{R_L}{R_f + R_L} = \frac{0.812}{\left(1 + \frac{R_f}{R_L}\right)}$$

As $R_f << R_L$, $\eta = 0.812$

% Efficiency = % η = 81.2 %

$81.2\% = 2 \times (40.6\%)$

Full wave rectifier Efficiency $= 2 \times$ (Half wave rectifier Efficiency)

$\therefore$ The maximum efficiency of a full wave rectifier is twice the maximum efficiency of a Half wave rectifier.

4) Ripple factor (Γ) :-

$$\Gamma = \frac{\text{rms value of a.c component}}{\text{dc value of component}}$$

$$\Gamma = \frac{V_{r,rms}}{V_{dc}}$$

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

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

$$\Gamma = 0.48.$$

5) Transformer Utilisation factor (TUF) :-

In a full wave rectifier, the secondary current flows through each half separately in every half cycle. while the primary of transformer carries current continuosly. Hence TUF is calculated for primary and secondary windings separately and the average TUF is determined.

$$\therefore \quad TUF = \frac{(TUF)_{primary} + (TUF)_{secondary}}{2}$$

$(TUF)_{primary}$:-

The primary of the transformer is feeding two half wave rectifiers separately. These two half wave rectifiers work independently of each other but feed a common load.

$$(TUF)_{primary} = 2 \times TUF \text{ of } HWR = 2 \times 0.287$$

$$\therefore \quad (TUF)_{primary} = 0.574$$

$(TUF)_{secondary}$:-

$$(TUF)_{secondary} = \frac{\text{dc power delivered to the load}}{\text{a.c rating of Transformer secondary}}$$

$$(TUF)_{secondary} = \frac{P_{dc}}{P_{ac\,rated}}$$

$$P_{dc} = I_{dc}^2 \times R_L = \left(\frac{2 I_m}{\pi}\right)^2 \times R_L = \frac{4 I_m^2}{\pi^2} R_L$$

$$P_{ac\,rated} = \text{rated voltage of transformer secondary} \times I_{rms}$$

$$P_{ac\,rated} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} = \frac{I_m (R_f + R_L)}{\sqrt{2}\,(\cancel{R_f + R_L})} \times \frac{I_m}{\sqrt{2}}$$

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

$$(TUF)_{secondary} = \frac{\frac{4 I_m^2}{\pi^2} \times R_L}{\frac{I_m^2}{2(\cancel{R_f + R_L})} (R_f + R_L)} = \frac{8}{\pi^2 \left(1 + \frac{R_f}{R_L}\right)}$$

As $R_f << R_L$, $(TUF)_{secondary} = 0.812$

$$\therefore \quad TUF = \frac{(TUF)_p + (TUF)_s}{2} = \frac{0.574 + 0.812}{2}$$

$$\boxed{TUF = 0.693}$$

6) <u>Peak inverse voltage (PIV)</u> :-

Peak inverse voltage can be defined as the maximum voltage that a diode can withstand under reverse biased condition.

In this case peak inverse voltage is calculated as follows. during positive half cycle, D_1 is conducting and D_2 is off. The maximum voltage at the lower part of the transformer is V_m and the voltage drop across the R_L due to diode D_1 conducting is V_m. Hence the total voltage across diode D_2 is $2V_m$ $(V_m + V_m)$

Therefore $PIV = 2V_m$

7) <u>Voltage Regulation</u> :- It is defined as variation in dc voltage with change in dc load current.

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

where V_{NL} = No load voltage

V_{FL} = Full load voltage.

8) Form factor $= \dfrac{\text{Rms value}}{\text{Average value}} = \dfrac{I_{rms}}{I_{dc}} = \dfrac{\frac{I_m}{\sqrt{2}}}{\frac{2I_m}{\pi}} = 1.11$

9) Peak factor $= \dfrac{\text{Peak value}}{\text{Rms value}} = \dfrac{I_m}{I_{rms}} = \dfrac{I_m}{I_m/\sqrt{2}} = \sqrt{2}$

Problem:

A 230 V, 60 Hz voltage is applied to the primary of a 5:1 step down, center tap transformer used in a full wave rectifier having a load of 900Ω. If the diode resistance and the secondary coil resistance together has a resistance of 100Ω. determine

a) dc voltage across the load b) dc current flowing through the load c) dc power delivered to the load d) PIV across each diode and e) ripple voltage and its frequency.

Solution: Given data

Primary voltage $V_1 = 230V$, $N_1 : N_2 = 5:1$

$R_L = 900\Omega$, $r_s + r_f = 100\Omega$.

secondary voltage V_2

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow \frac{230}{V_2} = \frac{5}{1} \Rightarrow V_2 = 46\ V$$

Voltage from Center tapping to one end = 23 V

$$V_m = \sqrt{2} \times 23\ V.$$

$$V_m = 23\sqrt{2}\ V$$

a) d.c voltage across the load $V_{d.c} = \frac{2V_m}{\pi}$

$$V_{d.c} = \frac{2 \times 23 \times \sqrt{2}}{\pi} = 20.7\ V$$

b) dc current flowing through the load

$$I_{dc} = \frac{V_{d.c}}{r_s + r_f + R_L}$$

$$I_{d.c} = \frac{20.7}{100+900} = 20.7\ mA.$$

c) d.c power delivered to the load

$$P_{d.c} = (I_{d.c})^2 \times R_L = (20.7 \times 10^{-3})^2 \times 900 = 0.386\ W$$

d) PIV across each diode $= 2V_m = 2 \times 23 \times \sqrt{2} = 65\ V$

e) ripple voltage $V_{r,rms} = \sqrt{(V_{rms})^2 - (V_{d.c})^2}$

$$V_{r.m.s} = \frac{V_m}{\sqrt{2}} = \frac{23\sqrt{2}}{\sqrt{2}} = 23$$

$$\text{Ripple voltage} = \sqrt{(23)^2 - (20.7)^2} = 10.05\ V$$

frequency of ripple voltage $2f_m = 2 \times 60 = 120\ Hz.$

Problem:

A full wave rectifier delivers 50 W to a load of 200 Ω. If the ripple factor is 1%. calculate the a.c ripple voltage across the load.

Solution: Given data $P_{d.c} = 50\ W$, $R_L = 200\ \Omega$

Ripple factor $(\Gamma) = 1\% = \frac{1}{100} = 0.01$

we know that $P_{d.c} = \frac{V_{d.c}^2}{R_L} \Rightarrow V_{d.c}^2 = P_{d.c} \times R_L$

therefore $V_{dc} = \sqrt{P_{d.c} \times R_L} = \sqrt{50 \times 200} = 100V$

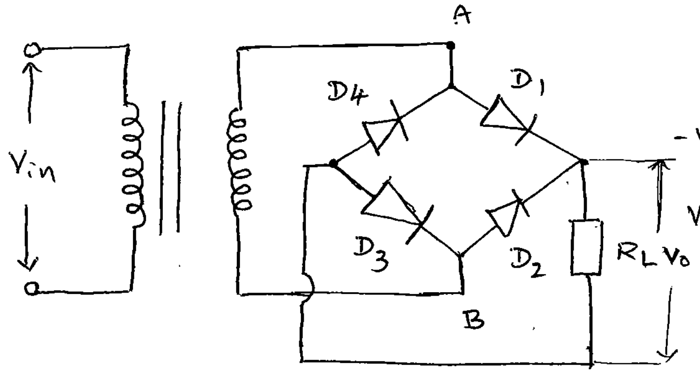
$$\text{Ripple factor } \Gamma = \frac{V_{r.rms}}{V_{d.c}} = \frac{V_{ac}}{V_{d.c}}$$

$$\Rightarrow 0.01 = \frac{V_{a.c}}{100} \Rightarrow V_{ac} = 1V$$

a.c ripple voltage across the load $= 1V.$

Full wave Bridge Rectifier :-

The need for a center tapped power transformer is eliminated in the bridge rectifier. It contains four diodes D_1, D_2, D_3 and D_4 connected to form bridge as shown in figure below.



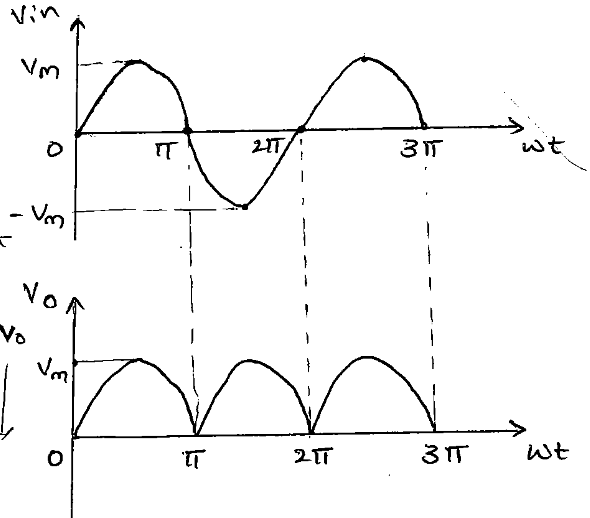


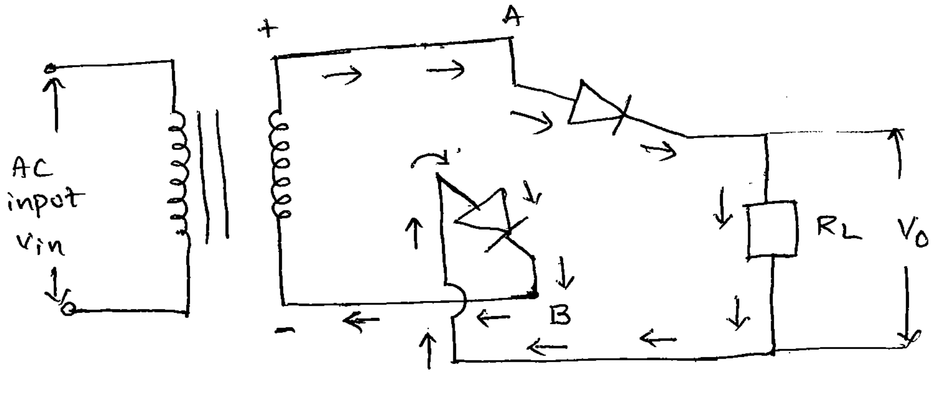
fig: Full wave bridge rectifier and wave forms

operation:-

During positive half cycle :

During positive half cycle the point A of the secondary winding becomes positive and point B becomes negative.

This makes diodes D_1 and D_3 forward biased while D_2 and D_4 are reverse biased.

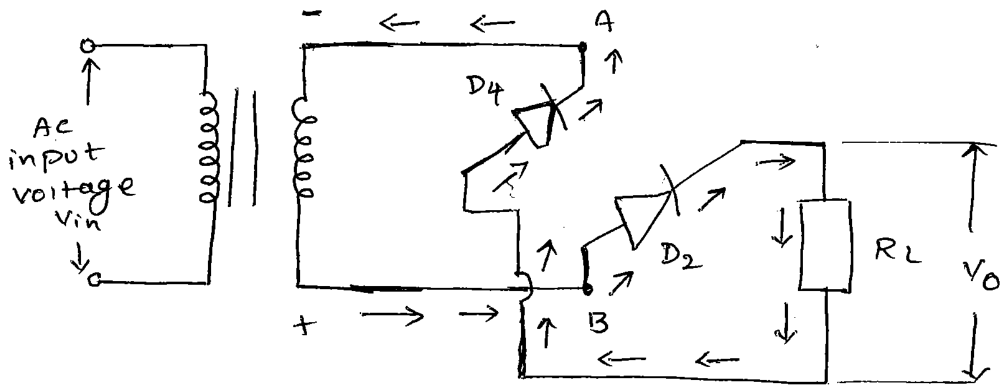


Therefore only diodes D_1 and D_3 conduct. These two diodes will be in series through the load R_L as shown in figure above.

The conventional current flow path ~~of~~ of full wave bridge rectifier is shown below

$$A \rightarrow D_1 \rightarrow R_L \rightarrow D_3 \rightarrow B$$

<u>During Negative half cycle</u> :-



During the Negative half cycle of Secondary voltage, the point A becomes Negative and point B becomes positive.

This makes diodes D_2 and D_4 becomes forward biased while diodes D_1 and D_3 becomes reverse biased. Therefore only diodes D_2 and D_4 conduct. These two diodes will be in series through the Load R_L as shown in figure above.

The conventional current flow of full wave bridge rectifier during Negative half cycle is shown below. $B \rightarrow D_2 \rightarrow R_L \rightarrow D_4 \rightarrow A$.

→ In both the case the current flowing through the resistor R_L is in same direction, thus it is called uni directional current.

→ The wave form of the load current is essentially the same as in the case of full wave rectifier. The ripple frequency of the output is twice that of the fundamental frequency.

<u>Harmonic components of bridge rectifier</u> :-

The average values of output voltage and load current for bridge rectifier are the same as for a center tapped full wave rectifier. Hence

$$V_{d.c} = \frac{2V_m}{\pi} \qquad V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$I_{dc} = \frac{2I_m}{\pi} \qquad I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$\text{Ripple factor}(\Gamma) = 0.48$$

$$\text{Rectifier Efficiency} = 81.2\%$$

$$\text{PIV across each diode} = V_m$$

$$\text{Ripple frequency} = f_m$$

<u>Note</u>: The derivations for bridge rectifiers are same as that of centre tapped FWR, except transformer utilisation factor (TUF)

In this case centre tapped transformer is not required hence the secondary utilisation factor itself defines the TUF

$$TUF = \frac{P_{dc}}{P_{ac\ rated}}$$

$$P_{dc} = (I_{d.c})^2 \times R_L = \left(\frac{2I_m}{\pi}\right)^2 \times R_L$$

$$P_{ac\ rated} = \text{rated voltage of a transformer} \times I_{rms} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}$$

$$P_{ac\ rated} = \frac{V_m I_m}{2} = \frac{I_m^2}{2R_L} \quad \left[\because V_m = \frac{I_m}{R_L}\right]$$

$$\therefore \boxed{TUF = 0.812}$$

→ Form factor and peak factor are same as that of Full wave rectifier.

Form factor = 1.11

Peak factor = $\sqrt{2}$

<u>Problem</u>: A 230V, 50 Hz voltage is applied to the primary of a 4:1 step down transformer used in a bridge rectifier having a load resistance of 600 Ω. Assuming the diodes to be ideal, determine (a) dc output voltage (b) dc power delivered to the load (c) PIV (d) output frequency.

<u>Solution</u>: Given data primary voltage $V_1 = 230V$

$N_1 : N_2 = 4:1$, $R_L = 600 \Omega$

secondary voltage V_2 ?

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow V_2 = V_1 \times \frac{N_2}{N_1} = 230 \times \frac{1}{4}$$

Secondary Voltage $V_2 = 57.5\,V$

$$V_m = \sqrt{2} \times \text{secondary voltage} = 81.3\,V$$

a) $V_{d.c} = \frac{2V_m}{\pi} = 52\,V$

b) $P_{d.c} = \frac{V_{d.c}^2}{R_L} = \frac{52^2}{1000} = 2.704\,W$

c) PIV across each diode $V_m = 81.3\,V$

d) output frequency $= 2f_m = 2 \times 50 = 100\,Hz$

Comparison of Rectifiers :-

S.NO	Parameter	Half wave	Full wave	Bridge
1	NO of diodes	1	2	4
2.	Maximum efficiency	40.6 %	81.2 %	81.2 %
3.	$V_{d.c}$ (no Load)	V_m/π	$2V_m/\pi$	$2V_m/\pi$
4.	Average current $I_{d.c}$	I_m/π	$2I_m/\pi$	$2I_m/\pi$
5.	Ripple factor	1.21	0.48	0.48
6.	Peak inverse voltage	V_m	$2V_m$	$2V_m$
7.	output frequency	f_m	$2f_m$	$2f_m$
8	TUF	0.287	0.693	0.812
9	Form factor	1.57	1.11	1.11
10	Peak factor	2	$\sqrt{2}$	$\sqrt{2}$

Introduction to Filters :

The output of the rectifier circuit is a pulsating dc, it contains both ac and dc components. The presence of ac components is undesirable feature, hence it has to be removed from the rectified output by using a suitable circuit. Such a circuit is known as a filter.

A filter may be defined as the circuit which removes the unwanted ac components of the rectifier output and allows only dc components to reach the load.

A filter circuit consists of a passive circuit elements, such as inductors, capacitors and their combinations.

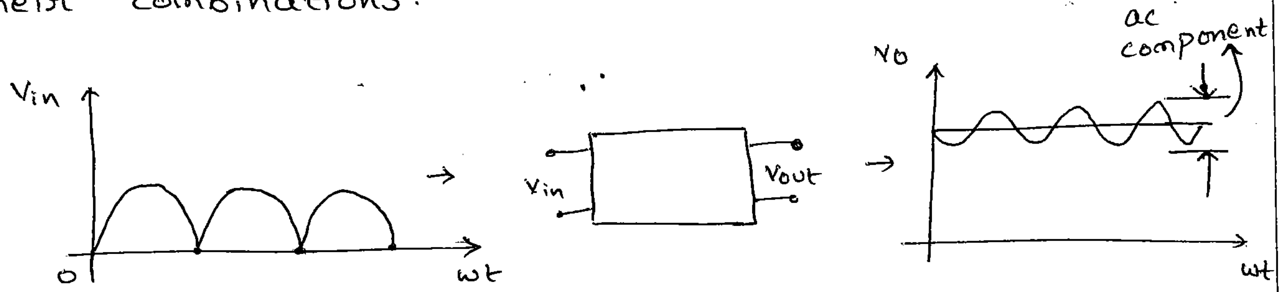


figure shows the concept of a filter, where the full wave rectified output voltage is applied at its input. The output of a filter is not exactly a constant d.c. level. But it also contains a small amount of a.c component. Some important filters are

1) Induction filter
2) capacitor filter
3) LC or L-section filter
4) CLC or π-type filter

Inductor Filter

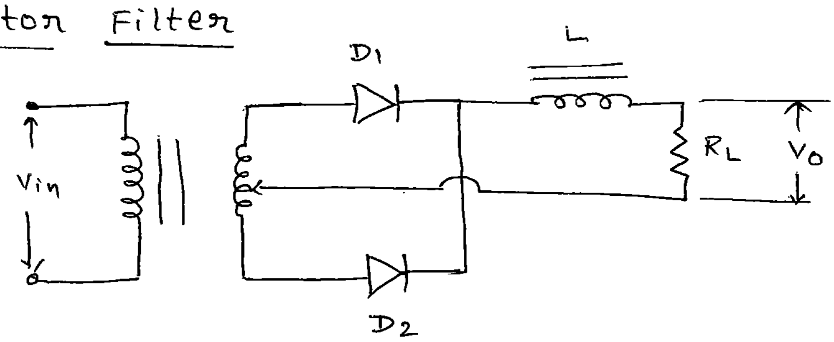


fig: Full wave rectifier with Inductor filter.

Figure shows the fullwave rectifier with inductor filter. when the output of the FWR passes through an inductor, it blocks the ac component and allows only the dc component to reach the load.

The ripple factor of the inductor filter is given by

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

It shows that the ripple factor will decrease when L is increased. and R_L is decreased. The inductor filter is more effective only when the load current is high (small R_L). The larger value of the inductor can reduce the ripple and at the same time the output d.c voltage will be lowered as a inductor has a higher d.c. resistance.

The operation of the inductor filter depends on its well known fundamental property to oppose any change of current passing through it.

Analysis of Inductor filter :

To analyse this filter for a full-wave, the fourier series can be written as

$$V_o = \frac{2V_m}{\pi} - \frac{4V_m}{\pi}\left[\frac{1}{3}\cos 2\omega t + \frac{1}{15}\cos 4\omega t + \frac{1}{35}\cos 6\omega t + \dots\right] \longrightarrow (1)$$

Assuming the third and higher terms contribute little output, the output voltage is

$$V_o = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi}\cos 2\omega t. \longrightarrow (2)$$

The diode, choke (L) and transformer resistances can be neglected since they are very small as compared with R_L. Therefore

The d.c component of current $I_m = \frac{V_m}{R_L}$

The impedance of series combination of L and R_L at 2ω is (for second harmonic)

$$Z = \sqrt{R_L^2 + (2\omega L)^2} = \sqrt{R_L^2 + 4\omega^2 L^2}.$$

Therefore ~~for~~ the a.c component of current

$$I_m = \frac{V_m}{\sqrt{R_L^2 + 4\omega^2 L^2}} \qquad \left(\because I_m = \frac{V_m}{Z}\right)$$

Therefore the resulting current is given by from Eq (2)

$$i = \frac{2V_m}{\pi R_L} - \frac{4V_m}{3\pi} \frac{\cos(2\omega t - \phi)}{\sqrt{R_L^2 + 4\omega^2 L^2}} \longrightarrow (3)$$

where $\phi = \tan^{-1}\left(\frac{2\omega L}{R_L}\right)$

where ϕ is the angle by which the load current lags behind the voltage, From eq (3)

$$I_{dc} = \frac{2V_m}{\pi R_L}, \quad I_{r.ms} = \frac{I_m}{\sqrt{2}}$$

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

The ripple factor which can be defined as the ratio of rms value of the ripple to the d.c value of the wave.

$$\text{Ripple factor } \Gamma = \frac{I_{rms}}{I_{dc}} = \frac{\frac{4V_m}{3\pi\sqrt{2}\sqrt{R_L^2 + 4\omega^2 L^2}}}{\frac{2V_m}{\pi R_L}}$$

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

If $\frac{4\omega^2 L^2}{R_L^2} >> 1$, then a simplified expression for Γ is

$$\Gamma = \frac{2}{3\sqrt{2}} \frac{1}{\sqrt{\frac{4\omega^2 L^2}{R_L^2}}} = \frac{2}{3\sqrt{2}} \times \frac{R_L}{2\omega L}$$

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

This expression clearly shows that reduced ripple will occor for larger values of L. But it also shows that the ripple will increase as the load increased to Infinite value

Hence this filter ~~is suitable for only~~ should only be used where R_L is consistently small.

Problem: Calculate the value of inductance to use in the inductor filter connected to a full-wave rectifier operating at 60Hz to provide a d.c output with 4% ripple for a 100Ω load.

Solution: Given data

$$f = 60\,Hz, \quad R_L = 100\,\Omega$$

$$\text{Ripple factor } \Gamma = 4\% = 0.04$$

We know that ripple factor of inductor filter is

$$\Gamma = \frac{R_L}{3\sqrt{2}\,\omega L}, \quad \omega = 2\pi f$$

$$0.04 = \frac{100}{3\sqrt{2}\times(2\times\pi\times 60)\times L}$$

$$\Rightarrow \quad L = 1.5625\ Hz.$$

Capacitor filter :- An inexpensive filter for light loads is found in the capacitor filter which is connected directly across the load as shown in figure below.

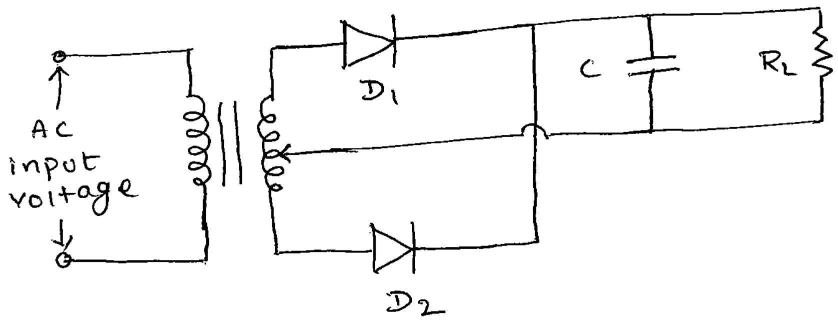
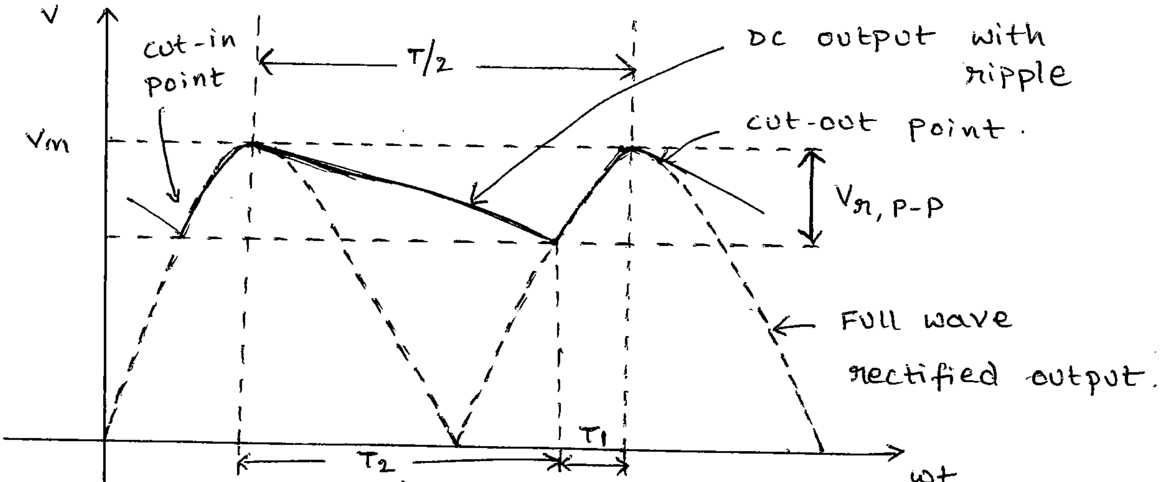


fig: Full wave rectifier with capacitor filter

The property of a capacitor is that it allows a·c component and blocks the dc component. The operation of a capacitor filter is to short the ripple to ground but leave the dc to appear at the output when it is connected across a pulsating d·c voltage.



fig(b) : Ripple voltage triangular waveform

During the positive half cycle, the capacitor charges up to the peak value of the transformer secondary voltage, V_m and will try to maintain this value as the full wave input drops to zero.

The capacitor will discharge through R_L slowly until the transformer secondary voltage again increases to a value greater than the capacitor voltage. The diode conducts for a period which depends on the capacitor voltage. The diode will conduct when the transformer secondary voltage becomes more than the diode voltage. This is called the cut-in voltage.

The diode stops conducting when the transformer voltage becomes less than the diode voltage. This is called cut-out voltage.

In figure (b) with slight approximation, the ripple voltage waveform can be assumed as triangular.

From the cut-in point to cut-out point, whatever ~~the~~ charge, the capacitor acquires, is equal to the charge, the capacitor has lost during the period of non-conduction. ie from cut out point to the next cut-in point.

The charge it has acquired $= V_{r,p-p} \times C \longrightarrow (1)$

The charge it has lost $= I_{d.c} \times T_2 \longrightarrow (2)$

Therefore $V_{r,p-p} \times C = I_{d.c} \times T_2 \longrightarrow (3)$

With the assumption made above, the ripple waveform will be triangular in nature and the rms value of the ripple is given by

$$V_{r,rms} = \frac{V_{r,p-p}}{2\sqrt{3}} \longrightarrow (4)$$

If the value of the capacitor is fairly large, or the value of the load resistance is very large, then it can be assumed that that the time T_2 is equal to the half the periodic time of the waveform

$T_2 = \frac{T}{2} = \frac{1}{2f}$ then from eq (3)

$$V_{r,p-p} = \frac{I_{d.c}}{2fC} \longrightarrow (5)$$

substituting eq 5 in eq 4

$$V_{r,rms} = \frac{I_{d.c}}{4\sqrt{3}\, fC}$$

$$V_{r,rms} = \frac{V_{d.c}}{4\sqrt{3}\, fC R_L} \qquad \left[\because\ I_{d.c} = \frac{V_{d.c}}{R_L}\right]$$

Therefore ripple $\Gamma = \frac{V_{r,rms}}{V_{d.c}} = \frac{1}{4\sqrt{3}\, fC R_L}$

The ripple may be decreased by increasing C (or) R_L (or both) with a resulting increase in d.c output voltage.

Problem :

Calculate the value of capacitance to use in a capacitor filter connected to a full-wave rectifier operating at a standard air craft power frequency of 400 Hz, If the ripple factor is 10 % for a Load of 500Ω.

Solution : Given data

ripple factor $= \frac{10}{100} = 0.1$

$f = 400\,Hz$, $R_L = 500\,\Omega$

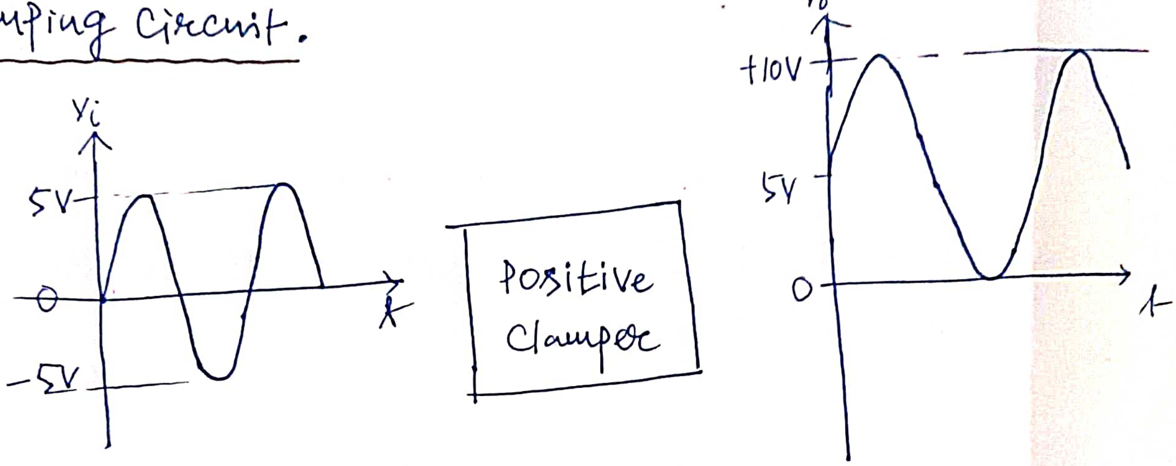
$$\Gamma = \frac{1}{4\sqrt{3}\, fC R_L}$$

$$0.1 = \frac{1}{4 \times \sqrt{3} \times 400 \times C \times 500}$$

$C = 72.2\,\mu F$.

CLAMPING CIRCUITS

A Circuit that Places either the Positive or negative Peak of a signal at desired dc level is known as Clamping Circuit.



→ Clamper essentially adds a dc component to the signal.

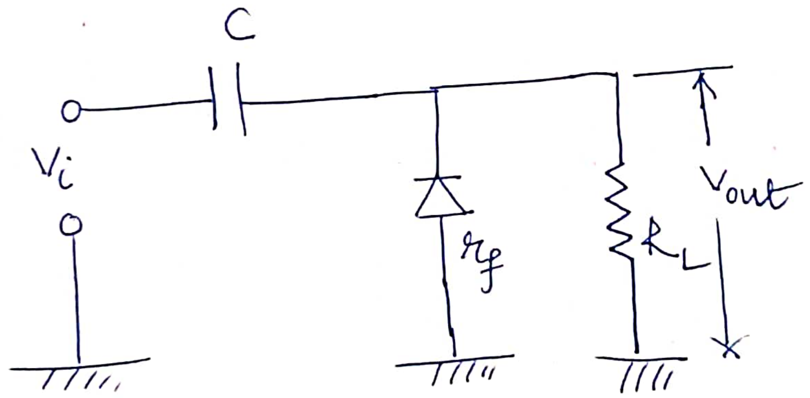
→ It may be seen that shape of original signal has not Changed; only there is vertical shift in the signal. Such a Clamper is called Positive Clamper.
Here negative peaks fall on zero level.

→ Negative Clamper Pushes signal downwards so that Positive Peaks falls on zero level.

Basic Idea of Clamper

A Clamper should not change peak-to-peak value of signal; it should only change dc level. To do so, Clamper Circuit uses a Capacitor, together with diode and a load resistor R_L.

The operation of clamper is based on principle that Charging time of Capacitor is made very small as compared to discharging time.



→ Charging time Constant $\tau_C = r_f \times C$ (few μs)

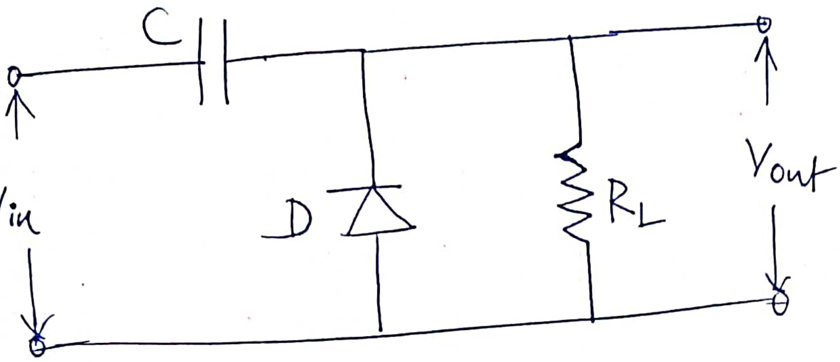
r_f = forward resistance of diode (few ohms)

→ Discharging time Constant $\tau_D = R_L \times C$ (few ms)

$(R_L >> r_f)$

$$\tau_D >> \tau_C \checkmark$$

POSITIVE CLAMPER



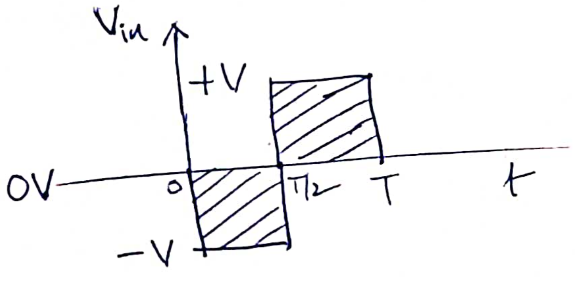
The input signal is assumed to be a square wave with time period T. Clamped output is obtained across R_L.

Two assumptions to be incorporated.

(i) values of C and R_L are so selected that time constant $\tau_D = CR_L$ is very large. This means voltage across capacitor will not discharge significantly during the interval the diode is non conducting.

(ii) $R_L C$ time constant is deliberately made much greater than the time period T of incoming signal (V_{in})

V_{in} →



When $0 < t < T/2$

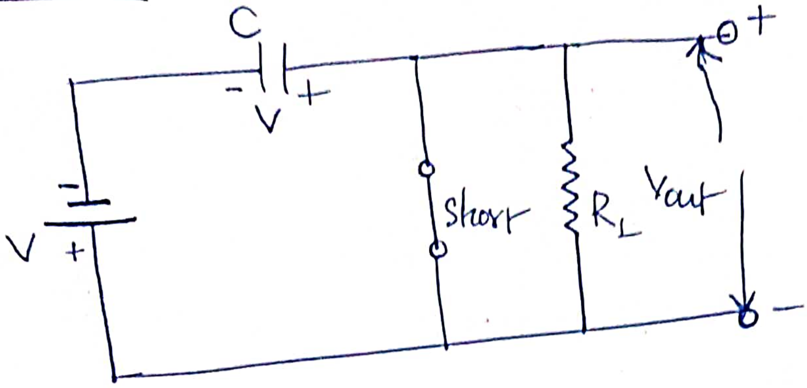
$V_{in} = -V$

When $\frac{T}{2} < t < T$

$V_{in} = +V$

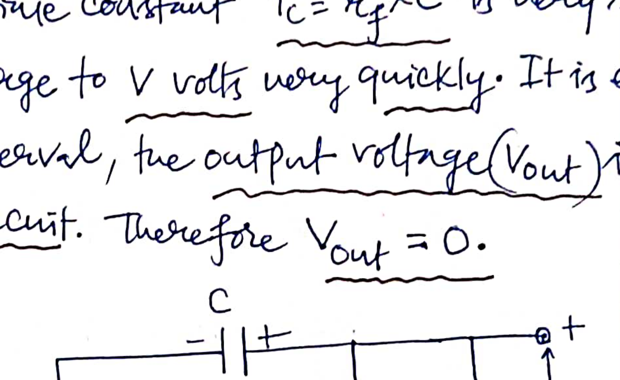
Operation

(i)



During negative half cycle of input signal, the diode is forward biased. Therefore, diode behaves as a short as shown in figure. The charging time constant $\tau_C = r_f \times C$ is very small so that capacitor will charge to V volts very quickly. It is easy to see that during this interval, the output voltage (V_{out}) is directly across short circuit. Therefore $V_{out} = 0$.

(ii) When the input switches to +V, (positive half cycle), the diode is reverse biased and behaves as an open as shown in figure.

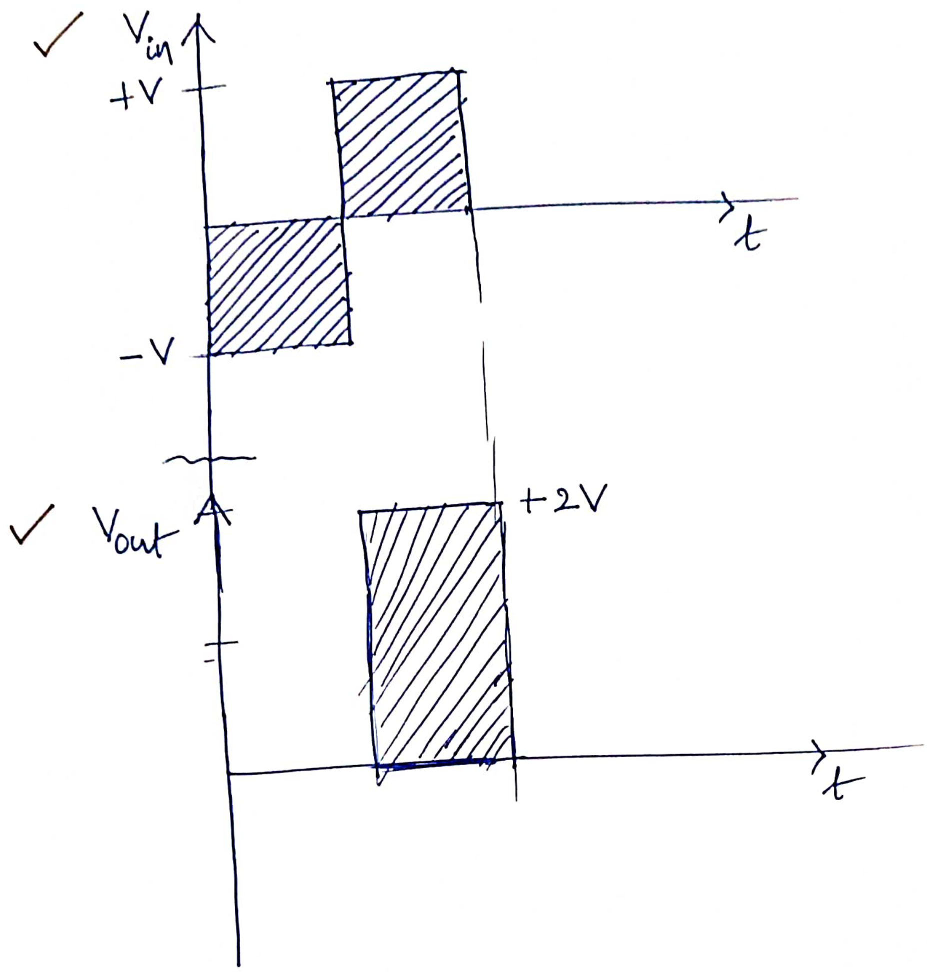


Since discharging time constant $\tau_D = R_L \times C$ is much greater than time period of input signal, the capacitor remains almost fully charged to V volts, during the off time of diode. Applying KVL to input loop, we have,

$$V + V - V_{out} = 0$$

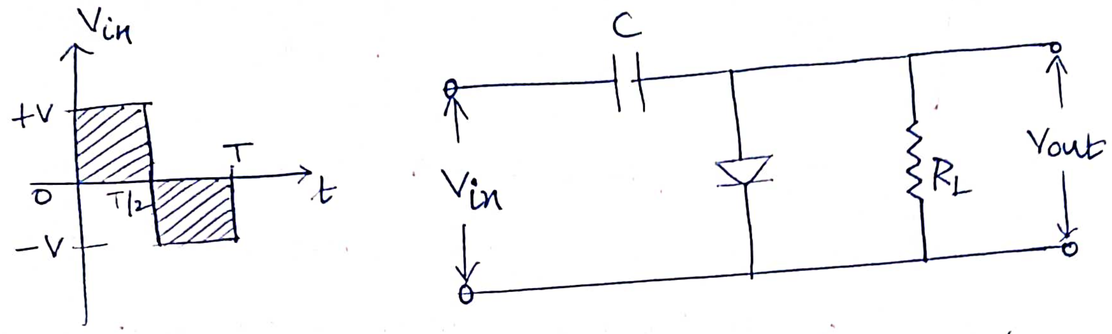
$$V_{out} = 2V$$ ✓

The resulting waveforms



(Positive clamper)

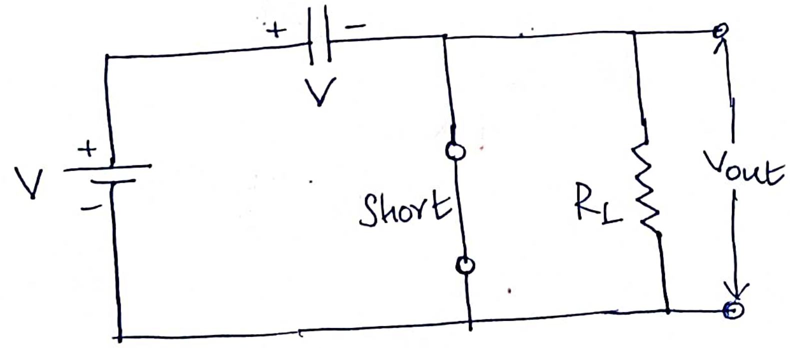
Negative clamper :

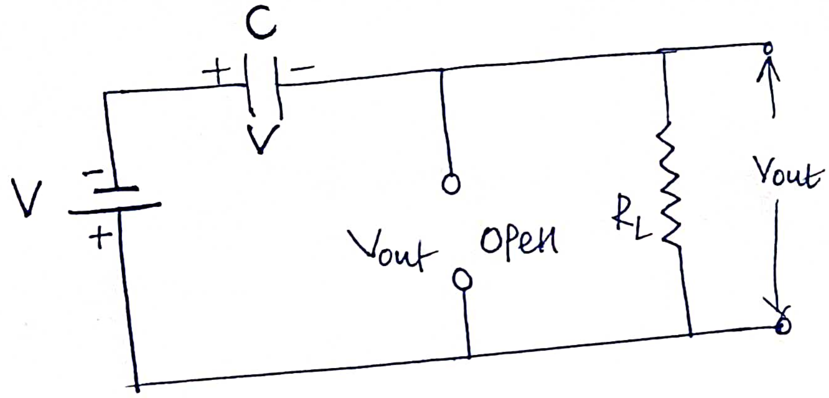


→ The Clamped output is taken across R_L. Note that only change from positive clamper is that connections of diode are reversed.

(i) During the positive half-cycle of input signal, the diode is forward biased. Therefore, the diode behaves as a short as shown in below figure. The charging time constant $(T_c = C \times r_f)$ is very small so that capacitor will charge to V volts very quickly. It is easy to see that during this interval, the output voltage (V_{out}) is directly across the short circuit. Therefore $\boxed{V_{out} = 0}$ ✓

↓

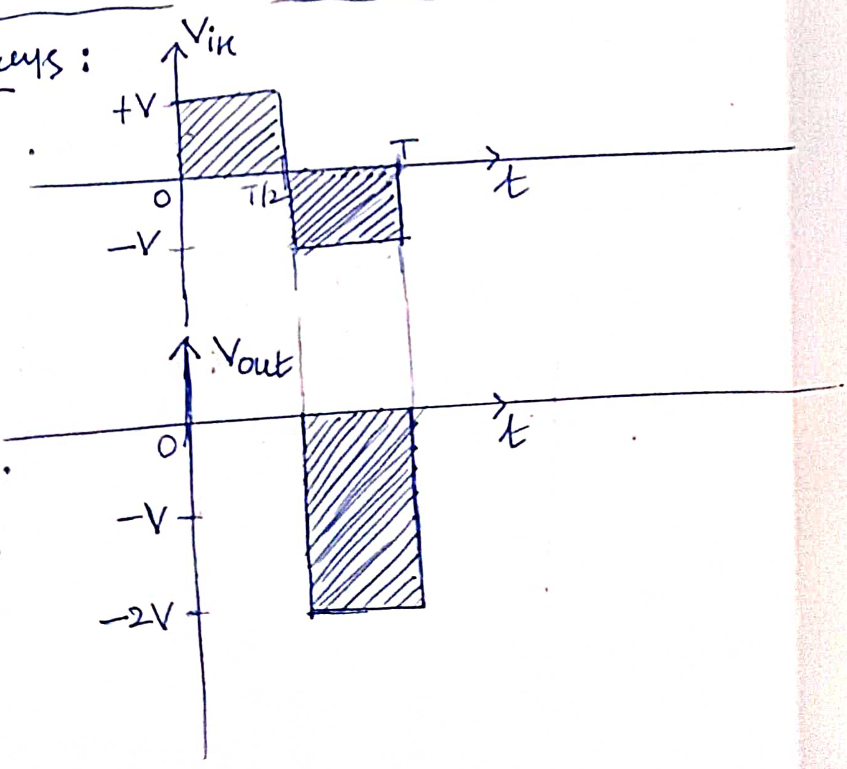




(ii) When the input switches to $-V$ state (i.e negative half cycle) the diode is reverse biased and behaves as an open as shown in figure. Since the discharge time constant $(= C \times R_L)$ is much greater than time period of input signal, the capacitor almost remains fully charged to V volts during the off time of the diode. Referring to figure, and applying KVL to input loop, we have,

$$-V - V - V_{out} = 0 \implies \boxed{V_{out} = -2V}$$

Resulting waveforms :

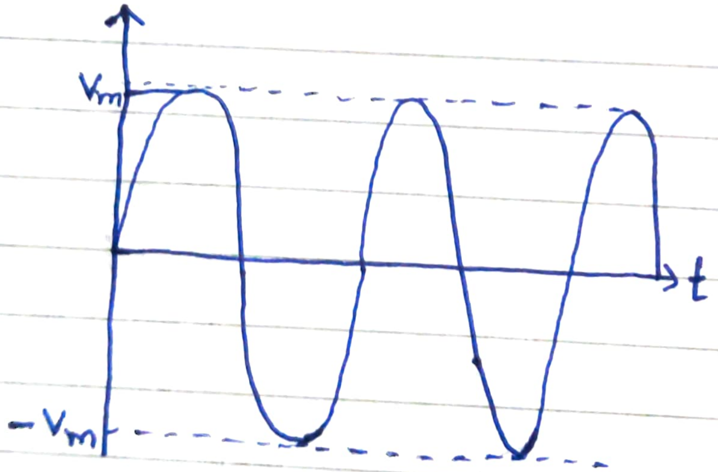


- To convert an AC to DC power, an rectifier ciruit comes for the rescue
- A simple p-n junction diode acts as a rectifier. The forward biasing and reverse biasing conditions of the diode makes the rectification

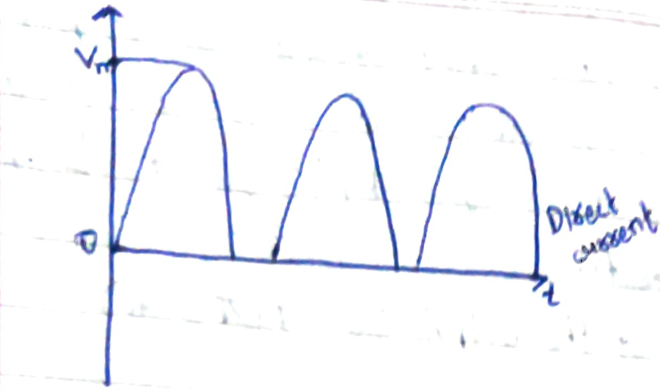
* rectification:-

An alternating current has the property to change its states continuously. These is understood by observing the sine wave by which an alternating current is indicated.

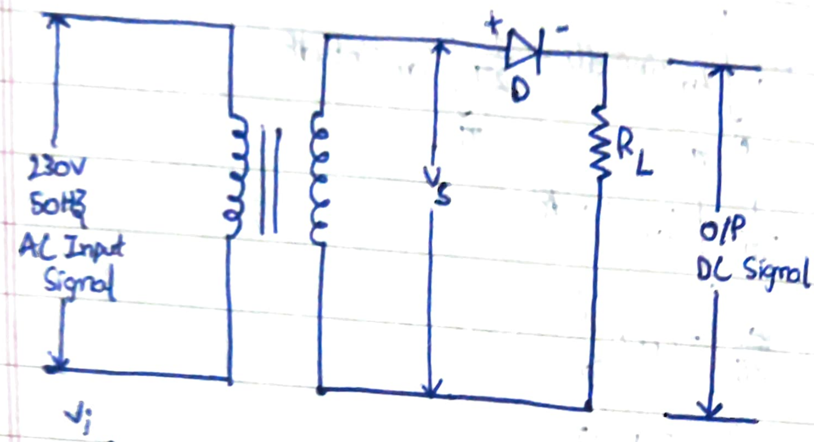
- It raises in its positive direction goes to a peak positive value, reduces from there to normal and again goes to negative portion and reaches to the negative peak and again get back to normal.

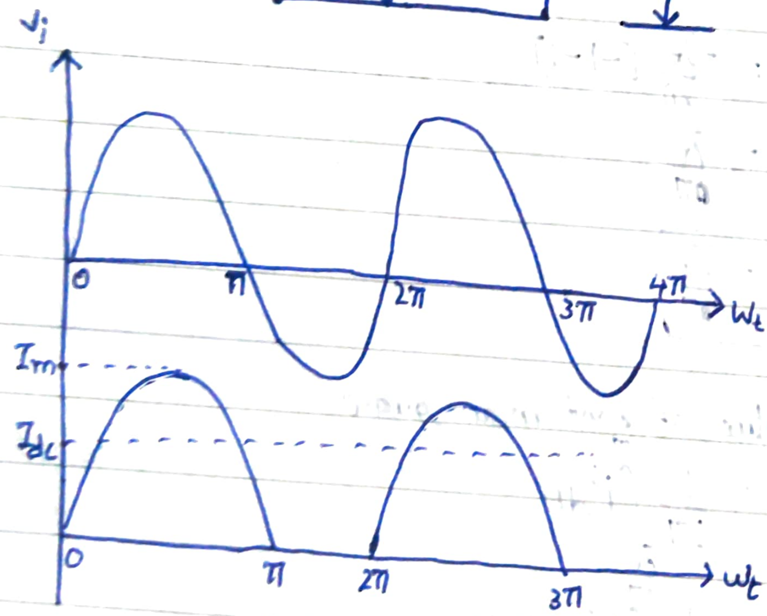


- In the formation of the wave we can observe that a wave goes in positive and negative directions actually it alters completely and hence the name alternative current.
- But during the process of rectifiation, this AC is changed to DC. The wave which flows in both positive and negative direction. Till then will get its direction, restricted only to the positive direction when converted to DC.
- Hence, the current is allowed to flow only in +ve direction and restricted in -ve direction



- Half-Wave Retifier -





- The AC voltages to be rectified is applied at the primary of the transformer, the secondary is connected to a load Resistance R_L through a diode D. let the diode be ideal.
- During the positive half cycle of input the diode D is forward bias and conducts hence the current i flows through resistance R_L
- During the negative half cycle of input the diode D is reverse

bias and in the closed circuit current does not p
resistance R_L i.e., the current flows in only one d

- The Output current i is given by $i = I_m \sin\theta$ 0 π

* parameters of rectifiers-

1. Average value of the output current (I_{dc})

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i\, d\theta$$

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

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

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

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

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

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

2. rms value of root mean square

$$I_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} i^2\, d\theta$$

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

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

$$= \frac{I_m^2}{2\pi}\int_0^{\pi}\left(\frac{1-\cos 2\theta}{2}\right) d\theta$$

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

$$= I_m^2 \times \pi$$

$$I_{rms}^2 = \frac{I_m^2}{4}$$

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

3. Efficiency - is defined as the ratio of dc powes delivered to the load a.c input power from transformer secondary

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

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

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

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

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

If $R_L >>> R_f$

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

$$\eta = \frac{4}{\pi^2} = 0.406 \approx 40.6\%$$

4. Voltage ~~Ven~~Regulation - The variation of dc output voltage as a function of dc output current is known as regulation.

- For an ideal power supply ~~VDC~~ V_{dc} is independent of I_{dc} i.e., the percentage regulation is zero

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

$\cancel{V} = \cancel{\sqrt{I_{rms}}}$ ~~NL~~

PIV → Peak Inverse voltage

→ It is defined as maximum reverse voltage that a diode can withstand, if the reverse bias voltage exceeds this value, the reverse current increase rapidly and the junction

breakdown the maximum peak inverse ... of
rectifier is V_m

- Ripple Factor (γ) - The fluctuating of AC components present along with dc current component of a rectif...

the ripple factor (γ) = $\frac{\text{ripple voltage}}{\text{dc voltage}}$

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

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

$$= 1.21$$

Transformer Utilisation Factor (TUF):-

It is defined as the ratio of dc power output to VA rating of transformer

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

$$TUF = 0.2865$$

⇒ Summary of Half Wave Rectifier.

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

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

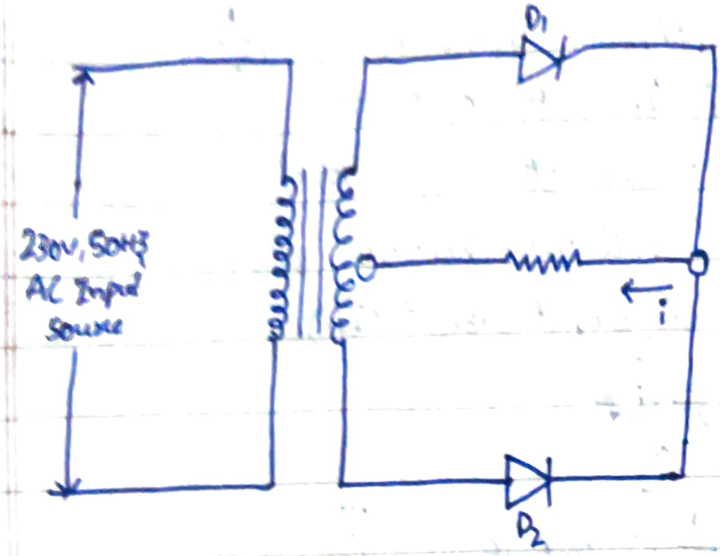
$$\eta = 40.6\%$$

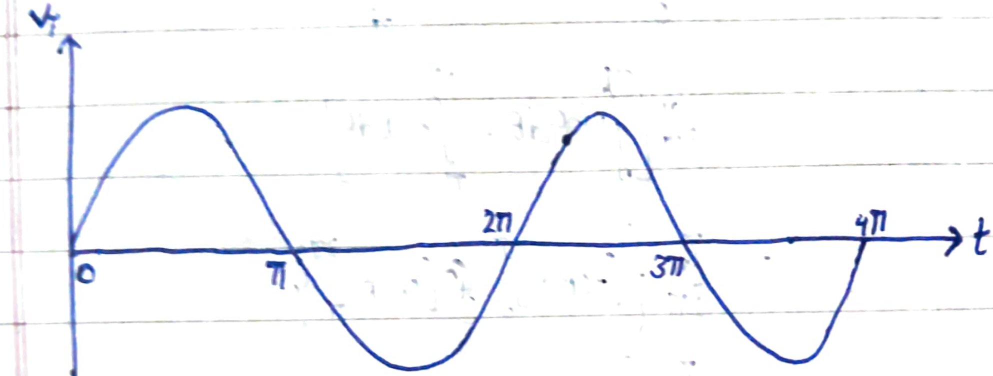
$$\%\ \text{regulation} = \frac{V_{NL} - V_{FL}}{V_{NL}} \times 100$$

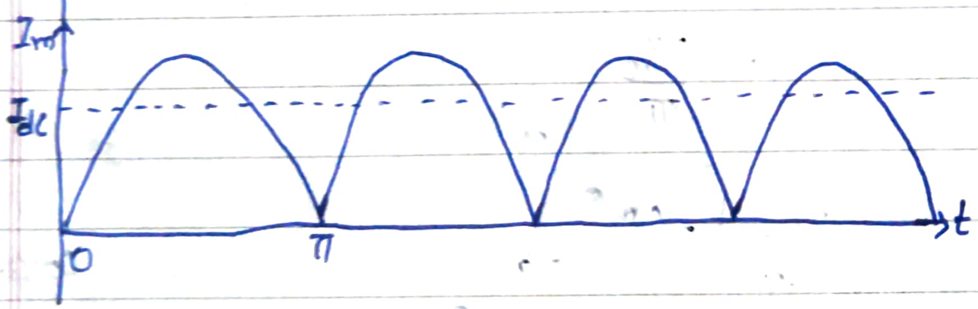
Ripple factor (γ) = $\frac{\text{ripple voltage}}{\text{d.c voltage}} = \sqrt{\left[\frac{I_{rms}}{I_{dc}}\right]^2 - 1} = 1.21$

TUF = $\frac{\text{dc power output}}{\text{VA ...}}$ = 0.2865

Full Wave Rectifier -







- It consists two diodes D_1 and D_2 and a centre taped transformer. The AC voltage to be rectified is applied to the primary of a transformer. let us assume the diode D_1 & D_2 are ideal.
- during the positive half cycle the diode D_1 is forward biased and D_2 is reverse biased so D_1 acts as short circuit and D_2 acts as open circuit hence current flows through Diode D_1.
- during the negative half cycle the diode D_1 is reverse biased and D_2 is forward biased so D_1 acts as an open circuit and D_2 acts

as short circuit. Hence current flows through Diode D_2

- The current through load resistor R_L is

$$i = I_m \sin\theta \quad 0 \le \theta \le \pi$$

$$= -I_m \sin\theta \quad \pi \le \theta \le 2\pi$$

- parameters of full wave rectifier

1. average value of output current (I_{dc})

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i\, d\theta$$

$$\frac{I_m}{2\pi}\int_0^{\pi} \sin\theta d\theta - \int_{\pi}^{2\pi} \sin\theta d\theta$$

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

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

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

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

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

$$\frac{I_m}{2\pi}\left[-\cos\theta\right]_0^{\pi}$$

$$\frac{I_m}{2\pi}\left[-(\cos\pi - \cos 0)\right.$$

$$-(-1-1)$$

$$\left.-(\cos 2\pi - \cos\pi)\right]$$

$$\frac{I_m}{2\pi}\left[-2\right.$$

cos 360°

cos 360°

$\cancel{8}$

cos(4×90+0

+cos 0°

=1

2. rms value of (root mean square)

$$I_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} i^2 d\theta$$

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

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

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

$$I_{rms}^2 = \frac{I_m^2}{4\pi} \times 2\pi$$

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

3. Voltage Regulation

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

But $I_m = \dfrac{V_m}{R_s + R_f + R_L}$

$$I_{dc} = \frac{2V_m}{\pi(R_s + R_f + R_L)}$$

$$I_{dc}(R_s + R_f) + I_{dc} R_L = \frac{2V_m}{\pi}$$

$$I_{dc} R_L = \frac{2V_m}{\pi} - I_{dc}(R_s + R_f)$$

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

4. Ripple factor

$$\gamma = \sqrt{\left[\frac{I_{rms}}{I_{dc}}\right]^2 - 1} = 0.48$$

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

$$P_{dc} = I_{dc}^2 R_L$$
$$= \left(\frac{2I_m}{\pi}\right)^2 R_L$$
$$= \frac{4I_m^2}{\pi^2} R_L$$

$$P_{ac} = I_{rms}^2 (R_L + R_f)$$
$$= \left[\frac{I_m}{\sqrt{2}}\right]^2 (R_L + R_f)$$
$$= \frac{I_m^2}{2} (R_L + R_f)$$

$$\eta = \frac{\frac{4I_m^2}{\pi^2} R_L}{\frac{I_m^2}{2}(R_L + R_f)} = \frac{8}{\pi^2} \times \frac{R_L}{R_L + R_f}$$

$$\eta = 0.812 = 81.2\%$$

Peak Inverse Voltage of full wave rectifier:-
The maximum reverse voltage that can be applied across the di
For a full wave rectifier the PIV across each diode is twice
the maximum transformer voltage
- The PIV of full wave rectifier is $2V_m$

Summary of full wave rectifier

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

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

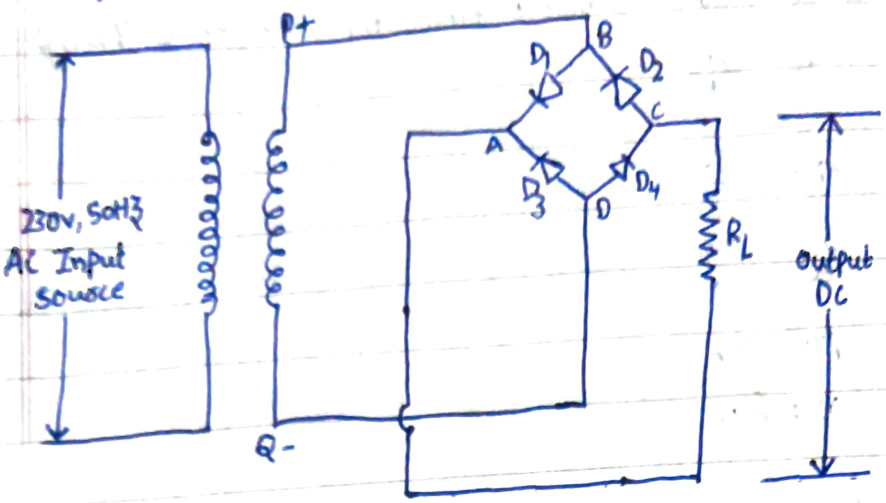
$$V_{dc} = \frac{2V_m}{\pi}$$

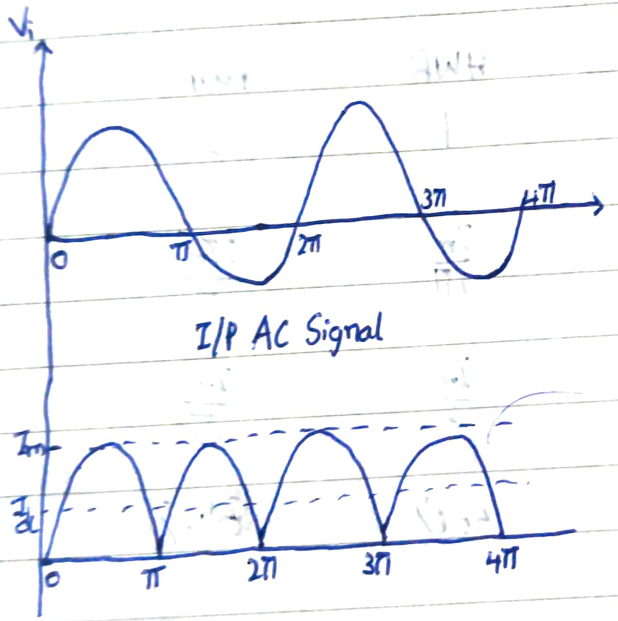
$$r = \sqrt{\left[\frac{I_{rms}}{I_{dc}}\right]^2 - 1} = 0.48$$

$$\eta = 81.2\%$$

PIV of full wave $= 2V_m$

Bridge Rectifier-





- It's basically a full wave rectifier but it does not need a centre taped transformer it has 4 diodes D_1, D_2, D_3, D_4 connected as a bridge. The AC voltage to be rectified is applied to the primary of the transformer
- During positive half cycle the Diode D_1 & D_4 are positive biased and D_2 and D_4 will conduct and the path for current is PBACDQ
- During negative half cycle the Diode D_1 & D_4 are reverse biased and

D_2 and D_4 will conduct and path for ...

- In both cycles current flows from A to C through R_L

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

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

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

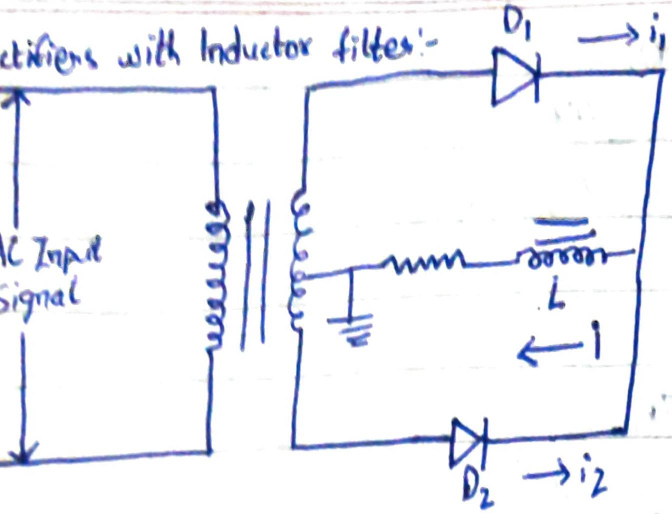
$PIV = V_m$

$\eta = 81.2$

⇒ Comparison b/w Half wave rectifier, full wave rectifier, Bridge wave rectifier

parameter	HWR	FWR	BR
No. of diodes	1	2	4
I_{dc}	$\frac{I_m}{2\pi}$	$\frac{2I_m}{\pi}$	$\frac{2I_m}{\pi}$
I_{rms}	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$	$\frac{I_m}{\sqrt{2}}$
η	40.6%	81.2%	81.2%
γ	1.21	0.48	0.48
PIV	V_m	$2V_m$	V_m
V_{dc}	$\frac{V_m}{2\pi}$	$\frac{2V_m}{\pi}$	$\frac{2V_m}{\pi}$
TUF	0.287	0.693	0.812

ctifiers with Inductor filter:-



An inductor opposes any changes of current in the circuit. So any sudden change that might occur in a circuit without an inductor are smooth out with the presence of inductor in the case of AC there is change in the magnitude of current with time. Inductor is a short circuit for DC and offers some impedance with for AC. It can be used as a filter. AC voltages are dropped across the inductors whereas DC passes through it. Therefore the AC is minimised in the output

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

Impedence due to L & R_L in series

$$|Z| = \sqrt{R_L^2 + (2\omega L)^2}$$

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

Substituting this expression for current

$$I = \frac{2I_m}{\pi} - \frac{4I_m}{3\pi}\cos 2\omega t + \text{--------}$$

By Inductor to higher frequencies like $4\omega t$,

$$i = \frac{2V_m}{\pi R_L} - \frac{4V_m}{3\sqrt{2\pi}\sqrt{R_L^2 + 4\omega^2 L^2}}$$

$$\theta = \tan^{-1}\left(\frac{2\omega L}{R_L}\right)$$

Ripple factor (γ):-

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

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

$$\gamma = \frac{4V_m \times \pi R_L}{3\sqrt{2}\pi\sqrt{R^2+4\omega^2L^2}\,2V_m}$$

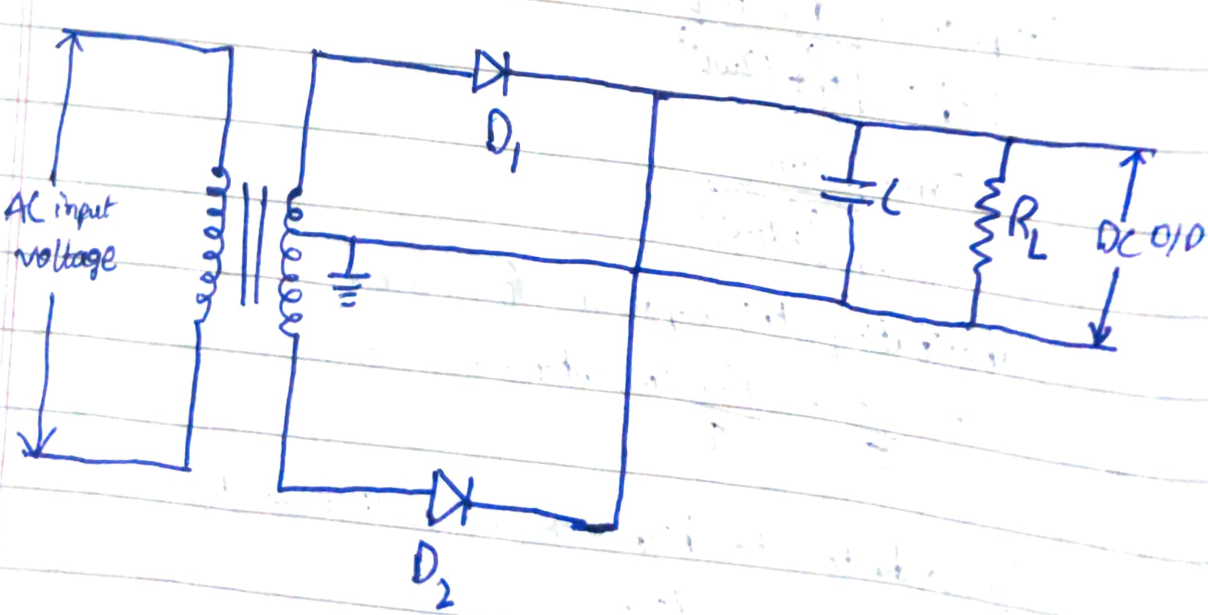
$$= \frac{2}{3\sqrt{2}} \times \frac{1}{\sqrt{1+\frac{4\omega^2L^2}{R_L^2}}}$$

If $\frac{4\omega^2L^2}{R_L^2} >> 1$

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

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

→ Capacitor filter -



The X_C should be smaller than R_L because the current should pass through capacitor C and get charged. If C value is very small, X_C will be large and the current flows through resistor R and no filter action takes place.
During a positive half cycle of a rectifier of a rectifier with a 'C' filter, C gets charged when the diode is conducting and gets discharged through load resistor R_L
when the input voltage $e = E_m \sin \omega t$ is greater than the capacitor voltage, C gets charged
when the input voltage is less than capacitor voltage C will discharged through load resistor R_L.
The stored energy in the capacitor maintaining the load voltage ~~for~~ at a high value for a long period. The diode conducts only for a short interval of high current. The capacitor opposes sudden fluctuations in voltages across it. So the ripple voltage is minimised

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

Clippers & clampers:-

- If the signal applied has an amplitude value greater than that of the range described this results in distortion
- There is another problem related to signals that are their levels the circuit level always maintained on the positive side but the sine wave consist of both positive and negative then in such cases the levels of the signals must be then operated on the electronic circuitary.
- for this processing of comparing the signals to define ranges and signal levels. clipper and clampers are used.

→ Clippers:

The clippers which are used to protect the electronic circuit by applying the AC input signal to the described voltage range. It will remove either positive half and negative half of the AC by considering requirement and defined voltage.

* Working of clipper circuit-

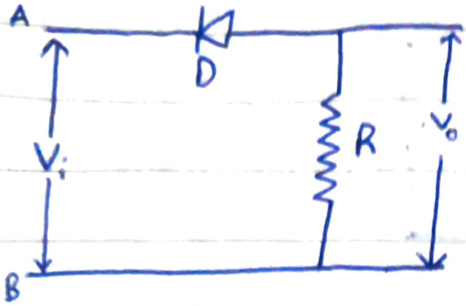
- A clipper circuit consists of linear elements known as resistors and non linear elements such as diodes but does not contain any energy storage device such as capacitor.
- These clippers are often limiting the voltage and current amplitudes. These are commonly refered to as slicers.

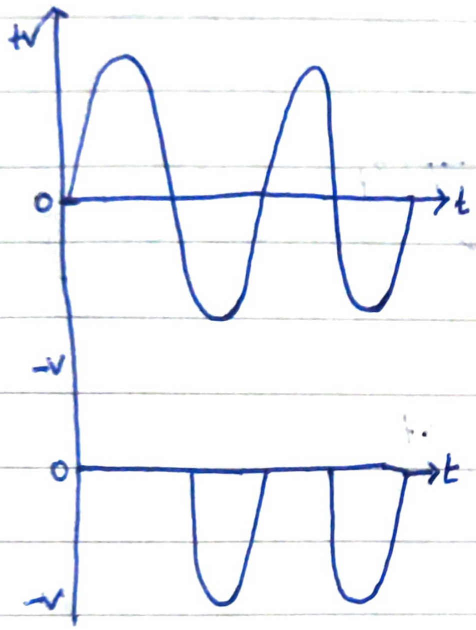
→ Types of clippers:-

1. Series clipper
2. Shunt clipper
3. dual clipper

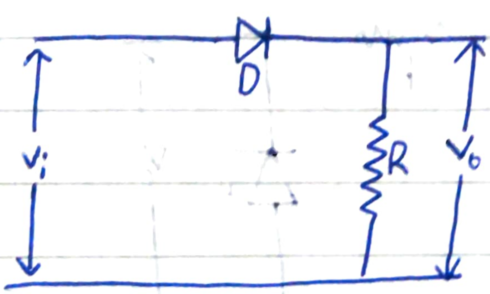
1. Series clipper:-

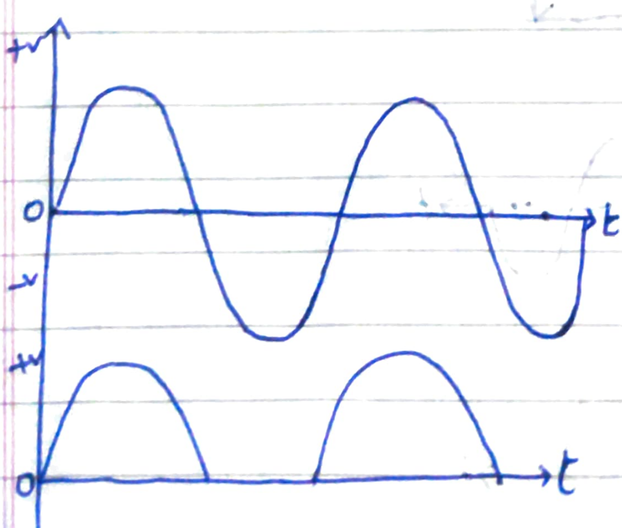
(i) Series positive clipper





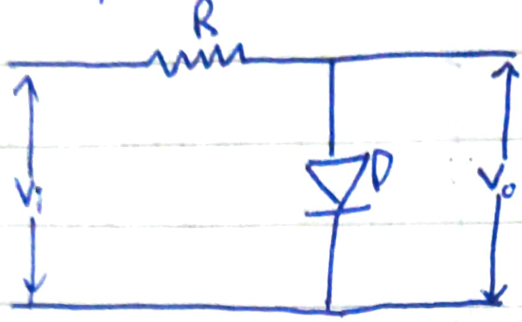
(ii) Series Negative clipper

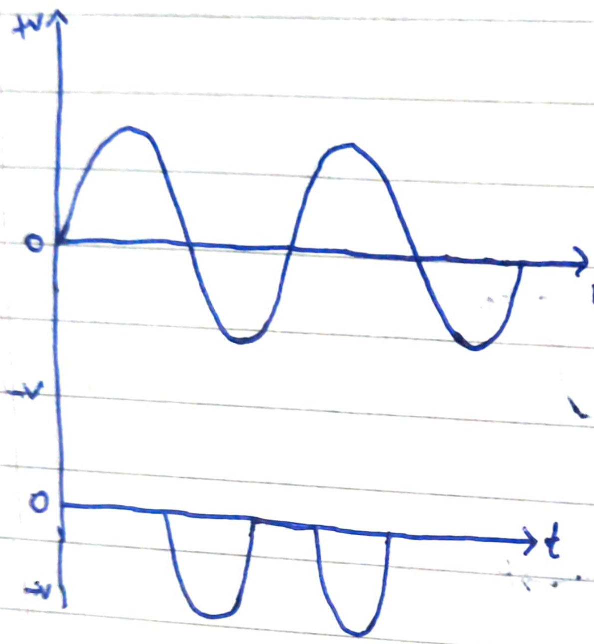




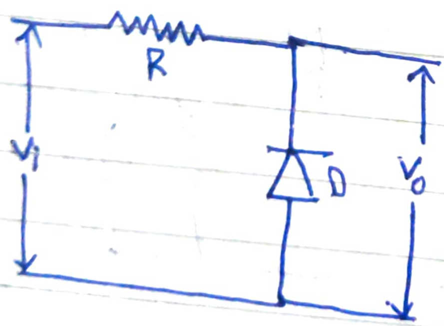
2. Shunt clipper

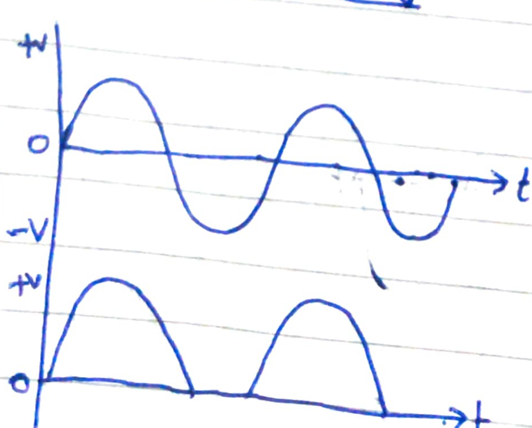
i) shunt positive clipper:





ii). Shunt negative clipper





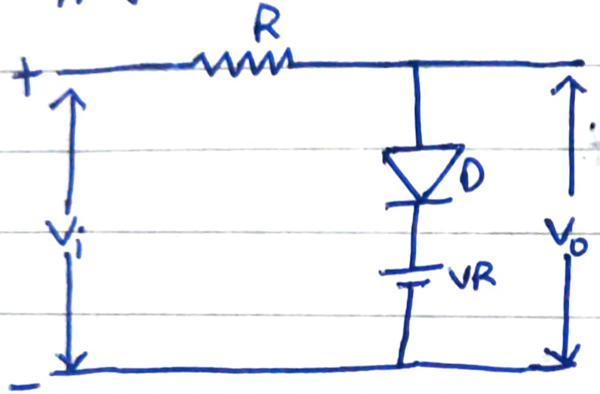
→ Series positive Clipper -

The positive cycle of the signal is clipped in this type of clippers these circuits consists of a diode connected in such a way that arrow is pointing towards input. It is connected along with series to the output load. The resistance is considered as load.

In exam

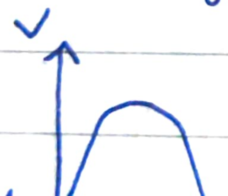
① shunt clippers

a. clipping above the ref. voltage (VR)

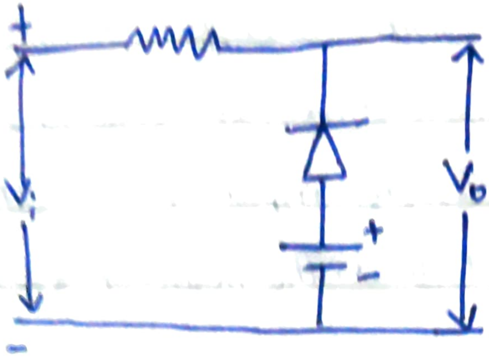


$V_o = V_i$ & $V_o < V_R$

$V_o = V_R$

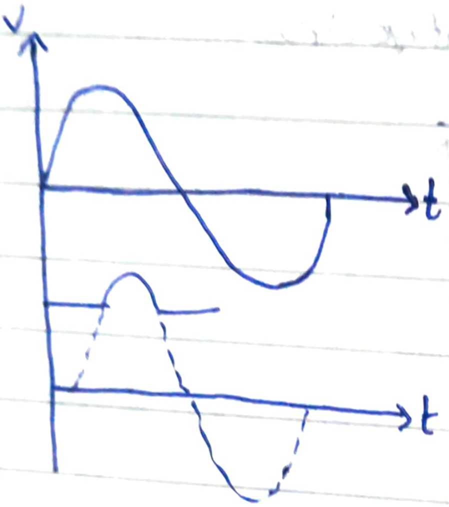


b. Clipping below the ref. voltage (V_R)



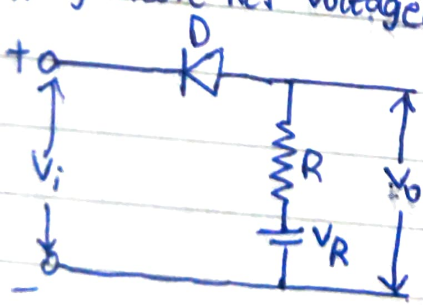
$V_i < V_R \quad V_o = V_R$

$V_i > V_R \quad V_i = V_o$



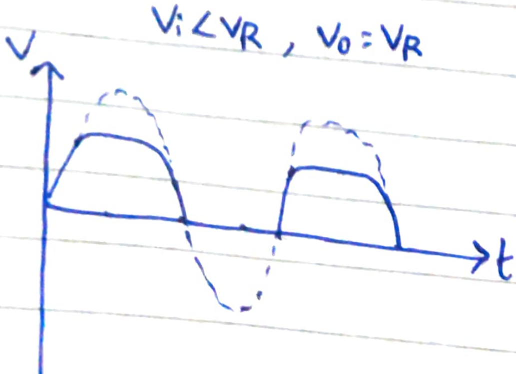
(2) Series clipping

(a) clipping above Ref voltage (V_R)

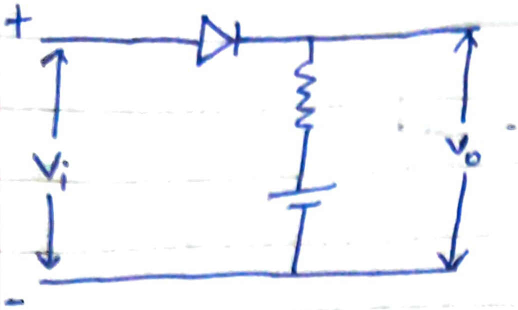


$V_i < V_R$; $V_o = V_i$

$V_i < V_R$, $V_o = V_R$

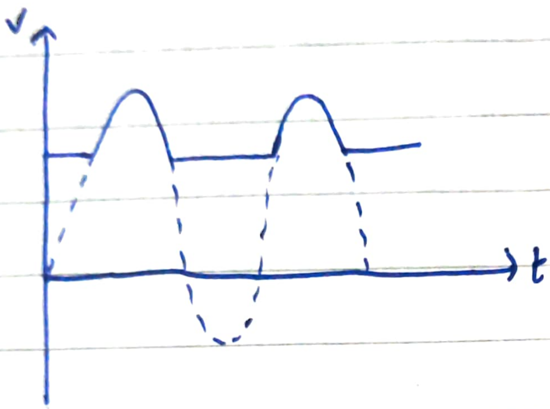


(b) clipping below the ref. voltage (V_R)

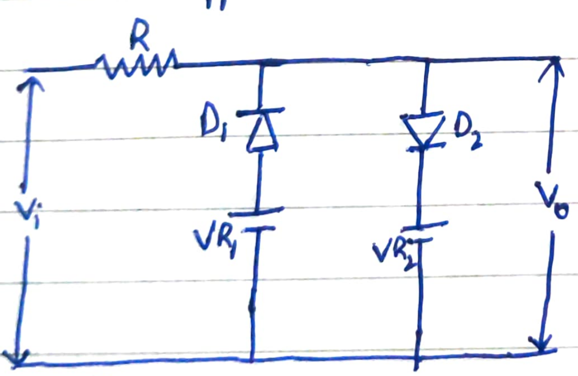


$V_i < V_R$; $V_0 = V_R$

$V_i > V_R$; $V_0 = V_i$



Two-Level clipper-



case (1):-

(a) $V_i < VR_1$

$\Rightarrow D_1 = F \cdot B \Rightarrow ON$

$D_2 = R \cdot B \Rightarrow OFF$

(b) $VR_2 > V_i > VR_1$

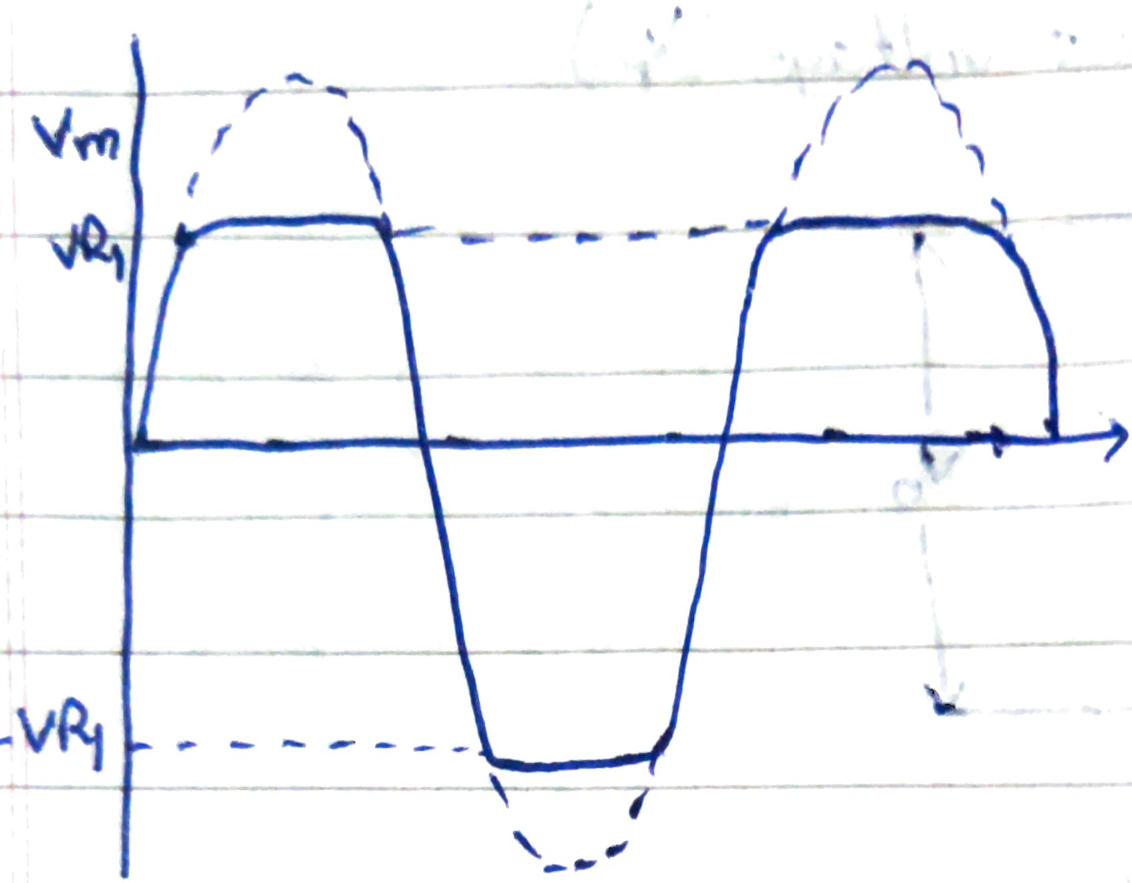
D_1 & D_2 : $R \cdot B \Rightarrow OFF$

Then $V_0 = V_i$

(c) $V_i > VR_2$

$D_2 = F \cdot B \Rightarrow ON$

$D_1 = R \cdot B \Rightarrow OFF$


Vm
VR1
-VR1