UNIT-II

Diode Applications

Rectifier : It is an electronic device that converts AC to pulsating DC is known as rectifier. And the process of conversion of AC to pulsating DC Rectification.

Classification of rectifiers:

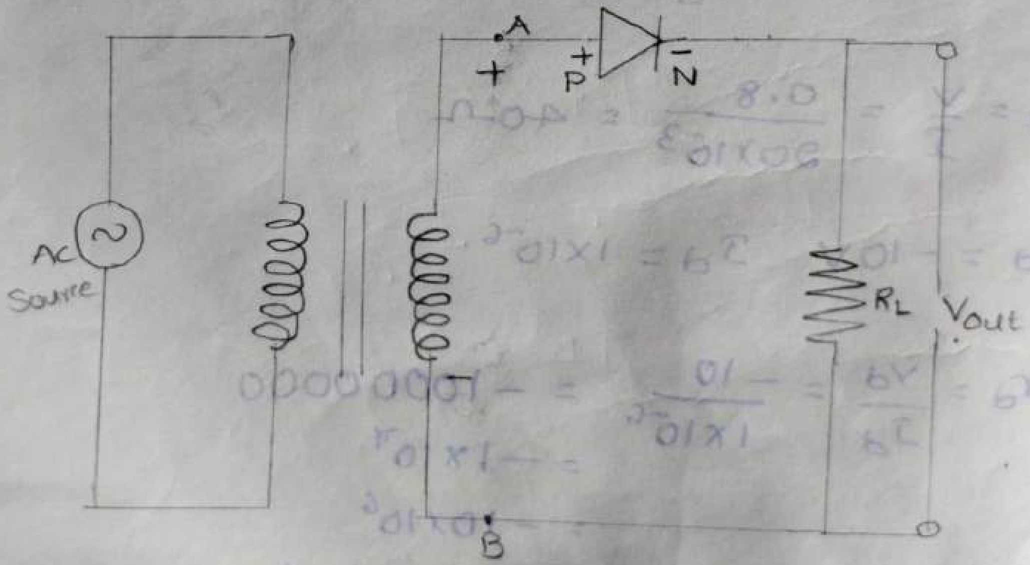
Rectifiers are classified into two categories based on period of conduction.

1. Half wave rectifier
2. Full wave rectifier

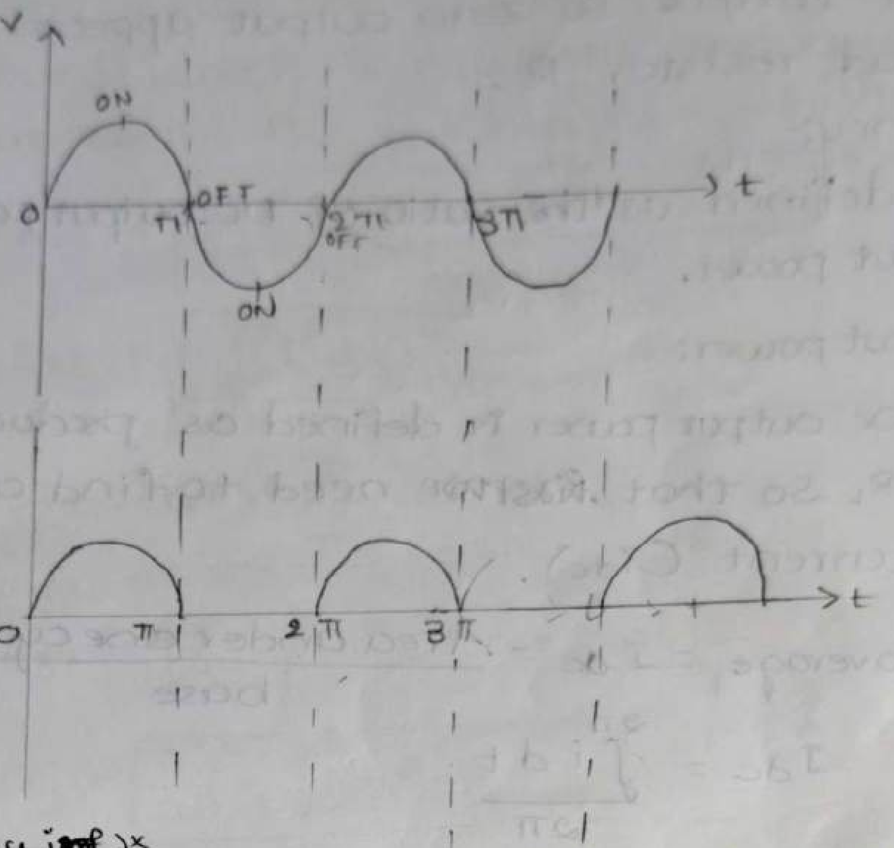
→ Fullwave rectifier is further classified into two types. they are

1. centertapped fullwave rectifier
2. Bridge fullwave rectifier

Half wave rectifier:



Wave forms:



Efficiency
→ A half wave rectifier is one which conducts current during the positive half cycle of the input supply the AC voltage to be rectified is applied to the input of transformer and the voltage across secondary is available for rectification.

Operation:-
→ During the positive half cycle of the input signal the upperend of secondary winding is positive with respect to lowerend.
→ At this instant diode is forward biased and conducts current so that output appears across the load resistor 'R_L'
→ During the negative halfcycle of the input signal the upperend of the secondary winding is negative with respect to lowerend.

→ At this instant the diode is reverse biased and doesnot conduct current so zero output appears across the load resistor 'R'.

Efficiency:

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

DC output power:

The DC output power is defined as product of $i_{dc}^2 \times R_L$. So that ~~...~~ we need to find average dc current (i_{dc}).

$$I_{average} = I_{dc} = \frac{\text{Area under one cycle of curve}}{\text{base}}$$

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

$i = i_m \sin\omega t \; ; \; 0 \le t \le \pi$

$i = 0 \qquad ; \; \pi \le t \le 2\pi$

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

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

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

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

$$= \frac{-i_m}{\cancel{2}\pi} \times -\cancel{2}$$

$$= \frac{i_m}{\pi}$$

$$P_{dc} = i_{dc}^2 \times R_L$$

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

AC power:-

In order to find the AC power, ac current has to be found which is equal to rms current.

(AC input power $P_{AC} = I_{rms}^2 \times (R_L + R_f)$).

$$I_{ac} = I_{rms} = \sqrt{\frac{(\text{Area of one cycle of curve})^2}{\text{base}}}$$

$$I_{ac} = \sqrt{\frac{\int_0^{2\pi} (i\, dt)^2}{2\pi}}$$

$i = i_m \sin\omega t$; $0 \le t \le \pi$

$i = 0$; $\pi \le t \le 2\pi$

$$I_{rms} = \left[\frac{1}{2\pi} \cdot \int_0^{\pi} i_m^2 \sin^2\omega t \, d\omega t\right]^{\frac{1}{2}}$$

$$= \sqrt{\frac{i_m^2}{2\pi} \int_0^{\pi} \sin^2\omega t \, dt}$$

$$= \sqrt{\frac{i_m^2}{2\pi} \int_0^{\pi} \frac{1-\cos 2\omega t}{2} \cdot dt}$$

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

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

$$= \sqrt{\frac{i_m^2}{4\pi} [\pi - 0 - 0 + 0]}$$

$$= \sqrt{\frac{i_m^2}{4\cancel{\pi}} \times \cancel{\pi}}$$

$$= \frac{i_m}{2}$$

$$I_{ac} = I_{rms} = \frac{i_m}{2}$$

$P_{ac} = i_{rms}^2 \times (R_L + R_f)$

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

$$\text{Efficiency } (\eta) = \frac{P_{dc}}{P_{ac}}$$

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

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

$$= \frac{\frac{i_m^2}{\pi^2} \times R_L}{\left(\frac{i_m}{2}\right)^2 \times R_L + R_f}$$

$$R_f << R_L$$

$$= \frac{\frac{i_m^2}{\pi^2} \times R_L}{\frac{i_m^2}{4} \times R_L}$$

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

$$= 0.405$$

$$= 40.5\%$$

Ripple factor (γ):-

It is seen that output of half wave rectifier not pure DC but a pulsating dc. The output contains pulsating components called ripples. Ideally there should not be any ripples in the rectifier output. The measure of such ripples present in the output is with the help a factor called ripple factor denoted by "γ". It tells how smooth is the output.

$$\text{Ripple factor}(\gamma) = \frac{\text{Rms value of ac component of output}}{\text{average or dc component of output}}$$

Now, the output current is composed of ac component as well as dc component. Let I_{ac} is equal to rms value of ac component present in o/p. I_{dc} is equal to dc component present in o/p.

I_{rms} = rms value of total output current.

$$I_{rms} = \sqrt{I_{ac}^2 + (I_{dc})^2}$$

$$(I_{rms})^2 = (I_{ac})^2 + (I_{dc})^2$$

$$(I_{ac})^2 = (I_{rms})^2 - (I_{dc})^2$$

$$I_{ac} = \sqrt{(I_{rms})^2 - (I_{dc})^2}$$

$$\text{Ripple factor}(\gamma) = \frac{\sqrt{(I_{rms})^2 - (I_{dc})^2}}{I_{dc}}$$

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

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

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

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

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

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

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

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

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

$$= 1.211 \times 100$$

$$= 121.03\,\%$$

→ This indicates that are ripple contents in the output are 1.211 times the dc component that is 121.1% of dc component.

→ The ripple factor for half wave is very high which indicates that the half wave circuit is not practically a pure converter of ac to dc.

Problems:

1. A Sinusoidal voltage of peak amplitude of 20 volts is applied to a half wave rectifier using P-n junction diode with a load resistance of 1000Ω and forward resistance of the diode is 10Ω.

i) calculate Peak current (I_m), average I_{dc}, I_{Rms}.

ii) Dc output power.

iii) Ac input power

iv) Rectifier efficiency

Sol Given data, $V_m = 20V$

$R_L = 1000\Omega$

$R_f = 10\Omega$

i) $I_m = \frac{V_m}{R_L + R_f} = \frac{20}{1000+10} = \frac{2}{101} = 0.019A$

ii) $I_{dc} = \frac{i_m}{\pi} = \frac{0.019}{3.14} = 6.047 \times 10^{-3} A$

$I_{ac} = \frac{i_m}{2} = \frac{0.019}{2} = 9.5 \times 10^{-3} A$

ii) $P_{dc} = i_{dc}^2 \times R_L$

$= (6.047 \times 10^{-3})^2 \times 1000$

$= 0.0365 W$

iii) $P_{ac} = i_{ac}^2 \times (R_L + R_f)$

$= (9.5 \times 10^{-3})^2 \times (1000+10)$

$= 0.0911 W$

iv) Rectifier efficiency $= \frac{P_{dc}}{P_{ac}} = \frac{0.0365}{0.0911}$

$= 0.400 \times 100$

$= 40.06\%$

2. An ac supply of 230 volts is applied to a half wave rectifier circuit through of a transformer of turns ratio 5:1. Find DC output voltage

i) Dc output voltage

ii) Efficiency (Assume that the diode to be ideal).

$V_{rms} = 230$ volts

$N_1 : N_2 = 5:1$

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

$V_m = \sqrt{2} \times 230$

$V_m = 325.26\,V$

Secondary maximum voltage $= \frac{N_2}{N_1} \times V_m$

$= \frac{1}{5} \times 325.26$

$V_m = 65.05\,V$

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

$i_m = \frac{V_m}{R_L + R_f} = \frac{V_m}{R_L} \quad (\because R_f << R_L) \rightarrow (2)$

sub (2) in (1)

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

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

$= \frac{V_m}{\pi \cancel{R_L}} \times \cancel{R_L}$

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

$V_{dc} = \frac{65.05}{\pi} = 20.71\,V$.

ii) Efficiency $= \frac{P_{dc}}{P_{ac}}$

$= \frac{I_{dc}^2 \times R_L}{I_{ac}^2 \times (R_L + R_f)}$

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

$\left[I_{ac} = \frac{I_m}{2} \right.$

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

$\left. I_{ac} = \frac{V_m}{2R_L} \right]$

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

$= 40.5\%$.

3. Determine the secondary voltage of transformer to deliver dc power of '1 Watt' for 1000Ω load for a halfwave rectifier.

Given $P_{dc} = 1$ watt

$R_L = 1000\Omega$

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

$1 = I^2dc \times 1000$

$I_{dc}^2 = \frac{1}{1000}$

$I_{dc}^2 = 1 \times 10^{-3}$

$I_{dc} = \sqrt{1 \times 10^{-3}}$

$I_{dc} = 0.031\,A$

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

$0.031 = \frac{i_m}{\pi}$

$i_m = 0.097\,A$

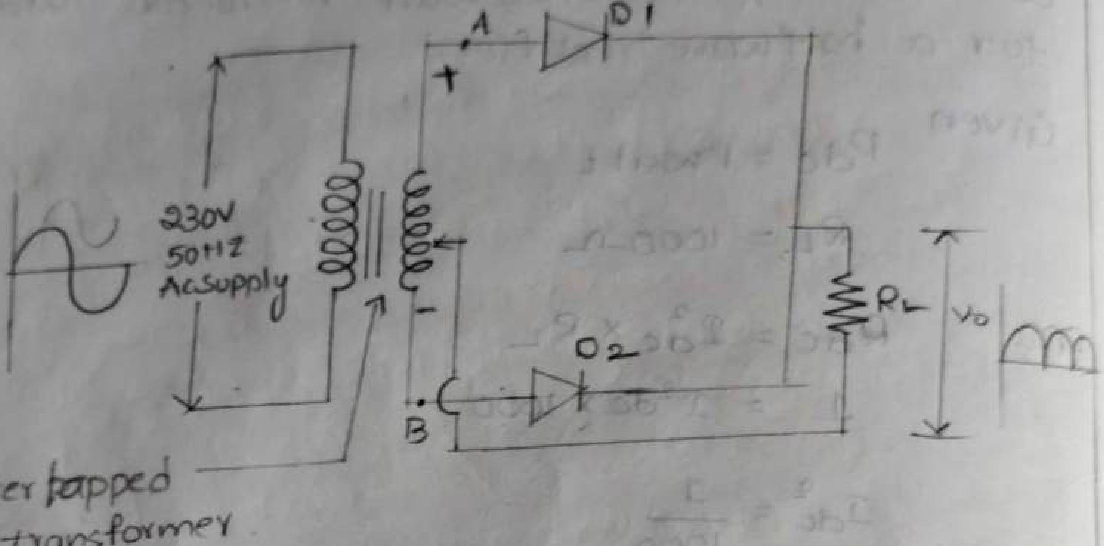
$(V_m = \frac{i_m}{R_L} = \frac{0.097}{1000} = 9.7 \times 10^{-5}) \times$

$V_m = i_m \times R_L = 0.097 \times 1000 = 97\,V$

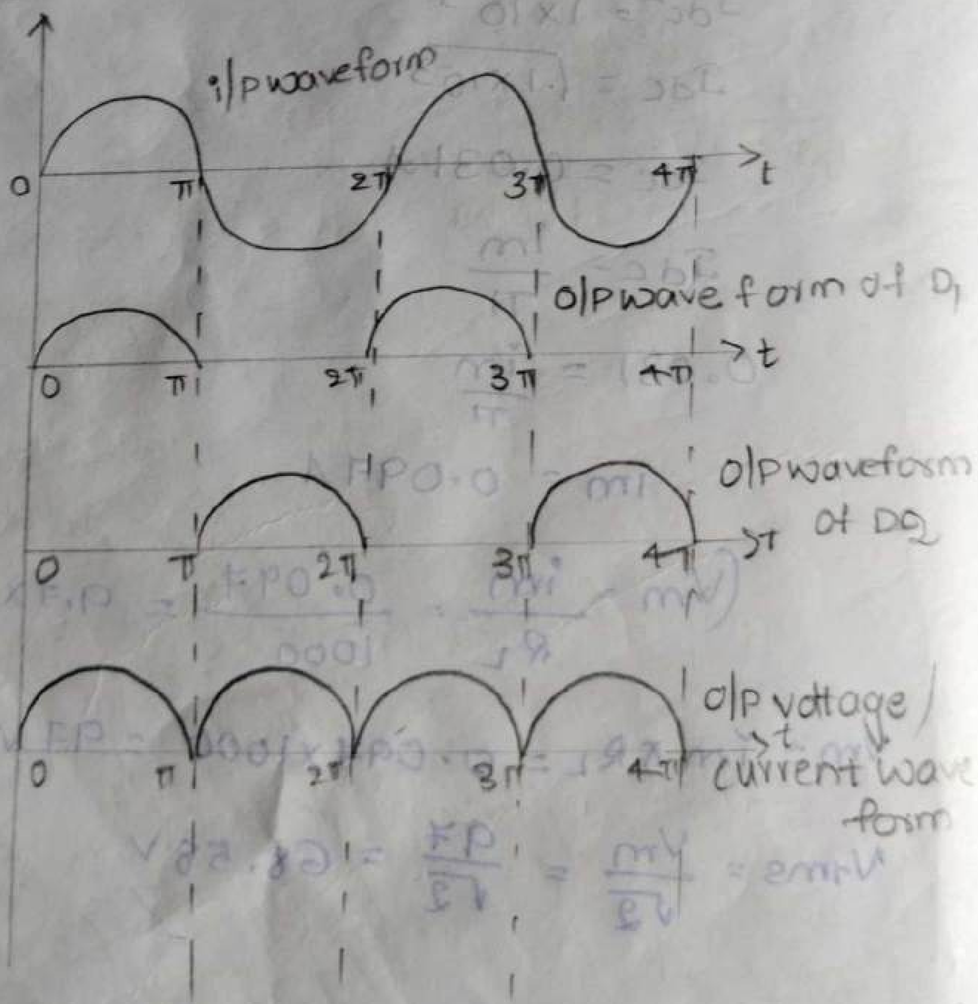
$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{97}{\sqrt{2}} = 68.58\,V$

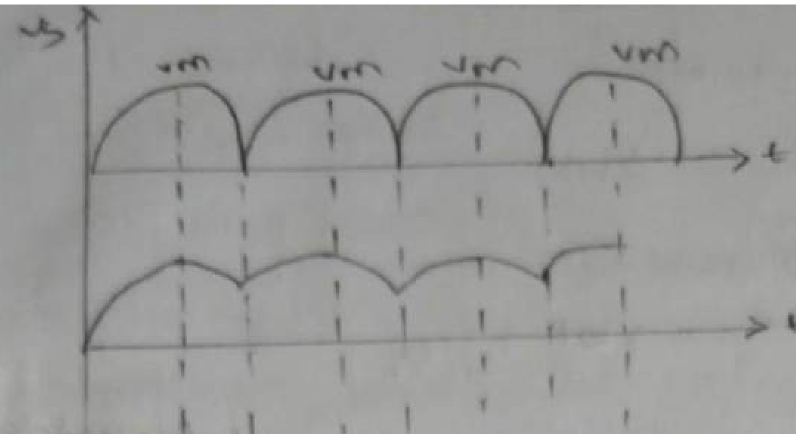
Full wave Rectifier:-

1) center tapped full wave rectifier:-



Half wave



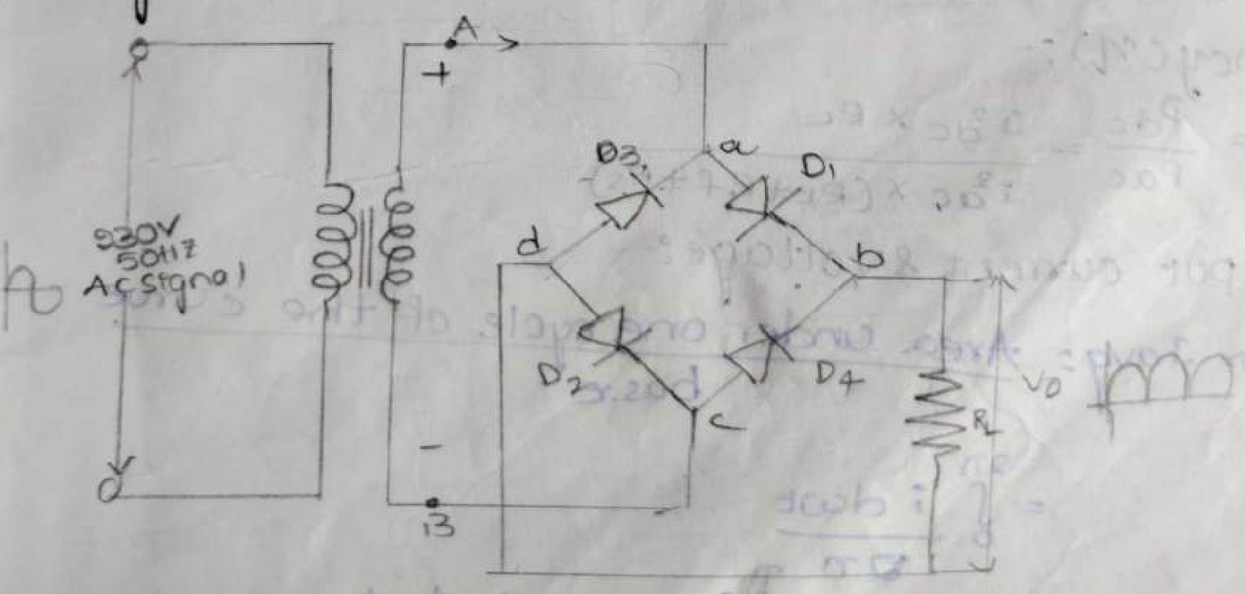


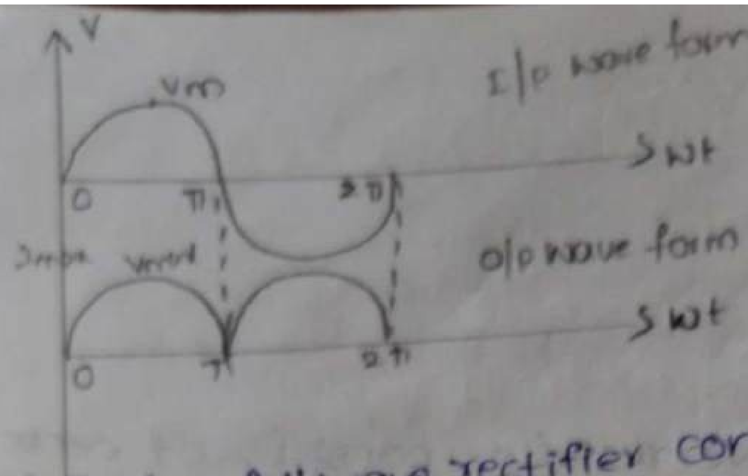
→ Center tapped full wave rectifier consists of center tapped transformer, two diodes named as D_1 and D_2 and load resistor R_L.

→ During positive half cycle input signal end A becomes positive with respect to end B at this instant D_1 is in forward bias and D_2 is in reverse bias so current conduction starts by diode D_1 through the path AD_1R_L so the output appears across load resistor R_L.

→ During negative half cycle of the input signal end B becomes positive with respect to end A at this instant D_2 is forward bias and D_1 is reverse bias so current conduction starts by diode D_2 through the path BD_2R_L so the output appears across load resistor R_L.

ii) Bridge rectifier (full wave) :-





→ Bridge fullwave rectifier consists general transformer four diodes named D_1, D_2, D_3 & D_4 and load resistor.

→ During positive half cycle of the input of signal upper end of secondary winding becomes positive with respect to lower end at this instant diodes D_1 and D_2 conduct as they are in forward bias and output appears across Load resistor R_L.

→ During positive half cycle the current flow the path aD_1bR_LC.

→ During negative half cycle of the input signal lower end secondary winding becomes positive with respect to upper end at this instant diodes D_3, D_4 conduct as they are in forward bias and output appears across load resistor R_L.

→ During negative half cycle the current flow the path $dD_4bR_LCD_3$. ($cD_4bR_LdD_3a$)

Efficiency(η):-

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I^2_{dc} \times R_L}{I^2_{ac} \times (R_L + R_f + R_s)}$$

DC output current & voltage:-

$$I_{dc} \text{ or } I_{avg} = \frac{\text{Area under one cycle of the curve}}{\text{base}}$$

$$= \int_0^{2\pi} \frac{i \, d\omega t}{2\pi}$$

$$= \frac{1}{2\pi} \times 2 \int_0^{\pi} I_m \sin\omega t \, d\omega t$$

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

$$= -\frac{i_m}{\pi}\left[\cos\pi - \cos 0\right]$$

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

$$= -\frac{i_m}{\pi}\times -2$$

$$\boxed{I_{dc} = \frac{2i_m}{\pi}}$$

$$V_{dc} = V_{avg} = I_{dc}\times R_L$$

$$= \frac{2i_m}{\pi}\times R_L$$

$$= \frac{2V_m}{\pi R_L}\times R_L \quad \left[\because i_m = \frac{V_m}{R_L}\right]$$

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

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

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

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

AC input current & Voltage:-

$$I_{rms} \text{ or } I_{ac} = \sqrt{\frac{(\text{Area under one cycle of the curve})^2}{\text{base}}}$$

$$= \sqrt{\frac{\int_0^{2\pi} i^2\, d\omega t}{2\pi}}$$

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

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

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

$$= \sqrt{\frac{i_m^2}{2\pi}\left[\left[\omega t\right]_0^{\pi} - \left[\frac{\sin 2\omega t}{2}\right]_0^{\pi}\right]}$$

$$= \sqrt{\frac{i_m^2}{2\pi}\left[\left[\pi - 0\right] - 0 + 0\right]}$$

$$I_{rms} = \sqrt{\frac{i_m^2}{2\pi}\times\pi} = \frac{i_m}{\sqrt{2}}$$

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

$= \frac{i_m}{\sqrt{2}} \times R_L$

$= \frac{V_m}{R_L + R_S + R_f} \times \frac{R_L}{\sqrt{2}} \quad \left[\because i_m = \frac{V_m}{R_L + R_S + R_f} \right]$

$= \frac{V_m}{R_L} \times \frac{R_L}{\sqrt{2}} \quad [\because R_S + R_f << R_L]$

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

$P_{ac} = I_{ac}^2 \times (R_L + R_f + R_S)$

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

$$\boxed{P_{ac} = \left(\frac{i_m}{\sqrt{2}}\right)^2 \times R_L} \quad (\because R_f + R_S << R_L)$$

$$\text{Efficiency}(\eta) = \frac{P_{dc}}{P_{ac}} = \frac{\frac{4 i_m^2}{\pi^2} \times R_L}{\frac{i_m^2}{2} \times R_L}$$

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

$$\eta = 0.8114$$

$$\boxed{\eta\% = 81.1\%}$$

Ripple factor (γ):-

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

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

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

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

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

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

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

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

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

$$= 0.483$$

$$\boxed{\gamma = 48.3\%}$$

Advantages of half wave rectifier:-

1. Simple construction
2. Less no of components are required.
3. Small size

Disadvantages of half wave rectifier:-

1. More amount of ripple content
2. Rectification efficiency is low.
3. low output voltage or current.
4. Generates harmonics

Advantages of centertopped full wave rectifier:-

1. The dc load voltage and current are more than half wave.
2. The efficiency is higher.
3. The ripple factor is less.
4. The large dc power output.

Disadvantage of center tapped fullwave rectifier:-

1. It is difficulty to locate the center tap on Secondary winding.
2. The DC output is small as each diode utilizes only one half of the transformer Secondary voltage.
3. The diode must have high peak inverse voltage.

Advantages of Bridge full wave rectifier:-

1. No center tap is needed in the transformer Secondary winding.
2. The peak inverse voltage is one half that of center tapped circuit.
3. The output is twice that of the Secondary tapped circuit for the Same Secondary voltage.

Disadvantages of Bridge full wave rectifier:-

1. It requires four diodes.
2. As during each half cycle of the ac input the two diodes that are conducting Series will drop ~~twicesx~~ voltage twice.

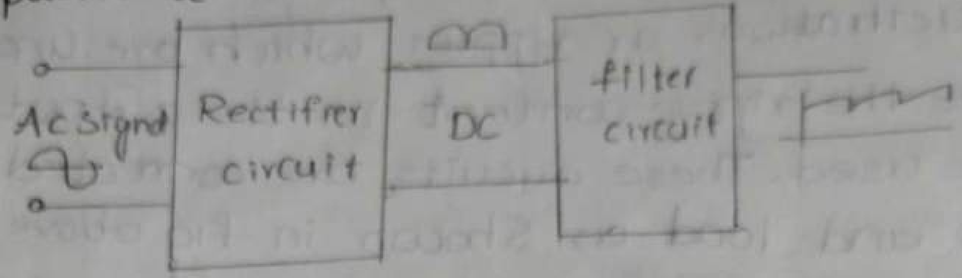
MID-1 IMP

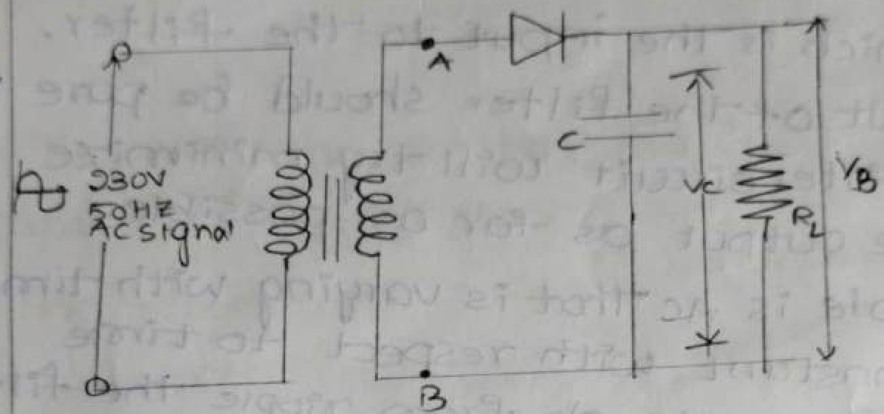
(2) Comparision of rectifiers:-

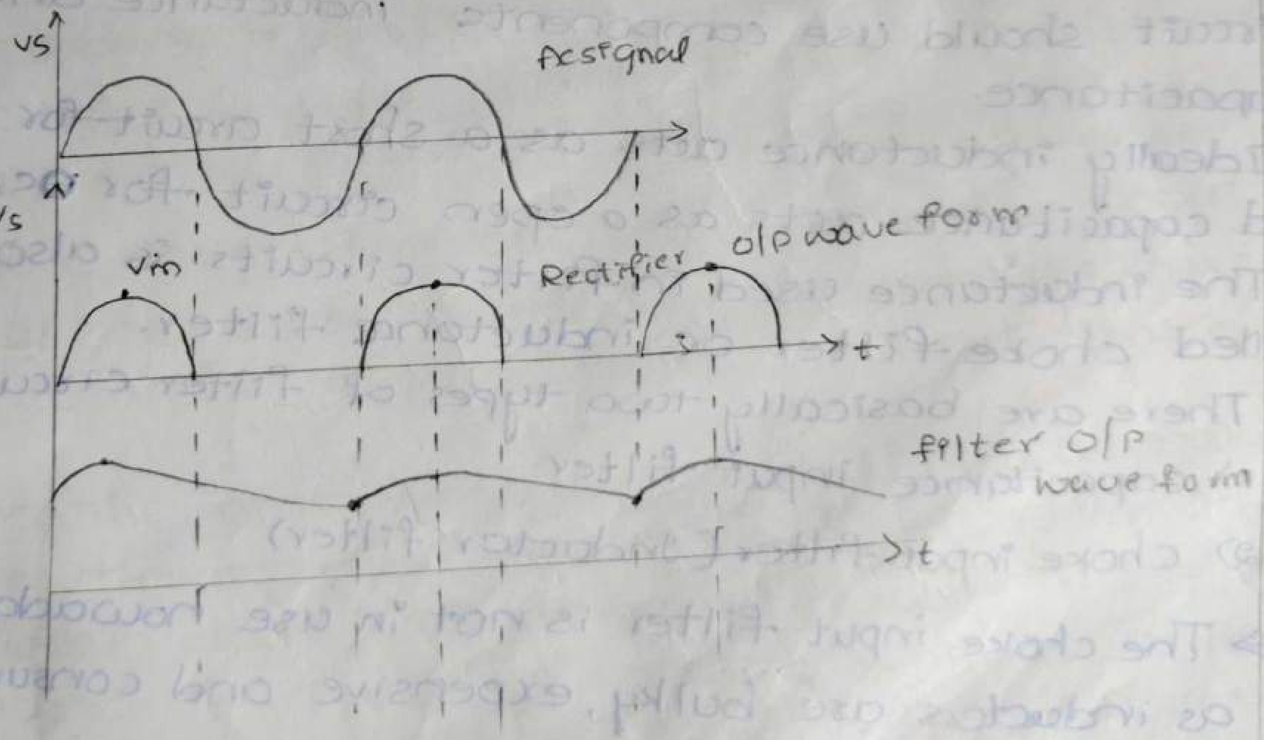
Particular / Parameter	Half wave rectifier	Center trapped fullwave rectifier	Bridge full wave rectifier
1. Number of diodes	1	2	4
2. Necessity of center-tapped transformer.	Not necessary	Neccessary	Not necessary
3. Maximum efficiency.	40.6%	81.1 or 2%.	81.1 or 2 %.
4. Ripple factor.	1.21	0.48	0.48
5. Output frequency (ripple frequency).	Same as input	twice the input	twice the input
6. Peak inverse voltage	Vm	2Vm	Vm

Filters :-

Capacitance filter :-







Filters circuits:-

→ It is seen that the output of half wave or full wave rectifier circuit, is not pure dc but it contains fluctuations or ripples which are undesi[rable]

→ To minimize the ripple content in the output fil[ter] circuits are used. These circuits are connected b/w the rectifier and load as shown in fig above

→ As an ac input is applied to the rectifier at the output of the rectifier there will be dc and ripple voltage present which is the input to the filter.

→ Ideally the output of the filter should be pure [dc] practically the filter circuit will try minimize the ripple at the output as far as possible.

→ Basically the ripple is AC that is varying with tim[e] while DC is a constant with respect to time hence, in order to seperate dc from ripple the fil[ter] circuit should use components inductance and capacitance.

→ Ideally inductance acts as a short circuit for DC and capacitance acts as a open circuit for DC.

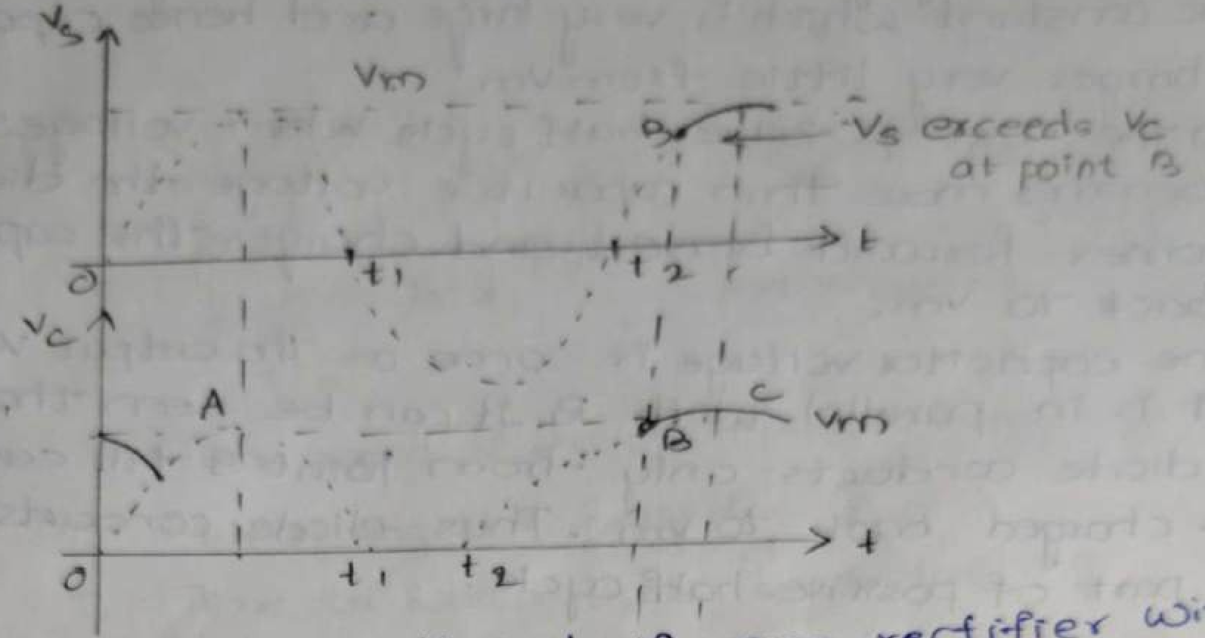
→ The inductance used in filter circuits is also called choke filter or inductance filter.

There are basically two types of filter circuits

1) capacitance input filter
2) choke input filter (Inductor filter)

→ The choke input filter is not in use nowadays as inductors are bulky, expensive and consume more power.

Capacitor input filter or ~~Series~~ Shunt capacitance filter:-



-> The fig shows that half wave rectifier with capacitor input filter.

-> The filter uses a single capacitor connected in parallel with the load represented by the resistance R_L.

-> In orderto minimize the ripples in the output the capacitor 'c' is used in the filter circuit is quite large of the order of tens of micro farads.

-> During the positive quarter cycle of the input signal the diode is forward biased this charges the capacitor to peak value of input that is V_m.

-> When the input starts decreasing below its peak value the capacitor remains charged at V_m and the ideal diode gets reverse biased. This is because the capacitor voltage which is cathode voltage of diode becomes more positive than anode.

->So, during the entire negative half cycle and some part of ~~the~~ positive half cycle, capacitor discharges through R_L.

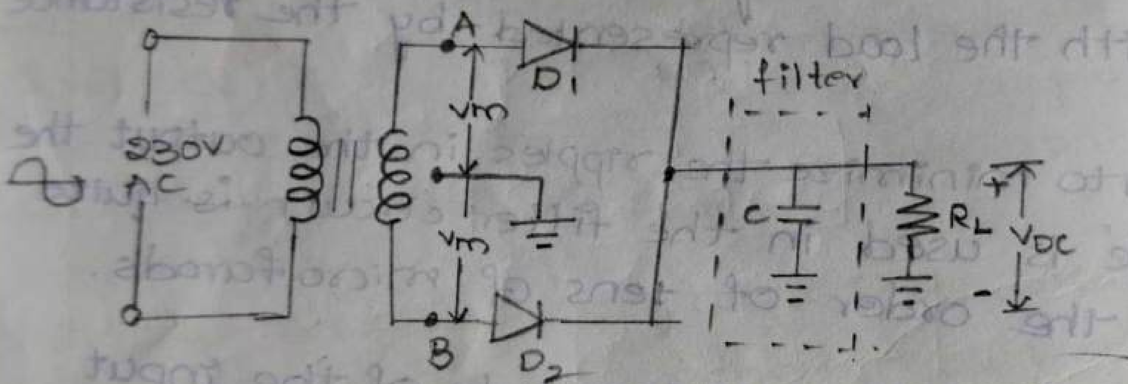
→ The discharging of capacitor is decided by $R_L \times C$ time constant which is very large and hence capacitor discharges very little from Vm.

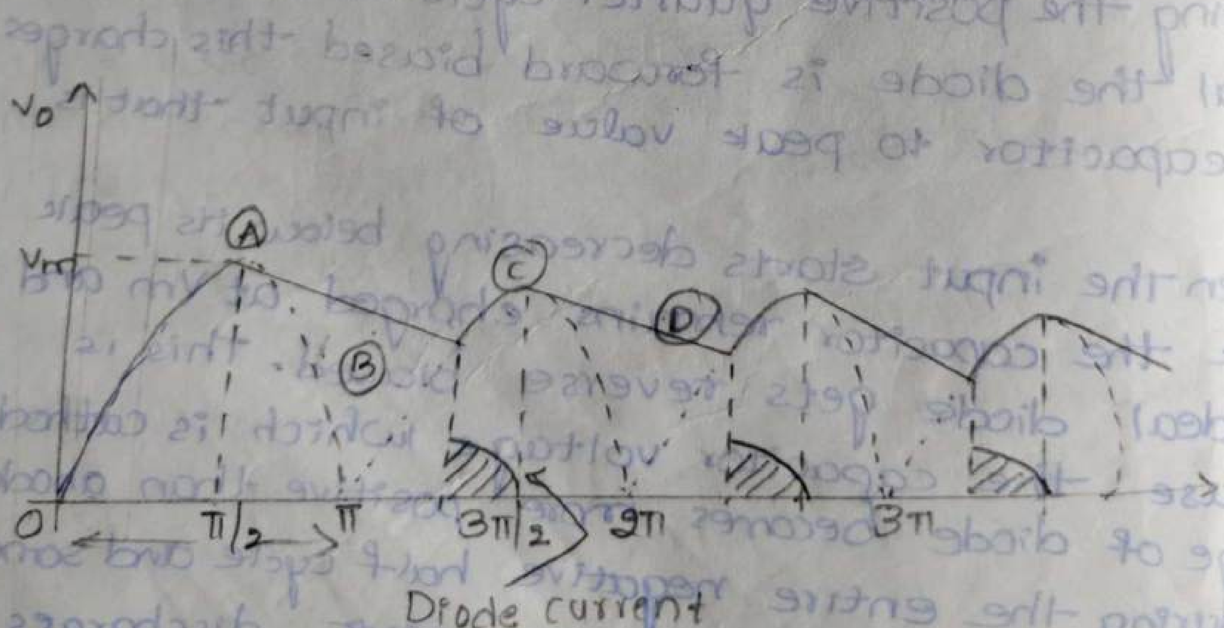
→ In the next positive half cycle when voltage source Vs becomes more than capacitor voltage the diode becomes forward biased and charges the capacitor C back to Vm.

→ The capacitor voltage is same as the output voltage as it is in parallel with R_L. It can be seen that the diode conducts only from point B till capacitor gets charged back to Vm. Thus, diode conducts only for part of positive half cycle.

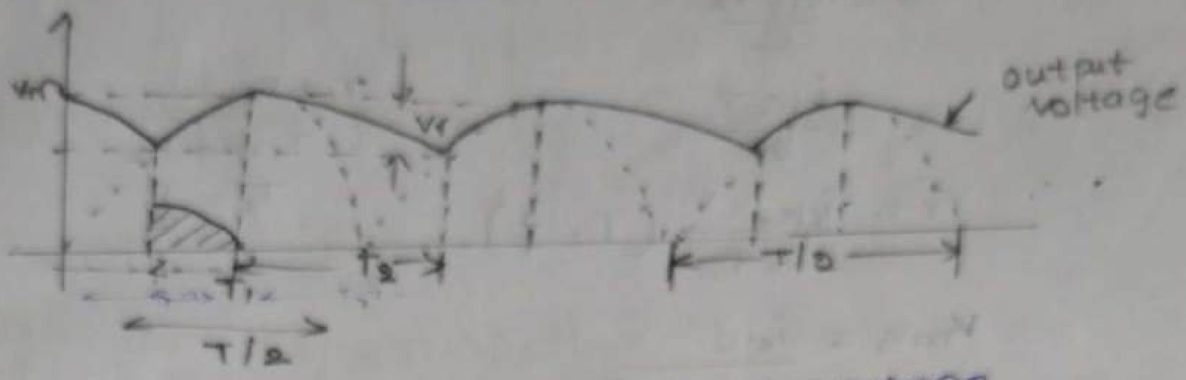
→ From point A to B the diode remains non conducting and conducts only for the period from B to C.

Full wave rectifier with capacitor filter:-





Expression for ripple factor :-



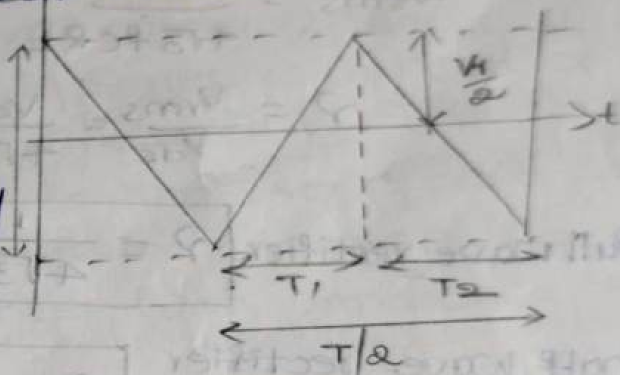
T = Time period of the ac input voltage

T/2 = Half of the time period

T_1 = Time for which diode is conducting

T_2 = Time for which diode is non conducting

Let V_r be the peak to peak value of ripple voltage which is assumed to be triangular as shown in fig.



→ It is known mathematically that the rms value of such a triangular wave form,

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

→ During the time interval t_2, the capacitor 'c' is discharging through the load resistance R_L. The charge lost is

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

$$i = \frac{dQ}{dt}$$

$$Q = \int_0^{t_2} i\, dt$$

$$Q = i_{dc}\,[t]_0^{T_2}$$

$$Q = i_{dc} T_2 \rightarrow (3)$$

$$C \cdot V_r = i_{dc} T_2$$

$$V_r = \frac{i_{dc} T_2}{C}$$

$$= \frac{i_{dc} T}{2C}$$

$T_1 + T_2 = \frac{T}{2}$

$T_1 << T_2$

$T_2 = \frac{T}{2}$

$$V_r = \frac{i_{dc} \times 1}{2Cf} \quad (T = \frac{1}{f})$$

$$V_{rms} = \frac{i_{dc}}{2fC \times 2\sqrt{3}}$$

$$V_{rms} = \frac{i_{dc}}{4\sqrt{3} fC}$$

We know, $\boxed{i_{dc} = \frac{V_{dc}}{R_L}}$

$$V_{rms} = \frac{V_{dc}}{4\sqrt{3} fC R_L}$$

$$\gamma = \frac{V_{rms}}{V_{dc}} = \frac{V_{dc}}{4\sqrt{3} fC R_L V_{dc}}$$

For full wave rectifier $\boxed{\gamma = \frac{1}{4\sqrt{3} fC R_L}}$

For half wave rectifier $\boxed{\gamma = \frac{1}{2\sqrt{3} fC R_L}}$

→ From the expression of the ripple factor it is clear that increasing the value of the capacitor 'c' the ripple factor gets decreased.

→ Thus, the output can be made smoother reducing the ripple content by selecting large value of capacitor

Inductor filter or Choke filter:-

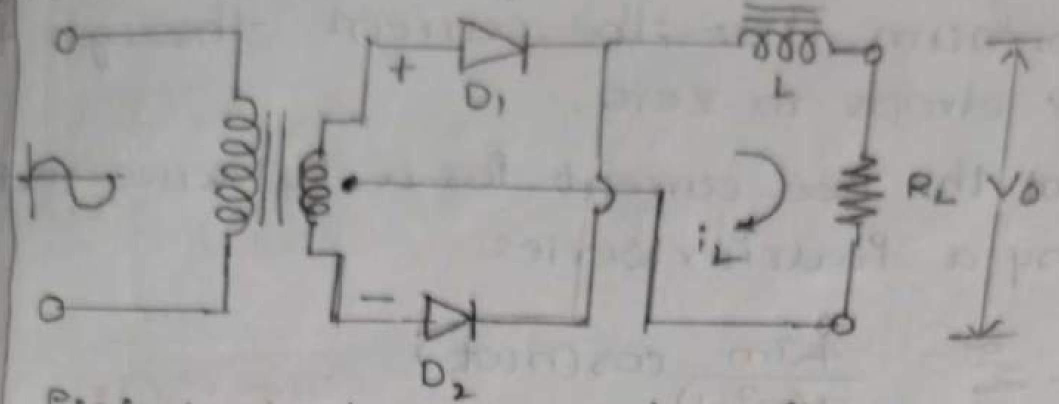


fig: circuit diagram of choke filter

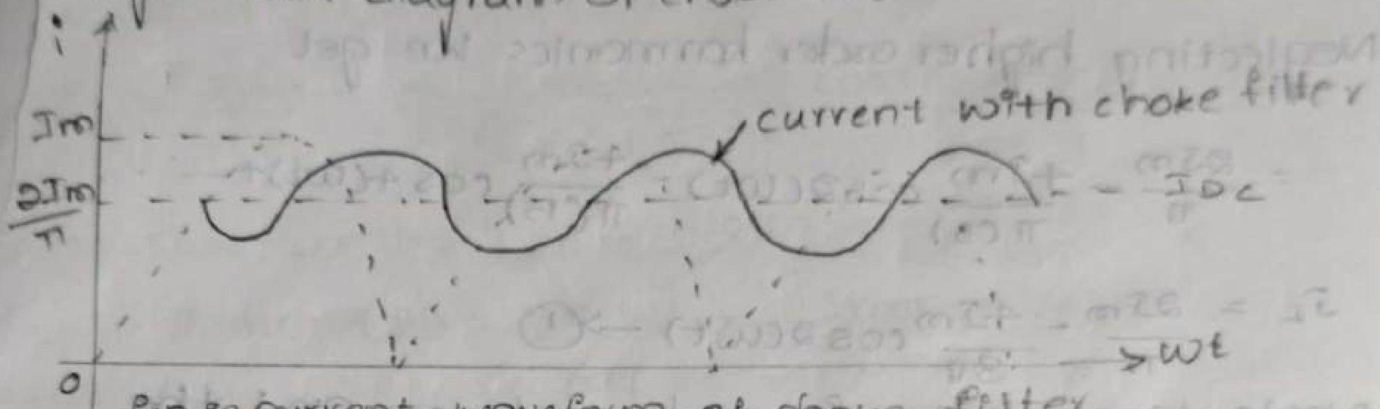


fig 2 current waveform of choke filter

→ An inductor is connected in series with load of the rectifier it is also called as choke filter. The fundamental property of an inductor is that to oppose any changes in the current passing through it. Thus an inductor presence high impedance to ac and none to DC.

→ The inductor stores energy in it as magnetic field when the current is above its average value and delivers that energy to the circuit, when the current tends to fall below the average value.

→ Thus, it reduces the pulsation of the rectifier output.

→ As shown in fig 2 when output tends to size above the average value magnetic energy is stored in the inductor which has the effect of toning ~~down~~ smothening the sudden raise in current. However, when current tends to fall below the average value. This stored energy is returned to circuit

→ In this way the current variations are reduced to the minimum. Thus the current through the load never drops to zero.

We know that the load current for a full wave rectifier is given by a fourier series

$$I_L = \frac{4I_m}{2\pi} - \sum_{n=2,4,6\ldots}^{\infty} \frac{4I_m}{\pi(n^2-1)} \cos(n\omega t)$$

Neglecting higher order harmonics we get

$$= \frac{2I_m}{\pi} - \frac{4I_m}{\pi(3)} \cos 2(\omega t) - \frac{4I_m}{\pi(15)} \cos 4(\omega t) + \ldots$$

$$I_L = \frac{2I_m}{\pi} - \frac{4I_m}{3\pi} \cos 2(\omega t) \rightarrow 1$$

Neglecting diode forward resistances and the resistance of choke and transformer secondary, we can write the dc component of current as

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

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

$$R_f + R_s << R_s$$

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

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

→ While the second harmonic component represents ac components or ripple presence can be written as

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

$$Z = R_L + j2X_L$$

$X_L = 2\pi f L$

$X_L = \omega L$

$Z = \sqrt{R_L^2 + (2X_L)^2}$

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

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

Hence equation ① modified as

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

Expression for the ripple factor :-

$$\text{Ripple factor } (\gamma) = \frac{V_{rms}}{V_{dc}} \text{ or } \frac{I_{rms}}{I_{dc}}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}} \qquad I_{rms} = \frac{I_m}{\sqrt{2}}$$

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

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

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

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

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

→ Initially, on no load condition $R_L \rightarrow \infty$ and hence $\frac{4\omega^2 L^2}{R_L^2} \rightarrow 0$ $\gamma = \frac{2}{3\sqrt{2}\sqrt{1}}$ $\gamma = 0.472 \Rightarrow 47.1\%$

→ This is very close to normal full wave rectifier without filtering.

→ But as load increases, R_L decreases hence $\frac{4\omega^2 L^2}{R_L^2} >> 1$ so neglecting one we get,

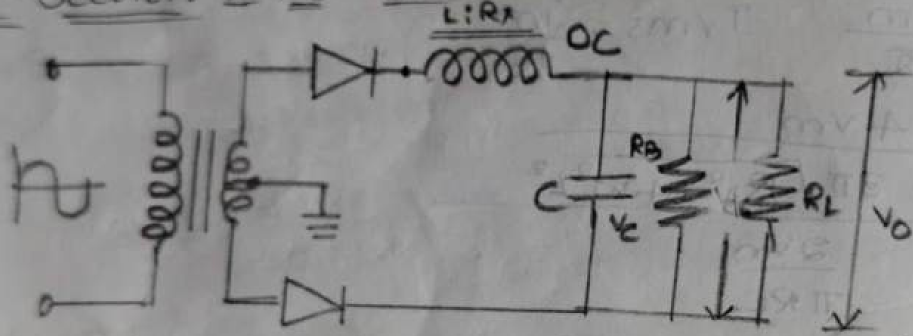
$$= \frac{2}{3\sqrt{2}\sqrt{\frac{4\omega^2 L^2}{R_L^2}}} = \frac{2}{3\sqrt{2}\frac{2\omega L}{R_L}}$$

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

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

→ So as load changes, ripple changes which is inversely proportional to the value of the inductor.

L - Section or LC filter:-



L : Short - DC
Open - AC

C : Short AC
Open DC

→ The dc winding resistance of the choke is R_x. The circuit is also called L-type filter or LC filter. The basic requirement of this filter circuit is that the current through choke must be continuous and not interupted.

→ An interupted current through choke may develop a large back emf which may be in excess of PIV rating of the diodes and maximum voltage rating of capacitor C.

→ Thus, this back emf is harmful to the diodes and capacitor. To eleminate the back emf developed across the choke, the current through it must be maintained continuous.

→ This is assumed by connecting a bleeder resistance R_B across the output terminals.

Bleeder resistance:-

→ In electronic's a bleeder resistor is a safety discharged resistor. It is a resistor connected in parallel with output of high voltage power supply. the electric circuit for the purpose of discharging the electric charge stored in the power supplies.

Expression for ripple factor:-

We know that the load current for a full wave rectifier is given by fourier series

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

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

$$I_m = \frac{V_m}{R_x + R}$$

$$R = R_B \parallel R_L$$

$$\boxed{R = \frac{R_B \cdot R_L}{R_B + R_L}}$$

$$I_{dc} = \frac{2 \cdot V_m}{\pi(R_x + R)}$$

$$V_{dc} = I_{dc} \times R$$

$$= \frac{2V_m}{\pi(R_x+R)} \times R$$

$$= \frac{2V_m}{\pi R} \times R \quad (\because R_x << R)$$

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

$$I_{ac} = \frac{V_{ac}}{Z}$$

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

$$I_{ac} = \frac{4V_m}{3\pi(X_L+X_C)}$$

$$I_{ac} = \frac{4V_m}{3\pi X_C\left(\frac{X_L}{X_C}+1\right)}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}} \quad \text{or} \quad I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$I_{ac} = \frac{4V_m}{3\sqrt{2}\pi X_C\left(\frac{X_L}{X_C}+1\right)}$$

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

$$= \frac{4V_m}{3\sqrt{2}\pi \cancel{X_C}\left(1+\frac{X_L}{X_C}\right)} \times \cancel{X_C}$$

$$\boxed{V_{rms} = \frac{4V_m}{3\sqrt{2}\pi\left(1+\frac{X_L}{X_C}\right)}}$$

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

$$\gamma = \frac{\frac{4V_m}{3\sqrt{2}\pi\left(1+\frac{X_L}{X_C}\right)}}{\frac{2V_m}{\pi}} = \frac{2}{3\sqrt{2}\left(1+\frac{X_L}{X_C}\right)} = \frac{2}{3\sqrt{2}\left(\frac{X_L}{X_C}\right)}$$

$$\frac{X_L}{X_C} >> 1$$

$x_L = 2\omega L$; $x_C = \frac{1}{2\omega C}$

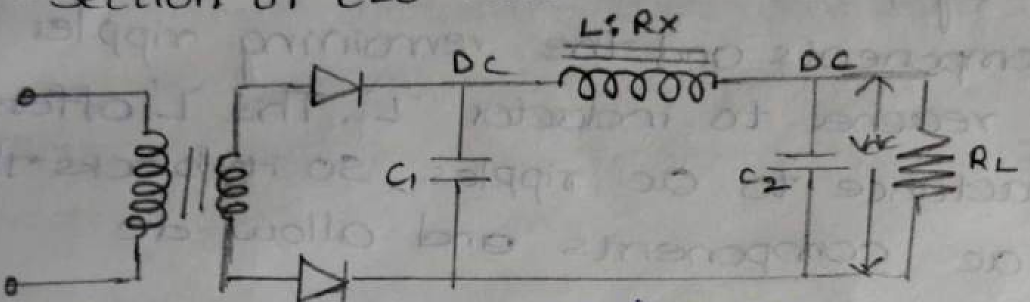
$$\gamma = \frac{2X_C}{3\sqrt{2}\,X_L}$$

$$\gamma = \frac{2}{3\sqrt{2}} \times \frac{1}{2\omega L \times 2\omega C}$$

$$\boxed{\gamma = \frac{1}{6\sqrt{2}\,\omega^2 LC}}$$

→ It is seen that ripple factor for choke L-section filter does not depend upon the load resistance unlike the capacitor input filter.

π - Section or CLC filter :-



L : Short DC
Open AC

C : Short AC
open DC

$$\gamma_{\pi.section} = \gamma_{capacitor} \cdot \gamma_{L-section}$$

$$= \frac{1}{4\sqrt{3}\,fC_1R_L} \times \frac{1}{6\sqrt{2}\,\omega^2 LC_2}$$

$$= \frac{\pi}{2\sqrt{3}\,2\pi f C_1 R_L} \times \frac{1}{6\sqrt{2}\,\omega^2 LC_2}$$

$$= \frac{\pi}{2\sqrt{3}\,\omega C_1 R_L} \times \frac{1}{6\sqrt{2}\,\omega^2 LC_2}$$

$$= \frac{\pi}{12\sqrt{6}\,\omega^3 C_1 C_2 R_L \cdot L}$$

$$= \frac{0.106}{\omega^3 C_1 C_2 L R_L}$$

→ It consists of Inductor L and two capacitors C_1 & C_2 these components are arranged in the form greek

letter 'π', hence the name π-section. In other words
a shunt capacitor filter is added to L-section
filter to from the π-section filter.
→ The π-section filter provides an output voltage that
approaches the peak value of the ac potential of
the supply, the ripple components being very small.
→ As we discussed in the previous section, the rectified
output is given to the filter in this case that is
to the capacitor C_1 followed by L-section (LC_2)
the capacitor C_1 offers very low reactance to the
ripples and by passes most of them.
→ The DC components and the remaining ripples
then ranges reaches to inductor 'L'. This 'L' offers
very high reactance to ac ripples, so it blocks the
maximum ac components and allow dc
components.
→ The remaining small amount ac ripples and dc
then reaches to the capacitor C_2 and it by passes
almost all the ripple and supplies almost pure
dc to the load R_L.
→ Thus, π-section filter produces a unidirectional
output voltage across the load R_L with negligible
ripples.

Clipper circuits are limiters:-

→ The basic action of clipper circuit is to remove the
certain portion of the wave form above or below
the certain level as per the requirements.
→ The circuits which are used to clip off unwanted
portion of the wave form, without distorting the
remaining port of the wave form are called
clipper circuits or clippers.

> The halfwave rectifier is the best and simplest type of clipper circuit which clips off the negative portion of input signal by changing the orientation of the diode in the circuit positive or negative portion of input signal can be clipped off.

> The clipper circuits are also called limiters or slicers.

> The clipper circuits are mainly classified depending upon the orientation of the diode in the circuit.

Clippers:- The circuit which removes a portion of input signal without distorting the remaining part of the input waveform is called clipper.

> clipper circuits are also reffered to as amplitude selector (or) voltage limiter

Clippers

- Unbiased clipper
  - Unbiased Series clipper
    - Unbiased Series Positive clipper
    - Unbiased Series Negative clipper
  - Unbiased shunt clipper
    - Unbiased shunt positive clipper
    - Unbiased shunt Negative clipper
- Biased clipper
- combination (or) Double ended clipper

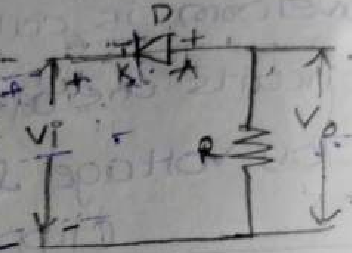
Biased clipper

- Biased series clipper
  - Biased series +ve clipper with +ve reference
  - Biased series +ve with -ve reference
  - Biased series -ve with +ve reference
  - Biased series -ve with -ve reference
- Biased shunt clipper
  - Biased shunt +ve clipper with +ve reference
  - Biased shunt +ve with -ve reference
  - Biased shunt -ve with +ve reference
  - Bi[ased] sh[unt] -v[e] wi[th] -v[e] ref[erence]

unbiased clippers:-

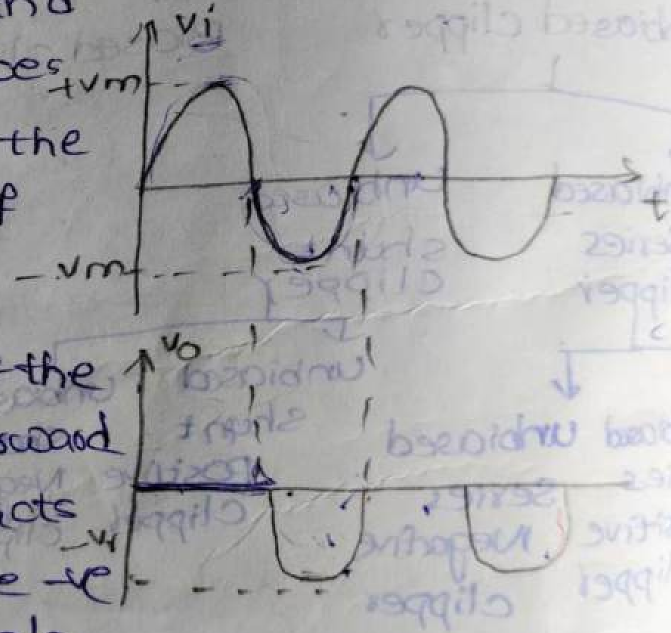
unbiased +ve clippers:-

1) unbiased series diode +ve clipper:-



→ During the +ve half cycle of the i/p voltage, the diode is reverse biased and does not conduct and acts as an open circuit and hence the +ve half cycle does not appear at the o/p. i.e the +ve half cycle is clipped off

$\boxed{i.e,\ V_0 = 0}$



→ During the -ve half cycle of the i/p voltage the diode is forward biased and conduct so it acts as a closed switch & hence -ve half cycle appears at the o/p.

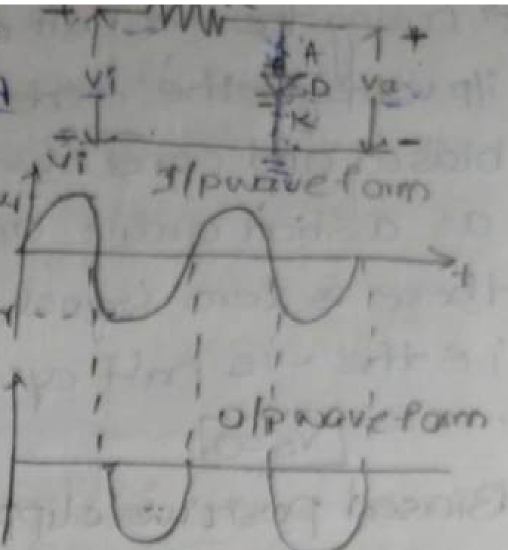
$\boxed{V_0 = V_i}$

2) unbiased shunt diode +ve clipper:-

→ During the +ve half cycle of the i/p voltage diode is Fw biased and conducts and acts as short ckt and hence there is zero signal at the o/p. i.e +ve half cycle is clipped off. $\boxed{V_0 = 0}$

→ During the -ve half cycle of the i/p voltage, the diode is reverse biased and does not conduct and acts as an open switch and hence negative half cycle appears at the o/p

$\boxed{V_0 = V_i}$

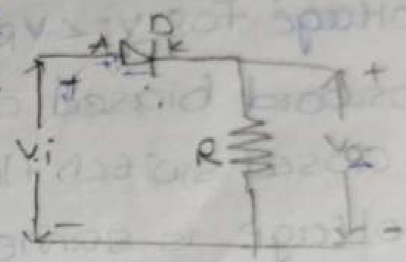


unbiased -ve clippers:-

Series diode -ve clipper:-

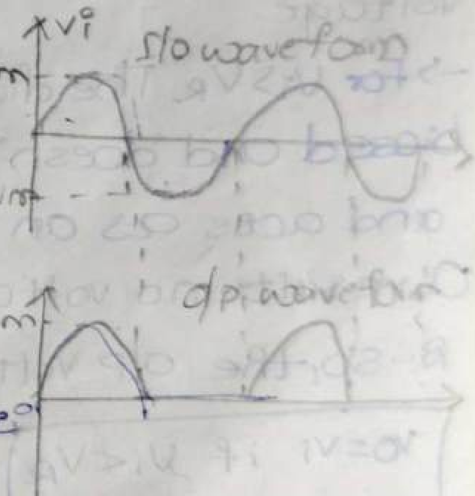
→ During the +ve half cycle of i/p voltage the diode is f.w biased and conducts so it acts as closed switch & hence +ve half cycle appears at the o/p.

$\boxed{V_0 = V_i}$



→ During the -ve half cycle of the i/p voltage the diode is reverse biased and doesn't conducts. so it acts as open switch and hence negative half cycle will not appear at the o/p i.e the negative half cycle is clipped off

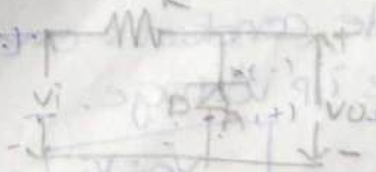
$\boxed{V_0 = 0}$



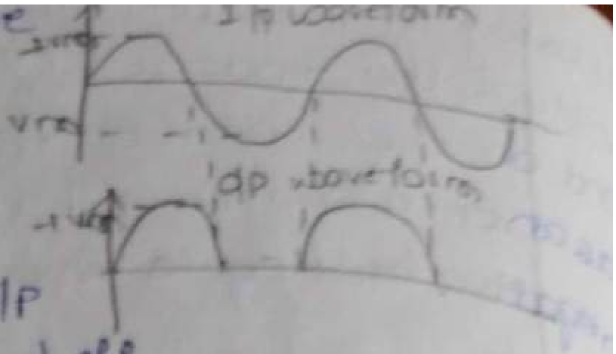
Shunt diode -ve clipper:-

→ During the +ve half cycle of the i/p voltage, the diode is reverse biased and doesn't conduct and acts as an open ckt. So, the +ve half cycle of the i/p voltage appears as the o/p.

$\boxed{V_0 = V_i}$



→ During the -ve half cycle of the i/p voltage, the diode is f.ω biased and conducts and acts as a short circuit and hence there is zero signal at the o/p i.e the -ve half cycle is clipped off

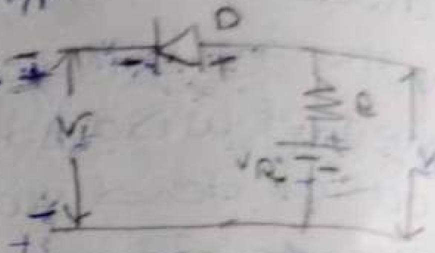


$\boxed{V_o = 0}$

Biased positive clippers:-

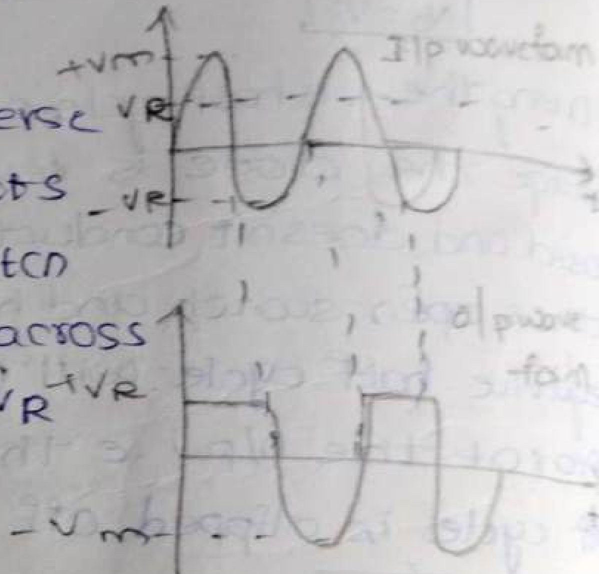
Series diode positive clipper:- with +ve reference

→ During the +ve halfcycle of the i/p voltage for $V_i < V_R$ the diode is forward biased and acts as a closed switch Hence the o/p voltage is same as the i/p voltage.



→ For $V_i > V_R$ The diode is reverse biased and doesn't conducts and acts as an open switch

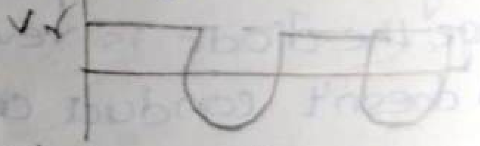
A result no voltage drop across R. so, the o/p voltage $V_o = V_R$



$$\boxed{\begin{array}{l} V_o = V_i \text{ if } V_i < V_R \\ V_o = V_R \text{ if } V_i > V_R \end{array}}$$

During the -ve half cycle of the i/p voltage, the diode conducts and hence o/p voltage is same as the i/p voltage.

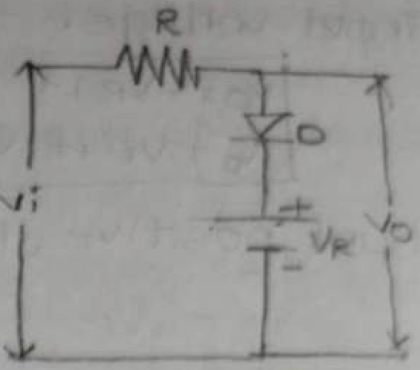
$\boxed{V_o = V_i}$



Shunt diode positive clipper with +ve reference:-

→ During the +ve half cycle of the i/p voltage for $V_i < V_R$ the diode is reverse biased and doesn't conducts and acts as open switch hence the o/p voltage same as the i/p voltage.

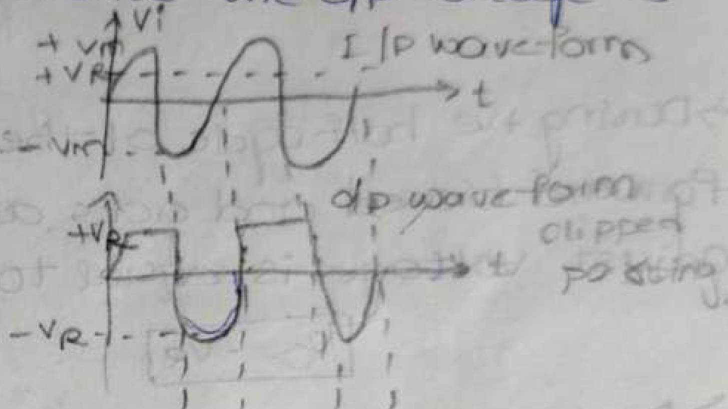
For $V_i > V_R$ the diode is forward biased and conducts and output remains at V_R until the V_i becomes less than V_R



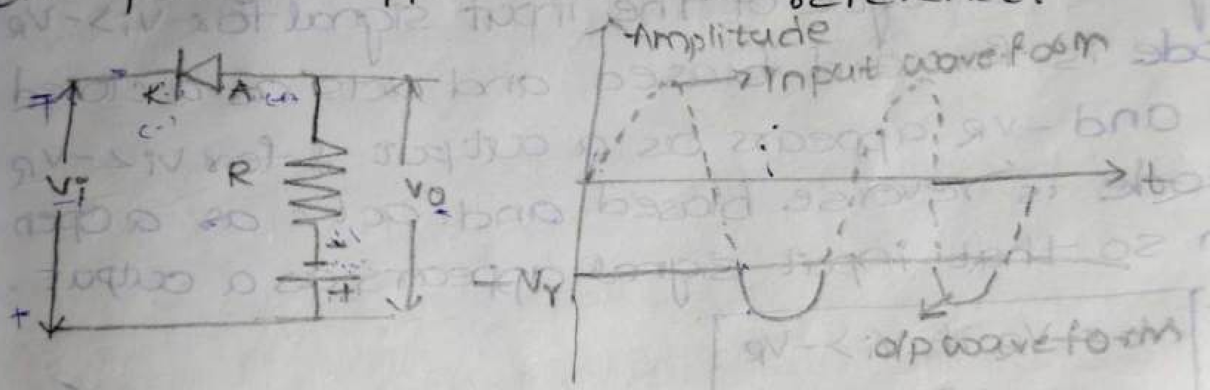
$$\boxed{\begin{array}{l} V_o = V_R \text{ if } V_i > V_R \\ V_o = V_i \text{ if } V_i < V_R \end{array}}$$

During the -ve half cycle of the i/p voltage the diode is reverse biased and does not conducts and acts as open switch and hence the o/p voltage is same as the i/p voltage.

$\boxed{V_o = V_i}$



Series positive clipper with -ve reference:-



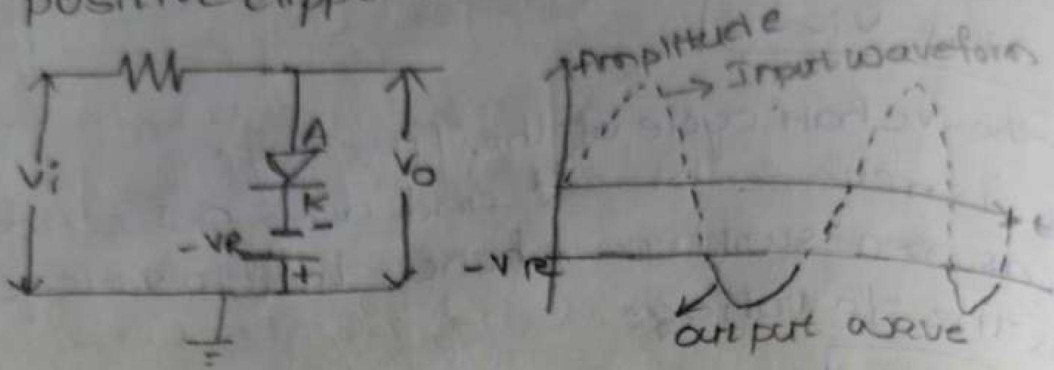
→ During +ve half cycle of the i/p signal the diode is reverse biased and acts as an open switch as a result no voltage appears across load resistor and output voltage V_o is equal to $-V_R$

$\boxed{V_o = -V_R}$

→ During -ve half cycle of the i/p signal for $V_i > -V_R$ the diode is reverse biased and doesn't conducts and output voltage is equivalent to $-V_R$ and for $V_i < -V_R$ the diode is forward biased and acts as a closed switch so that output voltage is same as input voltage.

$$\boxed{\begin{array}{l} V_0 = -V_R \text{ if } V_i > -V_R \\ V_0 = V_i \text{ if } V_i < -V_R \end{array}}$$

Shunt positive clipper with -ve reference



→ During +ve half cycle of the input signal the diode is forward biased and acts as a closed switch so, that adjust voltage is equal to reference voltage

$$\boxed{V_0 = -V_R}$$

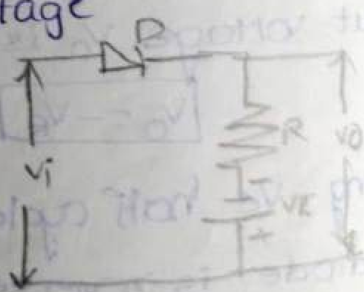
→ During -ve half cycle of the input signal for $V_i > -V_R$ the diode is forward biased and acts as a closed switch and $-V_R$ appears as a output & for $V_i < -V_R$ the diode is reverse biased and acts as a open switch so that input signal appears as a output

$$\boxed{\begin{array}{l} V_0 = -V_R \text{ if } V_i > -V_R \\ V_0 = V_i \text{ if } V_i < -V_R \end{array}}$$

Biased Negative clippers:-

Series diode negative clipper with -ve reference:

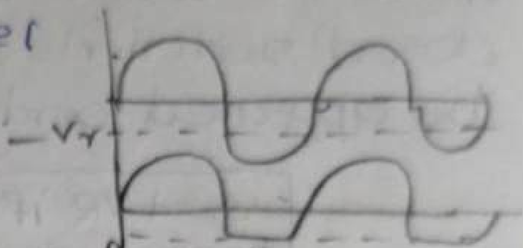
→ During the +ve half cycle of the i/p voltage the diode is forward biased and conducts and hence o/p voltage is same as the i/p voltage



$$\boxed{V_0 = V_i}$$

→ During the -ve half cycle of the i/p voltage for $V_i > V_R$ the diode is forward biased and acts as a closed switch. Hence the o/p voltage is same as the i/p voltage. For $V_i < V_R$ the diode doesnot conduct so the o/p voltage is at $-V_R$ level

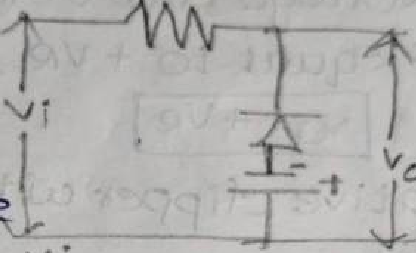
$$\boxed{\begin{array}{l} V_o = V_i \text{ for } V_i > -V_R \\ V_o = -V_R \text{ for } V_i < -V_R \end{array}}$$



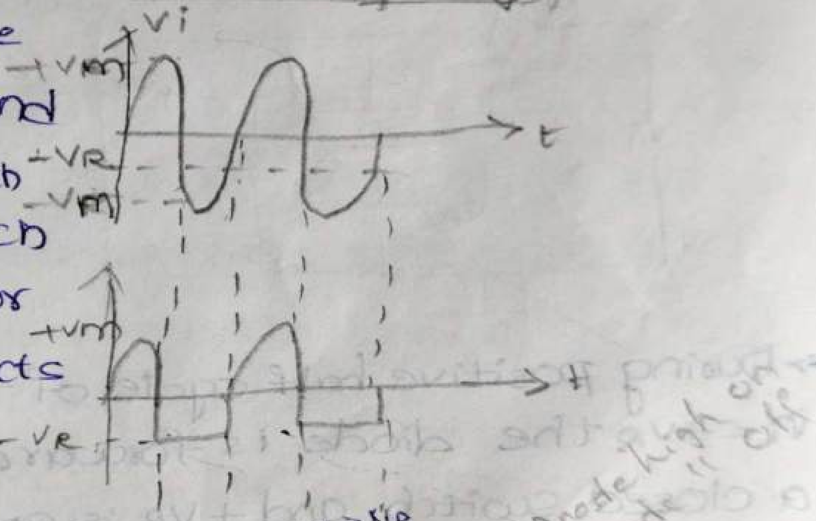
Shunt diode Negative clipper with -ve reference

→ During the +ve half cycle of the i/p voltage the diode is reverse biased and doesn't conducts and acts as open switch and hence the o/p is same as i/p voltage

$$\boxed{V_o = V_i}$$

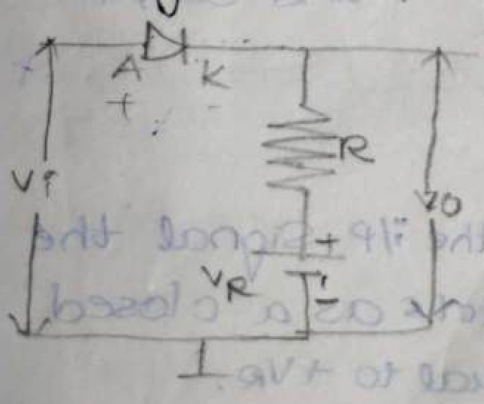


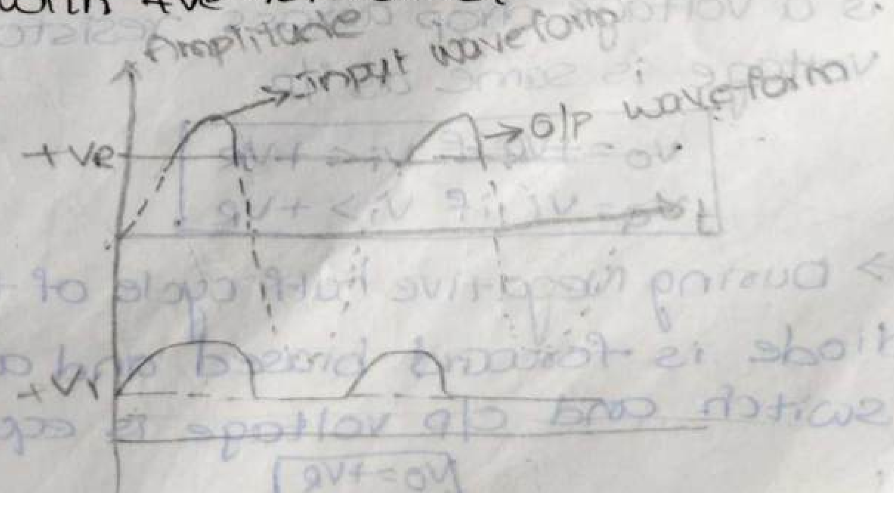
→ During the -ve half cycle of the i/p voltage for $V_i > -V_R$ the diode doesn't conduct and it acts as an open switch so, the o/p voltage switch is same as i/p voltage. For $V_i < -V_e$ the diode conducts and at $-V_R$ level.



$$\boxed{\begin{array}{l} V_o = V_i \text{ For } V_i > -V_R \\ V_o = -V_R \text{ For } V_i < -V_R \end{array}}$$

Series Negative clipper with +ve reference :-





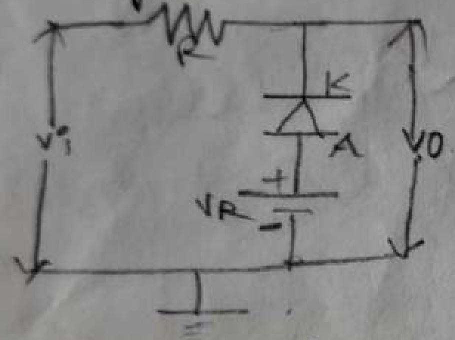
→ During +ve halfcycle of the i/p signal for $V_i < V_R$ the diode is reverse biased and acts as a open switch so that output voltage is equal $\boxed{\text{to} +V_R}$ and for $V_i > V_R$ the diode is forward biased and acts as closed switch. As a result voltage drop across R will be appeared and output voltage $\boxed{V_0 = V_i}$

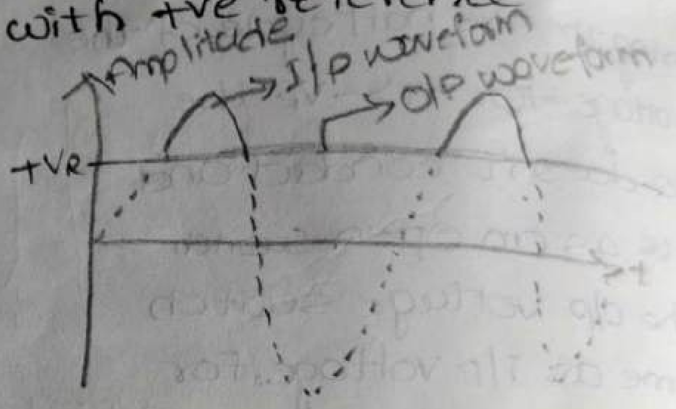
$$\boxed{\begin{matrix} V_0 = +V_R \text{ if } V_i < V_R \\ V_0 = V_i \text{ if } V_i > V_R \end{matrix}}$$

→ During -ve half cycle of the i/p signal the diode is reverse biased and acts as a open switch as a result no voltage drop across Resistor R. So, the output voltage is equal to $+V_R$.

$$\boxed{V_0 = +V_R}$$

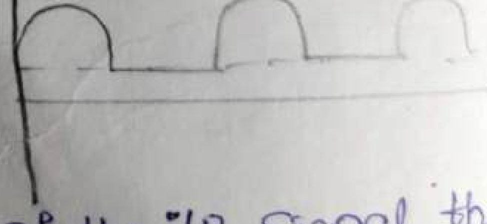
(2) Shunt Negative clipper with +ve reference





→ During positive half cycle of the input signal for $V_i < +V_R$ the diode is forward biased and acts as a closed switch and $+V_R$ is appears as output and for $V_i > +V_R$ the diode is reverse biased and there is a voltage drop across resistor R and output voltage is same as i/p.

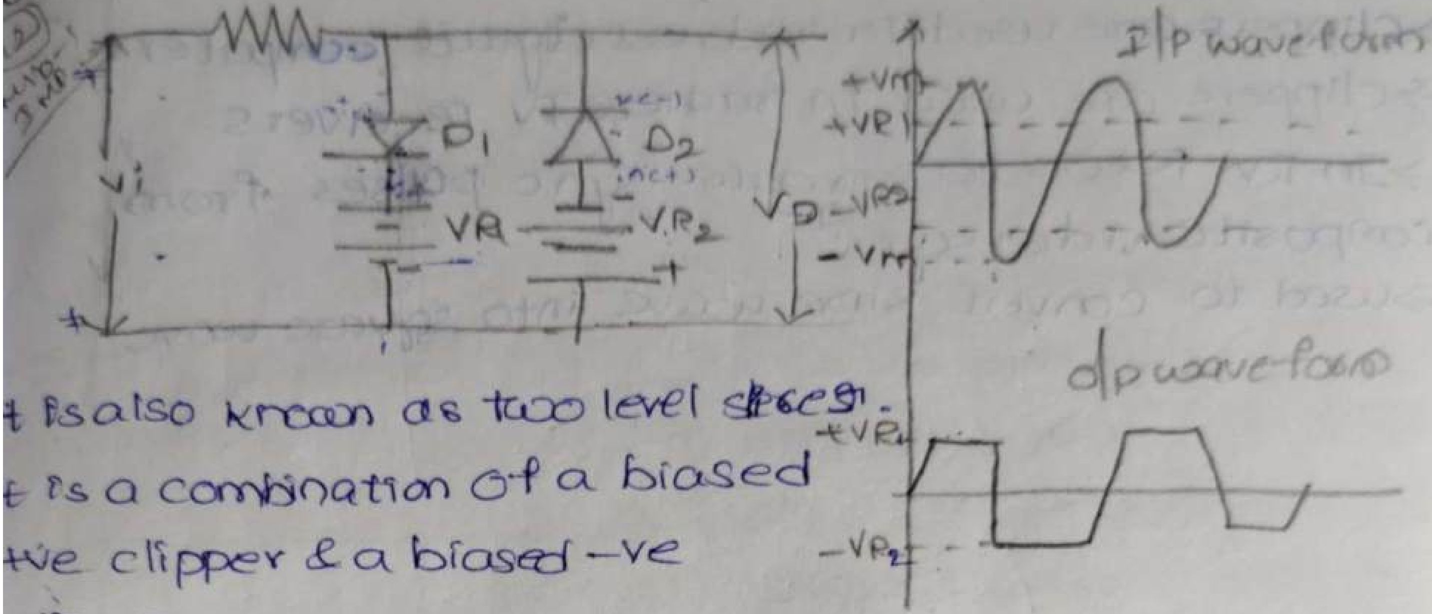
$$\boxed{\begin{matrix} V_0 = +V_R \text{ if } V_i < +V_R \\ V_0 = V_i \text{ if } V_i > +V_R \end{matrix}}$$



→ During Negative half cycle of the i/p signal the diode is forward biased and acts as a closed switch and o/p voltage is equal to $+V_R$.

$$\boxed{V_0 = +V_R}$$

Double ended clipper (or) Two level clipper:



It is also known as two level slicer.

It is a combination of a biased +ve clipper & a biased -ve clipper.

During the +ve half cycle of the i/p voltage, the diode D_2 is reverse biased & acts as open switch.

→ The Diode D_1 conducts for $V_i > +V_{R1}$ and acts as closed switch and o/p voltage is at $+V_{R1}$ level. If the i/p voltage $V_i < +V_{R1}$, the diode D_1 doesn't conduct & act as open switch so, the o/p voltage is same as i/p voltage. Hence, the o/p voltage V_o can't exceed the voltage level at $+V_{R1}$ during the half cycle.

ii) During the -ve half cycle of the i/p voltage, the Diode D_1 is R.B & acts as an open switch

If the i/p voltage $V_i < -V_{R2}$ the Diode D_2 conducts and acts as closed switch. So, the o/p voltage is at $-V_{R2}$ level. When the i/p voltage $V_i > -V_{R2}$ and Diode D_2 doesn't conduct and acts as an open switch. So, the O/P voltage is same as the i/p voltage. Hence, the o/p voltage V_o can't go below the voltage level of $-V_{R2}$ during the -ve half cycle.

→ The clipping levels may be changed by varying the values of V_{R1} & V_{R2}

Applications of clipper:-

→ Clippers are used in radars & digital computers.
→ clippers are used in radio & Tv receivers
→ In T.v Rxers to separate sync pulses from composite video sgl.
→ used to convert sine wave into square wave.

+ve half cycle

$V_{in} > +V_R \quad V_o = V_{r1}$

$V_{in} < +V_R \quad V_o = V_{in}$

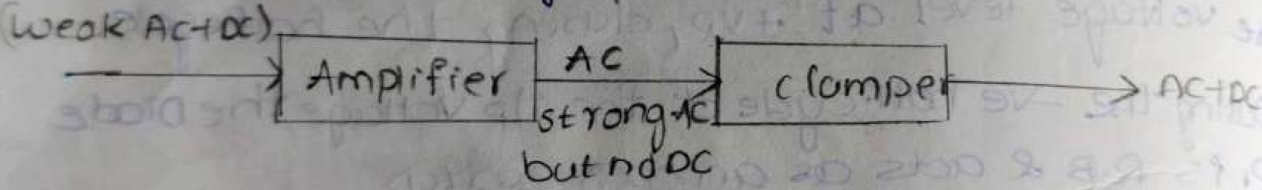
-ve half cycle

$V_{in} > -V_{r2}, V_o = V_{in}$

$V_{in} < -V_{r2}, V_o = -V_2$

06/06/2023

Clampers:- A circuit which adds DC value to an ac wave form without changing its shape. It is used to re-insert dc voltage level into an ac waveform, which has lost its dc by passing through the an electronic processing circuit such as amplifier.



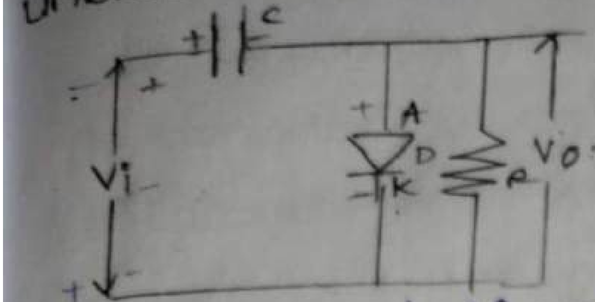
Types of clampers:-

1. +ve clamper — Biased / unbiased
2. -ve clamper — Biased / unbiased

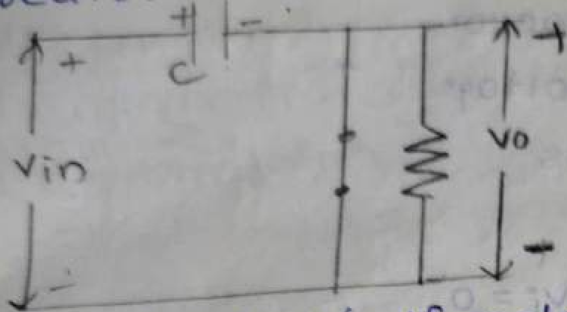
+ve clamper:- A positive clamper circuit is one that converts a diode, a resistor and a capacitor and that shifts the output signal to positive portion of the input signal.

-ve clamper:- A Negative clamper circuit is one that converts of a diode, a resistor and a capacitor and that shifts the output signal to negative portion of the input signal.

Unbiase...

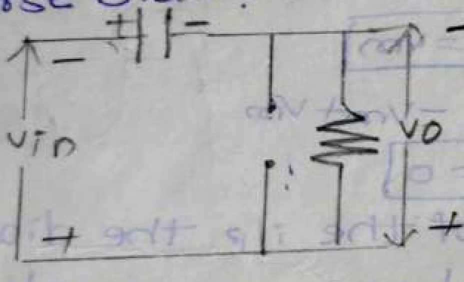


→ During the +ve half cycle : at that instant the diode is forward biased and acts as short circuit or closed circuit. Below The circuit is shown as below fig.



→ During the +ve half cycle the capacitor charges very fastly to the applied input voltage so the output voltage $V_o = 0$.

→ During the −ve half cycle : at this instant the diode is reverse bias and acts as open circuit as shown in fig.



Apply KVL to the circuit to get Vout

$-V_i - V_c + V_o = 0$

$V_o = V_{in} + V_c$

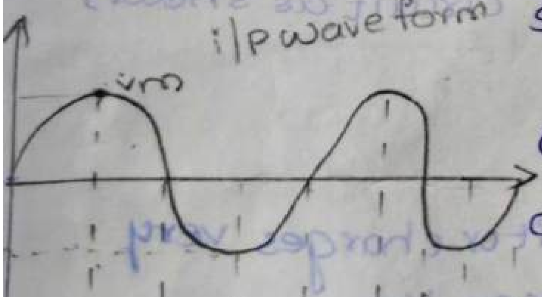
Substitue $V_c = -V_m$,

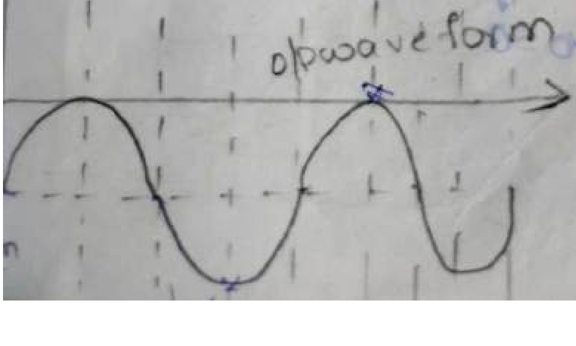
$V_o = V_{in} - V_m$

case i : $V_{in} = 0 \rightarrow V_o = -V_m$

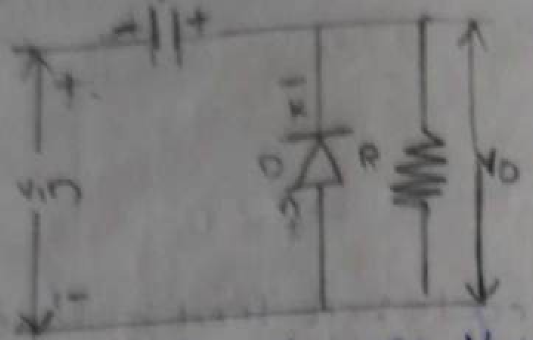
case ii : $V_{in} = -V_m \rightarrow V_o = -2V_m$

case iii : $V_{in} = V_m \rightarrow V_o = 0$



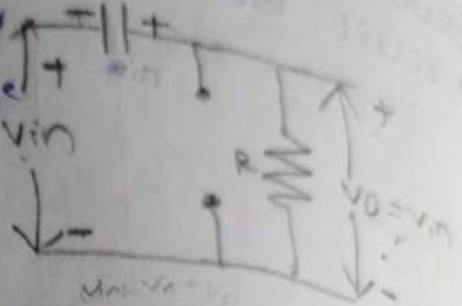


Unbiased +ve clamper:



→ During positive half cycle: At this instant the diode Reverse biased and acts as open circuit

→ During +ve half cycle the capacitor discharges to the applied voltage so output voltage $V_o = V_{in}$ is given by



By KVL ~~Vin - Vc~~ $V_m - V_o + V_i = 0$

To get o/p voltage Apply KVL to the circuit.

$\boxed{V_o = V_i + V_m}$

$V_i = V_m$; $V_o = V_m + V_m$

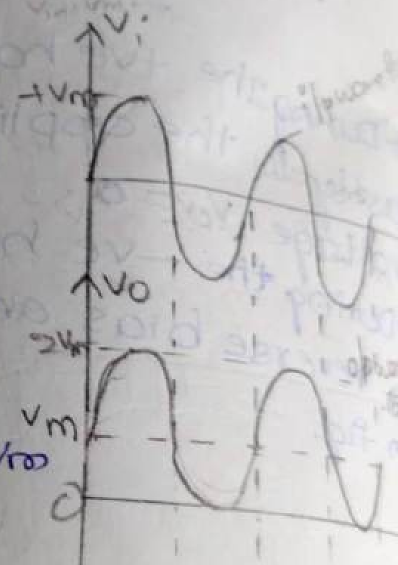
$\therefore \boxed{V_o = 2V_m}$

$V_i = 0$; $\therefore V_o = 0 + V_m$

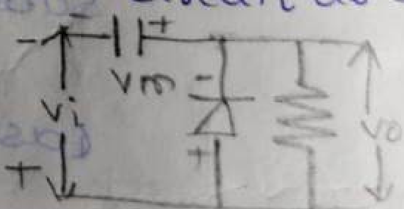
$\boxed{V_o = V_m}$

$V_i = -V_m$; $V_o = -V_m + V_m$

$\boxed{V_o = 0}$



→ During the -ve half cycle of the i/p the diode is forword bias and acts as short circuit as shown in below figure.



→ During the -ve half cycle the capacitor charges very partly to the applied ~~in~~ the voltage Vm

→ At this instant o/p voltage $V_o = 0$