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Unit-3:

Rectifiers And Filters:

For the operation of most of the electronic devices and circuit a DC source is required so it is advantageous to current Ac supply into DC voltage

The process of converting Ac voltage into DC Voltage is called as rectification.

This is achieved with the

1. Stepdown transformer
2. Rectifier
3. Filter / smoothing
4. Voltage regulator circuits.

230V Ac supply → Transformer → Rectifier → smoothing → Regulator → Regulated DC o/p

→ Transformer:

Stepdown 230V Ac supply to low voltage Ac ~~rectifier~~

→ Rectifier:

Converts Ac voltage to DC voltage but the output is varying

→ Filter.

Smooth the DC from varying greatly to small ripple regulator eliminates ripple by setting up DC output to a fixed value

→ P-N junction diode as a rectifier

A P-N junction diode is a two terminal device and it is polarity sensitive

When the diode is in forward bias then it Conducts and allows current to flow through it with-out any resistance, then the diode is in on state.

When the diode is in reverse bias then it does not conducts and no current flows through it then the diode is in off state

Thus, an ideal diode acts as a switch either open or close depending upon the polarity of voltage placed across it

Ideal diode has zero resistance under forward bias, and infinite resistance under reverse bias

Rectifier is defined as an electronic device used for converting AC voltage into ~~DC Voltage~~ Unidirectional voltage

A rectifier utilizes unidirectional conduction devices like a P-N diode

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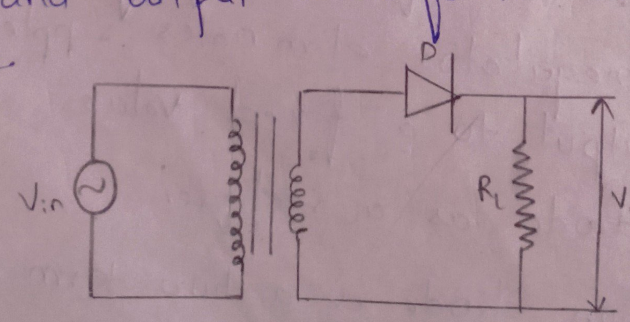
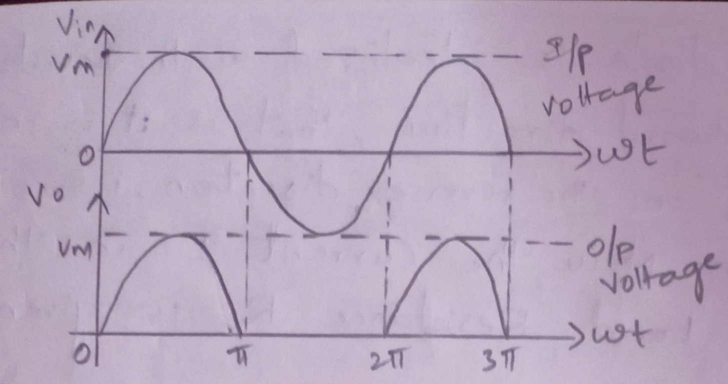
→ Half wave rectifier:

A half-wave rectifier is one which converts AC voltage ~~in~~ a pulssating voltage using only half cycle of the applied AC voltage

The basic half wave rectifier circuit along with its input and output wave forms is shown in below figure



Basic Circuit



The ac voltage to be rectified is applied to a single diode connected in series in a load resistor R_L when it is required to step up or step down the input voltage a power transformer is used ~~two~~

→ Working of half-wave rectifier:

For the positive half wave rectifier, the input ac voltage the diode D is in forward bias then it conducts. Now the current flows in the circuit and their is a voltage drop across R_L.

For the negative half cycles of input ac voltage the diode 'd' is in reverse bias then it does not conducts. Now no current flows in the circuit i.e, $I_d = 0$ and $V_d = 0$. Thus for the negative half cycle no power is delivered to the load

The output waveforms can be observed with the help of an ausilloscope by connecting it across the load resistor R_L.

Since Only half-cycles of input wave is used. So it is called as a halfwave rectifier.

Let a sinusoidal voltage (V_I) is applied to the input of the rectifier then $V_i = V_m \sin \omega t$ — (1)
where V_m is the maximum value of supply voltage

Let the diode is idealized with resistance R_f in the forward direction, That is, it is in 'ON' stage and R_r is in the reverse direction. i.e; it is in 'OFF' state. Now the current I in the diode or in the Load Resistance R_L is given by

$$i = I_m \sin\omega t \quad \text{for } 0 \leq \omega t \leq \pi \quad \text{— (2)}$$

$$i = 0 \quad \text{for } \pi \leq \omega t \leq 2\pi \quad \text{— (3)}$$

where $I_m = \dfrac{V_m}{R_f + R_L}$ — (4)

(i) The dc Output current :

– Average current I_{dc} is

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

$$I_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\omega t \,.\, d(\omega t) + \int_{\pi}^{2\pi} 0 \,.\, d(\omega t)\right]$$

$$I_{dc} = \frac{1}{2\pi}\left[I_m\left(-\cos\omega t\right)_0^{\pi}\right] = \frac{1}{2\pi}\left[I_m(1-(-1))\right]$$

$$I_{dc} = \frac{I_m}{\pi} = 0.318\, I_m \quad \text{— (5)}$$

Substituting the value of I_m,

we get $I_{dc} = \dfrac{V_m}{\pi(R_f + R_L)}$ — (6)

If $R_L >> R_f$ then,

$$\boxed{I_{dc} = \frac{V_m}{\pi R_L} = 0.318\frac{V_m}{R_L}} \quad \text{— (7)}$$

* The dc Output Voltage

The d.c Output voltage is given by

$$V_{dc} = I_{dc} \times R_L = \frac{I_m}{\pi} \times R_L \quad \text{— (8)}$$

$$= \frac{V_m \times R_L}{\pi(R_f + R_L)} = \frac{V_m}{\pi\left(1 + \frac{R_f}{R_L}\right)} \quad \text{— (9)}$$

if $R_L >> R_f$ then $\boxed{V_{dc} = \frac{V_m}{\pi} = 0.318\, V_m}$ — (10)

For a half-wave rectifier their is an output voltage for a period from 0 to π and their is no output for the period from π to 2π. The Average dc value of output voltage is given by V_{dc} =

$$V_{dc} = \frac{\text{area of the curve for full cycle}}{\text{base}}$$

$$V_{dc} = \int_0^{2\pi} \frac{V_i\, d(\omega t)}{2\pi} = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin \omega t\, d(\omega t)$$

$$V_{dc} = \frac{V_m}{2\pi}\left[-\cos\omega t\right]_0^{\pi} = \frac{V_m}{2\pi}\left[1-(-1)\right]$$

$$\boxed{V_{dc} = \frac{V_m}{\pi} = 0.318\, V_m}$$

(iii) Rms Current and Voltage:

The Value of Rms current is given by

$$I_{rms} = \left[\frac{1}{2\pi}\int_0^{2\pi} i^2\, d(\omega t)\right]^{1/2}$$

$$\therefore I_{rms} = \left[\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2 \omega t\, d(\omega t) + \frac{1}{2\pi}\int_{\pi}^{2\pi} 0 \cdot d(\omega t)\right]^{1/2}$$

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

$$= \left[\frac{I_m^2}{4\pi}\left\{(\omega t) - \frac{\sin 2\omega t}{2}\right\}_0^{\pi}\right]^{1/2}$$

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

$$I_{rms} = \frac{I_m}{2} \quad \text{— (11)}$$

$$I_{rms} = \frac{V_m}{2(R_f + R_L)} \quad \text{— (12)}$$

Rms voltage across the load is

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

(Or) $\boxed{V_{rms} = \frac{V_m}{2\left[1+\frac{R_f}{R_L}\right]}}$ — (13)

If $R_L >> R_F$ then $V_{rms} = \frac{V_m}{2}$ — (14)

→ Rectifier efficiency:-

The Rectifier efficiency is defined as the ratio of dc Output power to the ac input power. It should be represented with η (eta)

$$\eta = \frac{\text{dc power delivered to the load}}{\text{ac power input power from secondary transformer}}$$

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

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

$$= \frac{I^2m \cdot R_L}{\pi^2}$$

$P_{ac} = P_a + P_r$

P_a = Power dissipated at the Junction of diode

$P_a = I^2{rms} \times R_f \Rightarrow \frac{Im^2}{4} \times R_F$

P_r = Power dissipated in the load resistance

$= I_{rms}^2 \times R_L \Rightarrow \frac{I^2m}{4} \times R_L$

$\therefore P_{ac} = \frac{Im^2}{4} \times R_f + \frac{I^2m}{4} \times R_L$

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

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

$$\eta = \frac{0.406}{1+\frac{R_f}{R_L}}$$

% of rectifier efficiency

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

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{(I_{dc})^2 R_L}{(I_{rms})^2 R_L} \Rightarrow \frac{(V_{dc} R_L)^2 R_L}{(V_{rms} R_L)^2 R_L} = \frac{V_{dc}^2}{V_{rms}^2}$$

$$\frac{\left(\frac{V_m}{\pi}\right)^2}{\left(\frac{V_m}{2}\right)^2} \text{ (or) } \eta = \frac{4}{\pi^2} = 0.406 = 40.6\%$$

The maximum value of rectifier efficiency of a half wave rectifier is 40.6% when $\frac{R_f}{R_L} = 0$

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The Output of a rectifier consists of a dc component as well as ac component. The ac component in the Output is Called as ripple, more effective will be the rectifier. Thus the ripple factor gives an idea about the rectified voltage and it is defined as the ratio of the effective value of the ac component of Voltage or current to the direct or average value

$$r = \frac{\text{ripple Voltage}}{\text{dc Voltage}} = \frac{\text{rms Value of ac components}}{\text{dc Value of wave}}$$

$$= \frac{(V_r)(rms)}{V_{dc}} = \frac{V_{ac}}{V_{dc}} = \frac{(I_r)_{rms}}{I_{dc}} = \frac{I_{ac}}{I_{dc}}$$

where $(V_r)_{rms}$ = rms Value of a.c component of Output Voltage

V_{dc} = d.c Value of Output Voltage

Now, $V_{rms}^2 = \sqrt{V_{dc}^2 + (V_r)_{rms}^2} = \sqrt{V_{dc}^2 + V_{ac}^2}$

$$(V_r)_{rms} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

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

$$r = \sqrt{\frac{(V_m/2)^2}{(V_m/\pi)^2} - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} = 1.21$$

The ripple factor is also defined as $r = \frac{(I_r)_{rms}}{I_{dc}}$

The effective or rms value of current is given by

$$I_{rms} = \sqrt{I_{dc}^2 + I_1^2 + I_2^2 + I_3^2 + \cdots} \Rightarrow \sqrt{I_{dc}^2 + I_{ac}^2} = \sqrt{I_{dc}^2 + (I_r)_{rms}^2}$$

$$I_{ac} = (I_r)_{rms} = \sqrt{I_1^2 + I_2^2 + I_3^2 + \cdots}$$

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

$$\gamma = \sqrt{\frac{(I_m/2)^2}{(I_m/\pi)^2} - 1} = \sqrt{\underbrace{\left(\frac{\pi}{2}\right)^2}_{2.46} - 1} = 1.21 \;//$$

→ Voltage Regulation:

It is defined as variation ~~regulation~~ of dc Output voltage with change in dc load current. Thus, percentage of voltage regulation

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

where $V_{no\ load}$ = Voltage at no load

$V_{full\ load}$ = Voltage at full load.

For an ideal power supply, the output voltage should be independent of the load current. When an ideal power supply has a full load voltage is equal to its no load voltage, then it has zero percentage of regulation. However the percentage regulation better would be the power supply

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→ Transformer utillization factor:-

The DC power to be delivered to the load in a rectifier circuits decides the rating of the transformer used in the circuits. So, TUF is

$$TUF = \frac{\text{Dc power to deliverd to the load}}{\text{Ac rating of transformer secondary}}$$

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

According to the theory of transformer the rated voltage of secondary will be $V_m/\sqrt{2}$ and the actual rms current flowing through it will be $I_m/2$

$$TUF = \frac{(I_m/\pi)^2 \times R_L}{(V_m/\sqrt{2})\,(I_m/2)}$$

But $V_m = I_m(R_F + R_L)$

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

$$= \frac{2\sqrt{2}}{\pi^2} \times \frac{R_L}{R_F + R_L}$$

If $R_L >>> R_F$

$$TUF = \frac{2\sqrt{2}}{\pi^2} = 0.287$$

This mean that if the transformer rating is 1 KVA (1000 VA) then the half wave rectifier can deliver 287 watts to resistance load.

→ Peak inverse voltage: (PIV)

We have seen that during negative half cycles in AC input voltage the diode is in reverse bias and does not conducts. Therefore their no current. As a result their is no voltage drop across the load Resistance. So, for the negative voltage the input same amount appears as reverse voltage across the diode in the reverse direction. i.e; during non-conducting or off state. Now, we defined the peak inverse voltage as the maximum voltage across the diode in reverse direction.

* Form factor:

The form factor is defined as

$$F = \frac{\text{rms value}}{\text{avg value}}$$

$$F = \frac{I_m/2}{I_m/\pi} \Rightarrow \frac{0.5\,I_m}{0.314\,I_m} = 1.57$$

* Peak Factor:-

It is defined as $F = \frac{\text{Peak value}}{\text{rms value}} = \frac{V_m}{V_m/2} = 2$ //

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→ Full wave rectifier :-

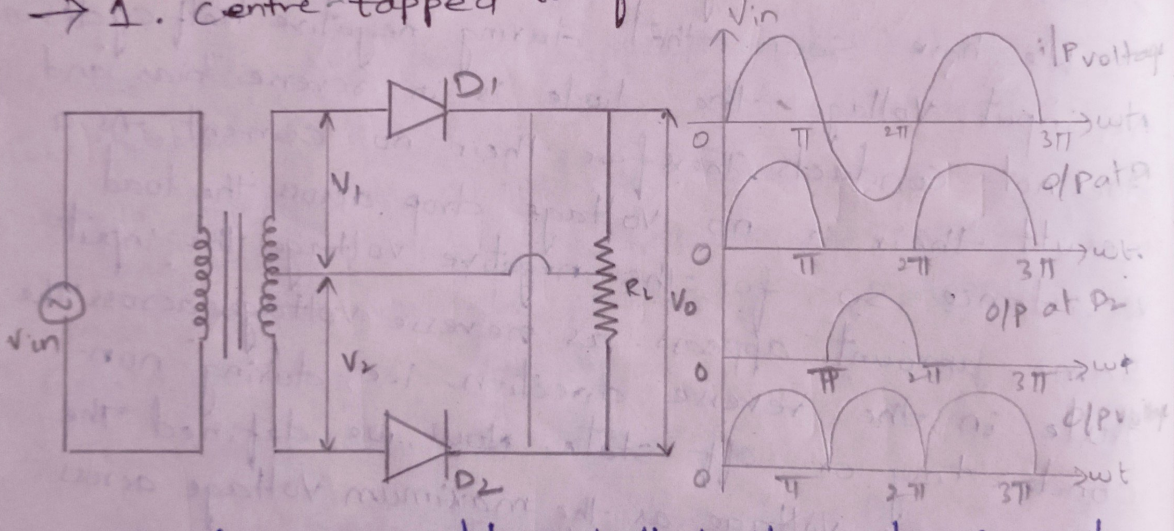
Full wave rectifier converts an Ac voltage into a pulsating DC voltage by using both half cycles of the applied Ac voltage

It uses two diodes one conducts during one half cycle while the other diode conducts during the other half cycle of the applied Ac Voltage.

Their two types of full wave rectifiers.

1. Centre tapped transformer full wave rectifier
2. Bridge rectifier

→ 1. Centre-tapped tansformer full wave rectifier.



In full wave rectifier both half-cycles of input are utilized with the help of two diodes working alternately. Therefore, in full wave rectifier circuit Current flows through load resistors for both direction half-cycles of input Ac voltage

→ Working of full wave rectifier:

During positive half-cycles of Ac input voltage, the terminal of the diode D_1 is positive and Diode D_2

is negative. Now the diode D_1 is in forward biased i.e; it conducts and causes a current in load resistor R_L the diode D_2 remains non-conducting with reverse biased

During negative half-cycles of Ac input voltage the terminal of diode D_2 becomes positive and the terminal D_1 becomes negative. Now the diode D_2 is in forward biased and it conducts and causes a current I in load resistor R_L. Then the diode D_1 remains in non-conducting with reverse biased with reverse biased.

Thus the current flows through R_L in the same direction in both half-cycles of the Ac input

→ Analysis of full wave recifier:-

Let the input voltage V_i is given by

$V_i = V_m \sin \omega t$

The current is i_1 through diode D_1 and load resistor R_L is given by

$i_1 = I_m \sin \omega t$ for $0 \leq \omega t \leq \pi$

$i_1 = 0$ for $\pi \leq \omega t \leq 2\pi$

where $I_m = V_m / R_f + R_L$ R_f being the diode resistance in ON condition.

Similarly the current flowing through R_L is the diode. D_2 and load resistor R_L is given by

$i_2 = 0$ for $0 \leq \omega t \leq \pi$

$i_2 = I_m \sin \omega t$ for $\pi \leq \omega t \leq 2\pi$

The total current flowing through R_L is the sum of the two current i_1 and i_2 ⇒ $i = i_1 + i_2$

(i) DC or Average Current :-

The average value of output current that a dc ammeter will indicate is given by

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i_1\, d(\omega t) + \int_0^{\pi} i_2\, d(\omega t)$$

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

$$I_{dc} = \frac{I_m}{\pi} + \frac{I_m}{\pi} = \frac{2I_m}{\pi} = 0.636 I_m$$

This is double that of a half-wave rectifier

(ii) DC output Voltage :-

The dc o/p voltage across load is given by

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

$$= \frac{2I_m}{\pi} R_L = 0.636\, I_m R_L$$

$$= \frac{2V_m}{\pi(R_f+R_L)} R_L \quad \text{if } R_L >> R_f$$

$$V_{dc} = \frac{2V_m}{\pi} = 0.636\, V_m$$

(iii) RMS Current :

The RMS value of the current is given by

$$I_{rms} = \left[\frac{1}{\pi}\int_0^{\pi} i^2\, d(\omega t)\right]^{1/2}$$

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

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

(iv) Rectifier Efficiency :-

The rectifier efficiency is defined by

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

Now $P_{dc} = (V_{dc})^2 / R_L = \left(\frac{2V_m}{\pi}\right)^2 / R_L$

and $P_{ac} = (V_{rms})^2 / R_L = \left(\frac{V_m}{\sqrt{2}}\right)^2 / R_L$

$$\eta = \frac{(2V_m/\pi)^2}{(V_m/\sqrt{2})^2} = \frac{8}{\pi^2} = 0.812 = 81.2\%$$

The dc output power $P_{dc} = I_{dc}^2 R_L = \frac{4I_m^2 R_L}{\pi^2}$

The ac input power $P_{ac} = I_{rms}^2 (R_f + R_L) = \frac{I_m^2}{2}(R_f+R_L)$

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

If $R_L >> R_f$ $\eta = \frac{8}{\pi^2} = 0.812$

$\%\eta = 81.2\%$

Thus, full wave Rectifier has efficiency twice that half-wave rectifier.

→ Ripple factor :-

The form factor of rectified output voltage wave rectifier is given by

$$F = \frac{I_{rms}}{I_{dc}} = \frac{I_m/\sqrt{2}}{2I_m/\pi} = 1.11$$

The ripple factor r is defined as

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

$$r = \sqrt{(1.11)^2 - 1} = 0.48$$

* Voltage Regulation :

The dc Output voltage is given by

$$V_{dc} = \frac{2I_m R_L}{\pi} = \frac{2V_m R_L}{\pi(R_f+R_L)}$$ where $R_L >> R_f$ then R_f can be neglected

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

→ Peak inverse voltage :-

PIV is the maximum possible voltage across a diode when it is in reverse biased.

Consider, the diode d_1 is in forward biased i.e; conducting and d_2 is in reverse biased i.e; non conducting. In this case a voltage V_m is developed across the load resistor R_L. Now the voltage across the diode d_2 is the sum of the voltages across load resistor. Hence PIV of diode $d_2 = 2V_m$

Similarly PIV of diode $d_1 = 2V_m$

→ Transformer Utilization factor (TUF):

The average TUF in full wave rectifier circuit is determined by considering the primary and secondary winding separately

$$\text{TUF of primary} = \frac{P_{dc}}{\text{Volt Amp rating of primary}}$$

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

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

where R_s is the resistance of secondary.

$$\text{TUF of primary} = \frac{8}{\pi^2}\left[\frac{R_L}{R_f + R_s + R_L}\right]$$

$$= \frac{8}{\pi^2} = 0.812$$

$$\text{But } (TUF)_{avg} = \frac{P_{dc}}{\text{VA rating of Transformer}}$$

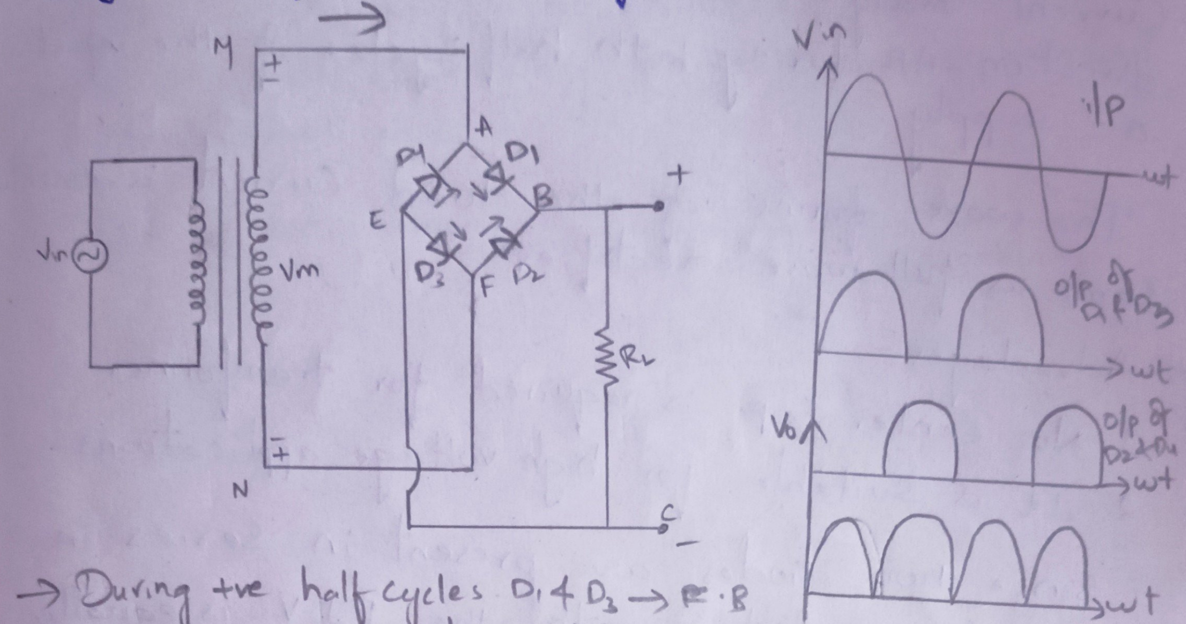
$$= \frac{(TUF)_P + (TUF)_S + (TUF)_S}{3}$$

$$= \frac{0.812 + 0.287 + 0.287}{3}$$

$$\boxed{TUF = 0.693}$$

8/8/22 → Full wave Bride Rectifier

A circuit frequently used for electronic dc power supply is a full wave bridge rectifier



→ During +ve half cycles D_1 & D_3 → F.B

→ During -ve half cycles D_1 & R_3 → R.B

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In full wave rectifier four diode is used

Here stepdown transformer is used for AC power supply

During the positive input halfcycle the terminal M of the secondary transformer is positive while the terminal N is negative Now the diodes d_1 and D_3 are in forword biased (ON position) i.e; they conduct whereas the diodes D_2 and D_4 are in reverse biased (OFF position) i.e; they do not conduct. So, a current flows along MABCEFN their will be a voltage drop across R_L during the negative input halfcycle the terminal N of the secondary transformer is negative while the terminal M is positive. Now the diodes D_1 and D_3 are in reverse biased (OFF position) i.e; they do not conduct wheras the diodes D_2 and D_4 are in forward biased (ON position) i.e; they ~~do not~~ Conduct

So, the current flows along NFBCEAM

It is obvious from the figure that the current through load resistance R_L in the same direction AB during both half cycles of the input ac supply.

The wave forms of the load current is essentially same as full wave rectifier

* Advantages:-

1. No center tap. is required for transformer.
2. It is suitable for high voltage applications

Since two diodes are present in series in ~~equ~~ each conduction path the PIV is equally shared by the two diodes. Thus, it has less PIV rating for diodes

→ Analysis:

1. $I_{dc} = \frac{2I_m}{\pi} = 0.636 I_m$

2. $V_{dc} = \frac{2V_m}{\pi} = 0.636 V_m = 0.636 I_m R_L$

3. $I_{rms} = \frac{I_m}{\pi}$

4. $\eta = \frac{0.812}{(1+R_F/R_L)} \Rightarrow 81.2\%$ when $R_F = 0$.

5. $\gamma = 0.48$

6. Peak inverse voltage (PIV)

PIV of a diode in bridge rectifier
for positive half cycles of input the diode D_1 and D_3 are in forward bias and D_2 and D_4 are in reverse bias. These diodes have maximum reverse voltage equal to the maximum secondary

voltage (V_m). Therefore peak inverse voltage of diode in bridge rectifier is given by $PIV = V_m$

→ TUF (Transformer utilization factor):

TUF of primary and secondary will be the same as their is always current through primary and secondary

$$TUF \text{ of secondary} = \frac{P_{dc}}{V.A \text{ rating of Secondary}}$$

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

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

$$= 0.812$$

Hence DC output power is 81.2 % of transformer rating

primary TUF = 0.812

$$TUF_{av} = \frac{(TUF)_p + (TUF)_s}{2}$$

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

$$(TUF)_{average} = 0.812$$

Q. A half wave rectifier supplies power to 1kΩ load the input voltage supply is 220 volts rms neglecting forward resistance (r_F) of the diode. Calculate (i) V_{dc} (ii) I_{dc} (iii) ripple voltage

Sol: (i) $V_{dc} = \frac{V_m}{\pi} \Rightarrow \frac{\sqrt{2}V}{\pi} \Rightarrow \cancel{\frac{\sqrt{2} \times 0.318}{\pi}} = \cancel{\frac{0.45V}{3.14}}$

$\Rightarrow \sqrt{2}V = \sqrt{2} \times 0.318 = 0.45V$

$\Rightarrow 0.45 \times 220V$

$V_{dc} = 99V$

(ii) $I_{dc} = \frac{V_{dc}}{R_L} = \frac{99V}{1000\Omega} = 99mA$

(iii) $\gamma = \frac{V_{rms}}{V_{dc}} \Rightarrow V_{rms} = \gamma \times V_{dc} = 99 \times 1.21 = 119.79V$

Q. A Sinusoidal Voltage of Amplitude 25V and frequency 50Hz is applied to a halfwave rectifier using PN diode. No filter is used and the load resistance is 1000(ohms)Ω, the forward resistance of ideal diode is 10Ω. Calculate

(i) Peak, Average, Rms values of load current

(ii) DC power Output

(iii) Ac power input

(iv) Rectifier efficiency

(v) Ripple factor

sol:

(i) $I_m = \frac{V_m}{R_f + R_L} = \frac{25}{10+1000} = \frac{25}{1010} = 24.7mA$

$I_{dc} = \frac{I_m}{\pi} = \frac{24.7}{\pi} = 7.86mA$

$I_{rms} = \frac{I_m}{2} = \frac{24.7}{2} = 12.35mA$ //

(ii) $P_{dc} = (I^2_{dc})R_L$

$= (7.86 \times 10^{-3})^2 \times 1000\Omega$

$= (7.86)^2 \times 10^{-6} \times 1000\Omega$

$= 61.77 \times 10^{-3}w = 61.77\ mw$ //

(iii) $P_{ac} = (I^2_{rms})[R_f + R_L]$

$= (12.35 \times 10^{-3})^2 [10+1000]$

$= (12.35 \times 10^{-6})(1010)$

$= 154\ mw$

(iv) $\eta = \frac{P_{dc}}{P_{ac}} \times 100 = \frac{61.77}{154} \times 100 = 40.11$

(v) $\gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} = \sqrt{\left(\frac{12.35}{7.86}\right)^2 - 1} = 1.21$ //

Q. AC Voltage of 230V applied to a half wave rectifier circuit through a transformer of turn ratio 10:1. The load resistance value is $1k\Omega$ and diode internal resistance is 20Ω. Calculate (i) I_m, I_{dc}, I_{rms} (ii) DC power Output (iii) AC power input (iv) Rectifier efficiency (v) DC Output Voltage (vi) PIV (Peak inverse voltage).

The rms value of voltage applied to the rectified circuit is given by $V_{rms} = \frac{N_2}{N_1} \times V_{in} = \frac{1}{10} \times 230V = 23V$

$V_m = \sqrt{2} V_{rms} = \sqrt{2} \times 23 = 32.53V$.

(i) $I_m = \frac{V_m}{R_f + R_L} = \frac{32.53}{20+1000} = 31.89 mA$

$I_{dc} = \frac{I_m}{\pi} = \frac{31.89}{\pi} = 10.15 mA$

$I_{rms} = \frac{I_m}{2} = \frac{31.89}{2} = 15.945 mA$

(ii) $P_{dc} = (I_{dc}^2) R_L = (10.15)^2 1000 \times (10^{-3})^2$

$= 103.02 \times 10^{-3}$

$= 103.02 mW$

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

$= (15.945)^2 \times (10^{-3})^2 (20+1000)$

$= 254.24 \times 1020 \times 10^{-6}$

$= 259324.8 \times 10^{-6} = 259.3248 \times 10^{-3}$

$= 259.3248 mW$

(iv) $\eta = \frac{P_{dc}}{P_{ac}} \times 100 = \frac{103.02}{259.3} \times 100 = 0.397 \times 100$

$= 39.7$

(v) $V_{dc} = I_{dc} \times R_L = 10.15 \times 1000 \times \cancel{10^{-3}} = 10150 \times 10^{-3} V$

$= 10.15V$

(vi) PIV of half-wave rectifier is $V_m = 32.53V$

Q. A full wave rectifier supplies a load $1k\Omega$. The Ac voltage applied to the diodes is 220Vrms if diode resistance is neglected. Calculate 1. Average dc voltage

2. Average dc current (I_{dc})
3. Ripple voltage (rms)

Sol:- (i) $V_{dc} = \frac{2V_m}{\pi}$

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

$V_m = V(\sqrt{2})$

$V_{dc} = 0.636 V_m = 0.636 \times 220 \times \sqrt{2}$

$V_{dc} = 198V$

(ii) $I_{dc} = \frac{V_{dc}}{R_L} = \frac{198}{1000} = 198mA$

(iii) $\gamma = \frac{V_r(rms)}{V_{dc}} \times 100$

Q.- A Full wave P-N diode rectifier uses load resistor of 1500 Ω no filter is used. assume each diode have ideolized characteristic with $R_f = 10 \Omega$ and $R_r = \infty$. Since wave voltage applied to each diode has amplitude of 30V and frequency 50Hz. Calculate
(i) Peak, dc and rms load current
(ii) Dc power output
(iii) Ac power input
(iv) Rectifier efficiency

Sol:- Given $V_m = 30V$, $R_L = 1500$
$R_f = 10$

(i) $I_m = \frac{V_m}{R_f + R_L} = \frac{30}{1500+10} = \frac{30}{1510} = 0.01986A$
$= 19.8mA$

$I_{dc} = \frac{2I_m}{\pi} = \frac{2(19.8 \times 10^{-3})}{3.14}$

$= \frac{39.6}{3.14} = 12.611 mA$

$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{19.8}{\sqrt{2}} = 14 mA$

(ii) $P_{dc} = (I^2_{dc}) R_L = (12.61)^2 (10^{-3})^2 \times 1500$

$= 159.01 \times 1.5 \times 10^{-3}$

$= 238.575 \times 10^{-3} = 238.5$ mw.

(iii) $P_{ac} = I^2_{rms} (R_F + R_L)$

$= (14 \times 10^{-3})^2 (10 + 1500) = 196 (10^{-6}) (1510)$

$= 295960 \times 10^{-6} = 295.9 \times 10^{-3}$ mw.

(iv) $\eta = \frac{P_{dc}}{P_{ac}} \times 100 = \frac{238.5}{295.9} \times 100 = 0.806 \times 100 = 80.6\%$.

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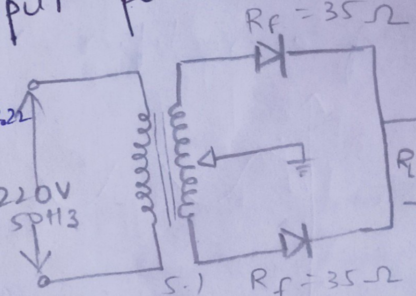
Q. In the centre tap circuit shown in below figure calculate

i) ~~Average~~ current ii) DC output voltage (VDC)

iii) DC output power iv) ~~Ac~~ input power

v) Rectifier efficiency



i) $V_{rms} = 220 \times \frac{N_2}{N_1} = 220 \times \frac{1}{5} = 44V$ & $V_m = 62.22$

Maximum voltage across secondary winding

$= \frac{V_m}{2} = \frac{62.22}{2} = 31.11$

$I_{dc} = \frac{2 I_m}{\pi} = 19.14 \times 10^{-3} \times 1000 = 19.14$ volts

ii) $V_{dc} = I^2_{dc} \times R_L = (19.14 \times 10^{-3})^2 \times 1000$

$= 366.33$ mA

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

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

$= \frac{V_m^2}{2 (R_F + R_L)}$

$P_{ac} = \frac{(V_m)^2}{(R_F + R_L)^2} \times 2 (R_f + R_L) = P_{ac} = 467.5$ mw //

v) Rectifier

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

$= \frac{366.33}{467.5} \times 100$

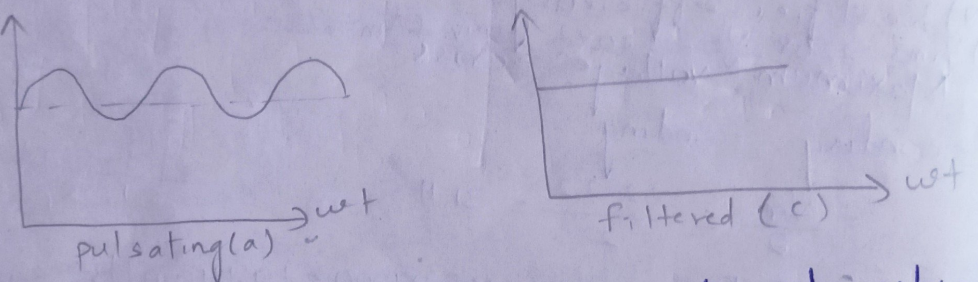
$\eta = 78.4\%$

efficiency $= 78.4\%$

Filter :-

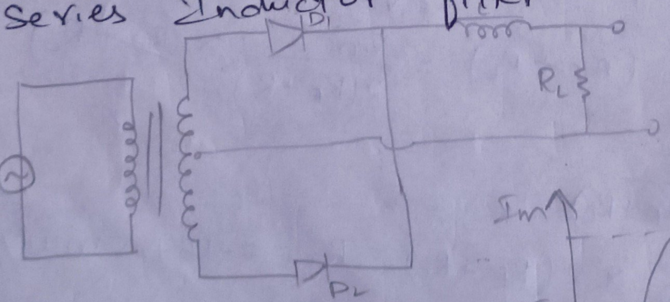
The Output of a rectifier is pulsating i.e; it has DC value and some AC variations known as ripples.

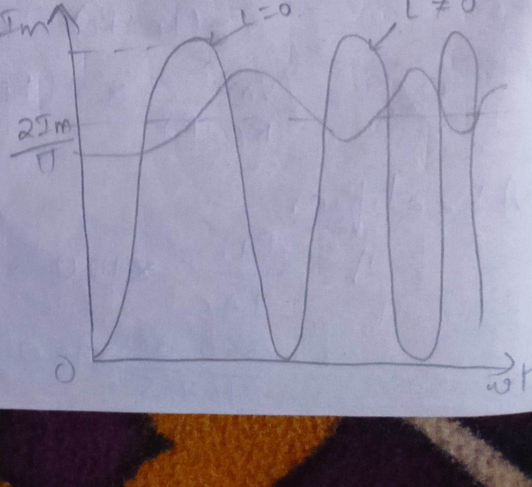
* In most of the electronic circuits or devices a very studied DC Output is required.
* This is achieved with the help of a device known as filter
* Thus a device that converts the pulsating output of a rectifier into a steady DC level.



* The filter circuits are commonly classified as 1 service inductor filter 2) shunt capacitor filter 3) LC filter 4) CLC filter or π filter

1. Series Inductor filter





A full wave rectifier with series inductor shown in above figure. The inductor is in series with the load ~~sho~~ serves as a filter

The inductor offers high impedence to Ac variations since the dc resistance of large inductance is very small. This action is based on the property of inductance to oppose any charge of current that may flow through it

Therefore, Ac component of rectifier output is blocked while the dc component reaches at the load. Theoritically the output should contains dc voltage, but practically it contains a small Ac component aswell

The above waveform shows the load current with and without filter

When the output current of the rectifier increases above a certain average value magnetic energy is stored in the inductor

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The current flowing in a full wave rectifier without filter is given by

$$i = \frac{2I_m}{\pi} - \frac{4I_m}{\pi} \sum_{K = \text{Even no} = 2} = \frac{\cos K\omega t}{(K-1)(K+1)}$$

$$i = \frac{2I_m}{\pi} - \frac{4I_m}{3\pi}\cos 2\omega t - \frac{4I_m}{15\pi}\cos 4\omega t$$

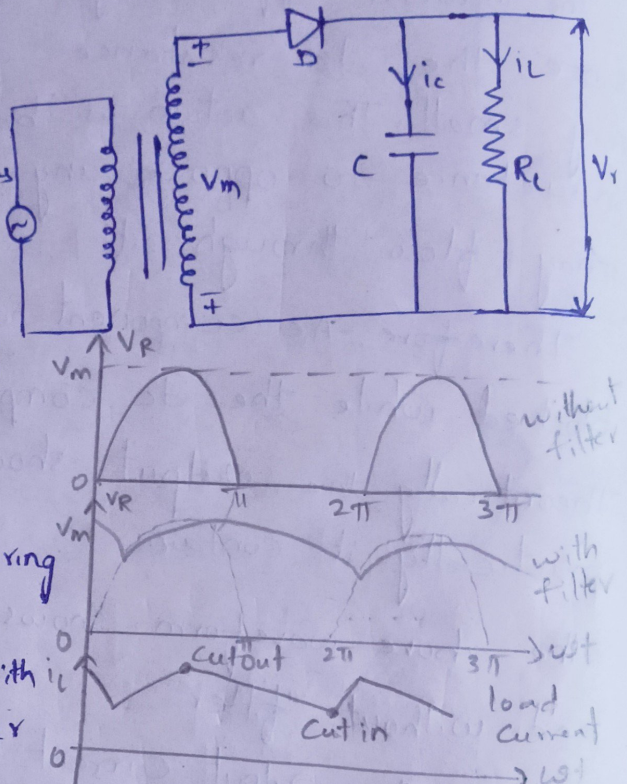
$$\therefore i = \frac{2I_m}{\pi} - \frac{4I_m}{3\pi}\cos 2\omega t \ //$$

→ Ripple factor:-

The ripple factor is defined as the ratio of rms value of the ac component to the dc value of the wave. i.e; $\gamma = \frac{(I_r)_{rms}}{I_{dc}}$

The inductor filter should be used when load resistance is small then effective filtering takes place if load current is high

→ Shunt Capacitor filter :-



The output of a rectifier is pulsating in nature. That is it contains a large no. of ripple components. These ripple components are filtered by putting a filter circuit ~~with the~~ b/w rectifier & load. Filtering is frequently done by shunting the capacitor with load. This type of filter is known as capacitor input filter

The action of the filter circuit is depend upon the fact that a capacitor stores energy when conducting (charging) and delivers this energy to the load during non-conduction (Discharging). Through this process the ripple components are reduced

During positive half cycles of ac input, the diode is in forward bias then it conducts and the capacitor quickly charges to a voltage Vm. when the capacitor is fully charged, it holds the charge till input ac supply to the rectifier goes negative

During negative half cycles of ac input, the diode is in reverse bias that is, it does not conduct, so the capacitor discharge through the load resistor

Usually the discharging time is 100 times more than the charging time. Hence the capacitor does not have sufficient time to discharge apprecia-bly. Due to this the voltage decreases slightly.

By considering the diode current it is significant to know over what portion of the complete cycle is the diode conducting.

The instant at which the conduction start is called the cutin point

The instant at which the conduction stops is called the cutout point

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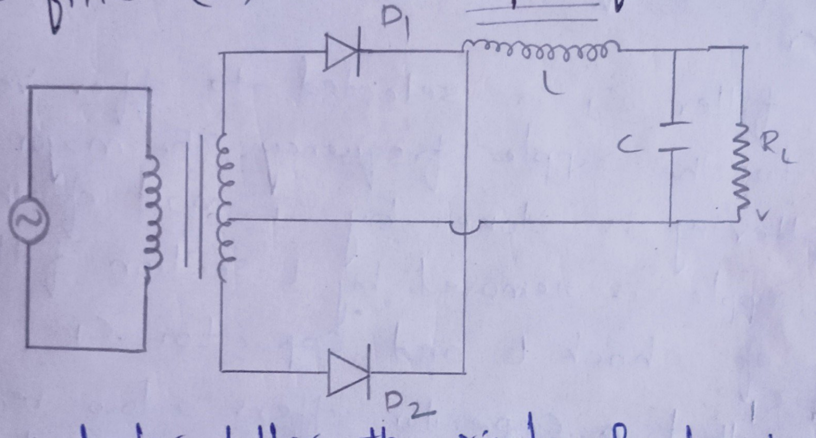
→ L.C filter (or) choke input filter:



In inductor filter the ripple factor is directly proportional to the load resistance while in capacitor filter inversely proportional to load resistance. Therefore the capacitor has low ripple at heavy loads while inductor filter has small loats.

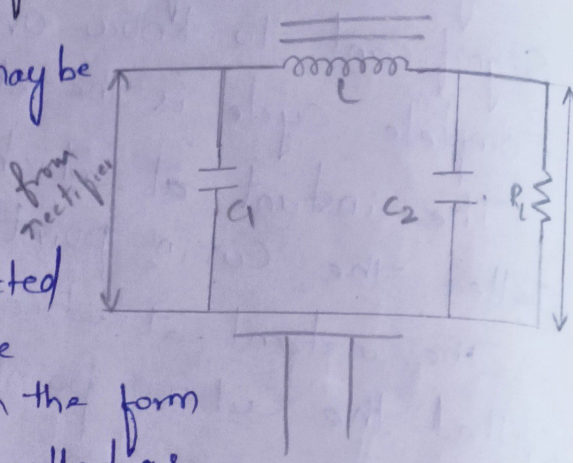
The ~~comp~~combination of these two filters may be selected to make the ripple independent of load resistances.

The resultant filter is called as shoke input filter (or) L-C filter

The capacitor is connected in shunt with the load and it offers very low reactants. On the other hand the inductor offers high impedence due to the combination of both capacitor and inductor. Most of the ripple voltage is eliminated from the load voltage

→ CLC filter (or) PI (π) filter :-

A very smooth output may be obtained by a filter consisting of one inductance and two capacitance connected across its each end as these components are arranged in the form of PI (π). So this filter is caplled as PI (π) filter.



In this filter C_1 is selected to offer very low reactance to the ripple frequency. The major part of the filtering is done by C_1, most of the remaining ripple is removed by L section filter consisting of chock L and capacitor C_1

→ Capacitor C_1:

We know that a capacitor offers a low reactants path to ac component of rectifier output while it offers infinite resistance to dc component. Therefore the capacitor C_1 bypasses the amount of ac component to ground and the dc component to pass through it

Inductor L :-

We know that an inductor offers a high reactants to ac component of rectifier output while zero resistance to dc component as a result it allows the dc component to pass through it and blocks the ac component which could not be bypassed by capacitor C_1

Capacitor C_2:

It further bypasses the ac component of rectifier output which could not be blocked by an inductor L

From fourier series analysis, of the waveform

$$v = V_{dc} - \frac{V_{m}}{\pi}\left[\sin 2\omega t - \frac{\sin 4\omega t}{2} + \frac{\sin 6\omega t}{3} + \cdots\right]$$

But $V_{rms} = \frac{I_{dc}}{2fc}$ $(v_r)_{rms}$

The second harmonic RMS value is

$$V_2' = \frac{V_{rms}}{\pi\sqrt{2}} = \frac{I_{dc}}{2\sqrt{2}\pi fc}$$

$$V_2' = \frac{I_{dc}}{\sqrt{2}(2\pi fc)} \times \frac{2}{2} = \sqrt{2}\, I_{dc} X_c$$

where $I_{dc} = \frac{V_{dc}}{R_L}$

$$V_2' = \sqrt{2}\left(\frac{V_{dc}}{R_L}\right) X_c$$

V_2' is applied to the L-section (L_1, C_1) by using the same logic the o/p ripple is

$$V_2'\left(\frac{X_{C_1}}{X_{L_1}}\right)$$

$$V_{r_{rms}} = V_2'\left(\frac{X_{C_1}}{X_{L_1}}\right)$$

$$V_{rrms} = \sqrt{2}\, V_{dc}\left(\frac{X_C}{R_L}\right)\left(\frac{X_{C_1}}{X_{L_1}}\right)$$

$$r = \frac{V_{rms}}{V_{dc}} = \sqrt{2}\left(\frac{X_C}{R_L}\right)\left(\frac{X_{C_1}}{X_{L_1}}\right)$$