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Unit – II

Rectifiers and Filters

P-n junction diode as a rectifier:

A p-n junction diode is a two terminal device that is polarity sensi--tive. When the diode is forward biased, the diode conducts and allows current to flow through it without any resis--tance i.e., the diode is on.

When the diode is reverse-biased, the diode doesnot conduct & no cu--rrent flows through it i.e., the diode is off.

Thus an ideal diode acts as a switch either open or closed.

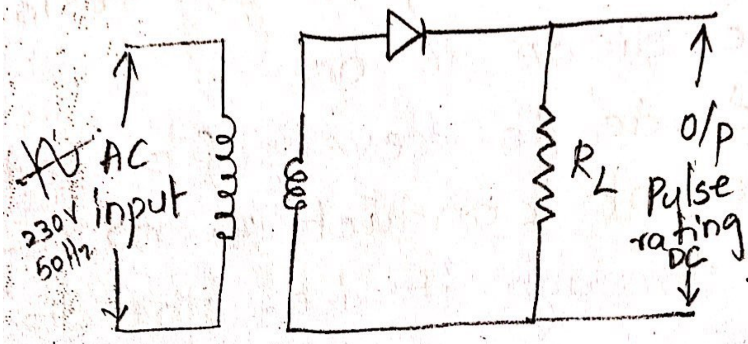
Depending upon the polarity of the voltage placed across it. The ideal diode has 0 resistance under forward-bias & infinite resistance under reverse bias.

Rectifiers: Rectifier is defined as an electronic device used for converting AC voltage into unidirectional voltage.

** It is assumed that the capacitor will hold on to all its charge & therefore voltage.)X

A rectifier utilises unidirectional conduction device like a vaccum dio[de] or p-n junction diode.

Rectifiers are classified depending upon the period of conduction as half-wave rectifier & full-wave rectifi[er]



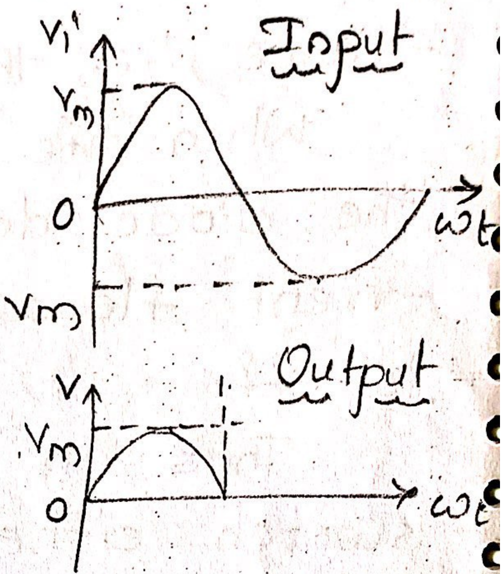


fig:- Half-wave Rectifier

Step-down Transformer:

Converts high voltage to low voltage i.e., 230VAC to 12V AC.

Half-wave Rectifier: It converts an AC voltage into a pulse-rating DC voltage using only one-half of the applied AC voltage.

* The rectifying diode conducts during one half of the AC cycle only.
* The figure shows the basic circuit &

waveforms of a half-wave rectifier.

* Let V_i be the voltage to the primary of the transformer & given by the equation,

$$V_i = V_m \sin \omega t , \quad V_m >> V_R$$

where, V_R is the cut-in voltage of diode.

* During the +ve half cycle of the input signal the anode of the diode becomes more +ve with respect to the cathode & hence diode 'D' conducts.
* For an ideal diode the forward voltage drop is zero (0) so the whole input ~~will~~ voltage will appear across the load resistance (R_L).
* During -ve half cycle of the input signal the anode of the diode becomes -ve with respect to the cathode & hence diode 'D' doesnot conduct.
* For an ideal diode the impedence offered by the diode is infinity(∞). So the whole input voltage appears across the diode 'D'.

Hence the voltage-drop across R_L is zero (0).

Ripple Factor (Γ):

The ratio of RMS value of Ac component to the Dc component in the output is known as ripple factor (Γ). i.e.,

$$\Gamma = \frac{\text{RMS value of Ac component}}{\text{RMS value of Dc component}}.$$

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

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

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

V_{av} is the average of the Dc content of the voltage across the load & is given by $V_{av} = V_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin \omega t \, d(\omega t) + \int_{\pi}^{2\pi} 0 \cdot d(\omega t)\right].$

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

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

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

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

* If the values of diode forward resistance r_f & the transformer secondary winding resistance r_s are also taken into account then

$$V_{dc} = \frac{V_m}{\pi} \cdot I_{dc}(r_s + r_f).$$

$$I_{dc} = \frac{V_{dc}}{(r_s + r_f) + R_L}$$

* RMS voltage at the load resistance can be calculated as

$$\cancel{V_{rms} = \frac{1}{2\pi} \int_0^{\pi} V_m^2 \sin^2\omega t \, (dt)}$$

$$V_{rms} = \left[\frac{1}{2\pi} \int_0^{\pi} V_m^2 \sin^2 \omega t \, d(\omega t)\right]^{1/2}.$$

$$V_{rms} = \left[\frac{1}{2\pi} \int_0^{\pi} V_m^2 \, \frac{1 - \cos 2\omega t}{2} \cdot d(\omega t)\right]^{1/2}$$

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

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

* $$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{\left(\frac{\cancel{V_m}/2}{\cancel{V_m}/\pi}\right)^2 - 1}$$

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

r, Ripple factor $= 1.21 = 121\%$

* From the expression it is clear that the amount of AC present in the output is 121 % of the DC voltage.

So the half-wave rectifier is not practically useful in converting AC into DC.

Efficiency(η): The ratio of dc outpower to AC input power. It is known as rectifier efficiency (η).

$$\eta = \frac{\text{dc o/p power}}{\text{ac i/p power}} = \frac{P_{dc}}{P_{ac}}$$

where, $P_{dc} = \frac{V_{dc}^2}{R_L}$ and $P_{ac} = \frac{V_{rms}^2}{R_L}$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{(V_{dc})^2}{\cancel{R_L}}}{\frac{(V_{rms})^2}{\cancel{R_L}}} = \frac{(V_{dc})^2}{(V_{rms})^2} = \frac{(V_m/\pi)^2}{(V_m/2)^2}$$

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

$\eta = 40.6\%$

The maximum efficiency of half-wave rectifier is 40.6 %.

Peak Inverse Voltage (PIV) :

It is defined as maximum reverse voltage that a diode can withstand without destroying the junction. The PIV across a diode is the peak of the negative half-cycle.

* For half-wave rectifier the peak inverse voltage is V_m.

Transformer Utilisation Factor (TUF) :

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

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

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

* In the half-wave rectifying circuit, the rated voltage of the transformer

secondary is $\frac{V_m}{\sqrt{2}}$. But the actual rms current flowing through the winding is $\frac{I_m}{2}$.

$$TUF = \frac{\frac{I_m^2}{\pi^2} \cdot R_L}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{2}} \quad \left\{ \begin{aligned} \because P &= VI \\ &= IR \times I \\ P &= I^2 R \end{aligned} \right.$$

$$= \frac{\frac{V_m^{\cancel{2}}}{\pi^2} \cdot \frac{1}{\cancel{R_L}}}{\frac{\cancel{V_m}}{\sqrt{2}} \cdot \frac{V_m}{2\cancel{R_L}}} \quad \left\{ \frac{V_m^2}{\pi^2 R_L^{\cancel{2}}} \times \cancel{R_L} \right. \quad \because I_m = \frac{V_m}{R_L}$$

$$= \frac{\cancel{V_m}}{\pi^2} \cdot \frac{2\sqrt{2}}{\cancel{V_m}}$$

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

$$TUF = 0.287$$

$\therefore$ The TUF for a half-wave rectifier is 0.287.

Form Factor:

$$\text{Form Factor} = \frac{\text{rms value}}{\text{avg value}}$$

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

$$\text{Form factor} = \pi/2 = 1.57$$

Peak Factor :

$$\text{Peak Factor} = \frac{\text{Peak value}}{\text{rms value}}$$

$$= \frac{\cancel{V_m}}{\cancel{V_m}/2}$$

Peak Factor = 2.

Problem :

1. A half-wave rectifier having a resistive load of 1000 Ω rectifies an alternating voltage of 325 volts peak value & a diode has forward resistance of 100 Ω. Calculate a) peak value of current
b) DC power output
c) AC input power
d) Efficiency of the rectifier.

Sol : a) Peak value of current.

Given data :

$R_L = 1000\ \Omega$

$V_m = 352\ V$

$R_f = 100\ \Omega$

$$I_m = \frac{V_m}{(r_f + R_L)} = \frac{352}{100+1000} = \frac{352}{1100}$$

$$\therefore I_m = 295.45\, mA$$

Average current, $I_{dc} = \frac{I_m}{\pi}$

$$= \frac{295.45}{\pi}$$

$$I_{dc} = 94.0923 \text{ mA}$$

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

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

$$= \frac{295.45}{2}$$

$$I_{rms} = 147.725 \text{ mA}.$$

b) Dc power output

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

$$= (94.046 \text{ (mA)})^2 \times 1000\,\Omega$$

$$= [94.046 \times 10^{-3} \times 94.046 \times 10^{-3}] \times 1 \times 10^3$$

$$P_{dc} = 8.845 \text{ Watts}.$$

c) Ac input power

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

$$= [147.725 \times 10^{-3} \times 147.725 \times 10^{-3}] \times [1 \times 10^3 + 100].$$

$$P_{ac} = 24 \text{ Watts}.$$

$$P_{ac} = 24 \text{ W}.$$

d) Efficiency of the rectifier :

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

$$= \frac{8.845}{24}.$$

$$\eta = 0.3685.$$

2. An ac supply of 230v is aapplied to 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) Dc output voltage

b) Peak inverse voltage

c) Maximum aver value of load current

d) Averge value of power delivered to the load

Sol : a) Dc output voltage

The transformer secondary voltage $= \frac{230}{5}$

$= 46V.$

Max. value of secondary voltage,

$$V_m = \sqrt{2} \times 46v = 65 \text{ v}.$$

$$V_{dc} = \frac{V_m}{\pi} = \frac{65}{3.14} = 20.69 \text{ v}.$$

b) Peak Inverse voltage

$$PIV = V_m = 65\,V.$$

c) Maximum average value of load current

$$I_m = \frac{V_m}{R_L} = \frac{65}{300} = 0.216\,A.$$

Max
~~d)~~ 1 Average value of power delivered to the load, ~~P_{av}~~

$$P_m = I_m^2 \times R_L.$$

$$= (0.216)^2 \times 300.$$

$$P_m = 13.99\,W.$$

d) Average value of power delivered to the load.

$$\text{Load current, } I_{dc} = \frac{V_{dc}}{R_L} = \frac{20.69}{300}$$

$$= 0.068\,A$$

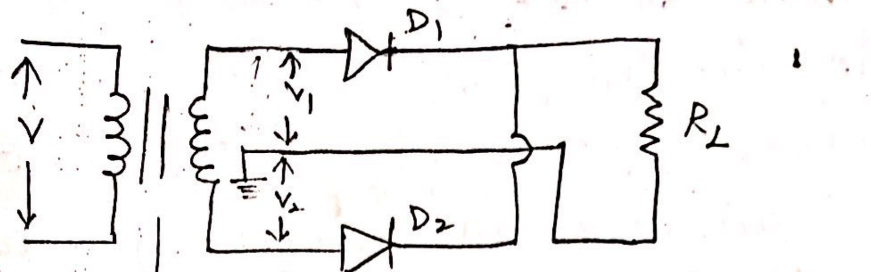
$$P_{dc} = I_{dc}^2 \times R_L$$

$$= (0.068)^2 \times 300.$$

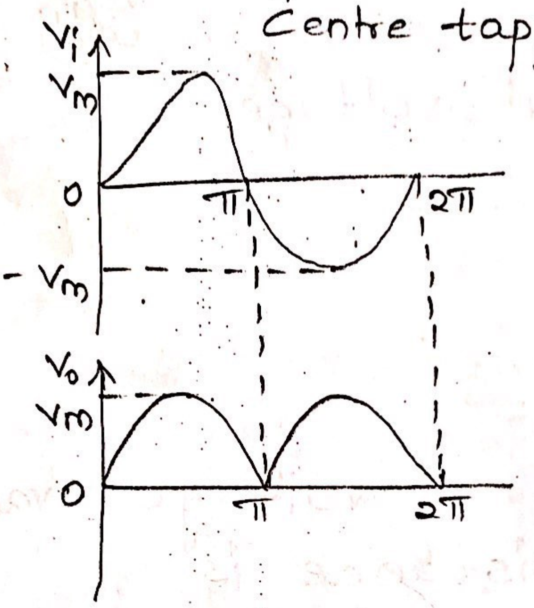
$$P_{dc} = 1.380\,\text{watts}.$$

Full-wave Rectifier:

It converts AC voltage into a pulse--rating DC voltage using both half-cycles of the applied AC voltage.



Centre tapped transformer.



* It uses two diodies of which one conducts during one-half cycle while the other diode conducts during other half cycle of the applied Ac voltage.
* During +ve half of the input signal anode of the diode D_1 becomes +ve & at the same time the anode of the diode D_2 becomes -ve. Hence D_1 conducts & D_2 doesnot conduct.
* The load current flows through D_1 & voltage drop across R_L will be equal to the input voltage.
* During the -ve half-cycle of the input,

the anode of the D_1 becomes -ve & the anode of the D_2 becomes +ve. Hence D_1 doesnot conduct & D_2 conducts.

* The load current flows through D_2 & the voltage drop across R_L will be equal to the input voltage.

Ripple Factor (Γ):

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

The avg voltage or dc voltage available across the load-resistance is

$$V_{dc} = \frac{1}{\pi}\left[\int_0^{\pi} V_m \sin \omega t \, d(\omega t)\right].$$

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

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

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

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

$$I_{dc} = \frac{2I_m}{\pi} \quad \left\{\because \frac{V_m}{R_L} = I_m\right.$$

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

If the diode is in forward resistance r_f & transformer secondary winding resistance r_s are included in analysis

$$I_{dc} = \frac{V_{dc}}{(r_f + r_s) + R_L}$$

$$I_{dc} = \frac{2V_m}{\pi(r_f + r_s) + R_L}$$

V_{rms} = Rms value of voltage at load resistance

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

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

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

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

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

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

$$\Gamma = 0.482$$

Efficiency (η): The ratio of DC output power to the AC input power.

$$\eta = \frac{\text{DC o/p power}}{\text{AC i/p power}} = \frac{P_{dc}}{P_{ac}}$$

$$P_{dc} = \frac{V_{dc}^2}{R_L}, \quad P_{ac} = \frac{V_{rms}^2}{R_L}$$

$$\eta = \frac{\frac{V_{dc}^2}{R_L}}{\frac{V_{rms}^2}{R_L}} = \frac{V_{dc}^2}{\cancel{R_L}} \times \frac{\cancel{R_L}}{V_{rms}^2}$$

$$\eta = \frac{V_{dc}^2}{V_{rms}^2}$$

$$= \frac{\frac{4V_m^2}{\pi^2}}{\frac{V_m^2}{(\sqrt{2})^2}} = \frac{4\cancel{V_m^2}}{\pi^2} \times \frac{2}{\cancel{V_m^2}} = \frac{8}{\pi^2}$$

$$\eta = 0.8105$$

$$\eta = 81.2\%$$

Transformer Utilisation Factor (TUF):

The average TUF in a full-wave rectifying circuit is determined by con-sidering the primary & secondary win-ing separately & it gives a value of 0.693.

Form Factor :

$$\text{Form Factor} = \frac{\text{rms value of o/p voltage}}{\text{avg value of o/p voltage}}$$

$$= \frac{V_m/\sqrt{2}}{2V_m/\pi} = \frac{\cancel{V_m}}{\sqrt{2}} \times \frac{\pi}{2\cancel{V_m}} = \frac{\pi}{2\sqrt{2}}.$$

Form Factor = 1.11

Peak Factor :

$$\text{Peak Factor} = \frac{\text{Peak value of o/p voltage}}{\text{rms value of o/p voltage}}.$$

$$= \frac{\cancel{V_m}}{\cancel{V_m}/\sqrt{2}} = \sqrt{2}$$

Peack Factor = 1.414.

* Peak Inverse Voltage for full-wave rectifier is $2V_m$.

Because the entire secondary voltage appears across the non-conducting diode.

Problem :

1. A 230 V, 60 Hz voltage is applied to the primary of a 5:1 step-down, centre tapped transformer used in a full-wave rectifier having a load of

900 Ω. If the diode resistance & secondary coil resistance together as a resistance of 100 Ω, determine

a) DC voltage across the load

b) DC current flowing through the load.

c) DC power delivered to the load.

d) Peak inverse voltage across each diode.

e) Ripple voltage & its frequency.

Sol: Voltage across the two ends of secondary $= \frac{230}{5} = 46V.$

Voltage from centre-tapping to one end, $V_{rms} = \frac{46}{2} = 23V.$

a) DC voltage across the load

$$V_{dc} = \frac{2V_m}{\pi} = \frac{2 \times 46 \times \sqrt{2}}{\pi}$$

$\left\{ V_{rms} = \frac{V_m}{\sqrt{2}} \quad \therefore V_m = V_{rms} \times \sqrt{2} \right.$

$V_{dc} = \cancel{0.90V.}\ 20.71V.$

b) DC current flowing through load

$$I_{dc} = \frac{V_{dc}}{(r_s + r_f) + R_L} = \frac{20.71}{100 + 900} = \frac{20.71}{1000}$$

$I_{dc} = 20.71\,mA. = 0.0207\,A.$

c) DC power delivered to the load.

$P_{dc} = I^2_{dc} \times R_L.$

$$= (20.71)^2 \times 900$$

$$P_{dc} = 0.386\,W.$$

d) PIV across each diode.

$$PIV = 2V_m$$

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

$$= 2 \times 46 \times \sqrt{2}$$

$$PIV = 65\,V.$$

e) Ripple Voltage

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

$$= \sqrt{(23)^2 - (20.71)^2}$$

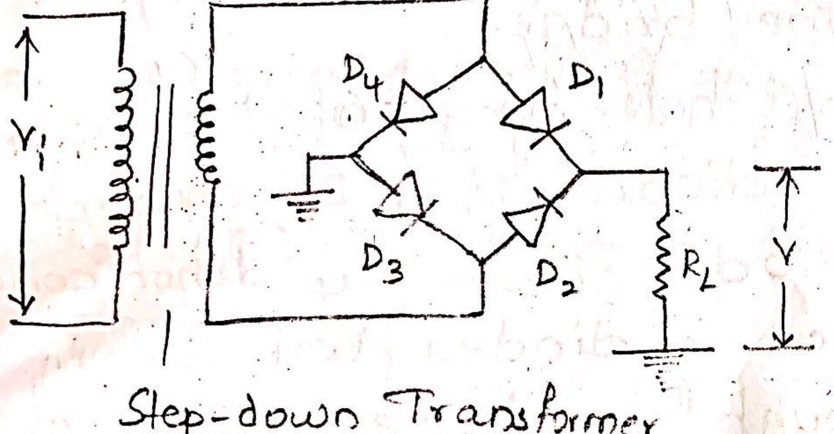
$$V_{r,rms} = 10\,V.$$

Frequency of Ripple Voltage $= 2F$

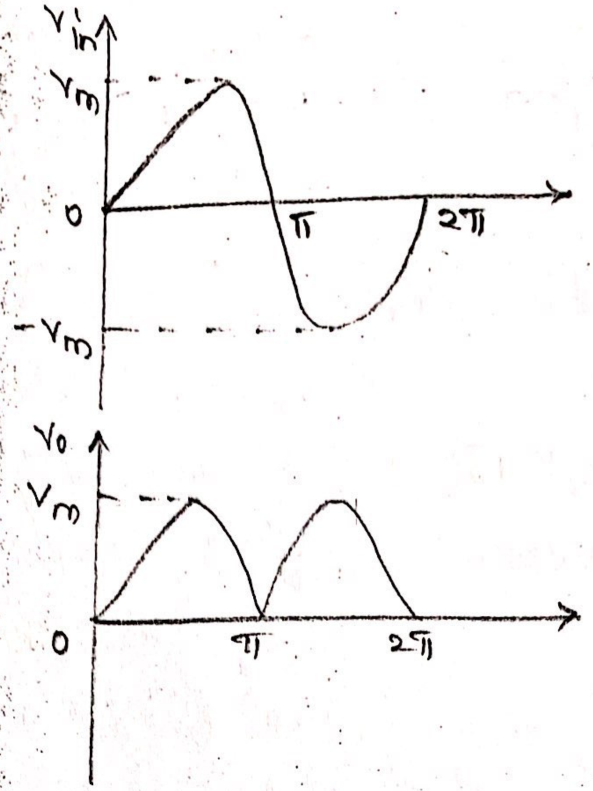
$$= 2 \times 60$$

$$= 120\,Hz.$$

Bridge Rectifier :



Step-down Transformer



* The need for a centre-tapped transformer in a full-wave rectifier is eliminated in the bridge rectifier. The bridge rectifier has 4 diodes connected to form a bridge.
* The AC input voltage is applied to the diagonally opposite ends of the bridge. The load resistance (R_L) is connected between the other two ends of the bridge.
* For the positive half-cycle of the input AC voltage diodes D_1 & D_3 conducts whereas diodes D_2 & D_4 donot conduct.
* The conducting diodes will be in series through load resistance (R_L)

so the load current flows through R_L

* For the negative half-cycle of the input AC voltage diodes D_2 & D_4 conducts where as diodes D_1 & D_3 doesnot conduct.
* The conducting diodes will be in series through load resistance so the load current flows through R_L.
* The current flows through R_L in the same direction as in previous half-cycle
* Thus a bidirectional wave is converted into unidirectional one

The average values of output voltage & load current for bridge rectifier are the same as for the centre-tapped full-wave rectifier.

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

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

* The maximum efficiency of a bridge rectifier is 81.2% & the Ripple Factor (γ) is 0.48.

PIV is V_m.

Advantages of the bridge rectifier:

* In the bridge rectifier, the ripple factor & efficiency of the rectification are the same as for the full-wave rectifier.

The PIV across either of the non-conducting diodes is equal to the peak-value of the transformer secondary voltage (V_m).

The bulky centre tapped transformer is not required.

The TUF is considerably high.

* Since the current flowing in the transformer secondary is purely alternating.

The TUF increases to 0.812 which is the main reason for the popularity of a bridge rectifier.

* The bridge rectifiers are used in applications allowing floating output terminals i.e., no output terminal is grounded.
* Bridge rectifier has only one disadvantage that it requires four

diodes as compared to two (2) diodes for centre tapped full-wave rectifier.

But the diodes are readily available at the cheaper rate.

* Apart from this, the PIV rating required for the diodes in a bridge rectifier is only half of that for a centre-tapped full-wave rectifier.

This is a great advantage of bridge rectifier.

Comparisions of rectifiers:

Particulars	Types of rectifier: Half-wave	Full-wave	Bridge
1. No. of diodes	1	2	4
2. Maximum Efficiency	40.6	81.2	81.2
3. V_{dc} (Max. load)	V_m/π	$2V_m/\pi$	$2V_m/\pi$
4. Average current for diode.	I_m/π	$2I_m/\pi$	$2I_m/\pi$
5. Ripple Factor	1.21	0.482	0.482
6. PIV	V_m	$2V_m$	V_m
7. Output Frequency			

8. TUF	0.287	0.693	0.693
9. Form Factor	1.57	1.11	1.11
10. Peak Factor	2	1.414	1.414

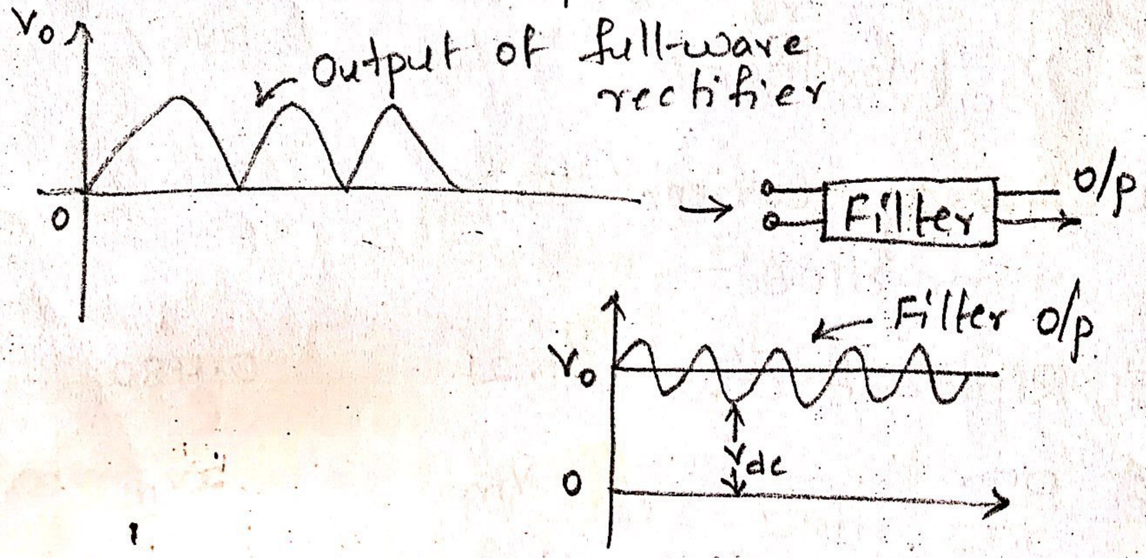
Filters :

Upto now we have seen the output of a rectifier contains DC component as well as AC component.

Filters are used to minimize the undesirable AC i.e., ripple leaving only the DC component to appear at the output.

The ripple in the rectified wave being very high. The factor being 48 % in the full-wave rectifier. Majority of the appli--cations which cannot tolerate this.

This will need an output which has been further processed

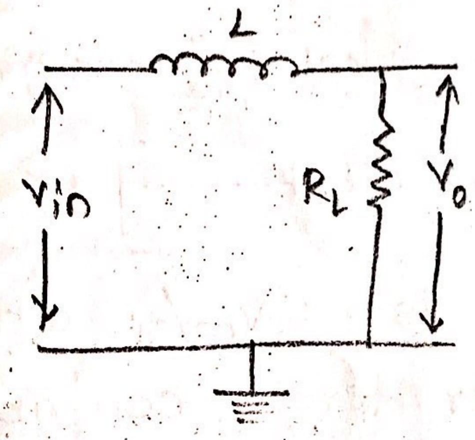


The output of a filter is not exactly a constant DC but it also contains a small amount of AC component.

Some important filters are

1. Inductor Filter
2. Capacitor Filter
3. LC (or) L-section Filter
4. CLC (or) π-type Filter.

1. Inductor Filter:



When the output of the rectifier passes through an inductor it blocks the AC component & allows only DC component to reach the load.

The ripple factor of inductor filter is given by $\gamma = \dfrac{R_L}{3\sqrt{2}\,\omega L}$.

It shows that the ripple factor will decrease when L is increased & R_L is decreased.

The inductor filter is more effective only when the load current is high. The large value of inductor can reduce the ripple & at the same time the output DC voltage will be lowered as the inductor has a higher DC resistance.

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

$$V_0 = \frac{2V_m}{\pi} - \frac{4V_m}{\pi}\left[\frac{1}{3}\cos 2\omega t + \frac{1}{15}\cos 4\omega t + \frac{1}{35}\cos 6\omega t + \cdots\right]$$

The DC component is $2V_m/\pi$ assuming the third & higher terms contribute little output

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

The diode, choke & transformer resistance can be neglected since they are very small as compared with R_L.

$\therefore$ The DC component of current $I_m = \frac{V_m}{R_L}$. The impedance of series combination of L & R_L at 2ω is

$$Z = \sqrt{(R_L)^2 + (L2\omega)^2}$$

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

$\therefore$ For AC component $I_m = \frac{V_m}{Z}$

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

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

$\therefore$ The resulting current (I) is given by

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

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

The ripple factor can be defined as the ratio of rms value of the ripple to the DC value of the wave.

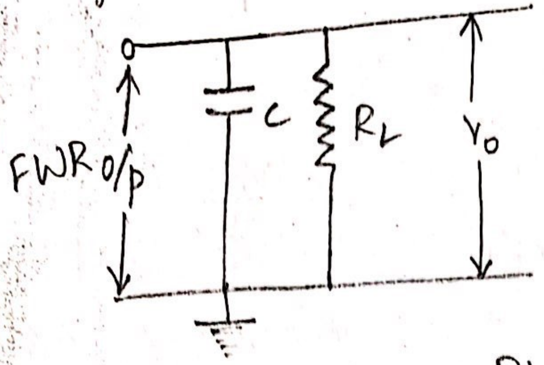
It is given by

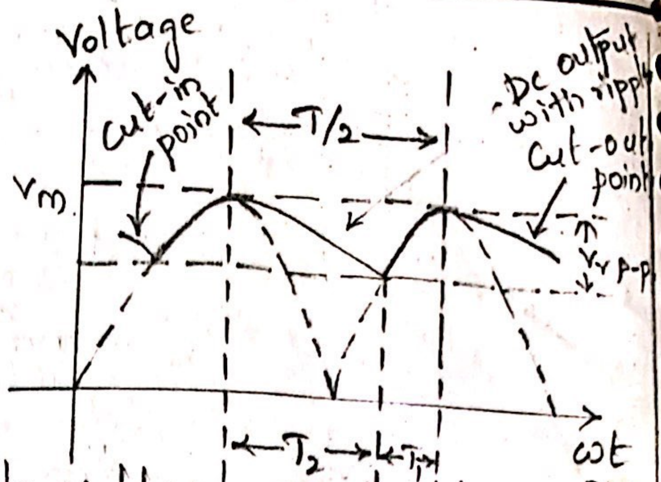
$$\Gamma = \frac{\frac{4V_m}{3\pi\sqrt{2}\sqrt{R_L^2 + 4\omega^2 L^2}}}{\frac{2V_m}{\pi R_L}} = \frac{2}{3\sqrt{2}} \cdot \frac{1}{\sqrt{1 + \frac{4\omega^2 L^2}{R_L^2}}}$$

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

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

Capacitive Filter:





Ripple voltage Triangular Wave form:

An inexpensive filter for light loads is found in the capacitor filter which is connected directly across the load. The property of the capacitor is that it allows AC component & blocks DC component

* The operation of a capacitor filter is to shot the ripple to the ground but leave the DC to appear at the output when it is connected across a pulse-rating DC voltage
* During the +ve half-cycle, the capa--citor charges upto the peak value of the transformer secondary voltage V_m & 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.

* From the figure with slight approximation, the ripple voltage waveform can be assumed as a triangular.

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

The charge it has acquired is

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$= V_{r\,p-p} \times C.$

* The charge it has lost $= I_{dc} \times T_2$

$= I_{dc} \times T_2.$

* The charge gained = The charge lost.

$$V_{r\,p-p} \times C = I_{dc} \times T_2.$$

* 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 the time T_2 = half the period in time of the wave-form.

i.e., $T_2 = \frac{T}{2} = \frac{1}{2f}$ $\left(\because T = 1/f\right).$

$$V_{r\,p-p} = \frac{I_{dc}}{2fC}.$$

* With the assumptions made above the ripple waveform will be triangular in nature & the rms value of the ripple is given by

$$V_{r,\,rms} = \frac{V_{r\,p-p}}{2\sqrt{3}}$$

$$V_{r,\,rms} = \frac{I_{dc}}{2fC \times 2\sqrt{3}} = \frac{I_{dc}}{4\sqrt{3}\,fC}$$

$$V_{r,rms} = \frac{V_{dc}}{4\sqrt{3} f C R_L} \quad \left(\because I_{dc} = \frac{V_{dc}}{R_L} \right)$$

$$\therefore \text{Ripple}, \, r = \frac{V_{r,rms}}{V_{d.c}} = \frac{1}{4\sqrt{3} f C R_L}.$$

* The ripple may be decreased by increasing C (or) R_L (or) both with the resulting increase in DC output voltage.

If $f = 50$ Hz, C in microfarads & R_L in ohms then

$$r = \frac{2890}{C R_L}.$$

Problem:

1. Calculate the value of capacitance to use in a capacitor filter connected to a full-wave rectifier operating at a standard aircraft power frequency of 400 Hz if the ripple factor is 10% for a load of 500Ω

Sol: Given, $f = 400$ Hz.

$r = 10\% = 0.01$

$R_L = 500\,\Omega$

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$$r = \frac{1}{4\sqrt{3} f C R_L}$$

$$C = \frac{1}{4\sqrt{3} f r R_L}$$

$$= \frac{1}{4\sqrt{3} \times 400 \times 500 \times 0.01}$$

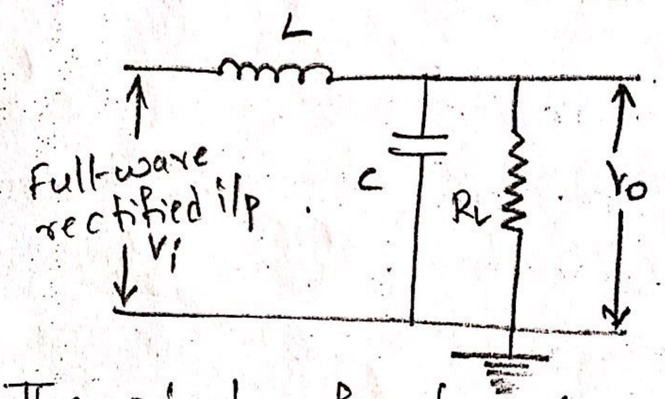
$$C = \cancel{866.025} \frac{1}{13856.40}$$

$$C = 7.2168817 3 \times 10^{-5}$$

$$C = 72.1688173 \times 10^{-6}$$

$$\therefore C = 72.2 \text{ microfarads.}$$

LC (or) L-section filter:



The ripple factor is directly proportional to the load resistance R_L in the inductor filter & inversely proportional to R_L in the capacitor filter.

$\therefore$ If these two filters are combined as LC or L-section filter, the ripple factor will be independent of R_L.

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If the value of inductance is in-creased, it will increase the time of induction at some critical value of in-ductance. One diode either D_1 or D_2 in full wave rectifier will also be conducting.

From the fourier series the output voltage can be expressed as

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

The DC output voltage $V_{dc} = \frac{2V_m}{\pi}$.

$$I_{rms} = \frac{4V_m}{3\pi\sqrt{2}} \times \frac{1}{X_L} = \frac{\sqrt{2}}{3} \cdot \frac{V_{dc}}{X_L}.$$

This current flowing through X_C creates the ripple voltage in the output

$$\therefore V_{r,rms} = I_{rms} \times X_C$$

$$V_{r,rms} = \frac{\sqrt{2}}{3} \cdot \frac{V_{dc}}{X_L} \times X_C$$

Ripple factor, $\gamma = \frac{V_{r,rms}}{V_{dc}}$

$$\gamma = \frac{\frac{\sqrt{2}}{3} \cdot \cancel{V_{dc}} \frac{X_C}{X_L}}{\cancel{V_{dc}}} = \frac{\sqrt{2}}{3} \frac{X_C}{X_L}$$

Since $X_C = \frac{1}{2\omega C}$, $X_L = 2\omega L$.

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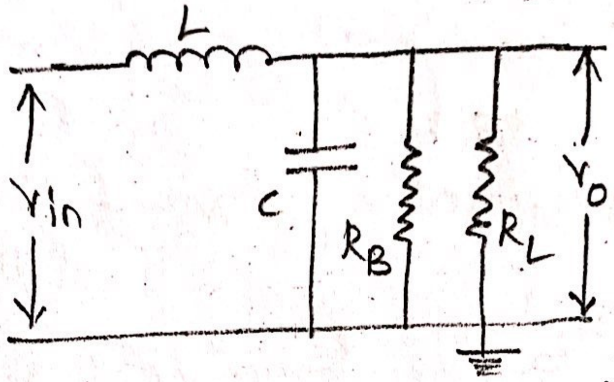
$$= \frac{\sqrt{2}}{3} \cdot \frac{\frac{1}{2\omega C}}{2\omega L}$$

$$r = \frac{\sqrt{2}}{3} \times \frac{1}{4\omega^2 LC}$$

If $f = 50\,Hz$, C is in microfarads & L is in Henry then ripple factor

$$r = \frac{1.194}{LC}.$$

Bleeder Resistor:



It was assumed that for a critical value of inductor either of diode is always conducting i.e., current does not fall to zero.

The incoming current consists of two components i) $I_{dc} = \frac{V_{dc}}{R_L}$ and second sinusoidal varying components with peak value of $\frac{4V_m}{3\pi X_L}$.

The negative peak of the AC current must always be less than DC i.e.,

$$\sqrt{2}\, I_{rms} \lesssim \frac{V_{dc}}{R_L}.$$

For LC filter $I_{rms} = \frac{\sqrt{2}}{3} \cdot \frac{V_{dc}}{X_L}$, hence

$$\frac{2V_{dc}}{3X_L} \leq \frac{V_{dc}}{R_L} \quad \text{i.e., } X_L \geq \frac{2}{3} R_L.$$

i.e., ~~LC~~ $L_c = \frac{R_L}{3\omega}$

where R_L = critical inductance

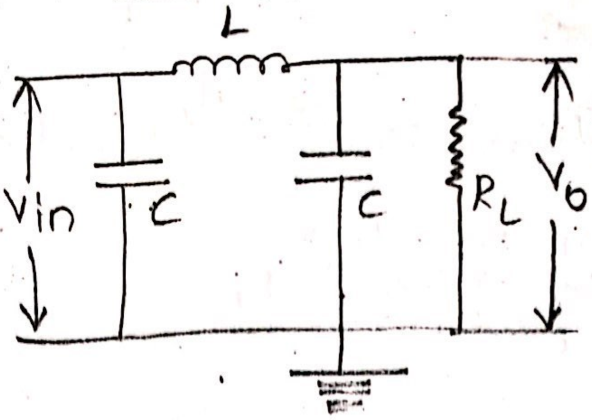
* At no load when the load resis-
-tance is ∞ (infinity) the value of the inductance will also tend to be infinity. To overcome this problem a bleeder resistor (R_B) is connected in parallel with the load resistance

∴ A minimum current will always be present for optimum operation of the inductor.

It improves voltage regulation of the supply by acting as the free load on the supply. Also it provides safety by acting as a discharging path for capacitor.

Note: Capacitor charges always and load resistance discharges.

CLC (or) π-section filter:



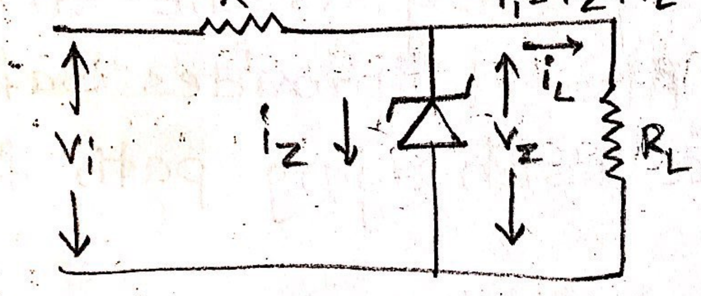
This filter offers a smooth output & is characterised by a highly peak diode currents & poor regulation proceeding the analysis as per the single L-section filter.

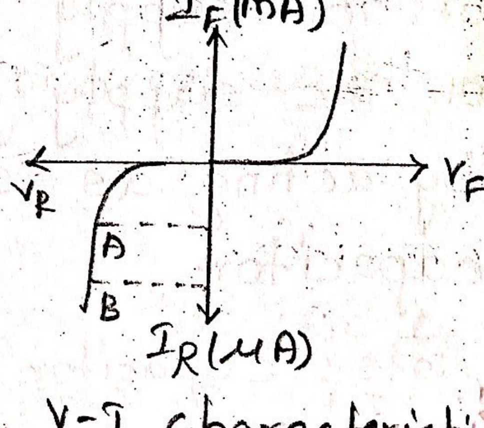
$$r = \sqrt{2} \cdot \frac{X_{C_1}}{R_L} \cdot \frac{X_{C_2}}{X_L}$$

If $f = 50\,Hz$, C is in microfards, L is in Henry & R_L is in ohms then

$$r = \frac{5700}{L C_1 C_2 R_L}$$

Voltage Regulation using zener diode:





V-I characteristic

A zener diode under reverse-biased breakdown condition can be used to regulate the voltage across the load irrespective to supply voltage or load current ~~variabl~~ variations.

A zener diode is selected with V_Z voltage desired across the load. Zener diode has the characteristic that under reverse-bias condition the voltage across it remains practically constant even if the current through it changes by a large extent. Under normal conditions the input current $i_i = i_Z + i_L$ flows through resistor R.

The input voltage V_i can be written as $V_i = i_i R + V_Z$. When input voltage V_i ~~decreas~~ increases, the voltage across zener diode remains constant.

The drop across resistor R when increases with corresponding increase in $i_L + i_Z$ as V_Z is constant, the voltage across load will also remain constant hence i_L will be constan

∴ An increase in $i_L + i_z$ will result in an increase in i_z which will not alter the voltage across the load.

It must be ensured that the reverse voltage applied to the zener diode never exceed the PIV of the diode.