Rectifiers :→

It is a device which converts a.c voltage to pulsating d.c. voltage using one or more p-n junction diode.

The p-n junction diodes conducts only in one direction. It conducts when forward biased practically while it does not conduct when reverse biased. Thus if an alternating voltage is applied across p-n junction diode, during +ve half cycle the diode will conduct while during negative half cycle it will not conduct at all. Thus conduction occurs during +ve half cycle.

Imartant Parameters of a Rectifier :→

- r.m.s and d.c. value –

d.c. value – It is also called average value denoted by $\bar{x}(t)$. Mathematically.

$$\boxed{x_{dc} = \bar{x}(t) = \frac{1}{T}\int_0^T x(t)\,dt}$$

rms. value -

It is also known as effective value.

$$\boxed{x_{rms} = \sqrt{\frac{1}{T}\int_0^T x^2(t)\,dt}}$$

Form Factor and Ripple factor →

$$\boxed{\text{form factor } (f) = \frac{x_{rms}}{x_{dc}}}$$

$$\text{Ripple factor } (r) = \frac{x_{rms(ac)}}{x_{dc}}$$

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

$$\Rightarrow \frac{x_{rms}}{x_{dc}} = \sqrt{\frac{x_{rms(ac)}^2 + x_{dc}^2}{x_{dc}^2}} \Rightarrow \sqrt{\left(\frac{x_{rms(ac)}}{x_{dc}}\right)^2 + \left(\frac{x_{dc}}{x_{dc}}\right)^2}$$

$$\Rightarrow f = \sqrt{r^2+1}$$

$$\Rightarrow \boxed{r = \sqrt{f^2-1}}$$

Thus,

ripple factor = $\sqrt{(\text{form factor})^2 - 1}$

Note - The o/p of the rectifier is of pulsating d.c. type. The amount of a.c. content in the output can be mathematically expressed by a factor called ripple factor. Less the ripple factor, better is the performance of the circuit.

Using one or more diodes, there are three types of rectifiers -

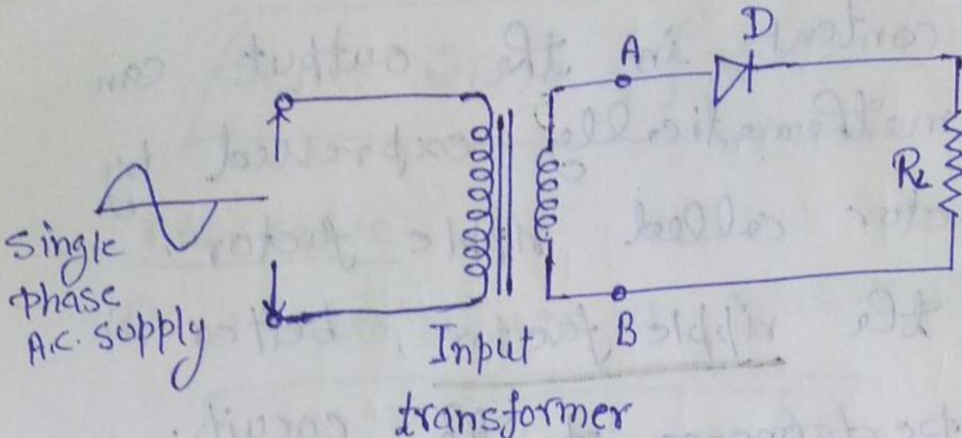
1- Half wave rectifier

2- Full wave rectifier

3- Bridge Rectifier

Half Wave rectifier →

This rectifier circuit consist of resistive load, rectifying element (diode) and the soure of a.c. voltage, all connected in series, as shown in the following figure



Halfwave rectifier

Operation of the circuit –

During the positive half cycle of input a.c. voltage, terminal A becomes positive with respect to terminal B. The diode is forward biased and the current flows in the circuit in the clockwise direction, as shown below in fig(a). This current is also flowing through the load resistance R_L hence denoted as i_L (load current).

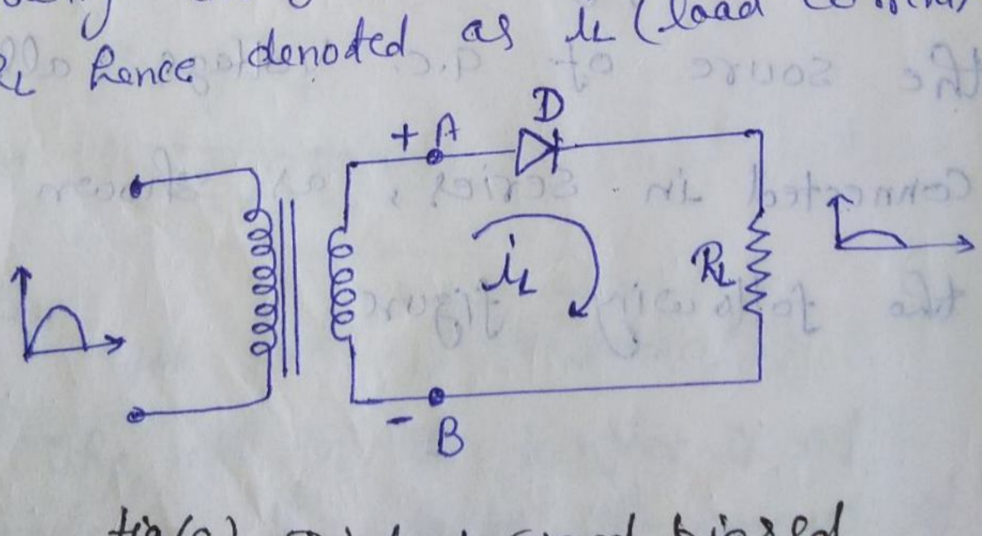


fig (a). Diode forward biased

During negative half cycle, terminal A is negative with respect to terminal B, diode becomes reverse biased. Hence no current flows in the circuit as show in below fig (b)

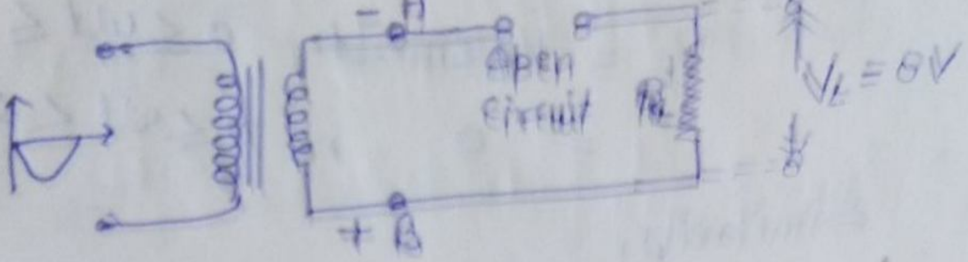
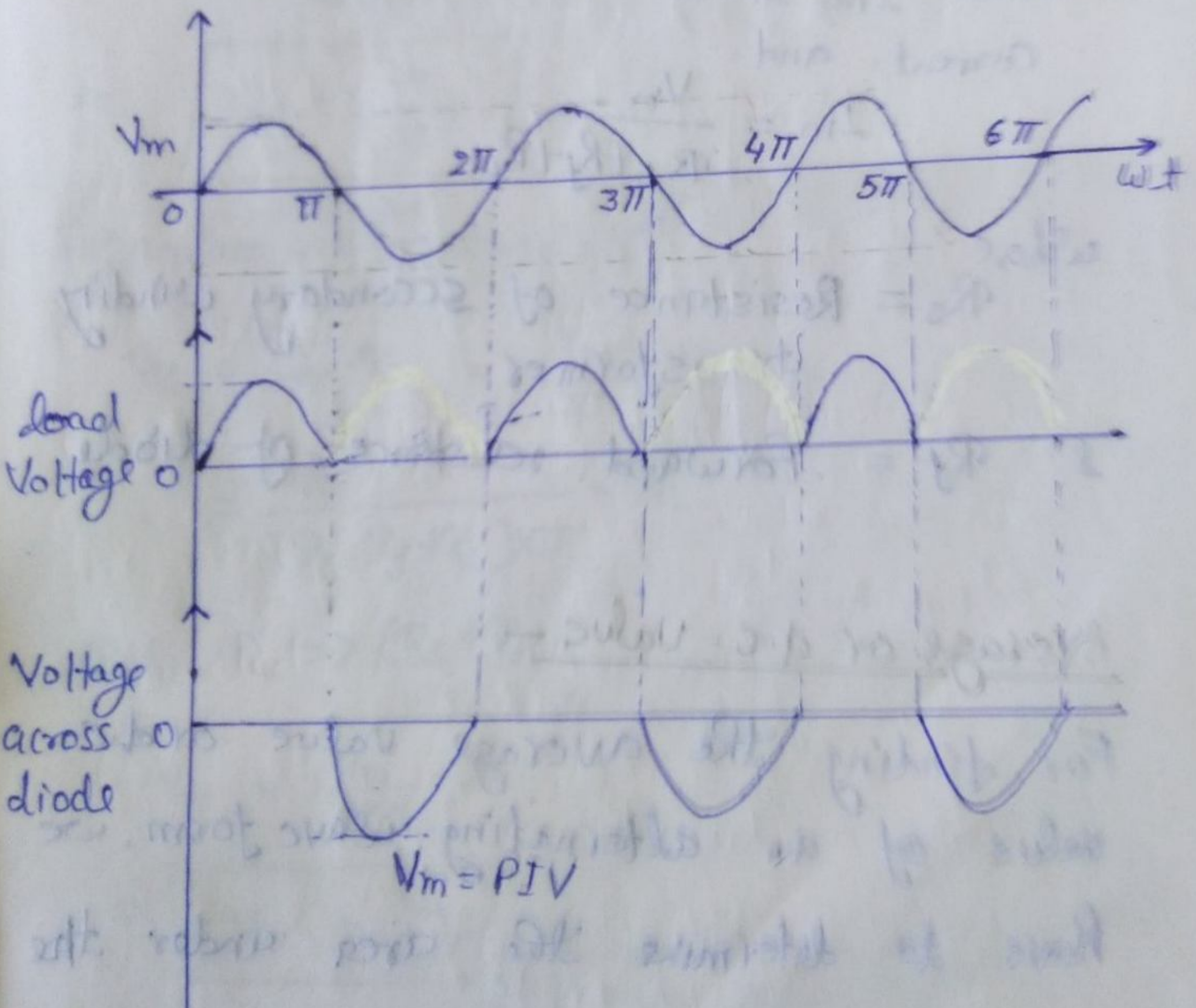


fig (b). Diode revers biased

The different waveforms are shown below-



Analysis of Half Wave Rectifier –

As we assume a sinusoidal input i.e. $V_i = V_m \sin\omega t$. Then output voltage is–

$$V_L = V_m \sin\omega t \; ; \quad 0 \le \omega t \le \pi$$
$$= 0 \; ; \quad \pi \le \omega t \le 2\pi$$

Similarily,

$$i_L = I_m \sin\omega t \; ; \quad 0 \le \omega t \le \pi$$
$$= 0 \; ; \quad \pi \le \omega t \le 2\pi$$

where I_m is the peak value of load current and

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

where R_s = Resistance of secondary winding transformer

& R_f = Forward resistance of diode

Average or d.c. value –

For finding the average value or d.c. value of an alternating wave form, we have to determine the area under the curve over one complete cycle i.e. from 0 to 2π. Then dividing it by 2π.

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i_L \cdot d\omega t = \frac{1}{2\pi}\int_0^{2\pi} I_m \sin(\omega t)\, d(\omega t)$$

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

$$= \frac{1}{2\pi}\int_0^{\pi} I_m \sin(\omega t) \cdot d(\omega t)$$

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

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

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

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

d.c. value of load voltage -

$$V_{dc} = I_{dc} \cdot R_L = \frac{I_m}{\pi} \cdot R_L$$

$$= \frac{V_m}{(R_S + R_f + R_L) \times \pi} \times R_L$$

But $R_L >> (R_S + R_f)$

$$\therefore V_{dc} = \frac{V_m}{\pi R_L} \times R_L$$

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

rms value of load current & voltage :→

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

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

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

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

$$(\because \cos 2x = 1 - 2\sin^2 x)$$

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

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

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

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

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

rms value of load voltage —

$$V_{rms} = I_{rms} \cdot R_L = \frac{I_m}{2} \cdot R_L$$

$$= \frac{V_m}{(R_s + R_f + R_L) \cdot 2} \times R_L$$

But $(R_s + R_f) << R_L$

$$\therefore V_{rms} = \frac{V_m}{2 \cdot R_L} \times R_L$$

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

d.c. power output →

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

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

$$\Rightarrow P_{dc} = \frac{V_m^2}{\pi^2 (R_s + R_f + R_L)^2} \cdot R_L$$

a.c. power input (P_{ac}) →

The a.c. power input taken from the secondary of transformer is the power supplied to three resistances namely R_L, diode resistance R_f and winding resistance R_s. Thus

$$P_{ac} = I_{rms}^2 [R_s + R_f + R_L]$$

but $I_{rms} = I_m / 2$

$$\therefore \boxed{P_{ac} = \frac{I_m^2}{4} [R_s + R_f + R_L]}$$

Rectifier efficiency →

The rectifier efficiency is defined as the ratio of output d.c. power to input a.c power.

$$\eta = \frac{\text{d.c. output power}}{\text{a.c. input power}} = \frac{P_{dc}}{P_{ac}}$$

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

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

$$= \frac{4}{\pi^2} \cdot \frac{1}{1 + \frac{R_s + R_f}{R_L}}$$

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

If $(R_s + R_f) << R_L$, then we get the maximum theoretical efficiency of half wave rectifier as,

$$\eta = 0.406$$

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

Note- More the rectifier efficiency, less are the ripple contents in the output.

Thus, in half wave rectifier maximum 40.6% a.c. power gets converted into d.c. power at the load.
Remaining 60% power is present in terms of ripples at the o/p which is fluctuating component present in the output.

Ripple Factor :→

It is clear the output of H.W.R. is not pure d.c. but a pulsating d.c. The o/p contains pulsating components called ripples. Ideally there should not be any ripples in the rectifier output.

The measure of ripples present in the o/p is with the help of a factor called ripple factor, denoted by r.

$\because$ form factor $(f) = \dfrac{I_{rms}}{I_{dc}} = \dfrac{I_m/2}{I_m/\pi}$

$$= \frac{\pi}{2} = 1.57$$

$\therefore$ Ripple factor $(\gamma) = \sqrt{f^2-1}$

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

$$\boxed{\gamma = 1.21}$$

This indicates that the ripple contends in the output are 1.21 times the d.c. component i.e. 121% of d.c. component.

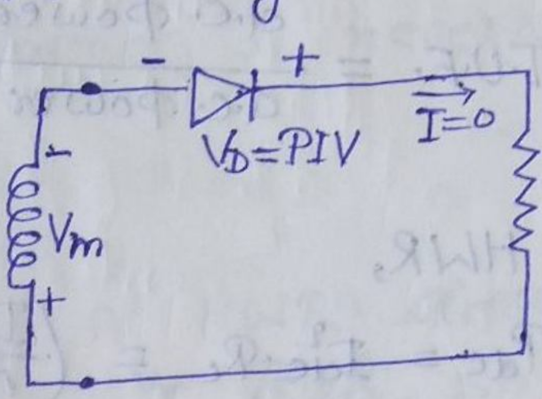
Thus the ripple factor for half wave rectifier is very high which indicates that the half wave circuit is a poor converter of a.c. to d.c.

<u>Note</u>- Smaller the ripple factor closer is the output to a pure d.c.

Peak Inverse Voltage (PIV) :→

The PIV is the peak voltage across the diode in the reverse direction i.e. when the diode is reverse biased. This is called PIV rating of a diode.

Apply KVL



$V_m - PIV = 0$

$\therefore \boxed{PIV = V_m}$

Advantages & Disadvantages of HWR :-

Advantages - 1- Only one diode is sufficient.
2- The circuit is easy to design
3- No centre tap on the transformer is necessary.

Disadvantages →

1- The ripple factor of HWR circuit is 1.21 which is quite high, so o/p contains lot of varying components.

2- Rectifier efficiency is found to be 40%., that indicates the half-wave rectifier circuit is quit insufficient.

3- The circuit has low T.U.F.. That shows the transformer is not fully utilised.