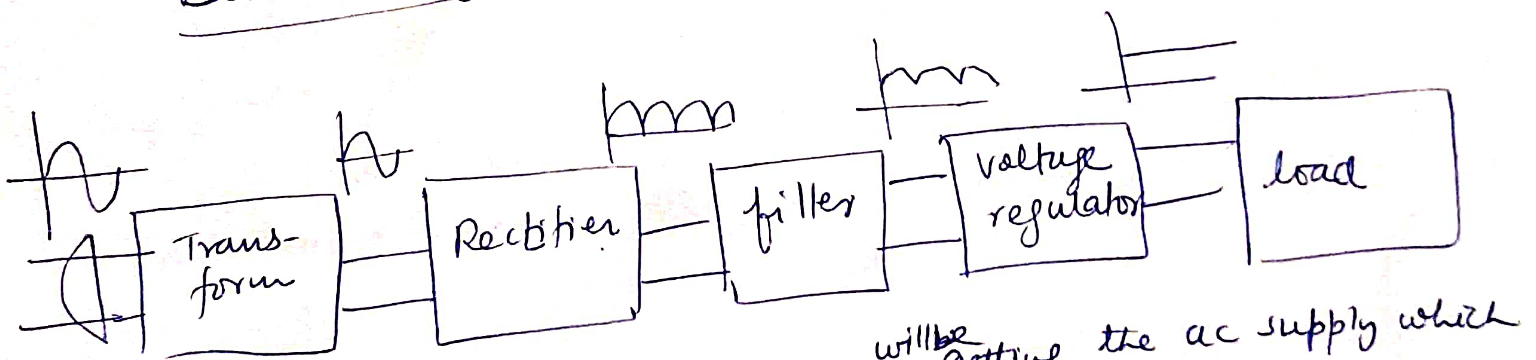
correction of errors/mistake = Rectification

Rectifiers

* Rectifiers are important application of diode
* Rectifier is ckt that ~~conv~~ rectifies an ac voltage into dc voltage
* Most electronics applications required dc voltage or constant voltage supply. In order to get constant dc voltage from the supplied ac voltage, (because most of our in ~~how~~ home ac supply), we will have to use rectifier ckt ~~that use~~ where diode is used.

DC power supplies has different stages starting from an ac supplies, then using a transformer to bring it to desired level of ac voltage & then rectifier ckt to rectifying the ac into unipolar voltage & then the filtering ckt to smoothened out the pulsating dc voltage which we will get after rectification & then another regulator ckt is there to finally keep it at a constant voltage level.

Block diagram of a Power supply



I stage is Transformer. This transformer will be getting the ac supply which will be given to the power supply, at the rated freq. ~~which is~~ 50 Hz. This our household devices we have ac supply at the ac i/p to the transformer is there to bring the level of the ac i/p to the desired level by transforming it, the voltage transformation is done, we can step up or step down the voltage by adjusting the turns ratio in the transformer. Then this rectifier ckt having the diode, which will ~~rectifier~~ ~~rectif~~ rectifying an ac voltage to unipolar dc voltage & then

This filtering ckt is there which is an extra ckt, which will be required to smoothening ~~ctp~~ out the pulsating dc then finally ~~a~~ voltage regulator ckt is there to regulate the voltage level even. when the load varies. Finally this load, that is the o/p of the ckt where we want to apply the dc voltage, will be getting the dc voltage & this dc voltage is desired & it should be constant level voltage.

For this rectifier ckt we have use the diode in

RECTIFIER

Rectifier is a device which converts the sinusoidal ac voltage into either positive or negative pulsating d.c

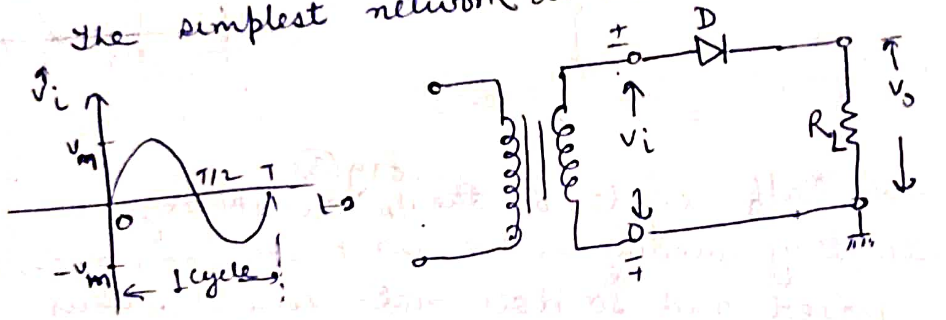
{ PN junction diode, which conducts when forward biased and practically does not conduct when reverse biased, can be used for rectification i.e. for conversion of ac to d.c.

Two types of Rectifiers i.e.

1) Half wave
2) Full wave (or centre tap or bridge)

Half wave Rectifier: Only one half of the ac voltage is rectified, for the other half we get zero o/p voltage.

The simplest network to examine half wave rectifier is



$v_i = V_m \sin\omega t$

fig ①

circuit: the diode is connected in series with secondary of the transformer and load resistance R_L, the primary of the transformer is being connected to the ac supply mains.

Working: The ckt. of fig ① is called half wave rectifier, will generate ~~ac to dc~~ a o/p waveform V_o that will have an average value of particular ~~value~~ use in ac to dc conversion process.

During interval $t = 0 \to T/2$, in fig ① the polarity of the applied voltage v_i is such as, to turn on the diode (ie make the the diode in forward biased) ie.

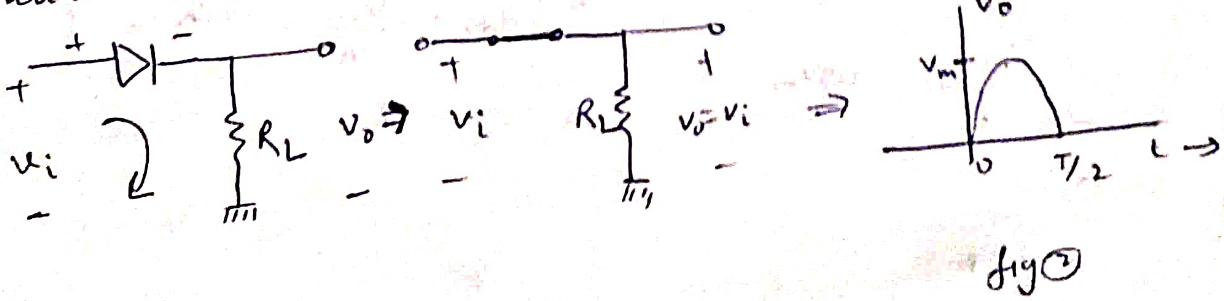


fig ②

In fig(2), During the +ve half cycle of the input ac voltage i.e. when upper end of secondary winding is +ve w.r.t. its lower end, the diode is forward biased & conducts current, & if the forward resistance of diode is assumed to be zero {in practice, however, small resistance exists} the input voltage during +ve half cycle is ~~is~~ directly applied to the load resistance R_L ~~o/p current~~ {because short ckt is substituted in place of diode}. The waveform or o/p voltage (or current) are of same shape as that of the input ac voltage.

For the period $T/2 \rightarrow T$, the polarity of V_i & equivalent ckt shown as

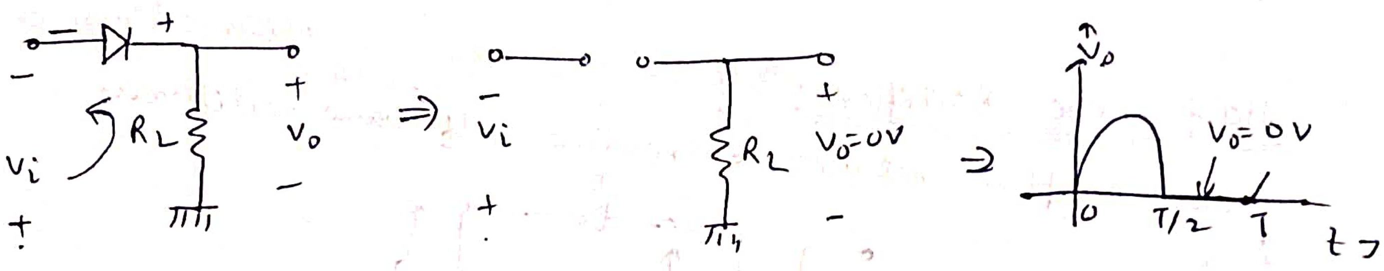
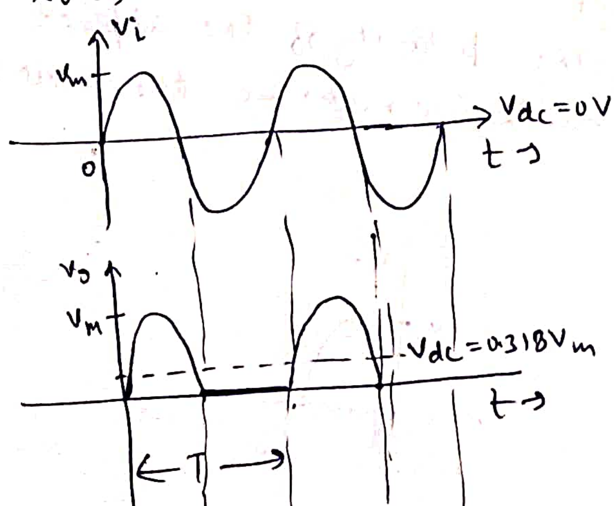


fig ③

from fig③, during −ve half cycle of the i/p ac voltage i.e. when the lower end secondary winding is +ve w.r.t. its upper end, the diode is reverse biased and so does not conduct. Thus during the −ve half cycles of the i/p ac voltage the current through and voltage across the load is zero if the reverse current, being very small in magnitude, is neglected. Thus for −ve half cycle the diode behaves as an open ckt & delivers no power to the load.

Now, the i/p & o/p {V_i & V_o} were skethed together as:



The o/p 'V_o' now has a net positive area above the axis over a full period & an average value determined by

$$\boxed{V_{dc} = \frac{V_m}{\pi} = .318 V_m}$$

2

For the analysis of Half wave rectifier, we need to consider the following terms as:

(i) Peak Inverse voltage: (PIV)

During the -ve half cycles of the i/p voltage, the diode is reverse biased, no current flows through the load resistance R_L and so causes no voltage drop across the load resistance R_L thus the whole of the input voltage appears across the diode.

Thus the maximum voltage that appears across the diode, is equal to the peak value of the secondary voltage i.e. V_{imax}'

Thus for half wave rectifier

$$\boxed{PIV = V_{imax}} \longrightarrow (1)$$

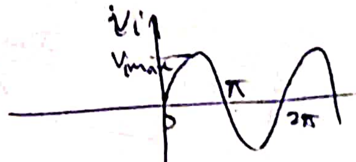
(ii) Peak current:

Peak value of the current flowing through diode is

$$I_{max} = \frac{V_{imax}}{R_F + R_L} = \frac{V_m}{r_D + R_L} \quad (2)$$

where $R_F \to$ forward resistance of diode (in ohms)

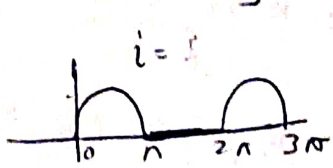
(iii) DC output current or. Average current



The average or dc value of o/p current is

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

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



$$= \frac{I_{max}}{\cancel{2}\pi} \times \cancel{2} = \frac{I_{max}}{\pi}$$

$$\boxed{I_{dc} = \frac{I_{max}}{\pi} = 0.318\, I_{max}} \longrightarrow (3)$$

put (2) eqn in eqn (3), thus we get

$$\boxed{I_{dc} = \frac{V_{imax}}{\pi(R_L + R_F)}} \longrightarrow (4) \quad \text{or} \quad I_{dc} = \frac{V_{imax}}{\pi R_L} \quad \text{if } R_L >> R_F$$

(4) **DC output voltage:** or average ~~dc~~ ~~vo~~ o/p voltage

Average or dc value of voltage across the load is

$V_{av} = V_{dc} = I_{dc} \cdot R_L$

$$\boxed{V_{dc} = \frac{V_{imax}}{\pi(R_L + R_F)} \times R_L = \frac{V_{imax}}{\pi\left(1 + \frac{R_F}{R_L}\right)}} \longrightarrow (5)$$

if $R_L >> R_F$ then $\boxed{V_{dc} \cong \frac{V_{imax}}{\pi} =} \ .318 V_{max}$

(5) **RMS value of current:** RMS value of current flowing through the diode (or load resistance R_L) is

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

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

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

$$= \frac{I_{max}^2}{4\pi}\left[(\pi - 0) - \frac{1}{2}(0)\right]$$

$$= \frac{I_{max}^2}{4\cancel{\pi}} \times \cancel{\pi}$$

$$I_{rms}^2 = \frac{I_{max}^2}{4\pi}\left[(\pi - 0) - 0\right] = \frac{I_{max}^2}{4\cancel{\pi}} \times \cancel{\pi}$$

$$\boxed{I_{rms} = \frac{I_{max}}{2}} \longrightarrow (6)$$

put the value of I_{max} from eqn (4) into (6)

$$\boxed{I_{rms} = \frac{V_{imax}}{2(R_F + R_L)}}$$

(6) **RMS value of o/p voltage:** The RMS value of voltage across the load is

$V_{o\,rms} = I_{rms} R_L$

$$\boxed{V_{o\,rms} = \frac{V_{imax} \times R_L}{2(R_F + R_L)} = \frac{V_{imax}}{2\left(1 + \frac{R_F}{R_L}\right)}}$$

if $R_L >> R_F$ $\boxed{V_{o\,rms} = \frac{V_{imax}}{2}}$

(7) Form Factor and Peak Factor:

The form factor defined as ratio of rms value to average value is given as

$$K_f = \frac{\text{RMS value}}{\text{Average value}} = \frac{I_{rms}}{I_{dc}}$$

$$= \frac{V_{imax}/2(R_F+R_L)}{V_{imax}/\pi(R_F+R_L)}$$

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

Peak factor is defined as the ratio of peak value to rms value is given by

$$K_p = \frac{\text{Peak value}}{\text{RMS value}} = \frac{V_{imax}/(R_F+R_L)}{V_{imax}/2(R_F+R_L)} = \frac{V_{imax}}{V_{imax}/2}$$

$$\boxed{K_p = 2}$$

(8) Output frequency:

In Half wave rectifier o/p freq. is same as i/p freq.

$f_{out} = f_{in}$ i.e. o/p freq. is same as i/p freq.

& this can be realized by comparing o/p waveform with the i/p waveform.

(9) Rectification Efficiency:

defined as the ratio of dc o/p power to the ac i/p power i.e.

$$\eta = \frac{\text{DC power delivered to the load}}{\text{AC i/p power from the transformer}} = \frac{P_{dc}}{P_{ac}}$$

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

& P_{ac} = Power dissipated in the diode junction + power dissipated in load resistance R_L.

$$P_{dc} = I_{rms}^2 R_L + I_{rms}^2 R_F$$

$$= \left(\frac{I_{max}}{2}\right)^2 R_F + \left(\frac{I_{max}}{2}\right)^2 R_L = \frac{I_{max}^2}{4}(R_F+R_L)$$

$$\therefore \eta = \frac{P_{dc}}{P_{a.c}} = \frac{I_{max}^2 R_L/\pi^2}{I_{max}^2(R_F+R_L)/4} = \frac{4}{\pi^2} \cdot \frac{R_L}{(R_F+R_L)} = \frac{0.406}{\left(\frac{R_F}{R_L}+1\right)}$$

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

if R_F is neglected, η becomes equal to 0.406 or 40.6 %.

$\eta = 40.6\%$ is the maximum possible efficiency for half wave rectifier.

(10) Ripple Factor: the pulsating o/p of the rectifier can be considered to contain a dc component and ac components called the ripples. The ripple current is undesirable and its value should be the smallest possible in order to make the rectifier effective.

The ripple voltage or current is measured in terms of the ripple factor which is defined as the ratio of the effective value of the a.c. components of voltage (or current) present in the o/p from the rectifier to ~~be~~ the direct or average value of the o/p voltage (or current). Ideally ripple factor should be zero i.e. ac current = 0

The effective value of the load current is given as

$$I^2 = I_{dc}^2 + I_{a.c}^2 = I_{dc}^2 + I_1^2 + I_2^2 + \cdots \longrightarrow (1)$$

where I_1, I_2 -- are the rms values of fundamental, 2nd fourth etc. harmonics and I_{ac}^2 is the sum of squares of the rms values of the ac components.

so ripple factor $\gamma = \frac{I_{ac}}{I_{dc}} = \frac{\sqrt{I^2 - I_{dc}^2}}{I_{dc}}$

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

$K_f \rightarrow$ form factor, for H.W. rectifier is given as:

$$K_f = \frac{I_{rms}}{I_{av}} = \frac{I_{max}/2}{I_{max}/\pi} = \frac{\pi}{2} = 1.57$$

$$\therefore \gamma = \text{ripple factor} = \sqrt{(1.57)^2 - 1} = 1.21$$

$\boxed{\gamma = 1.21} \Rightarrow$ high, so not preferred

11.) Transformer Utilization factor: (TUF) is defined as ratio of power delivered to the load and a c rating of the transformer secondary; i.e.

$$TUF = \frac{P_{dc}}{P_{ac}\,(\text{rated})} = \frac{I_{dc}^2 R_L}{V_{i\,rms}\, I_{rms}} = \frac{(I_{max}/\pi)^2 \cdot R_L}{\frac{V_{imax}}{\sqrt{2}} \cdot \frac{I_{max}}{2}}$$

$$TUF = \frac{2\sqrt{2}}{\pi^2} \frac{I_{max} R_L}{V_{imax}}$$

But $V_{imax} = I_{max}(R_F + R_L)$

$$\text{so} \quad TUF = \frac{2\sqrt{2}}{\pi^2} \frac{\cancel{I_{max}} R_L}{\cancel{I_{max}}(R_F + R_L)} = \frac{0.286\, R_L}{(R_F + R_L)}$$

$$\boxed{TUF = \frac{.286}{\left(1 + \frac{R_F}{R_L}\right)}}$$

neglect R_F then $\boxed{TUF = 0.286}$

12) Regulation: ~~The variation of dc o/p voltage as a f^n of dc load current is called regulation. Percentage regulation is given as:~~

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

Advantages:

: Simple circuit & low cost.

Disadvantages:

> The power o/p and therefore rectification efficiency is quite low (40%). This is due to the fact that power is delivered only half the time.
> TUF is low (only 28%) which indicates that transformer is not being used effecting
> Ripple factor is high (1.21)
> low DC o/p voltage and current
> {H.W rectifier is not normally used in practice because of these disadvantages.

Q A half wave rectifier uses diode with a forward resistance of 100Ω. If the i/p ac voltage is 220V (rms) and the load resistance is of $2k\Omega$. Determine i) I_{max}, I_{dc}, & I_{rms} (ii) peak inverse voltage when diode is ideal (iii) load o/p voltage (iv) dc o/p power and ac i/p power (v) ripple factor (vi) TUF (vii) Rectification efficiency

Sol: $V_{irms} = 220V$ $\left\{ \frac{V_m}{\sqrt{2}} = V_{rms} \right.$

$V_m = V_{imax} = 220 \times \sqrt{2}$; $R_F = 100\Omega = 0.1k\Omega$., $R_L = 2k\Omega$.

(i) $I_{max} = \dfrac{V_{imax}}{R_L + R_F} = \dfrac{220\sqrt{2}}{(2+0.1)\times 10^3} = 148.156\, mA$

$I_{dc} = \dfrac{I_{max}}{\pi} = \dfrac{148.156}{\pi} = 47.16\, mA.$

$I_{rms} = \dfrac{I_{max}}{2} = \dfrac{148.156}{2} = 74.078\, mA.$

(ii) ~~Peak~~ Peak inverse voltage $PIV = V_{imax} = 220\sqrt{2} = 311.127\, V$

(iii) V_{dc} = load o/p voltage $= I_{dc} R_L = 47.16 \times 10^{-3} \times 2 \times 10^3 = 94.34\, V.$

(iv) DC o/p power $P_{dc} = I_{dc}^2 R_L = (47.16 \times 10^{-3})^2 \times 2 \times 10^3 = 4.448\, W.$

AC i/p power $P_{ac} = \dfrac{I_{max}^2}{4}(R_F + R_L) = \dfrac{(148.156 \times 10^{-3})^2}{4} \times (0.1+2) \times 10^3$

$P_{ac} = I_{rms}^2 \times (R_L + R_F)$
$= \dfrac{I_m^2}{4}(R_L + R_F)$ $= 11.524\, W$

(v) Ripple factor $\gamma = 1.21 = \dfrac{I_{ac}}{I_{dc}} \Rightarrow$ {already proved}

vi) $TUF = \dfrac{0.286}{1 + R_F/R_L} = \dfrac{0.286}{1 + \frac{0.1}{2}} = 0.2724$ Ans

(vii) Rectification efficiency, $\eta = \dfrac{P_{dc}}{P_{ac}} \times 100 = \dfrac{4.448}{11.524} \times 100$

$\boxed{\eta = 38.6\%}$

Q: What is the ripple 2V on average of 50V?

Sol: RMS value of ac component $V_{rms} = 2V$

$V_{dc} = 50V$

Ripple factor $\gamma = \dfrac{V_{rms}}{V_{dc}} = \dfrac{2}{50} = 0.04$ Ans

FULL WAVE RECTIFIER:

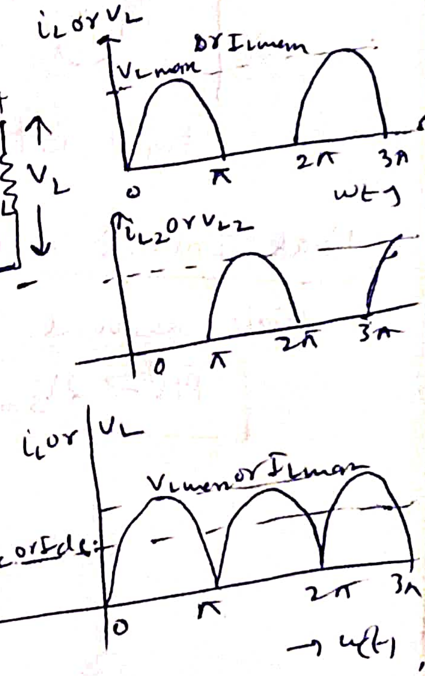
In half wave rectifiers only one half cycle of the input are utilized but in full rectifier both half cycles of i/p are utilized.

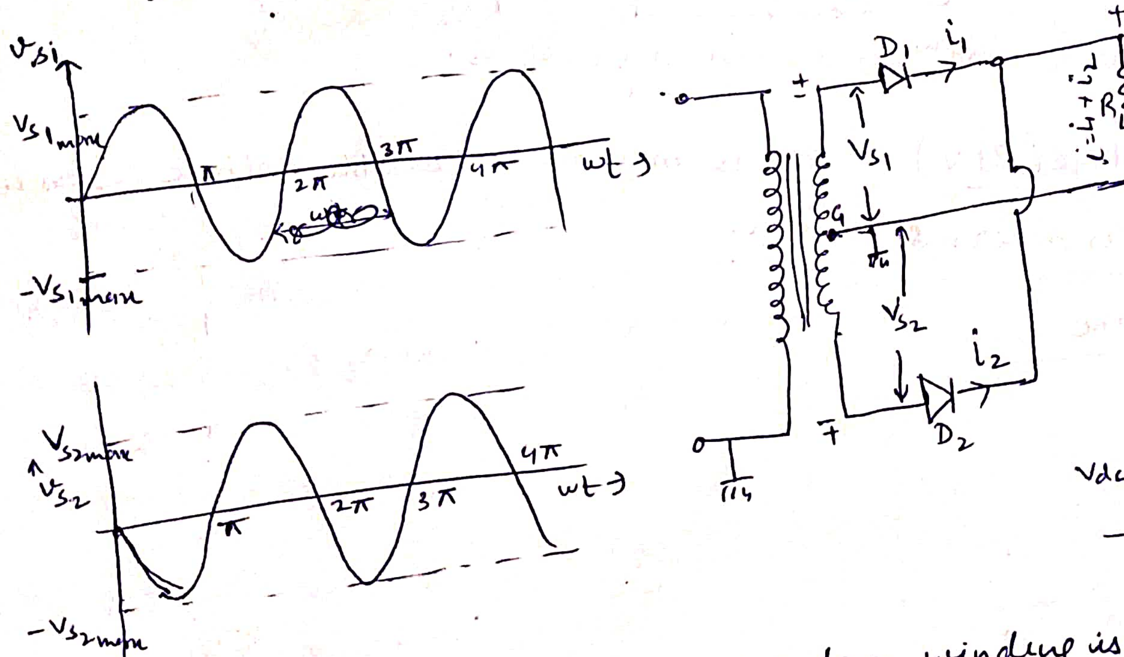
There are two types of full wave rectifiers circuits:

1) centre tap rectifier.
2) Bridge rectifier

> CENTRE TAP FULL WAVE RECTIFIER:

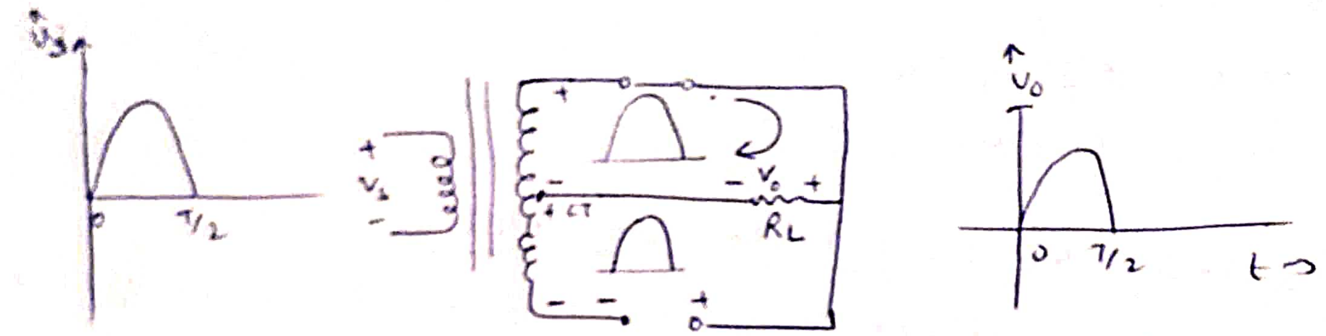
The ac input is applied through a transformer, the anodes of the two diodes D_1 and D_2 (having same characteristics) are connected to opposite ends of the centre tapped secondary winding and two cathodes are connected to each other and are connected also through the load resistance R_L and back to the centre of the transformer as shown:



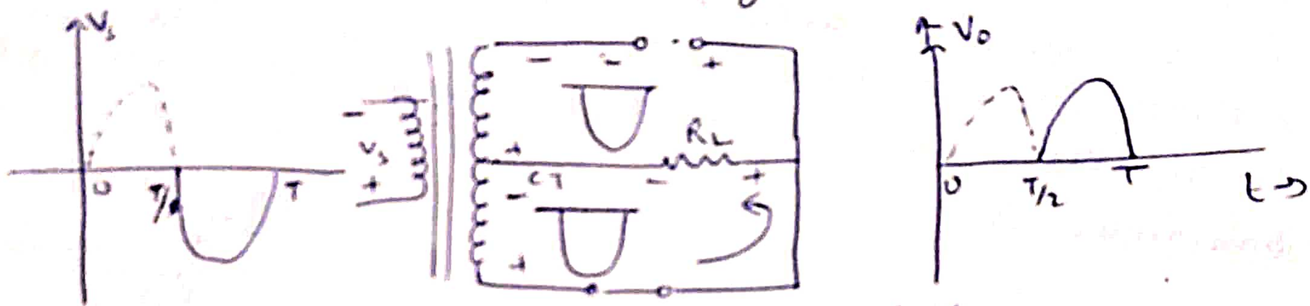


When top of the transformer secondary winding is +ve, say during first half cycle of the supply, the anode of diode D_1 is +ve, w.r.t. cathode, and anode of the diode D_2 is −ve, w.r.t. cathode. Thus only diode D_1 conducts, being F.B. and the current flows from cathode to anode of diode D_1, through load resistance R_L.

During the second half cycle of the input voltage the polarity is reversed, the bottom of the secondary winding +ve w.r.t. centre tap and thus diode D_2 is forward bias (behave as short ckt) & D_1 is reverse bias (behave as open ckt). Thus during this half cycle of the i/p, only D_2 conducts & current flows through R_L, is <u>+ve</u>.



fig(i) Network condn for the +ve region V_s.



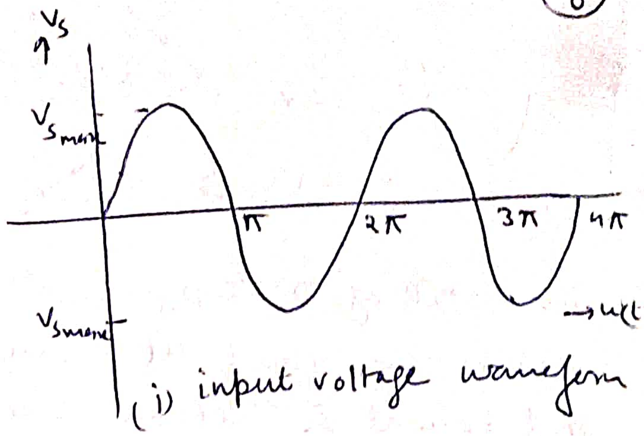
fig(ii) Network condn for the -ve region of V_s.

<u>Peak Inverse Voltage (PIV)</u> : PIV is maximum possible voltage across a diode when it is reversed biased.

$$\boxed{PIV \geq 2V_{s\,max}}$$

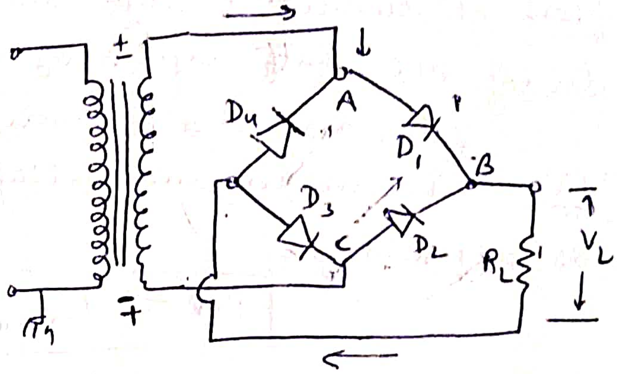
BRIDGE RECTIFIER :

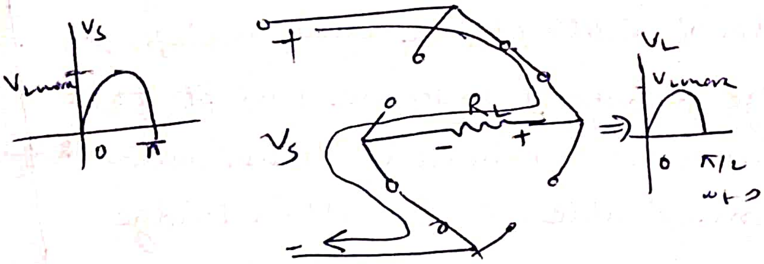
→ In the bridge ~~rectifier~~ ckt, four diodes are connected in the form of Wheatstone bridge



(i) input voltage waveform

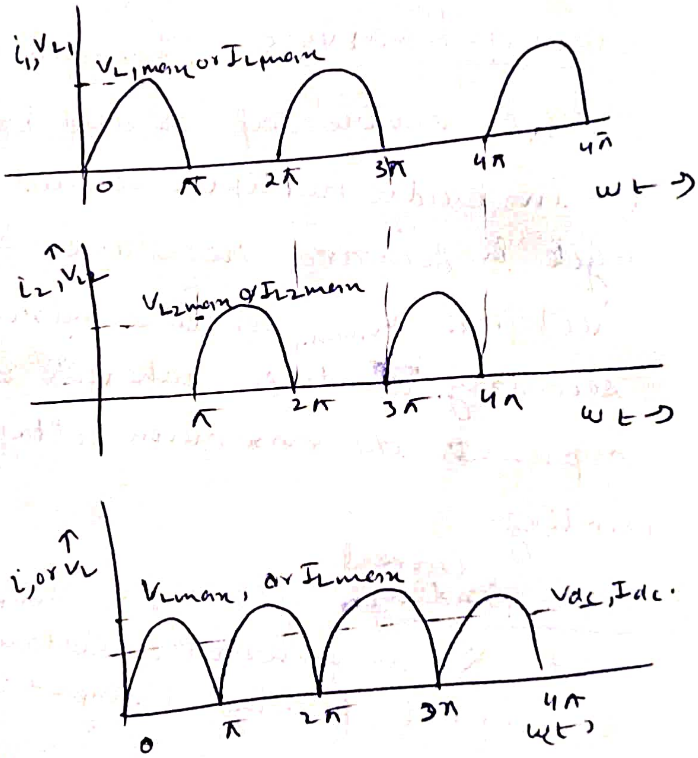
– When the upper end of the transformer secondary winding is +ve, say during first half cycles of the input supply, diodes D_1 and D_3 are forward biased and current flows as shown



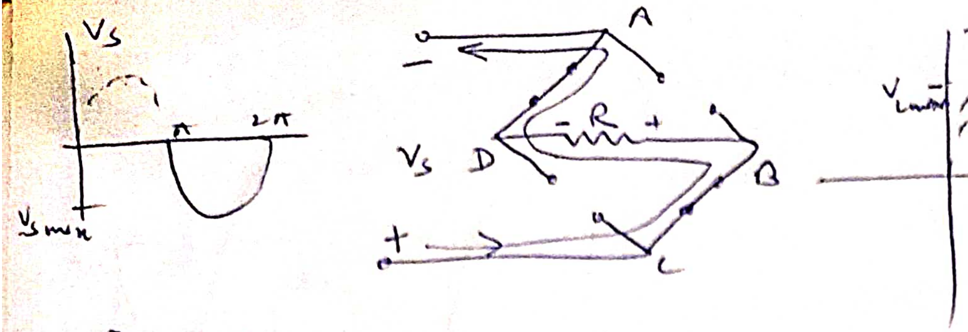


Thus during this half of each i/p cycle, the diodes D_2 and D_4 are reverse biased and so the current is not allowed to flow through in arms AD & BC.

In the second half of the i/p cycle the lower end of the ac supply becomes positive, diode D_2 & D_4 becomes forward bias and the current flows ~~as~~ as shown on the next page:



Rectified o/p voltage/current waveform



Due to F.B. of D_2 & D_4, the current flows through the arm CB enters the load at +ve terminal & leaves the load at -ve terminal & return back to arm DA. Thus the direction of flow of current through the load resistance R_L remains the same during both half cycles of the i/p supply voltage.

{when diode is not conducting then the volt

PIV : The maximum voltage across R_L is $V_{s\,max}$ and PIV rating is defined as:

{+ve half cy D_2, D_4 conduct D_1, D_3 off
$V_i - V_{D_4} = V_{D_1}$

$$\boxed{PIV \geq V_{s\,max}}$$

CIRCUIT-ANALYSIS : The analysis of both of full wave rectifier ckt (i.e. centre tap and bridge rectifier) is same except that (i) in bridge rectifier circuit two diodes conducts during each half cycle & forward resistance becomes double i.e. $2R_F$ (ii) in bridge rectifier $V_{s\,max}$ is the maximum voltage across the transformer secondary windings whereas in a centre tap rectifier ckt. $V_{s\,max}$ represents the maximum voltage across each half of the secondary winding.

1) Peak ~~winding~~ current: let $v_s = V_{s\,max} \sin \omega t$

let R_F is forward resistance & Reverse resistance $= \infty$ then the current flowing through the load resistance is:

$i_1 = I_{max} \sin \omega t$ & $i_2 = 0$ for first half cycle

$i_1 = 0$, $i_2 = I_{max} \sin \omega(t)$; for second half cycle. load resistance R_L is i & defined as

$\therefore$ total current through load resistance R_L is i & defined as

$i = i_1 + i_2 = I_{max} \sin \omega t$; for whole cycle.

thus the peak value of current through R_L is

$$I_{max} = \frac{V_{s\,max}}{R_F + R_L} \rightarrow (1) \Rightarrow \{\text{in case of centre tap}\}$$

$$I_{max} = \frac{V_{s\,max}}{2R_F + R_L} \rightarrow (2) \Rightarrow \text{for bridge rectifier}$$

2) **Output current:** { since the area above axis for one full cycle is now twice that obtained for a half-wave system, the dc level has also been doubled. (7)

let i_1 current between 0 to π

i_2 " " π to 2π

$$\therefore I_{dc} = \frac{1}{\pi}\int_0^{\pi} i_1\, d(\omega t) = \frac{1}{\pi}\int_0^{\pi} I_{max} \sin(\omega t)\, d(\omega t)$$

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

$$I_{dc} = \frac{2 I_{max}}{\pi} \longrightarrow (3)$$

(3) **DC output voltage** { V_{dc} is twice the HW Rectifier in case of FWR

$$V_{dc} = I_{dc} R_L = \frac{2}{\pi} I_{max} R_L = \frac{2V_m}{\pi} \longrightarrow (4) \quad \{ \text{use eq}^n (1)$$

$V_{dc} = .6366\, V_m$

(4) **RMS value of current:**

RMS or effective value of current flowing through the load R_L is

$$I_{rms}^2 = \frac{1}{\pi}\int_0^{\pi} i_1^2\, d(\omega t) = \frac{1}{\pi}\int_0^{\pi} I_{max}^2 \sin^2 \omega t\, d(\omega t)$$

$$I_{rms}^2 = \frac{I_{max}^2}{\pi}\int_0^{\pi} \frac{1}{2}(1 - \cos 2\omega t)\, d(\omega t)$$

$$= \frac{I_{max}^2}{2\pi}\left[(\pi - 0) - \left\{\frac{\sin 2\omega t}{2}\right\}_0^{\pi}\right] = \frac{I_m^2}{2\pi}\left[\pi - \frac{1}{2}(\sin 2\pi - \sin 0)\right]$$

$$= \frac{I_{max}^2}{2\pi} \times \pi = \frac{I_{max}^2}{2}$$

$$\boxed{I_{rms} = \frac{I_{max}}{\sqrt{2}}} \longrightarrow (5)$$

(5.) **RMS value of output voltage:**

$$V_{Lrms} = I_{rms} R_L = \frac{I_{max} R_L}{\sqrt{2}} = \frac{I_m R_L}{\sqrt{2}} \longrightarrow (6)$$

$$V_{Lrms} = \frac{V_m}{\sqrt{2}} = \frac{I_m R_L}{\sqrt{2}}$$

(6) **Form factor & Peak factor:**

$$\text{form factor } K_f = \frac{\text{RMS value}}{\text{Average value}} = \frac{I_{rms}}{I_{dc}} = \frac{I_{max}/\sqrt{2}}{2 I_{max}/\pi}$$

$$\boxed{K_f = \frac{\pi}{2\sqrt{2}} = 1.11} \longrightarrow (7)$$

Peak Factor $K_p = \frac{\text{Peak Value}}{\text{RMS value}} = \frac{I_{max}}{I_{max}/\sqrt{2}} = \sqrt{2}$

$$\boxed{K_p = \sqrt{2} = \cdot 707} \longrightarrow (8)$$

(7) Output frequency: In half wave $f_{in} = f_{out}$. But in full wave ~~rectifier~~ rectifier signal is double the input frequency. The full wave rectifier inverts each -ve half cycle, so that we get the number of +ve half cycles. The effect is to double the frequency. Thus for full wave rectifier;

$$\boxed{f_{out} = 2 f_{in}} \longrightarrow (9)$$

(8) Rectification Efficiency:

Power deleivered to load is

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

AC i/p power; $P_{ac} = I_{rms}^2 (R_L + R_F) = \frac{I_{max}^2}{2} (R_L + R_F) \longrightarrow (ii)$

Rectification efficiency $\eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{4}{\pi^2} I_{max}^2 R_L}{\frac{I_{max}^2}{2} (R_F + R_L)}$ { use (i) & (ii)

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

$$\boxed{\eta = \frac{0.812}{1 + \frac{R_F}{R_L}}} \longrightarrow (10)$$

In case of bridge reciifier, $\boxed{\eta = \frac{0.812}{1 + \frac{2R_F}{R_L}}} \longrightarrow (11)$

9 Ripple factor

$\because$ form factor $K_f = \frac{I_{rms}}{I_{av}} = \frac{I_{max}/\sqrt{2}}{2I_{max}/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$

& ripple factor is $\gamma = \sqrt{K_f^2 - 1} = \sqrt{(1.11)^2 - 1}$

$$\boxed{\gamma = 0.482}$$

11 Transformer Utilization factor for Centre Tap Transformer:

$$\text{TUF of primary} = \frac{P_{dc}}{\text{VA rating of primary}} = \frac{I_{dc}^2 R_L}{V_{s\,rms} \, I_{s\,rms}}$$

$$= \frac{\left(\frac{2 I_{max}}{\pi}\right)^2 R_L}{\frac{V_{max}}{\sqrt{2}} \times \frac{I_{max}}{\sqrt{2}}} = \frac{4 I_{max}^2 R_L/\pi^2}{\frac{I_{max}(R_F + R_L)}{\sqrt{2}} \times \frac{I_{max}}{\sqrt{2}}}$$

$$= \frac{4 \cancel{I_{max}^2} R_L}{\pi^2} \times \frac{\sqrt{2} \times \sqrt{2}}{\cancel{I_{max}^2}(R_F + R_L)}$$

$$= \frac{8}{\pi^2} \frac{R_L}{(R_F + R_L)} = \frac{8}{\pi^2}\left(\frac{1}{1 + \frac{R_F}{R_L}}\right)$$

$$\boxed{(TUF)_{full\ primary} \cong 0.812}$$

centre tap can be thought of as two Half wave rectifiers feeding to a common load. Hence TUF of two half secondaries can be written as:

$$\boxed{(TUF)_{full\ secondary} = 2 \times (TUF)_{half\text{-}wave} = 2 \times 0.286 = 0.572}$$

$$(TUF)_{av} = \frac{(TUF)_{PRIMARY} + (TUF)_{secondary}}{2} = \frac{0.812 + 0.572}{2}$$

$$\boxed{(TUF)_{av} = 0.692}$$

(12) TUF for Bridge Rectifier : The current flow through both of primary & secondary windings are ~~sinus~~ sinusoidal. Due to this TUF of both the primary & secondary are 0.812 & overall TUF is 0.812. & $(TUF)_{av}$ for centre tap is 0.692 i.e. TUF of bridge rectifier is larger than that of centre tap rectifier, for the same dc o/p power, a smaller transformer can be used in bridge ckt.

Merits & Demerits of Full Wave Rectifiers Over Half Wave Rectifiers

Merits :

1) Rectification efficiency of Full wave rectifier is double of that of a half wave rectifier.
2) Ripple voltage is low in F.W., thus simple filtering ckt. is required
3) $\gg$ o/p voltage ; $\gg$ o/p power ; $\gg$ TUF] in full wave

(4) **Demerits**

→ F.W rectifier needs more circuit element & is costlier.

Merits & Demerits of Bridge Rectifier Over centre tap Rectifiers :

Bridge rectifier is more popular than centre tap rectifier because of its low cost, high reliability and small sized silicon diodes. It has many advantages over centre tap as:

1) No centre tap is required in transformer secondary, so in case of bridge rectifier the simpler transformer is required.
(2) The PIV is one half of centre tap rectifier. Hence bridge is highly suited for high voltage application.
(3) $[TUF]_{bridge} > [TUF]_{centre\ tap}$.

The main drawback of a bridge rectifier is that it needs four diodes, two of which conduct in alternate half cycles. Because of this the total voltage drop in diode becomes double of that in case of centre tap rectifier, losses are increased and rectification efficiency is somewhat reduced. This pose a problem when low voltage are required.

An other drawback of bridge rectifier is that the load resistor R_L and supply source have no common point which may be earthed.

Q: The load resistance of centre tapped full wave rectifier is 500Ω and the necessary voltage is $60 \sin(100\pi t)$. Calculate (i) peak, average and rms values of current; (ii) ripple factor and (iii) Rectification efficiency of the rectifier. Each diode has an idealised I-V characteristics having slope corresponding to a resistance of 50Ω.

Soln given; $V_{smax} = 60V$, $R_F = 50\Omega$, $R_L = 500\Omega$

(i) Peak current $I_{max} = \dfrac{V_{smax}}{R_L + R_F} = \dfrac{60}{50+500} = 0.109\ A$

average current $I_{dc} = \dfrac{2 I_{max}}{\pi} = \dfrac{2 \times 0.109}{\pi} = 0.0695\ A$

$I_{rms} = \dfrac{I_{max}}{\sqrt{2}} = \dfrac{0.109}{\sqrt{2}} = 0.077\ A$

(ii) Ripple factor $\gamma = \sqrt{K_f^2 - 1} = \sqrt{\left(\dfrac{I_{rms}}{I_{dc}}\right)^2 - 1} = \sqrt{\left(\dfrac{.077}{.0695}\right)^2 - 1}$

$= 0.482$

(iii) $\eta = \dfrac{0.812}{1 + \dfrac{R_F}{R_L}} = \dfrac{0.812}{1 + \dfrac{50}{500}} \times 100 = 73.82\ \%$