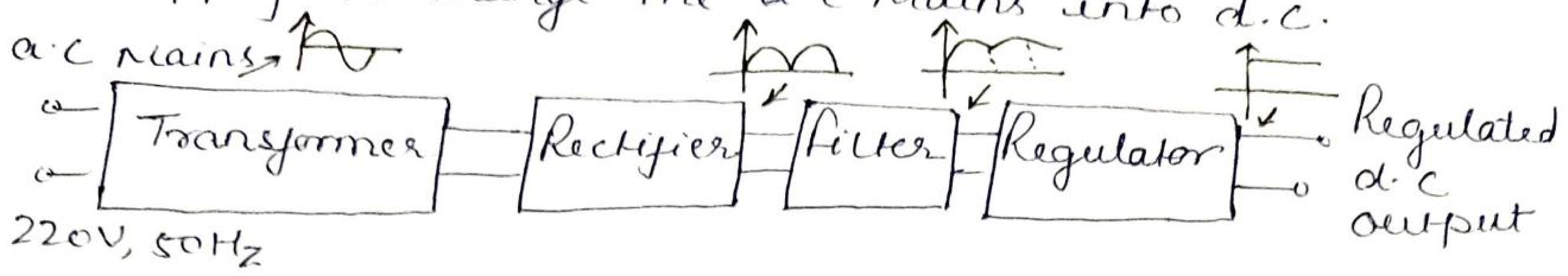
REGULATED POWER SUPPLY:

All most all electronic ~~Com~~ equipments contain a circuit called power supply to change the a.c mains into d.c.



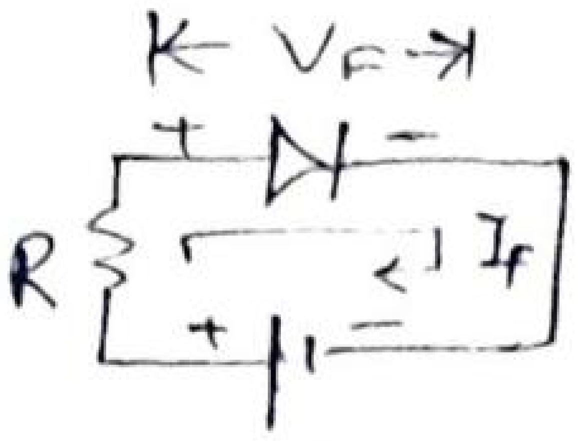
~~Rec~~ i) **TRANSformer**: Steps up or steps down the ac main voltage according to requirement of d.c to the circuit. Transformer also provides isolation

ii) **RECTIFIER**: The function of the rectifier is to convert the a.c. voltage into d.c voltage.

iii) **FILTER**: The d.c. output of rectifier may contain ripples. These ripples are removed with the help of filters.

iv) **REGULATOR**: The function of the regulator is to provide constant d.c voltage or regulated d.c voltage irrespective of the change in load or input voltage.

DIODE RATINGS:



1) Forward Voltage drop: It is the anode to cathode voltage measured across a forward biased diode
$V_F = 0.3$ for germanium and 0.7 V for silicon

2) Maximum forward Current: defined as the maximum value of forward current that can be allowed to pass through a forward biased diode without damaging it.

3) Average forward current: defined as the maximum average rectified current which can flow through a forward biased diode without damaging it

4) Reverse Saturation current: defined as the current flowing through a diode in reverse biased state due to minority charge carriers.
⇒ nA for silicon and µA for Germanium

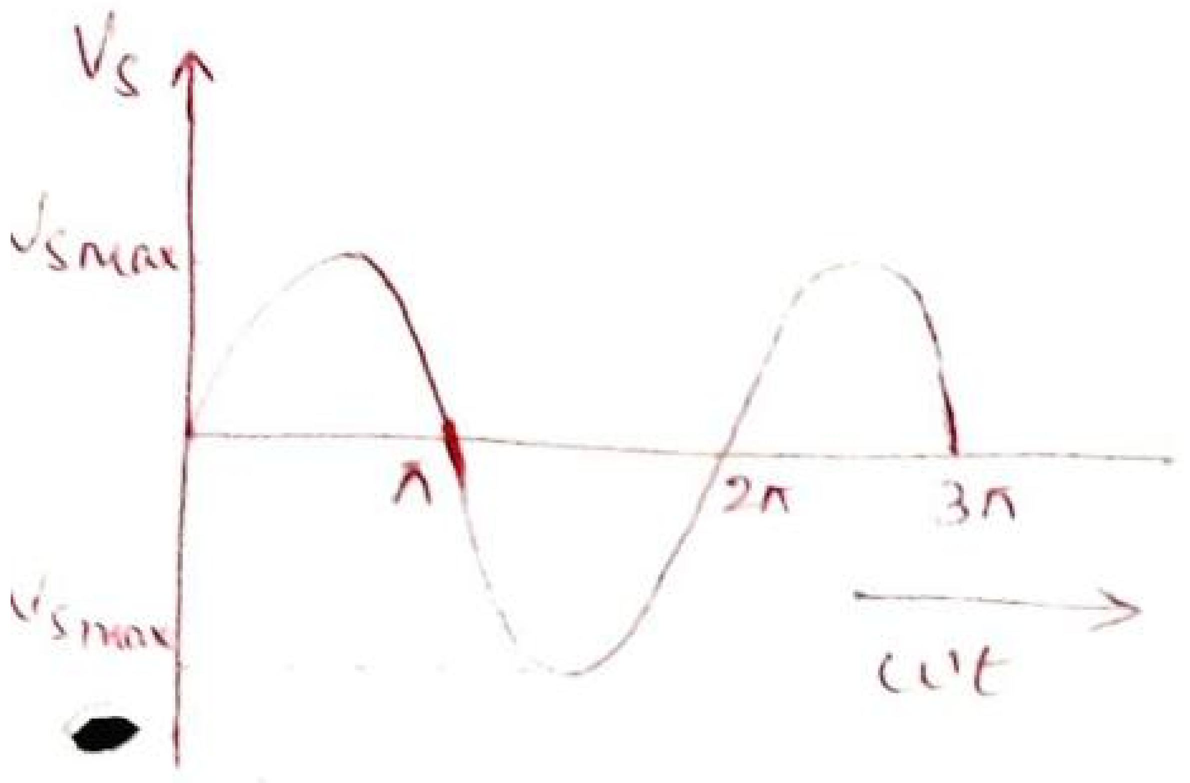
5) Power dissipation: defined as the maximum power a diode can dissipate without damaging itself

$P_D = V_F \times I_F$ V_F = forward voltage across diode
I_F = forward current.

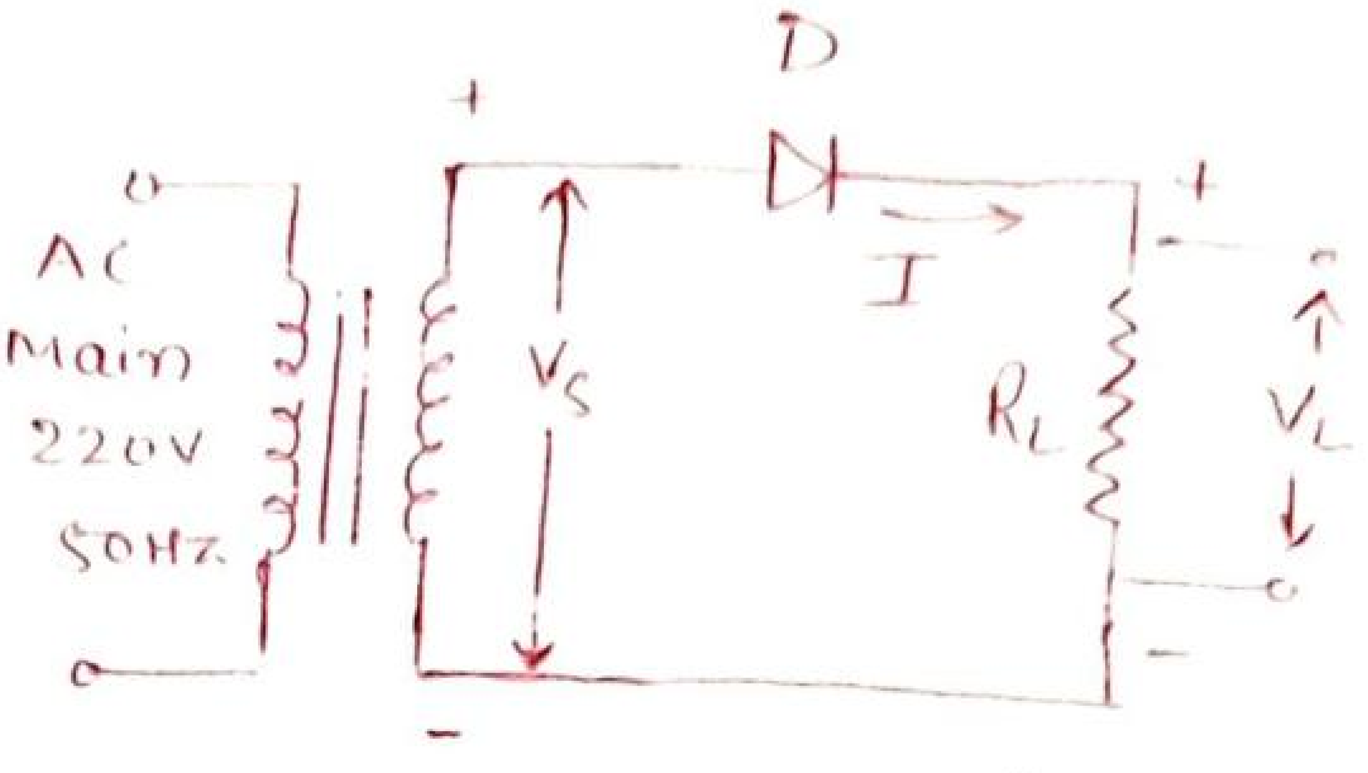
6) Peak Inverse Voltage: It is maximum reverse voltage which can be applied across a diode without damaging it.

Junction Temperature [$T_{j(max)}$]: Maximum temperature a junction is allowed to operate at, without getting damaged

HALF WAVE RECTIFIER : It converts alternating voltage into unidirectional pulsating voltage, using one-half cycles of the applied voltage, the other half cycles being suppressed because it conducts only in one direction.



input voltage waveform



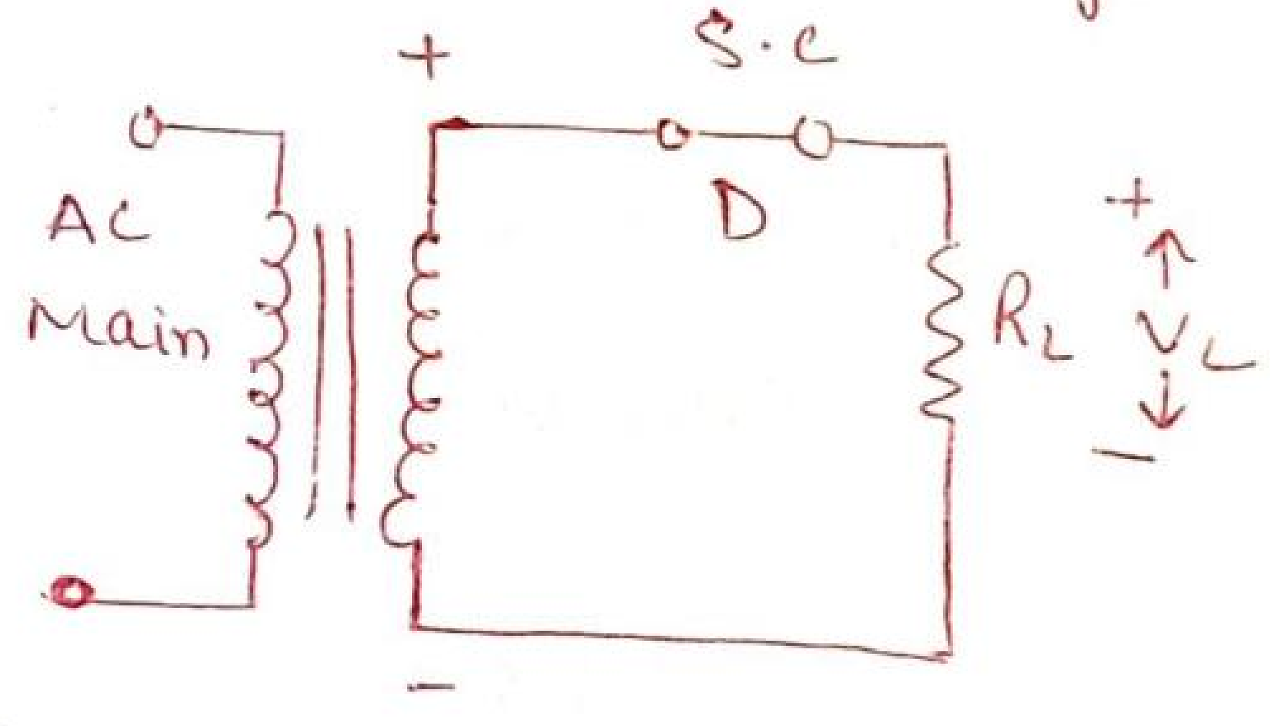
Half-wave Rectifier Circuit

CIRCUIT : The diode is connected in series with the secondary of the transformer and the load Resistance R_L, the primary of the transformer is being connected to the a.c supply mains.

Working:

a) During Positive half cycle of the input ac voltage

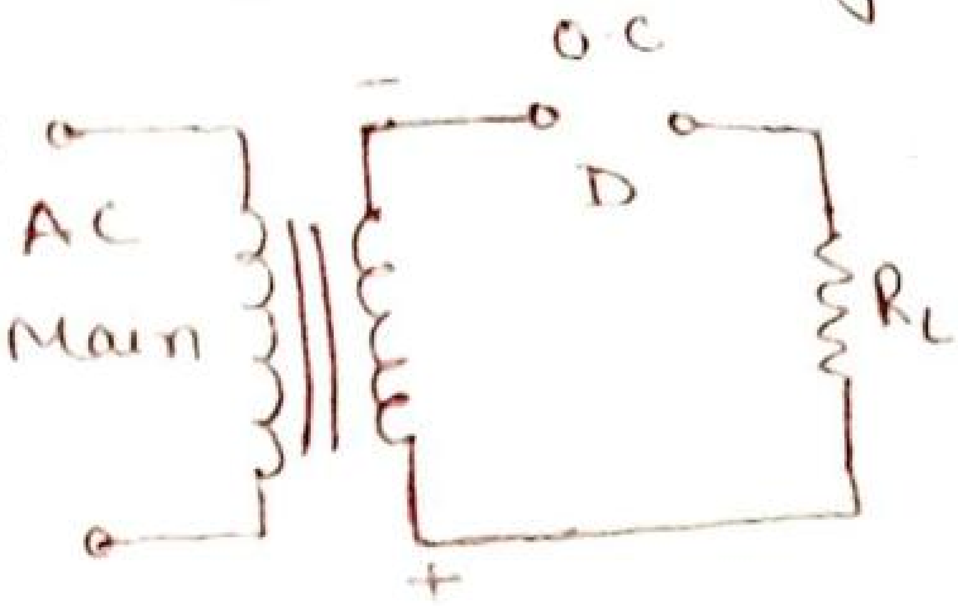
The diode is forward biased and conducts current. If the forward resistance of the diode is assumed to be zero, the input voltage is directly applied to the load resistance R_L.

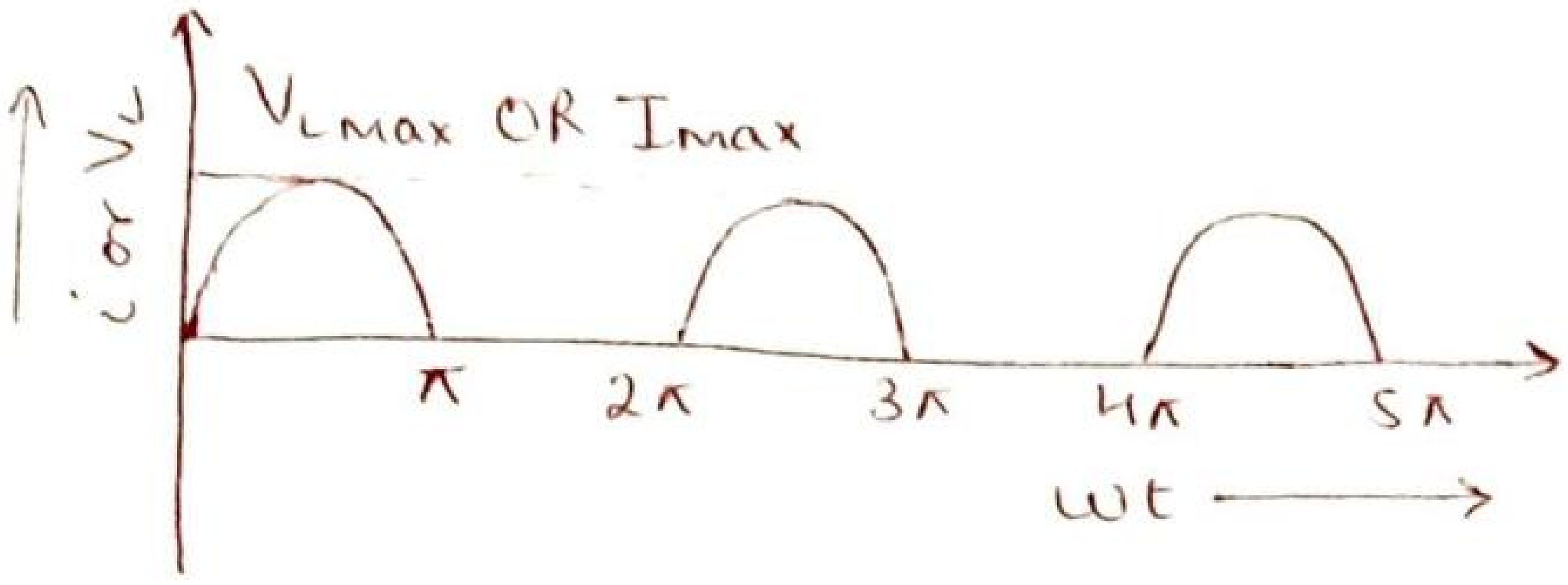


∴ The waveforms of the output current and voltage are of the same shape as that of the input ac voltage.

During the Negative half Cycles of the input ac Voltage

The diode is reverse biased and doesn't conduct. Thus no power is delivered to the load.





Rectified Output Voltage / current Waveform

ANALYSIS OF HALF-WAVE RECTIFIER

1) Peak Inverse Voltage (PIV) : During negative half-cycles of the input voltage, the diode is reverse biased, no current flows through the load Resistance R_L and whole of the input voltage appears across ~~Thus~~ the diode.

Thus, the Max^m voltage, that appears across the diode is equal to the peak value of the Secondary voltage.

i.e $\boxed{PIV = V_{Smax}}$

2) Peak Current : Current flowing through diode (or load R_L)

$$i = \begin{cases} I_{max} \sin \omega t & \text{for } 0 \leq \omega t \leq \pi \\ 0 & \text{for } \pi \leq \omega t \leq 2\pi \end{cases}$$

Where peak value of current flowing through diode or (load R_L) is

$$\boxed{I_{max} = \frac{V_{smax}}{R_F + R_L}}$$

where,

$I_{max} \rightarrow$ peak current

$V_{smax} \rightarrow$ peak value of voltage across secondary of transformer.

$R_F \rightarrow$ forward Resistance of Diode

$R_L \rightarrow$ Load Resistance.

3) DC Output Current (average o/p current):

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

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

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

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

$$= \frac{I_{max}}{2\pi} \left[1 + 1 \right]$$

$$\boxed{I_{dc} = \frac{I_{max}}{\pi}} \quad \text{OR} \quad \boxed{I_{dc} = 0.318 \, I_{max}}$$

Substituting the value of I_{max}

$$\boxed{I_{dc} = \frac{V_{smax}}{\pi(R_L + R_F)}}$$

$$\left\{ \because I_{max} = \frac{V_{smax}}{R_L + R_F} \right\}$$

$$\boxed{I_{dc} = \frac{V_{smax}}{\pi R_L}} \quad \text{if } R_L >> R_F$$

4) <u>DC output Voltage</u> (across load)

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

$$= \frac{V_{smax}}{\pi(R_L + R_F)} \cdot R_L$$

$$\boxed{V_{dc} = \frac{V_{smax}}{\pi\left(1 + \frac{R_F}{R_L}\right)}}$$

$$\boxed{V_{dc} \simeq \frac{V_{smax}}{\pi}} \quad \text{if } R_L >>> R_F$$

5) <u>RMS Value of Current</u> flowing through diode or load

$$I_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} i^2 \, d(\omega t) \qquad \left\{ \sin^2\theta = \frac{1 - \cos 2\theta}{2} \right\}.$$

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

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

$$I_{rms}^2 = \frac{I_{max}^2}{2\cancel{\pi}} \times \frac{\cancel{\pi}}{2} \Rightarrow \boxed{I_{rms} = \frac{I_{max}}{2}}$$

Substituting the value of I_{max}

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

6) RMS value of Output Voltage : Rms voltage across the load

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

$$V_{L\,rms} = \frac{V_{smax} \times R_L}{2(R_F + R_L)}$$

$$\boxed{V_{L\,rms} = \frac{V_{smax}}{2\left[1 + \frac{R_F}{R_L}\right]}}$$

$$\boxed{V_{L\,rms} = \frac{V_{smax}}{2}} \quad \text{if } R_L >> R_F$$

7) Form Factor : defined as the ratio of Rms to average Value

$$K_f = \frac{I_{rms}}{I_{dc}} = \frac{V_{smax}/2(R_F + R_L)}{V_{smax}/\pi(R_F + R_L)}$$

$$K_f = \frac{\pi}{2} \quad \text{OR} \quad \boxed{K_f = 1.57}$$

8) Peak Factor : defined as ratio of Peak value of rms value

$$K_p = \frac{I_{max}}{I_{rms}} = \frac{V_{smax}/(R_F + R_L)}{V_{smax}/2(R_F + R_L)} \Rightarrow \boxed{K_p = 2}$$

9) Output frequency: Output frequency is same as that of input frequency.

$$\boxed{f_{out} = f_{in}}$$

10) Rectification efficiency: is defined as the ratio of dc output power to the ac input power

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

dc power delivered to the load

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

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

ac power input from the transformer

P_{ac} = Power dissipated in diode junction + Power dissipated in load resistance

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

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

$$\eta = \frac{I_{max}^2 R_L / \pi^2}{I_{max}^2 (R_F + R_L)/4}$$

$$= \frac{4}{\pi^2} \cdot \frac{R_L}{R_F + R_L}$$

$$\boxed{\eta = \frac{0.406}{1 + \frac{R_F}{R_L}}} \qquad \boxed{\eta = 40.6\,\%} \quad \text{if } R_F << R_L$$

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11) Ripple factor : is defined as the "ratio of the effective value of the ac components of Voltage or Current present in the output from the rectifier to the direct or average value of the output Voltage or Current."

effective value of the load Current is

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

Ripple factor, $\gamma = \dfrac{I_{ac}}{I_{dc}} = \dfrac{\sqrt{I^2 - I_{dc}^2}}{I_{dc}}$

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

$$\gamma = \sqrt{\left(\frac{I_{max}/2}{I_{max}/\pi}\right)^2 - 1}$$

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

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

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

12) Transformer Utilisation factor : is defined as the ratio of power delivered to the load and ac rating of the transformer secondary

$$TUF = \frac{P_{dc}}{P_{ac\,(rated)}} = \frac{I_{dc}^2 R_L}{V_{s\,rms}\, I_{rms}}$$

$$= \frac{(I_{max}/\pi)^2 R_L}{\frac{V_{s\,max}}{\sqrt{2}} \cdot \frac{I_{max}}{2}}$$

$$TUF = \frac{2\sqrt{2}}{\pi^2} \cdot \frac{I_{max} R_L}{I_{max}(R_F + R_L)} \qquad \because V_{smax} = I_{max}(R_F + R_L)$$

$$\boxed{TUF = \frac{0.286 R_L}{R_L + R_F}} \quad \text{OR} \quad \boxed{TUF = 0.286}$$

if $R_L >> R_F$

Advantages and Disadvantages of a Half-wave Rectifier:

Advantages:

1) Simple Circuit and low Cost.

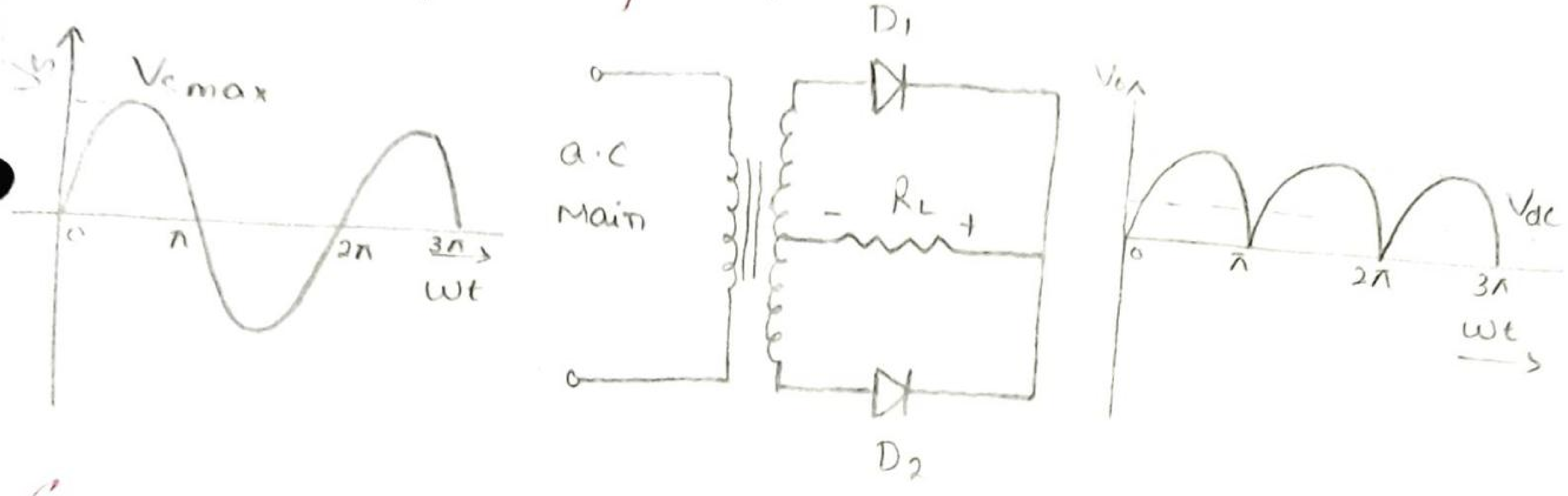
Disadvantages

1) Ripple factor is high $\therefore$ an elaborate filtering is required to give steady dc output.
2) Power output is low, because power is delivered only half the time
3) Rectification Efficiency is quite low
4) Transformer Utilization factor is low.

... In full wave rectifiers both half cycles of the input are utilized. Alternate half cycles are inverted to give unidirectional load current.

There are two types of full-wave rectifier circuits 1) Centre-tap Rectifier 2) Bridge rectifier

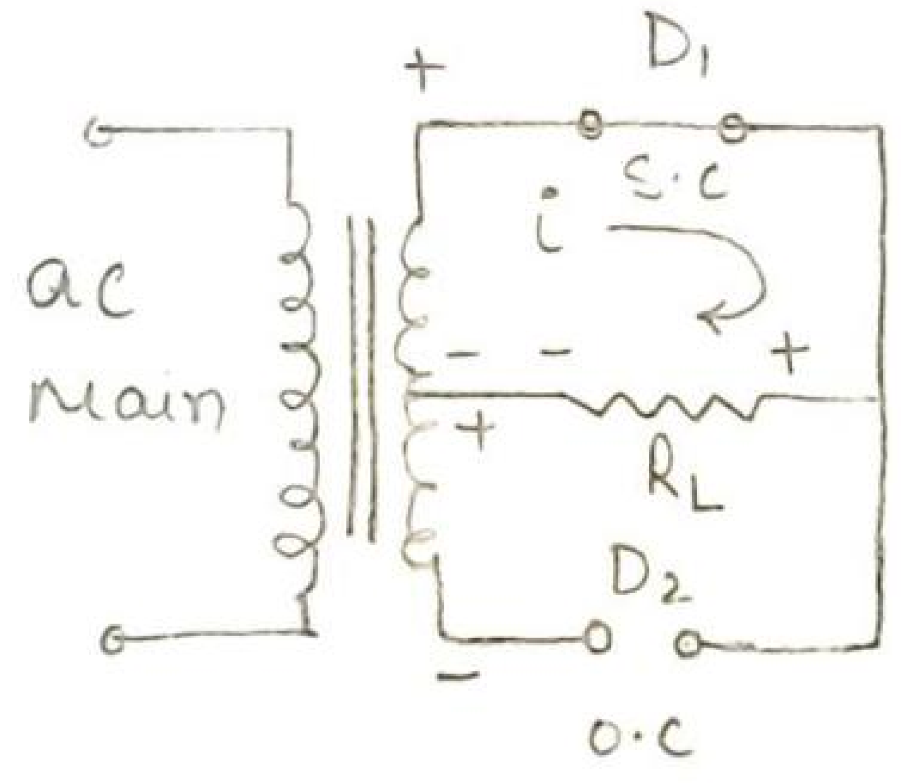
1) Centre-tap Rectifier:



Construction: The ac input is applied through a transformer, anodes (P-type) of Diodes D_1 and D_2 are connected to the opposite ends of the secondary windings and cathodes are connected to each other and also through the load resistance R_L to the centre of the transformer.

Working:

During Positive half Cycle:



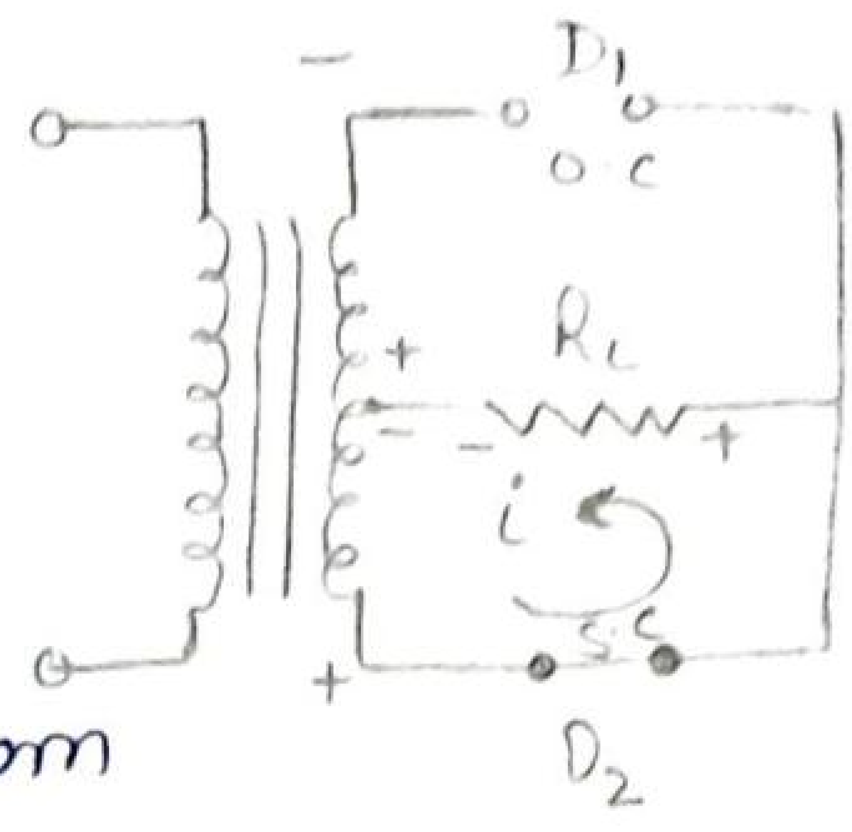
The Diode D_1 is forward bias as anode of D_1 is positive w.r.t cathode and anode of Diode D_2 is negative w.r.t cathode i.e D_2 is reverse biased

∴ only D_1 conducts and current flows from cathode to anode of Diode D_1, through load resistor R_L.

During negative half cycle

D_2 is forward biased and D_1 is reverse biased

$\therefore$ D_2 conduct and current flows through the load resistor R_L and bottom of the transformer Secondary.



Thus the direction of flow current through the load Resistance R_L remains the same during both halves of the input supply voltage.

Peak Inverse Voltage: During any half cycle of the supply one of Diode conduct and other remain reverse biased (o.c) i.e. forward biased diode conduct and offers almost zero resistance. So whole of the voltage V_{smax} of half winding is developed across the load resistance R_L

$\therefore$ The voltage across the non-conducting diode is the sum of voltage across the half of the transformer winding and the voltage across the load resistance R_L

$$PIV = V_{smax} + V_{smax}$$

$$\boxed{PIV = 2V_{smax}}$$

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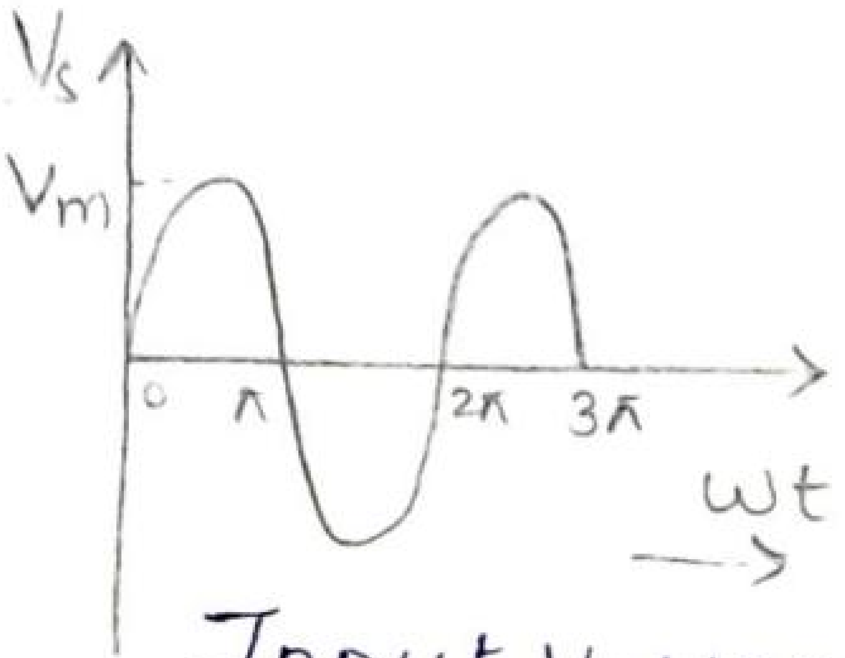
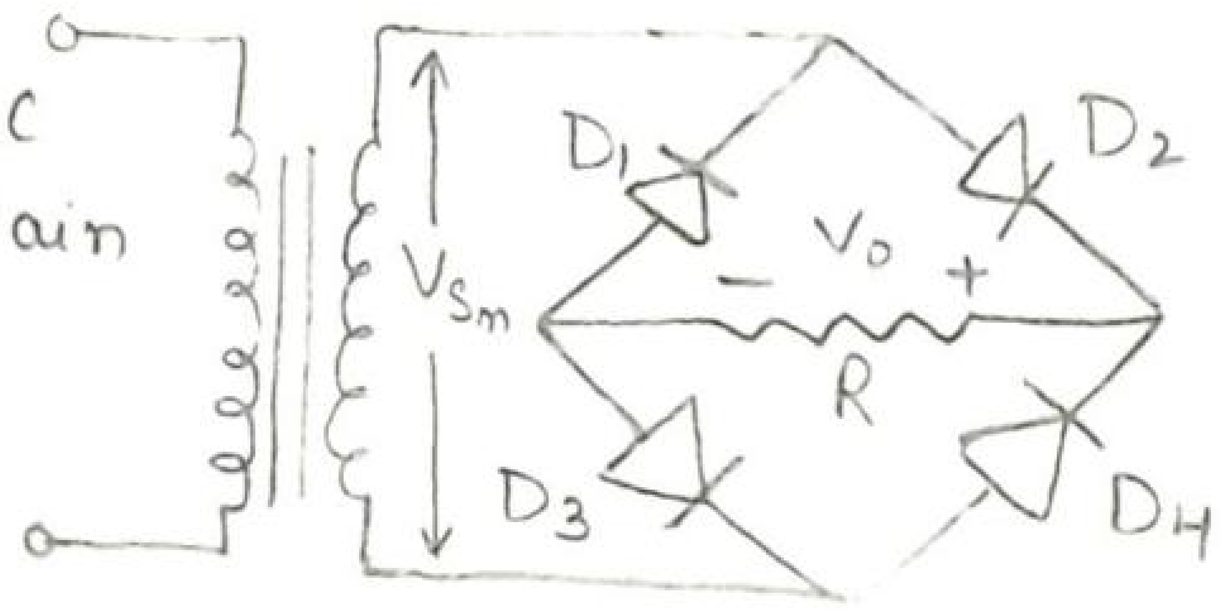
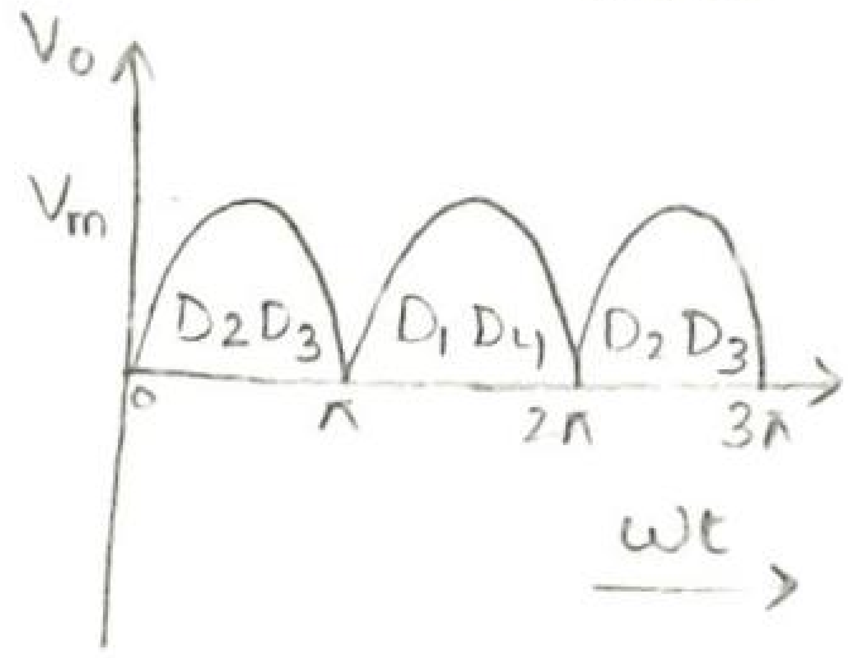
Bridge Rectifier: In bridge Rectifier circuit four diodes are connected in the form of a Wheatstone bridge, two diametrically opposite junctions of the bridge are connected to the secondary of a transformer and the other two are connected to the load.



Input Voltage waveform



Bridge Rectifier Circuit

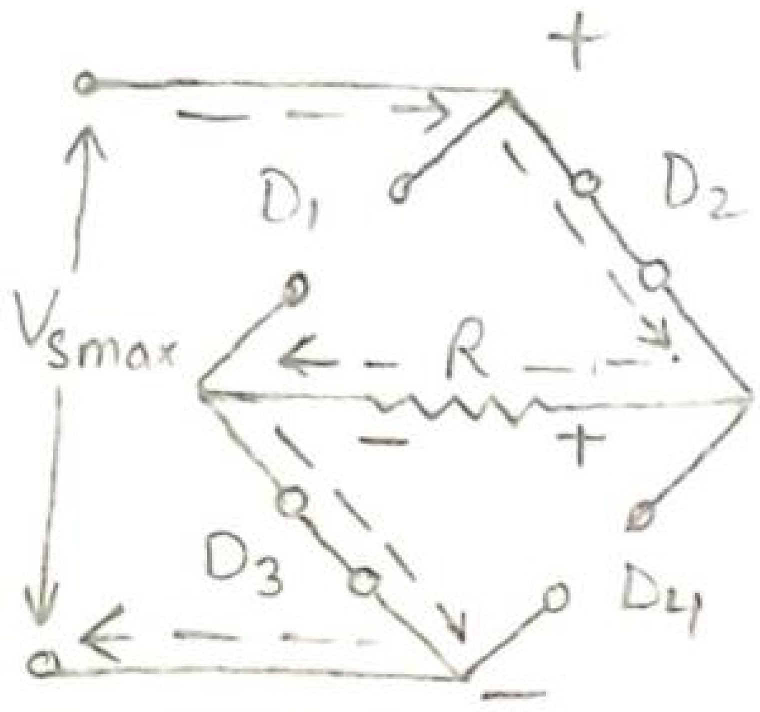


Output Voltage waveform

Working:

During positive half Cycle (first half Cycle of input Supply)

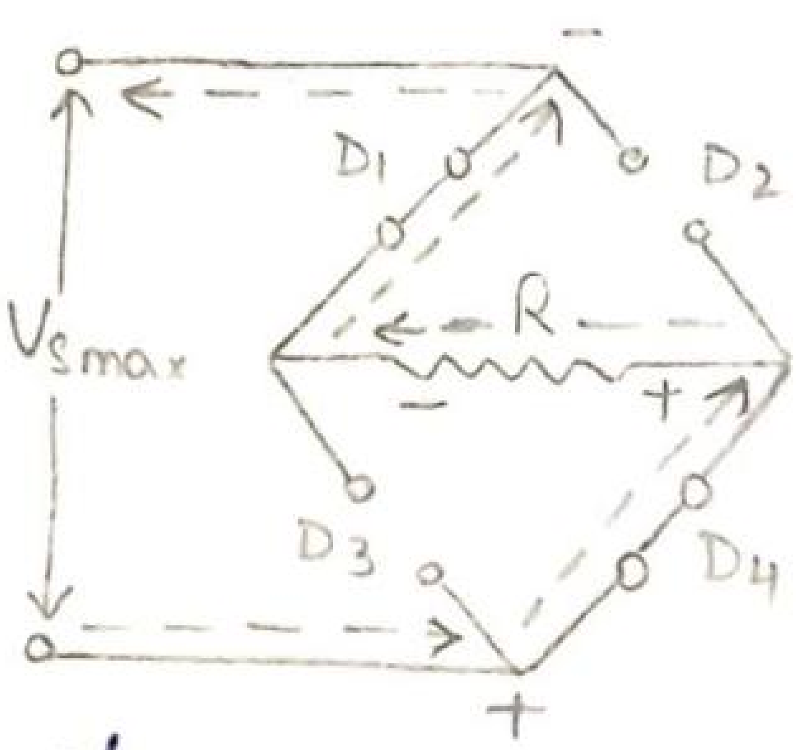
Diode D_2 and D_3 are forward biased and current flow through them, enters the load at positive terminal and leaves the load at negative terminal.



The diode D_1 and D_4 are reverse biased and no current flow through them.

During negative half Cycle (Second half Cycle of input Supply)

Diode D_1 and D_4 are forward biased and current flow through them, enter the load at positive terminal and leaves at negative terminal



Diode D_2 and D_3 are reverse biased and no current flows through them.

Thus the direction of flow of current through the load resistance R_L remains the same during both half cycles of the input supply voltage.

Peak Inverse Voltage : The entire voltage of the transformer secondary winding, V_{smax} is developed across the load Resistance R_L. The same voltage (V_{smax}) act across each of the non-conducting diodes.

$$\boxed{PIV = V_{smax}}$$

1) Peak Current : total current flowing through the load Resistance R_L

$$i = I_{max} \sin\omega t \quad \text{for} \quad 0 \leq \omega t \leq 2\pi$$

$$\boxed{I_{max} = \frac{V_{smax}}{R_F + R_L}}$$

(for Centre-tap)

$$\boxed{I_{max} = \frac{V_{smax}}{2R_F + R_L}}$$

(for bridge Rectifier)

2) Output Current :

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

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

3) DC output Voltage :

$$V_{dc} = I_{dc} R_L \Rightarrow \boxed{V_{dc} = \frac{2V_{smax}}{\pi}}$$

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4) RMS Value of Current : rms or effective value of current flowing through load R_L

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

$$I_{rms}^2 = \frac{I_{max}^2}{2} \Rightarrow \boxed{I_{rms} = \frac{I_{max}}{\sqrt{2}}}$$

5) RMS Value of Output Voltage :

$$V_{L\,rms} = I_{rms} \cdot R_L$$

$$\boxed{V_{L\,rms} = \frac{I_{max}}{\sqrt{2}} \cdot R_L}$$

6) Form factor :

$$K_f = \frac{I_{rms}}{I_{dc}} = \frac{I_{max}/\sqrt{2}}{2 I_{max}/\pi}$$

$$K_f = \frac{\pi}{2\sqrt{2}} \Rightarrow \boxed{K_f = 1.11}$$

7) Peak factor :

$$K_p = \frac{I_{max}}{I_{rms}} = \frac{I_{max}}{I_{max}/\sqrt{2}}$$

$$\boxed{K_p = \sqrt{2}}$$

8) Output frequency : The full-wave rectifier inverts each negative half cycle, so a full-wave output has twice as many cycles as the sine-wave input.

$$\boxed{f_{out} = 2 f_{in}}$$

9) Rectification Efficiency :

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{4}{\pi^2} I_{max}^2 R_L}{\frac{1}{2} I_{max}^2 (R_L + R_F)}$$

$$\boxed{\eta = \frac{8}{\pi^2} \frac{1}{\left(1 + \frac{R_F}{R_L}\right)}} \Rightarrow \boxed{\eta = \frac{0.812}{1 + 2\frac{R_F}{R_L}}}$$

$$\boxed{\eta = 81.2\,\%}$$

10) Ripple factor :

$$K_f = \frac{I_{rms}}{I_{dc}} = 1.11$$

$$\gamma = \sqrt{K_f^2 - 1} \qquad \boxed{\gamma = 0.482}$$

11) Regulation :

$$V_{dc} = \frac{2 V_{smax}}{\pi} - I_{dc} R_F \qquad \{\text{for Centre-tap}\}$$

$$V_{dc} = \frac{2 V_{smax}}{\pi} - 2 I_{dc} R_F \qquad \{\text{for Bridge}\}$$

12) Transformer Utilization factor :

$$\boxed{\text{Average TUF} = 0.692}$$

(Bridge) TUF $= 0.81$