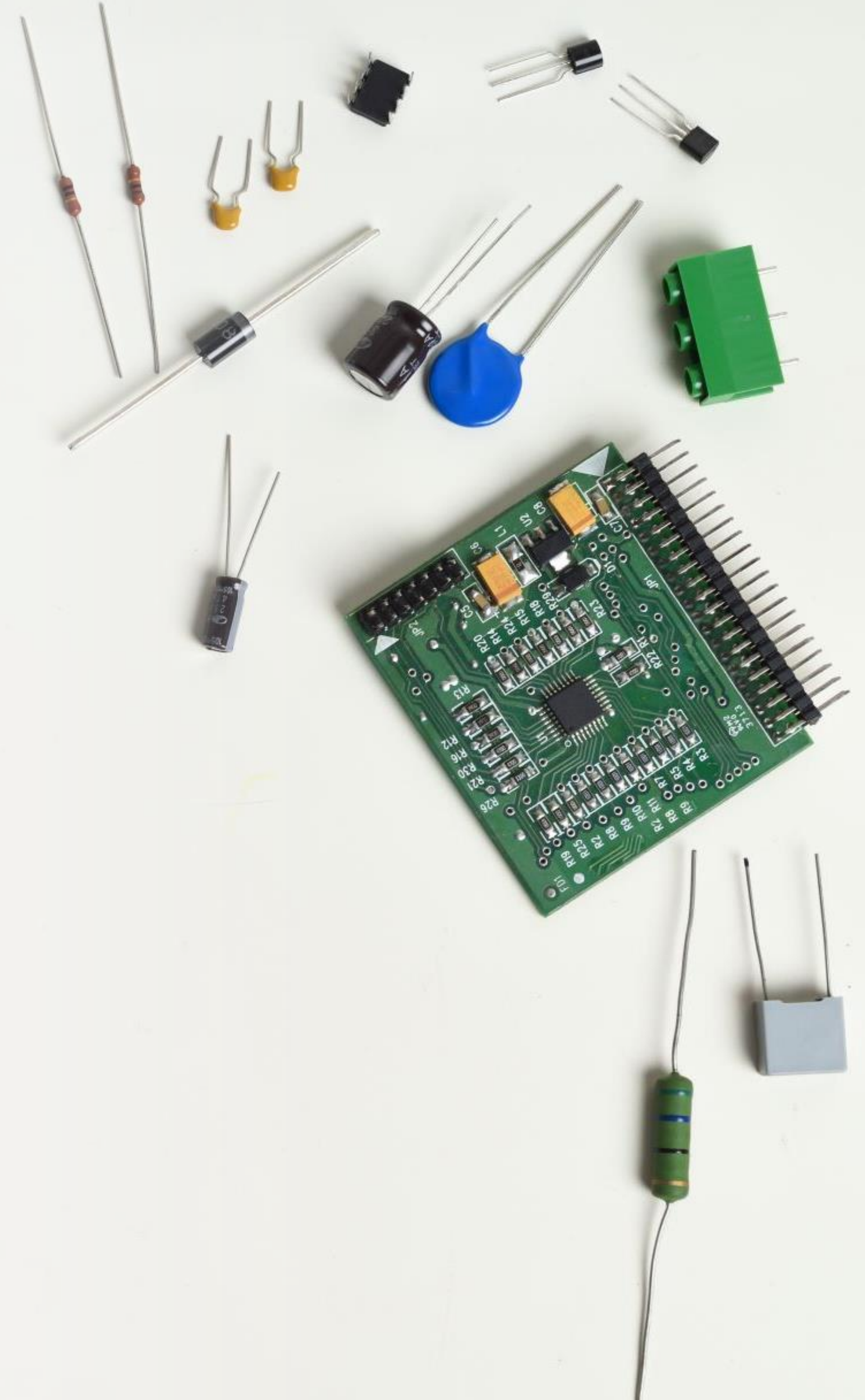
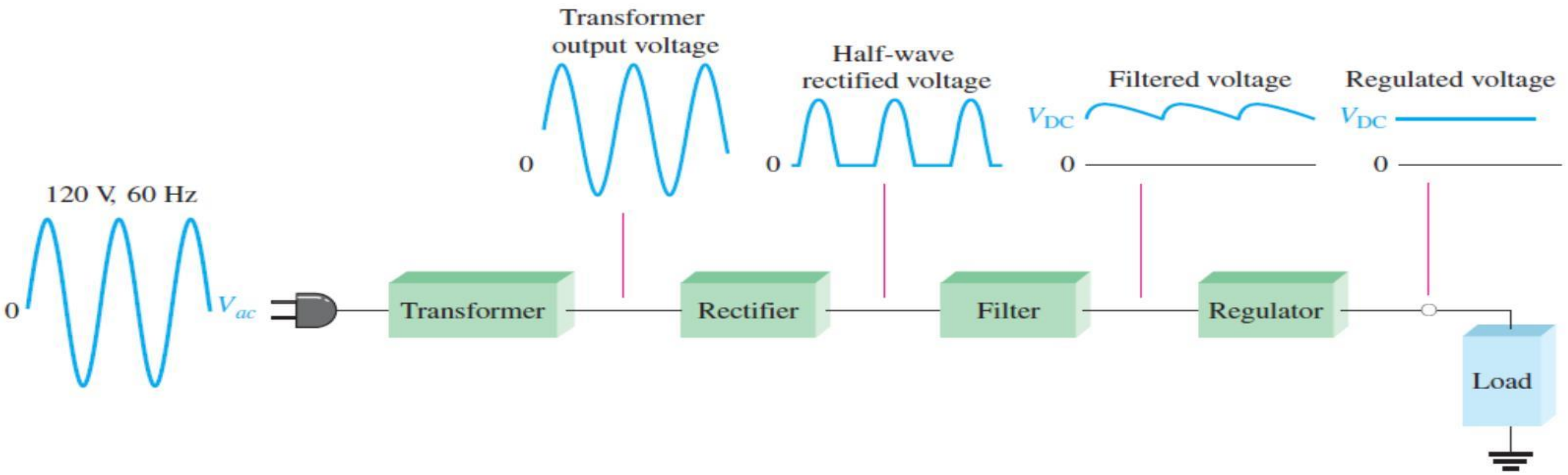
104010 : BASIC ELECTRONICS ENGINEERING

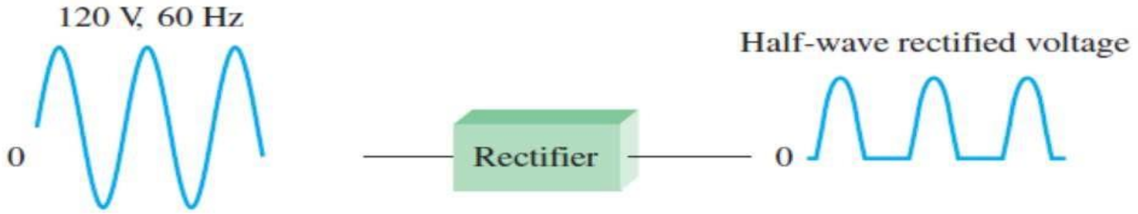


UNIT I

Introduction to Electronics

DC Power Supply

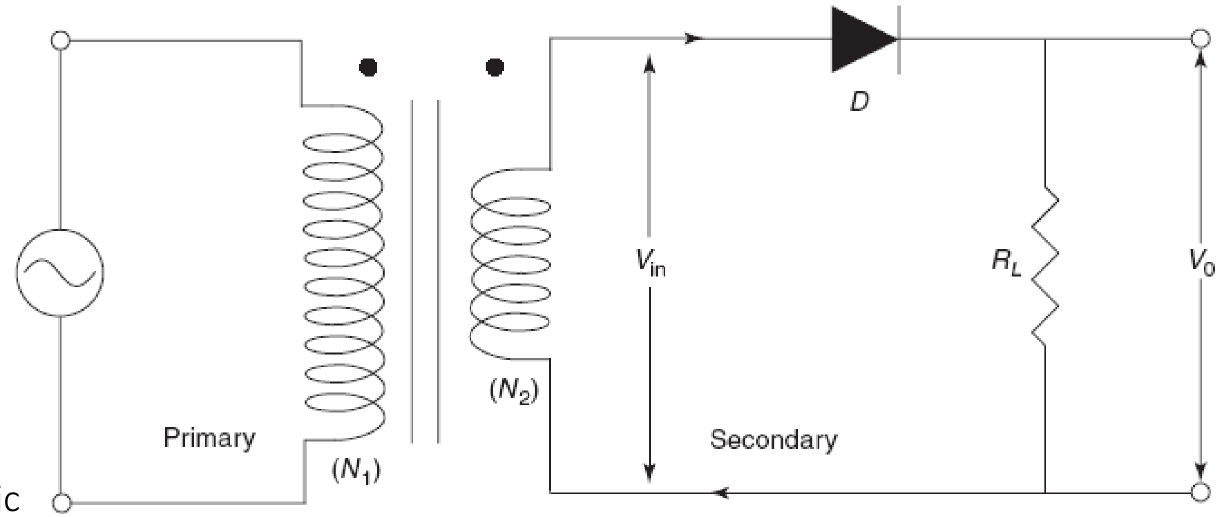


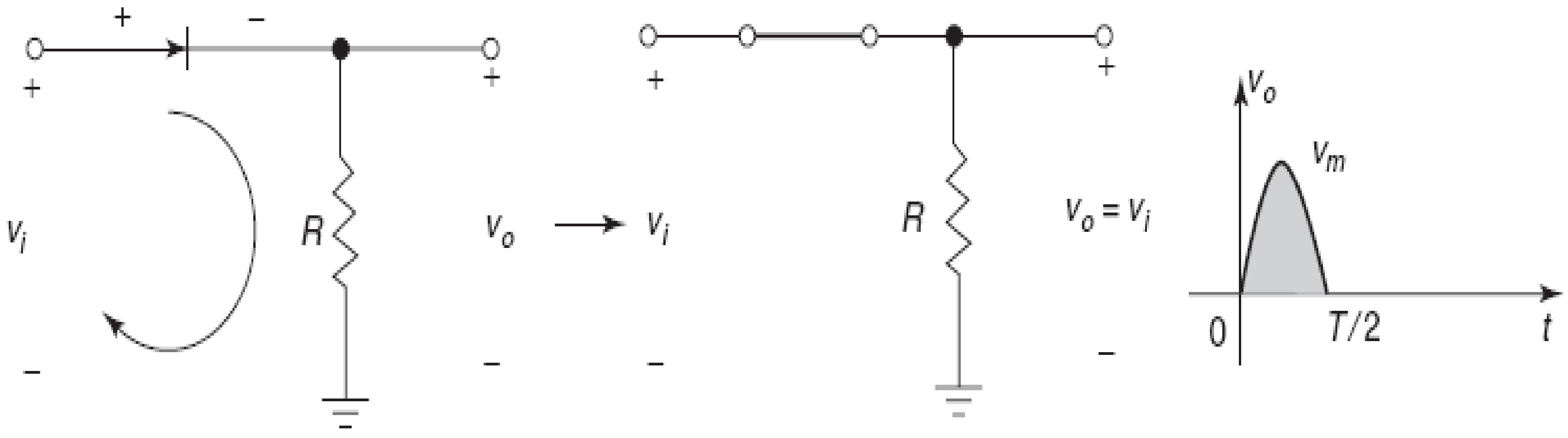


(b) Half-wave rectifier

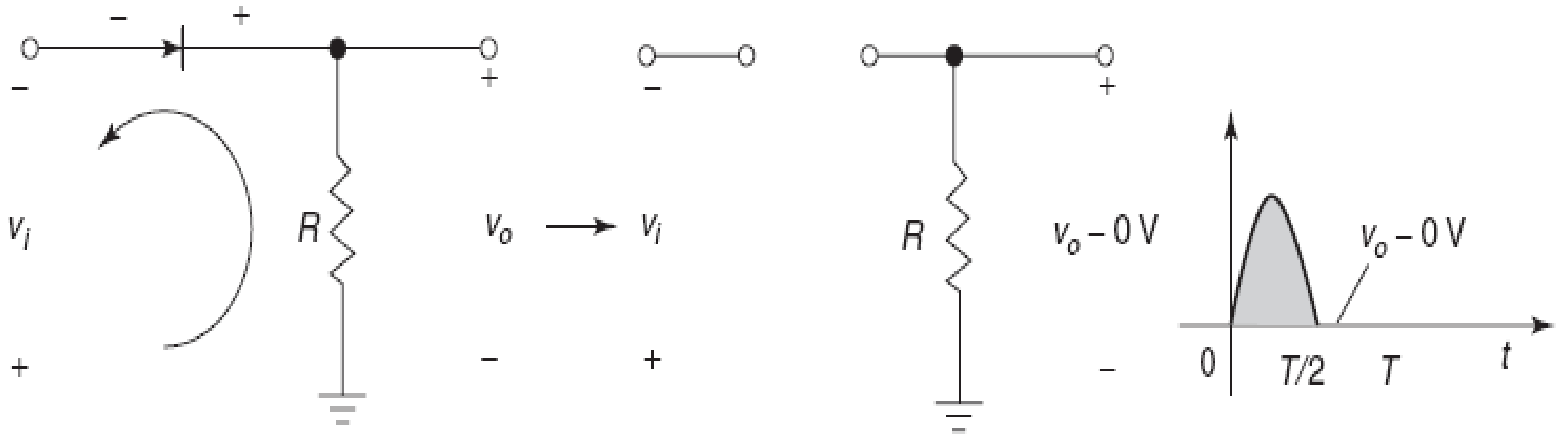
Half Wave Rectifier

- In a half-wave rectifier, the output waveform occurs after each alternate half-cycle of the input sinusoidal signal.
- The half-wave rectifier will generate an output waveform vo. Between the time interval t = 0 to T/2, the polarity of the applied voltage *Vi* is such that it makes the diode forward-biased.
- As a result the diode is turned on, i.e., the forward voltage is more than the cut-in voltage of the diode.

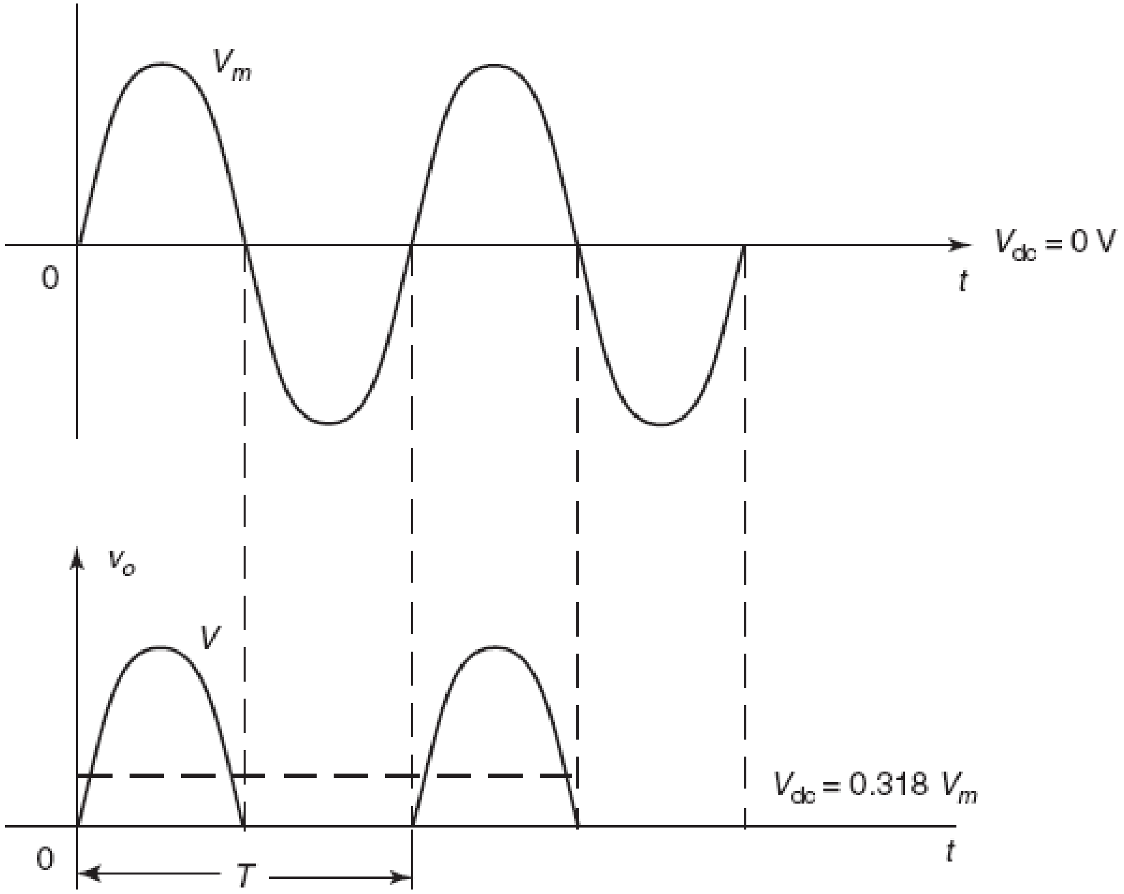




Conduction region (0 to *T/2)*

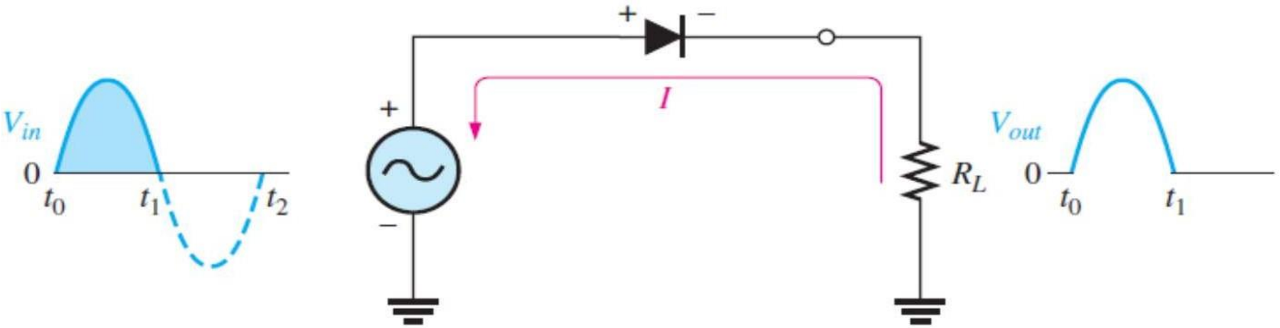


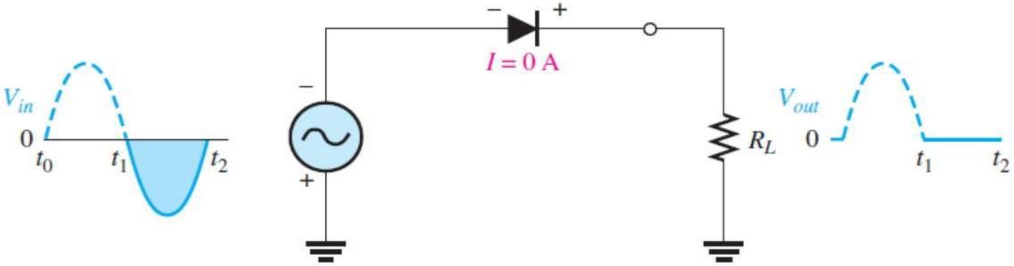
Non-conducting region (*T/2 to T)*

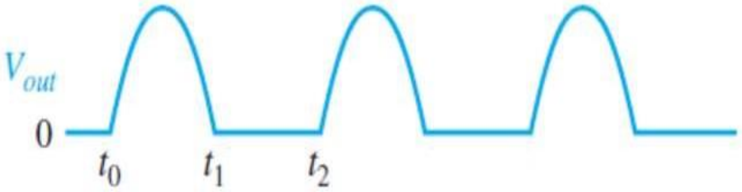


Half-wave rectified signal

Half Wave Rectifier

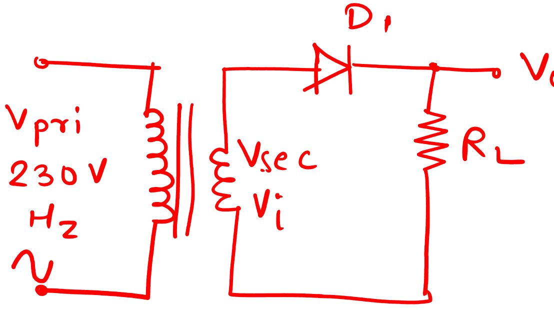


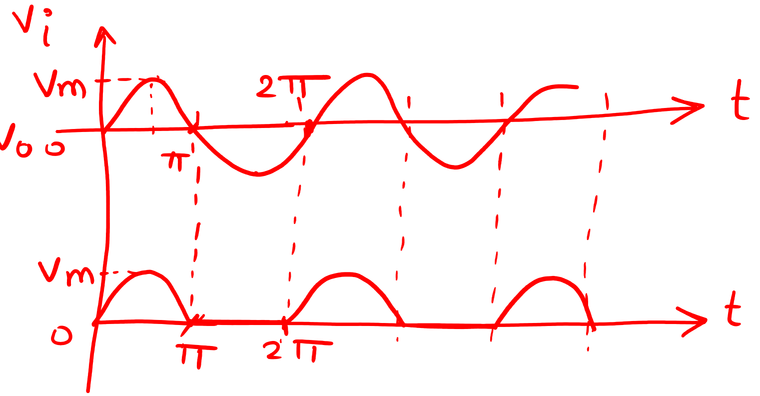




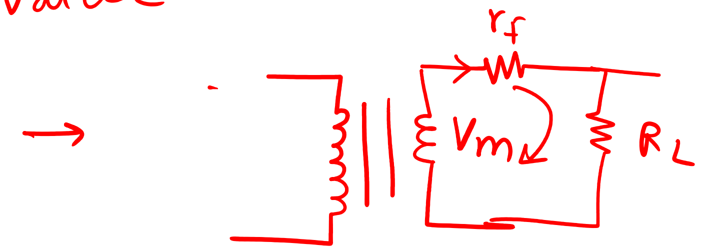
$$y(t) = \begin{cases} x(t) & x(t) \geq 0 \\ 0 & x(t) < 0 \end{cases}$$

HWR :





Peak value



$$I_m = \frac{V_m}{r_f + R_L}$$

R_L = Load resistance

r_f = Resistance of diode (internal) ($r_f << R_L$)

i) V_m and I_m : Peak values of voltage and current

ii) Average value :

$$V_{dc}/V_{avg} = \frac{\text{Area under the curve over a cycle}}{\text{Base}} = \frac{\int v_i \, d\theta}{\text{Base}}$$

$$V_{dc}/V_{avg} = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\theta \, d\theta = \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\theta \, d\theta + \int_{\pi}^{2\pi} \cancel{V_m \sin\theta \, d\theta}^{\,0}\right]$$

$$= \frac{1}{2\pi}\int_0^{\pi} V_m \sin\theta \, d\theta = \frac{V_m}{2\pi}\left|-\cos\theta\right|_0^{\pi} = \frac{V_m}{2\pi}\left(-(-1-1)\right) = \frac{V_m}{2\pi}(2) = \frac{V_m}{\pi}$$

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

$I_{dc} \rightarrow$

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} \frac{V_m}{r_f + R_L} \sin\theta \, d\theta = \frac{1}{2\pi}\int_0^{\pi} \frac{V_m}{r_f + R_L} \sin\theta \, d\theta = \frac{V_m}{2\pi(r_f + R_L)}\int_0^{\pi} \sin\theta \, d\theta$$

$$= \frac{V_m}{2\pi(r_f + R_L)} \left| -\cos\theta \right|_0^{\pi} = \frac{V_m}{\cancel{2}\pi(r_f + R_L)}(\cancel{2}) = \frac{V_m}{\pi(r_f + R_L)}$$

But, $I_m = \dfrac{V_m}{r_f + R_L} \Rightarrow \boxed{I_{dc} = \dfrac{I_m}{\pi}} = I_{avg}$

iii) V_{rms} and I_{rms} :

$$V_{rms} = \left[\frac{1}{T}\int_0^T v_i^2 \, d\theta\right]^{1/2} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (V_m \sin\theta)^2 \, d\theta}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{2\pi}\int_0^{\pi} \sin^2\theta \, d\theta} = V_m \sqrt{\frac{1}{2\pi}\int_0^{\pi} \left(\frac{1 - \cos 2\theta}{2}\right) d\theta}$$

$$= V_m \sqrt{\frac{1}{4\pi}\int_0^{\pi} (1 - \cos 2\theta) \, d\theta} = \frac{V_m}{2}\sqrt{\frac{1}{\pi}\left[(\pi - 0) - 0\right]} = \frac{V_m}{2}\sqrt{\frac{1}{\cancel{\pi}}(\cancel{\pi})}$$

$$\boxed{V_{rms} = \frac{V_m}{2}} \; ; \; \boxed{I_{rms} = \frac{I_m}{2}}$$

IV) Rectifier Efficiency (η):

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

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

$$P_{ac} = (I_{rms})^2 (r_f + R_L) = \frac{I_m^2}{4} (r_f + R_L)$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\cancel{I_m^2}/\pi^2 \cdot R_L}{\cancel{I_m^2}/4\,(r_f + R_L)}$$

$$\therefore \eta = \frac{4R_L}{\pi^2(r_f + R_L)} = \frac{4/\pi^2}{(1 + r_f/R_L)}$$

$$= \frac{0.406}{(1 + r_f/R_L)}$$

$\hookrightarrow$ if $r_f << R_L$; $1 + \frac{r_f}{R_L} \simeq 1$

$$\therefore \eta = 0.406 \times 100$$

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

V) Form Factor (FF):

$$FF = \frac{\text{rms value}}{\text{average value}}$$

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

$$= \pi/2$$

$$\boxed{\therefore FF = 1.57}$$

vi) Ripple Factor (R.F.) (γ) :

$$\gamma = \frac{\text{rms value of ac component}}{\text{Value of dc component}} = \frac{I_{ac}}{I_{dc}}$$

Now, the effective value of total load current is,

$$I_{rms} = \sqrt{I_{ac}^2 + I_{dc}^2} \Rightarrow I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

$$\therefore \gamma = \frac{I_{ac}}{I_{dc}} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}} = \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2}$$

$$= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} = \sqrt{\left(\frac{I_m/2}{I_m/\pi}\right)^2 - 1} = \sqrt{\frac{\pi^2}{4} - 1} \quad \boxed{\therefore RF = \gamma = 1.21}$$

vii) Peak Inverse Voltage (PIV) :

$$\boxed{PIV = V_m}$$

Average Value of the Output Voltage

- Average value of a Signal

$$\frac{1}{T}\int_{0}^{T} x(t)dt$$

- Output Signal of HW Rectifier

$$x(t) = \begin{cases} \sin(2\pi f_0 t) \ldots \ldots .0 \leq \mathrm{t} \leq \frac{T}{2} \\ 0 \ldots \ldots \ldots \ldots \ldots . . \frac{T}{2} \leq \mathrm{t} \leq T \end{cases}$$

Comparison of Rectifiers

- **Average Voltage**:

  DC Component $$\frac{1}{T}\int_{0}^{T} x(t)dt$$

- **RMS Voltage**

  The RMS value is the square root of the mean (average) value of the squared function of the instantaneous values.

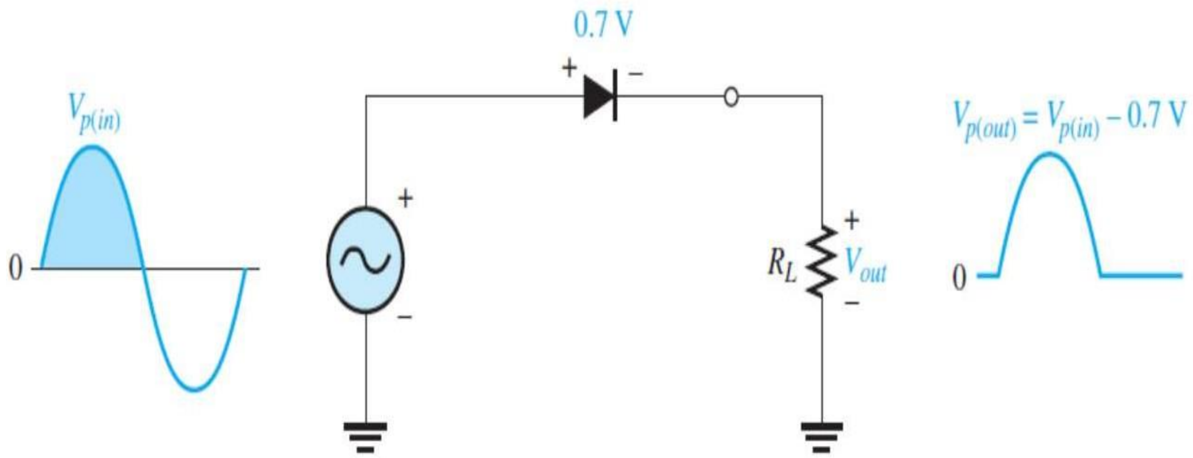
  $$V_{RMS} = \sqrt{\frac{1}{T}\int_{0}^{T} V_m^2 \cos^2(\omega t)\, dt}$$

- **Ripple factor** (γ):

  Defined as the ratio of the root mean square (rms) value of the **ripple** voltage to the absolute value of the DC component of the output voltage, usually expressed as a percentage. Measure of the Purity of DC

Effect of Barrier Potential

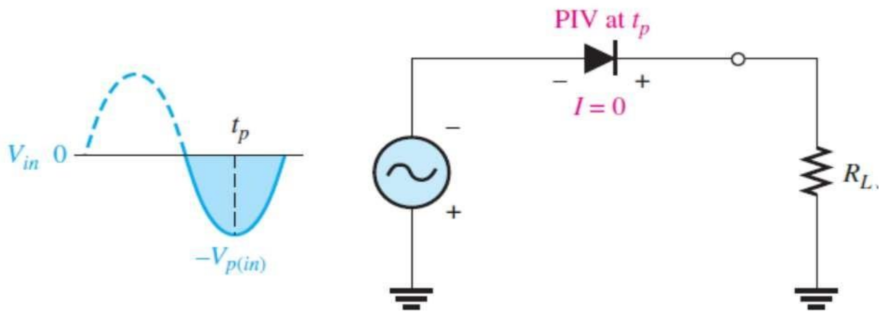
$$V_{p(out)} = V_{p(in)} - 0.7\,V$$



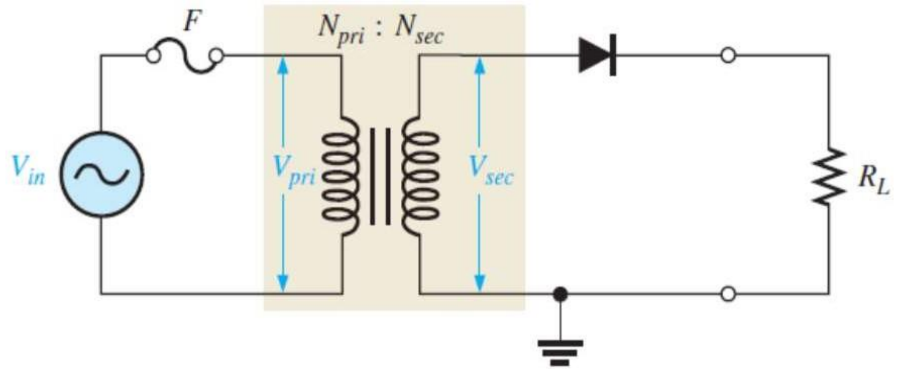
Peak Inverse Voltage

- The **peak inverse voltage (PIV)** equals the peak value of the input voltage, and the diode must be capable of withstanding this amount of repetitive reverse voltage
- The maximum value of reverse voltage, designated as PIV, occurs at the peak of each negative alternation of the input voltage when the diode is reverse-biased
- A diode should be rated at least 20% higher than the PIV

$$PIV = V_{p(in)}$$



Transformer Coupling



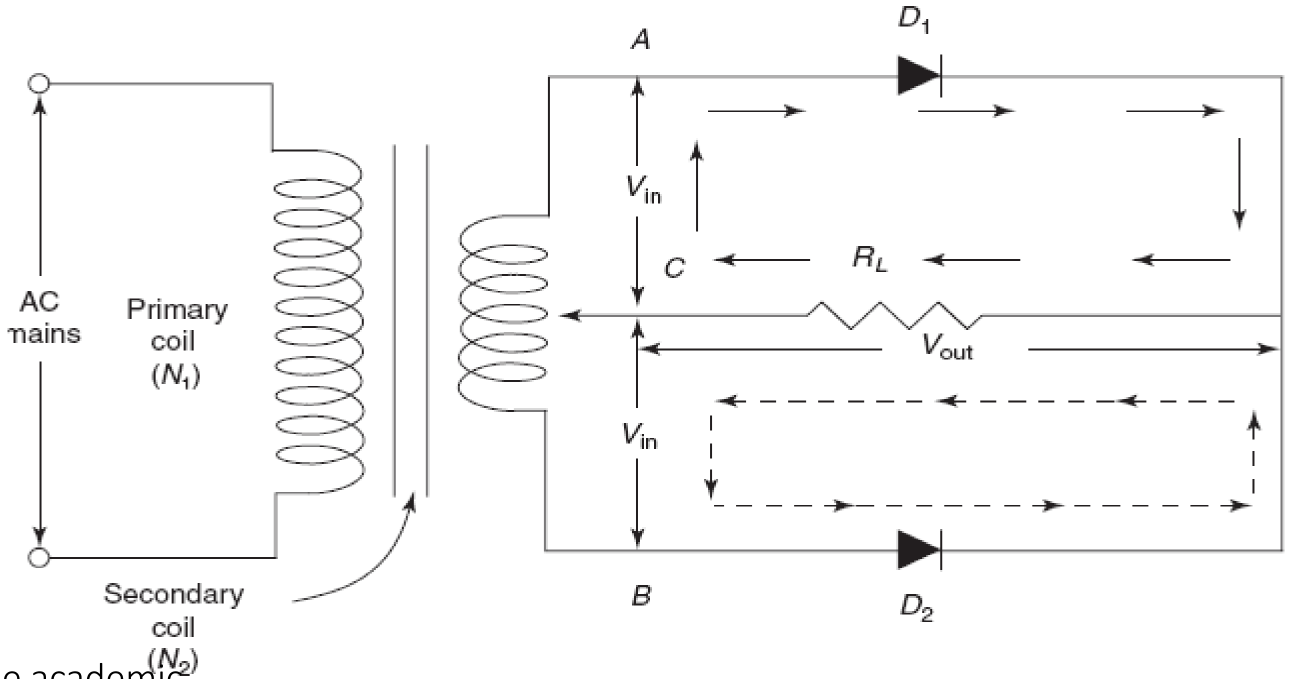
- Transformer coupling provides two advantages
- First, it allows the source voltage to be stepped down as needed.
- Second, the ac source is electrically isolated from the rectifier, thus preventing a shock hazard in the secondary circuit
- n= "the number of turns in the secondary (*Nsec*) divided by the number of turns in the primary (*Npri*)."

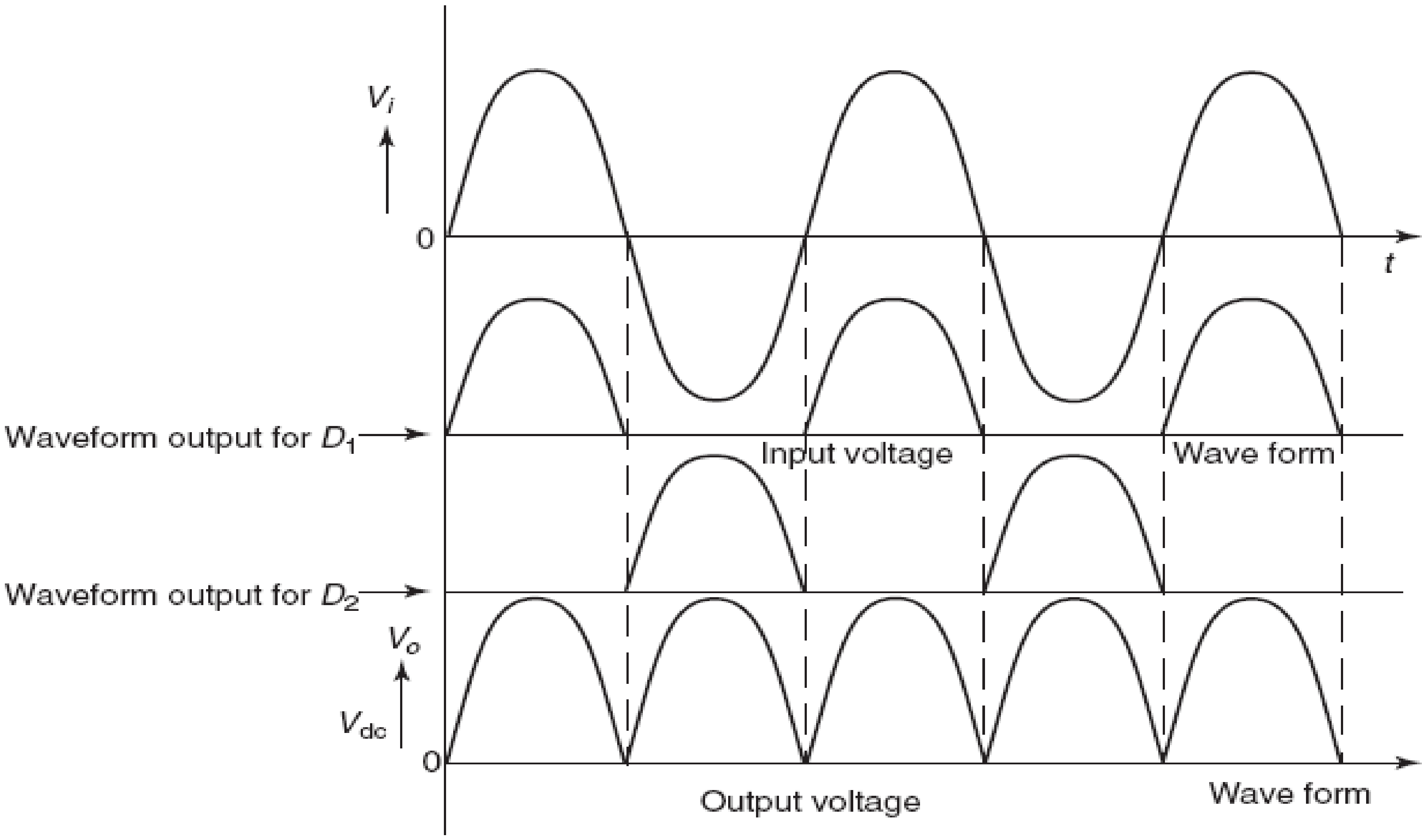
$$V_{sec} = nV_{pri} \qquad V_{p(out)} = V_{p(sec)} - 0.7\,\text{V} \qquad \text{PIV} = V_{p(sec)}$$

Full Wave Rectifier

The full-wave rectifier can be classified into two distinct types.

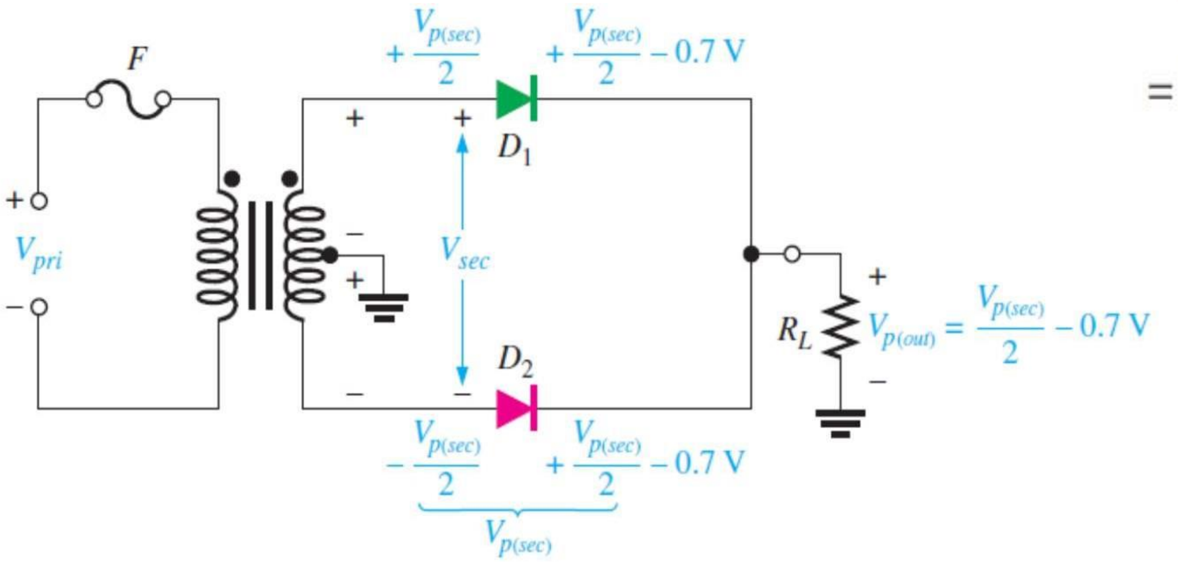
(i) Centre-tapped transformer full-wave rectifier:- It comprises of two half-wave circuits, connected in such a manner that conduction takes place through one diode during one half of the power cycle and through the other diode during the second half of the cycle.





Waveform for full-wave rectifier

Peak Inverse Voltage



$$\text{PIV} = \left(\frac{V_{p(sec)}}{2} - 0.7\text{ V}\right) - \left(-\frac{V_{p(sec)}}{2}\right) = \frac{V_{p(sec)}}{2} + \frac{V_{p(sec)}}{2} - 0.7\text{ V}$$

$$= V_{p(sec)} - 0.7\text{ V}$$

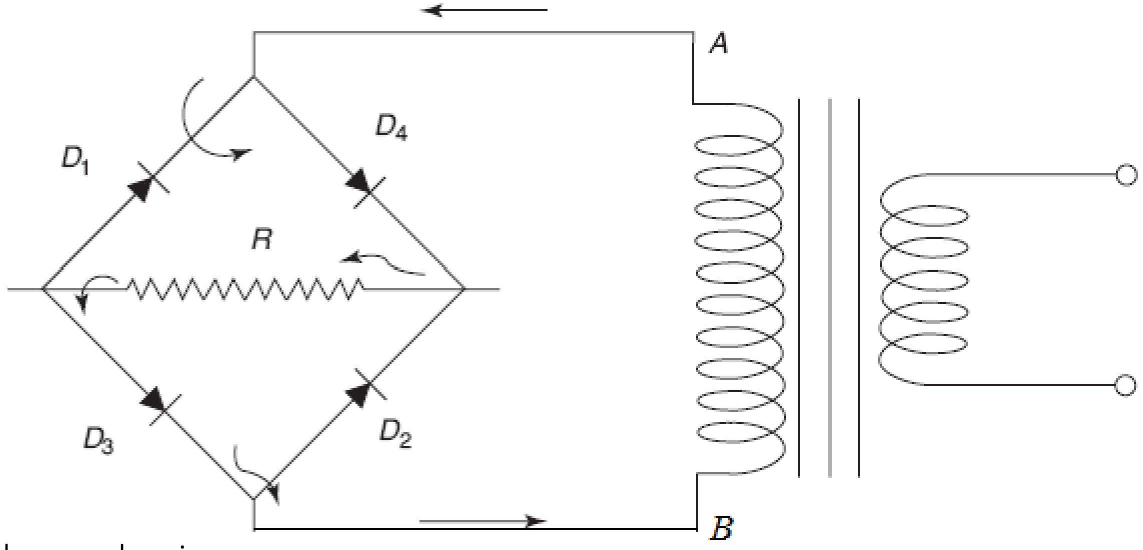
$$V_{p(out)} = V_{p(sec)}/2 - 0.7\text{ V}$$

$$V_{p(sec)} = 2V_{p(out)} + 1.4\text{ V}$$

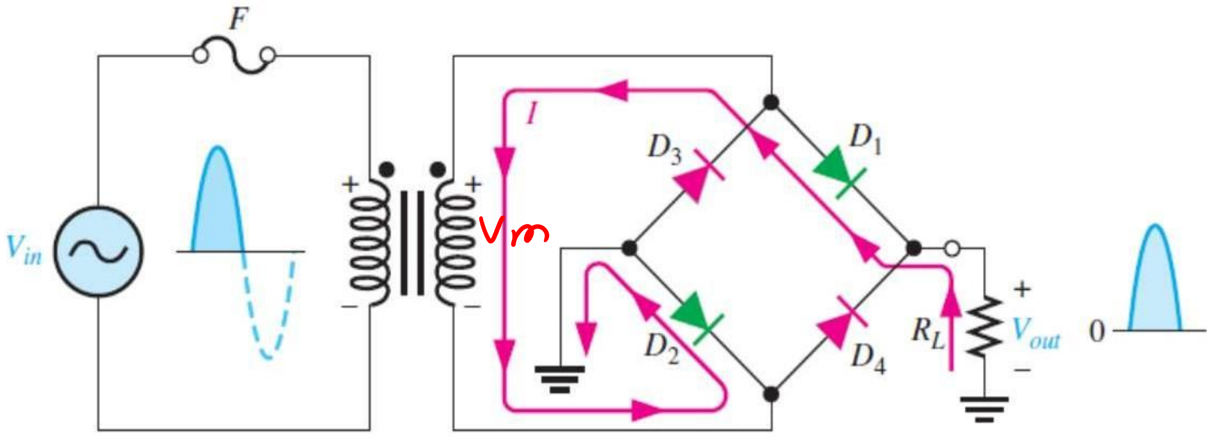
$$\text{PIV} = 2V_{p(out)} + 0.7\text{ V}$$

Full Wave Rectifier

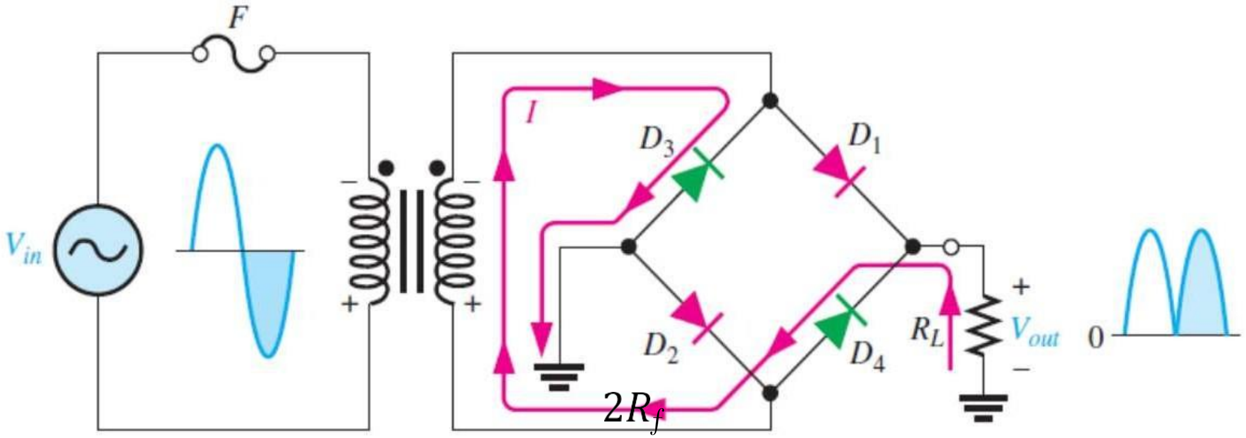
(ii) <u>Bridge type full-wave rectifier</u>:- The most important disadvantage of the centre-tapped rectifier is that it brings in the use of a heavy transformer with three terminals at its output, i.e., a centre-tapped transformer. The centre tapping may not be perfect in most cases. This problem can be solved by designing another circuit with four diodes and a simple transformer. This is called a bridge rectifier.



Bridge Full Wave Rectifier

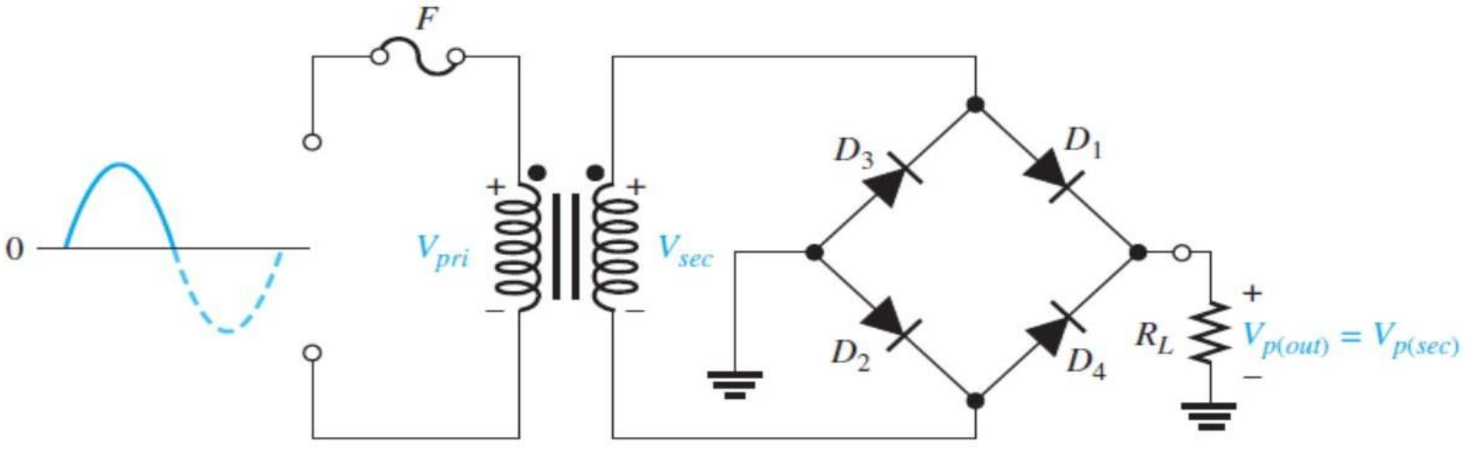


(a) During the positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

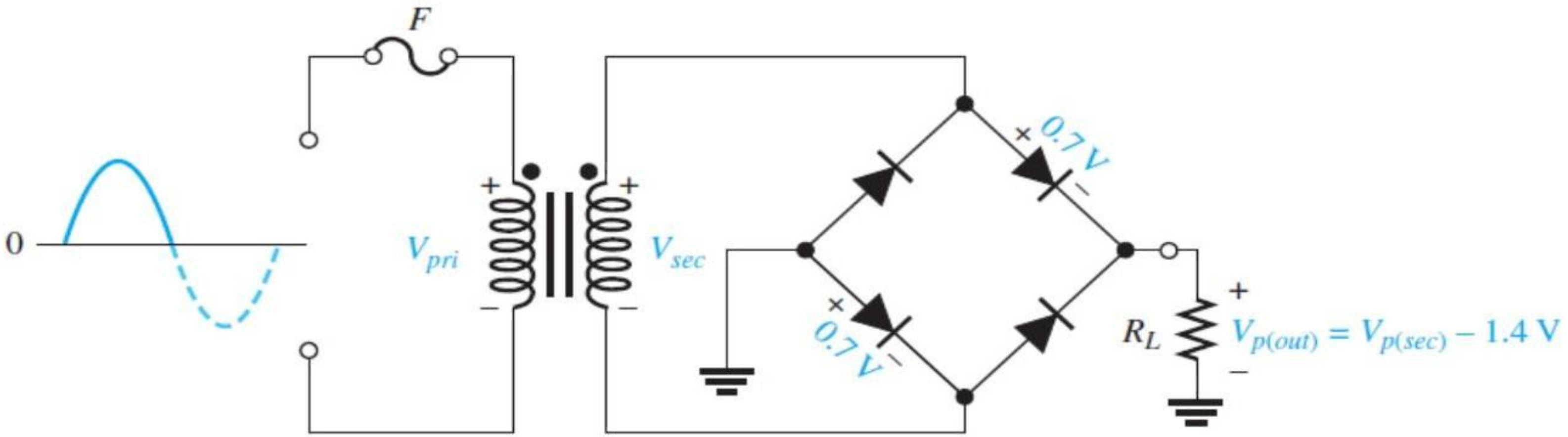


(b) During the negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

Bridge Full Wave Rectifier



(a) Ideal diodes



(b) Practical diodes (Diode drops included)

Advantages of a Bridge Rectifier

(i) In the bridge circuit a transformer without a centre tap is used.

(ii) The bridge circuit requires a smaller transformer as compared to a full-wave rectifier giving the identical rectified dc output voltage.

(iii) For the same dc output voltage, the PIV rating of a diode in a bridge rectifier is half of that for a full -wave circuit.

(iv) The bridge circuit is more appropriate for high-voltage applications, thus, making the circuit compact.

Disadvantages of a Bridge Rectifier

(i) Two or more diodes are required in case of a bridge rectifier, as a full-wave rectifier uses two diodes whereas a bridge rectifier uses four diodes.

(ii) The amount of power dissipated in a bridge circuit is higher as compared to a full-wave rectifier. Hence, the bridge rectifier is not efficient as far as low voltages are concerned.

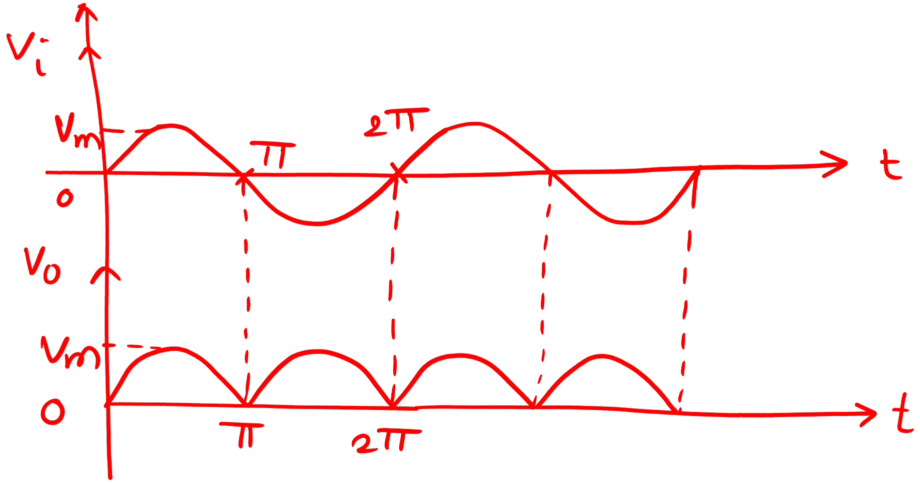
Parameters of Full Wave Rectifier:

V_m and I_m : Peak values.

1) V_{dc} or V_{avg}

$$V_{dc} = \frac{\text{Area under the curve}}{\text{Base}}$$

$$= \frac{\int_0^{2\pi} V_m \sin\theta \, d\theta}{2\pi}$$



$$V_{dc} = \frac{1}{\pi}\left[\int_0^{\pi} V_m \sin\theta \, d\theta\right] = \frac{V_m}{\pi}\int_0^{\pi} \sin\theta \, d\theta \Rightarrow V_{dc} \text{ or } V_{avg} = \frac{2V_m}{\pi}$$

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

2) V_{rms} and I_{rms}

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi}(V_m \sin\theta)^2 d\theta} = \frac{V_m}{\sqrt{2}}$$

$\therefore V_{rms} = V_m/\sqrt{2}$

& $I_{rms} = I_m/\sqrt{2}$

3) Rectifier Efficiency (η):

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

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

$P_{ac} = (I_{rms})^2 (r_F + R_L) = \left(\frac{I_m}{\sqrt{2}}\right)^2 (R_L + r_f)$

$$\therefore \eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{4\cancel{I_m^2}}{\pi^2} R_L}{\frac{\cancel{I_m^2}}{2}(r_F + R_L)}$$

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

$$= \frac{8/\pi^2}{1 + r_f/R_L}$$

If $r_f << R_L$,

$\frac{r_f}{R_L} \rightarrow$ Negligible

$$\therefore \eta = \frac{8}{\pi^2}$$

$\therefore \eta = 81.2\%$

4) Form Factor:

$$F.F. = \frac{\text{rms value}}{\text{average value}}$$

$$= \frac{I_{rms}}{I_{avg}}$$

$$= \frac{I_m/\sqrt{2}}{2I_m/\pi} = 1.11$$

$\therefore F.F. = 1.11$

5> Ripple Factor:

$$R.F. (\gamma) = \frac{I_{ac}}{I_{dc}}$$

$$I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

$$\therefore \gamma = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

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

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

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

$$\therefore \gamma = 0.483$$

For HWR,

$$PIV = V_m = V_{psec}$$

For CTFWR,

$$PIV = 2V_m$$

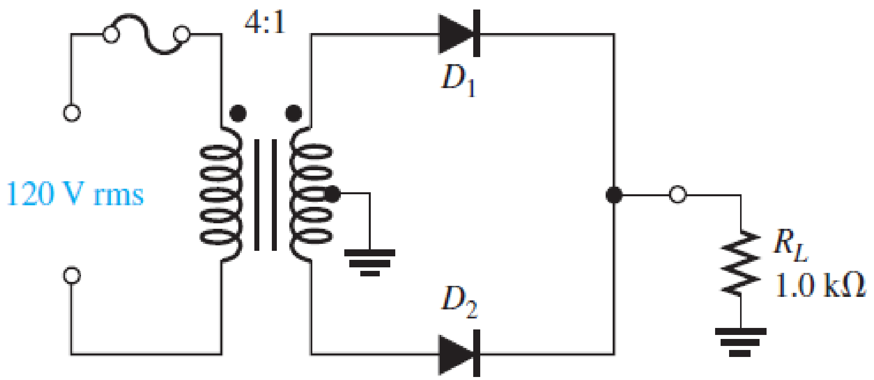
$$= 2\left(\frac{V_{psec}}{2}\right)$$

For BR,

$$PIV = V_m$$

$$= V_{psec}$$

Determine the DC and RMS voltage across the load resistance considering the ideal diodes.



$V_{pri} = 120\,V_{rms}$

$\therefore V_{sec} = \frac{120}{4} = 30\,V_{rms}$

$\therefore V_m \text{ at sec} = 30\sqrt{2} = 42.4V$

$V_{DC} = \frac{2V_m}{\pi} = 27.01\ V$

$V_{rms} = \frac{V_m}{\sqrt{2}} = 30V$

$I_m = \frac{V_m}{R_L}$

$I_m = \frac{V_m}{r_f + R_L}$

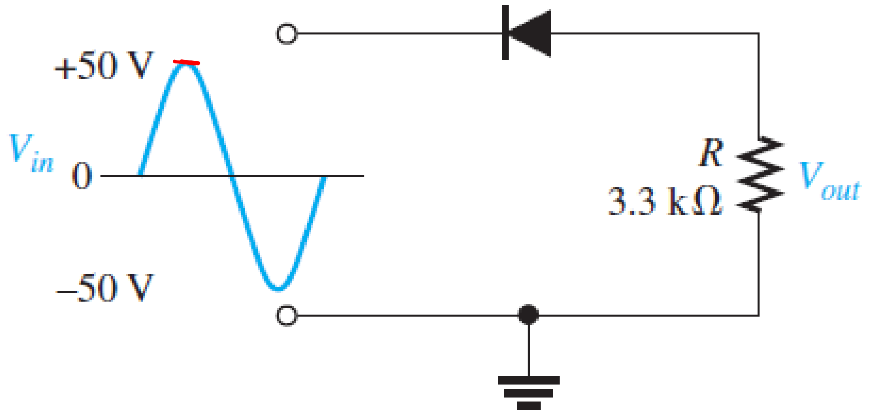
$I_{dc} = \frac{2I_m}{\pi} = \frac{2V_m}{\pi R_L}$

I_{DC}

$\hookrightarrow V_{DC}.$

$I_{dc} \cdot R_L = \frac{2V_m}{\pi \cancel{R_L}} \cdot \cancel{R_L} = \frac{2V_m}{\pi}$

What is the Peak Inverse Voltage across the Diode in the following Circuit? Consider the diode to be Ideal.



$PIV = V_m = 50V$

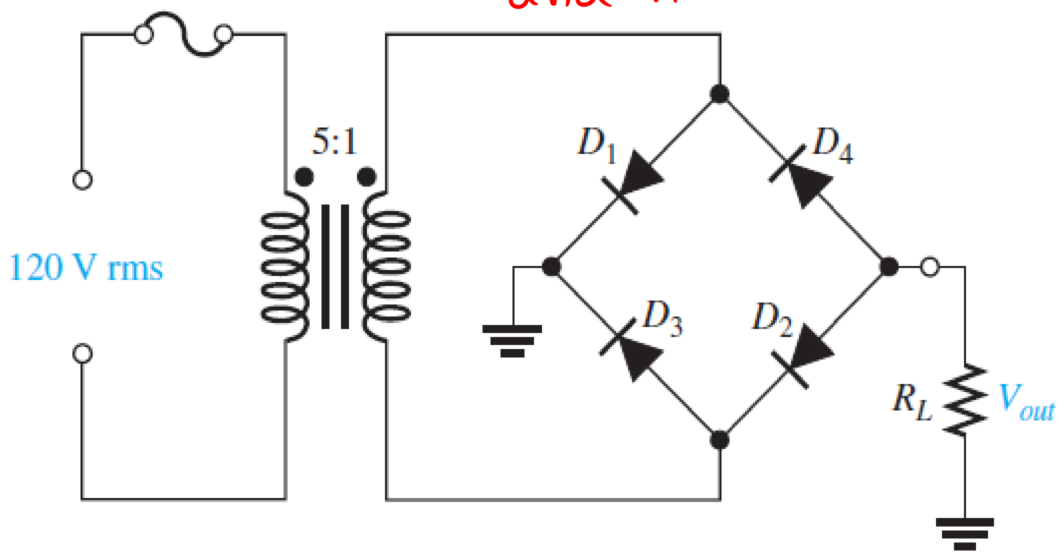
Peak voltage appearing at the primary of the transformer with 10:1 turns ration, is 220V, what would be the Peak Inverse Voltage for the diodes used in Centre Trapped Full wave Rectifier?

$V_{p(pri)} = 220V$; Turns ratio = 10:1

$V_{p(sec)} = \frac{220}{10} = 22V$

$PIV = 2 \cdot \left(\frac{V_{psec}}{2}\right) = 22V$

Determine the DC power delivered to the load for the load resistance of 1kΩ. and AC



$V_{dc} = \frac{2V_m}{\pi} = 21.61V$

$V_{rms} = \frac{V_m}{\sqrt{2}} = 24V$

$V_{pri} = 120 V_{rms}$

$V_{sec} = \frac{120}{5} = 24 V_{rms}$

$\therefore V_m = 24\sqrt{2}$

$= 33.94V$

→ $P_{dc} = (I_{dc})^2 R_L$

$= \frac{(V_{dc})^2}{R_L}$

$= \frac{(21.61)^2}{1 \times 10^3}$

$\therefore P_{dc} = 0.466 W$

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

$= \frac{(V_{rms})^2}{R_L}$

$= \frac{(24)^2}{1 \times 10^3}$

$\therefore P_{ac} = 0.576 W$

Comparison of HWR and FWR

SI.No	Parameter	Type of the rectifier		
		Halfwave	Fullwave	Bridge
1.	Number of diodes	1	2	4
2.	V_{dc}	V_m/π	$2V_m/\pi$	$2V_m/\pi$
3.	Peak inverse voltage	V_m	$2V_m$	V_m
4.	Ripple factor	1.21	0.48	0.48
5.	Rectifier efficiency	40.6%	81.2%	81.2%
6.	Transformer Utilization factor	0.287	0.693	0.812
7.	Form factor	1.57	1.11	1.11

Acknowledgements

1. Electronic Devices, Thomas L. Floyd
2. Web Resources

Thank You..