

SAMPLE STUDY MATERIAL

Instrumentation Engineering IN



Postal Correspondence Course

GATE & PSUs

Analog Electronics

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CHAPTER-1

DIODE APPLICATION

1. Rectifier: A diode rectifier (alternating to unidirectional converter) forms an essential building block of the dc power supplies required to electronic equipment.



Alternating (DC value = 0)

Unidirectional (Pulsating DC)
(+ve DC value)

Important Terms

1. Ripple Factor: $r = \frac{\text{RMS value of AC component}}{\text{DC value}}$

$$r = \frac{V_{ac\ rms}}{V_{dc}}$$

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

$$\left[\text{Form factor (F)} = \frac{\text{RMS value } V_{rms}}{\text{DC value } V_{dc}} \right]$$

Hence, $r = \sqrt{F^2 - 1}$

Note: Ideal value $r = 0$, $F = 1$ (AC component = 0)

2. Crest Factor: $C = \frac{\text{Peak value}}{\text{RMS value}}$

3. Ripple Voltage: Ripple voltage is defined as deviation of output voltage from its DC value



Output of rectifier \Rightarrow Pulsating DC

$$\text{DC value} = V_{dc}$$

$$\text{RMS value} = V_{ms}$$

4. PIV (Peak Inverse Voltage)

It is maximum voltage applied to diode in reverse bias condition and decide voltage handling capacity of diode circuit.

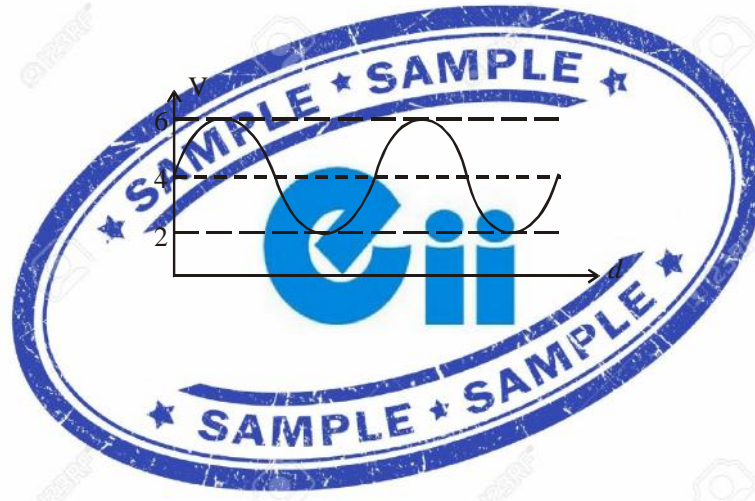
Note: PIV should be low.

5. Transformer utilization factor: It shows the degree of utilization of the transformer in rectifier circuit.

It must be very high and decide cost of circuit

<p>Output Rectifier</p> $V = V_{DC} + V_{AC}$ $V_{rms} = \sqrt{(V_{DC})^2 + (V_{AC_{rms}})^2}$ $\Rightarrow V_{AC_{rms}} = \sqrt{V_{rms}^2 - V_{DC}^2}$

Example: Let $V = 4 + 2 \sin \omega t$



- $V_{DC} = 4$
- $V_{AC_{rms}} = \frac{2}{\sqrt{2}}$
- $V_{rms} = \sqrt{4^2 + \left(\frac{2}{\sqrt{2}}\right)^2} = \sqrt{16 + 2} = \sqrt{18}$
- **Ripple Factor (r)** $= \frac{V_{AC_{rms}}}{V_{dc}} = \frac{\frac{2}{\sqrt{2}}}{4} = \frac{1}{2\sqrt{2}} = 0.35$
- Form Factor

$$F = \frac{V_{rms}}{V_{DC}} = \frac{\sqrt{18}}{4} = 1.06$$

Rectifier

1. Half wave rectifier

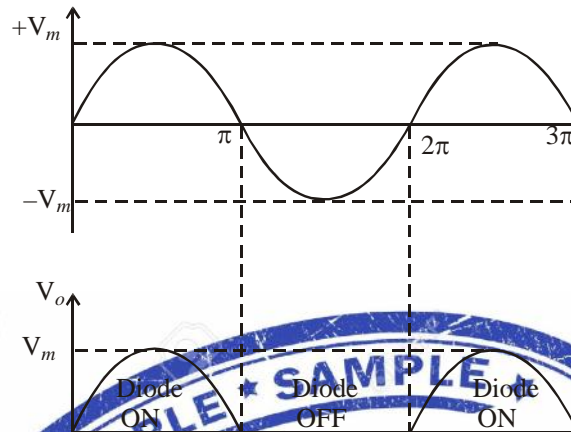
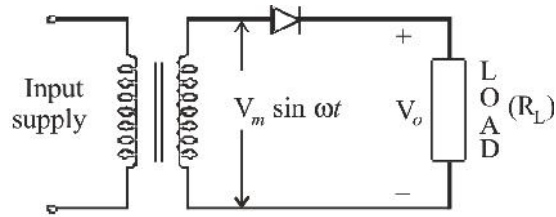
2. Full wave rectifier

(a) Centre taped rectifier

(b) Bridge rectifier

• Half Wave Rectifier

The half wave rectifier utilizes alternate half cycles of the input signal.



⇒ During +ve half cycle of supply voltage diode on and during -ve half it is off.

$$1. V_{\text{avg}} = V_{\text{DC}}$$

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

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

3. Form Factor

$$F = \frac{V_{\text{rms}}}{V_{\text{DC}}} = \frac{\frac{V_m}{2}}{\frac{V_m}{\pi}} = \frac{\pi}{2} = 1.58$$

4. Ripple Factor

$$r = \sqrt{F^2 - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} = 1.21$$

5. Crest Factor:

$$C = \frac{\text{Peak value}}{\text{RMS value}} = \frac{V_m}{\frac{V_m}{2}} = 2$$

6. Rectifier Efficiency:

$$\eta = \frac{\text{DC output power}}{\text{AC input power}} \times 100 = \frac{P_{dc}}{A_{AC}}$$

$$P_{dc} = V_o I_o = \frac{V_m}{\pi} \times \frac{I_m}{\pi} = \frac{V_m I_m}{\pi^2} \quad \left(I_m = \frac{V_m}{R_L} \right)$$

$$\text{RMS output voltage } V_{rms} = \frac{V_m}{2}$$

$$\text{RMS output current } I_{rms} = \frac{V_{rms}}{R_L} = \frac{V_m}{2R_L} = \frac{I_m}{2}$$

$$P_{ac} = V_{rms} I_{rms} = \frac{V_m}{2} \times \frac{I_m}{2} = \frac{V_m I_m}{4}$$

$$\eta(\%) = \frac{P_{dc}}{P_{ac}} = \frac{\frac{V_m I_m}{\pi^2}}{\frac{V_m I_m}{4}} = \frac{4}{\pi^2} = 40.53\%$$

$$7. \text{ TUF : } = \frac{P_{dc}}{\text{VA rating of transformer}} = \frac{\frac{V_m I_m}{\pi^2}}{\frac{V_m I_m}{2\sqrt{2}}} = 0.286$$

Voltage is available for full time period and current is available for half of time period

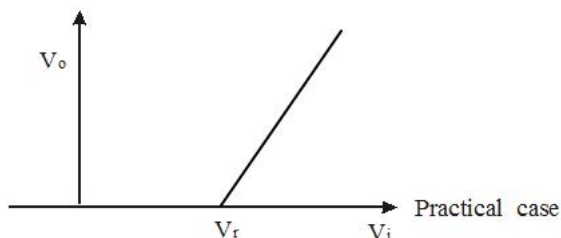
Note: Transformer is under utilized

$$8. \text{ PIV: Peak inverse voltage} = V_m$$

9. Ripple Frequency: Source frequency

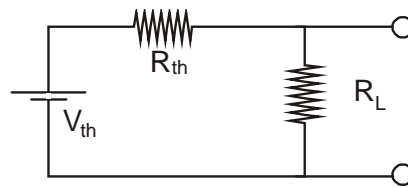
$$f_r = f_s$$

⇒ **Transfer curve of H.W.R.** (Diode is assumed ideal)



V_i	D	V_o
$V_i > 0$	ON	V_i
$V_i < 0$	OFF	0

Thevenin equivalent of half wave rectifier



$$I_{dc} = \frac{V_{TH}}{R_{TH} + R_L}$$

$$I_L = \frac{V_m \sin \check{S}t - V_r}{R_s + R_f + R_L} \cong \frac{V_m \sin \check{S}t}{R_s + R_f + R_L}$$

$$I_{dc} = \frac{1}{2f} \int_0^f I_L d(\check{S}t) \quad I'_m \sin \check{S}t \text{ where } I'_m = \frac{V_m}{R_s + R_f + R_L}$$

$$I_{dc} = \frac{1}{2f} \int_0^f I_L d(\check{S}t) = \frac{1}{2f} \int_0^f I'_m \sin(\check{S}t) d(\check{S}t)$$

$$= \left(\frac{I'_m}{f} \right) = \frac{V_m / f}{R_s + R_f + R_L} = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)$$

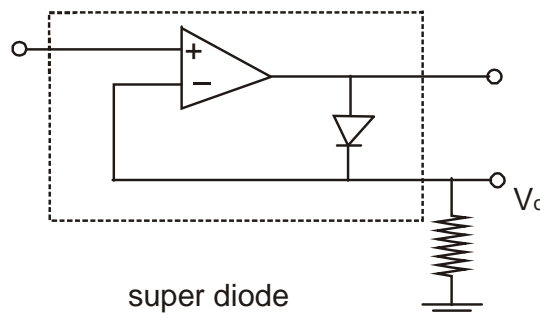
Thus $V_{Th} = \frac{V_m}{f}$

$$R_{Th} = R_s + R_f$$

Drawbacks :

- Excessive ripple factor ≈ 1.21
- Low rectifier efficiency
- Low TUF
- d.c. Saturation of transformer secondary

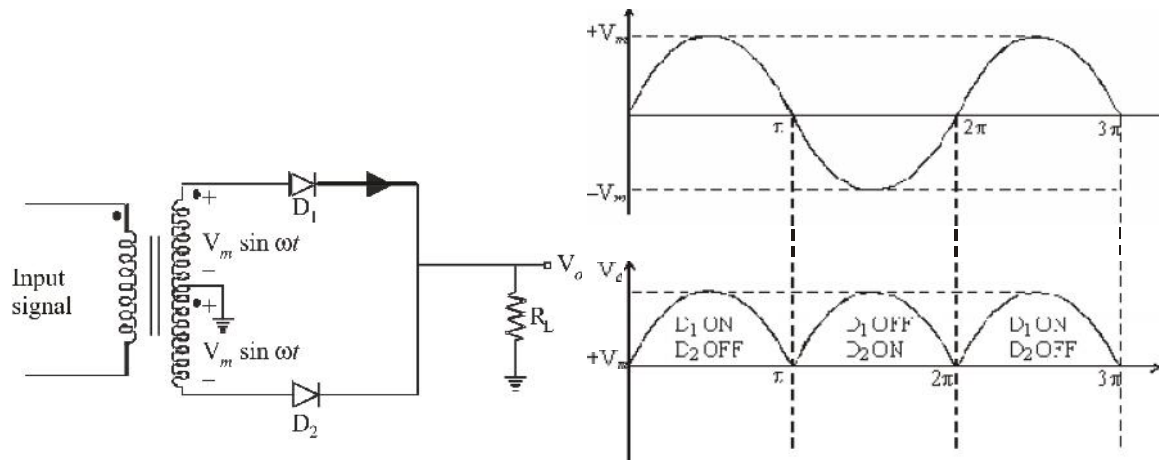
Precision Half wave rectifier :



10. Full Wave Rectifier

In the full wave rectifier, rectification takes place for both the half cycle of input signal.

1. Centre Tapped F.W.R. (Using Ideal Diodes)



Note: Ripple frequency = 2 (source frequency)

$$f_r = 2f_s$$

(i) Average Value

$$V_{\text{average}} = V_{\text{DC}} = \frac{1}{\pi} \int_0^{\pi} V_m \sin \omega t \cdot d(\omega t) = \frac{2V_m}{\pi}$$

(ii) RMS Value

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

(iii) Form Factor

$$F = \frac{V_{\text{rms}}}{V_{\text{DC}}} = \frac{\frac{V_m}{\sqrt{2}}}{\frac{2V_m}{\pi}} = \frac{\pi}{2\sqrt{2}} = 1.11$$

(iv) Ripple Factor

$$r = \sqrt{F^2 - 1} = \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1} = 0.48$$

(v) Crest Factor

$$C = \frac{V_m}{\frac{V_m}{\sqrt{2}}} = \sqrt{2}$$

(vi) Rectifier Efficiency

$$\eta\% = \frac{P_{dc}}{P_{ac}} \times 100 = \frac{4}{\pi^2} \frac{V_m I_m}{\left(\frac{V_m I_m}{2}\right)}$$

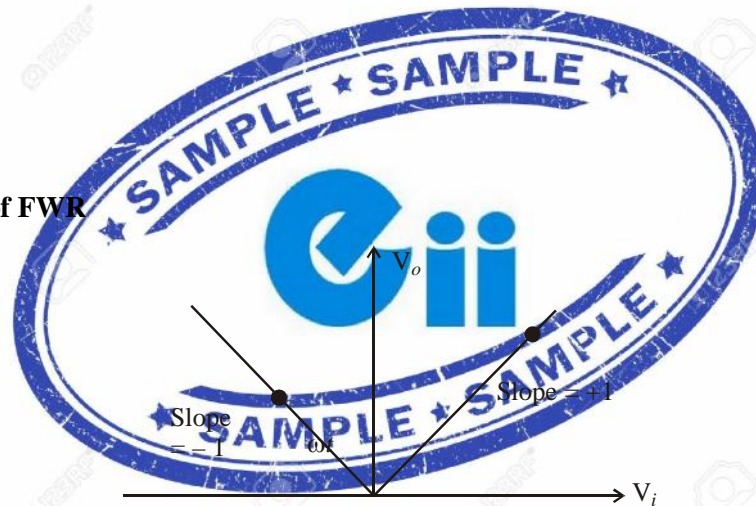
$$= \frac{8}{\pi^2} \quad \left(I_m = \frac{V_m}{R_L} \right)$$

$$(vii) \text{ TUF} = \frac{P_{dc}}{\text{VA Rating of transformer}} = \frac{\frac{4}{\pi^2} V_m I_m}{0.6035 V_m I_m} = 0.672$$

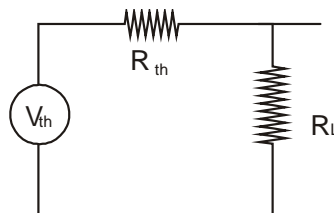
Note: In FWR case utilization of transformer takes place in both +ve and -ve half hence TUF increases.

(viii) PIV = $2V_m$; Higher PIV is disadvantages to circuit as it effect diode operation.

Transfer Curve of FWR



Thevenin equivalent of full wave rectifier



$$I_{th} = \frac{V_{th}}{R_L + R_{th}}$$

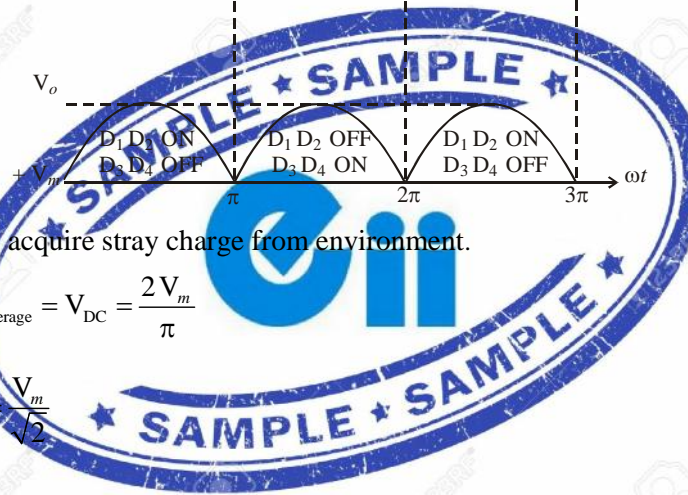
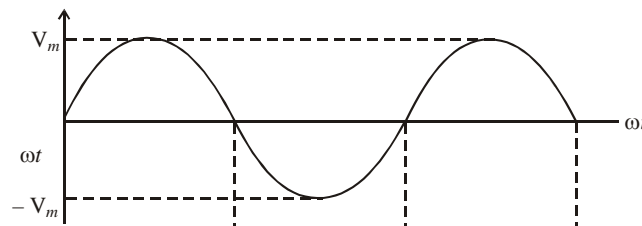
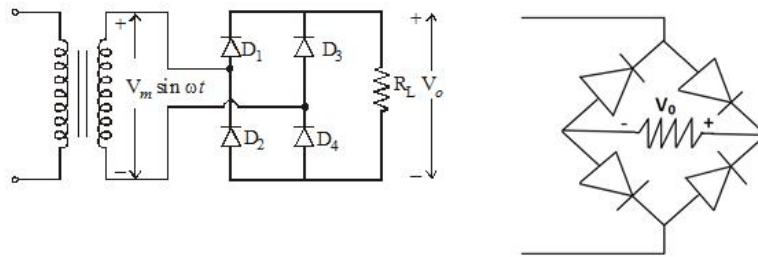
$$I_L = \frac{V_m \sin \check{S}t - V_r}{R_S + R_F + R_L} \cong \frac{V_m \sin \check{S}t}{R_S + R_F + R_L} = I'_m \sin \check{S}t \quad \because I'_m = \frac{V_m}{R_S + R_F + R_L}$$

$$I_{dc} = \frac{1}{2f} \int_0^f I_L d(\check{S}t) = \frac{2I'_m}{f} = \frac{2V_m / f}{R_S + R_F + R_L}$$

$$V_{th} = \frac{2V_m}{f}$$

$$R_{Th} = R_S + R_F$$

2. Bridge Type FWR (Using Ideal Diode):



Floating resistance may acquire stray charge from environment.

(i) **Average value:** $V_{\text{average}} = V_{\text{DC}} = \frac{2V_m}{\pi}$

(ii) **RMS value:** $V_{\text{rms}} = \frac{V_m}{\sqrt{2}}$

(iii) **Form factor:** $F = \frac{\pi}{2\sqrt{2}} = 1.11$

(iv) **Ripple factor:** $r = 0.48$

(v) **Rectification efficiency** = 81.06%

Note: As waveform is same for centre tapped and bridge type FWR hence above (v) quantities are same.

(vi) **TUF:** TUF = 0.812

Note: Transformer is properly utilized.

(vii) **PIV** = V_m

Key Points:

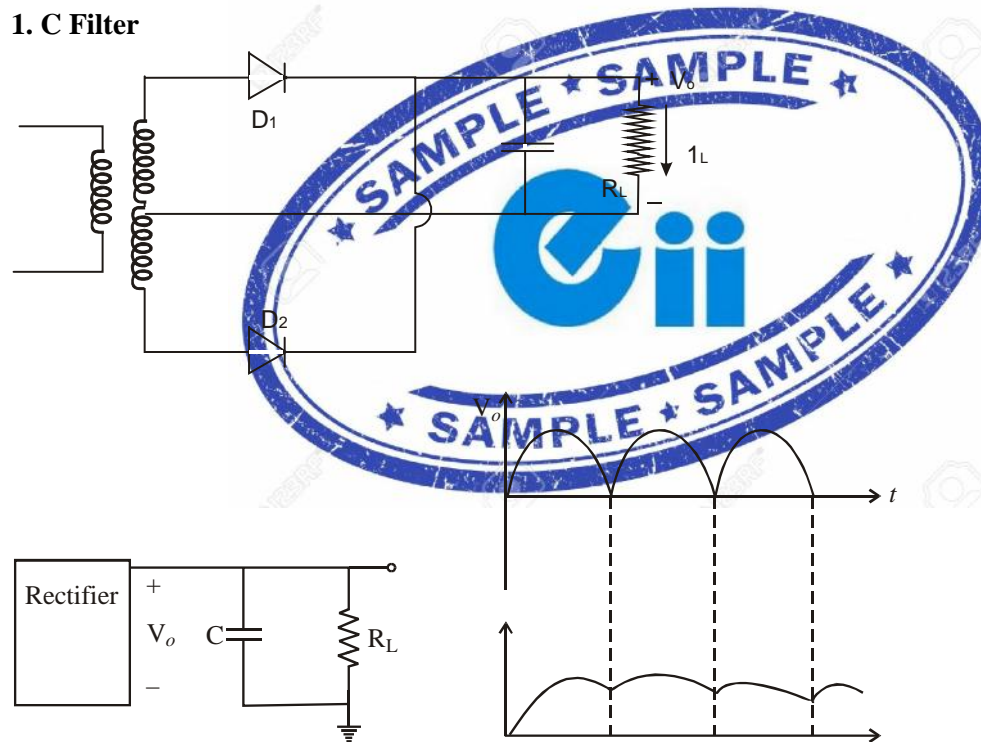
- (i) Both full wave rectifiers are better than the half wave rectifier in so far as voltage ripple factor, rectification efficiency, TUF and crest factor are concerned.
- (ii) TUF of bridge type FWR is better than centre tapped FWR therefore transformers required in the centre tapper FWR is bulky.
- (iii) PIV of diodes in bridge rectifier is half of that of the diodes used in centre tapped FWR.
- (iv) Overall, a bridge rectifier using four diodes is more economical.

Filter Circuits:

- ⇒ As the output of the rectifier circuit is pulsating DC containing AC and DC component filter circuits are used to suppress the AC component.
- ⇒ It reduces ripple factor to negligible value.
- ⇒ Important components of the filters are capacitor and inductor.

Types of Filter Circuit:

1. C Filter



Here, ripple voltage is approximated as triangular waveform and on this basis d.c. and r.m.s value is calculate.

$$V_{rpp} \begin{cases} \text{dc value} \rightarrow \frac{V_{rpp}}{2} \\ \text{rms value} \rightarrow \frac{V_{rpp}}{2\sqrt{3}} \end{cases}$$

⇒ A capacitor C across load R_L offers direct short circuit to AC component, these are therefore not allowed to reach the load. However dc gets stored in the form of energy in C and this allows the maintenance of almost constant dc output voltage across the load.

⇒ C-filter is suitable for load having low current (High Load Resistance)

⇒ HWR with C-filter Ripple factor $r = \frac{1}{2\sqrt{3} f C R_L}$

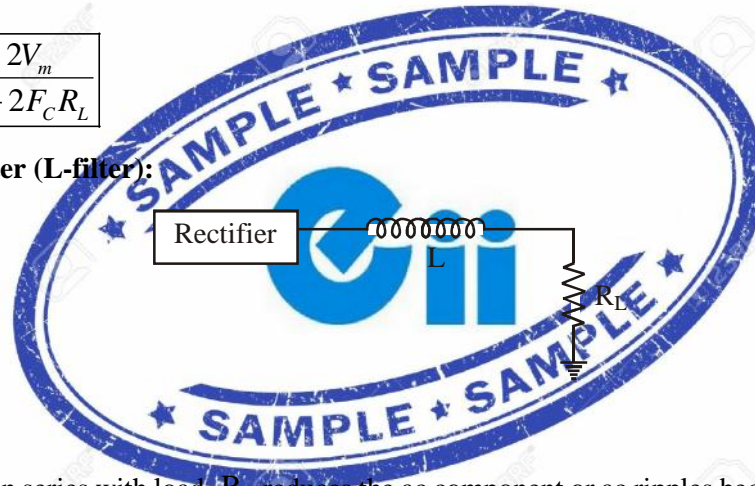
⇒ FWR with C-filter Ripple factor $r = \frac{1}{4\sqrt{3} f C R_L}$

$$V_{dc} = V_m - \frac{1}{2} V_{rpp}$$

$$V_{rpp} = \frac{V_{dc}}{F_C R_L}$$

$$V_{rpp} = \frac{2V_m}{1 + 2F_C R_L}$$

(ii) Inductor Filter (L-filter):



⇒ An inductor L in series with load R_L reduces the ac component or ac ripples because L in series with R_L offers high impedance to ac component but very low resistance to dc.

⇒ L-filter is suitable for loads requiring high load current (low value of R_L).

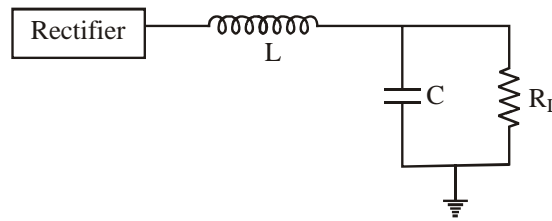
Note: In both C-filter and L-filter, time constant should be large for better waveform *i.e.*,

$$\tau = \frac{L}{R_L} = C R_L \text{ should be high.}$$

(ii) Ripple factor (r) =
$$\frac{2}{3\sqrt{2}} \frac{1}{\sqrt{1 + \left(\frac{X_L}{R_L}\right)^2}}$$

where, $X_L = \omega L$ for HWR

= $Z \omega L$ for FWR

(iii) L section or LC Filter:

⇒ An LC filter consists of inductor L in series with the load and capacitor C across the load. This filter possesses the advantage of both L filter and C filter.

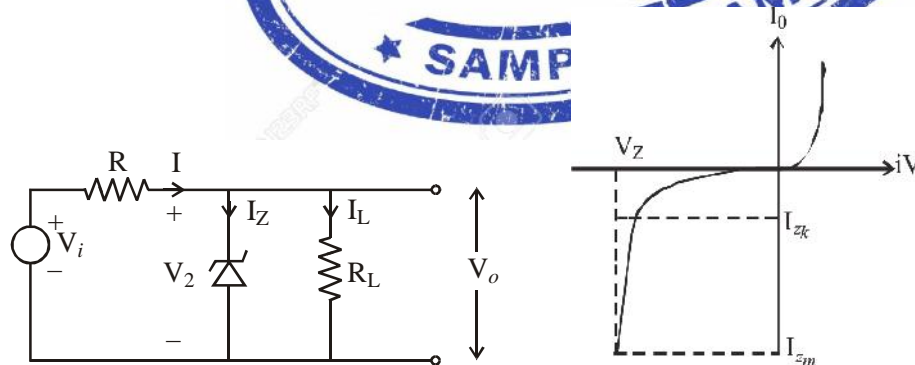
$$\Rightarrow \text{Ripple factor } r = \frac{\sqrt{2} X_C}{3 X_L}$$

Note: (i) Ripple factor (r) is independent of R_L (ii) $r \propto \frac{1}{f^2}$

Voltage Regulator

⇒ Voltage regulator is a circuit whose purpose is to provide constant DC voltage between its output terminals.

⇒ Voltage regulator circuits can be implemented using Zener diode, transistors, etc.

1. Voltage Regulator Using Zener Diode:

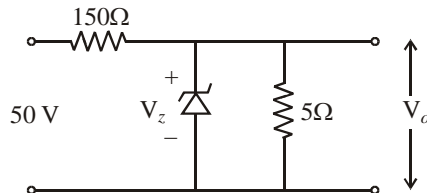
- V_i is output of the filter circuit.
- Zener diode should be RB and breakdown.
- I_{ZK} = KNEE current = The minimum current flowing through the zener diode when zener breakdown has just occurred.
- I_{Zm} = The maximum zener current.
- P_{Zm} = Maximum power dissipated in zener diode = $V_Z I_{Zm}$

- For satisfactory operation of circuit.

$$I \geq I_{ZK} + I_L$$

$$\frac{V_i - V_o}{R} \geq I_{ZK} + I_L$$

Example: Find P_Z Given $V_Z = 15V$



Solution: Voltage across reverse bias zener diode = $\frac{5}{150 + 5} \times 50 = 1.612 V$

This voltage is less than V_Z hence zener is off and $I_Z = 0$ hence $P_Z = V_Z I_Z = 0$

Example. If in the above problem 5Ω resistor is replaced by 100Ω resistor. Now find P_Z ?

Solution: Voltage across RB zener diode

$$V_o = \frac{100}{150 + 100} \times 50 = 20V$$

Now $V_o > V_Z$

Hence, diode will go into breakdown mode.

Hence, $(V_o = V_Z = 15V)$

$$I = \frac{50 - 15}{150} = 0.23 A$$

$$I_L = \frac{15}{100} = .15 A$$

$$I_Z = I - I_L = 0.23 - 0.15 = 0.08 A$$

$$P_Z = V_Z I_Z = 15 \times 0.08 \text{ watts}$$

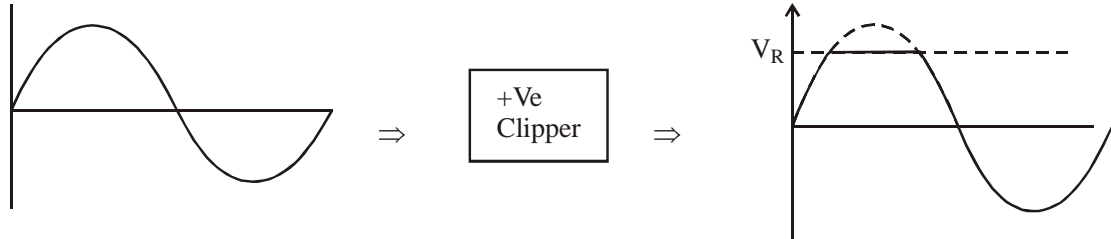
$$= 1.2 \text{ watts}$$

Clipping (Limiting) Circuits

⇒ These are used to select the part of waveform that lie above or below some reference level.

(i) Positive Clipper:

- Clipping above reference level.



(ii) Negative Clipper:

- Clipping below reference level

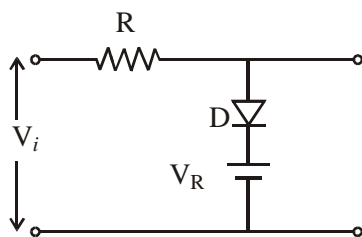


(iii) Two Level Clipper:



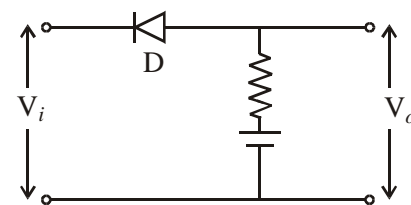
⇒ On the basis of position of diode w.r.t load

(i) Shunt Clipper



(Shunt +ve clipper)

(ii) Series Clipper

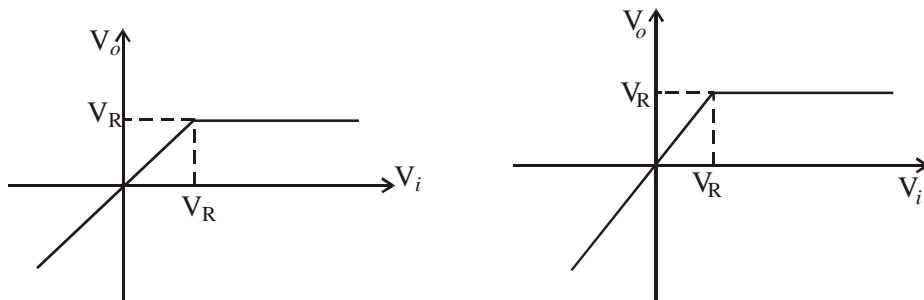


Series +ve clipper

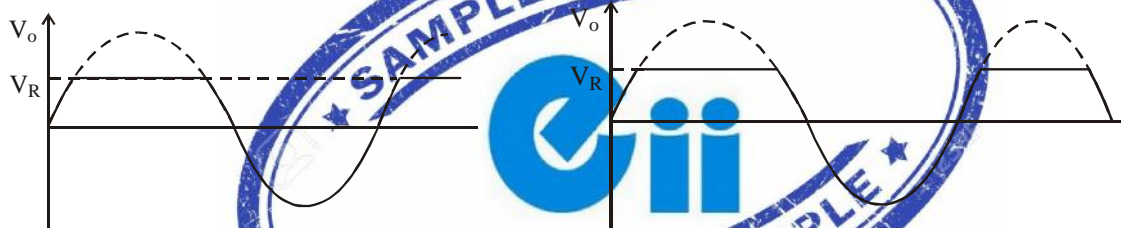
Range of V_i	D	V_o
$V_i < V_R$	OFF	V_i
$V_i \geq V_R$	ON	V_R

Range of V_i	D	V_o
$V_i < V_R$	ON	V_i
$V_i \geq V_R$	OFF	V_R

- **Transfer Curve**



- **Wave form**



77 Final Selections in Engineering Services 2014.

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1	171298	SAHIL GARG	EE
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6	088542	SUNEET KUMAR TOMAR	ECE
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10	207735	VASU HANDA	ECE
22	005386	RAN SINGH GODARA	ECE
22	032483	PAWAN KUMAR	EE
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35	003853	SHANKAR GANESH K	ECE
35	091781	KOUSHIK PAN	EE

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