

# SAMPLE STUDY MATERIAL

## Electrical Engineering EE/EEE



**Postal Correspondence Course**

**GATE , IES & PSUs**

**Analog Electronics**

## CONTENT

1. DIODE APPLICATION .....	03-29
2. OPERATIONAL AMPLIFIER.....	30-46
3. TRANSISTOR BIASING AND STABILIZATION .....	47-60
4. BJT AT LOW FREQUENCY .....	61-73
5. BJT AT HIGH FREQUENCY .....	74-93
6. FET AMPLIFIER .....	94-101
7. OSCILLATOR .....	102-112
8. FEEDBACK AMPLIFIER .....	113-123
9. POWER AMPLIFIER .....	124-131
10. MULTI VIBRATORS AND WAVE SHAPING CIRCUITS .....	132-138
11. ANALOG ELECTRONICS GATE Practices Set .....	139-156
12. ANALOG ELECTRONICS IES Objective .....	157-225

# 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.

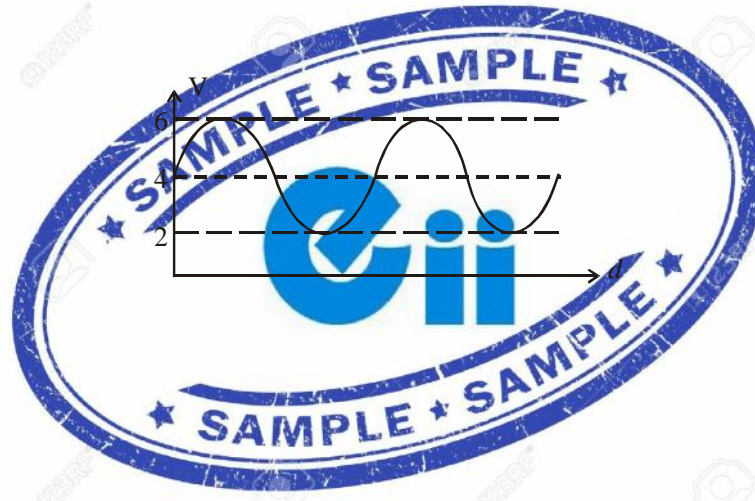
**Note:** PIV should be low.

**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

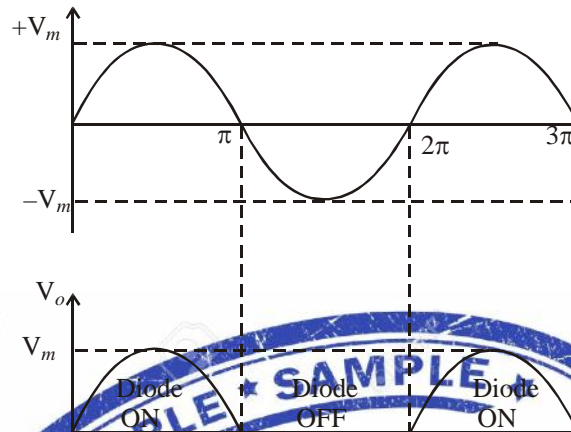
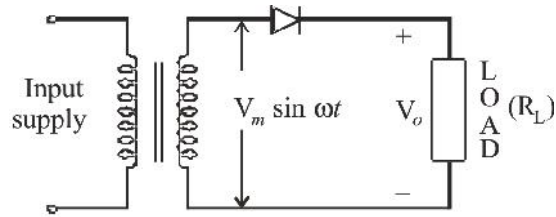
2. Full wave rectifier

(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

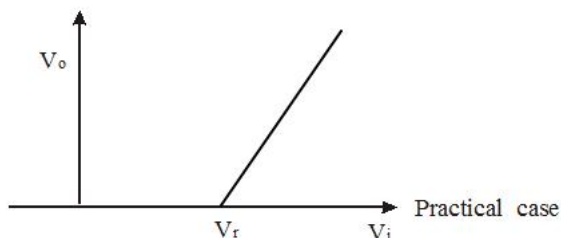
**Note:** Transformer is under utilized

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

**9. Ripple Frequency:** Source frequency

$$f_r = f_s$$

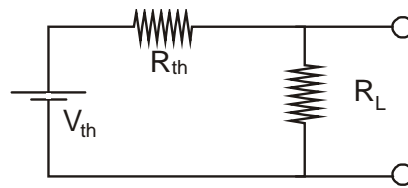
⇒ **Transfer curve of H.W.R.** (Diode is assumed ideal)



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



Thevenin equivalent of half wave rectifier



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

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

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

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

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

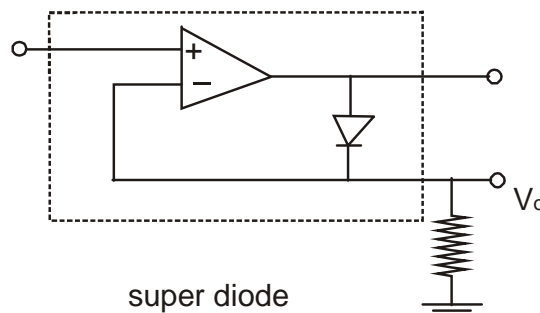
Thus  $V_{Th} = \frac{V_m}{f}$

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

**Drawbacks :**

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

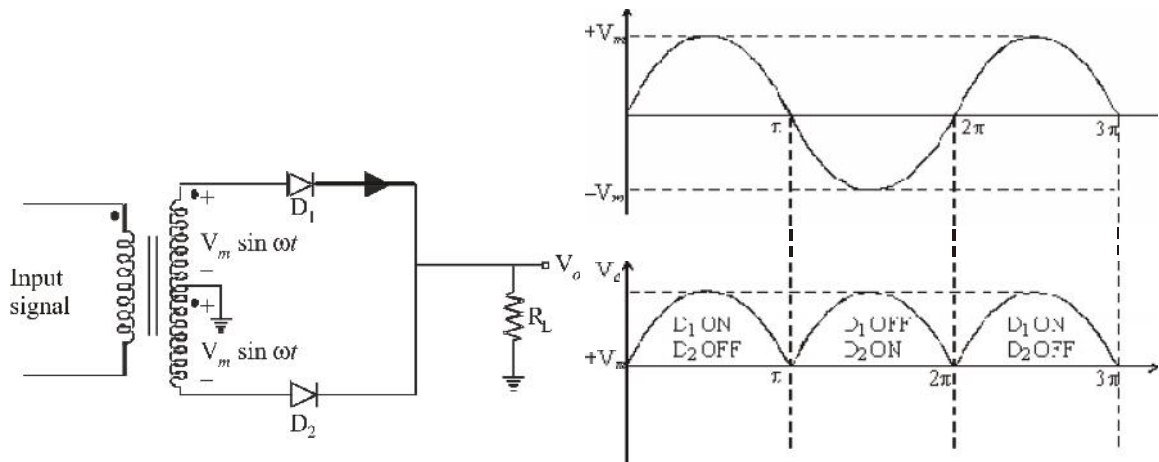
**Precision Half wave rectifier :**



## 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**

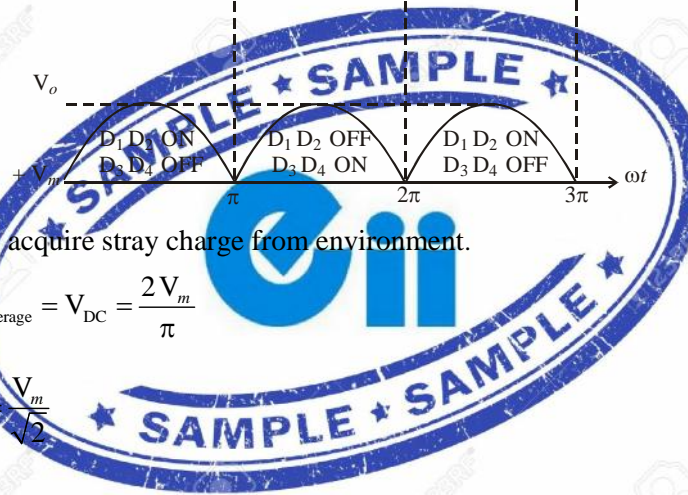
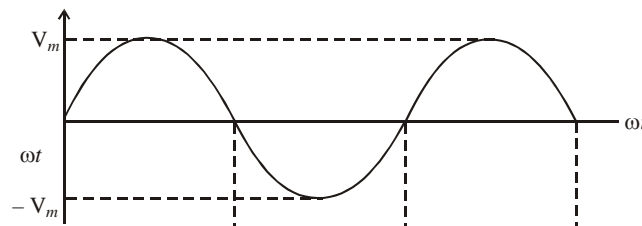
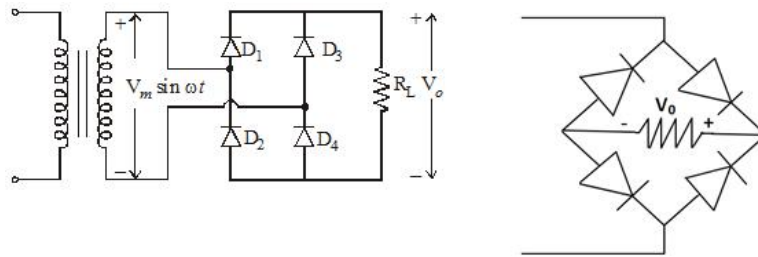




$$V_{th} = \frac{2V_m}{f}$$

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

## 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:

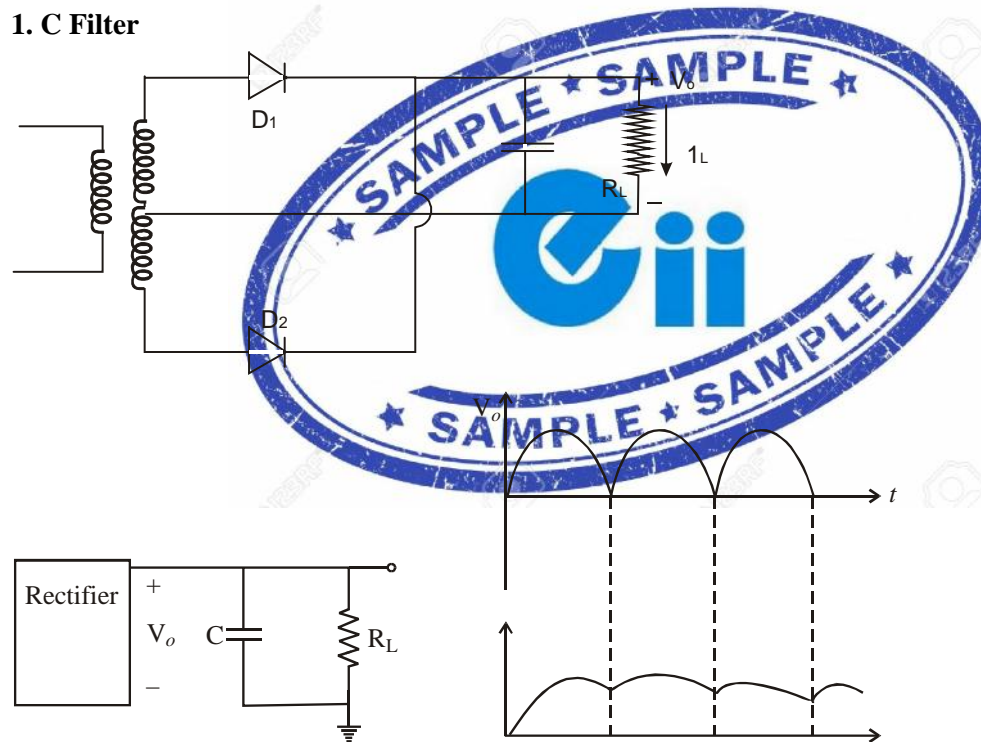
- (i) Both full wave rectifiers are better than the half wave rectifier in so far as voltage ripple factor, rectification efficiency, TUF and crest factor are concerned.
- (ii) TUF of bridge type FWR is better than centre tapped FWR therefore transforms required in the centre tapper FWR is bulky.
- (iii) 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  $r = \frac{1}{2\sqrt{3} f C R_L}$

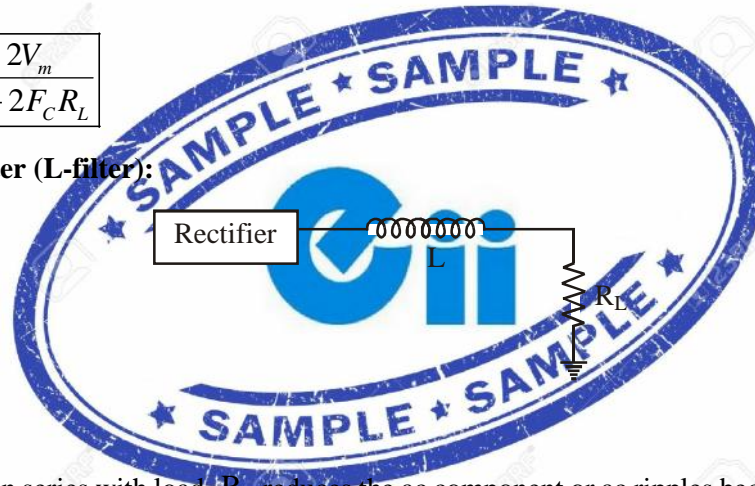
⇒ FWR with C-filter      Ripple factor  $r = \frac{1}{4\sqrt{3} f C R_L}$

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

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

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

(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.*,

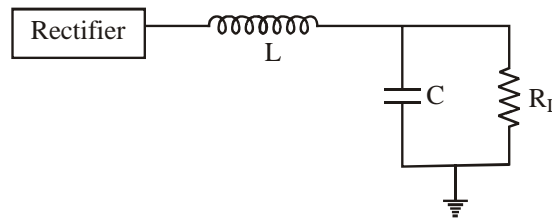
$$\tau = \frac{L}{R_L} = C R_L \text{ should be high.}$$

(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.

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

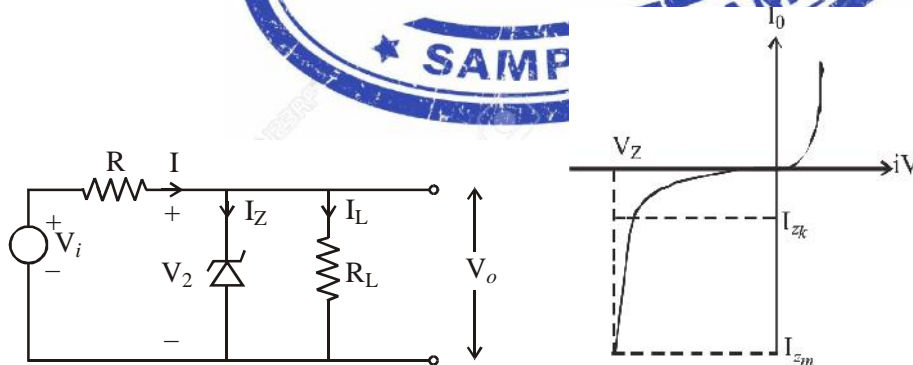
**Note:** (i) Ripple factor ( $r$ ) is independent of  $R_L$       (ii)  $r \propto \frac{1}{f^2}$

### 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:



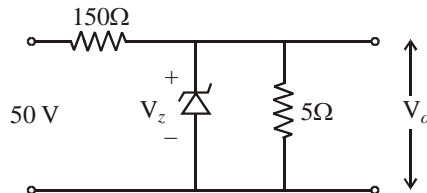
- $V_i$  is output of the filter circuit.
- Zener diode should be RB and breakdown.
- $I_{ZK}$  = KNEE current = The minimum current flowing through the zener diode when zener breakdown has just occurred.
- $I_{Zm}$  = The maximum zener current.
- $P_{Zm}$  = Maximum power dissipated in zener diode =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

- 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  $5\Omega$  resistor is replaced by  $100\Omega$  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,  $(V_o = V_Z = 15V)$

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

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

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

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

$$= 1.2 \text{ watts}$$

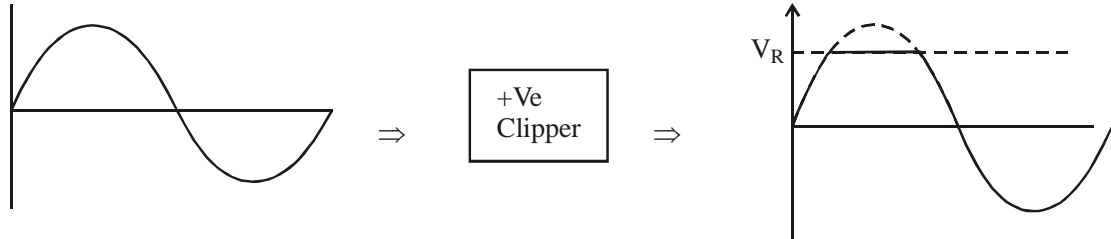
### Clipping (Limiting) Circuits

⇒ 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

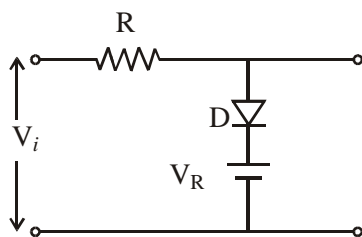


**(iii) Two Level Clipper:**



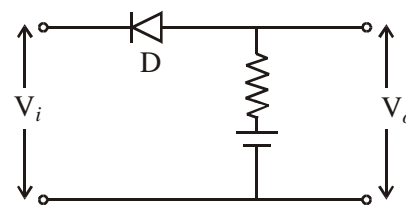
⇒ On the basis of position of diode w.r.t load

**(i) Shunt Clipper**



(Shunt +ve clipper)

**(ii) Series Clipper**

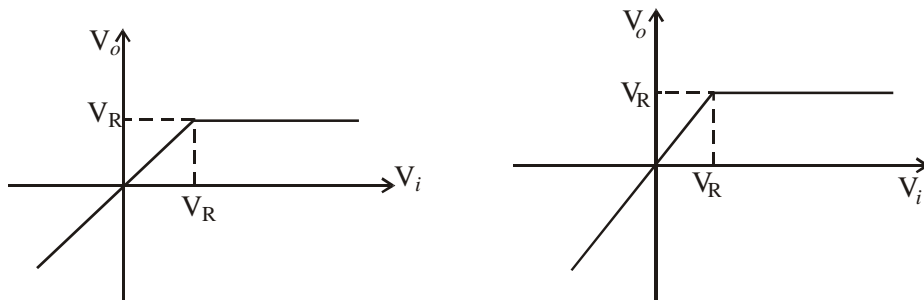


Series +ve clipper

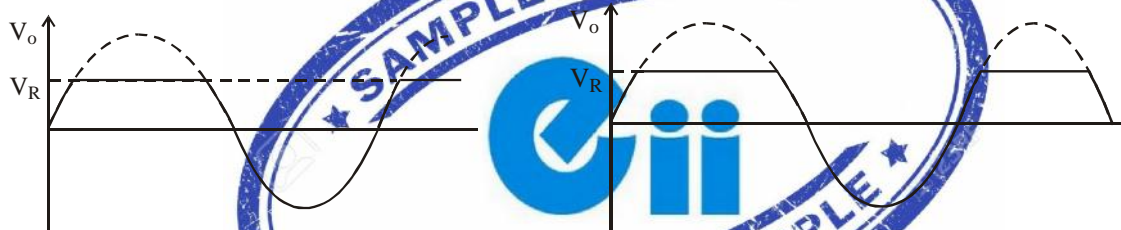
Range of $V_i$	D	$V_o$
$V_i < V_R$	OFF	$V_i$
$V_i \geq V_R$	ON	$V_R$

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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10	207735	VASU HANDA	ECE
22	005386	RAN SINGH GODARA	ECE
22	032483	PAWAN KUMAR	EE
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