SAMPLE STUDY MATERIAL

Electronics Engineering

EC/E & T

Postal Correspondence Course

GATE , IES & PSUs

Analog Electronics

CONTENT

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: $r = \dfrac{\text{RMS value of AC component}}{\text{DC value}}$

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

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

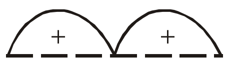
$$\left[\text{Form factor (F)} = \frac{\text{RMS value}}{\text{DC value}} = \frac{V_{rms}}{V_{dc}}\right]$$

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

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

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

3. Ripple Voltage: Ripple voltage is defined as deviation of output voltage from it's DC value



Output of rectifier $\Rightarrow$ Pulsating DC

DC value = V_{dc}

RMS value = V_{rms}

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

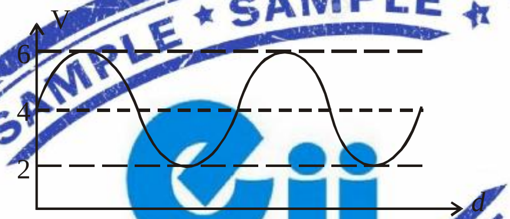
Output Rectifier

$$V = V_{DC} + V_{AC}$$

$$V_{rms} = \sqrt{(V_{DC})^2 + (V_{AC_{rms}})^2}$$

$$\Rightarrow \quad V_{AC_{rms}} = \sqrt{V_{rms}^2 - V_{DC}^2}$$

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



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

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

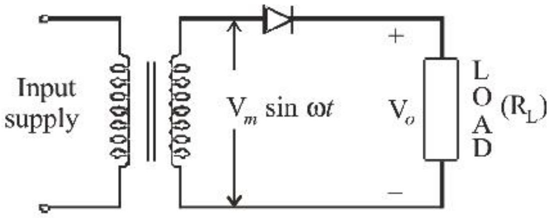
Rectifier

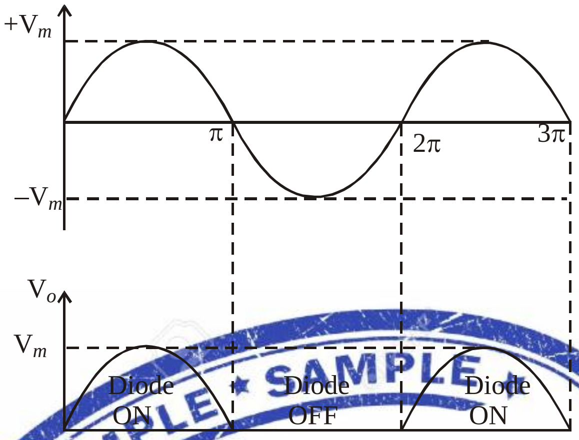
1. Half wave rectifier
2. Full wave rectifier

(*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. $V_{avg} = V_{DC}$

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

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

3. Form Factor

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

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:

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

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

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

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

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

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

7. 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

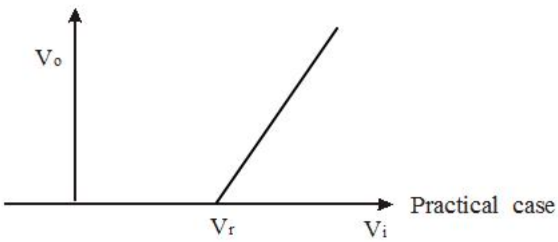
Note: Transformer is under utilized

8. PIV: Peak inverse voltage = V_m

9. Ripple Frequency: Source frequency

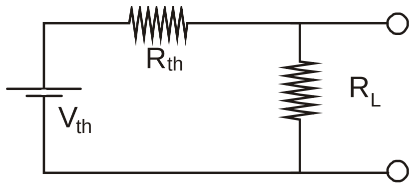
$$\boxed{f_r = r_s}$$

⇒ **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



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

$$I_L = \frac{V_m \sin \mu t - V_r}{R_S + R_F + R_L} \cong \frac{V_m \sin \mu t}{R_S + R_F + R_L}$$

$$I_{dc} = \frac{1}{2\text{®}} \int_o^{\text{®}} I_L d(\mu t) \qquad I'_m \sin \mu t \;\; where \;\; I'_m = \frac{V_m}{R_S + R_F + R_L}$$

$$I_{dc} = \frac{1}{2\text{®}} \int_o^{\text{®}} I_L d(\mu t) = \frac{1}{2\text{®}} \int_o^{\text{®}} I'_m \sin(\mu t) d(\mu t)$$

$$= \left(\frac{I'_m}{\text{®}}\right) = \frac{V_m/\text{®}}{R_S + R_F + R_L} = \left(\frac{V_{Th}}{R_{Th} + R_L}\right)$$

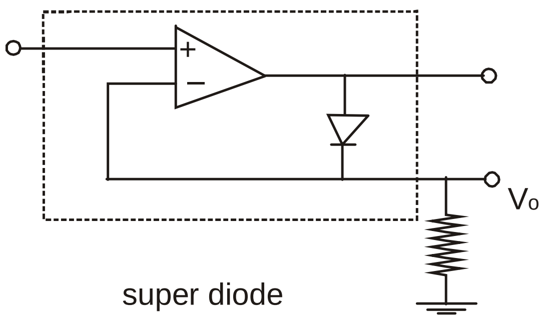
Thus $\boxed{V_{Th} = \frac{V_m}{\text{®}}}$

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

Drawbacks :

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

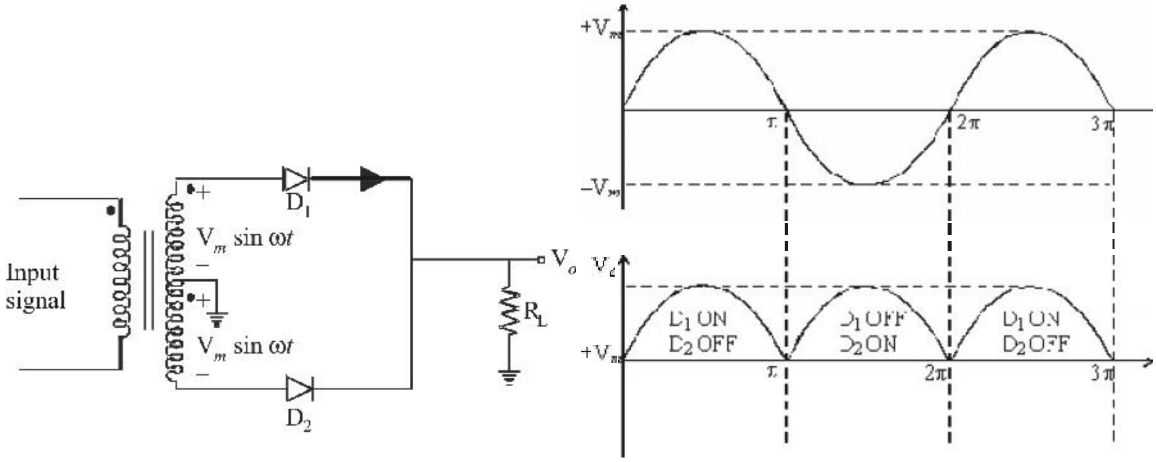
Precision Half wave rectifier :



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)

$$\boxed{f_r = 2 f_s}$$

(*i*) Average Value

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

(*ii*) RMS Value

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

(*iii*) Form Factor

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

(*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

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

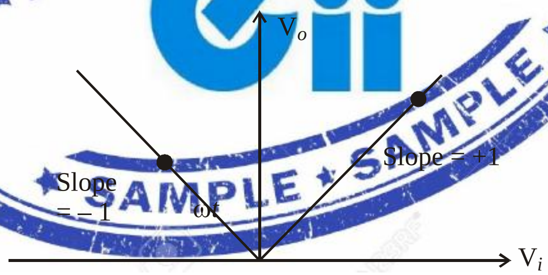
$$= \frac{8}{\pi^2} \qquad \left(I_m = \frac{V_m}{R_L}\right)$$

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

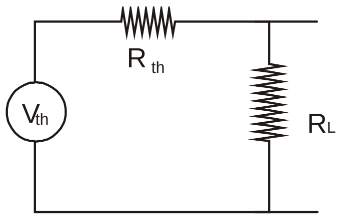
Note: In FWR case utilization of transformer takes place in both +ve and –ve half hence TUF increases.

(*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



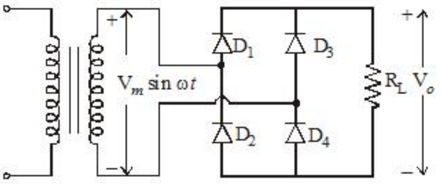
$$I_{th} = \frac{V_{th}}{R_L + R_{th}}$$

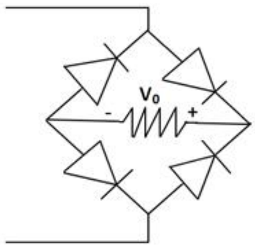
$$I_L = \frac{V_m \sin \mu t - V_r}{R_S + R_F + R_L} \cong \frac{V_m \sin \mu t}{R_S + R_F + R_L} = I_m' \sin \mu t \quad \because I_m' = \frac{V_m}{R_S + R_F + R_L}$$

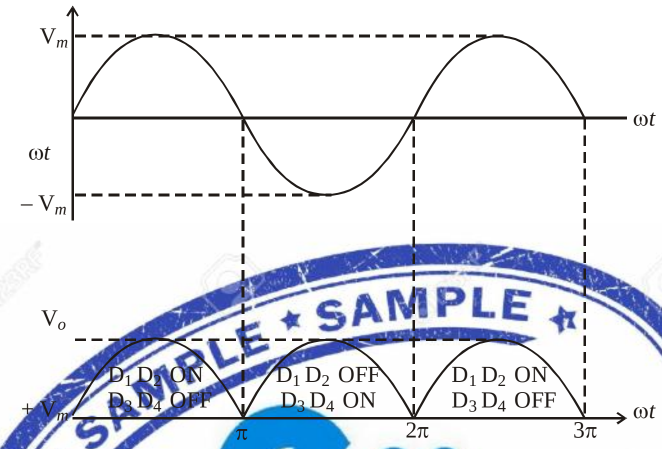
$$I_{dc} = \frac{1}{2®}\int_o^{®} I_L d(\mu t) = \frac{2I_m'}{®} = \frac{2V_m / ®}{R_S + R_F + R_L}$$

$$V_{th} = \frac{2V_m}{®}$$ $$R_{Th} = R_S + R_F$$

2. Bridge Type FWR (Using Ideal Diode):







Floating resistance may acquire stray charge from environment.

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

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

(*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 some for centre tapped and bridge type FWR hence above (*v*) quantities are same.

(*vi*) TUF: TUF = 0.812

Note: Transformer is proper 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:

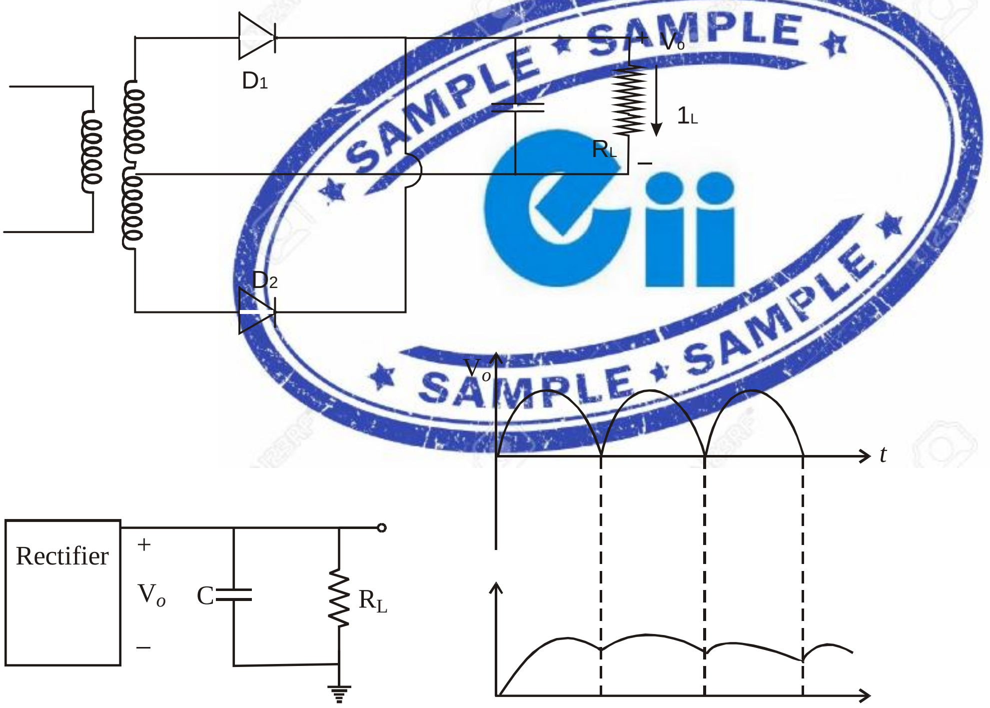
⇒ As the output of the rectifier circuit is pulsating DC containing AC and DC component filter circuits are used to suppress the AC component.

⇒ 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.

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

⇒ 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 maintence 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 $r = \dfrac{1}{2\sqrt{3}\, f\, CR_L}$

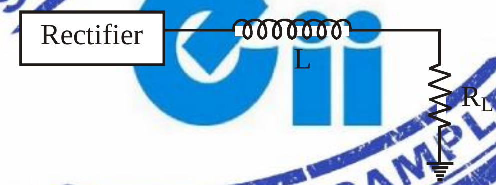
⇒ FWR with C-filter Ripple factor $r = \dfrac{1}{4\sqrt{3}\, f\, CR_L}$

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

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

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

(*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.*,

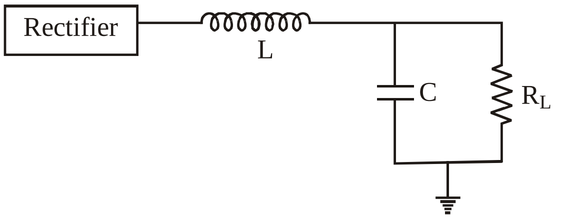
$\tau = \dfrac{L}{R_L} = CR_L$ should be high.

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

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.

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

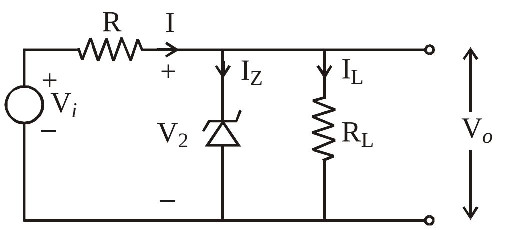
Note: (*i*) Ripple factor (*r*) is independent of R_L (*ii*) $r \propto \frac{1}{f^2}$

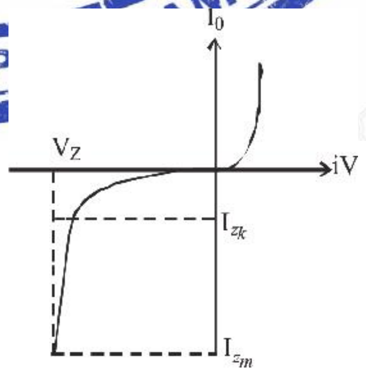
Voltage Regulator

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

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

1. Voltage Regulator Using Zener Diode:





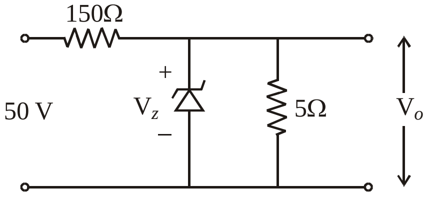
- V_i is output of the filter circuit.
- Zener diode should be RB and breakdown.
- I_{ZK} = KNEE current = The minimum current flowing through the zener diode when zener breakdown has just occurred.
- I_{Zm} = The maximum zener current.
- P_{Zm} = Maximum power dissipated in zener diode = $V_Z I_{Zm}$

- 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

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

Now $V_o > V_Z$

Hence, diode will go into breakdown mode.

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

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

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

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

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

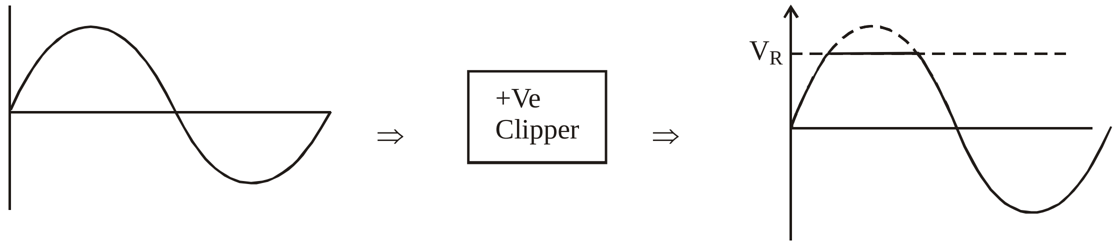
= 1.2 watts

Clipping (Limiting) Circuits

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

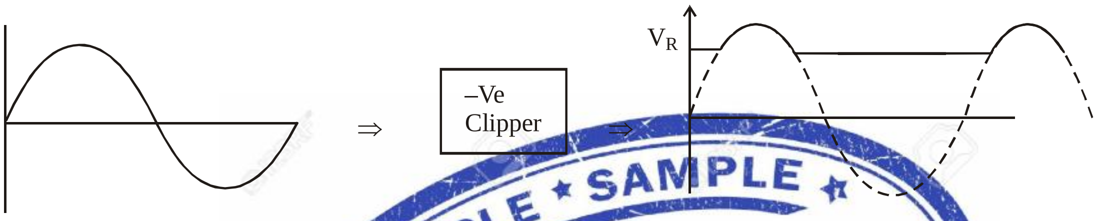
(*i*) Positive Clipper:

- Clipping above reference level.

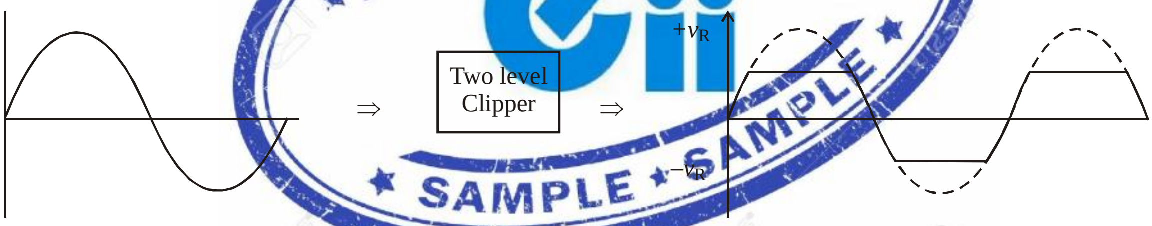


(*ii*) Negative Clipper:

- Clipping below reference level

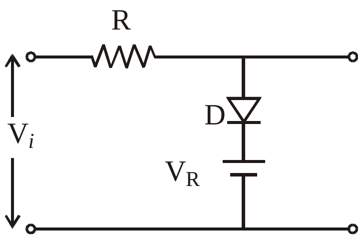


(*iii*) Two Level Clipper:



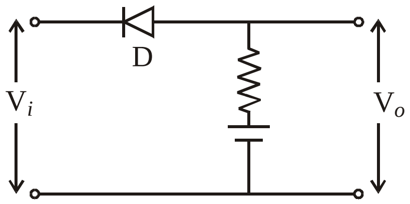
⇒ On the basis of position of diode w.r.t load

(*i*) Shunt Clipper



(Shunt +ve clipper)

(*ii*) Series Clipper

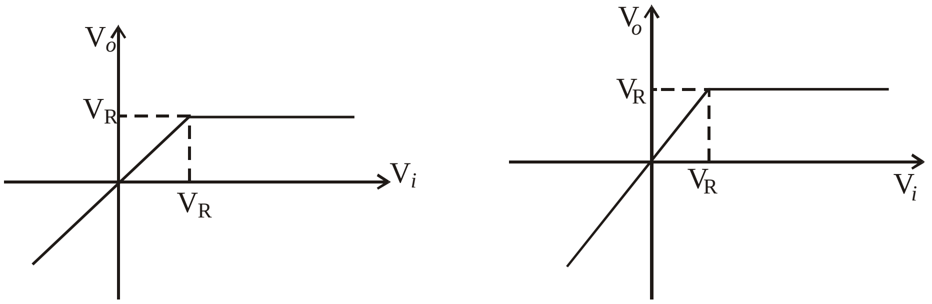


Series +ve clipper

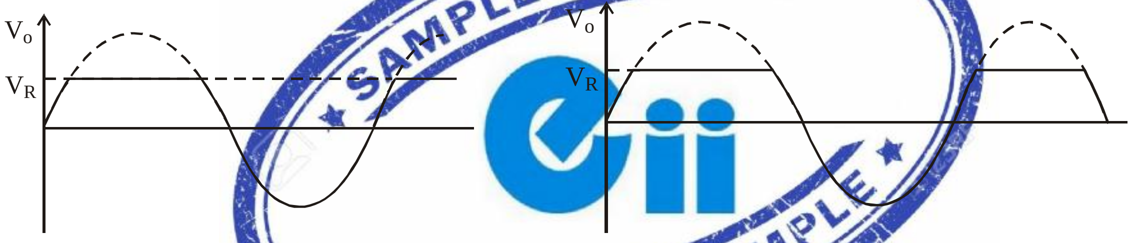
Range of V_i	D	V_o
$V_i < V_R$	OFF	V_i
$V_i \geq V_R$	ON	V_R

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

- **Transfer Curve**



õ **Wave form**



77 Final Selections in Engineering Services 2014.

Rank	Roll	Name	Branch
1	171298	SAHIL GARG	EE
3	131400	FIRDAUS KHAN	ECE
6	088542	SUNEET KUMAR TOMAR	ECE
8	024248	DEEPANSHU SINGH	EE
10	207735	VASU HANDA	ECE
22	005386	RAN SINGH GODARA	ECE
22	032483	PAWAN KUMAR	EE
29	070313	SAURABH GOYAL	EE
31	214577	PRAMOD RAWANI	EE
33	075338	DIPTI RANJAN TRIPATHY	ECE
35	003853	SHANKAR GANESH K	ECE
35	091781	KOUSHIK PAN	EE

36	052187 ANOOP A	ECE
37	008233 ARPIT SHUKLA	ECE
38	106114 MANISH GUPTA	EE
41	018349 VINAY GUPTA	ECE
44	098058 LEENA P MARKOSE	EE
45	029174 NAVNEET KUMAR KANWAT	EE

9 Rank under AIR 100 in GATE 2015 (Rank 6,8,19,28,41,56,76,91,98)

and many more............................