NARAJOLE RAJ COLLEGE

Department of Physics

SEM – IV (GE)

Paper :- GE 4 T (Digital, Analog Circuits & Instrumentation)

Topic :- Power Supply

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Introduction :-

Different applications of diode have been considered in this portion. dc power supply are essential for different electronic circuits and system like amplifier oscillators, battery chargers, radio, TV, computer, etc. Our normal electric supplies are ac, therefore, ac to dc conversion is essential. The most importants applications of diodes are in the rectifier circuits which converts the ac to unidirectional current. Half wave, full wave and bridge rectifiers have been considered along with filter circuits to reduce the ripple from the rectified output.

Half-wave rectifier :-

A rectifier is a device which changes an alternating into a direct current. A diode valve can works as an excellent rectifier. It allowers electron flow from cathode to plate when the plate is positive with respect to cathod, but not when plate is negative with respect to cathode. Thus if ac voltage is applied across the plate and the cathode current flows through the tube only during the positive half cycle. A single diode is therefore known as a 'half wave rectifier'.

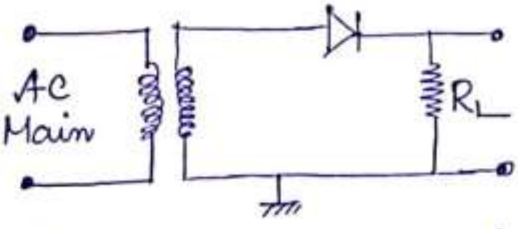


fig:- Half wave rectifier.

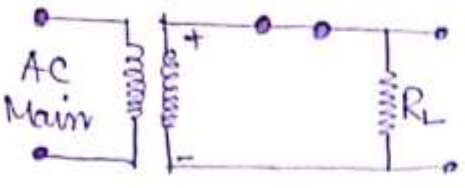


Fig: HW rectifier forward biased.

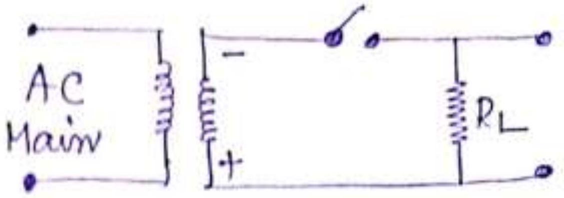
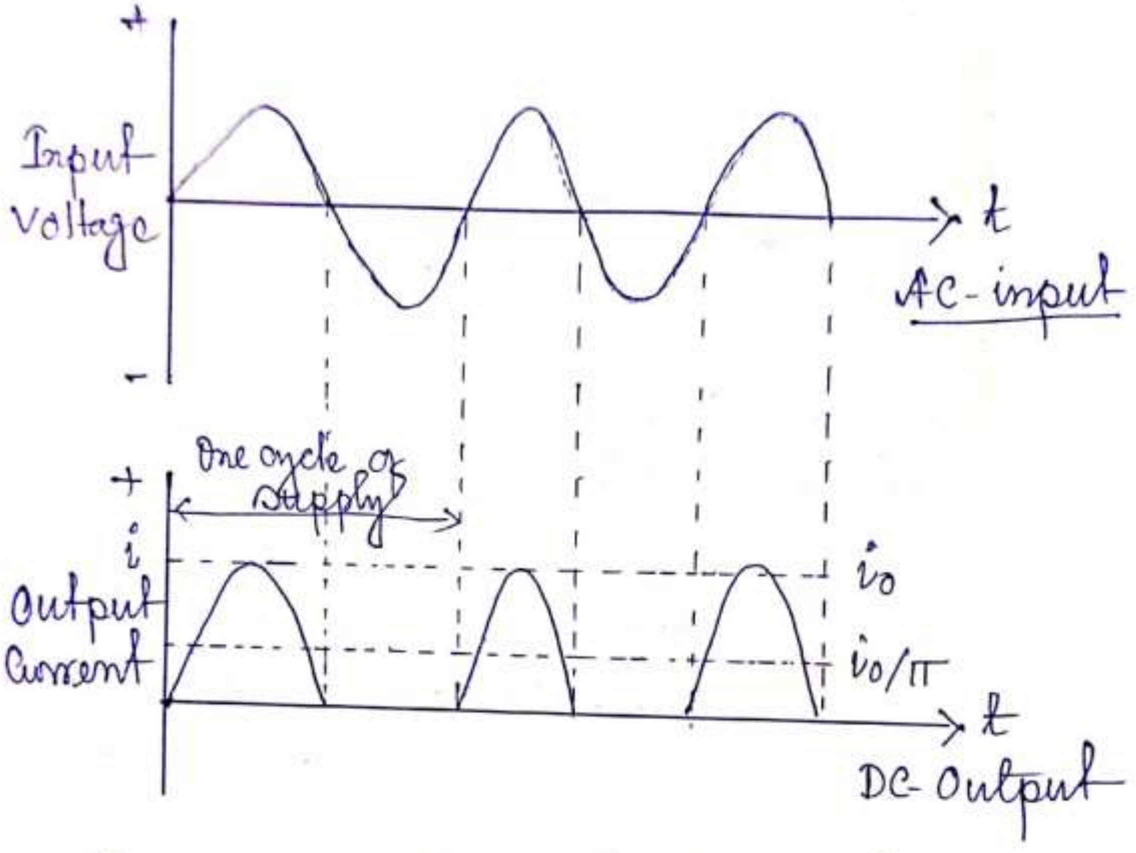


Fig: HW rectifier in reverse biased



Let r_p be the dynamic plate resistance of the diode. The load resistance is R. Let the input voltage applied to the plate of the diode rectifier is given by,

$$E = E_0 \sin \omega t$$

The instantaneous output current through the load resistance R is

$$i = \frac{E}{r_p + R} = \frac{E_0 \sin \omega t}{r_p + R} = i_0 \sin \omega t$$

Where $i_0 = \frac{E_0}{r_p + R}$ is the peak value of the current.

The dc (average) value of the output current over one complete cycle is given by—

$$i_{dc} = \frac{1}{T}\int_0^T i\,dt$$

Since, $\left\{ \begin{array}{ll} i = i_0 \sin\omega t & \text{from } t=0 \text{ to } t=T/2 \\ i = 0 & \text{from } t=T/2 \text{ to } t=T \end{array} \right\}$

$$\therefore\ i_{dc} = \frac{1}{T}\left[\int_0^{T/2} i_0 \sin\omega t\,dt + \int_{T/2}^{T} 0 . dt\right]$$

$$= \frac{1}{T}\int_0^{T/2} i_0 \sin\omega t\,dt$$

$$= \frac{\omega}{2\pi}\int_0^{\pi/\omega} i_0 \sin\omega t\,dt$$

$$= \frac{\omega}{2\pi}\cdot\frac{i_0}{\omega}\left[-\cos\omega t\right]_0^{\pi/\omega}$$

$$= \frac{i_0}{2\pi}\left[-\cos\pi + \cos 0\right] = \frac{i_0}{2\pi}(1+1) = \frac{i_0}{\pi}$$

$$\therefore\ E_{dc} = i_{dc}\times R = \frac{i_0 R}{\pi}$$

But $i_0 = \dfrac{E_0}{r_p+R}$ $\quad\therefore\ E_{dc} = \dfrac{E_0 R}{\pi(r_p+R)}$

Rectifier Efficiency :-

The dc power output across the load R is given by,

$$P_{dc} = i_{dc}^2 R = \frac{i_0^2 R}{\pi^2} \quad \left[\because i_{dc} = \frac{i_0}{\pi}\right]$$

$$\therefore\ P_{ac} = i_{rms}^2 (r_p+R)$$

$$= \frac{i_0^2}{4}(r_p+R) \quad \left[\because i_{rms} = \frac{i_0}{2}\right]$$

$\therefore$ Efficiency $\eta = \frac{P_{dc}\text{ (output)}}{P_{ac}\text{ (input)}} \times 100$

$$\Rightarrow \eta = \frac{i_0^2 R/\pi^2}{i_0^2 (r_p+R)/4} \times 100 = \frac{4R}{\pi^2 (r_p+R)} \times 100$$

$$\Rightarrow \eta = \frac{400}{\pi^2} \cdot \frac{1}{(1+r_p/R)} = \frac{40.5}{1+r_p/R}$$

Thus smaller the ratio r_p/R, the higher the efficiency of the rectifier. The maximum efficiency would be when $r_p/R = 0$ and equal to 40.5%.

Ripple Factor :—

The ripple factor r is defined as.

$$r = \frac{\text{rms value of the ac components of the output}}{\text{dc value of the output}}$$

$$= \frac{i_{ac}}{i_{dc}} = \frac{\sqrt{(i_{rms}^2 - i_{dc}^2)}}{i_{dc}}$$

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

For an HW rectifier, $i_{rms} = \frac{i_0}{2}$ and $i_{dc} = \frac{i_0}{\pi}$

$$\therefore \frac{i_{rms}}{i_{dc}} = \frac{\pi}{2}$$

$$\therefore r = \sqrt{\left(\frac{\pi^2}{4} - 1\right)} = 1.21$$

The ripple factor being greater than 1 means that the ac component of the output exceeds the d.c value.

Full-wave diode rectifier :-

A full wave rectifier makes use of a double diode valve and gives an output current which is unidirectional as well as continuous.

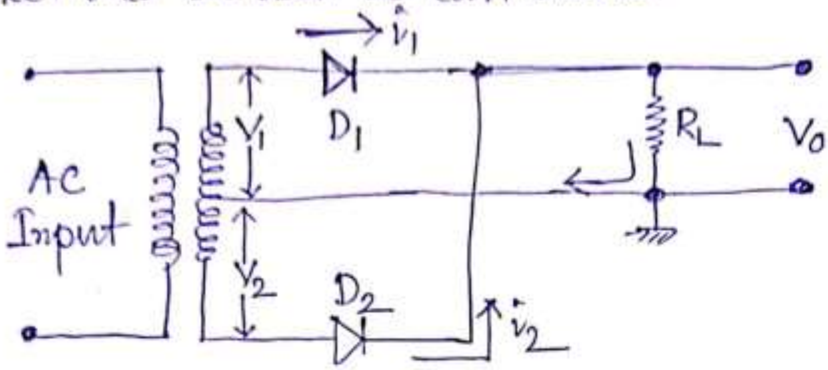
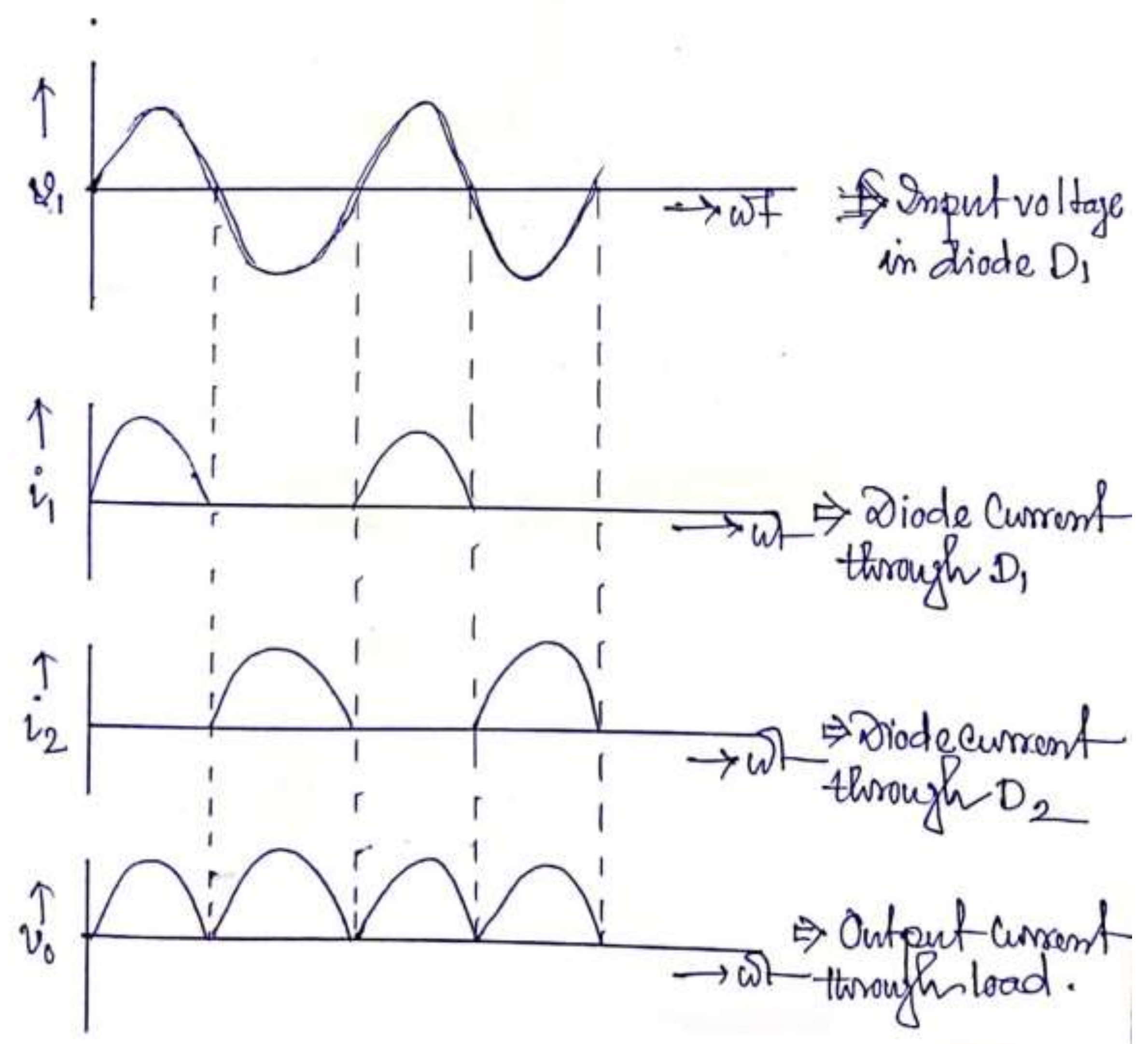


fig : Full wave rectifier.



Let the input voltage applied each plate of the double diode is given by,

$$E = E_0 \sin \omega t$$

If r_p is the dynamic plate resistance of the diode, then the instantaneous output current through the load resistance R is, $i = \frac{E}{r_p + R} = \frac{E_0 \sin \omega t}{r_p + R}$

$$= i_0 \sin \omega t.$$

Where $i_0 = \frac{E_0}{r_p + R}$ is the peak value of current.

$$\therefore \; i_{dc} = \frac{1}{T}\int_0^T i\,dt$$

$$\left\{ \begin{array}{ll} i = i_0 \sin \omega t & \text{from } t = 0 \text{ to } t = T/2 \\ i = -i_0 \sin \omega t & \text{from } t = T/2 \text{ to } t = T \end{array} \right\}$$

$$i_{dc} = \frac{1}{T}\left[\int_0^{T/2} i_0 \sin \omega t\,dt - \int_{T/2}^{T} i_0 \sin \omega t\,dt\right]$$

$$= \frac{\omega}{2\pi} \cdot \frac{i_0}{\omega}\left[\left| -\cos \omega t \right|_0^{\pi/\omega} - \left| -\cos \omega t \right|_{\pi/\omega}^{2\pi/\omega} \right]$$

$$= \frac{i_0}{2\pi}\left[(-\cos \pi + \cos 0) - (-\cos 2\pi + \cos \pi)\right]$$

$$= \frac{i_0}{2\pi}\left[(1+1) - (-1-1)\right]$$

$$i_{dc} = \frac{2 i_0}{\pi}, \quad E_{dc} = i_{dc} \times R = \frac{2 i_0 R}{\pi}$$

$$\therefore \; E_{dc} = \frac{2 E_0 R}{\pi (r_p + R)} \qquad \text{But, } i_0 = \frac{E_0}{r_p + R}$$

⊘ Rectifier Efficiency :-

$$P_{dc} = i_{dc}^2 \cdot R = \frac{4 i_0^2 R}{\pi^2} \quad \left[\because i_{dc} = \frac{2 i_0}{\pi}\right]$$

$$P_{ac} = i_{rms}^2 (r_p + R)$$
$$= \frac{i_0^2}{2} (r_p + R) \quad \left[\because i_{rms} = \frac{i_0}{\sqrt{2}}\right]$$

$$\therefore \eta = \frac{P_{dc}\,(\text{output})}{P_{ac}\,(\text{input})} \times 100 = \frac{4 i_0^2 R/\pi^2}{i_0^2 (r_p+R)/2} \times 100$$

$$= \frac{8R}{\pi^2 (r_p + R)} \times 100 = \frac{800}{\pi^2} \left(\frac{1}{1 + r_p/R}\right)$$

$$= \frac{81}{1 + r_p/R}$$

It is maximum when $\frac{r_p}{R} = 0$ and equal to 81%.

⊘ Ripple factor of Full wave Rectifier :-

The ripple factor r is defined as,

$$r = \frac{i_{ac}}{i_{dc}} = \frac{\sqrt{(i_{rms}^2 - i_{dc}^2)}}{i_{dc}} = \sqrt{\left[\left(\frac{i_{rms}}{i_{dc}}\right)^2 - 1\right]}$$

For a full wave rectifier, we have,

$$i_{rms} = \frac{i_0}{\sqrt{2}} \text{ and } i_{dc} = \frac{2 i_0}{\pi}$$

$$\therefore \frac{i_{rms}}{i_{dc}} = \frac{i_0/\sqrt{2}}{2 i_0/\pi} = \pi/2\sqrt{2}$$

$$\therefore r = \sqrt{\left(\frac{\pi^2}{8} - 1\right)} = 0.482 \ (\text{or } 48.2\%)$$

Thus the ripple factor of a full wave rectifier is much less than that of a HW rectifier.

Filter :-

Rectified output from HW rectifier and F-W rectifier contains large ripples. So a filter circuit is necessary to smoothing the rectifier output. Simple Capacitor filter, inductor filter and Combination of capacitor and inductor filter action such as LC filter and π-section filter have been considered in this section.

Capacitor filter :-

Smoothing of the output voltage may be affected by shunting the load with suitable capacitor. Actually, the shunt capacitor are most satisfactory simple filter circuit. It bypass the ac components as its reactance is much lower in comparison with the load. In this circuit the capacitor stores charges during the conduction period and during the non-conducting period it delivers the same to the load resistance so it decreases the ripple in the output.

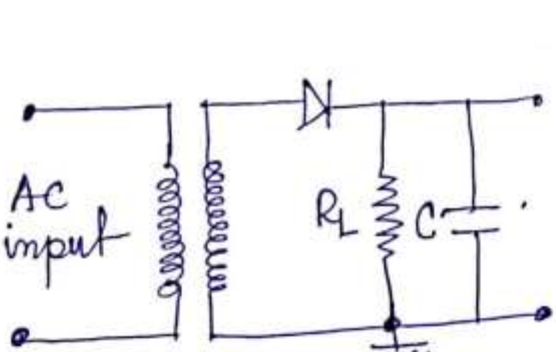


Fig: Capacitor filter applied to HW rectifier

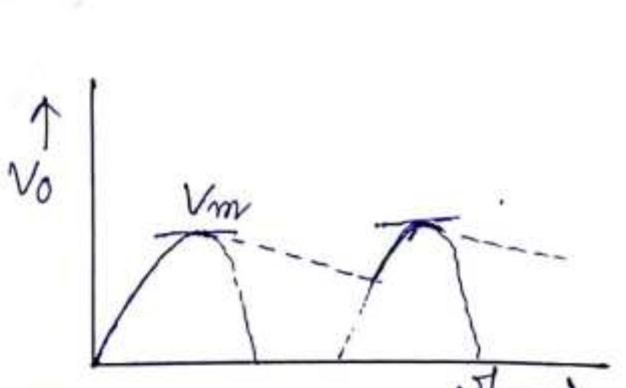


Fig: Response of the circuit.

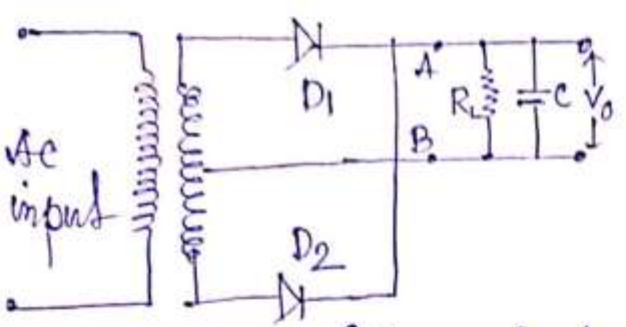


Fig:- Capacitor filter applied to full wave rectifier

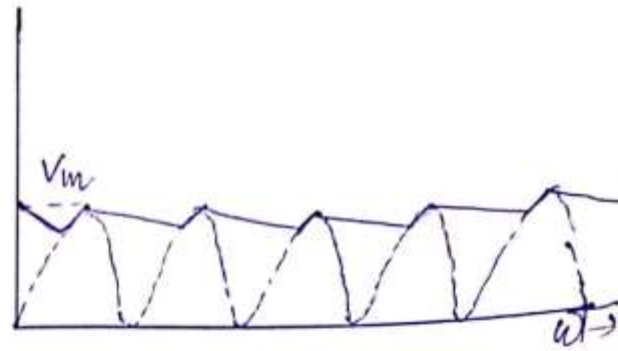


Fig:- Approximate load voltage wave from a full wave rectifier with capacitor filter

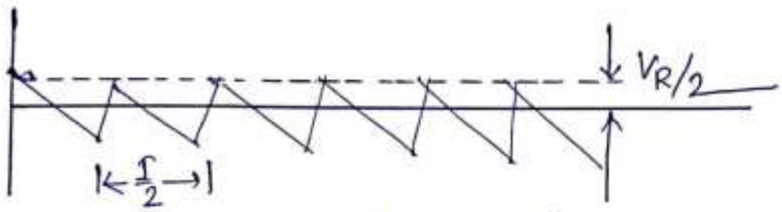


Fig:- Triangular ripple wave from.

Zener diode and Voltage Regulation :-

Rectifier diodes are not used in the break down region because it may damage these diodes. A Zener diode is a specially designed silicon p-n junction for operating in the reverse breakdown region of the V-I Characteristics. Generally it is a junction between heavily doped p-type with heavily doped n-type ($p^+ - n^+$ junction) silicon. The circuit symbol of zener diode has been shown in figure. Zener diodes are essential elements for voltage regulator circuit for production of reference voltage.

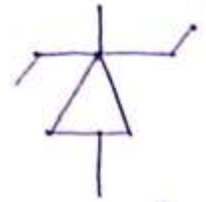


Fig :- Circuit symbol of Zener diode.

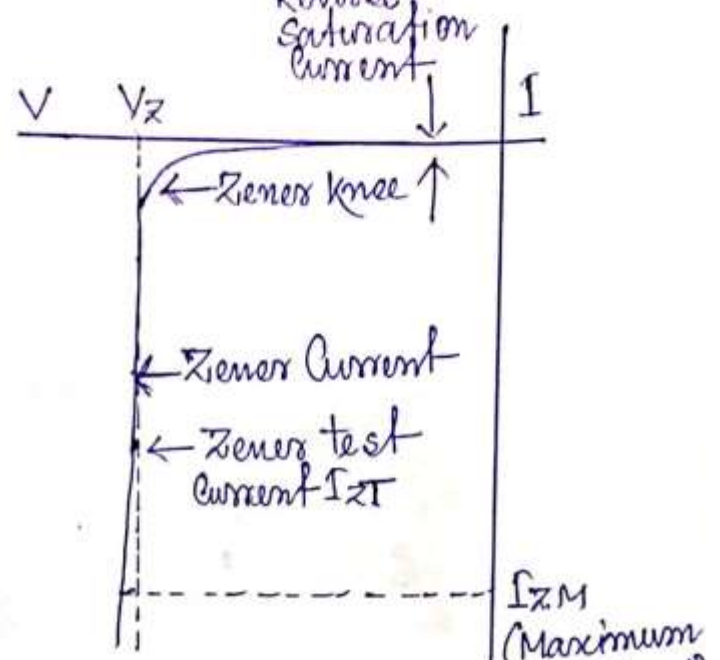


Fig : Zener characteristics.

The resistance of the zener diode is equal to the inverse slope of the characteristic curve. Thus more vertical is the characteristics, smaller the zener resistance. The zener resistance R_Z is given by.

$$R_Z = \Delta V_Z / \Delta I_Z$$

The power dissipation rate is given by,

$$P_D = V_Z . I_Z$$

Therefore maximum power dissipation rate is given by.

$$P_{Dmax} = V_Z I_{ZM}$$

So from Zener diode voltage regulator fig. it is clear that total current I from the unregulated supply is sum of Zener current I_Z and load current I_L, i.e $I = I_Z + I_L$

If I_Z is within the breakdown region of the zener then the voltage across zener diode or load can be taken as V_Z

Therefore $I_L = \frac{V_Z}{R_L}$

So we can finds that, $I = I_Z + \frac{V_Z}{R_L}$

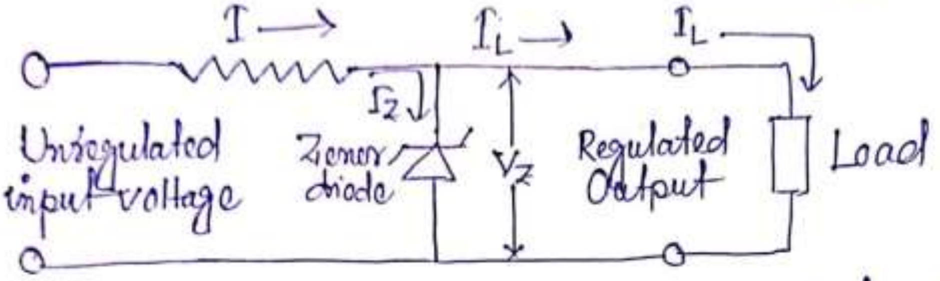


Fig :- Zener diode voltage regulator circuit.

From the above mentioned discussion it is clear that the limit of maximum current in a simple zener diode regulator is small, for larger current limit elements with current gain is essential. Actually the zener diode produces reference voltage in a voltage regulator circuit.

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