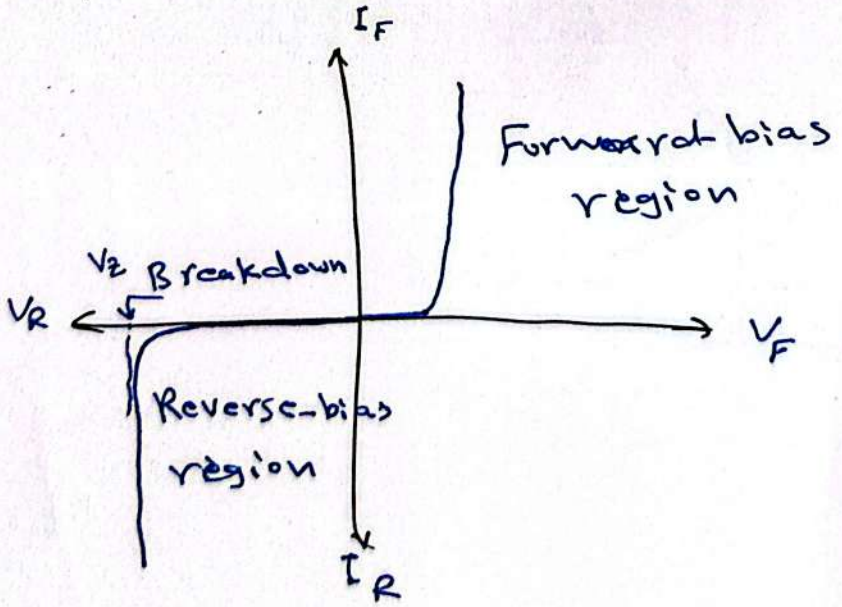
3-1 Zener Diods:-

The zener diode is used for voltage regulation and, like the rectifier diode, is important in many power-supply applications. The schematic symbol is shown in Figure below.

Zener diode symbol.

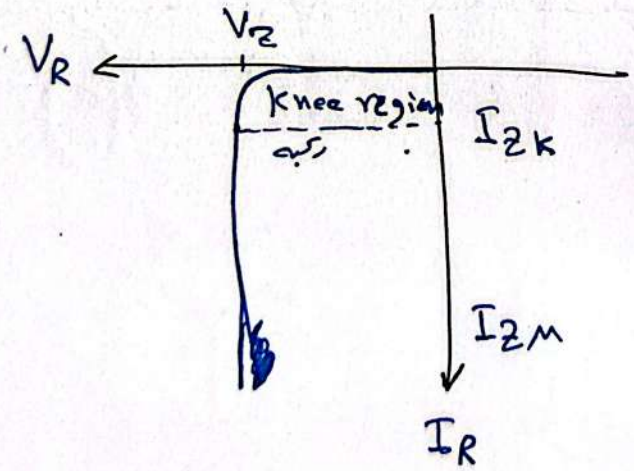
The zener is a silican pn junction divice that differs from the rectifier diode in that it is optimized for operation in the revers breakdown rigion. The breakdown voltage of a zener diode is set by carefully controlling the doping level during manufacture. This volt-ampere characteristic is



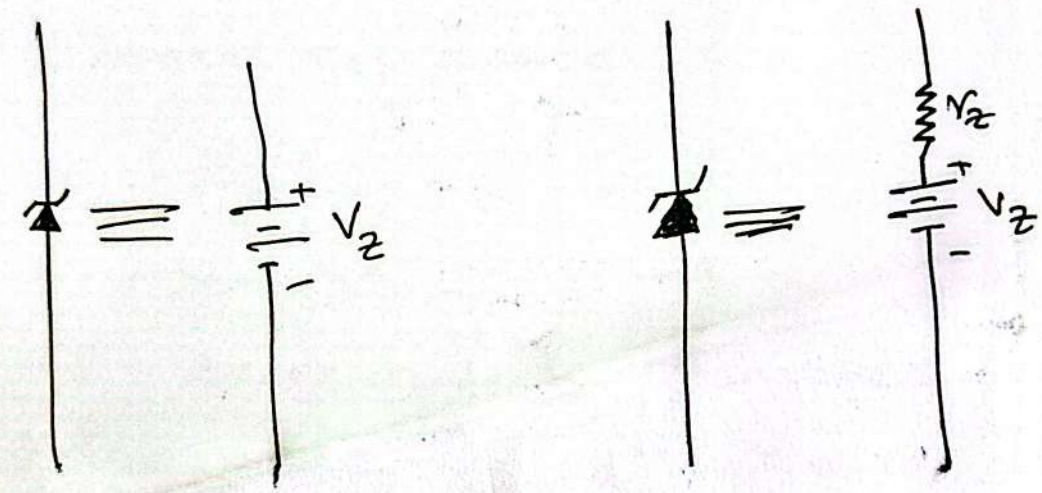
Zener Breakdown:-

The breakdown voltage (V_Z). Zener diodes with breakdown voltage of less Than approximately 5V operate predominatly in zerer breakdown. Those with breakdown voltage greater Than approximately 5 V operate perdominately in avalanche breakdwon. Both types, however, are called Zener diods. Zeners are Commercially availabe withe breakdown voltages of 1.8V to 200V.

- Breakdown Characterisfics

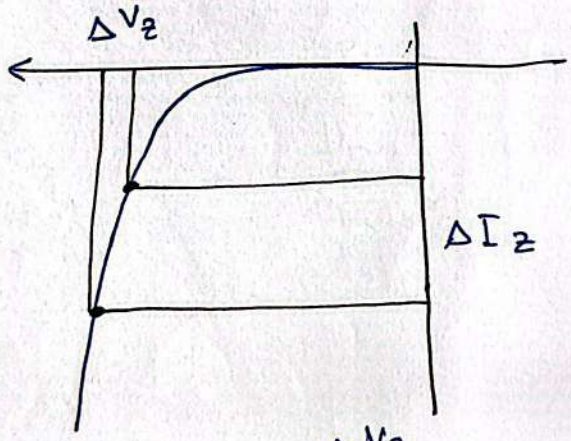


= Zener Equivalent Circuit



A. Ideal

B. practical



C. $r_z = \frac{\Delta V_z}{\Delta I_z}$

fig: Zener equivalent circuit.

The resistance of Zener

$$r_z = \frac{\Delta V_z}{\Delta I_z}$$

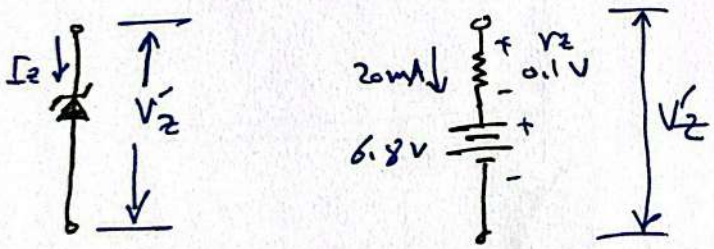
Ex 1) A certain diode exhibits a 50 mV change in V_Z for 2 mA change in I_Z. what is the zener resistance

Soln

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z} = \frac{50\,mV}{2\,mA} = 25\,\Omega$$

Ex 2) A 6.8 V zener diode has resistance of 5 Ω what is the actual voltage across its terminals when the current is 20 mA?

Soln



$$V_Z' = V_Z + I_Z r_Z$$

$$= 6.8\,V + (20\,mA)(5\,\Omega)$$

$$= 6.8\,V + 100\,mV$$

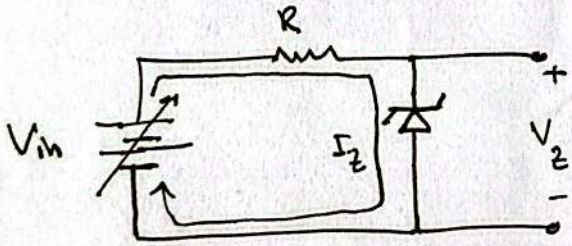
$$= 6.9\,V$$

-Zener voltage Regulation

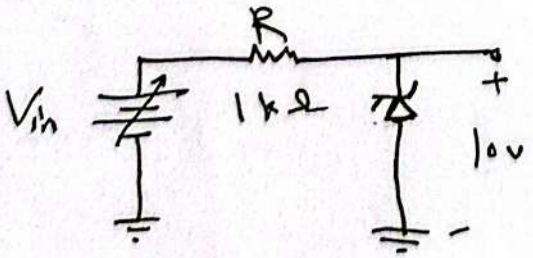
1- Regulation with a Varying Input voltage

Zener diodes are widely used for voltage regulation. Figure below shows how a Zener diode can be used to regulate a varying dc voltage. This is called input or line regulation.

However, as V_{in} changes, I_Z will change proportionally so That The limitations on the input variation are set The minimum and maximum current values with which The Zener can operat. R is the series current-limiting resistor.



ex1) Suppose That The Zener diode in figure below can maintain regulation over a range of current values from 4mA to 40mA.



Sol) for minimum current

$V_R = (4mA)(1k\Omega) = 4V$

since $V_R = V_{in} - V_Z \Rightarrow V_{in} = V_R + V_Z$

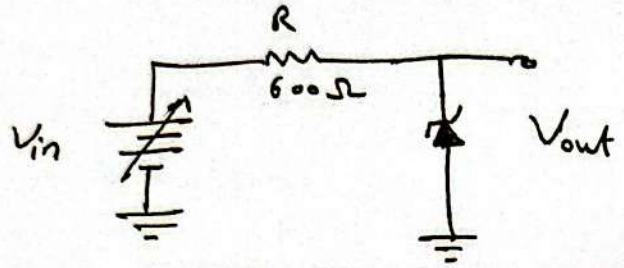
$\therefore V_{in} = 4V + 10V = 14V$

for The maximum current

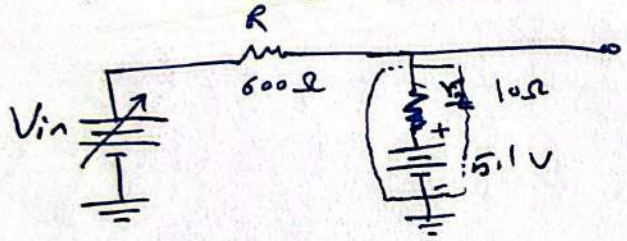
$V_R = (40mA)(1k\Omega) = 40V$

$V_{in} = 40V + 10V = 50V$

ex) Determin the minimum and the maximum input voltages which can be regulated by the Zener diode.
Assume $I_{zk} = 1\,mA$, $I_{zm} = 15\,mA$, $V_z = 5.1\,V$ and $r_z = 10\Omega$



Solution:- The equivalent circuit is.



At $I_{zk} = 1\,mA$

$$V_{out} = V_z + I_{zk} r_z$$
$$= 5.1\,V + (1\,mA)(10\Omega)$$
$$= 5.11\,V$$

There for $V_{in(min)} = I_{zk} R + V_{out}$

$$V_{in(min)} = (1\,mA)(600\Omega) + 5.11\,V$$
$$= 5.71\,V$$

At $I_{zm} = 15\,mA$, The output voltage is

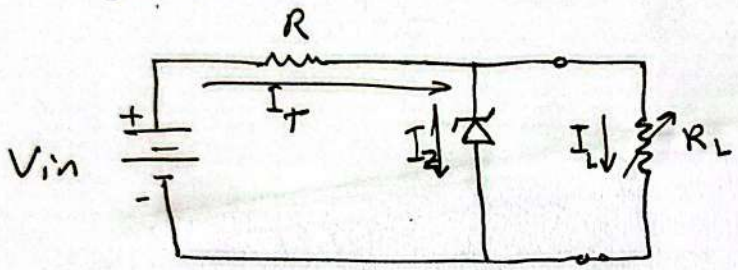
$$V_{out} = V_z + I_{zm} r_z$$
$$= 5.1\,V + (15\,mA)(10\Omega)$$
$$= 5.1\,V + 0.15\,V$$
$$= 5.25\,V$$

Therefor

$$V_{in(max)} = I_{zm} R + V_{out}$$
$$= (15\,mA)(600\Omega) + 5.25\,V$$
$$= 14.25\,V$$

2- Regulation with a varying load

The zener diode maintains a constant voltage across R_L as long as the zener current is greater than I_{zk} and less than I_{zm}. This is called load regulation.



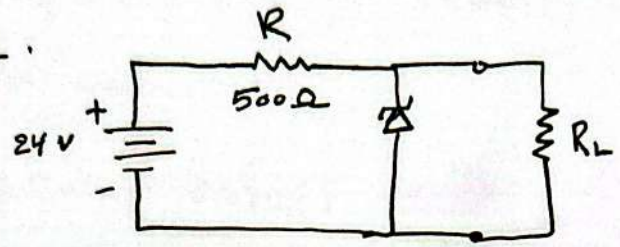
Zener regulation with avariable Load.

3- No load to full load

* when the output terminals are open ($R_L = \infty$), the load current is zero and all of the current is through the zener. when a load resistor is connected, part of the total current is through the zener and part through R_L.

* As R_L is decreased, I_L goes up and I_Z goes down. The zener diode continues to regulate until I_Z reaches its minimum value, I_{zk}. At this point the load current is maximum.

Example: Determin The minimum and The maximum load currents for which The zener diode will maintion regulation. what is The minimum R_L That can be used? $V_Z = 12\,V$, $I_{ZK} = 3\,mA$, and $I_{ZM} = 90\,mA$ Assume $r_Z = 0\,\Omega$.



solution:-

when $I_L = 0\,A$, I_Z is maximum and equal to The total ~~current~~ circuit current I_T.

$$I_Z = \frac{V_{in} - V_Z}{R} = \frac{24\,V - 12\,V}{500\,\Omega} = 24\,mA = I_T$$

Since This is much less than I_{ZM}, 0 A is an acceptale minimum for I_L

$$I_{L(min)} = 0\,A$$

The max. Value of I_L occurs when I_Z is minimum, Sowe can solve for $I_{L(max)}$ as follows:

$$I_{L(max)} = I_T - I_{Z(min)}$$

$$= 24\,mA - 3\,mA = 21\,mA$$

The minimum value of R_L is

$$R_L = \frac{V_Z}{I_{L(max)}} = \frac{12\,V}{21\,mA} = 571\,\Omega$$