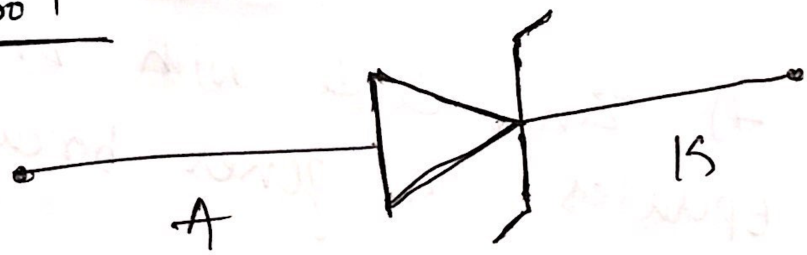
Zener Diode

The zener diode is a silicon pn junction device that is designed to operate in the reverse-breakdown region. the breakdown voltage of a zener diode is set by the doping level during manufacturing.

Symbol



Operation :→

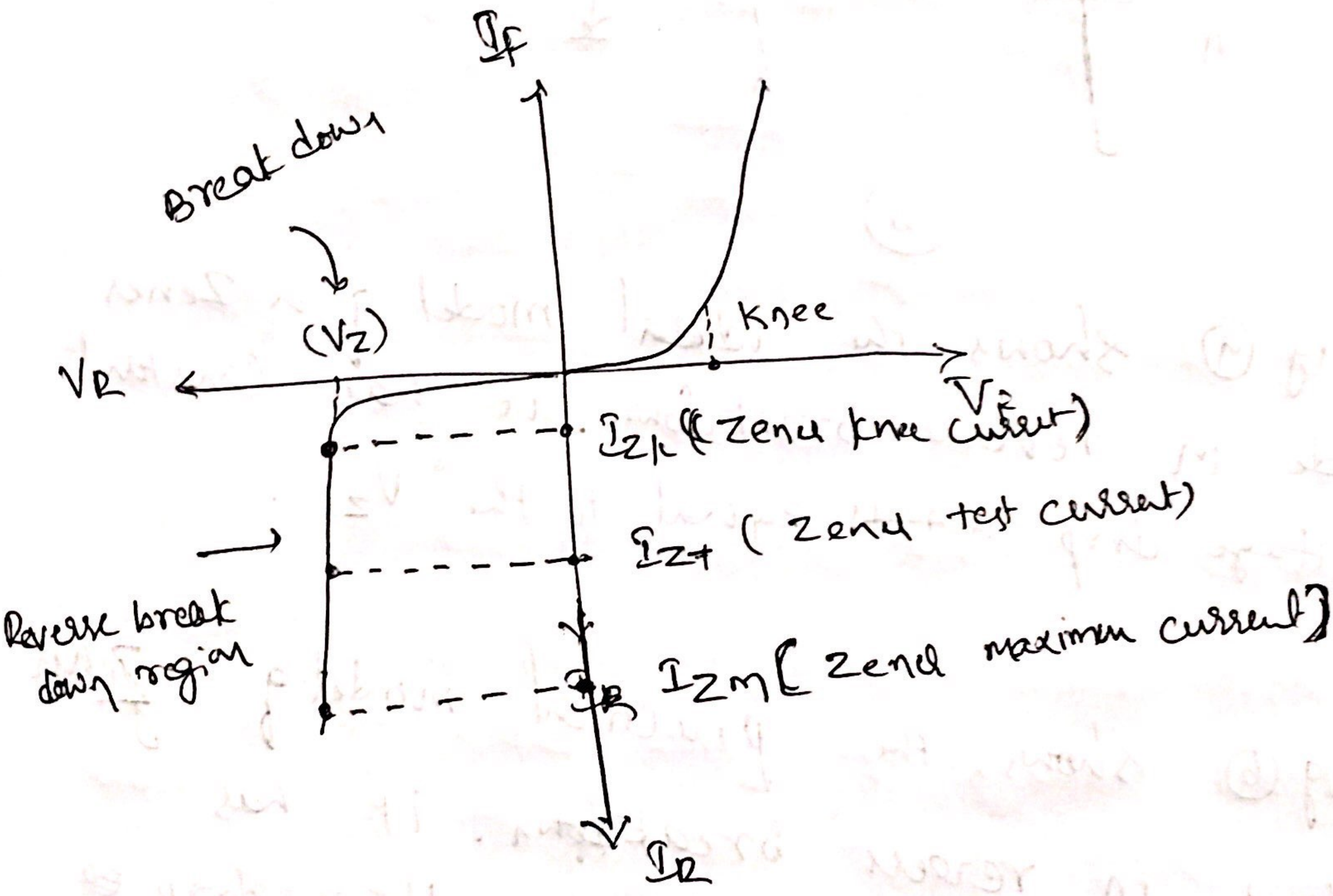
In forward bias the zener diode operates same as normal diode. In reverse bias a small current flows thro' the diode & is called reverse saturation current. at a certain Reverse voltage the reverse breakdown occurs & current through the zener diode increases rapidly that voltage is called zener voltage [V_Z]

Zener Breakdown :-

Zener diodes are designed to operate in reverse breakdown. Two types of breakdown in zener diode are zener & avalanche breakdown. where zener breakdown occurs in zener diode at low reverse voltages. a zener diode is heavilly dopped to reduce the breakdown voltage. this causes a very thin depletion region. as a result, an intense electric field exist with in the depletion region. near the zener breakdown voltage (V_Z) the field ~~field~~ is intense enough to pull the electron from their valatence band & creats current.

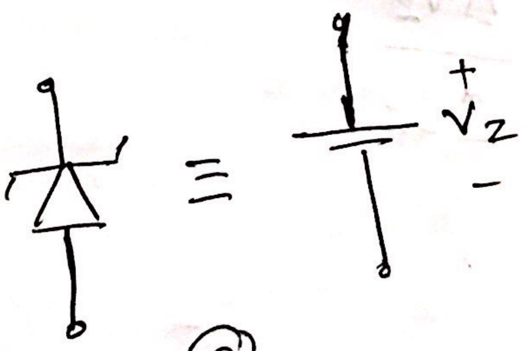
A Zener diode with breakdown. less the 5v operates in zener breakdown Those with breakdown voltage greater than 5V operates in avalanche breakdown.

The V-I characteristics of Zener Diode is as shown bellow.

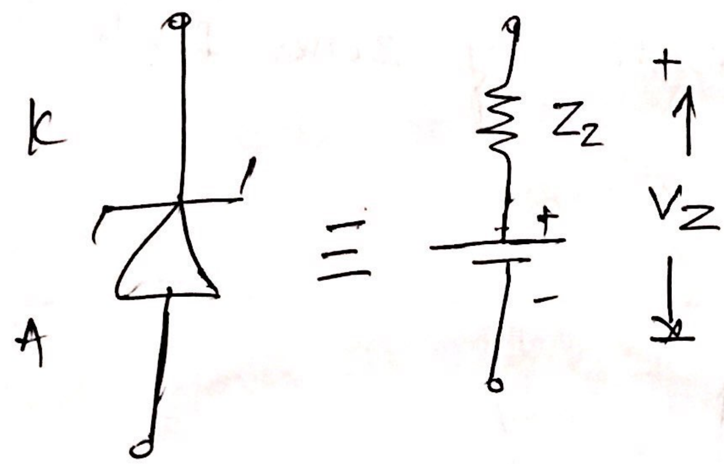


Zener equivalent circuit

Ideal



(ii) practical

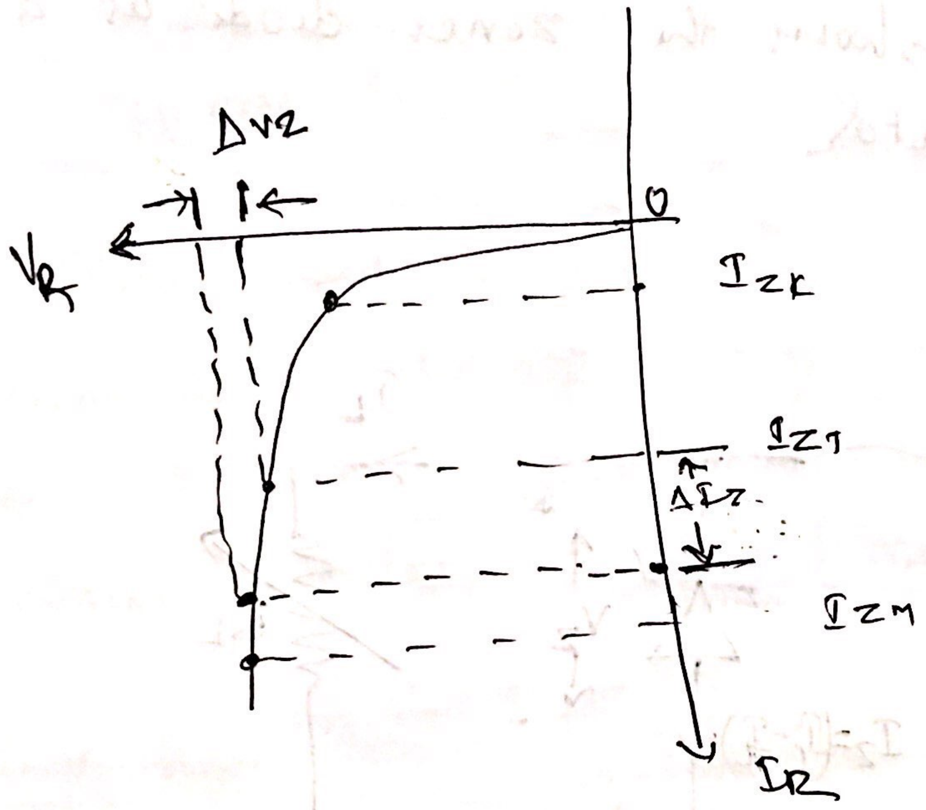


(b)

Fig (a) shows the ideal model of a Zener diode in reverse breakdown. it has constant voltage drop ~~across~~ equal to the "V_Z".

Fig (b) shows the practical model of a Zener diode in reverse breakdown. it has Zener impedance & constant voltage drop

$$Z_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

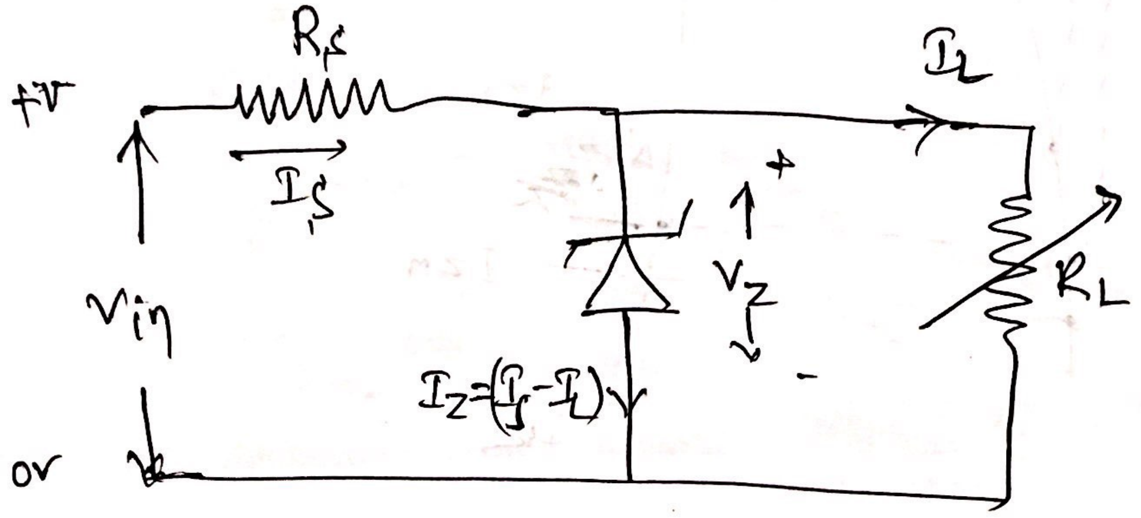


Zener Diode as Voltage Regulator

The zener Diode can be used as a type of voltage regulator for providing a stable referance voltage.

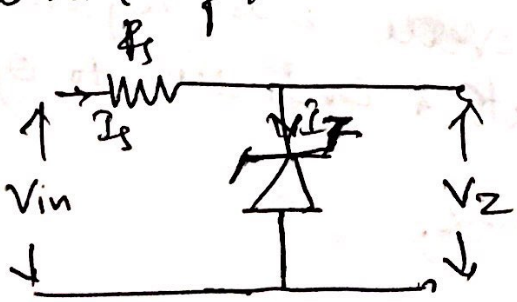
Voltage regulators are the device used to maintain a Constant voltage across the load despite of fluctuation in the input voltage and load current. The zener diode int its reverse bias region is widly used as a voltage regulator & continues to operate as with I_{Zmin} & I_{Zmax}.

The figure shows the zener diode as a voltage regulator



Case - 1 :- when no load is connected ($I_L = 0$)

The current flowing in the circuit entirely passes through the zener diode. the diode dissipates maximum power. Thus utmost care must be taken while selecting the series resistance so as to maintain the power dissipation with in the range of maximum power dissipating capability of the diode.

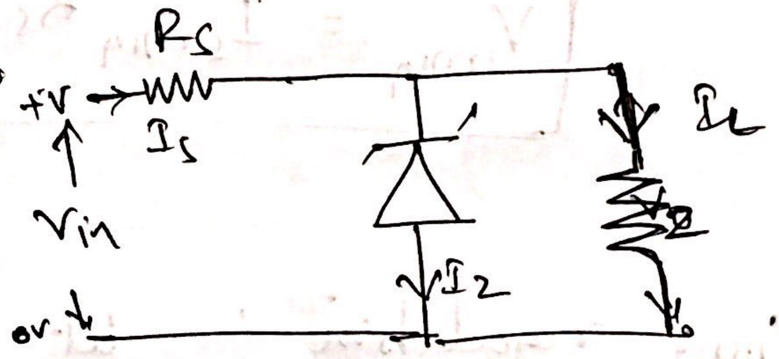


$$I_Z = \frac{V_{in} - V_Z}{R_S}.$$

case – II :- when load resistance R_L is connected across the diode.

Since load is connected in parallel with zener diode, the o/p voltage will be equal to V_Z. the zener current must alway be above $I_{Z(min)}$ & bellow $I_{Z(max)}$ [Max. power rating]

~~Line Regulation~~ :→



$$\boxed{I_S = \frac{V_{in} - V_Z}{R_S}} = I_Z + I_L$$

$$\boxed{I_S = I_Z + I_L}$$

Line regulation :→ In this case series resistance (R_s) & R_L load resistance are kept constant. & all the variation arises due to the input voltage fluctuation.

$$\boxed{V_{imax} = I_{smax} R_s + V_Z}$$

$$\boxed{V_{imin} = I_{smin} R_s + V_Z}$$

Load regulation :- Let V_{in} is kept constant & load resistance R_L is varied, the variation of R_L changes the current I_L through it.

When load resistance R_L increases the load current I_L decreases, this causes increase in the zener current (I_Z) as result the voltage across the diode remains constant

$$R_{Lmax} = \frac{V_Z}{I_{Lmin}} = \frac{V_Z}{I_s - I_Z(max)}$$

$$I_{L(min)} = \frac{V_{\cancel{out}}}{R_L} = \frac{V_Z}{R_{L(max)}}.$$

when load resistance(R_L) decreases the load current increases. this causes zener current (I_Z) to decrease. As a result voltage across zener diode is maintained constant.

$$\boxed{R_{L(min)} = \frac{V_Z}{I_{L(max)}} = \frac{V_Z}{I_S - I_{Z(min)}}}.$$

$$\boxed{I_{L(max)} = \frac{V_Z}{R_{L(min)}}}$$

Related formulas

$$I_{Z(min)} = I_S - I_{L(max)} = \frac{V_{imin} - V_Z}{R_S} - I_{L(max)}$$

$$I_{Z(max)} = I_S - I_{L(min)} = \frac{V_{in(max)} - V_Z}{R_S} - I_{L(min)}.$$

$$R_{S(min)} = \frac{V_i - V_Z}{I} = \quad V_{in\,mi}$$

$$\boxed{R_{S(min)} = \frac{V_{i(min)} - V_Z}{I_{Zmax} + I_{L\,min}}}$$

$$R_{S(max)} = \frac{V_i - V_Z}{I}$$

$$\boxed{R_{S(max)} = \frac{V_{i(max)} - V_Z}{I_{Z(min)} + I_{L(max)}}.}$$