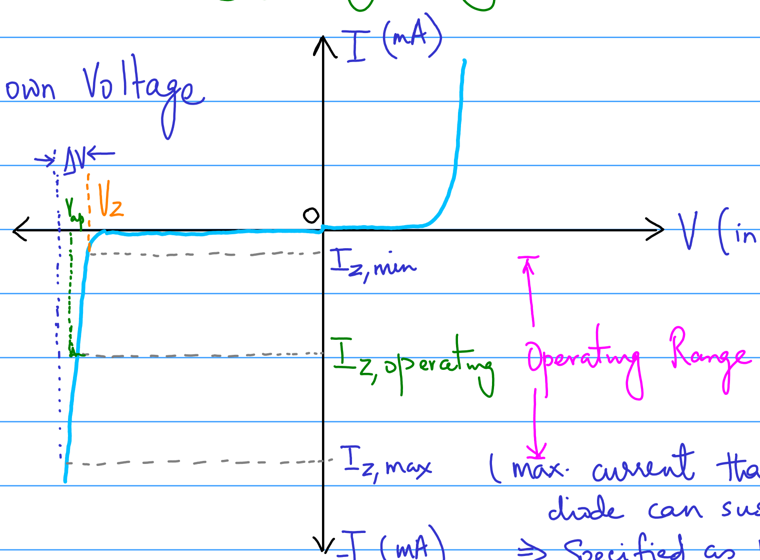
31.01.2022

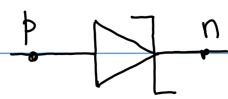
Zener Diode : Voltage Regulation

V_Z : Zener Breakdown Voltage



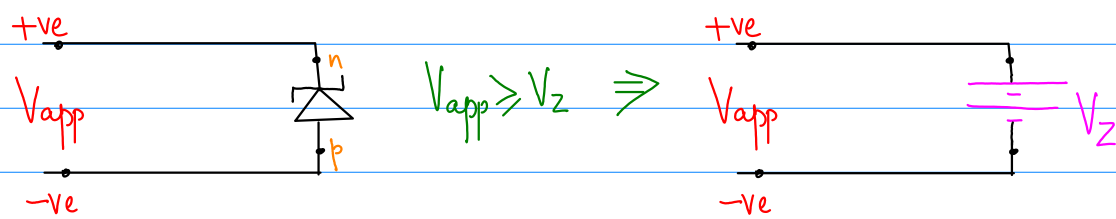
(max. current that the given Zener diode can sustain w/o burning)
⇒ Specified as per power rating

Circuit Model of a Zener Diode in Reverse-Bias :

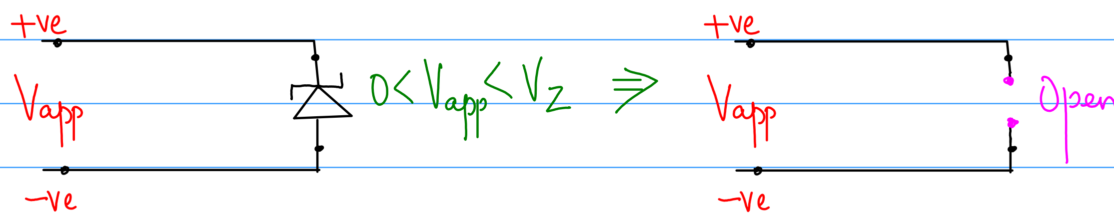


Circuit Symbol.

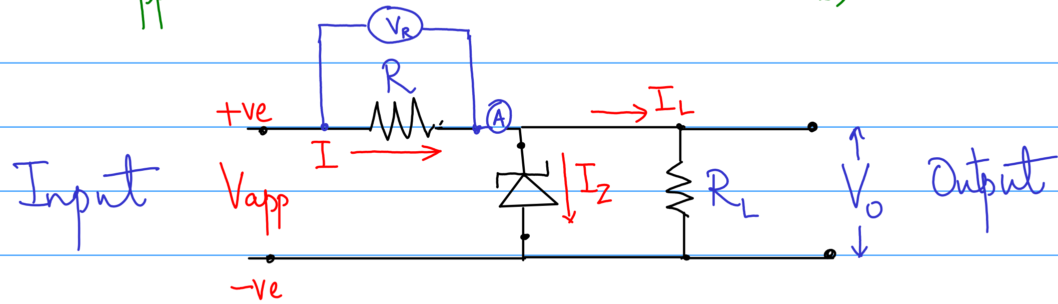
(i) Zener in ON-state : $V_{app} \geq V_Z$ (Breakdown voltage of the Zener Diode)



(ii) Zener in OFF-state : $0 < V_{app} < V_Z$



(1) V_{app} and the load resistance (R_L) are constant: (Time-invariant)



- Input Current through the resistor R

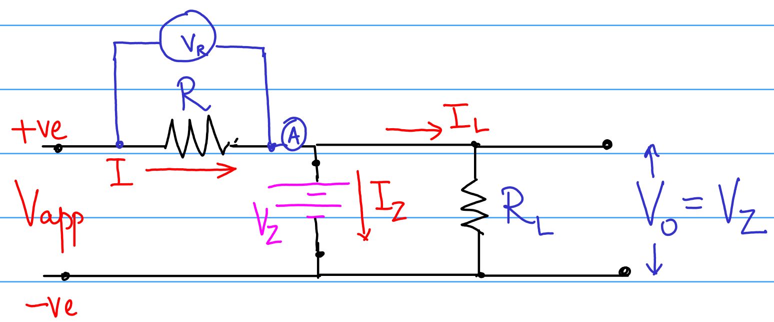
$$I = I_Z + I_L \quad \text{------------} \quad (1)$$

- Voltage drop across 'R', $V_R = V_{app} - V_0$ ---------- (2)

- The value of resistance $R = \dfrac{V_{app} - V_0}{I_Z + I_L}$ ---- (3)

Note: When we design the ckt properly, the load voltage (V_0) remains essentially constant (equal to V_Z) even though either input voltage V_{app} or the load resistance 'R_L' may vary over a wide range.

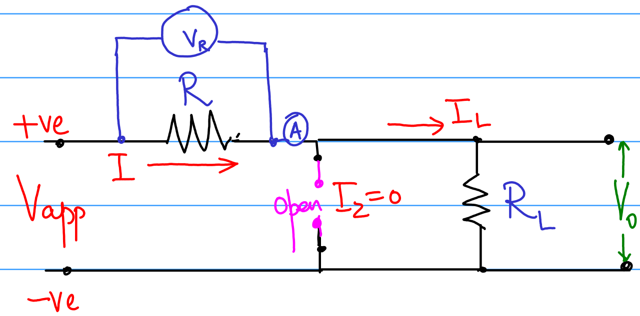
Case(i): $V_{app} \geq V_Z$ (ie, Zener is 'ON')



(a) $I_Z = I - I_L$; (b) $I_L = \dfrac{V_Z}{R_L}$

(c) Power dissipated in Zener $P_Z = I_Z V_Z$

Case (ii) $\quad 0 < V_{app} < V_Z \quad$ (Zener is "OFF-state")



- $I_Z = 0$

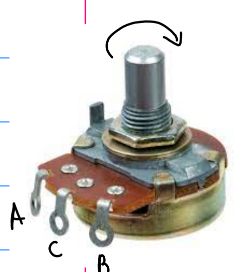
  $\Rightarrow I = I_L$

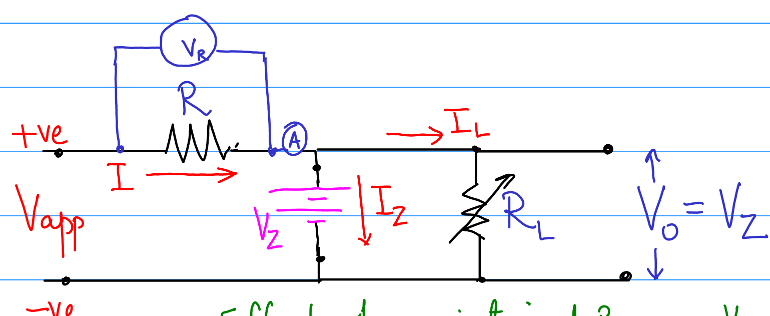
- $V_R = IR \quad ; \quad V_0 = \left[\dfrac{R_L}{R_L + R}\right] \cdot V_{app}$

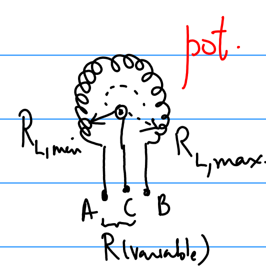
- $P_Z = 0 \quad$ (since $I_Z = 0$)

(2) Load Regulation : V_{app} is fixed but R_L is variable ($R_{L,min}$ to $R_{L,max}$)

Case (i) : $V_{app} \geq V_Z$ (Zener is 'ON')







Effect of variation of R_L on V_0

- Input Current $I = I_Z + I_L = \text{Constant}$

- $V_0 = V_Z = \text{Constant}$

- Here, we are going to vary R_L b/w $R_{L,min}$ to $R_{L,max}$

- We, know that for $R_{L,min}$; $I_{L,max}$.

  Since, $I = I_Z \downarrow + I_L \uparrow = \text{Constant}$

- Similarly; for $R_{L,max}$; $I_{L,min}$.

  Since, $I = I_Z \uparrow + I_L \downarrow = \text{constant}$

- $$V_0 = V_Z = \frac{R_L}{R_L + R} \cdot V_{app}.$$

- For $R_{L,min}$: $$V_Z = \frac{R_{L,min}}{R_{L,min} + R} V_{app}.$$

$$\boxed{R_{L,min} = \frac{R \cdot V_Z}{V_{app} - V_Z} \; ; \; I_{L,max} = \frac{V_Z}{R_{L,min}}}$$

- For $R_{L,max} \Rightarrow I_{L,min}$.

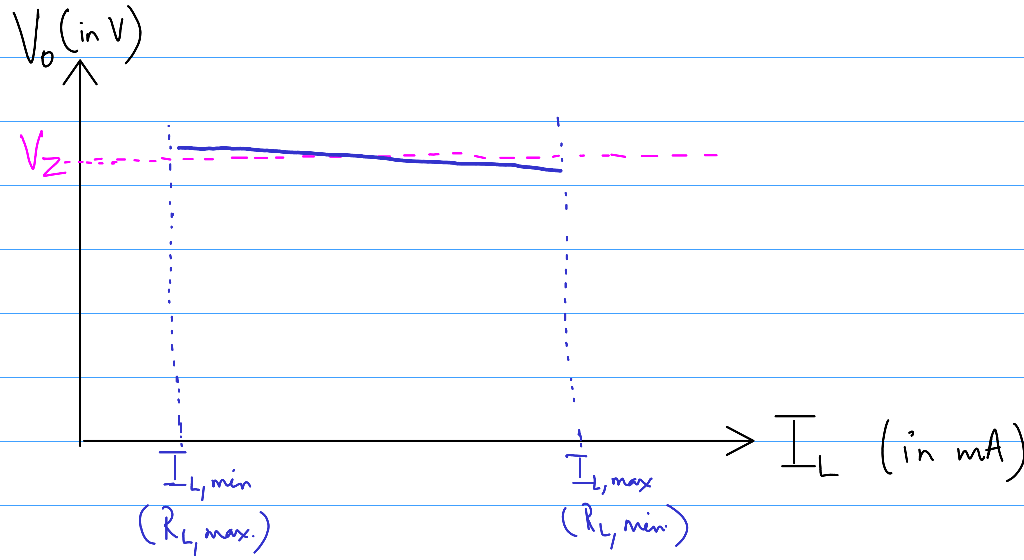
$$I = I_Z \uparrow + I_L \downarrow = \text{Constant}$$

$$\Rightarrow \quad I_Z = I - I_L$$

$$I_{Z,max} = I - I_{L,min}$$

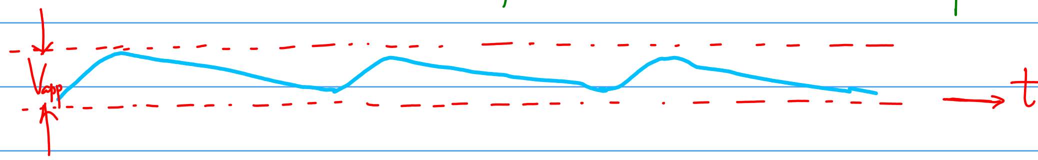
The min allowable current through the load resistance is given as: $\boxed{I_{L,min} = I - I_{Z,max}.}$

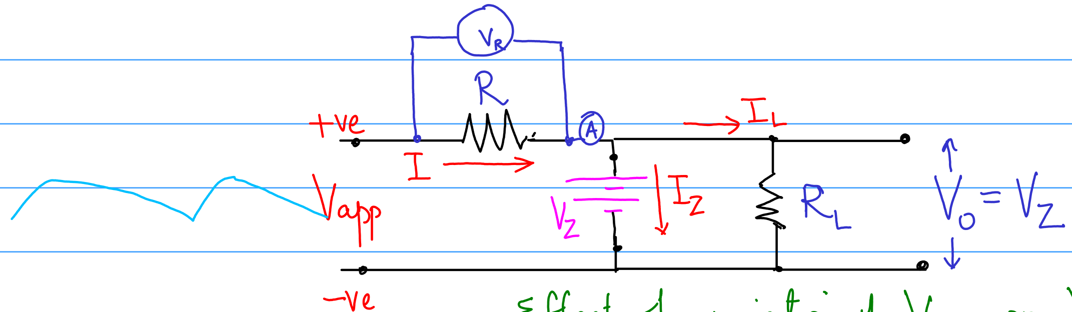
$$\boxed{R_{L,max} = \frac{V_Z}{I_{L,min}}}$$



③ Line Regulation : Variable input voltage and fixed R_L

Output of the filter ckt.





Effect of variation of V_{app} on V_o

Input Current : $\underset{\text{Vary}}{I} = \underset{\text{fixed}}{I_L} + I_Z \uparrow\downarrow$

a) We are interested to determine the minimum applied voltage so that it keeps the Zener in 'ON' state.

$$V_o = V_Z = \frac{R_L}{R_L + R} \cdot V_{app,\,min}$$

$$\boxed{V_{app,\,min} = \left(\frac{R + R_L}{R_L}\right) V_Z}$$

(ii) Since,

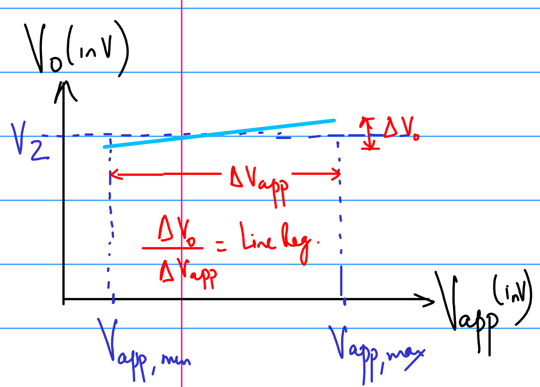
$$I \uparrow = I_Z \uparrow + I_L \quad \text{fixed}$$

$$\Rightarrow \quad I_{max} = I_{Z,max} + I_L$$

Using KVL

$$V_{app} = IR + V_Z$$

$$V_{app,\,max} = I_{max} \cdot R + V_Z$$



$$\boxed{V_{app,\,max} = \left(I_{Z\,max} + I_L\right) R + V_Z}$$