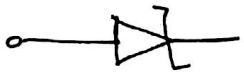
Lec (5)

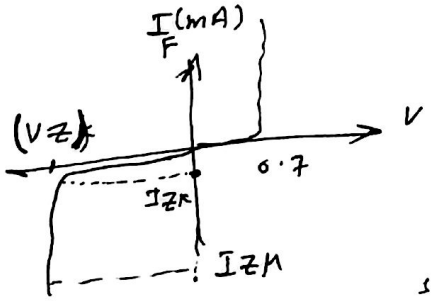
Zener diode (diode Applications)

(a) symbol 

it is a semi Conductor diode designed to operate in both Forward and Reverse Connection.

→ in Forward Connection it looks like normal diode (battery of 0.7V), while in Reverse connection it still open until the Voltage across its terminals exceed the input Voltage, so it act as a Constant Voltage Source (Constant battery) and pass a current Through it → Zener diode Also Called (breakdown diode)

(b) characterstics of Zener



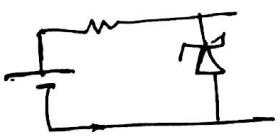
- I_{ZK} .. knee Current (minimum Zener Current at V_z)
- I_{ZM} .. Maximum Safe Current

(c) Uses of Zener diode

→ it is used as a voltage Regulator, so it is Found in Power supply (charger) Circuits.

(d) Connection of Zener diode

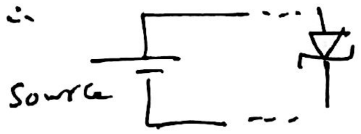
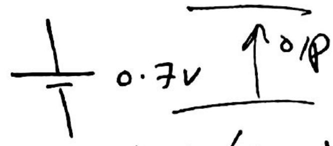
to use Zener as a Regulator, So it is connected in Reverse Connection with Supply (+ve of supply with Cathode of Zener)



(e) Zener Model [Zener Connect in Shunt with source) ②

توازي

→ if Anode Connected to +ve of source (forward)

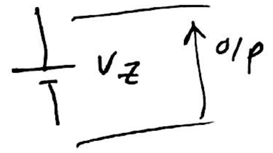
∴  ⇒ ∴ o/p like silicon diode ≡ 

الزينر هنا كأنه دايود عادي 0.7 ولهذا لا نوصل الزينر بهذا الشكل لأنه لم يكن له استفادة .

So → Zener Connect as shown 

There are 2 cases in this Connection

(1) On state ($V_{in} \geq V_Z$) → so o/p like Battery (constant voltage source $= V_Z$)

∴ o/p ≡ 

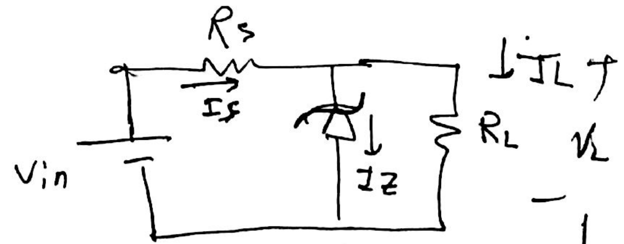
(2) off state ($V_{in} < V_Z$) → so it acts like (open circuit)

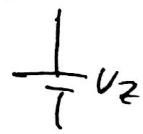
∴ o/p ≡ 

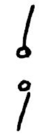
(f) Zener diode Analysis

1. at V_i and R_L const
2. at fixed V_i and Variable R_L — load Regulation
3. fixed R_L and Variable (V_i) — (line regulation)

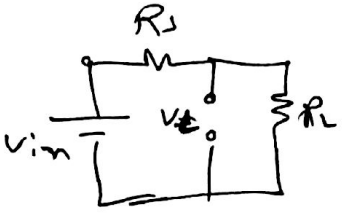
[1] Const (Fixed) V_i and Fixed R_L



* First step assume Zener (open) and calculate the voltage across it
* if $V_L \geq V_Z$ ∴ Zener Really on and its equivalent circuit is 

  if $V_L < V_Z$ ∴ Zener off & acts as open circuit 

Using voltage divider



$\therefore V_L = \frac{V_{in} R_L}{R_L + R_s}$

Now, if $V_{in} < V_z$ $\therefore$ Zener (off) $\Rightarrow$ open & $V_z = \frac{V_{in} R_L}{R_L + R_s}$, $I_z = 0$

if $V_{in} > V_z$ $\therefore$ Zener (on) $\Rightarrow$ V_z

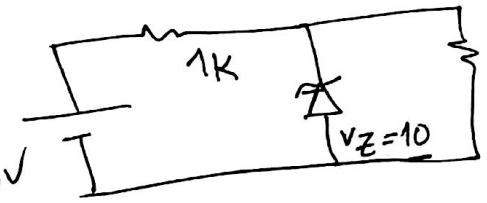
assume on $\therefore$

$\rightarrow \because V_L = V_z$ & $I_L = \frac{V_z}{R_L}$

$\rightarrow I_s = \frac{V_{in} - V_z}{R_s}$

$\rightarrow I_s = I_z + I_L$ or $I_z = I_s - I_L$

$\rightarrow P_z$ (Power dissipated by zener) $= V_z I_z$

EX) 

find V_L, V_R, I_z, P_z

sol assume zener open $\therefore V_L = \frac{16 \times 1.2}{1 + 1.2} = 8.73\ V$

$\therefore 8.73 < 10\ V_{(V_z)}$, $\therefore$ zener off (open)

$\rightarrow$ and $V_L = 8.73$

$\rightarrow V_R = V_{in} - V_L = 16 - 8.73 = 7.27\ V$

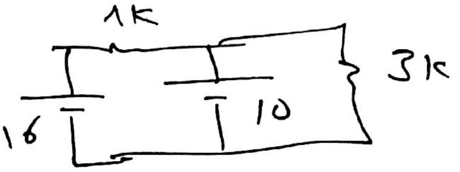
$\rightarrow I_L = \frac{V_L}{R_L} = \frac{8.73}{1.2K} = 7.27\ mA$

$I_R = \frac{16 - 8.73}{1K} = 7.27\ mA$

$\therefore P_z = V_z I_z = 0$

b) $\because R_L = 3K$ repeat problem

$\therefore V_L = \dfrac{16 \times 3k}{1k + 3k} = 12V$



$V_L > V_Z \therefore$ Zener on

$\therefore V_Z = V_L = 10V$

$I_L = \dfrac{10}{3K} = 3.33\,mA$

$I_R = \dfrac{16-10}{1K} = 6\,mA$

$\to I_Z = I_R - I_L = (6 - 3.33)\,mA = 2.67\,mA$

$P_Z = V_Z I_Z = (2.67\,mA)(10) = 26.7\,mW$

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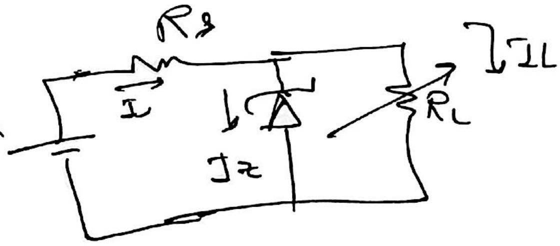
2 Load Regulator [Fixed V_i & Variable R_L]



R_L changes between minimum & maximum value (R_{Lmin} & R_{Lmax})

Note $\because R_L$ (Too small) $\to V_L$ (small) $\therefore$ Zener off)

by the same previous equations [on state]

تعني أقل قيمة مقاومة كافية لتشغيل الزينر

[on] $V_Z = V_L = V_{in} \dfrac{R_{Lmin}}{R_{Lmin} + R_s} \longrightarrow R_{Lmin}$

← هنا بنفترض أن الزينر شغال للفولتية أقل عالية

$\because R_{Lmin} \Rightarrow R_{Lmin} \Rightarrow$ تقابل $I_{Lmax} \Rightarrow$

$$\boxed{R_{L_{min}} = \frac{V_Z}{I_{LMax}}}$$

$$\boxed{R_{Lmax} = \frac{V_Z}{I_{Lmin}}}$$

$\to V_R = V_{in} - V_Z \quad , \quad I_s = V_R / R_s$

$\to I_Z = I_s - I_L$
- $\because I_{Lmax} \therefore I_{Zmax} = I_s - I_{ZK}$
- $\because I_{Lmin} \therefore I_{Lmin} = I_s - I_{Zmax}$

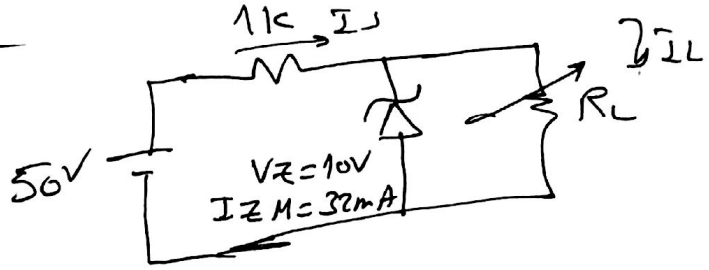
أقصى تيار للزينر (I_{ZM}) تقابله أقل تيار في المقاومة R_s (I_{smin}) والعكس

Example For The Circuit shown

ⓐ find the range of R_L and I_L that will result in V_{RL} being Maintained at 10V

ⓑ Find The maximum voltage rating of the diode

Sol



$$V_L = \frac{50\, R_{Lmin}}{R_{Lmin} + (1K)}$$

let $V_L = 10V$ (desired)

$$\therefore 10 = \frac{50\, R_{Lmin}}{R_{Lmin} + 1000} \quad \therefore \; R_{Lmin} \geq 250\,\Omega$$

$$\therefore R_{Lmin} + 1000 = 5 R_{Lmin}$$

$$\text{or } 4R_{Lmin} = 1000 \quad \therefore R_{Lmin} = \frac{1000}{4} = 250\,\Omega$$

$$\therefore V_R = V_{in} - V_L = 50 - 10 = 40V$$

$$I_R = \frac{40}{1K} = 40mA$$

$$I_{Z\,max} = 32\,mA$$

$$\therefore I_{L\,min} = I_R - I_{Z\,max} = 40 - 32 = 8\,mA$$

$$\therefore V_L = 10 \quad \therefore \; R_{L\,max} = \frac{V_L}{I_{L\,min}} = \frac{10}{8\,mA} = 1.25\,k\Omega$$

$$\rightarrow R_{Lmin} = \frac{V_L}{I_{Lmax}}$$

& I_{Lmax} at I_{Zmin} (≈ 0)

$$\therefore I_{Lmax} \approx I_S = 40mA$$

$$\therefore R_{Lmin} = \frac{10}{40\,mA} = 250\,\Omega$$

$\therefore$ range of Resistance is between 250 Ω & 1.25 kΩ

ⓑ $P_{max} = V_Z I_{Zmax} = (10)(32 \times 10^{-3}) = 320\,mW$

C Fixed R_L and Variable input (line Regulation)

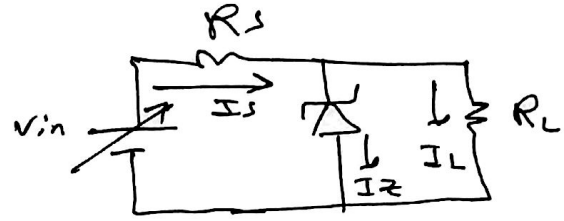
note V_{in} must be large to turn on Zener, minimum voltage required to turn on Zener can be Calculated From Relation

where $V_L = \frac{V_{in}(R_L)}{R_L + R_S}$ or $\boxed{V_{in(min)} = \frac{V_L(R_L + R_S)}{R_L}}$

and $I_{Zmax} = I_{S_{max}} - I_L$

→ So $I_{S_{max}} = I_{Zmax} + I_L$

→ $V_{R_S} = I_{S_{max}} * R_S$

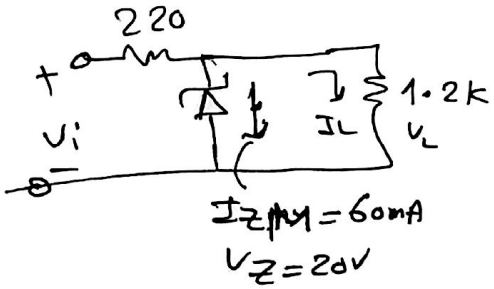


$$\rightarrow V_{in(max)} = V_S + V_L = I_{S_{max}} R_S + V_L = (I_{Zmax} + I_L) R_S + V_L$$

(V_L = V_Z; V_L = V_Z)

EX(3) For the shown Circuit, Find the range of V_i that will zener on

$I_L = \frac{V_Z}{R_L} = \frac{20}{1.2k} = 16.67mA$



$V_{in(min)} \Rightarrow$

$V_Z = 20 = \frac{V_{in(min)}(1.2k)}{(1.2k) + 220}$

$\boxed{\therefore V_{in_{min}} = 23.67V}$

$I_{Smax} = I_{Zmax} + I_L = 60mA + 16.67mA = 76.67mA$

$\therefore V_{in(max)} = I_{Smax} * R_S + V_Z = 220 \times 76.67 \times 10^{-3} + 20 = 36.87\ V$

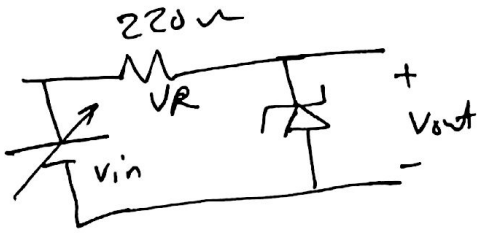
$\therefore$ V_{in} changed From (23.67 → 36.87 V)

Example (4)

Suppose Zener diode in shown circuit with the following specification

$V_Z = 10V$, $I_{ZK} = 0.25mA$, $P_{Dmax} = 1W$

Find the i/p limits for Regulation.



Sol • $I_{ZMax} = \frac{P_{Dmax}}{V_Z} = \frac{1W}{10V} = 0.1A = 100mA$

• $I_{ZK} = 0.25mA$ (minimum)

$V_{in} = V_R + V_{out}$

$= 10 + I_S \times 220$ ($I_S = I_Z$)

$V_{inmin} = 10 + 220\, I_{Smin} = 10 + 220\,[I_{Zmin}]$

$= 10 + 220 \times 0.25 \times 10^{-3} = 10.055\,V$

$V_{inmax} = 10 + 220\, I_{Smax} = 10 + 220\,[I_{Zmax}]$

$= 10 + 220 \times 100 \times 10^{-3} = 32\,V$

∴ input changes From $10.055 \longrightarrow 32\,V$