Lec (5)

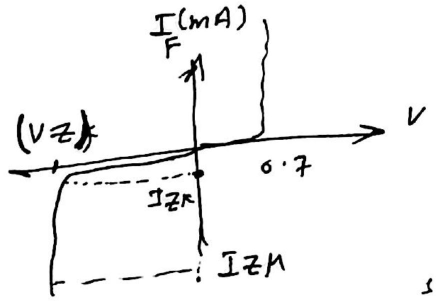
Zener diode (diode Applications)

(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 (break down diode)

(b) characterstics of Zener



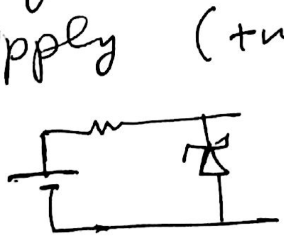
- IZK .. knee Current (minimum Zener Current at V_Z)
- IZM - Maximum Safe Current , أقصى تيار يتحمله الزينر بدون تلف

(c) uses of Zener diode

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

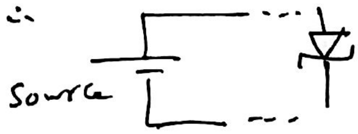
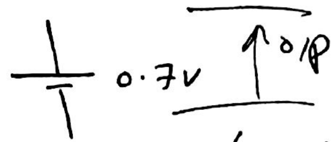
(d) Connection of Zener diode

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 (توازي) with source] (2)

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

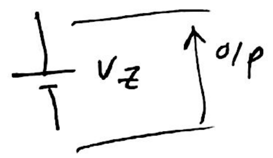
∴  ⇒ ∴ o/p like silicon diode ≡ 

الزنير هنا يعامل كأنه 0.7 وهنا لا نوصل الزنير بهذا الشكل لأنه لم يكن له استفادة.

So → Zener Conned as shown 

There are 2 cases in this Connection

(1) On state ($V_{in} > V_Z$) → 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)

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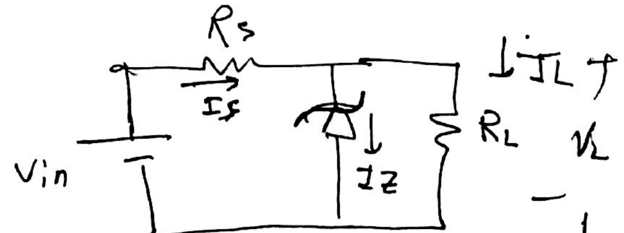
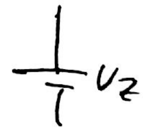
[1] Const (Fixed) V_i and Fixed R_L

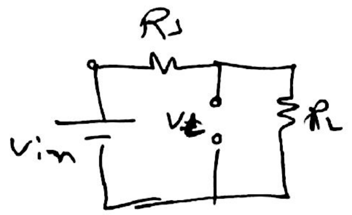


* First step assume Zener (open) and calculate the voltage across it

* If $V_L > V_Z$ ∴ Zener Really on and its equivalent circuit is 

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

using voltage divider

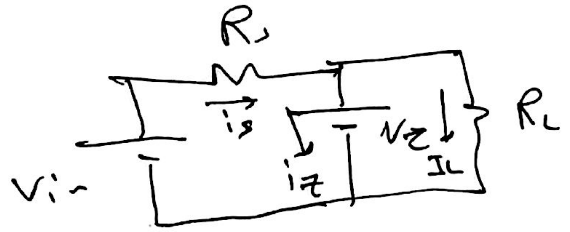


$\therefore V_Z = \frac{V_{in} R_L}{R_L + R_s}$

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 $V_{in} \geq V_Z$ $\therefore$ Zener (on) $\Rightarrow$  V_Z

assume on $\therefore$



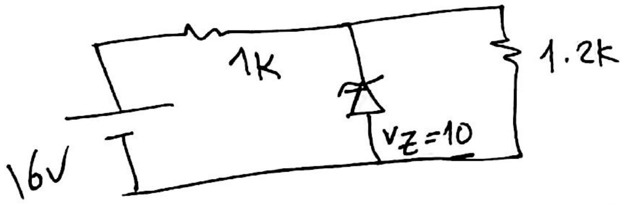
→ $\therefore V_L = V_Z$ & $I_L = \frac{V_Z}{R_L}$

→ $I_s = \frac{V_{in} - V_Z}{R_s}$

→ $I_s = I_Z + I_L$ or $I_Z = I_s - I_L$

→ P_Z (Power dissipated by zener) $= V_Z I_Z$

EX)



find V_L, V_R, I_Z, P_Z

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

$\therefore 8.73 < 10V$ (V_Z) $\therefore$ Zener off (open)

→ and $V_L = 8.73$

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

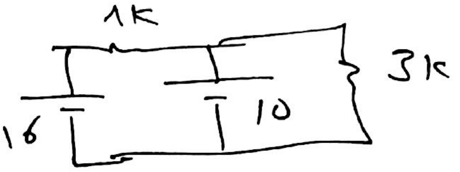
→ $I_L = \frac{V_L}{R_L} = \frac{8.73}{1.2K} = 7.27\ mA$

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

$\therefore P_Z = V_Z I_Z = 0$

b) if $R_L = 3K$ repeat problem

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



$V_L > V_Z \therefore$ Zener on

$\therefore V_Z = V_L = 10V$

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

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

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

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

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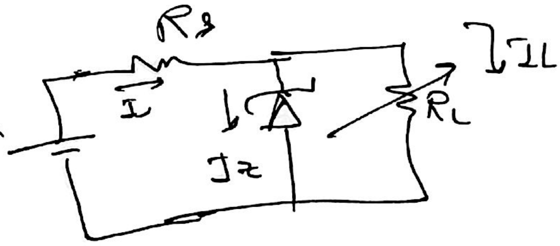
2 Load Regulator [Fixed V_i & Variable R_L]



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

<u>Note</u> if R_L (Too small) $\rightarrow V_L$ (small) $\therefore$ Zener off)

by the same previous equations [on state]

[on] $V_Z = V_L = V_{in} \dfrac{R_{Lmin}}{R_{L_{min}} + R_s} \longrightarrow R_{Lmin}$ تعني أقل قيمة مقاومة كافية لتشغيل الزينر

← هنلاقي أقصى تيار للزينر شغال لو المقاومة أقل قيمة

if $R_{Lmin} \Rightarrow R_{Lmin} \Longrightarrow$ تقابل $I_{Lmax} \Rightarrow$

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

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

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

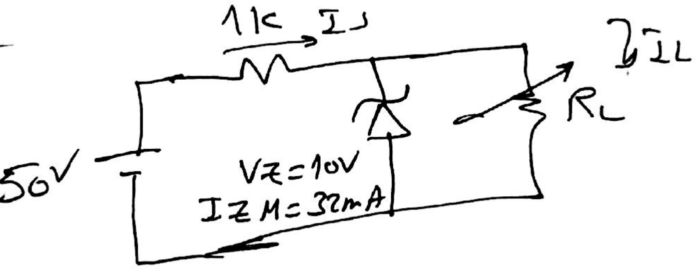
$\rightarrow I_Z = I_s - I_L$
- if $I_{Lmax} \therefore I_{Zmax} = I_s - I_{ZK}$
- if $I_{Lmin} \therefore I_{Lmin} = I_s - I_{Zmax}$

أقصى تيار للزينر (I_{ZM}) تقابله أقل تيار، و مقاومة R_s (I_{smin}) والعكس

Example For The Circuit shown

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

(b) Find The maximum voltage rating of the diode



Sol

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

let $V_L = 10V$ (نعوض)

$$\therefore 10 = \frac{50 R_{Lmin}}{R_{Lmin} + 1000}$$

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

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

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

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

$I_{Zmax} = 32\,mA$

$\therefore I_{Lmin} = I_R - I_{Zmax} = 40 - 32 = 8\,mA$

$\because V_L = 10$ $\therefore$ $R_{L\,max} = \frac{V_L}{I_{Lmin}} = \frac{10}{8\,mA} = 1.25\,k\Omega$

$R_{Lmin} = \frac{V_L}{I_{Lmax}}$ & I_{Lmax} at I_{Zmin} (≈ 0) $\therefore$

$I_{Lmax} \simeq I_S = 40mA$

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

$\therefore$ range of Resistance is between $250\,\Omega$ & $1.25\,k\Omega$

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

C Fixed R_L and Variable input (line Regulation)

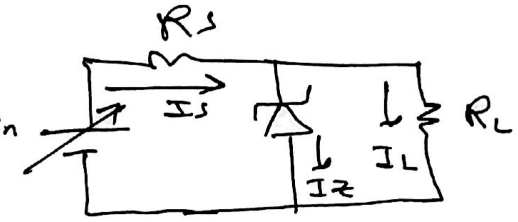
note V_{in} must be large to turn on Zener, minimum voltage required to turn on zener can be calculated from relation where

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

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

$\rightarrow$ so $I_{S_{max}} = I_{Zmax} + I_L$

$\rightarrow$ $V_{R_S} = I_{S_{max}} * R_S$

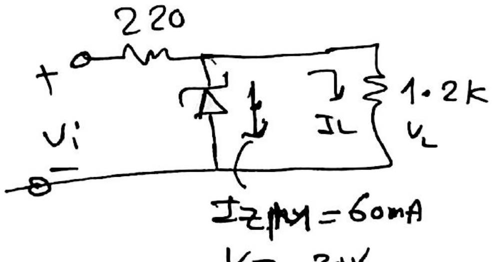


$$\rightarrow V_{in(max)} = V_s + V_L = I_{S_{max}} R_s + V_L = (I_{Zmax} + I_L) R_s + V_L$$

($V_L \rightarrow V_Z$)

EX(3) For the shown Circuit, find the range of V_i that will Zener on

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



$V_{in(min)} \Rightarrow$

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

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

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

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

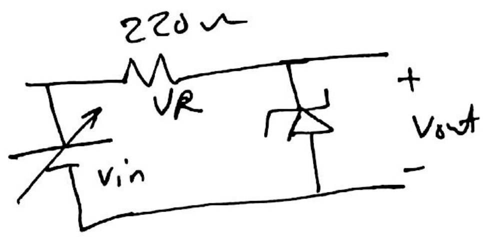
$\therefore V_{in}$ changed from $(23.67 \rightarrow 36.87V)$

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.

- $I_{Z Max} = \frac{P_{Dmax}}{V_Z} = \frac{1W}{10V} = 0.1A = 100mA$
- $I_{ZK} = 0.25 mA$ (minimum)

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

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

$V_{in min} = 10 + 220 I_{S min} = 10 + 220 [I_{Z min}]$

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

$V_{in max} = 10 + 220 I_{S max} = 10 + 220 [I_{Z max}]$

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

∴ input changes from $10.055 \rightarrow 32$