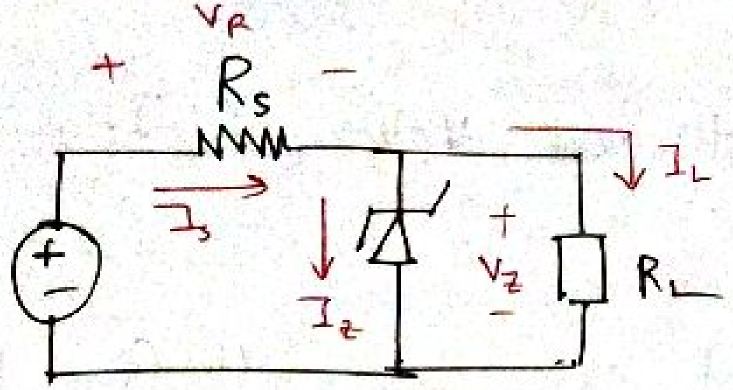
1



The Zener diode is specified as

$V_{Z_0} = 3V$

$r_Z = 0\Omega$

$I_{ZK} = 1mA$

The load current can vary from 0mA to 50mA.

The source has a nominal value of 5V and can vary ±10%.

(a) Find $V_s(min)$, $V_s(max)$, $I_L(min)$, $I_L(max)$

Soln: 10% of 5V = 0.5V

$\therefore V_s(min) = 5 - 0.5 = 4.5V$

$V_s(max) = 5 + 0.5 = 5.5V$

$I_L(min) = 0 \ mA$

$I_L(max) = 50mA.$

(b) What is the worst case values of I_L, I_Z and V_s?

Solⁿ: In worst case, I_{ZK} will flow through the zener diode. [If the current falls below this, the regulation will not be maintained]

KCL $\Rightarrow$ $I_Z = I_S - I_L$

and $I_s = \dfrac{V_s - V_L}{R_s}$

So, I_Z is minimum when I_L is maximum and V_s is minimum.

$\therefore$ Worst case $\Rightarrow$

$I_L = I_L(max) = 50\,mA$

$I_Z = I_Z(min) = I_{ZK} = 1\,mA$

$V_s = V_s(min) = 4.5\,V$

(c) For worst case, what is the value of I_s?

Solⁿ: $I_s = I_Z + I_L = 50 + 1 = 51\,mA$.

~~(d) For worst case,~~

(d) For worst case, what is the value of V_R?

Sol^n: In worst case scenario, the zener diode will barely maintain its voltage.

~~So $V_L = V_{Z0}$~~

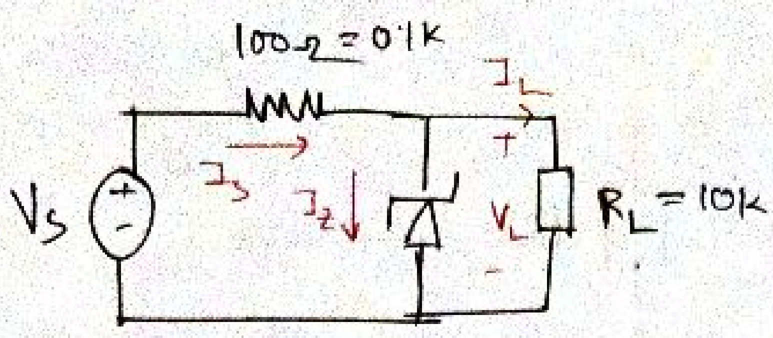
So, $V_L = V_Z = V_{Z0} + I_Z r_Z = 3V$.

$$\therefore V_R = V_S - V_L$$
$$= 4.5 - 3$$
$$= 1.5V$$

(e) Find the value of R_s, for which the Zener diode maintains regulation in worst case scenario.

Sol^n: $R_s = \frac{V_R}{I_s} = \frac{1.5}{51} \approx 30\Omega$.

(2)



Zener diode specification: $V_{Z_0} = 3V$

$r_z = 0\Omega$

$I_{ZK} = 1mA.$

Find the minimum value of V_s for which the Zener diode maintain its regulation.

<u>Soln</u>: In worst case scenario, $I_Z = I_{ZK} = 1mA.$

$\therefore V_L = V_Z = V_{Z_0} + I_Z r_Z = 3V.$

$$\therefore I_L = \frac{V_L}{R_L} = \frac{3V}{10K\Omega} = 0.3mA$$

$\therefore I_s = I_Z + I_L$ (KCL)

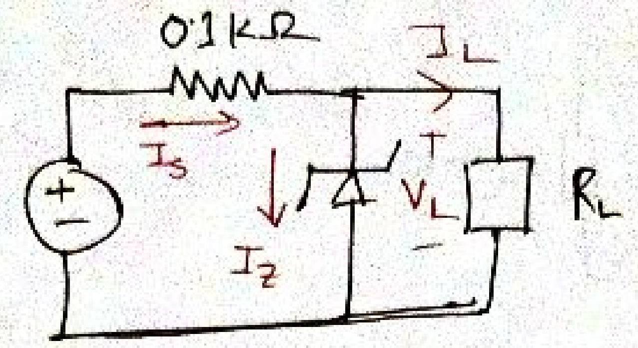
$= 1.3mA$

$$I_s = \frac{V_s - V_L}{0.1K} = 1.3mA$$

$$\Rightarrow \frac{V_s - 3}{0.1K} = 1.3mA$$

$\Rightarrow \boxed{V_s = 3.13V}$ $\therefore \boxed{V_s(min) = 3.13V}$

(3)



Zener diode specification: $V_{Z0} = 3V$,

$r_Z = 0\Omega$

$I_{ZK} = 1mA$

The source V_S has a nominal value of 5V and can vary ±10%.
Find the worst case/minimum value of R_L so that regulation is maintained.

<u>Solⁿ</u>: In worst case, $I_Z = I_Z(min) = I_{ZK} = 1mA$

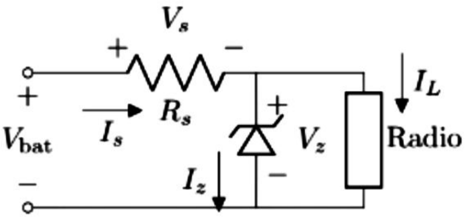
$$V_L = V_Z = V_{Z0} + I_Z r_Z = 3V$$

In worst case, $V_S = V_S(min) = 5 - 10\% = 5 - 0.5 = 4.5V$

$$\therefore I_S = \frac{V_S - V_L}{0.1K} = \frac{4.5 - 3}{0.1K} = 15mA$$

$$\therefore I_L = I_S - I_Z \text{ [KCL]}$$
$$= 15 - 1$$
$$= 14mA.$$

$$\therefore \boxed{R_L = \frac{V_L}{I_L} = \frac{3V}{14mA} \approx 214\Omega}$$



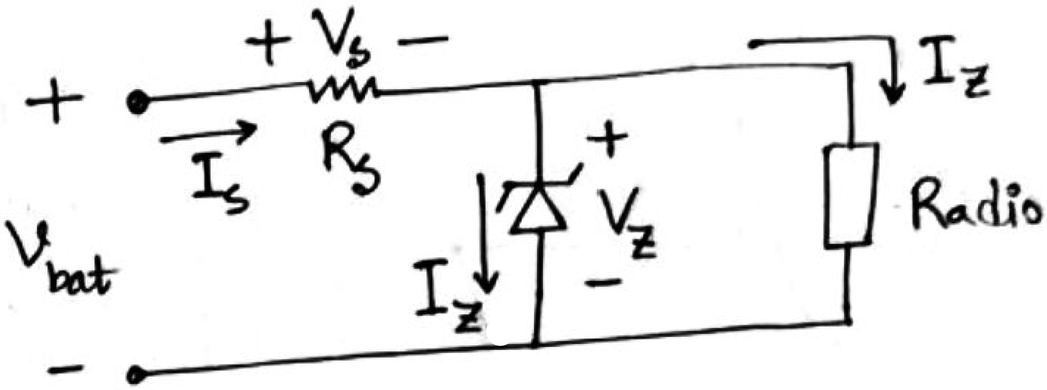
The circuit above is a voltage regulator used to power a car radio (which requires ≈ 9 V) from the car battery, V_{bat} whose voltage may vary between 11 and 13.6 V. The current in the radio, I_L, will vary between 0 (off) to 9 mA (full volume). The Zener diode in the circuit is specified with parameter $V_{z0} = 9$ V, $r_z = 0.05$ kΩ, and $I_{\text{zk}} = 1$ mA.

(a) **Identify** the worst-case conditions and **calculate** the Zener current (I_z), Zener voltage (V_z), the input voltage (V_{bat}), and the load current (I_L) in this worst-case scenario. [1+1+1+1+1]

(b) **Calculate** the current (I_s) and the voltage (V_s) the input resistor R_s in the worst-case scenario. [2]

(c) **Design** the circuit, i.e., find the value of R_s, such that even in the worst-case scenario voltage regulation is maintained. Calculate the line regulation for this circuit. [2+1]

⑤



Given that, $V_{bat} = 11\,v \sim 13.6\,v$

$$I_L = 6 \sim 9\ mA$$

$V_{Z0} = 9v$, $r_z = 0.05\ k\Omega$, $I_{ZK} = 1\ mA$

ⓐ Worst case conditions:

① $V_{bat(min)} = 11\,v.$

② $I_{Z(min)} = I_{ZK} = 1\ mA.$

So, $I_Z = 1\ mA$. (Ans) $V_{bat} = 11v$. (Ans)

$$V_z = V_{Z0} + I_Z r_Z$$

$\Rightarrow V_z = 9 + 1\times10^{-3} \times 0.05\times10^{3}$

$\Rightarrow V_z = 9.05\,v$. (Ans)

$I_L = I_{L(max)} = 9\ mA.$

⑤ Applying KVL we get, $V_{bat} = V_s + V_z$

$\hookrightarrow V_s = V_{bat} - V_z$

$\hookrightarrow V_s = (11 - 9.05)\,v$

$\hookrightarrow V_s = 1.95\,v$. (Ans)

Applying KCL we get,

$I_s = I_z + I_L$

$\hookrightarrow I_s = (1+9)\,mA$

$\hookrightarrow I_s = 10\ mA$. (Ans)

(c) $R_s = \frac{V_s}{I_s} = \frac{1.95}{10 \times 10^{-3}} = 195\,\Omega$. (Ans)

Line Regulation,

$$\frac{\Delta V_L}{\Delta V_{bat}} = \frac{r}{r+R}$$

here,

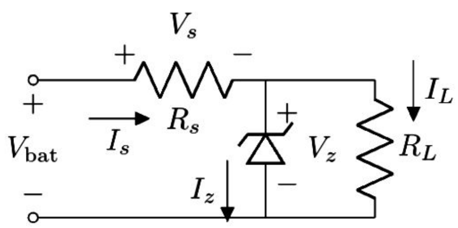
$r = r_z = 0.05\,K\Omega$

$R = R_s = 195\,\Omega$

$$= \frac{0.05 \times 10^3}{0.05 \times 10^3 + 195}\ V/V$$

$$= 0.20408\ V/V$$

$$= 204.08\ mV/V. \text{ (Ans)}$$



The circuit above is a voltage regulator used to power a load R_L from a battery V_{bat}. For this circuit, $R_s = 0.2\ \text{k}\Omega$, $R_L = 2\ \text{k}\Omega$, $V_{z_0} = 4$ V, $r_z = 0\ \Omega$, and $I_{zk} = 0.5$ mA.

(a) **Identify** the zener current I_z in the worst-case scenario. In this worst-case scenario, **calculate** the zener voltage V_z, load current I_L and input current I_s. [5]

(b) **Design** the circuit, *i.e.*, find the minimum value of the input voltage V_{bat} such that, voltage regulation is maintained even in the worst-case scenario. [3]

(c) **Determine** whether the circuit will maintain regulation if V_{bat} is increased. If yes, **argue** if it should be increased or not. [2]

1 ⓐ Worst case

$$I_Z = I_{ZK} = \boxed{0.5 mA}$$

$$V_Z = V_{Z0} + I_Z r_Z$$
$$= \boxed{4V}$$

$$I_L = \frac{V_Z}{R_L} = \frac{4}{2} = \boxed{2mA}$$

$$I_S = I_Z + I_L$$
$$= \boxed{2.5 mA}$$

1 ⓑ $V_{bat} = V_S + V_Z$

$$= I_S R_S + V_Z$$
$$= \boxed{4.5V}$$

1 ⓒ Line regulation $= \frac{r_Z}{R_S + r_Z}$

Load " $= -\frac{r_Z R_S}{R_S + r_Z}$

Neither of the regulations depends on V_{bat}. So, if V_{bat} is increased, regulation will be maintained.

Now, $V_{bat} = (I_Z + I_L) R_S + V_Z$

$$= \left(I_Z + \frac{V_Z}{R_L}\right) R_S + V_Z$$

$V_{bat} \uparrow \quad I_Z \uparrow \therefore I_Z > I_{ZK} \rightarrow$ ensures breakdown.

$\downarrow$

working as regulator.