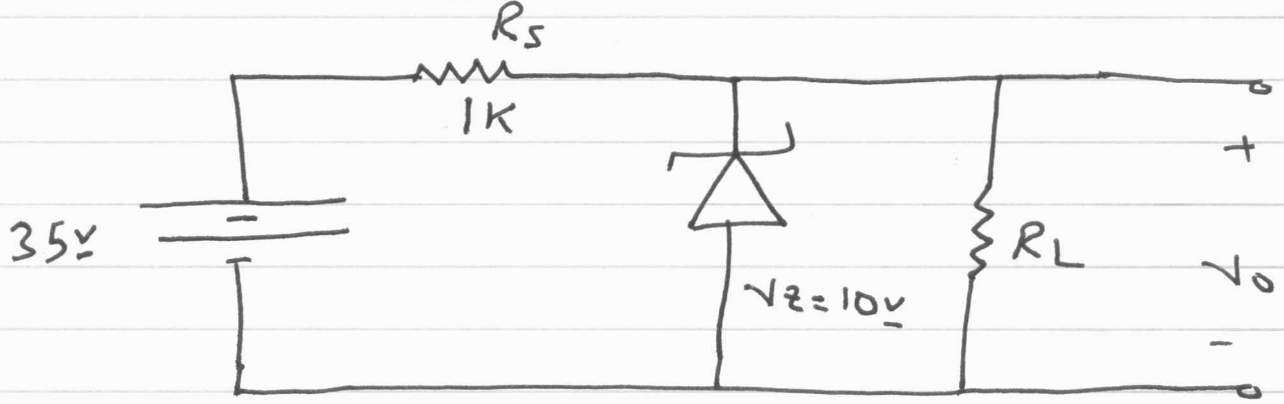
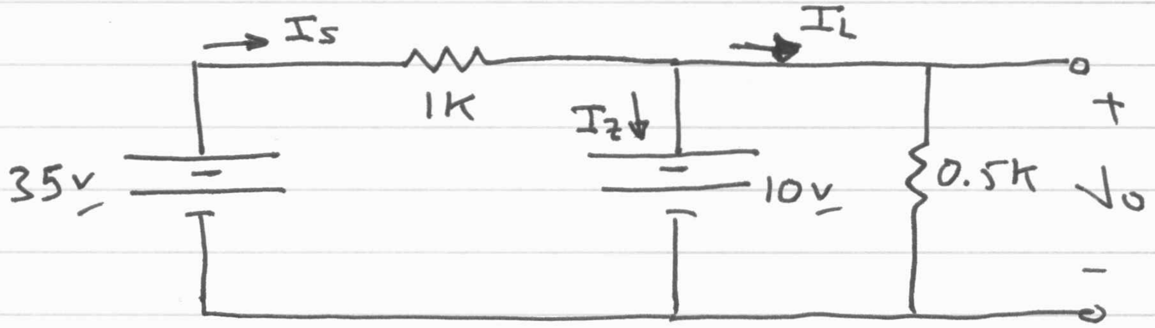
2) Voltage regulation with load variation



a) Let $R_L = 0.5K$

The Zener diode is in the breakdown region. Prove !!



$\therefore \; V_o = V_Z = 10\,V$

$$I_S = \frac{35-10}{1K} = 25\,mA$$

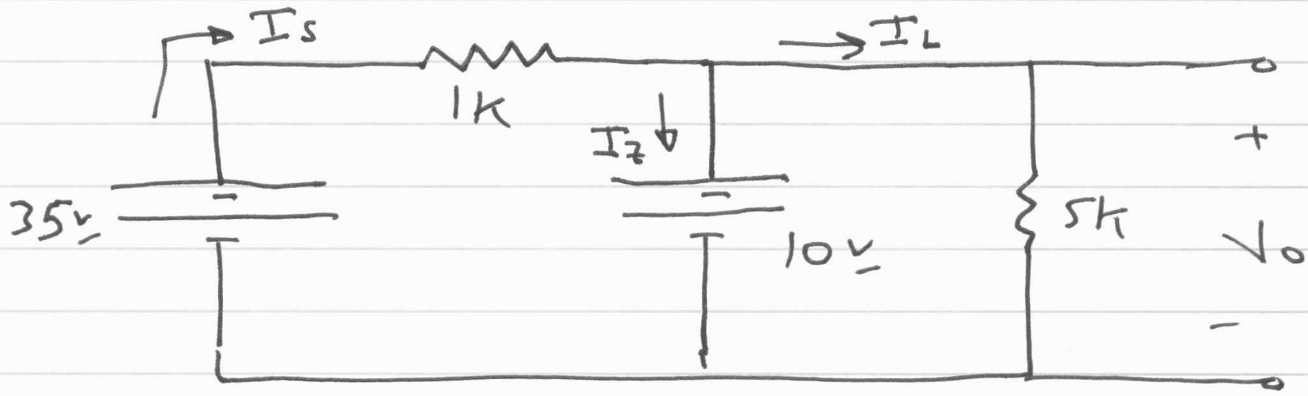
$$I_L = \frac{V_o}{R_L} = \frac{10V}{0.5K} = 20\,mA$$

$\therefore$

$$I_Z = I_S - I_L = 5\,mA$$

b) let $R_L = 5K$

∴ the Zener diode is in the breakedown region. Prove !!



$$V_o = V_Z = 10\,v$$

$$I_s = \frac{35-10}{1K} = 25\,mA$$

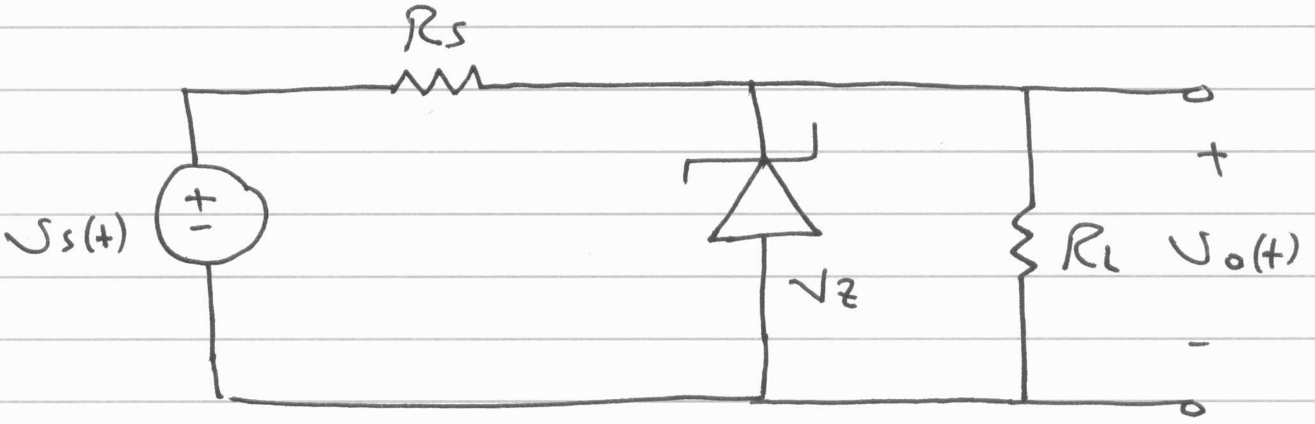
$$I_L = \frac{V_o}{R_L} = \frac{10v}{5K} = 2\,mA$$

$$\therefore\ I_Z = I_s - I_L = 23\,mA$$

In the four Cases we must verify that

$$I_Z(max) > I_Z > I_Z(min)$$

Desig of R_s



given : $V_s(min)$ and $V_s(max)$

$R_L(min)$ and $R_L(max)$

and $(V_z, I_z(min), I_z(max))$

$$I_z = I_s - I_L$$

$$* \quad I_z = \frac{V_s(t) - V_z}{R_s} - I_L > I_z(min)$$

The worst condition

$$\frac{V_s(min) - V_z}{R_s} - I_L(max) > I_z(min)$$

$$\therefore \quad R_s < \frac{V_s(min) - V_z}{I_z(min) + I_L(max)}$$

$$* \quad I_z = \frac{V_s(t) - V_z}{R_s} - I_L < I_z(max)$$

The worst Condition

$$\frac{V_s(max) - V_z}{R_s} - I_L(min) < I_z(max)$$

$$\therefore \quad R_s > \frac{V_s(max) - V_z}{I_z(max) + I_L(min)}$$

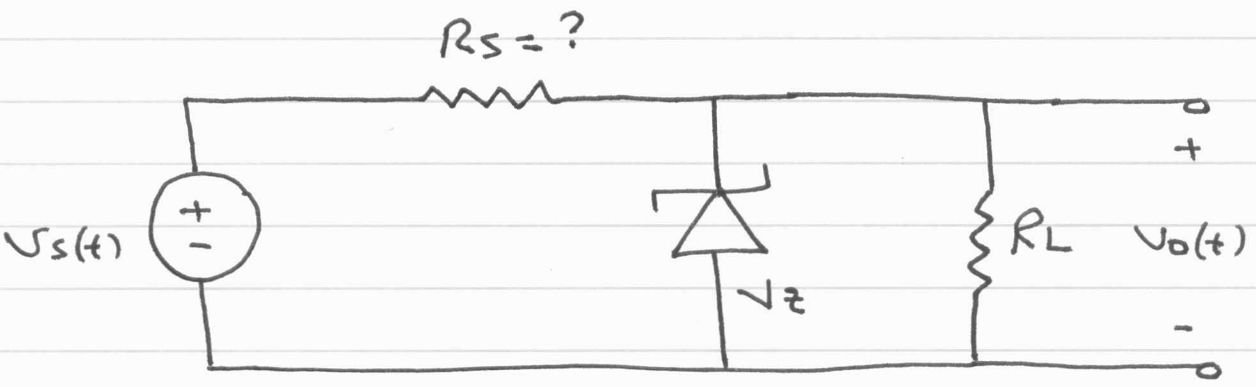
Combining the two results

$$\frac{V_s(min) - V_z}{I_z(min) + I_L(max)} > R_s > \frac{V_s(max) - V_z}{I_z(max) + I_L(min)}$$

not that $I_L(max) = \frac{V_z}{R_L(min)}$

and $I_L(min) = \frac{V_z}{R_L(max)}$

Example



given :

Zener diode : $I_z(\min) = 5\,mA$
$I_z(\max) = 200\,mA$

Load : $R_L(\min) = 500\,\Omega$; $\therefore I_L(\max) = 20\,mA$
$R_L(\max) = \infty$; $\therefore I_L(\min) = 0$

input signal : $V_s(\min) = 15\,V$
$V_s(\max) = 20\,V$

$$\frac{V_s(\min) - V_z}{I_z(\min) + I_L(\max)} > R_s > \frac{V_s(\max) - V_z}{I_z(\max) + I_L(\min)}$$

$$200 > R_s > 50\,\Omega$$

$\therefore$ let $R_s = 100\,\Omega$

To determin the effectivenem of the voltage regulator, we difine two indicator

a) Load regulation $= \frac{\Delta V_o}{\Delta I_L}$

assuming V_s Constant

b) Line regulation $= \frac{\Delta V_o}{\Delta V_s}$

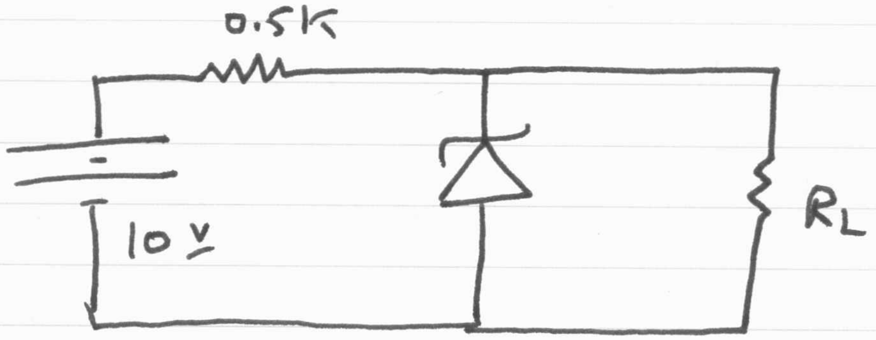
assuming R_L Fixed

For the simple voltage regulator, and using ideal model for the Zener diode

$$\frac{\Delta V_o}{\Delta I_L} = 0$$

and $\frac{\Delta V_o}{\Delta V_s} = 0$

a) Load regulation = $\frac{\Delta V_o}{\Delta I_L}$



$\infty \geq R_L \geq 2K$

The Zener have

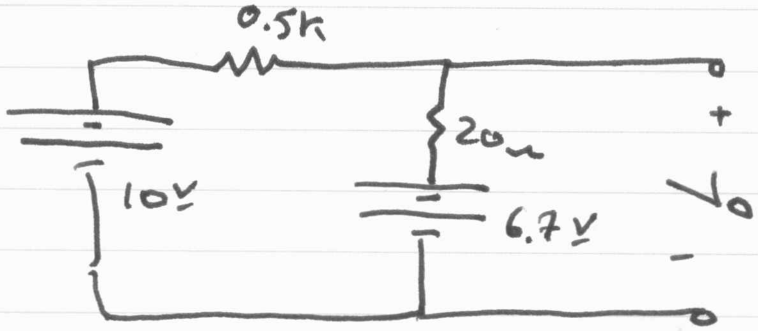
$V_{ZT} = 6.8$ V @ $I_{ZT} = 5$ mA and $r_Z = 20\Omega$

$V_Z = V_{Z0} + r_Z I_Z$

$\therefore V_{Z0} = 6.7$ V

1) let $R_L = \infty$

Since $V_S > V_{Z0}$ $\therefore$ The Zener is in breakdown

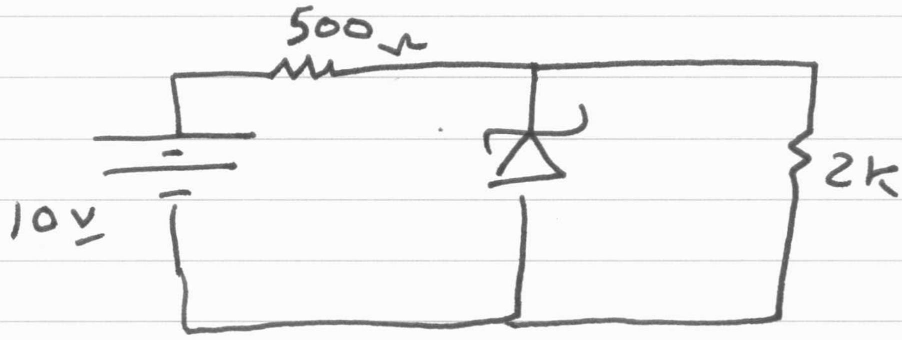


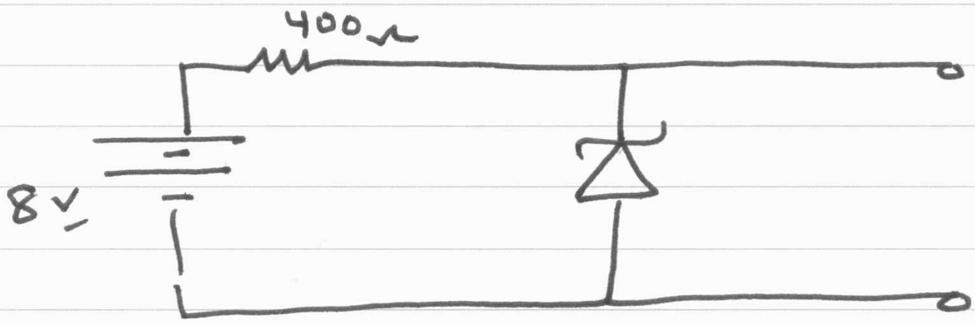
$V_o = 20 I_Z + 6.7$

$I_Z = \frac{10 - 6.7}{520} = 6.35$ mA

$\therefore V_o = 6.83$ V

2) let $R_L = 2k\Omega$





$$V_{TH} = \frac{2000}{2000+500} \cdot 10 = 8\,\underline{V}$$

$$R_{TH} = 500 \,\|\, 2000 = 400\,\Omega$$

Since $V_{TH} > V_{Z0}$, Zener in breakdown

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

$$V_o = 6.7 + 20\left(\frac{8-6.7}{420}\right) = 6.76\,\underline{V}$$

$$I_L = \frac{V_o}{R_L} = \frac{6.76}{2k} = 3.38\,mA$$

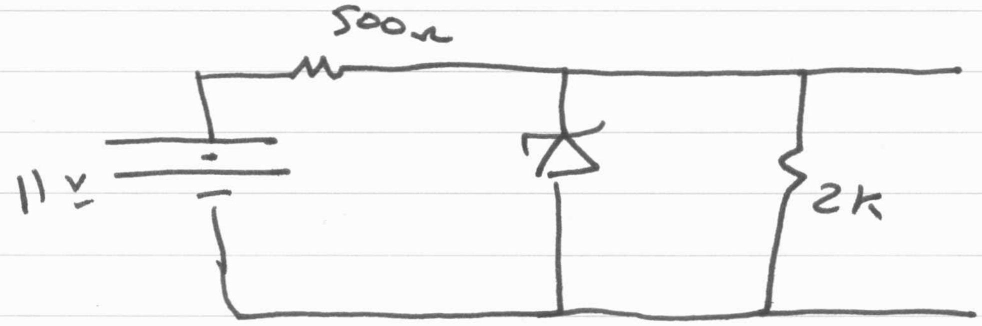
$$\frac{\Delta V_o}{\Delta I_L} = \frac{6.76-6.83}{3.38-0} = \frac{-70\,mV}{3.38\,mA} = -20.7\,\frac{mV}{mA}$$

b) <u>Line regulation</u> $= \dfrac{\Delta V_o}{\Delta V_s}$

1. when $V_i = 10\ \underline{v}$ $\qquad\qquad 11\,v \geq V_s \geq 10\ v$

$V_o = 6.76\ \underline{v}$

2. when $V_s = 11\ \underline{v}$



$V_{TH} = 8.8\ \underline{v}$
$R_{TH} = 0.4K$

$V_o = V_{zo} + r_z I_z$

$$V_o = 6.7 + 20\left(\frac{8.8 - 6.7}{420}\right) = 6.8$$

$$\frac{\Delta V_o}{\Delta V_s} = \frac{6.8 - 6.76}{11-10} = +38\ \frac{mv}{v}$$

For the following circuit; calculate and sketch the output voltage for

$v_s(t) = 10 \sin \omega t$ V

given $V_Z = 5$ V

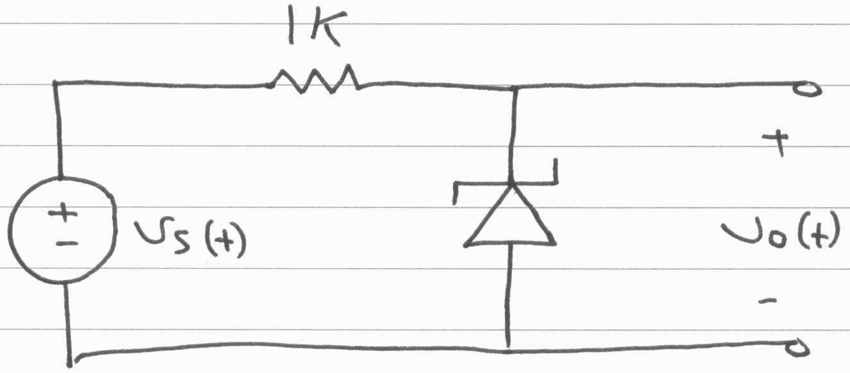


Fig. (1)

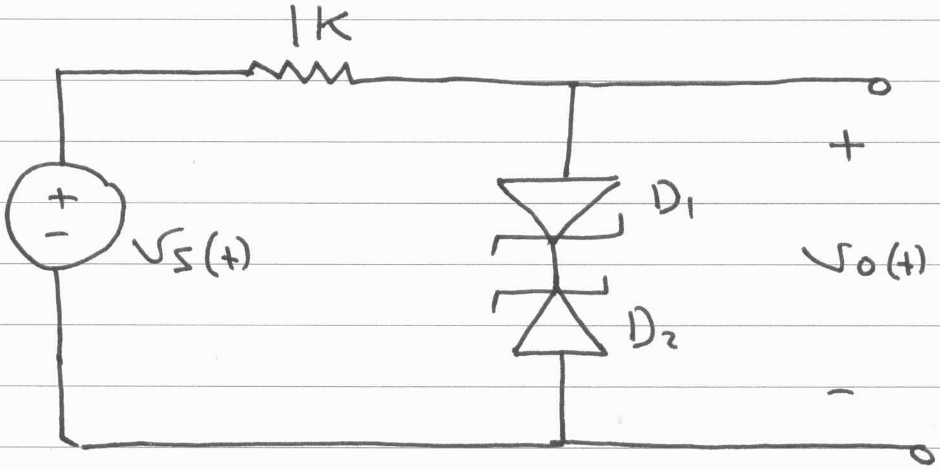


Fig. (2)