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Problems on Zener diode voltage regulator

Important mathematical expressions on Zener diode voltage regulator:

1. **Design of R:**

Current through the Zener diode depends on input voltage. When the input voltage is maximum, Zener current is maximum and should not increase $I_{Z(max)}$ rating of the Zener diode. In order to limit this, minimum value of R should be selected.
Similarly, when the input voltage is minimum, Zener current is also minimum and it should not fall below $I_{Z(min)}$ in order to do so maximum value of R should be selected.
Hence, in voltage regulator circuit, R acts as a current limiting resistor.

W.K.T.,

$$R = \frac{V_{in} - V_Z}{I} --- (1)$$

Assume I_L is constant

$$\text{If } V_{in} = V_{in}(max)$$
$$I_z = I_Z(max)$$
$$I = I_Z(max) + I_L$$
$$R_{min} = \frac{V_{in}(max) - V_Z}{I_Z(max) + I_L} --- (2)$$
$$\text{If } V_{in} = V_{in}(min)$$
$$I_Z = I_Z(min)$$
$$I = I_z(min) + I_L$$
$$R_{max} = \frac{V_{in}(min) - V_Z}{I_Z(min) + I_L} --- (3)$$

2. **IF the voltage across the Zener diode is greater than the Zener diode voltage, then inly Zener diode is working under break down region.**
3. $$V_{out} = V_{in} * \frac{R_L}{R_L + R} --- (4)$$

And $Vout \geq V_Z --- (5)$

4. **Finding the Zener diode voltage regulator parameters**
5. $$I = \frac{V_{in} - V_Z}{R} --- (6)$$

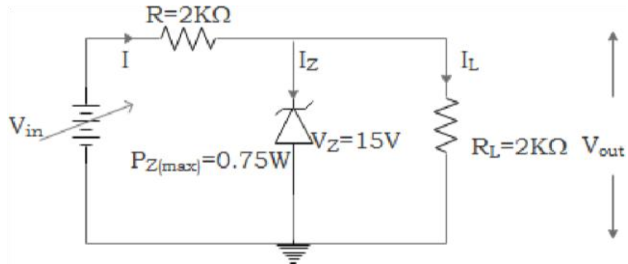
$P_Z = V_Z * I_Z - - - (7)$
$I = I_Z + I_L - - - (8)$

6. If RL is variable

$$R_L = R_L(max)$$
$$I_L = I_L(min)$$
$$I = I_Z(max) + I_L(min)$$
$$R_L = R_L(min)$$
$$I_L = I_L(max)$$
$$I = I_Z(min) + I_L(max)$$

Solved Problems

1. **Find the currents I, Iz and IL for the Zener diode voltage regulator circuit shown in figure, justify, how the circuit maintains constant voltage across the load if the input supply increases from 40V to 80 V**



Given data:

$$V_{in(minimum)} = 40V, V_{in(maximum)} = 80V, P_Z(maximum) = 0.75W, V_Z = 15V, R = 2R_L = 2K\Omega$$

To find:

I, I_Z, I_L *and justification for line regulation* **Solution:**

Verify the Zener diode is in the breakdown region or not, by finding the potential at the cathode terminal of the Zener diode.

$$V_{out} = V_{in} * \frac{R_L}{R_L + R}$$

If $V_{in} = 40V$, $V_{out} = 20$ V ($> V_Z$, hence Zener diode is in break down region)

If $V_{in} = 80V$, $V_{out} = 40$ V ($> V_Z$, hence Zener diode is in break down region)

$$P_Z = V_Z * I_Z => 0.75W$$

$$I_Z = 50mA$$

$$I_L = \frac{V_Z}{R_L} => \frac{15}{2K} => 7.5mA$$

$$I = \frac{V_{in} - V_Z}{R}$$

$$I_{min} = 12.5mA \text{ and } I_{max} = 32.5mA \text{ for } V_{in} 40 \text{ V and } 80V \text{ respectively}$$

Justification: If V_{in} varying from 40V to 80V, the reverse voltage applied across the Zener diode is greater than the Zener voltage, hence Zener diode is under break down region and it acts as a voltage source of V_Z volts. R_L is connected across the V_Z and hence output voltage is a constant 15V.

2. Zener diode voltage regulator circuit is designed to provide 20V constant voltage across the load of 2K Ohms, if the input is 50V find the value of series resistance required. Also find diode current. Given PZ=0.5W and VZ =20V.

Given data:

$P_Z = 0.5W, V_{out} = V_Z = 20V, R_L = 2KOhms, V_{in} 50V.$

To find:

, Z   R I

$$R = \frac{V_{in} - V_Z}{I}$$
$$I = I_Z + I_L$$
$$I_Z = \frac{P_Z}{V_Z} => 25mA$$
$$I_L = \frac{V_Z}{R_L} => 10mA$$
$$I = 35mA$$
$$R = 24.48KOhms$$

Solution:

3. In a Zener diode voltage regulator circuit, the output requirements are 5V and 20mA across the load, if Zener current are 5mA and 20mA, find the value of R required. Given input DC is 10V±20%.

Given data:

$I_Z(min) = 5mA$, $I_Z(max) = 60mA$, $V_{out} = 5V$, $I_L = 20mA$, $V_{in} = 10V \pm 20\%$ To Find:

$R\_$ min and

R_max Solution:

$$V_{in(min)} = 10 - 20\% * 10 = 8V$$
$$V_{in(max)} = 10 + 20\% * 10 = 12\,V$$
$$R_{min} = \frac{V_{in}(max) - V_Z}{I_L + I_Z(max)} => 87.5\ Ohms$$
$$R_{max} = \frac{V_{in}(min) - V_Z}{I_L + I_Z(min)} => 120\ Ohms$$

Average of Rmin and Rmax can be connected to the circuit. Hence **R≈100Ohms**