Experiment #6- Part#2

Zener Diode Application

- **The Zener Diode as a Voltage Regulator**

The zener diode is often used as a voltage regulator in DC power supplies. Fig.4 presents a simple voltage regulator circuit. In this circuit, the zener diode should maintain a constant output voltage against variations in input voltage Vin, or load resistance RL. Resistor RS is used as a series current limiting resistor.

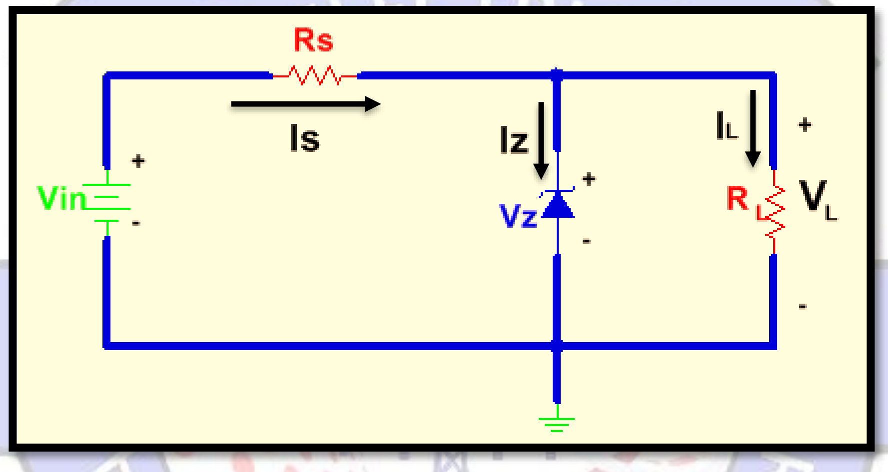

Figure 4: Simple Zener Diode Voltage Regulator

The analysis of the circuit depends on the state of the zener diode if it enters the zener breakdown region or not. To determine the state of the zener diode, we can remove it from the circuit temporarily and calculate the voltage across the open circuit. The load voltage in this case can be obtained from the voltage divider rule:

$$V_L = \frac{R_L . V_{in}}{R_S + R_L}$$

If $V_L \geq V_Z$, then the zener diode is ON, and the appropriate equivalent model can be substituted. On the other hand, if $V_L < V_Z$, the zener diode is OFF, and it is substituted with an open circuit.

When the zener diode operates in its zener breakdown region, it can be substituted simply with a constant voltage source V_Z. In this case:

$$V_L = V_Z$$

The source current $I_S$can be found from the equation:

$$I_S = \frac{V_{in} - V_Z}{R_S}$$

The load current is calculated as the ratio of load voltage to load resistance:

$$I_L = \frac{V_L}{R_L}$$

The zener current is obtained by applying Kirchhoff's current law:

$$I_Z = I_S - I_L$$

The power dissipated by the zener diode is determined from:

$$P_Z = V_Z . I_Z$$

This value of $P_Z$must be less than the maximum power rating of the diode P_{ZM}in order to avoid damaging the zener diode.

- **Zener Voltage Regulator with a Variable Load Resistance**

Fig.5 shows a zener voltage regulator with a variable load resistor across the output terminals. The zener diode maintains a nearly constant voltage across RL as long as the zener current is greater than I_{ZK} and less than I_{ZM}. This is called load regulation.

When the output terminals of the zener regulator are open ($R_L = \infty$), the load current is zero and the entire source current IS passes through the zener diode. When a load resistor $R_L$is connected, part of the source current passes through the zener diode, and part through R_L. As

$R_L$is decreased, the load current $I_L$increases and $I_Z$decreases. The source current passing through $R_S$remains essentially constant.

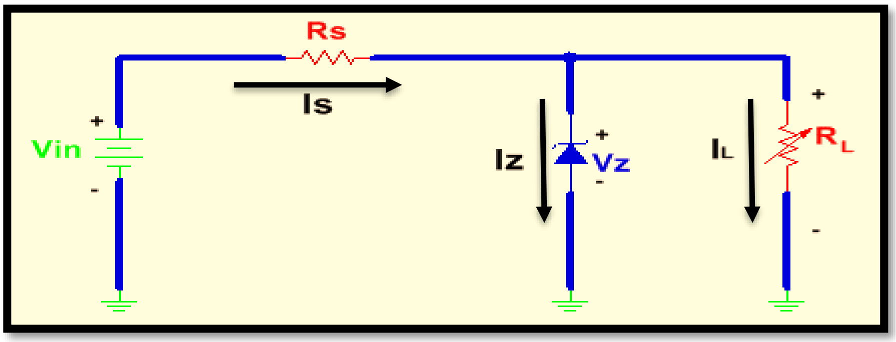

Figure 5: Zener Regulator with Variable Load Resistance and Fixed Input Voltage

To determine the minimum load resistance that will turn on the zener diode, we simply calculate the value of R_L that will result in a load voltage $V_L = V_Z$. Assuming I_{ZK}=0, we have from voltage divider rule:

$$V_L = V_Z = \frac{R_L . V_{in}}{R_S + R_L}$$

Solving for R_L yields:

$$R_{L(\text{min})} = \frac{R_S . V_Z}{V_{in} - V_Z}$$

- **Zener Voltage Regulator with a Variable Input Voltage**

Fig.6 illustrates how a zener diode can be used to regulate a varying input DC voltage. This is called input or line regulation.

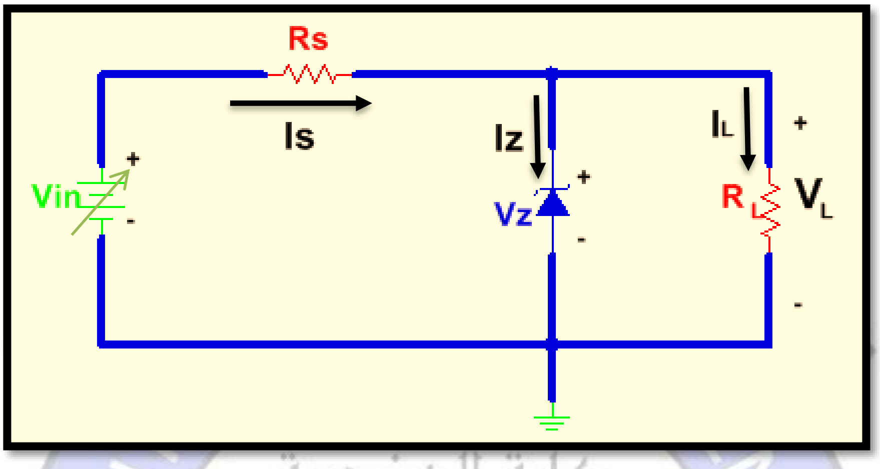

Figure 6: Zener Regulator with Variable Input Voltage and Fixed Load Resistance

For fixed values of R_L , the input voltage must be sufficiently large to turn on the zener diode. Neglecting I_{ZK} , the minimum turn-on voltage is determined by:

$$V_L = V_Z = \frac{R_L . V_{in}}{R_S + R_L}$$

Solving for V_{in}, we have:

$$V_{in(\min)} = \frac{(R_S + R_L). V_Z}{R_L}$$

The maximum value of $V_{in}$is limited by the maximum zener current I_{ZM}. We have:

$$I_{s(\max)} = I_{ZM} + I_L$$

I_L is given by:

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L}$$

Therefore, the maximum input voltage is given by:

$$V_{in(\max)} = I_{s(\max)} . R_S + V_Z$$

Or,

$$V_{in(\max)} = \left(I_{ZM} + \frac{V_Z}{R_L}\right) . R_S + V_Z$$