# Experiment: ZENER VOLTAGE REGULATOR

**AIM:** To study Zener diode as a voltage regulator

**Equipment and Components::** Zener diode, multimeter, breadboard, power supply, resistors, connecting wires.

**THEORY:** Zener diode is a P-N junction diode specially designed to operate in the reverse biased mode. Zener diode acts like a normal diode in the forward bias condition. In reverse bias, at a particular voltage known as Zener breakdown voltage, the current through the diode increases sharply. In the case of a normal PN junction diode, the diode damages at the breakdown voltage. However, when operated Zener voltage, if the power consumption through the diode is limited, the Zener diode can be safely operated in the reverse breakdown region, an important characteristic of a Zener diode is it Zener breakdown. The reason for Zener conduction is as follows. The depletion region in a diode is a function of doping concentration and bias voltage. When a diode is heavily doped, the depletion region will be very thin. By applying a suitable voltage, a strong electric field across the junction is created. The carriers form one side of the junction can cross the junction to reach on the other side and in this process, electron-hole pairs are generated, which are swept away by the inbuilt electric field across the junction. Once the voltage across the diode reaches a value, known as Zener voltage, $V_Z$, the current flow increases sharply, and heavy current starts flows. This phenomenon is known as Zener break down. Once the Zener breakdown condition is reached, the voltage across the diode remains constant. If the current flow is not controlled, due to excess heat, the diode breaks down. This characteristic of Zener diodes is used to design voltage regulator circuits. The circuit shown in fig.1 describes a Zener voltage regulator.

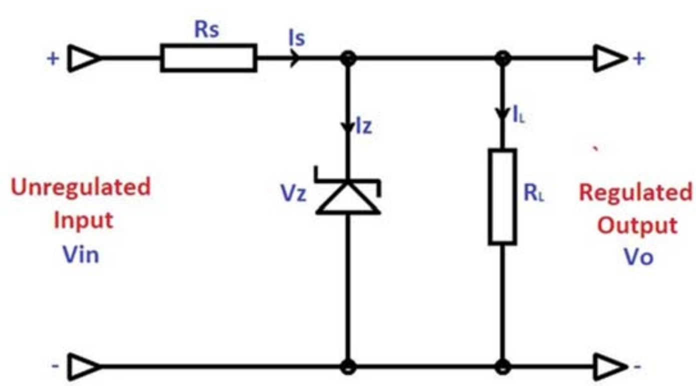


Fig. 1: Schematic representation of a Zener voltage regulator

The voltage regulator circuit consists a current limiting resistor $R_S$ connected in series with an unregulated input voltage $V_s$ and Zener diode with a zener voltage $V_Z$. The proper functioning of a voltage regulator requires a voltage drop equal to $V_Z$ across the zener diode. The load resistance $R_L$ is connected in parallel to the Zener diode. In reverse bias, the output voltage across the zener diode is limited to a maximum of $V_z$.

From the circuits shown in Fig. 1, the current in the circuit can be written as in (1).

$$I_S = I_Z + I_L \tag{1}$$

The voltage drop across the series resistance $R_S$ is given by (2). Where $V_Z$ is the voltage across the diode.

$$V_{R_S} = V_{in} - V_Z \tag{2}$$

Thus, $I_S$ is given by (3).

$$I_S = \frac{V_{in} - V_Z}{R_S} \tag{3}$$

From (1) and (3),

$$\frac{V_{in} - V_Z}{R_S} = I_Z + I_L \tag{4}$$

**Line Regulation:** In line regulation, for a fixed load, the variation of input on the load voltage is studied. Line regulation is defined as the change in regulated voltage with respect to variation in line voltage. In line regulation, for a given load resistance, as the input voltage varies, the load current remains constant. If the input voltage increases, as given by (3), $I_S$ also varies accordingly. Therefore, Zener current $I_z$ increases. The extra voltage drops across the series resistance $R_S$. The minimum current that can flow through Zener diode $I_{Zmin}$ = 0 A. The maximum current that can flow through Zener diode is $I_{Zmax}$ is determined by the maximum power the Zener diode can withstand in the reverse bias. If $P_{Zmax}$ is the maximum power that a Zener can withstand, then $I_{Zmax}$ is given by (5).

$$I_{Zmax} = \frac{P_{Zmax}}{V_Z} \tag{5}$$

Even though an increment in $I_z$ will still have a constant $V_Z$ equal to $V_{out}$, the output voltage will remain constant. If $V_{in}$ decreases, $I_Z$ decreases, but a constant load current results in a reduced $I_S$, and the voltage drop across Rs reduces. Even though $I_Z$ may change, $V_Z$ remains constant. Hence, the output voltage remains constant.

**Load regulation:** Load regulation is defined as a change in load voltage with respect to variations in the load current. In load regulation, the input voltage is constant, and the output voltage varies due to change in the load resistance value. In load regulation, input voltage $V_{in}$, $I_S$, and $R_S$ constant. As the voltage across the load resistance is fixed at $V_Z$, a change in load current is compensated by a change in the Zener current Iz, but in an opposite sense, meaning an increase in $I_L$ results in a reduction in $I_Z$ and vice-versa. Form the reverse bias characteristics of a Zener diode, even $I_Z$ changes, $V_Z$ remains constant. Hence, the output voltage remains fairly constant.

**PROCEDURE:-**

**A) Line Regulation:**

1. Connect the circuit as shown in fig. 1.
2. Keep load resistance fixed value; vary DC input voltage ($V_{in}$) from $V_Z \pm 0.4V_Z$ to 15V.

**Observation Table for Line Regulation:**

| S.No. | $V_{in}$ (volts) | $V_L$ (in volts) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

3. Plot the graph between $V_{in}$ versus $V_L$.
4. When the output voltage, $V_{HL}$, as a load voltage with high line (input) voltage; and the output voltage $V_{LL}$, as a load voltage with low line (input) voltage.
5. Calculate the percentage line regulation (LR) is given by (6). Here $V_{NOM}$ is the nominal load voltage under the typical operating conditions. For ex. $V_{NOM} = 9.5 \pm 4.5$ V.

$$LR = \frac{V_{HL} - V_{LL}}{V_{NOM}} \times 100 \qquad (6)$$

**Load Regulation:**

1. For finding load regulation, connect the circuit as shown in fig. .
2. Keep input voltage constant say 10V, vary load resistance value.

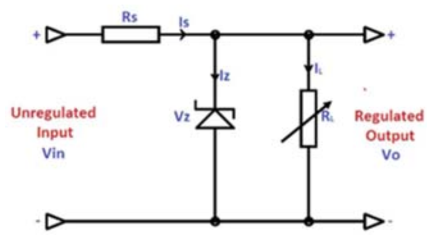


Fig. 2: Load regulation

**Observation Table for Load Regulation:**

| S.no. | $R_L$ (in ohm) | $V_L$ (in volts) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

3. Plot the graph between $V_L$ vs $R_L$.
4. From the graph, note down output voltage as a load voltage with high line voltage '$V_{HL}$' and as a load voltage with low line voltage '$V_{NL}$.' Here $V_{NL}$ is the load voltage at no load meaning, $I_L = 0$ and $V_{FL}$ is the load voltage at full load when $I_L = I_{Lmax}$.
5. The load regulation is given by (7).

$$\%\ load\ \ regulation\ = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100 \tag{7}$$

**CONCLUSIONS:**