Experiment No. 4

To Plot the V-I characteristics of a Zener diode, find Zener breakdown voltage in reverse bias condition, find static and dynamic resistance in both forward and reverse bias conditions and perform Zener diode voltage regulator.

Apparatus required: Bread Board, Zener Diodes, Resistors –1kΩ, Digital Multimeter, DC Ammeters (0-200mA), Regulated Power Supply(0-30V), Connecting wires.

Theory

A Zener diode is heavily doped p-n junction diode, specially made to operate in the break down region. A p-n junction diode normally does not conduct when reverse biased. But if the reverse bias is increased, at a particular voltage it starts conducting heavily. This voltage is called Break down Voltage. High current through the diode can permanently damage the device.

To avoid high current, we connect a resistor in series with Zener diode. Once the diode starts conducting it maintains almost constant voltage across the terminals whatever may be the current through it, i.e., it has very low dynamic resistance. It is used in voltage regulators.

A portion of the reverse characteristic of the Zener diode where the current increases suddenly and the reverse current becomes almost independent of the voltage across Zener diode is known as breakdown region of the given Zener diode. This portion is very important for voltage regulation purpose.

The value of current limiting resistance (R_S) is determined by maximum allowable current through the given Zener diode. If I_{Zm} be the maximum allowable Zener current, then

$$R_S = \frac{V_i - V_Z}{I_{Zm}} = \frac{V_i - V_Z}{P_Z/V_Z} = \frac{V_i - V_Z}{P_Z} V_Z$$

Where P_Z is the power rating of the given Zener diode, say ¼ Watt and V_Z is the Zener breakdown voltage, say 5.6 Volt. So for input voltage 10 volt, the value of series resistance becomes $\frac{10.0-5.6}{1/4} \times 5.6 = 98.56 \approx 100$ Ohm.

The wattage rating of series resistance would be $(V_i - V_Z) \times I_{Zm} = (10.0 - 5.6) \times \frac{\frac{1}{4}}{5.6} = 0.1964 \approx 0.20 \approx \frac{1}{5}$ *Watt.*

Minimum value of load resistance (R_L) required to achieve Zener breakdown region is given by $R_L = \frac{V_Z}{I_{Zm}} = \frac{V_Z}{P_Z/V_Z} = \frac{5.6}{1/4} \times 5.6 \approx 125$ Ohm.

For forward Bias

Static resistance $R_f = \frac{V_f}{I_f}$ .... (1)

Dynamic resistance $r = \frac{\Delta V_f}{\Delta I_f}$ .... (1a)

For Reverse Bias

Static resistance $R_R = \frac{V_R}{I_R}$ .... (2)

Dynamic resistance $r = \frac{\Delta V_R}{\Delta I_R}$ .... (2b)

If V_{NL} be the no-load voltage across the Zener diode and V_L be the voltage across the Zener diode or load at the rated load current, then the Load regulation percentage is given by

$$R = \frac{V_{NL} - V_L}{V_L} \% \quad \text{.........} (3)$$

The variation of the output voltage due to variation of the input at a fixed load resistance is known as line regulation characteristics of the given Zener diode. The input regulation factor at a rated load voltage is given by

$$S_i = \frac{\textit{change in load voltage } (\Delta V_L)}{\textit{change in input voltage } (\Delta V_i)}$$

Steps to be followed

Forward Bias

1. Arrange the circuit with proper value of series resistance (R_S) as shown in **Fig. 4.1.**
2. Vary the input voltage (V_I) in steps and measure the forward voltage (V_F) across the diode using digital Voltmeter or multimeter and forward current (I_F) through diode using Ammeter.
3. Tabulate the values of V_F and I_F. At the knee point when the forward current just starts to increase, take reading in close intervals.
4. By using the values of V_F and I_F, plot the forward bias characteristics.
5. At suitable operating point in the characteristic, calculate the static and dynamic resistance of diode using the formula given in the theory.

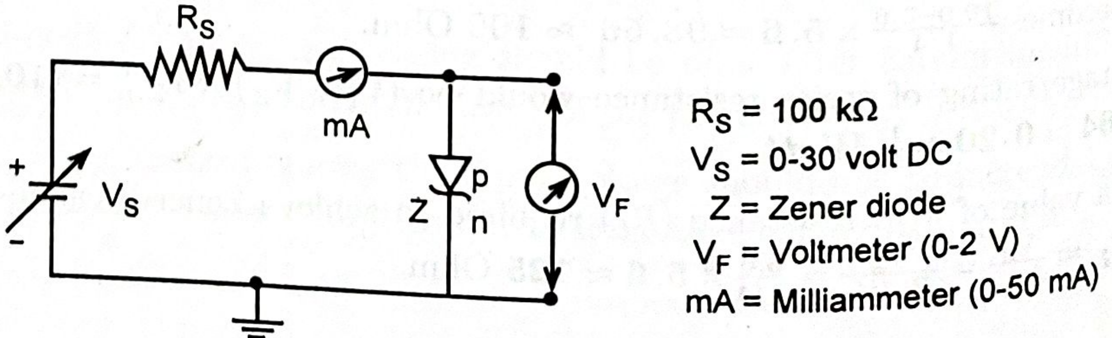
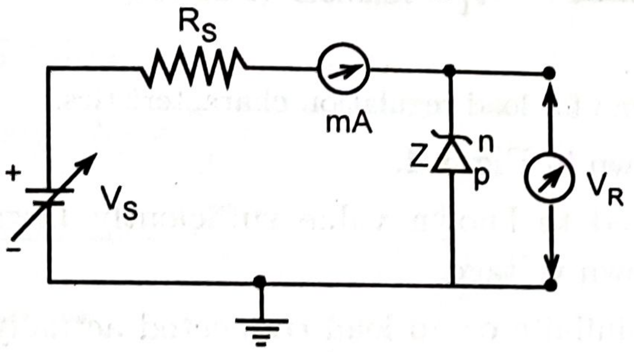


Fig.4.1: Circuit diagram of forward bias characteristics.

Reverse Bias

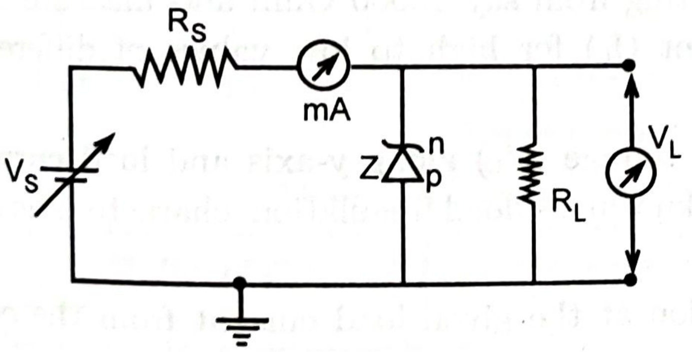
1. Arrange the circuit with proper value of series resistance (R_S) as per the given circuit diagram in **Fig. 4.2.**
2. Vary the reverse input voltage (V_I) in steps and measure the reverse voltage (V_R) across the diode using digital voltmeter or digital multimeter and reverse current (I_R) through diode using micro ammeter.
3. Tabulate the values of V_R and I_R. At the knee point when the forward current just starts to increase, take reading in close intervals.
4. By using the values of V_R and I_R, plot the reverse bias characteristic curve.
5. At suitable operating point in the characteristics, calculate the static and dynamic resistance of diode given in the theory.



R_S = 100 kΩ
V_S = 0-30 volt DC
Z = Zener diode
V_R = Voltmeter (0-20 V)
mA = (0-50 mA)

Fig.4.2: Circuit diagram for the reverse bias characteristics.

Line Regulation Characteristics



R_S = 100 Ω
V_S = 0-30 volt DC
mA = Milliammeter (0-100 mA)
Z = Zener diode
R_L = load resistance box (0-50,000 Ω)
V_L = Voltmeter (0-20 volt)

Fig.4.3: Circuit diagram for line regulation characteristics.

1. Arrange the circuit as shown in **Fig. 4.3.**
2. The load resistance is fixed to known value (about five times the value of series resistance).
3. Vary the input voltage from zero in suitable steps and measure the input voltage (V_I) with a digital dc voltmeter and the corresponding load voltage (V_L) using digital voltmeter.
4. Draw the graph taking input voltage (V_I) along x-axis and load voltage (V_L) along y-axis.
5. Observe the value of input voltage above which the load voltage is almost constant. The Zener diode is fired or got breakdown region at that value of input voltage.

6. Calculate the input regulation factor from the graph at a rated load voltage is given by

$$S_i = \frac{change\ in\ load\ voltage\ (\Delta V_L)}{change\ in\ input\ voltage\ (\Delta V_i)}$$

Load Regulation Characteristics:

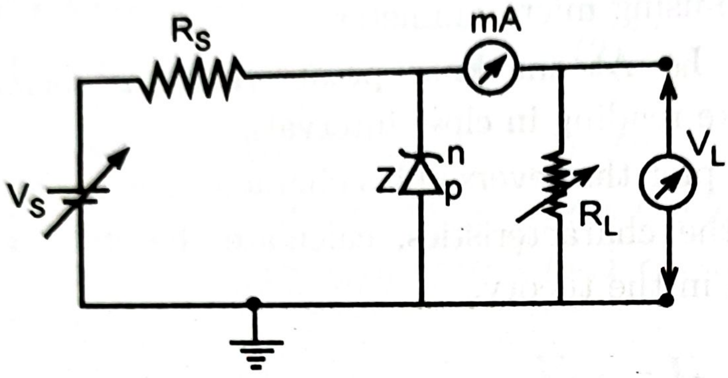


Fig.4.4: Circuit diagram for load regulation characteristics.

1. Arrange the circuit as shown in **Fig.4.4**.
2. Set the input voltage fixed to known value sufficiently larger (almost 1.5 times) than Zener breakdown voltage.
3. Set the load resistance to infinite or no load connected actually and note the no load voltage V_{NL}) from the voltmeter. In this situation no load current is passing obviously.
4. Vary the load resistance starting from say 10000 Ohm and measure the load voltage (V_L) and load current (I_L) for high to low values of different load resistances in steps.
5. Draw the graph taking load voltage (V_L) along y-axis and load current (I_L) along x-axis. This curve is known as load regulation characteristics of the given Zener diode.
6. Calculate percentage regulation at the given load current from the equation (3).

Experimental Observations

Table 1: Data for Forward biased I~V characteristics of the given diode No. ......

Sl. No. of obs	Source Voltage (V_I)(optional) in Volt	Forward Voltage (V_F) against diode in Volt	Forward current (I_F) in mA

Table 2: Data for Reverse biased I~V characteristics of the given diode No. ......

Sl. No. of obs	Source Voltage (V_I) (optional) in Volt	Reverse Voltage (V_R) against diode in Volt	Reverse current (I_R) in mA

Calculation: Plot I~ V graph for both types of biasing and obtain the following.

For forward Bias

Static resistance $R_f = \frac{V_f}{I_f} = ...$

Dynamic resistance $r = \frac{\Delta V_f}{\Delta I_f}$

For Reverse Bias

Static resistance $R_R = \frac{V_R}{I_R}$

Dynamic resistance $r = \frac{\Delta V_R}{\Delta I_R}$

Table 3: Data for Reverse biased line regulation characteristics of the given Zener diode No. ......

The fixed load resistance (R_L) =....... Ohm

Sl. No. of obs	Source Voltage (V_I) in Volt	Load Voltage (V_L) in Volt

Table 4: Data for Reverse biased Load regulation characteristics of the given Zener diode No. ......

Fixed Input Voltage: ...... Volt

Sl. No. of obs	Value of Load resistance (R_L) (optional) in Ohm	Load Voltage (V_L) in Volt	Load current (I_L) in mA
1	∞	.....	0

Calculation: Plot $I_L \sim V_L$ graph for both line and load regulations.

Line Regulation percentage

$$S_i = \frac{change\ in\ load\ voltage\ (\Delta V_L)}{change\ in\ input\ voltage\ (\Delta V_i)}$$

Load regulation percentage

$$R = \frac{V_{NL} - V_L}{V_L}\ \%$$

Discussions

1. Ensure that the polarities of the power supply and the meters as per the circuit diagram.
2. Ensure the proper value of series resistance and its wattage to protect the circuit from burn out.
3. Be sure that load terminal never short circuited to avoid huge current flows that results in burn out.
4. During load regulation the load current should not be very high, in that case the voltage across the Zener becomes very low and may not reach the breakdown voltage.
5. During line regulation, the load resistance should be about five times the R_S value. It ensures that during input voltage variation of 0 to 10 volt, the voltage across the Zener reaches the breakdown region for a significant portion of the input voltage variation part.
6. Keep the input voltage knob of the regulated power supply in minimum position both when switching ON or switching OFF the power supply.
7. Ensure that the ratings of the meters are as per the circuit design for precision.