Experiment

Setting up a power supply using a Zener Diode as Voltage Regulator

1 Objectives

To set up a power supply using a Zener diode as a voltage regulator and to calculate percentage of regulation.

2 Circuit components/equipment

1. A Zener diode
2. Resistor (value 1 kΩ to 5 kΩ)
3. Breadboard
4. Capacitor
5. Multimeters
6. Connecting wire

3 Theory

Zener diodes are generally used in the reverse bias mode. You have seen already in one of your previous experiments that the Zener diode has a region of almost a constant voltage in its reverse bias characteristics, regardless of the current flowing through the diode. This voltage across the diode (Zener Voltage, V_Z) remains nearly constant even with large changes in current through the diode caused by variations in the supply voltage or load. This ability to control itself can be used to great effect to regulate or stabilize a voltage source against *supply* or *load* variations. The Zener diode maintains a constant output voltage until the diode current falls below the minimum I_Z value in the reverse breakdown region, which means the supply voltage, V_i, must be much greater than V_Z for a successful breakdown operation. When no load resistance, R_L, is connected to the circuit, no load current ($I_L = 0$), is drawn and all the circuit current passes through the Zener diode which dissipates its maximum power. So, a suitable current limiting resistor, (R_S) is always used in series to limit the Zener current to less than its maximum rating under this “no-load” condition.

From the previous experiments on rectifiers, you know that the d.c. output voltage from the half or full-wave rectifiers contains ripples superimposed on the DC voltage and that the average output voltage changes with load. As shown in the circuit diagram, a more stable reference voltage can be produced by connecting a simple Zener regulator circuit across the output of the rectifier. The breakdown condition of the Zener can be confirmed by calculating the Thevenin voltage, V_{TH}, facing the diode is given as:

$$V_{TH} = V_i \frac{R_L}{R_S + R_L}$$

This is the voltage that exists when the Zener is disconnected from the circuit. Thus, V_{TH} has to be greater than the Zener voltage to facilitate breakdown. Now, under this breakdown condition, irrespective of the load resistance value, the current through the current limiting resistor, I_S, is given by

$$I_S = \frac{V_i - V_Z}{R_S}$$

The output voltage across the load resistor, V_L, is ideally equal to the Zener voltage and the load current, I_L, can be calculated using Ohm's law.

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

Thus, the Zener current, I_Z, is

$$I_Z = I_S - I_L$$

Now that you have constructed a basic power supply, its quality depends on its load and line regulation characteristics as defined below.

1. **Load regulation:** It indicates how much the load voltage varies when the load current changes. Quantitatively, it is defined as:

   $$\text{Load regulation } = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100,$$

   where V_{NL} is the no load voltage with the no load current ($I_L = 0$) and V_{FL} is the full load current. The smaller the regulation, the better is the power supply.

2. **Line regulation:** It indicates how much the load voltage varies when the input line voltage changes.

   Quantitatively, it is defined as

   $$\text{Line regulation } = \frac{V_{HL} - V_{LL}}{V_{LL}} \times 100,$$

   where V_{HL} is the load voltage with high input line voltage, and V_{LL} is the load voltage with low input line voltage. As with load regulation, the smaller the regulation, the better is the power supply.

4 Circuit diagram

The circuit diagram of a zener diode regulated power supply is shown in Figure 1. V_Z is the zener breakdown voltage and V_L is voltage across load. V_i shows DC power supply (0 – 30 V) connection and mA is used to measure current using multimeter.

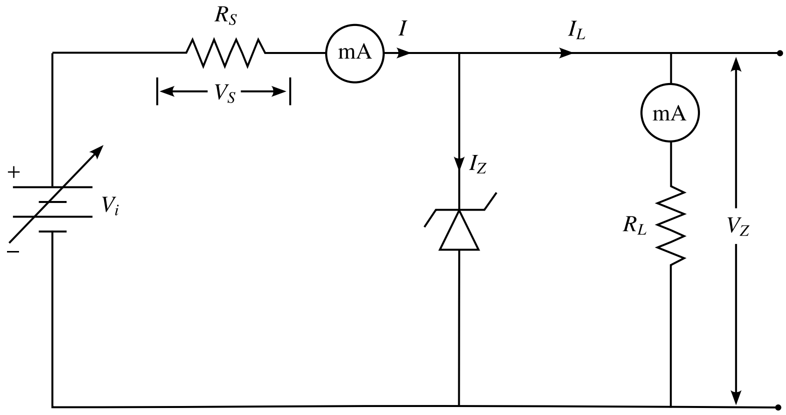

Figure 1: Circuit diagram of a zener diode regulated power supply.

5 Procedure

1. Make the circuit connection as shown in the above circuit diagram. Make sure all the connections are correctly made before connecting the power supply.
2. Connect DC power supply to supply input voltage
3. Note down all the values of the components being used including the Zener breakdown voltage. Use the Zener diode with breakdown voltage below 15 V.
4. Keeping input voltage suitably fixed, use different values of R_L and measure both the output DC voltage and current using multimeter (in DC mode). Calculate V_L before each measurement and ensure that the Zener is operating in breakdown region.
5. Similarly, keeping R_L fixed, vary the input voltage and measure again the output DC voltage, current and input unregulated DC voltage across capacitor. Calculate V_L before each measurement.
6. Tabulate all your data and calculate percentage regulation in each case.

6 Observations

Specifications of Zener diode

Breakdown voltage = ______ V
R_S = ______ kΩ

Table 1: Load regulation: Input unregulated DC voltage = ______ V.

Sl. No.	Load (R_L) (kΩ)	DC input voltage (V_i)	$V_{TH} = R_L V_i/(R_S + R_L)$ (V)	Output DC voltage (V_L) (V)	Output current (I_L) (mA)	Percentage regulation (%)
1				V_{FL} =		
2						
3						
				V_{NL} =		

Table 2: Line regulation: R_L = ______ kΩ.

Sl. No.	DC input voltage (V_i)	$V_{TH} = R_L V_i/(R_S + R_L)$ (V)	Output DC voltage (V_L) (V)	Output current (I_L) (mA)	Percentage regulation (%)
1			V_{LL} =		
2					
3					
			V_{HL} =		

7 Graphs

1. Plot graph of R_L vs. Output voltage (V_L)
2. Plot graph of V_i vs. Output voltage (V_L).
3. Plot graph of I_L and V_L for each set of observations.

8 Results

9 Precautions

1. While doing the experiment do not exceed the readings of the diode. This may lead to damaging of the diode.
2. Do not exceed input voltage beyond 15 V.
3. Connect voltmeter and ammeter in correct polarities.
4. Do not switch ON the power supply unless you have checked the circuit connections as per the circuit diagram.