ZENER DIODES: AN EXTENSION OF SEMICONDUCTORS

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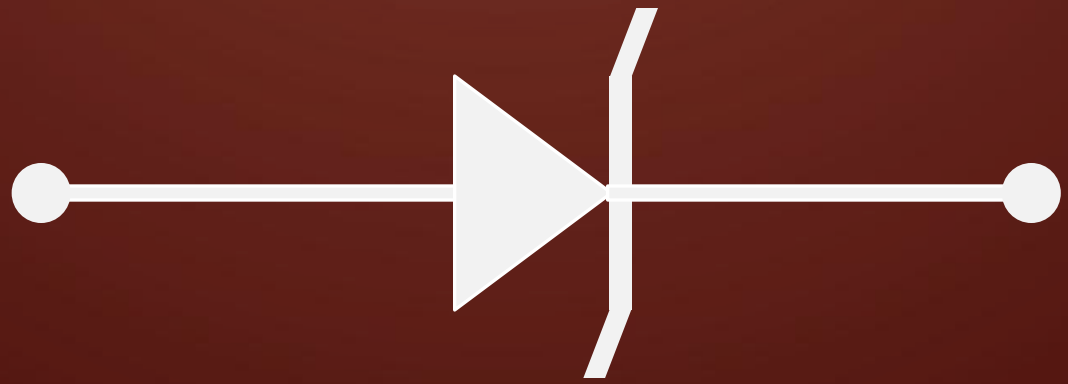
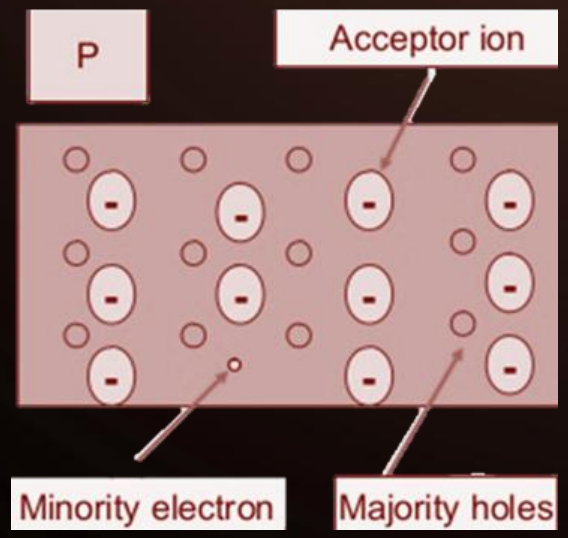
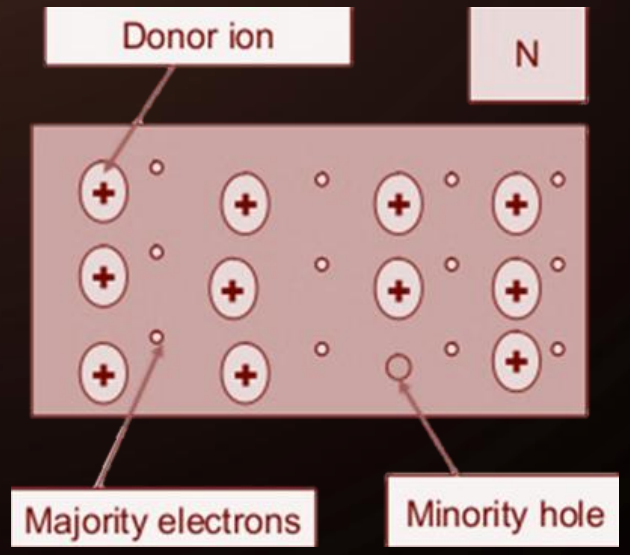


WHAT ARE SEMICONDUCTORS?

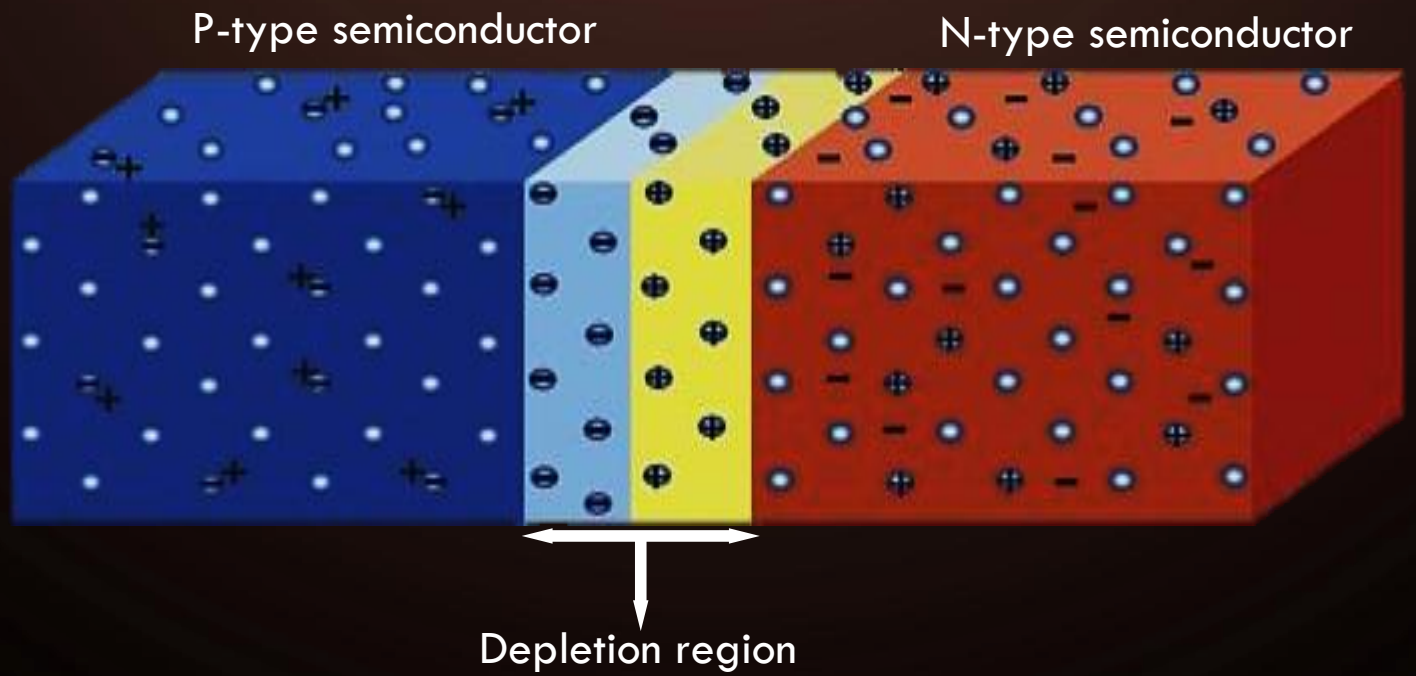
- Semiconductors are materials with electrical conductivity between that of conductors and insulators
- Two main types – P-type semiconductor and N-type semiconductor
- Their behavior can be controlled by doping, temperature, or applied voltage.





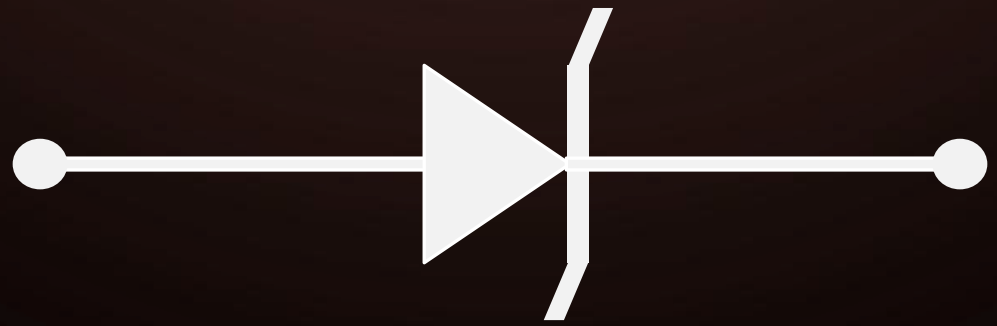
SEMICONDUCTOR DIODES

- A semiconductor diode is a device made from a p-n junction in a semiconductor material, allowing current to flow in one direction while blocking it in the opposite direction



WHAT ARE ZENER DIODES ?

- Zener diodes are a special class of diodes designed to operate in reverse breakdown mode.
- Two main types – Zener breakdown diode and Avalanche breakdown Diode
- Their primary function is to provide voltage regulation, protection, or voltage reference in electrical circuits.

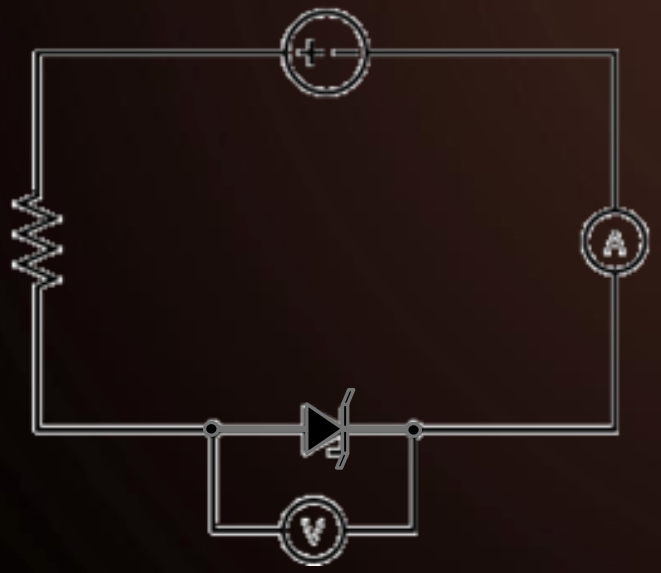


COMPARISON OF ZENER AND AVALANCHE DIODES

Features	Zener Breakdown	Avalanche Breakdown
Voltage Range	$V_Z < 5V$	$V_Z > 5V$
Breakdown mechanism	Quantum Tunneling	Impact Ionization
Temperature Coefficient (α)	Negative ($\alpha < 0$)	Positive ($\alpha > 0$)
Depletion Region Width	Narrow	Wider
Applications	Precision Voltage Regulation	Higher Voltage Applications

EXPERIMENT 1: DETERMINING THE BREAKDOWN VOLTAGE (V_Z) OF A ZENER DIODE

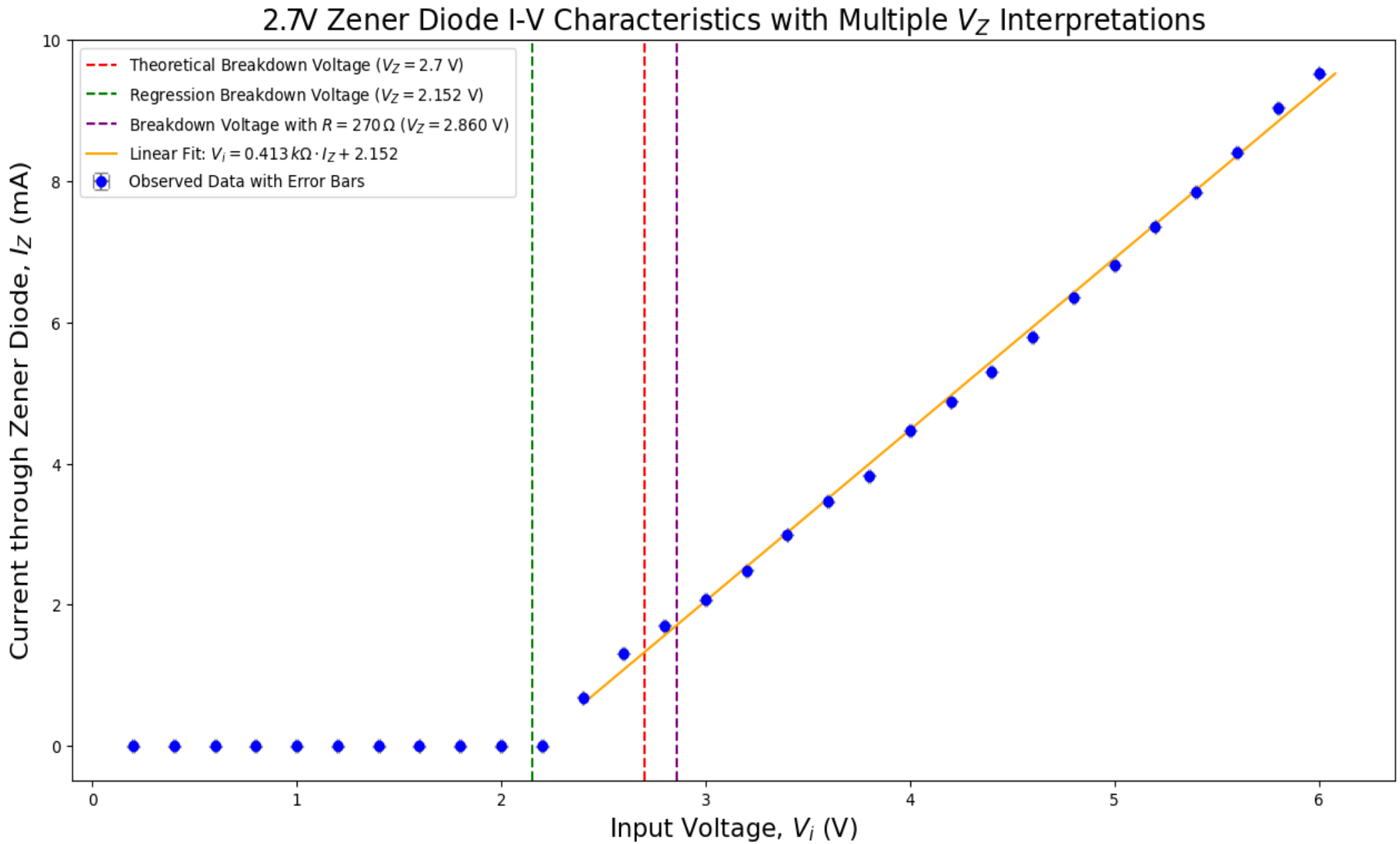
SETUP AND METHOD

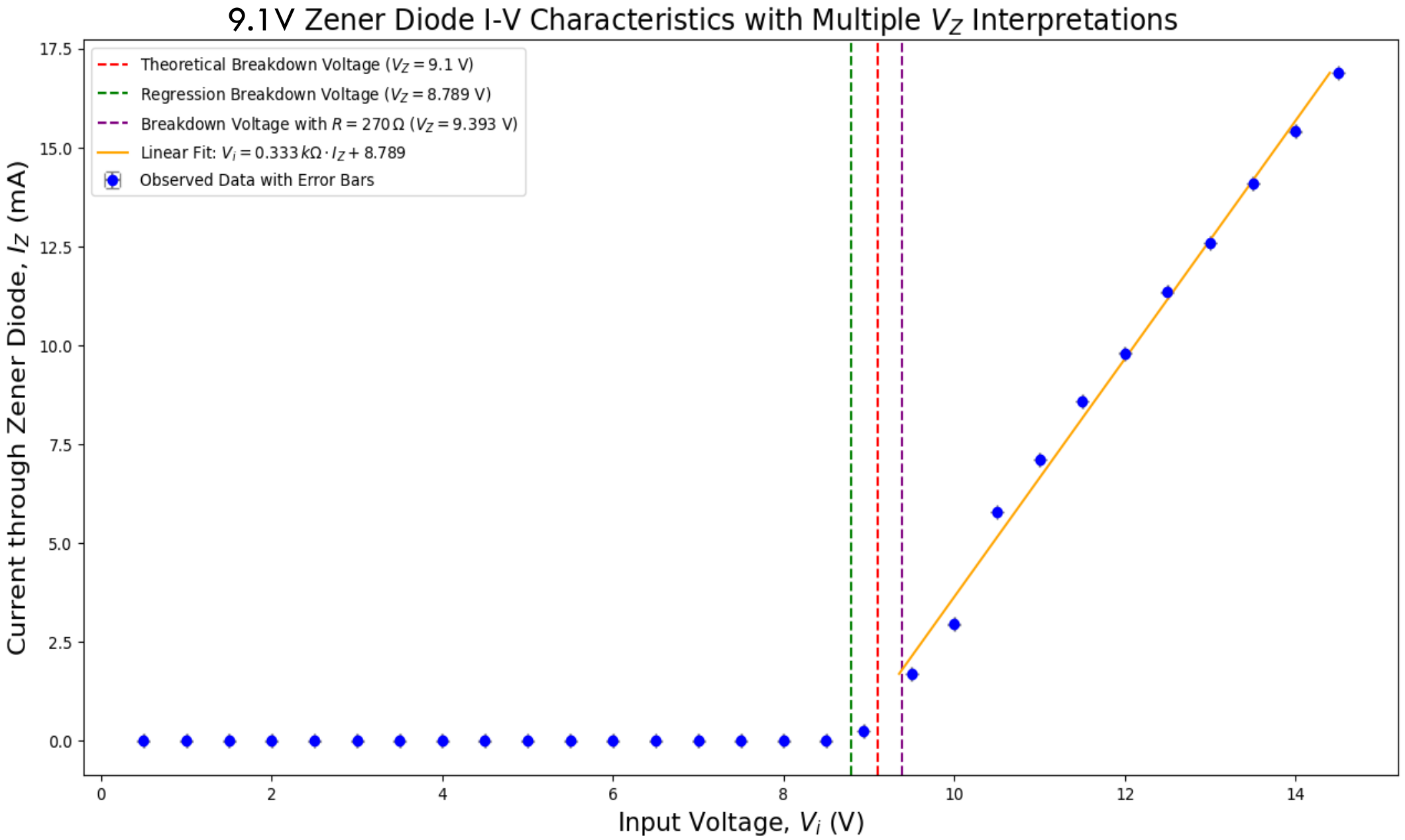


- A 270Ω resistor was used
- Input voltage, V_I was Gradually increase the from 0 V
- For each step, the following were record:
  - Voltage across the Zener diode, V_Z and V_I
  - Current through the Zener diode, I_Z
- The point where the voltage stabilizes was identified
- This was done for both Zener diode and Avalanche diode

RESULT AND ANALYSIS

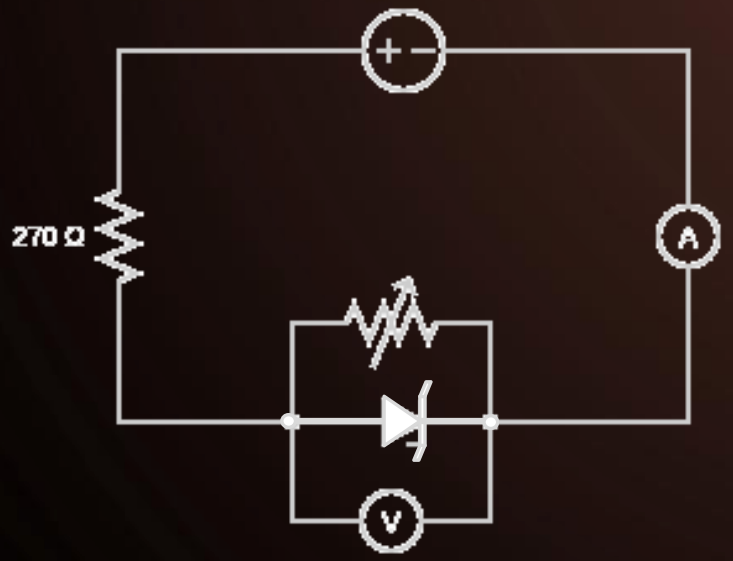
- Reverse I-V characteristics of the Zener diode was plotted
- The point where the current starts to increase rapidly and the voltage stabilizes, was located. This voltage is the breakdown voltage (V_Z).
- A linear regression and a verification was performed using the eq $V_I = I_Z R + V_Z$


2.7V Zener Diode I-V Characteristics with Multiple V_Z Interpretations
Theoretical Breakdown Voltage ($V_Z = 2.7$ V)
Regression Breakdown Voltage ($V_Z = 2.152$ V)
Breakdown Voltage with $R = 270\,\Omega$ ($V_Z = 2.860$ V)
Linear Fit: $V_i = 0.413\,k\Omega \cdot I_Z + 2.152$
Observed Data with Error Bars
Current through Zener Diode, I_Z (mA)
Input Voltage, V_i (V)
0
2
4
6
8
10
0
1
2
3
4
5
6


9.1V Zener Diode I-V Characteristics with Multiple V_Z Interpretations
Theoretical Breakdown Voltage ($V_Z = 9.1$ V)
Regression Breakdown Voltage ($V_Z = 8.789$ V)
Breakdown Voltage with $R = 270\,\Omega$ ($V_Z = 9.393$ V)
Linear Fit: $V_i = 0.333\,k\Omega \cdot I_Z + 8.789$
Observed Data with Error Bars
Current through Zener Diode, I_Z (mA)
Input Voltage, V_i (V)
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
2
4
6
8
10
12
14

EXPERIMENT 2: VOLTAGE REGULATION TEST

SETUP AND METHOD



- A 270Ω series resistor and a variable load resistor was used
- Input voltage, V_I was Gradually increase the from 0 V in small steps
- For each step, the following were record:
  - Voltage across the load resistor, V_Z and V_I.
  - Current through the Zener diode, I_Z
- This was done for a range of load resistances but was only done for the avalanche diode

RESULT AND ANALYSIS

- Similar V-I characteristics graph, to the previous experiment, were obtained
- The voltage across the load resistor or the Zener diode remains near constant at the breakdown voltage
- This was verified using different values of resistances

$V_z = 9.1\ V$

For 500 Ω

Vi	Vz
1	0.346
2	0.637
3	0.713
4	0.742
5	0.757
6	0.77
7	0.78
8	0.789
9	0.795
10	0.803
11	0.809
12	0.814
13	0.819
14	0.824
15	0.829

For 600 Ω

Vi	Vz
1	0.398
2	0.672
3	0.723
4	0.745
5	0.759
6	0.77
7	0.779
8	0.787
9	0.793
10	0.8
11	0.804
12	0.81
13	0.814
14	0.819
15	0.824

For 700 Ω

Vi	Vz
1	0.42
2	0.683
3	0.739
4	0.768
5	0.793
6	0.814
7	0.833
8	0.849
9	0.866
10	0.88
11	0.82
12	0.827
13	0.832
14	0.839
15	0.845

For 800 Ω

Vi	Vz
1	0.481
2	0.692
3	0.732
4	0.754
5	0.769
6	0.78
7	0.79
8	0.789
9	0.796
10	0.801
11	0.806
12	0.811
13	0.815
14	0.82
15	0.823

For 900 Ω

Vi	Vz
1	0.476
2	0.698
3	0.732
4	0.751
5	0.765
6	0.775
7	0.783
8	0.789
9	0.796
10	0.801
11	0.806
12	0.812
13	0.816
14	0.82
15	0.825

ERRORS AND PRECAUTIONS

- The resistor values chosen were below the diode's maximum rating.
- The maximum power dissipation of the Zener diode given by $P_Z = V_Z \cdot I_Z$ was not exceeded
- Proper grounding and secure connections were ensured
- Some leakage current was also taken into account

CONCLUSION

- The Zener diode maintained a stable breakdown voltage (V_Z) in reverse bias, confirming its role in voltage regulation.
- It effectively stabilized output voltage under varying input or load conditions.
- Its non-linear I-V behavior highlights its utility in power supplies and overvoltage protection in circuits.

QUESTIONS