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EC160: Experiment 7
Zener Diode

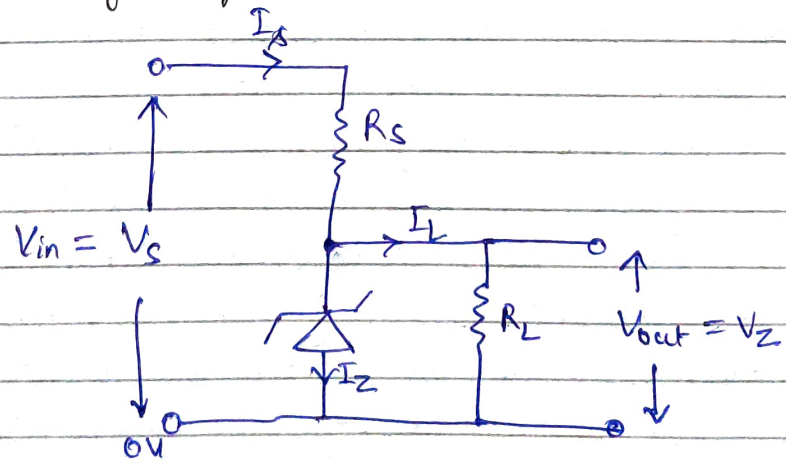
Objective: (i) to study the function of a Zener diode.
(ii) to understand Zener diode as Voltage Regulator.

Theory: Function of Zener Diode

(i) Zener diodes are special kind of diodes which permits current to flow in the forward direction as normal, but they also allow it to flow in the reverse direction when the voltage is above a certain value.

(ii) Zener diodes allow current to flow in reverse direction above a certain value known as breakdown voltage.

Zener Voltage Regulator Circuit and its Working:



In the reverse bias, there is practically no current flow until the break down voltage is reached.

When reverse bias voltage exceeds the rated voltage of the device, breakdown occurs and the current flowing through the Zener diode increases dramatically to the maximum circuit value and once achieved, this reverse saturation current remains fairly constant over a wide range reverse voltage. The voltage point at which the voltage across the zener diode becomes constant is known as Zener Voltage.

The point at which the zener voltage triggers the current flow through the diode can be very accurately controlled in the doping stages giving the diode a specific zener breakdown voltage. This zener voltage on the I-V curve is almost a vertical straigth line.

The voltage across the zener diode in the breakdown region remains almost constant even with large changes in current providing the zener diode current between breakdown current (I_{Zmin}) and its maximum current rating (I_{Zmax}). The zener voltage regulator consists of a current limiting resistor R_s connected in series with the input voltage V_s. With the zener diode connected in parallel with the load R_L in this reverse biased condition.

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Range of source resistor (R_s) for a given load resistor (R_L)

ΔV is the potential across zener diode

a) $\Delta V \geq V_Z$

$$\left(\frac{R_L}{R_L + R_S}\right) V_S \geq V_Z$$

$$R_L V_S \geq R_L V_Z + R_S V_Z$$

$$R_S \leq \frac{R_L V_S - R_L V_Z}{V_Z}$$

$$R_S \leq R_L \left(\frac{V_S - V_Z}{V_Z}\right)$$

$$\therefore R_{S\,max} = R_L \left(\frac{V_S - V_Z}{V_Z}\right)$$

b) $I_S = I_Z + I_L$

$$\frac{V_S - V_Z}{R_S} = I_Z + I_L$$

$$R_S = \frac{V_S - V_Z}{I_Z + I_L}$$

$$R_{S\,min} = \frac{V_S - V_Z}{I_{Z(max)} + I_L}$$

Range of Load Resistor (R_L) for a given source resistor (R_s)

ΔV = potential difference across Zener diode

a) $\Delta V \geq V_Z$

$$\left(\frac{R_L}{R_L + R_S}\right) V_S \geq V_Z$$

$$R_L V_S \geq R_L V_Z + R_S V_Z$$

$$R_L \geq R_S \left(\frac{V_Z}{V_S - V_Z}\right)$$

$$R_{L\,min} = R_S \left(\frac{V_Z}{V_S - V_Z}\right)$$

b) $I_L R_L = V_Z$

$$R_V = \frac{V_Z}{I_L} = \frac{V_Z}{I_S - I_Z}$$

$$R_{L\,max} = \frac{V_Z}{I_S - I_{Z(max)}}$$

Voltage Regulation

Voltage regulators are widely used in electronic power supply circuits. They provide very high degree of regulation and low level of ripples, although their level of efficiency are much lower than another form of regulator called the switch mode regulator.

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It is possible to make voltage regulator circuits from both discrete components as well as being able to use IC regulators. The IC regulators enable very high levels of performance to be achieved, often comparatively few components.

In short, a voltage regulator is an electronic circuit that provides a stable DC voltage independent of the load current, temperature and AC line voltage variations. The voltage across the zener diode will remain steady at its breakdown voltage V_Z for all values of zener current I_Z as long as current remains in the breakdown region. Hence $V_o = V_Z$ is obtained across R_L. It is of two types-

(i) Line Regulation-: R_S & R_L are constant, V_S varies.
(ii) Load Regulation-: V_S fixed, R_L varies.

Procedure for the Experiment

i) Zener Diode - Line Regulation
(Connect the circuit and check if it is right connection)

Step 1: Set Zener Voltage V_Z, series resistance R_S and load resistance R_L.

Step 2: Vary DC voltage
(Voltmeter is placed parallel to load resistor and ammeter in series with resistor).

Step 3-: Note voltmeter and ammeter reading for different DC voltages.

Step 4-: Note the load current I_L, Zener current I_Z, output voltage V_o.

Step 5-: Calculate voltage regulation.

(ii) Zener diode - Load Regulation

Step-1: Connect the circuit and check if it is right connection.
Step-2: Set DC voltage, Series resistance (R_s), zener voltage (V_z).
Step-3: Vary the load resistance (R_L).
Step-4: Choose load resistance in such a manner, such that Zener diode is 'ON'.
Step-5: Note Voltmeter and Ammeter Readings.
Step-6: Note Load current I_L, Zener current I_z, output voltage V_o.
Step-7: Calculate voltage regulation.

(iii) Zener Diode Characteristics

Step-1: Connect the circuit and check if it is a right connection.
Step-2: Set the rheostat $R_h = 1\ \Omega$.
Step 3: By adjusting the rheostat, voltmeter reading is increased from 0 and note the corresponding reading in milliammeter.
Step 4: Take the reading and note the voltmeter reading across Zener diode.
Step 5: Plot V-I graph and observe the change.

Simulation Results

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Zener Diode - LINE Regulator

INSTRUCTION

CONTROLS

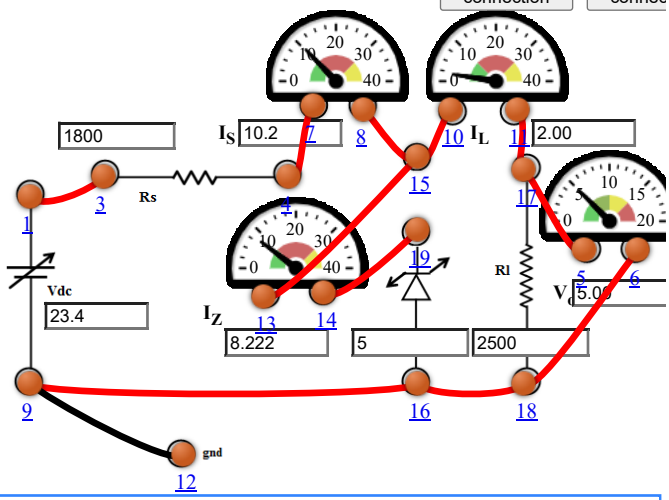
DC volt :
Zener Diode(V_Z) :
Resistance(R_S) :
Resistance(R_L) :

Add to Table | Plot | Cle
Check connection | Delete connec

EXPERIMENTAL TABLE

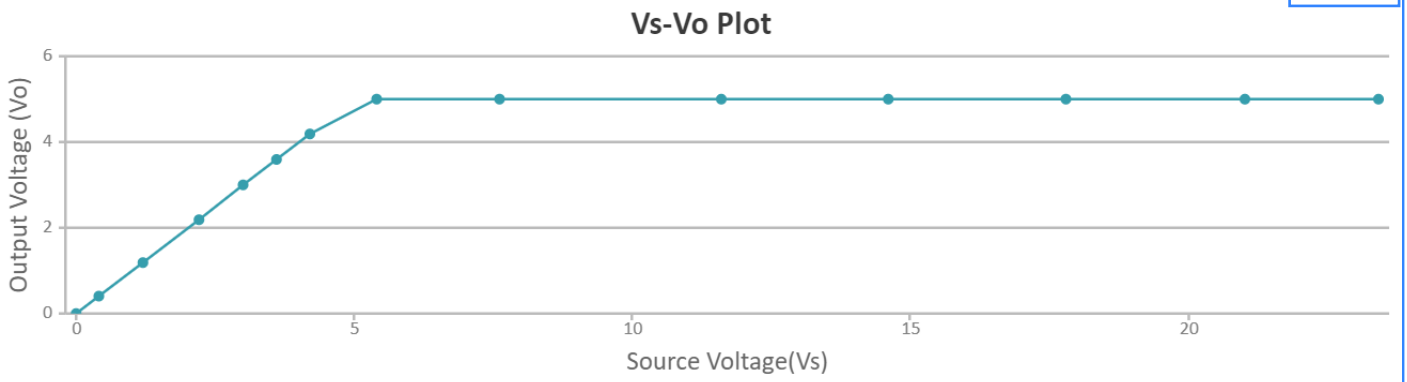
Zener Voltage(V_Z): 5 V
Series Resistance(R_S): 1.8 KΩ
Load Resistance (R_L): 2.5 KΩ

Serial No.	Unregulated supply voltage(V_S) V	Load Current(I_L) mAmp	Zener Current(I_Z) mAmp	Regulated Output Voltage(V_O) V	% Voltage Regulation
1	0	2.00	0	0	NaN
2	0.4	2.00	0	0.4	NaN
3	1.2	2.00	0	1.2	100
4	2.2	2.00	0	2.2	100
5	3	2.00	0	3	100
6	3.6	2.00	0	3.6	100



GRAPH PLOT

Print



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Zener Diode - LINE Regulator

INSTRUCTION

Print It

Take another sets of Output Volatge
for another Zener value

CONTROLS

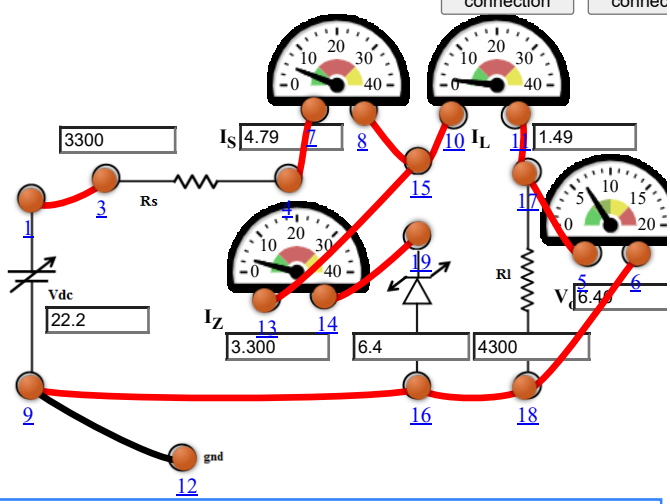
DC volt :
Zener Diode(V_Z) :
Resistance(R_S) :
Resistance(R_L) :

Add to Table | Plot | Cle
Check connection | Delete connec

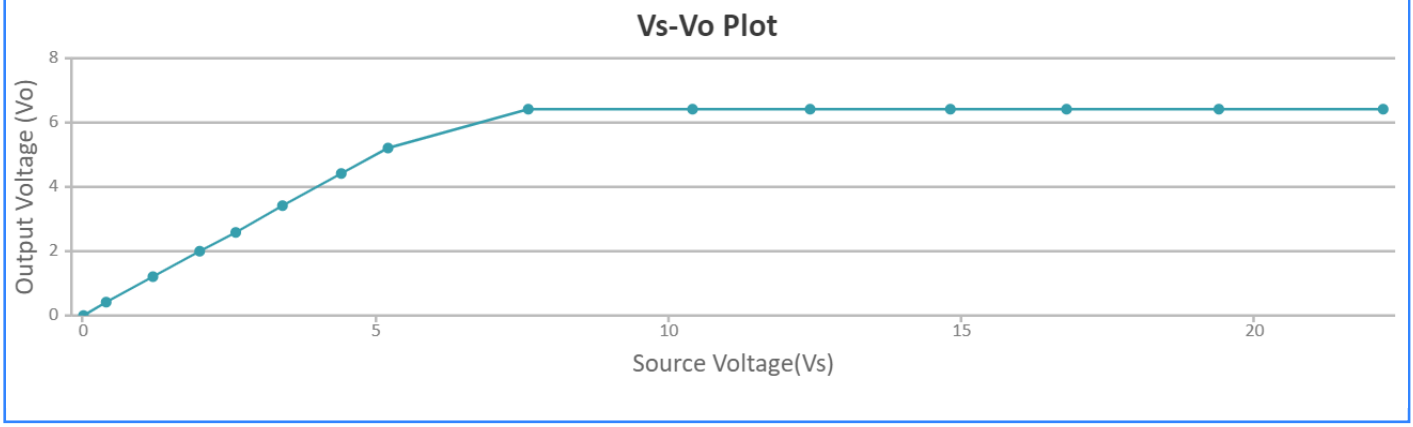
EXPERIMENTAL TABLE

Zener Voltage(V_Z): 6.4 V
Series Resistance(R_S): 3.3 KΩ
Load Resistance (R_L): 4.3 KΩ

Serial No.	Unregulated supply voltage(V_S) V	Load Current(I_L) mAmp	Zener Current(I_Z) mAmp	Regulated Output Voltage(V_O) V	% Voltage Regulation
1	0	1.49	0	0	NaN
2	0.4	1.49	0	0.4	NaN
3	1.2	1.49	0	1.2	100
4	2	1.49	0	2	100
5	2.6	1.49	0	2.6	100
6	3.4	1.49	0	3.4	100



GRAPH PLOT



Zener Diode - LOAD Regulator

INSTRUCTION

Print It

Take another sets of Output Volatge
for another Zener value

CONTROLS

DC volt :
Zener Diode(V_Z) :
Resistance(R_S) :
Resistance(R_L) :

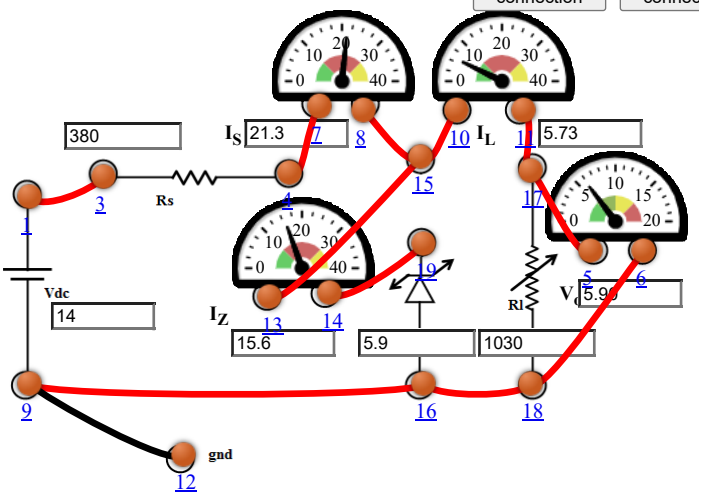
EXPERIMENTAL TABLE

DC Voltage (V_{DC}): 14 V Zener Voltage(V_Z): 5.9 V

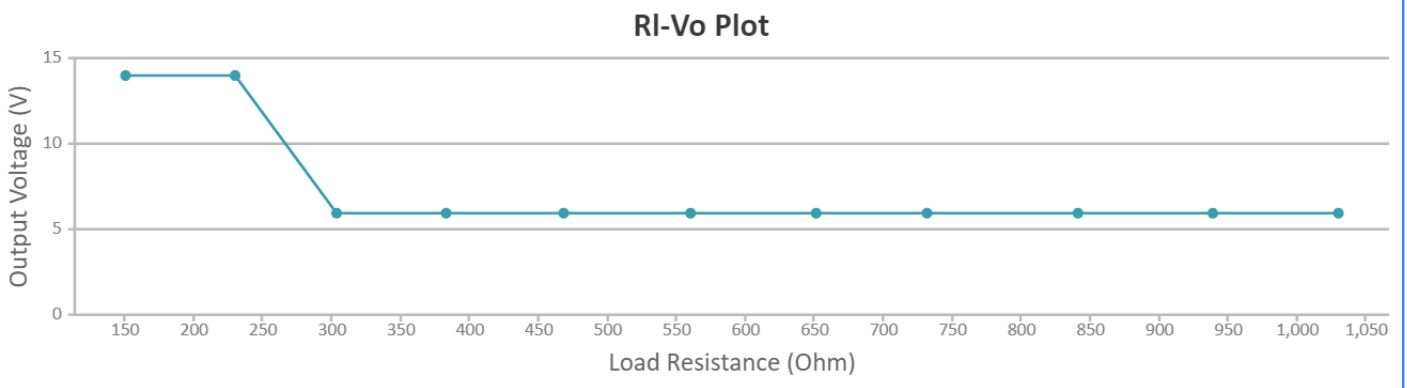
Series Resistance(R_S): 0.38 KΩ

Serial No.	Load Resistance(R_L) Ohm	Load Current(I_L) mAmp	Zener Current(I_Z) mAmp	Regulated Output Voltage(V_O) V	% Voltag Regulatio
1	150	39.3	0	14	71.7
2	230	25.7	0	14	62.3
3	303	19.5	1.84	5.90	55.6
4	383	15.4	5.91	5.90	49.8
5	468	12.6	8.71	5.90	44.8
6	560	10.5	10.8	5.90	40.4

Add to Table | Plot | Cle
Check connection | Delete connec



GRAPH PLOT



Zener Diode - LOAD Regulator

INSTRUCTION

CONTROLS

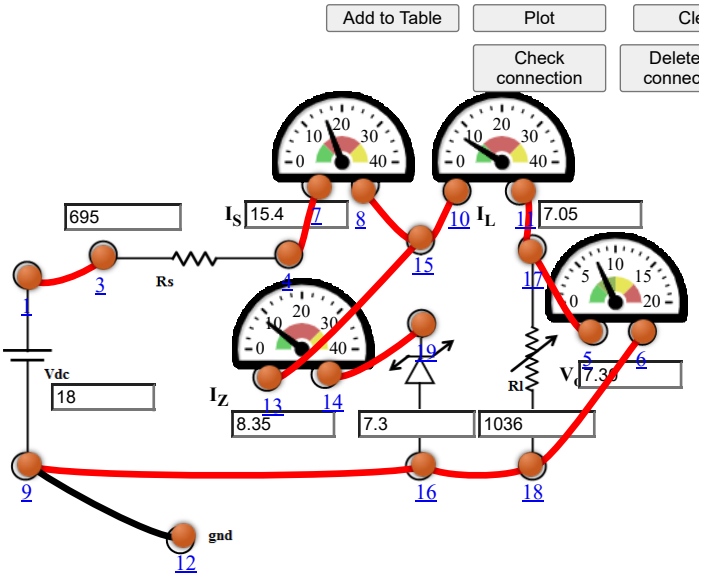
DC volt :
Zener Diode(V_Z) :
Resistance(R_S) :
Resistance(R_L) :

EXPERIMENTAL TABLE

DC Voltage (V_{DC}): 18 V Zener Voltage(V_Z): 7.3 V

Series Resistance(R_S): 0.695 KΩ

1	150	48.7	0	18	82.2
2	218	33.5	0	18	76.1
3	291	25.1	0	18	70.5
4	383	19.1	0	18	64.5
5	499	14.6	0.766	7.30	58.2
6	603	12.1	3.29	7.30	53.5
7	706	10.3	5.06	7.30	49.6
8	810	9.01	6.38	7.30	46.2
9	902	8.09	7.30	7.30	43.5
10	1036	7.05	8.35	7.30	40.2



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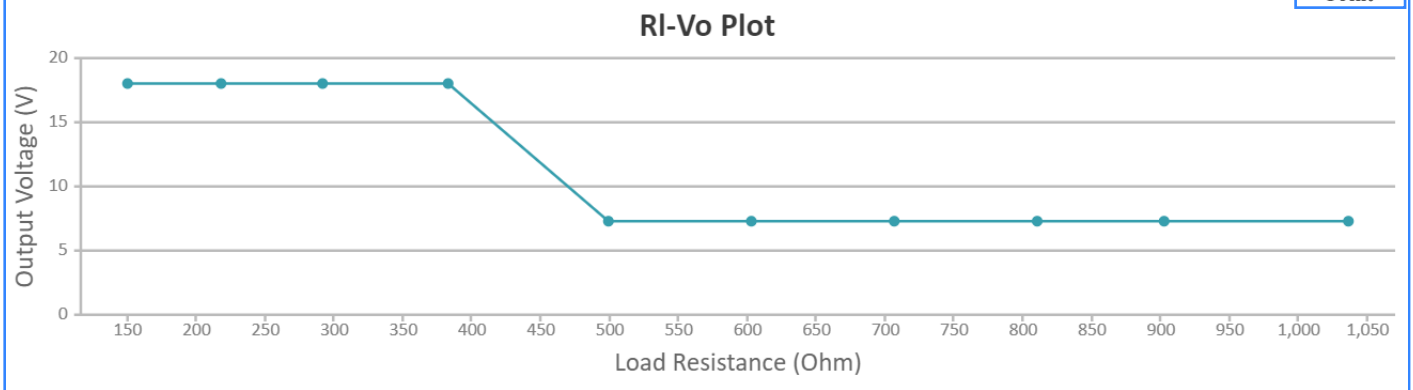

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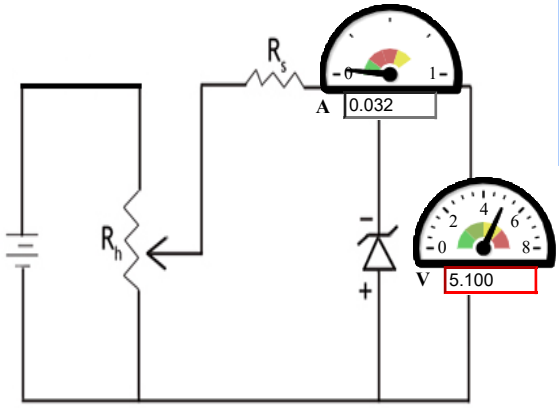
Zener characteristics

INSTRUCTION

EXPERIMENTAL TABLE

Serial No.	Zener Voltage(Volt)	Current(mAmp)
1	0.120	0.000
2	0.719	0.000
3	1.297	0.000
4	2.360	0.001
5	3.362	0.002
6	4.341	0.003
7	5.100	0.005



CONTROLS

Select Diode: IN4733A 5.1

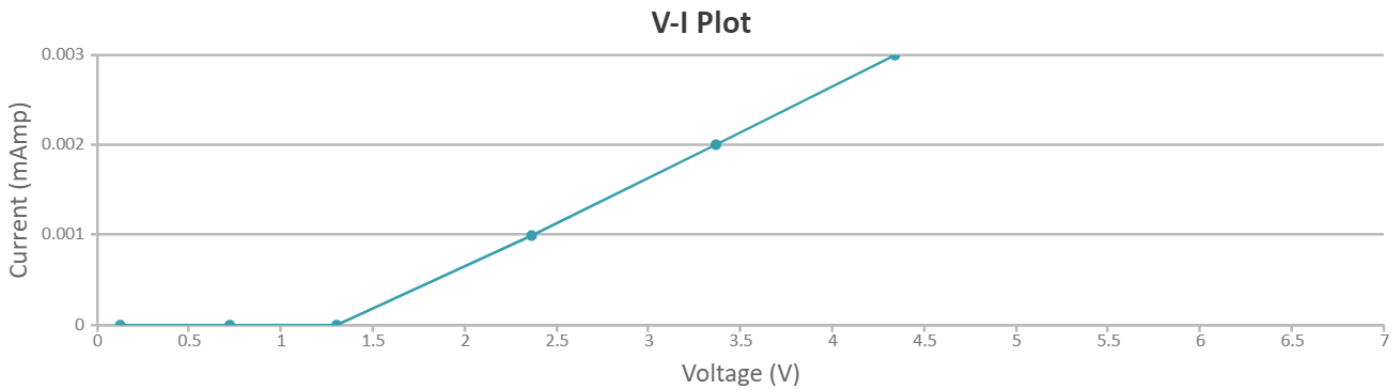
R_h : ohms 96

Add to Table Plot Clear

Vary Rheostat

Print It

GRAPH PLOT



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Conclusions :- Performing the experiment, following conclusions can be drawn,

i) Zener diode is a special kind of diode which allows current to flow through it in reverse direction above a certain value known as breakdown voltage.

(ii) In standard diode, the zener voltage is high, and the diode is permanently damaged if a reverse current above $I_{Z(max)}$ is passed through it.

(iii) The voltage across Zener diode will remain steady at its breakdown voltage V_Z for all values of zener current I_Z as long as the current remains in breakdown region. Hence, $V_{out} = V_Z$ is constant across R_L whenever V_{in} remains within a particular range.

(iv) In line regulation, load resistance (R_L) and series resistance (R_S) is fixed and input voltage V_S varies. On the other hand, in load regulation, input voltage V_S is fixed and load resistance (R_L) varies.

Quiz Performance

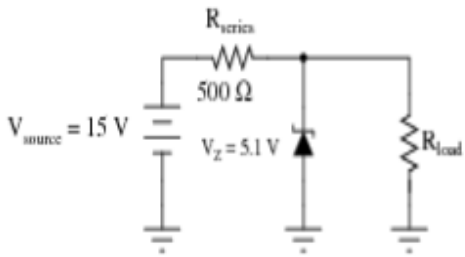
Zener Diode-Voltage Regulator

THEORY (#) PROCEDURE (#) SIMULATION (#) QUIZ (#) ASSIGNMENT (#) REFERENCES (#)

Quiz

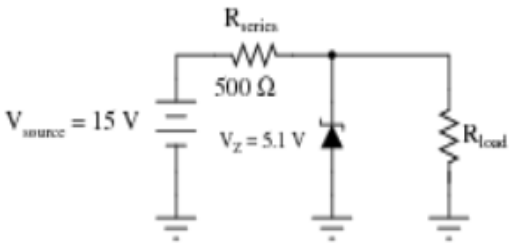
Test Your Knowledge!!

✓ 1. Calculate the current through the zener diode with a load resistance of 1kΩ:



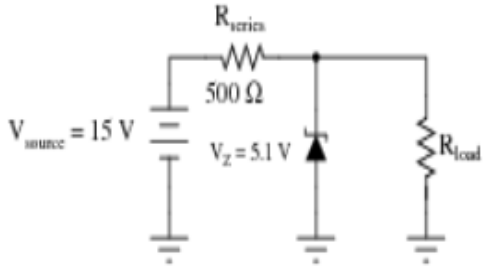
- ○ 12.5 mA
- ○ 15.5 mA
- ○ 13.8 mA
- ● 14.7 mA

✓ 2. Calculate the current through the zener diode with a load resistance of 910Ω:



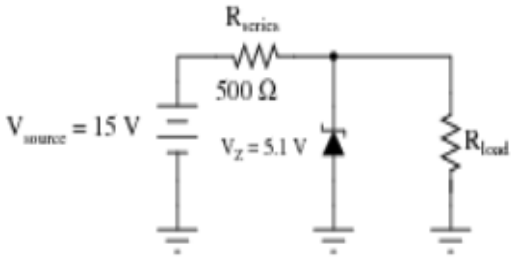
- ● 14.2 mA
- ○ 12.4 mA
- ○ 13.8 mA
- ○ 15.2 mA

✓ 3. Calculate the current through the zener diode with a load resistance of 680Ω:



- 11.6 mA
- 12.8 mA
- 12.3 mA
- 13.5 mA

✓ 4. Calculate the current through the zener diode with a load resistance of 330Ω:



- 4.25 mA
- 3.35 mA
- 4.35 mA
- 4.45 mA

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