Voltage Regulation using Zener Diode

Chirag Verma
Enrollment Number : 21615007

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1 Aim

- Line Regulation using Zener Diode
- Load Regulation using Zener Diode

2 Apparatus Required

Zener Diode, rheostat, DC voltage source, miliammeter, voltmeter

3 Diagram

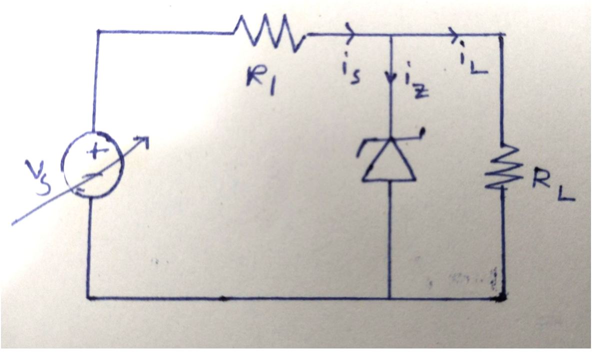

Figure 1: Line Regulation

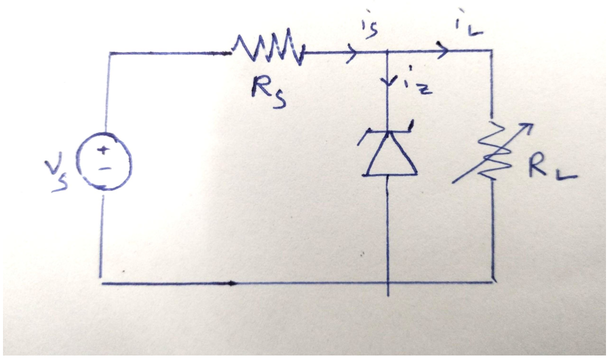

Figure 2: Load Regulation

4 Theory

4.1 Zener Diode

Zenor Diode is a special kind of diode that works in the breakdown region. In essence, it allows the current to flow "backwards" when a certain set reverse voltage, known as the Zener voltage, is reached.

4.2 Voltage Regulation

A voltage regulator is an electronic circuit that provides a stable DC voltage independent of the load current, temperature and AC line voltage variations. Therefore, a Zener diode can work as a rvoltage regulator in its breakdown region.

A Zener diode of break down voltage V_Z is reverse connected to an input voltage source V_I across a load resistance R_L and a series resistor R_S. The voltage across the zener will remain steady at its break down voltage V_Z for all the values of zener current I_Z as long as the current remains in the break down region.

4.2.1 Line Regulation

In this type of regulation, series resistance and load resistance are fixed, only input voltage is changing. Output voltage remains the same as long as the input voltage is maintained above a minimum value.

The input voltage, V_I, must be sufficiently large to turn the diode ON.

$$V_L = V_z = \frac{V_{\mathrm{I_{min}}} R_L}{R_s + R_L} \tag{1}$$

$$V_{\mathrm{I_{min}}} = \frac{V_z(R_s + R_L)}{R_L} \tag{2}$$

IF $V_I < V_Z$: THEN $V_o = V_I$
IF $V_I > V_Z$: THEN $V_o = V_I - I_s R_s$

4.2.2 Load Regulation

In this type of regulation, input voltage is fixed and the load resistance is varying. Output volt remains same, as long as the load resistance is maintained above a minimum value.

Too small a Load Resistance R_L ,will result in $V_{\mathrm{Threshold}} < V_Z$ and Zener Diode will be OFF.

$$V_L = V_z = \frac{V_{\mathrm{I_{min}}} R_L}{R_s + R_L} \tag{3}$$

$$R_{\mathrm{L_{min}}} = \frac{V_z R_s}{V_I - V_Z} \tag{4}$$

IF $R_L < R_{L_{\mathrm{min}}}$: THEN $V_o = V_I$
IF $R_L > R_{L_{\mathrm{min}}}$: THEN $V_o = V_I - I_s R_s$

5 Observations and Plots

5.1 Line Regulation

5.1.1 Set 1:

Zener Voltage: $V_z = 5V$
Series Resistance: $R_s = 2500\Omega$
Load Resistance: $R_L = 5000\Omega$

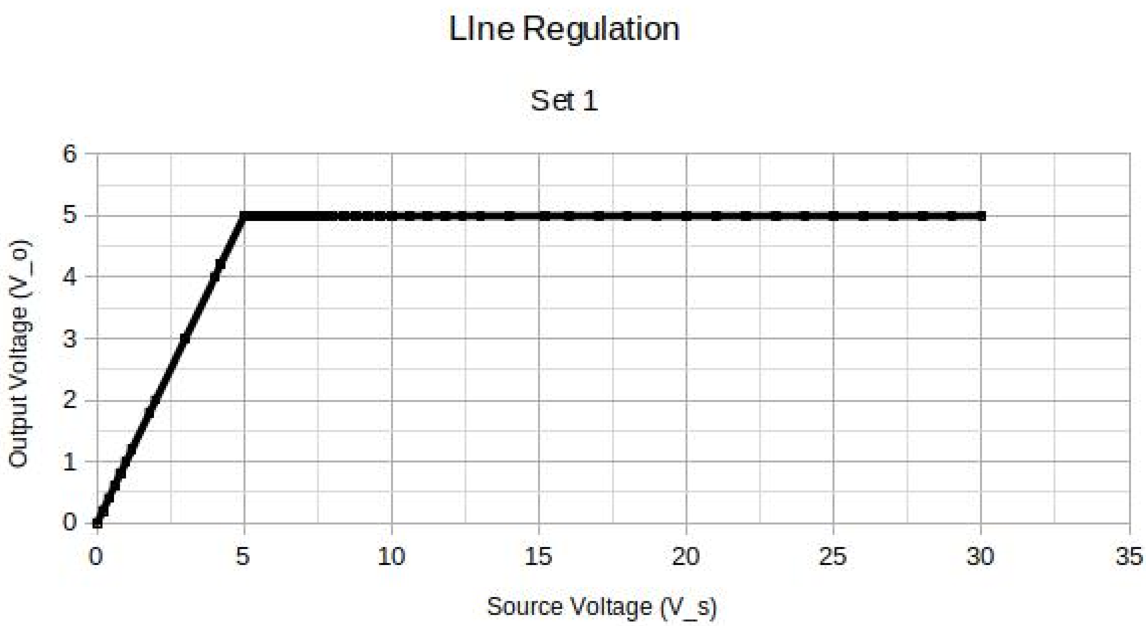

Figure 3: Line Regulation - Set 1: $V_z = 5V, R_s = 2500\Omega, R_L = 5000\Omega$

Unregulated Supply Voltage $V_s(V)$	**Load Current** $I_c mA$	**Zener Current** $I_z(mA)$	**Regulated Output Voltage** $V_o(V)$	**% Voltage Regulation**
1.0	1.0	0	1.0	100
2.0	1.0	0	2.0	100
3.0	1.0	0	3.0	100
5.0	1.0	0	5.0	100
5.2	1.0	-0.92	5.0	100
5.4	1.0	-0.84	5.0	100
5.8	1.0	-0.68	5.0	100
5.6	1.0	-0.76	5.0	100
6.0	1.0	-0.6	5.0	83.3
6.2	1.0	-0.52	5.0	83.3
6.4	1.0	-0.44	5.0	83.3
6.6	1.0	-0.36	5.0	83.3
6.8	1.0	-0.28	5.0	83.3
7	1.0	-0.2	5.0	71.4
7.6	1.0	0.04	5.0	71.4
7.2	1.0	-0.12	5.0	71.4
7.4	1.0	-0.04	5.0	71.4
7.6	1.0	0.04	5.0	71.4
7.8	1.0	0.12	5.0	71.4
8.0	1.0	0.2	5.0	62.5
8.4	1.0	0.36	5.0	62.5
8.8	1.0	0.52	5.0	62.5
9.2	1.0	0.68	5.0	55.6
9.6	1.0	0.84	5.0	55.6
10.0	1.0	1.0	5.0	50.0
10.6	1.0	1.24	5.0	50.0
11.2	1.0	1.48	5.0	45.5
11.8	1.0	1.72	5.0	45.5
12.4	1.0	1.96	5.0	41.7
13.0	1.0	2.2	5.0	38.5
14.0	1.0	2.6	5.0	35.7
15.2	1.0	3.08	5.0	33.3
16.0	1.0	3.4	5.0	31.3
17.0	1.0	3.8	5.0	29.4
18.0	1.0	4.2	5.0	27.8
19.0	1.0	4.6	5.0	26.3
20.0	1.0	5	5.0	25.0
21.0	1.0	5.4	5.0	23.8
22.0	1.0	5.8	5.0	22.7
23.0	1.0	6.2	5.0	21.7
24.0	1.0	6.6	5.0	20.8
25.0	1.0	7	5.0	20.0
26.0	1.0	7.4	5.0	19.2
27.0	1.0	7.8	5.0	18.5
28.0	1.0	8.2	5.0	17.9
29.0	1.0	8.6	5.0	17.2
30.0	1.0	9.0	5.0	16.7

5.1.2 Set 2:

Zener Voltage: $V_z = 10V$
Series Resistance: $R_s = 2500\Omega$
Load Resistance: $R_L = 5000\Omega$

Unregulated Supply Voltage $V_s(V)$	**Load Current** $I_c mA$	**Zener Current** $I_z(mA)$	**Regulated Output Voltage** $V_o(V)$	**% Voltage Regulation**
0	2	0	0	NaN
1	2	0	1	100
2	2	0	2	100
3	2	0	3	100
4	2	0	4	100
5	2	0	5	100
9	2	0	9	100
9.8	2	0	9.8	100
10	2	0	10	100
11	2	-1.6	10	90.9
12	2	-1.2	10	83.3
13	2	-0.8	10	76.9
13.8	2	-0.48	10	76.9
14	2	-0.4	10	71.4
15	2	0	10	66.7
16	2	0.4	10	62.5
16.8	2	0.72	10	62.5
17	2	0.8	10	58.8
18	2	1.2	10	55.6
19	2	1.6	10	52.6
20	2	2	10	50
21	2	2.4	10	47.6
22	2	2.8	10	45.5
23	2	3.2	10	43.5
24	2	3.6	10	41.7
25	2	4	10	40
26	2	4.4	10	38.5
27	2	4.8	10	37
28	2	5.2	10	35.7
30	2	6	10	33.3

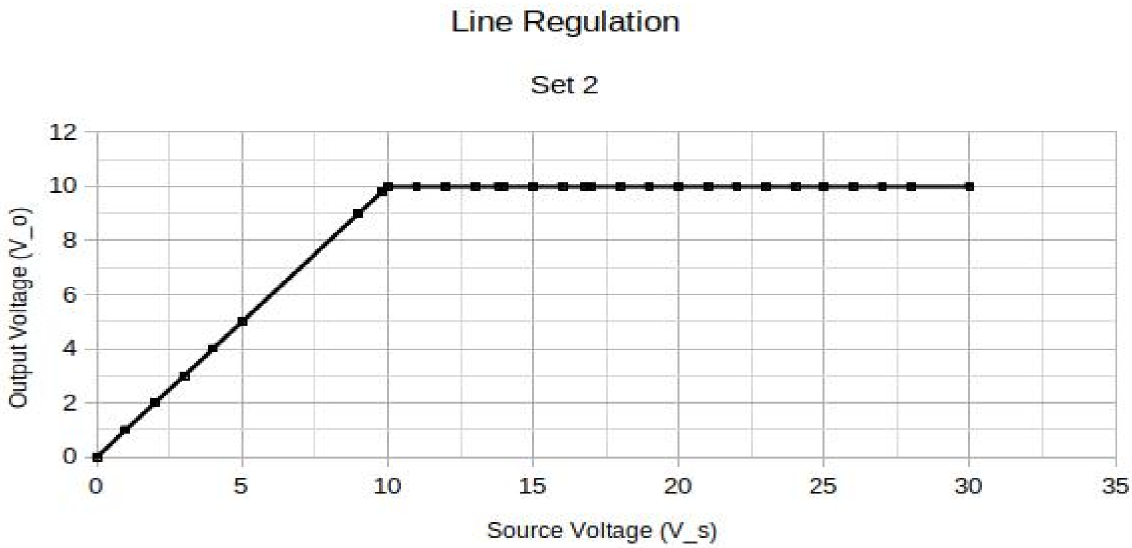

Figure 4: Line Regulation - Set 2: $V_z = 10V, R_s = 2500\Omega, R_L = 5000\Omega$

5.2 Load Regulation

5.2.1 Set 1:

DC Voltage: $V_{DC} = 6V$
Series Resistance: $R_s = 100\Omega$
Zener Voltage$R_Z = 5.1V$

Load Resistance $R_l(\Omega)$	**Load Current** $I_c(mA)$	**Zener Current** $I_z(mA)$	**Regulated Output Voltage** $V_o(V)$	**% Voltage Regulation**
150	34	0	6	40
200	25.5	0	6	33.3
300	17	0	6	25
400	12.8	0	6	20
500	10.2	0	6	16.7
600	8.5	0.5	5.1	14.3
650	7.85	1.15	5.1	13.3
700	7.29	1.71	5.1	12.5
750	6.8	2.2	5.1	11.8
800	6.38	2.63	5.1	11.1
850	6	3	5.1	10.5
900	5.67	3.33	5.1	10
950	5.37	3.63	5.1	9.52
1000	5.1	3.9	5.1	9.09
1100	4.64	4.36	5.1	8.33
1200	4.25	4.75	5.1	7.69
1250	4.08	4.92	5.1	7.41

Figure 5: Load Regulation - Set 1: $V_{DC} = 6V, R_s = 100\Omega, V_z = 5.1V$

5.2.2 Set 2:

DC Voltage: $V_{DC} = 12V$
Series Resistance: $R_s = 100\Omega$
Zener Voltage$R_Z = 10V$

Load Resistance $R_l(\Omega)$	**Load Current** $I_c(mA)$	**Zener Current** $I_z(mA)$	**Regulated Output Voltage** $V_o(V)$	**% Voltage Regulation**
150	66.7	0	12	40
300	33.3	0	12	25
450	22.2	0	12	18.2
550	18.2	1.82	10	15.4
500	20	0	10	16.7
600	16.7	3.33	10	14.3
700	14.3	5.71	10	12.5
770	13	7.01	10	11.5
850	11.8	8.24	10	10.5
915	10.9	9.07	10	9.85
1000	10	10	10	9.09
1140	8.77	11.2	10	8.06
1205	8.3	11.7	10	7.66
1250	8	12	10	7.41

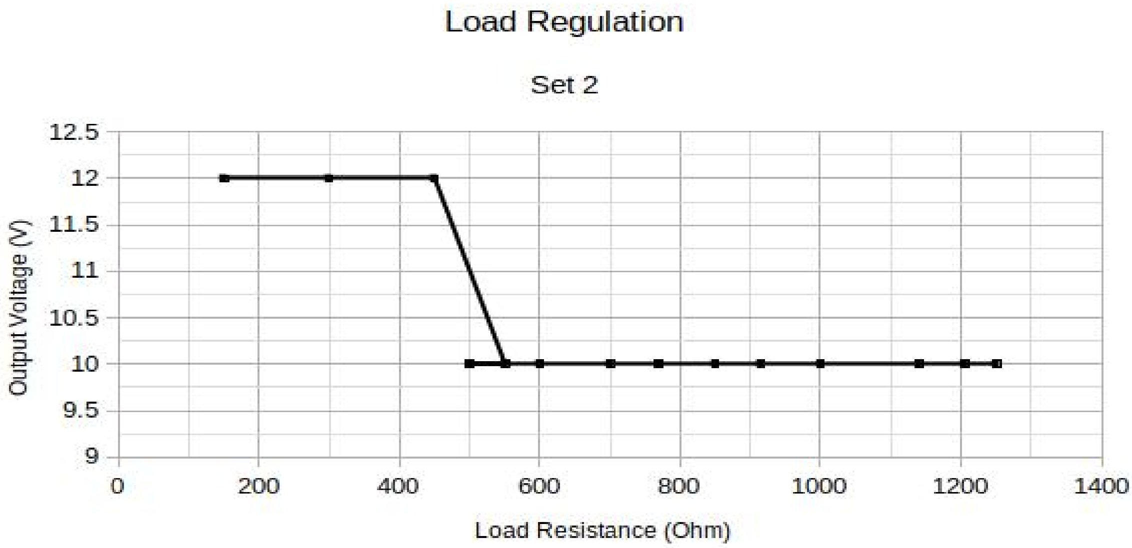

Figure 6: Load Regulation - Set 2: $V_{DC} = 12V, R_s = 100\Omega, V_z = 10V$

6 Results and Discussions

The Voltage Regulation Percentages have been calculated out in Section 5, where the formulae from Section 4 were used.

After the breakdown region, one could easily see (subject to the simulation's tolerance) that the output voltage is constant across a particular range for both line and load regulated cicuits.

This inherently proves that a Zener Diode provides a constant output voltage when it is operated in its breakdown region.