PH3204: Electronics Laboratory

Experiment 01: Study of Zener Diode as a Voltage Regulator and Use of IC 7805 Voltage Stabilizer

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1 Theory

1.1 Zener Diode as Voltage Regulator

Zener Diode is a heavily doped p-n junation diode which is designed to operate in reverse bias. When operated in reverse bias , if the voltage across the diode exceeds the zener breakdown voltage V_Z, the diode enters the *zener breakdown region* where voltage across the diode remains constant irrespective of the current flowing through it.
This property of the zener diode is exploited for Voltage Regulation. The circuit diagram of a zener diode used as a voltage regulator has been shown below.

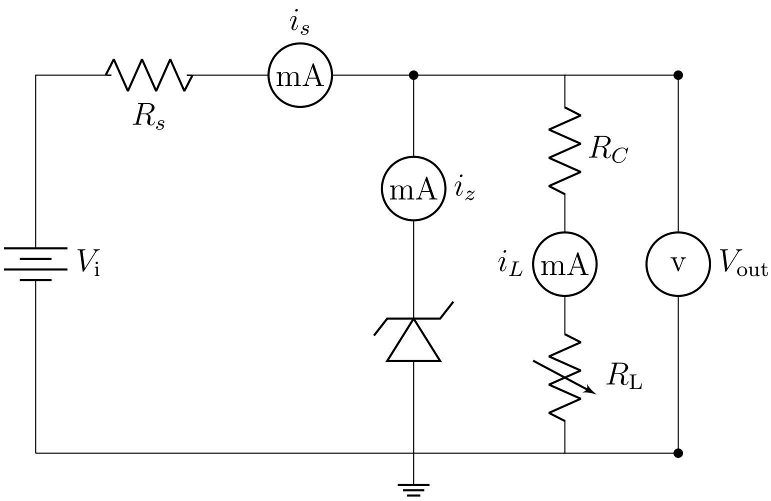

Figure 1: Circuit Diagram for Zener Diode as a Voltage Regulator

Line Regulation

Line regulation corresponds to the ability of keeping the output voltage constant despite changes in the input voltage. It is defined as the change in output volatge for a unit change in input voltage.
To measure this we remove the resistor (R_L) and keep the resistor (R_L) fixed. We then vary the input voltage V_i in regular intervals and measure the output voltage V_{out}. When the input volatge goes beyond the breakdown voltage, the output voltage V_{out} remains constant at V_Z. The current through the resistor R_L therefoee becomes constant.

$$\delta i_s = \delta i_z$$

Load Regulation

Load regulation corresponds to the ability of keeping the output voltage constant despite changes in the load resistance. It is defined as the change in output voltage for a unit change in load resistance. When the load resistance goes beyond a threshold value, the output voltage V_{out} remains constant. The current through the load resistor therefore becomes constant. Thus,

$$\delta i_z = -\delta i_L$$

1.2 Voltage Regulator IC7805

As mentioned in the above section, a zener diode can be used as a volatge regulator. But, usually the output voltage doesn't remain completely stable and there is a small variation in the output voltage. To overcome this, we use a voltage regulator IC. The IC 7805 is a voltage regulator IC which provides a stable output voltage of $5V$. The circuit diagram for using IC 7805 as a voltage regulator has been shown below.

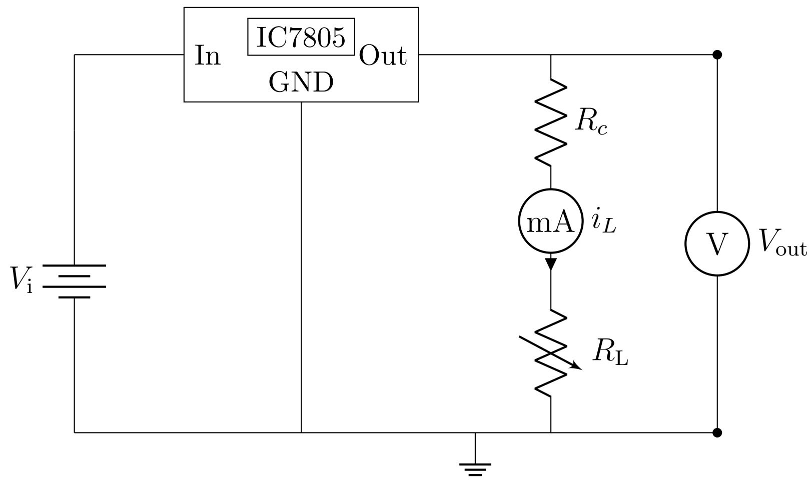

Figure 2: Circuit Diagram for regulation using IC 7805

2 Zener Diode as a voltage Regulator

2.1 Line Regulation

To study the line regulation property of zener diode, we keep the resistance R_C fixed at $2.2k\Omega$. We then vary the input voltage V_i in regular intervals and measure the output voltage V_{out}, the current through the diode, I_z and through the series resistance ,I_S. The data has been tabulated below

V_{i} (V)	I_{s} (mA)	V_{out} (v)	I_{z} (mA)
0	0	0	0
0.53	0.12	0.27	0
1.02	0.23	0.51	0
1.5	0.35	0.77	0
2	0.46	1.01	0
2.51	0.58	1.27	0
2.98	0.69	1.51	0
3.5	0.81	1.77	0
4.01	0.93	2.03	0
4.51	1.05	2.28	0
5.09	1.18	2.58	0
5.49	1.27	2.78	0.0002
6.02	1.39	3.03	0.0008
6.49	1.51	3.28	0.0023

V_i (V)	I_s (mA)	V_{out} (V)	I_z (mA)
7	1.63	3.54	0.004
7.49	1.74	3.78	0.0083
7.99	1.86	4.03	0.0161
8.52	1.98	4.29	0.0337
9.02	2.11	4.54	0.0637
9.5	2.22	4.77	0.1132
9.98	2.34	4.99	0.1666
10.51	2.48	5.16	0.2
10.98	2.68	5.29	0.25
11.45	2.85	5.39	0.3
12	3.07	5.46	0.6
12.5	3.28	5.51	0.7
12.95	3.47	5.54	0.9
13.46	3.7	5.57	1.1
14.06	3.97	5.59	1.4
14.49	4.17	5.61	1.5
14.96	4.38	5.63	1.8

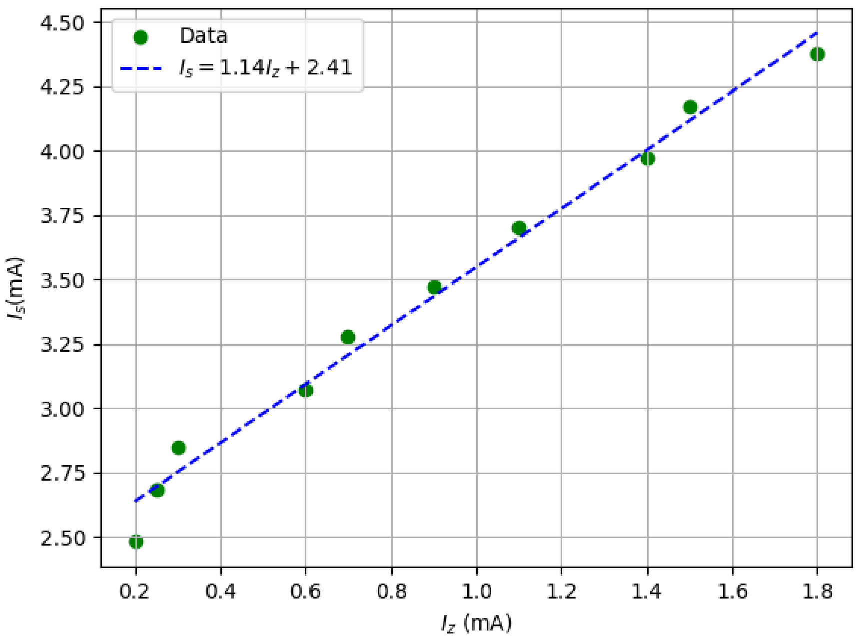

Figure 3: Plot of I_z v/s I_s

We plot a graph between I_z and I_s. Upon fitting the curve with a straight line we get the following fit curve.

$$I_s = 1.14I_z + 2.41$$

The slope of the grpah is found to be 1.14 ± 0.002V which verifies the fact that $\delta I_s = \delta I_z$

To estimate the breakdown voltage V_Z we plot a graph between V_{out} and V_i. In the graph plotted below it is clear that when the input voltage V_i crosses $10.51V$, the output voltage V_{out} remains almost constant,indicating that breakdown has occured. The breakdown voltage is estimated to be $5.59V$.

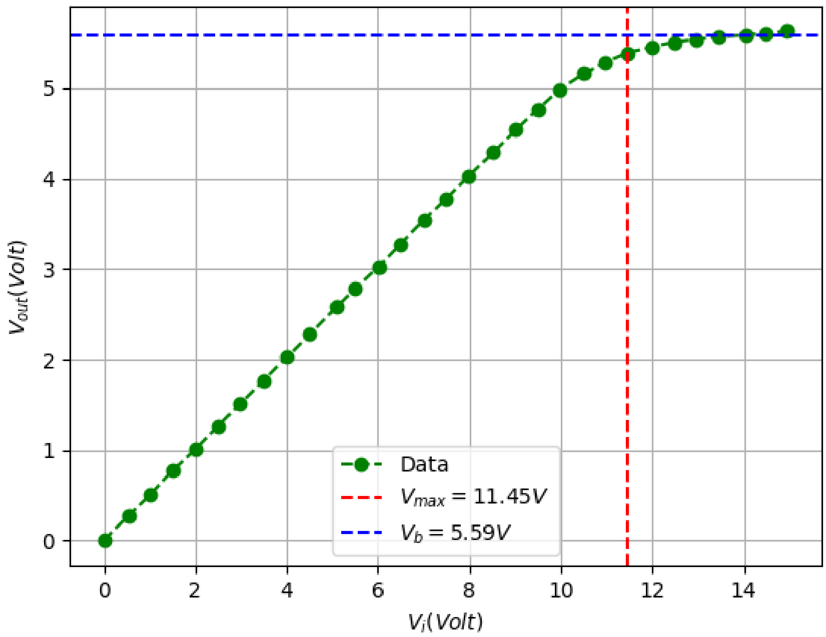

Figure 4: Plot of V_i v/s V_{out} to estimate the breakdown volatge

Note that the following part of the experiment was done on Day 2 with a different zener diode with a different breakdown voltage.

2.2 Load Regulation

In this part of the experiment we keep the input voltage V_i fixed at $14.6V$. The load resistance R_L is varies from $1k\Omega$ to $10k\Omega$ in regular intervals. The output voltage V_{out}, the current through the diode, I_z and through the load resistance ,I_L are measured. The data has been tabulated below.
The data has been taken twice, once without the current limiting resistor R_C and once with it.

Without current limiting resistor R_C

R_L (Ω)	i_L (mA)	i_Z (mA)	V_{out} (V)
1.2	6.9	0	0.0108
48.2	6.6	0	0.32
99.1	6.4	0	0.797
151.4	6.2	0	1.111
213	6.2	0	1.389

R_L (Ω)	i_L (mA)	i_Z (mA)	V_{out} (V)
278	6	0	1.678
303	5.9	0	1.876
359	5.8	0	2.1
403	5.7	0	2.31
452	5.4	0	2.92
502	5.5	0	2.77
556	5.4	0	3.01
603	5.2	0	3.16
655	5.3	0	3.26
697	5.1	0	3.55
751	5	0	3.78
806	4.9	0	3.95
859	4.8	0	4.15
902	4.8	0	4.29
955	4.6	0	4.61
1007	4.6	0	4.64

From the above table, we see that the maximum output voltage reached without using R_C is $V_{out} = 4.64V$ which is less than the output voltage obtained after reaching the breakdown voltage ($6.55V$) calculated from the previous part, indicating that the breakdown has not been reached, which is why we are getting negligible current.

With current limiting resistor R_C

R_L (Ω)	i_L (mA)	i_Z (mA)	V_out (V)
1.3	3	0.8	6.54
50.7	2.9	0.8	6.54
101.5	2.8	0.9	6.54
151	2.8	0.9	6.54
203	2.7	1	6.54
258	2.7	1	6.54
303	2.6	1.1	6.54
360	2.5	1.2	6.54
405	2.5	1.2	6.54
452	2.5	1.2	6.54
505	2.4	1.3	6.54
556	2.4	1.3	6.54
604	2.3	1.4	6.54
646	2.3	1.4	6.54
701	2.3	1.4	6.54
755	2.2	1.5	6.54
798	2.2	1.5	6.54
858	2.1	1.6	6.54
907	2.1	1.6	6.54
951	2.1	1.6	6.54
1010	2	1.7	6.54

We plot a graph between I_z and I_L. Upon fitting the curve with a straight line we get the following fit curve.

$$I_L = -1.00I_z + 3.70$$

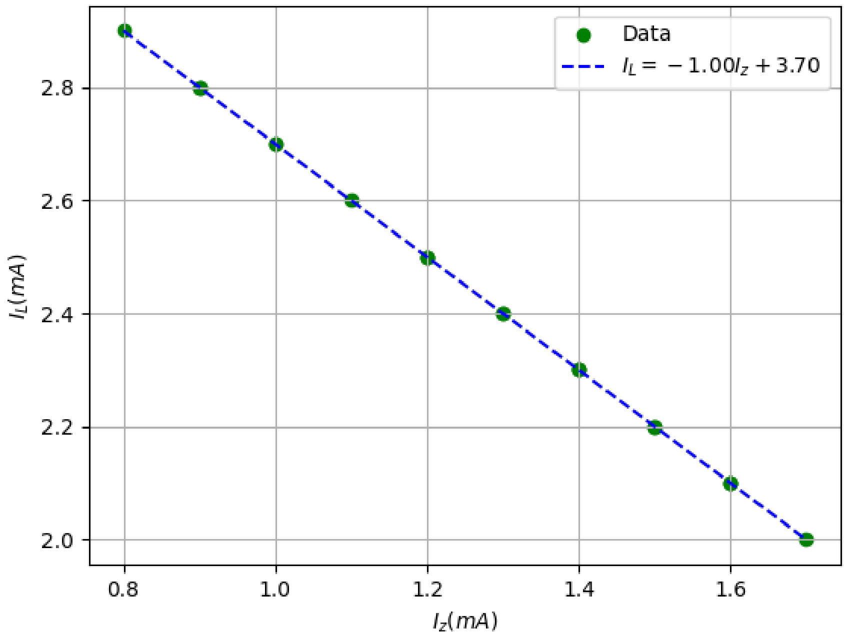

Figure 5: Plot of I_z v/s I_L with constant V_i=14.6V

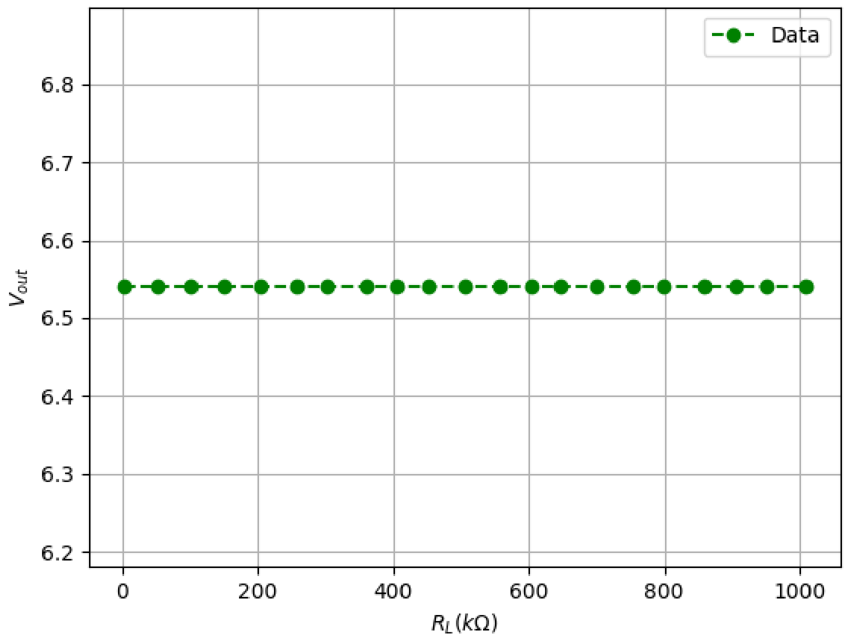

Figure 6: Plot of R_L v/s V_{out} with constant V_i=14.6V

From the graph plotted above we could verfiy that the breakdown voltage of the zener diode is $6.54V$.

3 IC7805 as a Voltage Regulator

3.1 Line Regulation

In line regulation, we have used current limiting resistor $R_C = 2.2k\Omega$ and have removed the resistance R_L.The input voltage V_i is varied from $0V$ to $10V$ in regular intervals and the output voltage V_{out} is measured. The data has been tabulated below.

V_i(V)	I_L(mA)	V_{out}(V)
0.04	0	0.01
0.51	0	0.01
1.01	0	0.01
1.51	0	0.1
2	0.59	1.26
2.5	0.81	1.71
2.99	1.02	2.17
3.5	1.25	2.63
4.01	1.46	3.09
4.51	1.69	3.56
5	1.9	4.01
5.51	2.12	4.47
6.04	2.36	4.96
6.45	2.37	4.99
7	2.37	4.99
7.54	2.37	4.99
8.03	2.37	4.99
8.55	2.37	4.99
9.05	2.37	4.99
9.47	2.37	4.99
10.01	2.37	4.99

In the graph plotted in the next page, we see that after the input voltage crosses 6.04V the output volatge remains constant at $4.99V(\approx 5V)$, which is what we had expected.

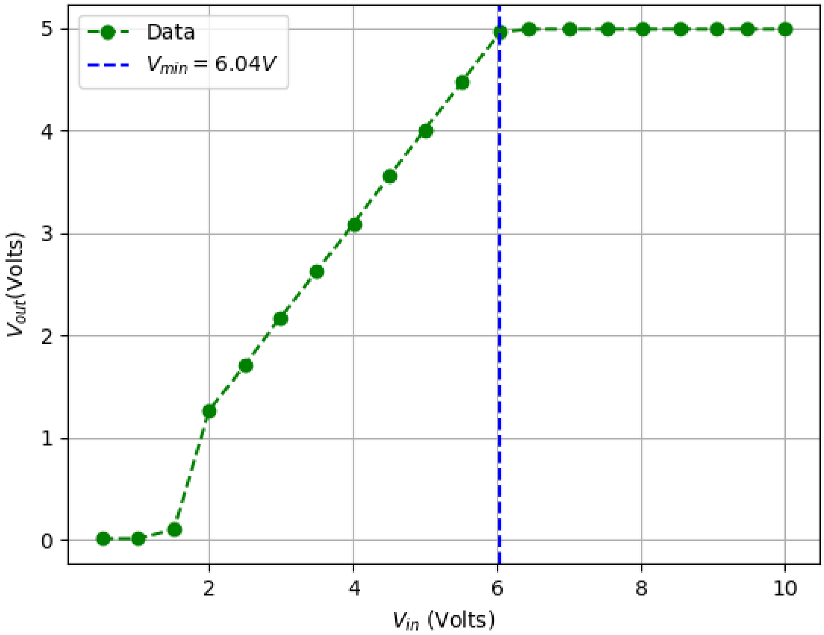

Figure 7: Plot depicting V_i v/s V_{out}

3.2 Load Regulation

For load regulation, we have kept the input voltage V_i at 14.6 V, and while the resistor R_L is varied from $0k\Omega$ to $10k\Omega$ in regular intervals. The output voltage V_{out} is measured. The data recorded has been tabled below.

R_L (Ω	i_L (mA)	V_0 (V)
1.1	2.38	5
50.6	2.32	5
100.2	2.27	5
149.6	2.22	5
205	2.17	5
258	2.12	5
308	2.08	5
361	2.04	5
403	2	5
453	1.97	5
499	1.93	5
560	1.89	5
599	1.86	5
656	1.82	5
703	1.8	5
753	1.77	5
798	1.74	5
860	1.7	5
901	1.68	5

$R_L(\Omega)$	i_L (mA)	V_0 (V)
957	1.63	5
1008	1.62	5

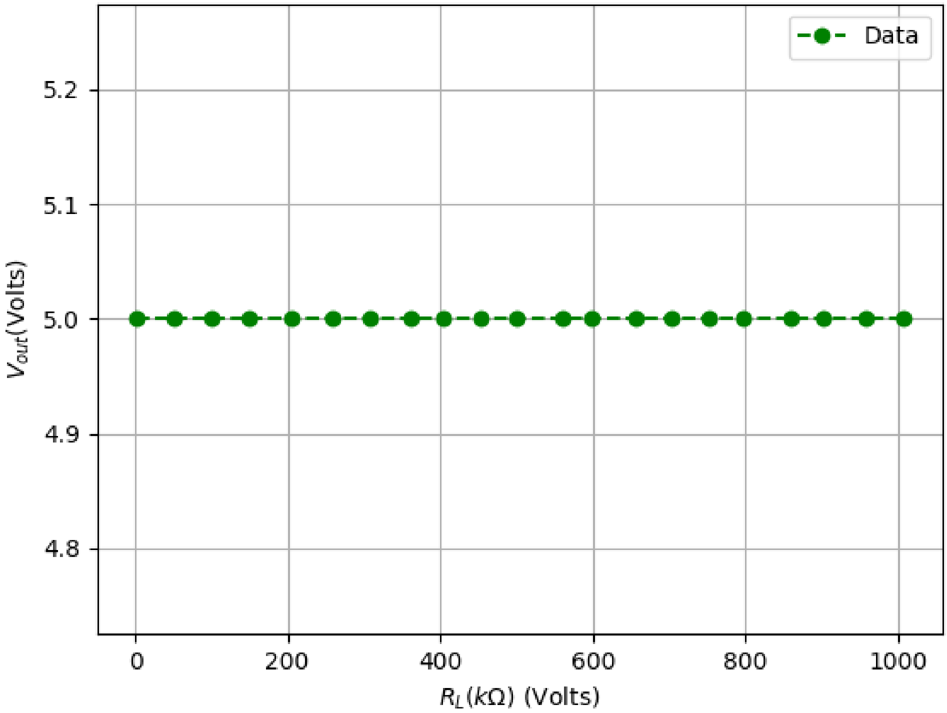

Figure 8: Plot of R_L v/s V_{out}

4 Conclusion

In this experiment we studied the voltage regulation property of zener diode. We determined the average breakdown volatge of the diode to be 5.63V, while on the second day (owing to a different zener diode), we found the breakdown voltage to be $6.54V$ We also verified the fact that the voltage across the diode remained the same once we cross the breakdown voltage.

Next we studied the voltage regulation property of IC 7805. We verfifed that the stable voltage of the IC is 5V. We could also observe that the IC gave better regulation when compared to the zener diode.

5 Sources of Error

The sources pf error in this experiment are as follows:

- There can be inaccuracies in the measurement of the volatge and current using the multimeter. There may also be inaccuracies in the measurement of the resistance using the multimeter.
- The wires used in the experiment may not have negligible resistance. The same goes for the breadboard, the resistance of which may not be negligible.