

Study of the Zener diode as a voltage regulator and the use of IC 7805 as a voltage stabilizer

PH3204 - Electronics Laboratory

Debayan Sarkar
22MS002

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1 Introduction

In this experiment we have studied the properties of a Zener Diode, under varying input and output signals. Later, we also used the LM7805 IC to see the voltage stabilizer in action.

1.1 Zener Diode

A Zener Diode is a special type of Diode that is typically operated in Reverse Bias. It is designed to allow current to flow "backwards" when a certain amount of reverse voltage is reached. Because of this property, it can be used as a voltage regulator in circuits.

The Zener diode's operation depends on the heavy doping of its p-n junction. The depletion region formed in the diode is very thin and hence the electric field is very high even for a small reverse bias voltage, allowing electrons to tunnel from the valence band of the p-type material to the conduction band of the n-type material.

1.2 LM7805 Regulator

In the second part of the experiment, we replaced the Zener Diode with a dedicated Voltage Regulator Integrated Circuit. We used the LM7805 Regulator, which is a member of the 78xx series of fixed linear voltage regulators. Below you can see the 7805 Voltage Regulator Pin Diagram.

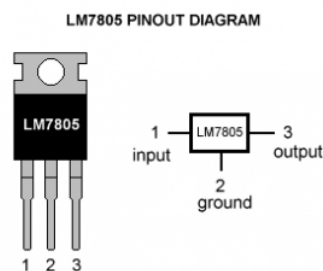


Figure 1: LM7805 Regulator Pinout (Souce: The Internet)

Here's a small description for each of the pins.

1. **INPUT:** Input voltage (7V-35V)
2. **GROUND:** Ground (0V)
3. **OUTPUT:** Regulated output; 5V (4.8V-5.2V)

1.3 Experimental Setup

The circuit for this experiment was prepared on a breadboard. Below is the Circuit Diagram for the setup used in this experiment.

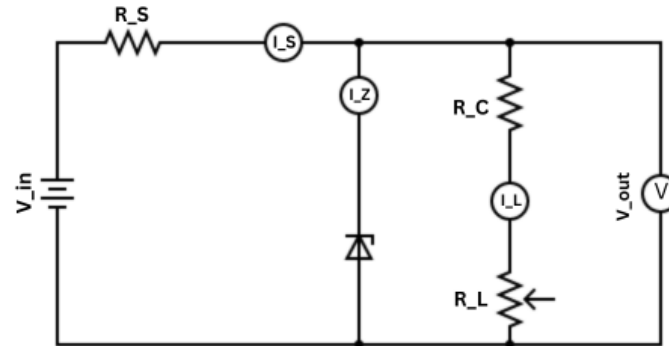


Figure 2: Circuit Diagram of the Setup

Where,

- V_{in} is the input voltage (0 - 15 V) being produced using a DC Power Supply.
- $R_S = 2.2k\Omega$
- I_S is the total current flowing in the circuit being measured using a DT-830D multimeter.
- I_Z is the total current flowing through the Zener Diode (or LM7805 IC) being measured using a DT-830D multimeter.
- I_L is the load current, being measured using a DT-830D multimeter.
- $R_C = 2.2$ (or 1) $k\Omega$
- $R_L = 0$ to $1k\Omega$ is a potentiometer.
- V_{out} is the output voltage being measured using a 8007 multimeter. Note that this is also the voltage drop across the Diode.

2 Studying a Zener Diode

In this part of the experiment, we studied the properties of the given Zener Diode.

2.1 Line Regulation

In this part of the experiment, we varied the input voltage (V_{in}) from 0 to 15 Volts with a constant load resistance of $R_c = 2.2k\Omega$.

2.1.1 Data

Table 1: Line Regulation data for the Zener Diode

R_L ($k\Omega$)	R_c	V_{in} (V)	I_s (mA)	I_z (mA)	V_{out} (V)
0	2.2	0	0	0	0
0	2.2	0.5	0.094	0	0.298
0	2.2	1	0.187	0	0.592
0	2.2	1.49	0.279	0	0.88
0	2.2	1.99	0.373	0	1.177
0	2.2	2.5	0.469	0	1.473
0	2.2	2.99	0.559	0	1.76
0	2.2	3.5	0.653	0.001	2.06
0	2.2	3.9	0.749	0.003	2.35
0	2.2	4.51	0.848	0.007	2.65
0	2.2	5.04	0.953	0.021	2.93
0	2.2	5.52	1.058	0.048	3.18
0	2.2	5.99	1.174	0.095	3.39
0	2.2	6.48	1.307	0.164	3.58
0	2.2	7.01	1.464	0.263	3.75
0	2.2	7.5	1.622	0.375	3.88
0	2.2	7.99	1.79	0.501	3.98
0	2.2	8.48	1.966	0.643	4.07
0	2.2	8.99	2.21	0.868	4.18
0	2.2	9.49	2.4	1.038	4.24
0	2.2	10	2.61	1.218	4.29
0	2.2	10.51	2.81	1.403	4.34
0	2.2	11.02	3.02	1.595	4.39
0	2.2	11.51	3.22	1.784	4.42
0	2.2	12.01	3.43	1.972	4.45
0	2.2	12.5	3.63	2.39	4.48
0	2.2	12.98	3.93	2.59	4.53
0	2.2	13.52	4.17	2.82	4.55
0	2.2	14.02	4.39	3.05	4.58
0	2.2	14.51	4.6	3.27	4.6
0	2.2	15	4.84	3.5	4.61

2.1.2 Analysis

Below are the plots generated from the above data.

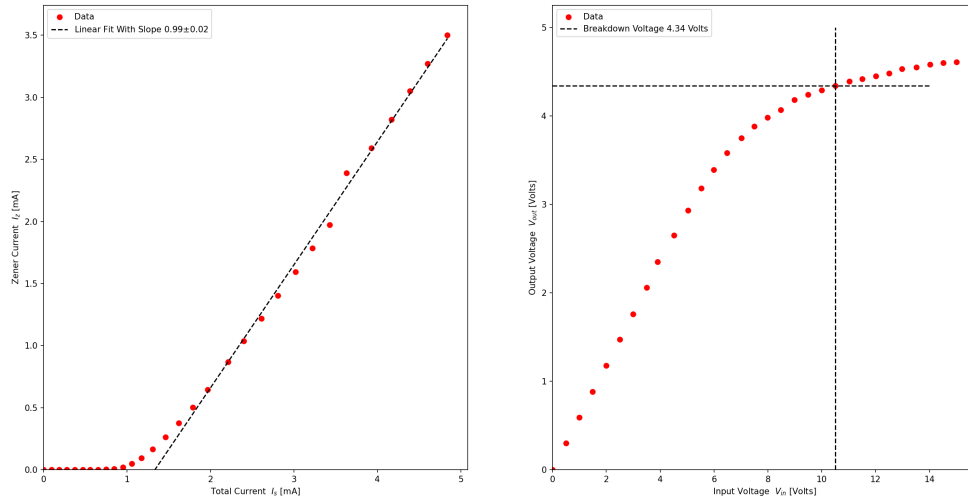


Figure 3: Plots of the Zener Diode data

From the plots, we can see that the graph between I_z and I_s is approximately a straight line after reaching a threshold voltage. From the fit for the I_z vs I_s plot we can see that

$$\frac{\delta I_z}{\delta I_s} = 0.99 \pm 0.02$$

$$\Rightarrow \delta I_z = (0.99 \pm 0.02) \delta I_s$$

From the V_{in} vs V_{out} plot we can see that **Zener Breakdown** is occurring at $V_{out} = 4.34V$

2.2 Load Regulation

In this part of the experiment, we kept the input voltage V_{in} constant at 15 Volts, and changed the Load Resistance, using a potentiometer.

$$R_c = 1k\Omega$$

2.2.1 Data

Table 2: Load Regulation data for the Zener Diode with $R_c = 1k\Omega$

V_{in} (V)	R_L ($k\Omega$)	I_L (mA)	I_z (mA)	V_{out} (V)
15	1.45	4.15	0	6.03
15	1.473	4.13	0	6.07
15	1.486	4.12	0	6.1
15	1.492	4.11	0	6.12
15	1.497	4.1	0	6.14
15	1.521	4.09	0	6.16
15	1.528	4.07	0.01	6.18
15	1.584	4.06	0.02	6.22
15	1.563	4.03	0.02	6.26
15	1.583	3.98	0.04	6.34
15	1.626	3.96	0.05	6.35
15	1.616	3.95	0.06	6.36
15	1.661	3.88	0.1	6.41
15	1.967	3.29	0.67	6.44
15	2.04	3.16	0.8	6.46

2.2.2 Analysis

Below are the plots generated from the above data.

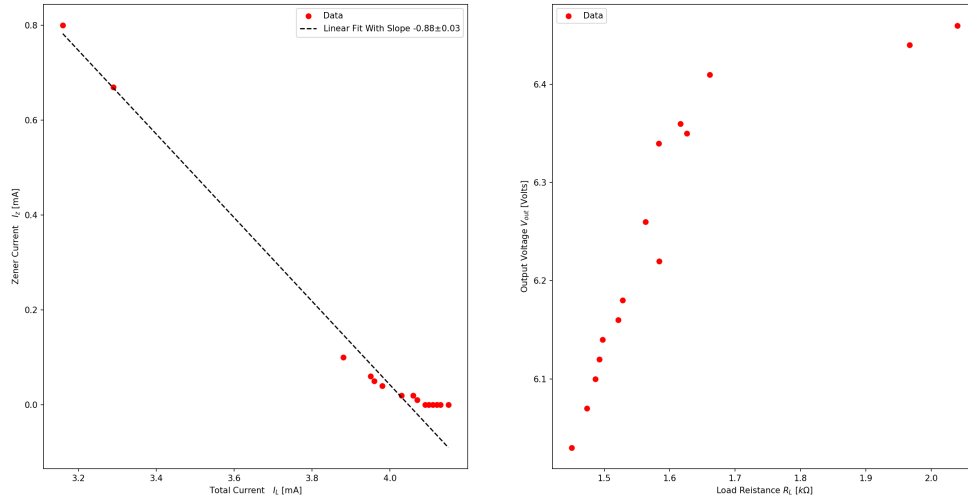


Figure 4: Plots of the Zener Diode load regulation data with $R_c = 1k\Omega$

As we can see in the above plots, we haven't reached the breakdown voltage yet, since the Load resistance is too small. We can see however, just like in the previous section,

$$\frac{\delta I_z}{\delta I_s} = -0.88 \pm 0.03$$

$$\Rightarrow \delta I_z = (-0.88 \pm 0.03) \delta I_s$$

$$R_c = 2.2k\Omega$$

2.2.3 Data

Table 3: Load Regulation data for the Zener Diode with $R_c = 2.2k\Omega$

V_{in} (V)	R_L ($k\Omega$)	I_L (mA)	I_z (mA)	V_{out} (V)
15	0	2.1	2.89	4.56
15	0.034	2.08	2.93	4.56
15	0.071	2.05	2.95	4.57
15	0.106	2.02	3.01	4.57
15	0.126	2	3.02	4.58
15	0.17	1.96	3.06	4.58
15	0.195	1.94	3.08	4.58
15	0.232	1.91	3.11	4.58
15	0.274	1.88	3.13	4.59
15	0.305	1.86	3.15	4.59
15	0.323	1.84	3.17	4.59
15	0.359	1.82	3.19	4.59
15	0.387	1.8	3.22	4.59
15	0.435	1.77	3.24	4.59
15	0.473	1.72	3.33	4.6
15	0.561	1.69	3.3	4.6
15	0.633	1.65	3.34	4.6
15	0.721	1.6	3.37	4.6
15	0.826	1.55	3.44	4.61
15	0.919	1.48	3.53	4.62
15	1.025	1.45	3.53	4.62

2.2.4 Analysis

Below are the plots generated from the above data.

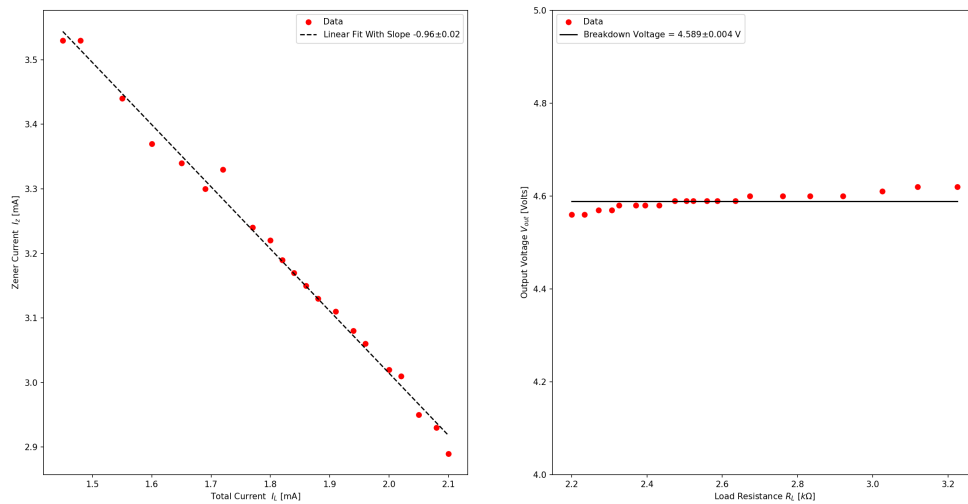


Figure 5: Plots of the Zener Diode load regulation data with $R_c = 2.2k\Omega$

$$\frac{\delta I_z}{\delta I_s} = -0.96 \pm 0.02$$
$$\Rightarrow \boxed{\delta I_z = (-0.96 \pm 0.02)\delta I_s}$$

From the V_{in} vs V_{out} plot we can see that **Zener Breakdown** is occurring at $\boxed{V_{out} = 4.589 \pm 0.004V}$

3 LM7805 Regulator IC

In this part of the experiment we studied the properties of the LM7805 Regulator IC.

3.1 Line Regulation

Again, as seen before here we varied V_{in} while keeping the load resistance constant at $R_c = 2.2k\Omega$.

3.1.1 Data

Table 4: Line Regulation data for IC 7805

R_c ($k\Omega$)	V_{in} (V)	I_L (mA)	V_{out} (V)
2.2	0.1	0	0
2.2	0.52	0	0
2.2	1	0	0.0001
2.2	1.5	0.02	0.05
2.2	2.06	0.63	1.299
2.2	2.49	0.81	1.697
2.2	3.02	1.04	2.19
2.2	3.45	1.23	2.61
2.2	4.03	1.47	3.1
2.2	4.5	1.67	3.53
2.2	5.04	1.9	4.03
2.2	5.54	2.12	4.49
2.2	6.03	2.33	4.94
2.2	6.48	2.42	5.12
2.2	6.95	2.42	5.11
2.2	7.47	2.42	5.11
2.2	8	2.41	5.11
2.2	8.52	2.43	5.11
2.2	9.01	2.43	5.11

3.1.2 Analysis

Below are the plots generated from the above data.

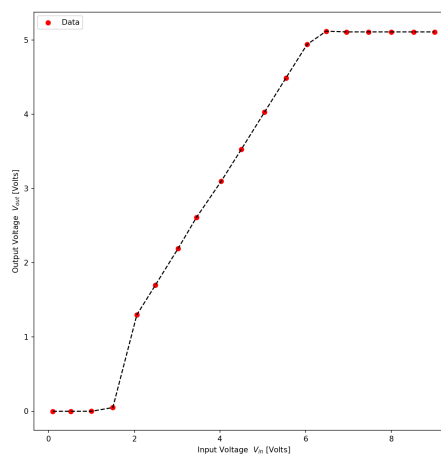


Figure 6: Plots of the Zener Diode data

As we can see from both the data and the plot, the minimum voltage after which V_{out} was constant was found to be $V_{min} = 6.95V$

3.2 Load Regulation

Again, as seen before here we varied R_L while keeping V_{in} constant at 15 Volts. The total load resistance is $R_c + R_L = R_L + 2.2k\Omega$

3.2.1 Data

Table 5: Load Regulation data for IC 7805

R_L ($k\Omega$)	V_{in} (V)	I_L (mA)	V_{out} (V)
0 ele	15	2.35	5
0.072	15	2.3	5.02
0.161	15	2.21	5.04
0.227	15	2.15	5.03
0.312	15	2.08	5.02
0.397	15	2	5.01
0.508	15	1.93	5.04
0.58	15	1.87	5.03
0.686	15	1.78	5.03
0.809	15	1.71	5.02
1.019	15	1.61	5.01

3.2.2 Analysis

Below are the plots generated from the above data.

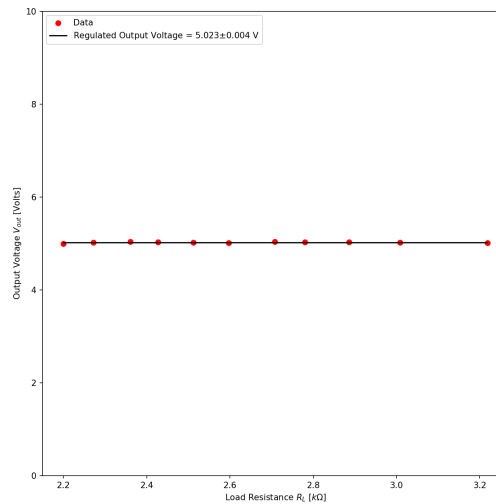


Figure 7: Plots of the Zener Diode data

From the V_{in} vs V_{out} plot we can see that the output voltage is being regulated at $V_{out} = 5.023 \pm 0.004V$

4 Conclusion

In conclusion, in this experiment we looked at how a Zener Diode can be used as a Voltage Regulator, by varying both the input and the load. We also used the LM7805 Regulator IC, and saw how it is remarkably effective at regulating the output voltage.

5 Sources Of Error

1. Loose Contacts between the Breadboard and the components, could lead to fluctuations in measurements.
2. The multimeters are not ideal ammeters or voltmeters, hence the reading given by them isnt exact. Inaccucies due to the finite internal resistance of these devices also leads to some errors in the measurements.