

# Experiment 01: Study of Zener Diode and IC 7805

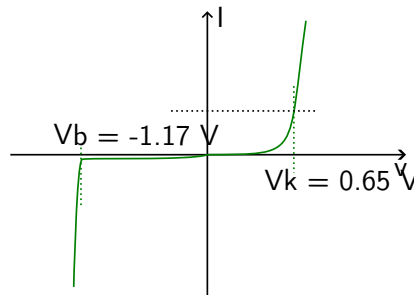
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## 1 Aim

- To study Zener diode as a voltage regulator.
- To study IC 7805 as a voltage stabiliser.

## 2 Theory

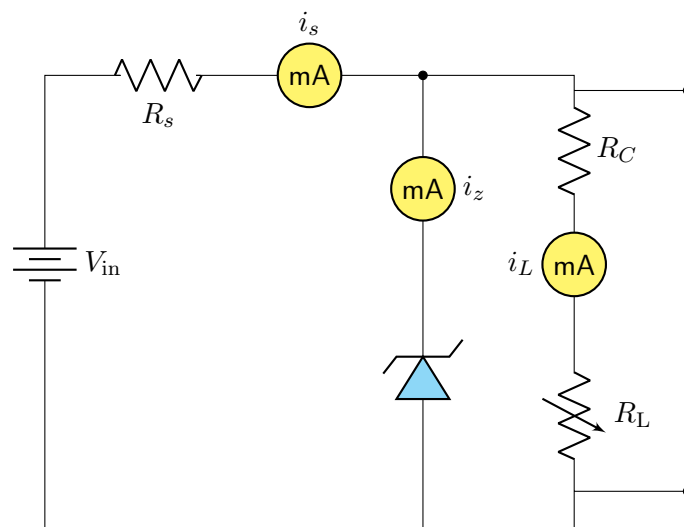
### 2.1 Zener Diode



**Figure 1:** Typical Zener diode characteristic curve

Zener diode is a specialised diode which works as a regular diode when forward biased but on reverse biasing, the voltage remain constant for a wide range of current after *Avalanche* breakdown. Thus, Zener diode is used as a shunt voltage regulator for regulating voltage across small loads.

Initially there is negligible current in the diode in the reverse bias condition but as breakdown voltage is reached, the current increases rapidly, however the voltage across the diode remains nearly constant.



**Figure 2:** Circuit Diagram for Load and Line Regulation Using a Zener Diode

From the above circuit diagram, we have:

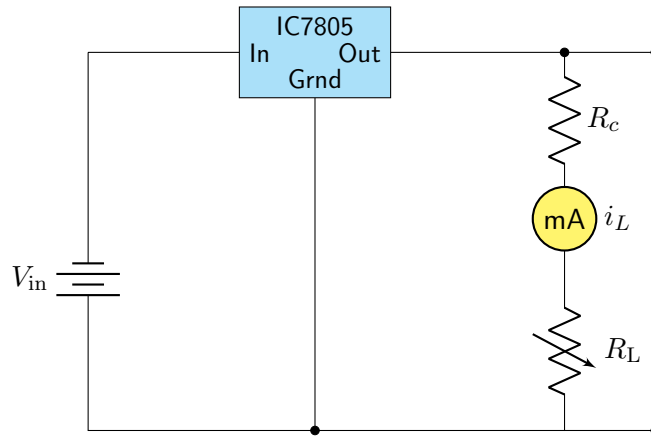
$$I_s = I_z + I_L \implies I_s = \underbrace{\frac{V_i - V_z}{R_s}}_{I_z} + \underbrace{\frac{V_o}{R_L}}_{I_L}$$

Hence in line regulation, where  $R_s$  and  $R_L$  are kept constant and  $V_o$  becomes constant after breakdown, from where we get  $\delta I_s = \delta I_z$ . Thus, we are expected to get a linear graph between  $I_z$  and  $I_s$  with slope 1.

In load regulation, we keep  $V_i$  constant and vary  $R_L$ .  $I_s$  independent of load resistance, hence from above equation we get  $\delta I_z = -\delta I_L$ . Thus, we are expected to get a linear graph between  $I_z$  and  $I_L$  with slope -1.

## 2.2 Integrated Circuit based Regulator

In Zener diode, the regulation is not perfect and output voltage increases very slowly with increasing reverse input voltage. To resolve this, we use Integrated Circuit (IC) based voltage regulators. We will use IC 7805 for the experiment. The 7805 IC voltage regulator has 3 pins. Pin 1 takes the input voltage and Pin 3 produces the output voltage. The ground of both input and output are given to Pin 2.



**Figure 3:** Circuit Diagram for load and line regulation using IC 7805

## 3 Data and Calculation

### 3.1 Zener Diode:

#### 3.1.1 Line Regulation

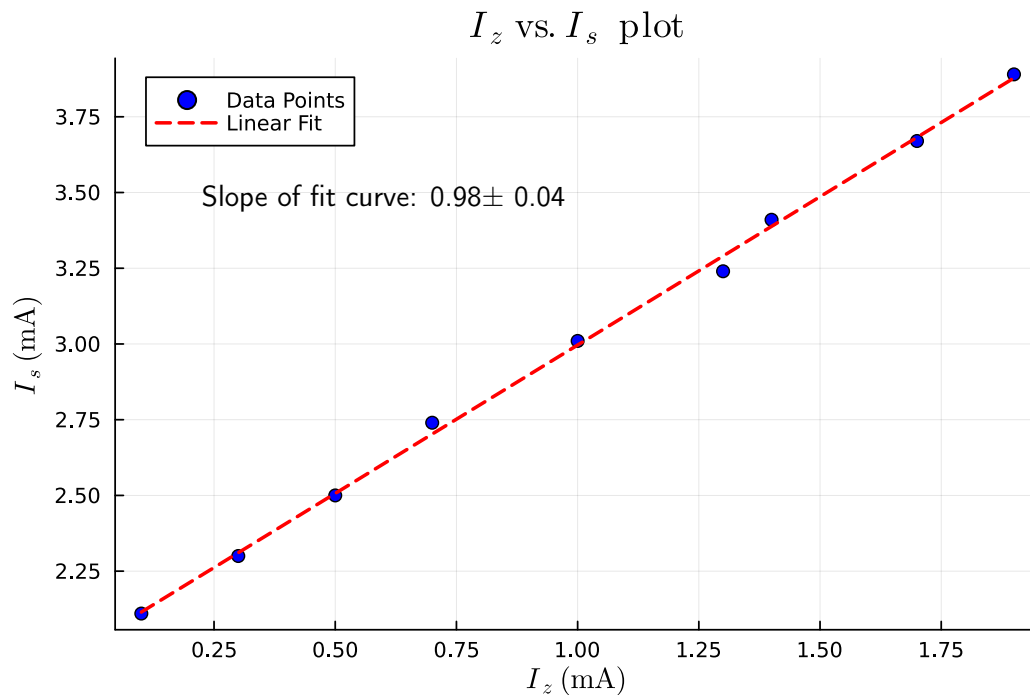
For the line regulation, we first fixed the load resistance to  $R_L = 1.1 \text{ k}\Omega$  and varied the input voltage. The output voltage, current across zener diode and the current in the circuit was measured for each input voltage. The data is tabulated below:

$V_i$ (V)	$I_s$ (mA)	$I_z$ (mA)	$V_o$ (V)
0	0	0.00000	0.01
0.6	0	0.00000	0.4
1	0.12	0.00000	0.69
1.6	0.23	0.00000	1.02
2.1	0.35	0.00000	1.31
2.4	0.46	0.00000	1.52
3	0.12	0.00000	1.85
3.5	0.23	0.00000	2.16
3.9	0.58	0.00000	2.43
4.5	0.69	0.00000	2.77
5	0.81	0.00002	3.09
5.4	0.93	0.00008	3.31

$V_i$ (V)	$I_s$ (mA)	$I_z$ (mA)	$V_o$ (V)
6	1.05	0.00023	3.68
6.5	1.18	0.00040	3.92
7	1.27	0.00083	4.23
7.5	1.39	0.00161	4.57
8	1.51	0.00337	4.87
8.5	1.63	0.00637	5.16
8.9	1.74	0.01132	5.40
9.5	1.86	0.01666	5.71
10	1.98	0.03700	6.05
10.5	1.58	0.04000	6.35
11	2.11	0.10000	6.50
11.5	2.30	0.30000	6.53
11.9	2.50	0.50000	6.57
12.5	2.74	0.70000	6.55
13	3.01	1.00000	6.56
13.6	3.24	1.30000	6.57
13.9	3.41	1.40000	6.57
14.5	3.67	1.70000	6.57
15	3.89	1.90000	6.58

### Proportionality of Zener and circuit current:

From the data, we plotted  $I_z$  vs  $I_s$  and found that the graph is linear. Initially the current was very low (in range of microamperes). At around  $V_i = 10.5$  V, the current started to increase rapidly (in range of milliamperes). The graph for data points after  $V_i = 10.5$  V is shown below along with linear fit curve:

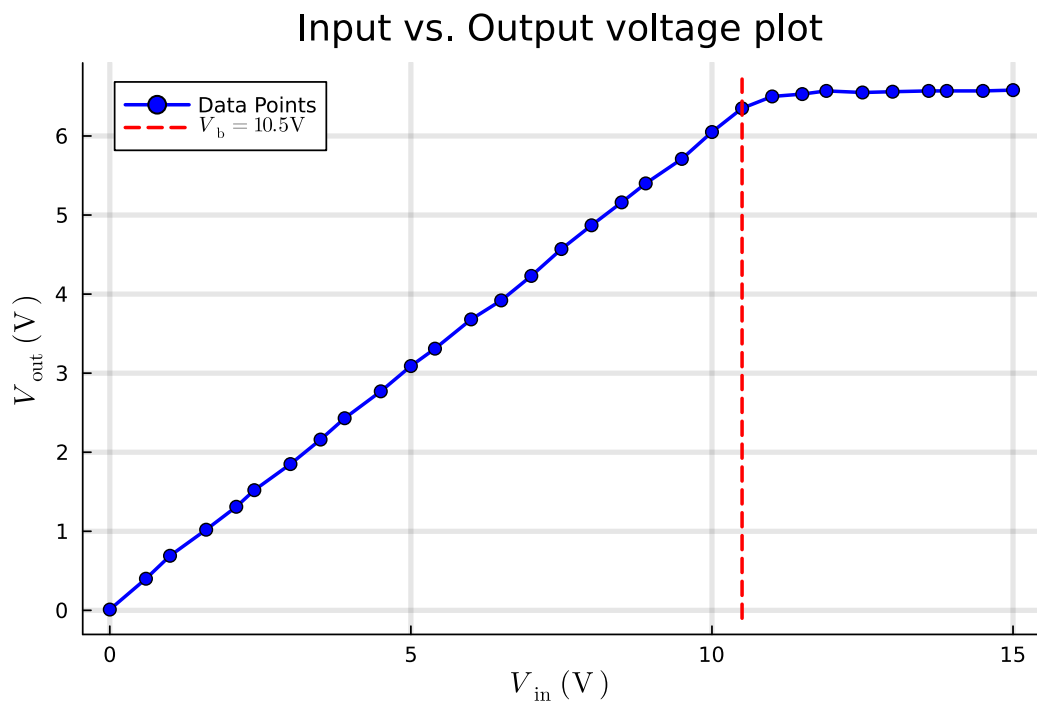


**Figure 4:** Plot of  $I_z$  vs  $I_s$  with constant load

From the linear fit, we obtained the slope to be  $m = 0.98 \pm 0.04$  which verifies  $\delta I_z = \delta I_s$ .

### Estimating Breakdown Voltage

From the above table, we plot the input vs the output voltage.



**Figure 5:** Plot between input and output voltage with constant load

From the plot, we can see that initially there gradual change in the output voltage with changing input but after  $V_{in} = 10.5$ , the output voltage saturated and became constant. Thus, from the experimental plot, we can estimate the breakdown voltage of the given Zener diode to be:

$$V_b = 10.5V$$

### 3.1.2 Load Regulation

**Without  $R_c$  :**

For the load regulation, we fixed the input voltage to  $V_i = 15 V$  and varied the load resistance using a potentiometer. The output voltage, current across zener diode and the load current was measured for each load resistance. The data is tabulated below:

$R_L (k\Omega)$	$I_L (mA)$	$I_z (mA)$	$V_o (V)$
0.007	6.92	0	0.2
0.057	6.76	0	0.5
0.106	6.61	0	0.9
0.153	6.5	0	1.2
0.203	6.36	0	1.4
0.249	6.25	0	1.7
0.304	6.11	0	2.1
0.354	6.02	0	2.3
0.396	5.92	0	2.6
0.452	5.78	0	2.8
0.513	5.64	0	3.1
0.551	5.53	0	3.3
0.609	5.44	0	3.5
0.655	5.34	0	3.7
0.713	5.24	0	3.9
0.751	5.16	0	4.1
0.802	5.06	0	4.3
0.856	5	0	4.5
0.906	4.92	0	4.7

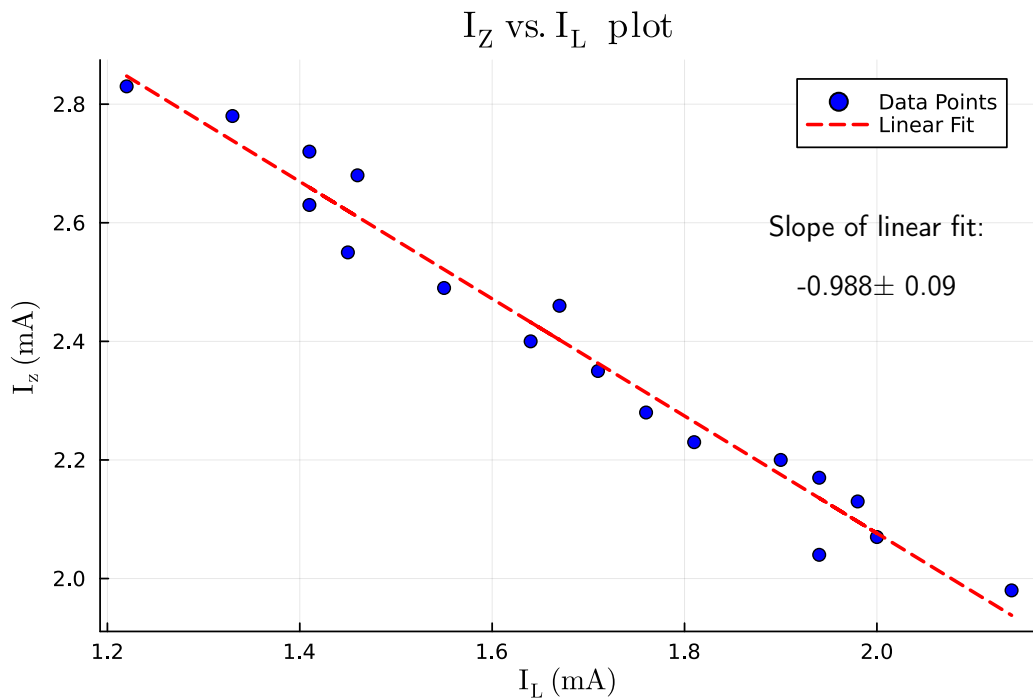
$R_L$ (k $\Omega$ )	$I_L$ (mA)	$I_z$ (mA)	$V_o$ (V)
0.955	4.84	0	4.9
1.017	4.73	0	5

From the above table, we see that the maximum output voltage reached without using  $R_c$  is  $V_o = 5$  V which is much less than the output voltage obtained after the breakdown voltage (close to 6V) calculated from the previous part. Thus, it indicates that the breakdown has not been reached and explains why we are obtaining negligible current through the zener diode since breakdown has not been reached.

**With  $R_c : 2.2\text{k}\Omega$**

We now introduce a current limiting resistor  $R_c = 2.2$  k $\Omega$

$R_L$ (k $\Omega$ )	$I_L$ (mA)	$I_z$ (mA)	$V_o$ (V)
0.065	2.83	1.22	6.4
0.107	2.78	1.33	6.4
0.154	2.72	1.41	6.4
0.177	2.68	1.46	6.4
0.242	2.63	1.41	6.6
0.312	2.55	1.45	6.52
0.317	2.49	1.55	6.6
0.406	2.46	1.67	6.6
0.467	2.4	1.64	6.6
0.532	2.35	1.71	6.7
0.61	2.28	1.76	6.6
0.672	2.23	1.81	6.4
0.713	2.2	1.9	6.6
0.752	2.17	1.94	6.6
0.815	2.13	1.98	6.6
0.902	2.07	2	6.6
0.951	2.04	1.94	6.6
1.033	1.98	2.14	6.6

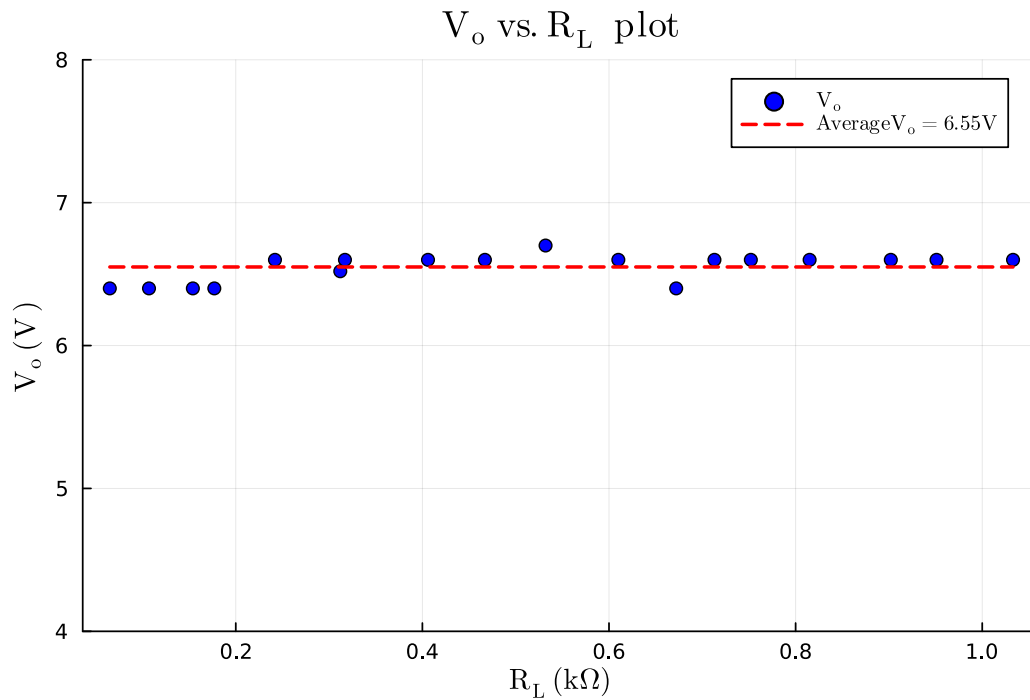


**Figure 6:** Plot of  $I_z$  vs  $I_L$  with  $R_c = 2.2\text{k}\Omega$

From the above plot, we obtained the slope for the linear fit curve as:  $m = -0.98 \pm 0.09$ , thus verifying  $\delta I_z = -\delta I_L$

### Constancy of Output Voltage:

In this case, with the use of  $R_c$ , we see that the output voltage is greater than 6V, indicating that breakdown has been reached. It remains constant for a wide range of load resistance. The plot of output voltage vs load resistance is shown below:



**Figure 7:** Plot of  $V_o$  vs  $R_L$  with  $R_c = 2.2k\Omega$

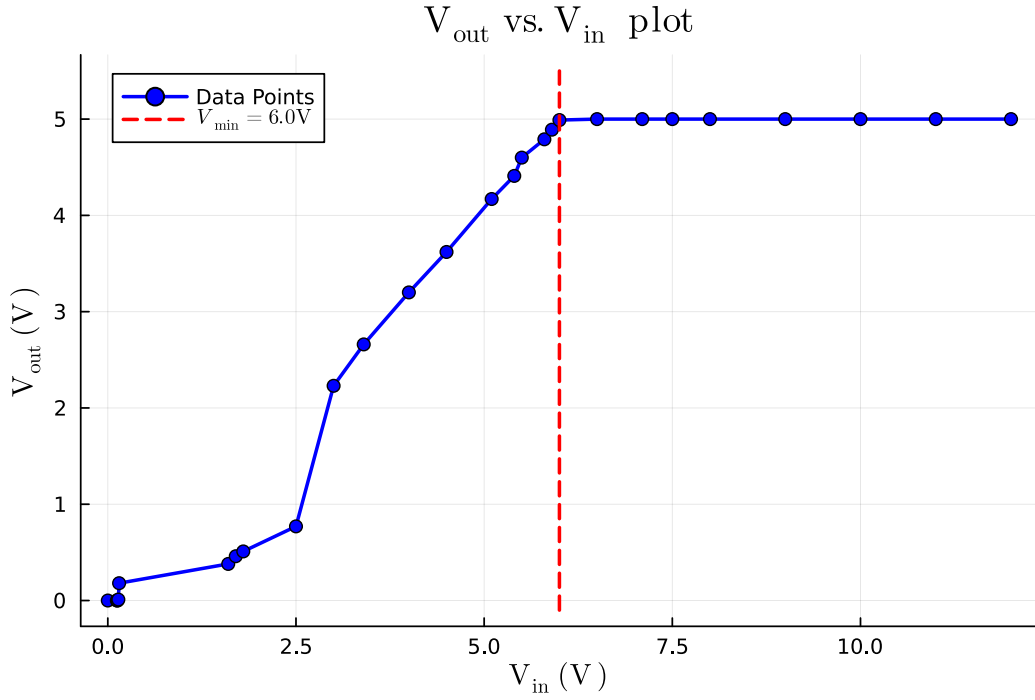
## 3.2 IC 7805

### 3.2.1 Line Regulation

For the line regulation, kept the resistance  $R_c + R_L = 2.2 k\Omega$  and varied the input voltage. The output voltage, current across IC 7805 and the current in the circuit was measured for each input voltage. The data is tabulated below:

$V_{in}(V)$	$I_L(mA)$	$V_o(V)$
0	0	0
0.12	0	0
0.13	0	0
0.14	0.01	0.01
0.15	0.76	0.18
1.6	0.85	0.38
1.7	1.04	0.46
1.8	1.17	0.51
2.5	1.76	0.77
3	1.02	2.23
3.4	1.22	2.66
4	1.47	3.2
4.5	1.67	3.62
5.1	1.92	4.17
5.4	2.03	4.41
5.5	2.12	4.6

$V_{in}(V)$	$I_L(mA)$	$V_o(V)$
5.8	2.21	4.79
5.9	2.25	4.89
6	2.3	4.99
6.5	2.31	5.0
7.1	2.3	5.0
7.5	2.3	5.0
8	2.3	5.0
9	2.3	5.0
10	2.3	5.0
11	2.3	5.0
12	2.3	5.0



**Figure 8:** Plot of  $V_o$  vs  $V_i$  for IC 7805

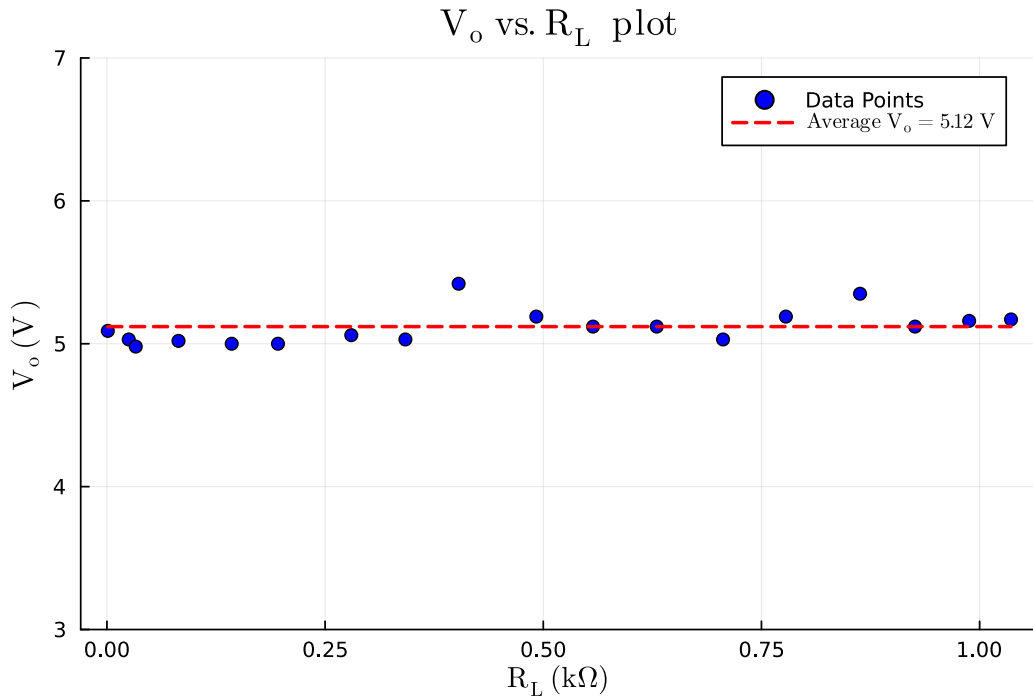
We plotted the input voltage by varying the output voltage. From the plot, we can see that the output voltage remains constant for a wide range of input voltage after  $V_{in} = 6$  V. Thus, from the experimental plot, we can estimate the minimum voltage of the given IC to be 6 V. The stable voltage obtained after the minimum applied voltage is 5 V which matches with the expectation since the last digit of the IC implies so.

### 3.2.2 Load Regulation

For the load regulation, we fixed the input voltage to  $V_i = 15$  V and varied the load resistance using a potentiometer. The output voltage, current across load was measured for each load resistance. The data is tabulated below:

$R_L (\Omega)$	$i_L (A)$	$V_o (V)$
0.001	2.35	5.09
0.025	2.29	5.03
0.033	2.27	4.98
0.082	2.23	5.02
0.143	2.16	5.00
0.196	2.12	5.00
0.28	2.07	5.06

$R_L (\Omega)$	$i_L (A)$	$V_o (V)$
0.342	2.00	5.03
0.403	2.08	5.42
0.492	1.95	5.19
0.557	1.88	5.12
0.63	1.83	5.12
0.706	1.75	5.03
0.778	1.77	5.19
0.863	1.76	5.35
0.926	1.66	5.12
0.988	1.64	5.16
1.036	1.61	5.17



**Figure 9:** Plot of  $V_o$  vs  $R_L$  for IC 7805

From the above plot, we can see that the output voltage remains constant for a wide range of load resistance. The output voltage remains constant at an average voltage of 5.12 V which matches closely with our expectation for IC7805. Thus, the IC 7805 is a good voltage stabiliser.

## 4 Conclusion

We studied the line and load regulation of Zener diode. From the line regulation, we found out the breakdown voltage of the Zener diode to be 10.5 V. We found out that the voltage across the diode remains constant for input voltage greater than the breakdown voltage.

To improve the regulation, we used IC 7805 as voltage regulator. From the line regulation, we found out the minimum voltage required for the IC to achieve a stable voltage to be 6 V. The stable voltage for the IC was found to be 5 V as expected.