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

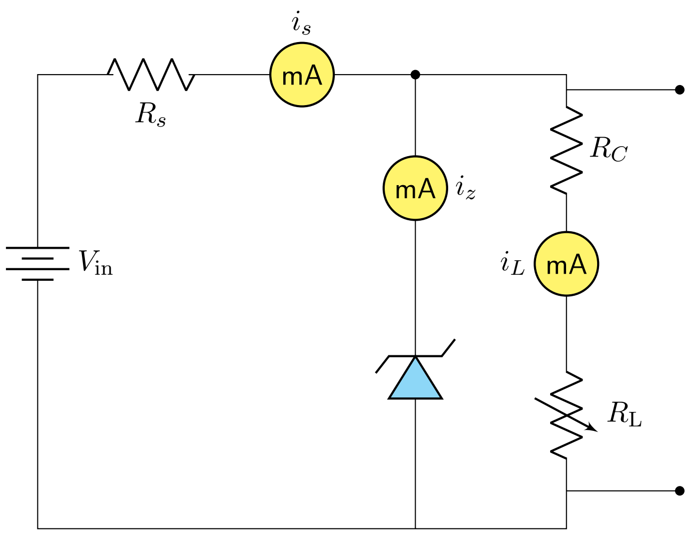

Figure 1: Circuit Diagram for Load and Line Regulation Using a Zener Diode

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. Thus, Zener diode is used as a shunt voltage regulator for regulating voltage across small loads. The breakdown voltage of Zener diodes will be constant for a wide range of current. Zener diode is connected parallel to the load to make it reverse bias and once the Zener diode exceeds knee voltage, the voltage across the load will become constant.

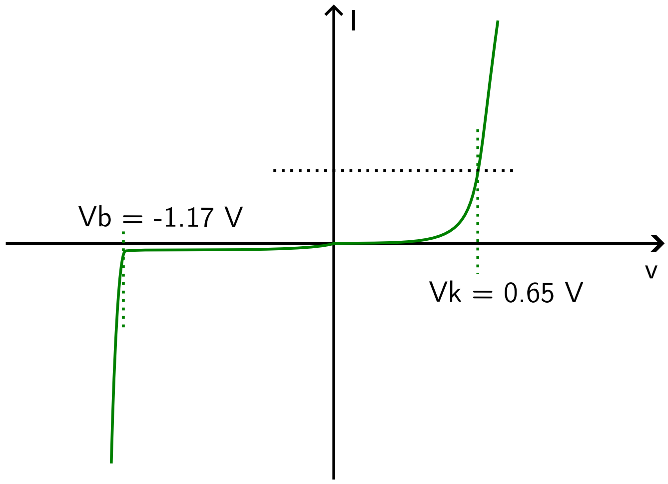

Figure 2: Typical Zener diode characteristic curve

2.2 Integrated Circuit

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.

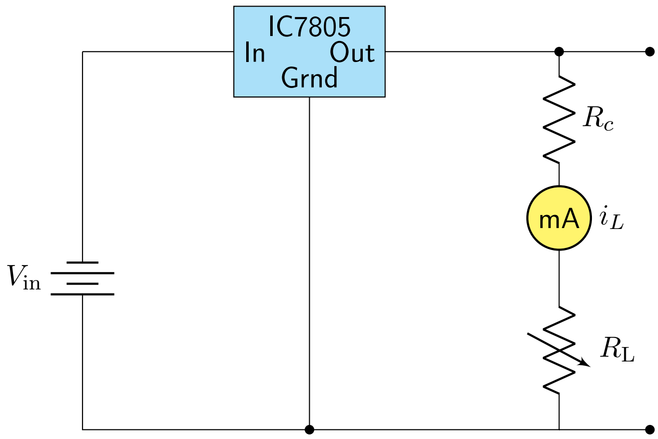

Figure 3: Circuit Diagram for load and line regulation using IC 7805

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)	Is (mA)	Iz (mA)	Vo (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

V_i (V)	Is (mA)	Iz (mA)	Vo (V)
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
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 Iz vs Is and found that the graph is linear. Intially 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:

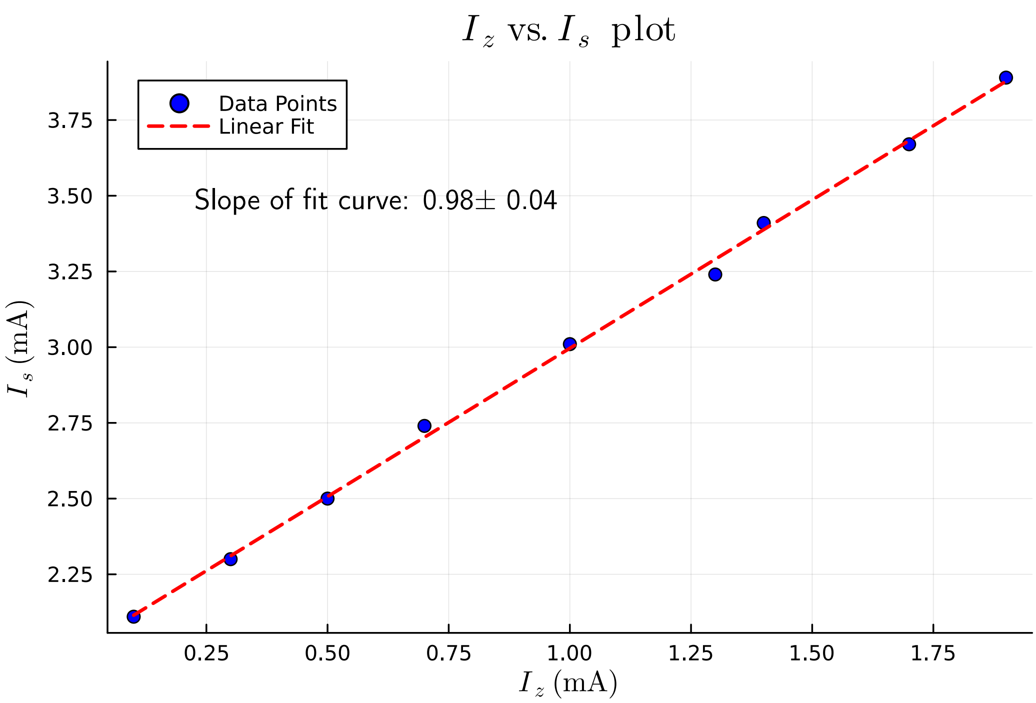

Figure 4: Plot of Iz vs Is with constant load

From the linear fit, we obtained the slope to be $m = 0.98 \pm 0.04$ which verifies $\delta\text{Iz} = \delta\text{Is}$.

Estimating Breakdown Voltage

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

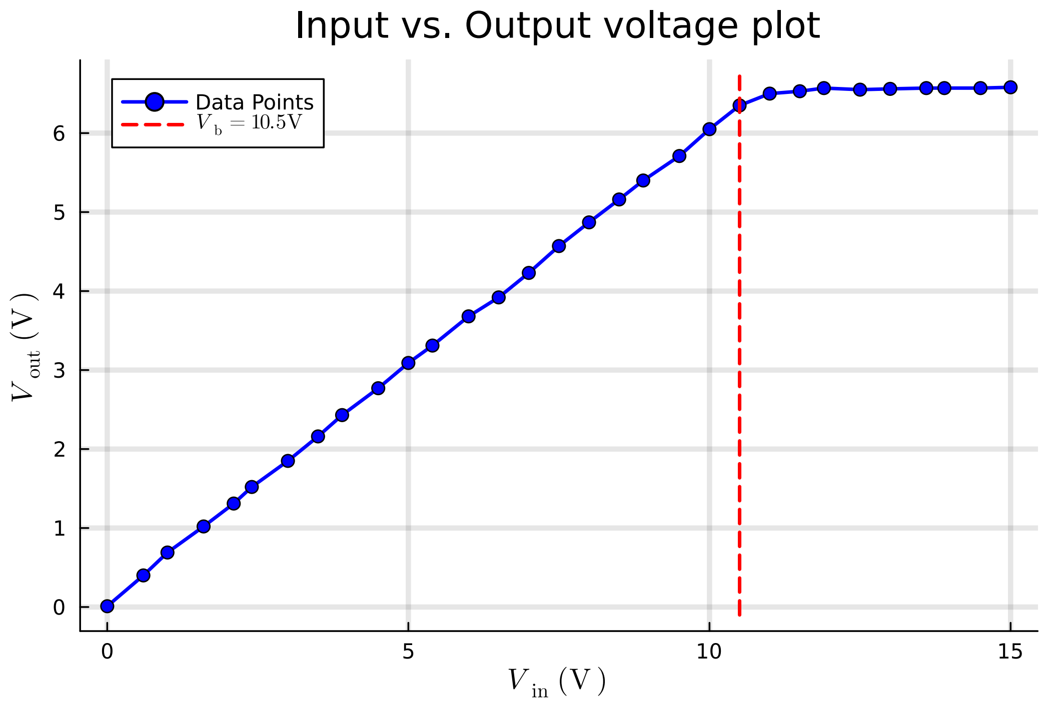

Figure 5: Plot between input and output voltage with constant load

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:

$$\boxed{V_b = 10.5\text{V}}$$

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 (kΩ)	I_L (mA)	Iz (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

R_L (kΩ)	I_L (mA)	Iz (mA)	V_o (V)
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
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 $\mathrm{R_c}$ is $V_o = 5\ \mathrm{V}$ which is much less than the output voltage obtained after the breakdown voltage (close to $6V\mathrm{V}$) 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 $\mathrm{R_c} : 2.2\mathrm{k\Omega}$

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

R_L (kΩ)	I_L (mA)	Iz (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

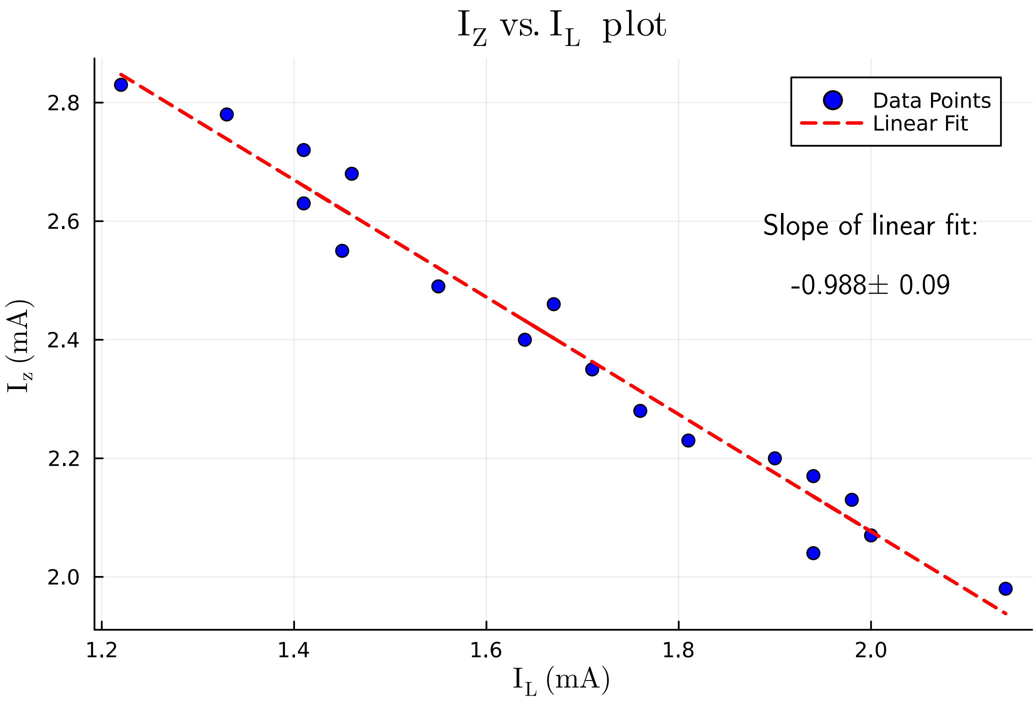

Figure 6: Plot of I_z vs I_L with $R_c = 2.2k\Omega$

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:

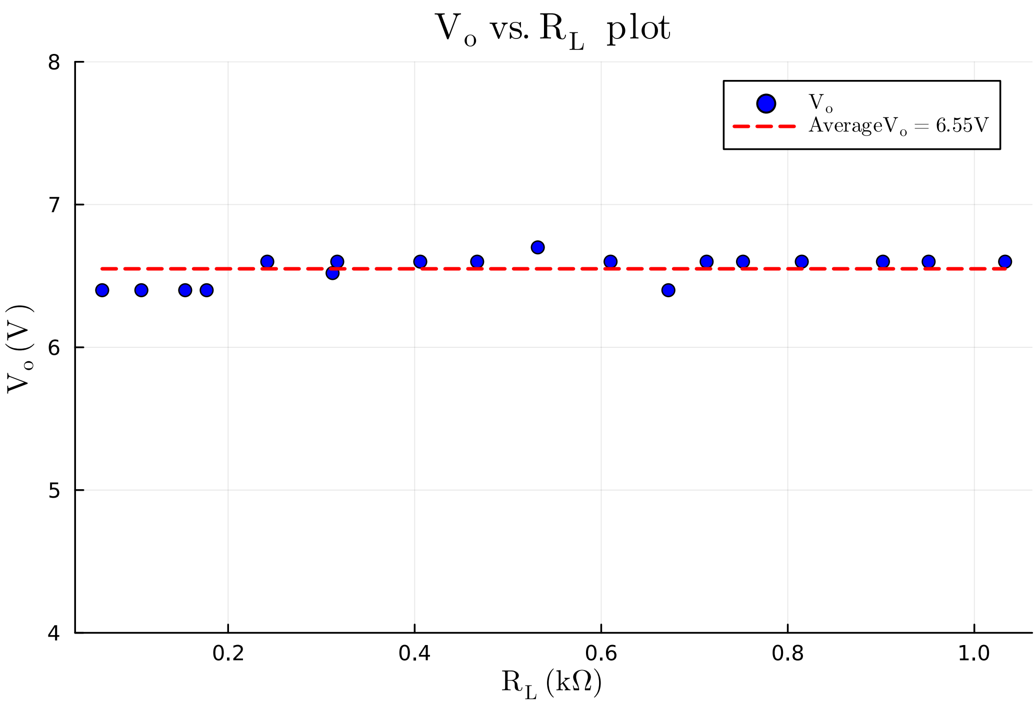

Figure 7: Plot of V_o vs R_L with $R_c = 2.2k\Omega$

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
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

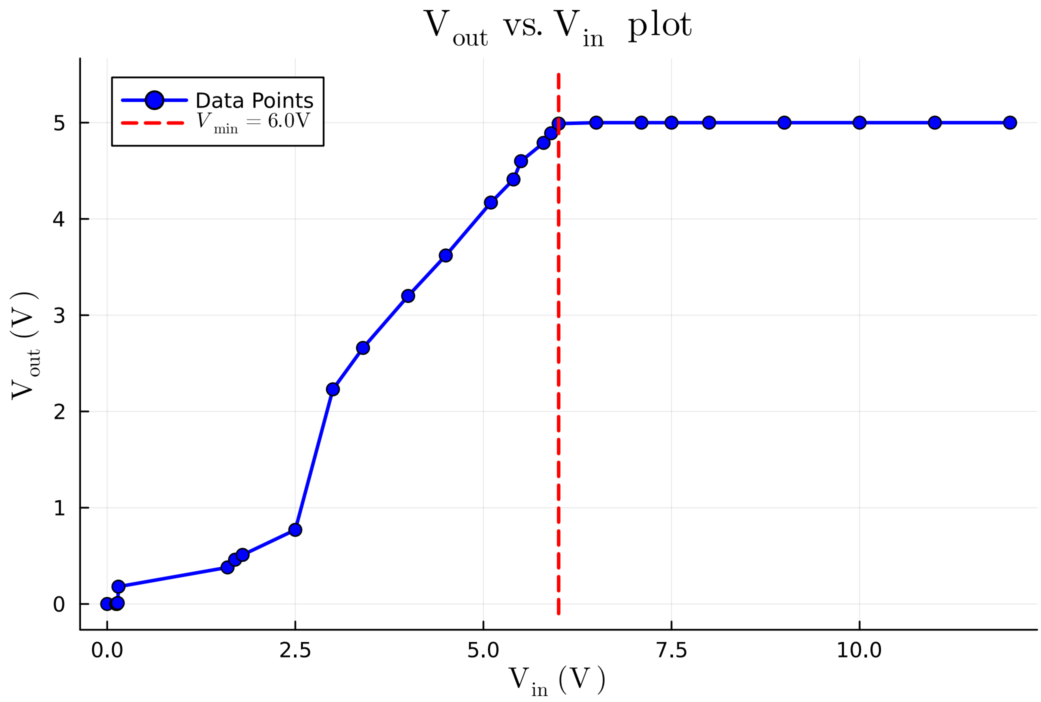

Figure 8: Plot of V_o vs V_i for IC 7805

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:

Table 5: Resistance, Current, and Voltage Measurements with Boxed Lines Spanning Multiple Pages

R_L (Ω)	i_L (A)	V_0 (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
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

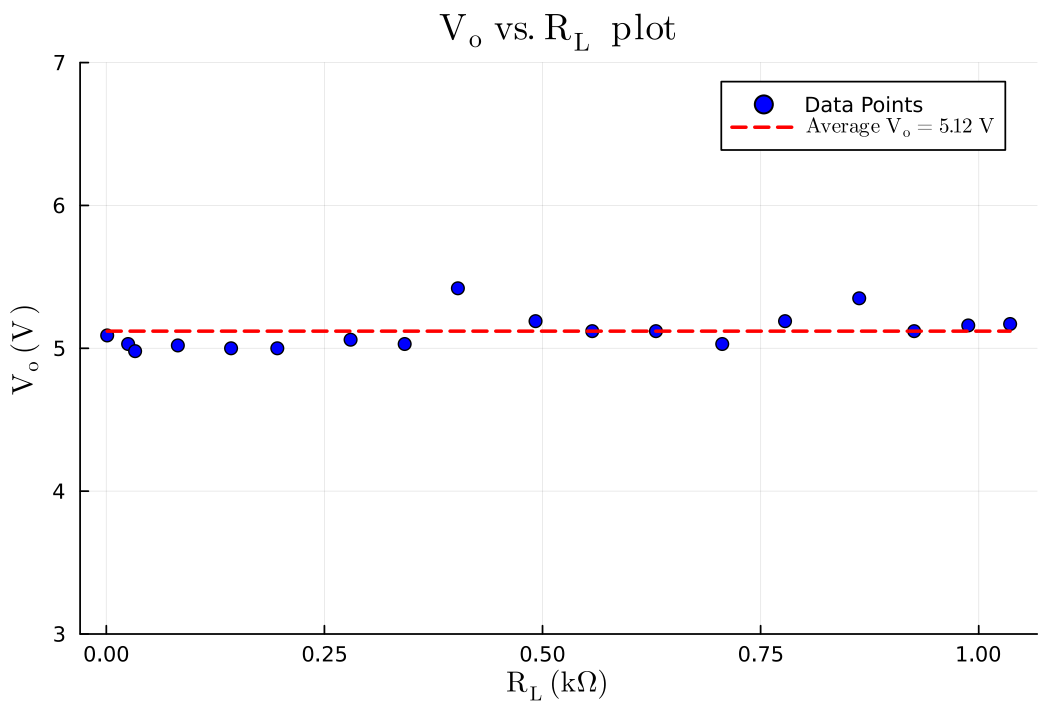

Figure 9: Plot of V_o vs R_L for IC 7805

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 avrage voltage of 5.12 V which matches closely with out expectation for IC7805. Thus, the IC 7805 is a good voltage stabiliser.

4 Conclusion