ECE 205: Lab 2

Regulators

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1 Statement of Purpose

The purpose of this lab was to develop familiarity with voltage regulators, specifically the LM317 voltage regulator, and data-sheets. We accomplished this by modeling a circuit with various input voltages and attempted to control the output voltage of the regulator. To construct this model, we utilized the software LTspice.

2 PreLab Deliverables

To begin, the voltage, V_x for each of the three circuits below is found utilizing loop analysis.

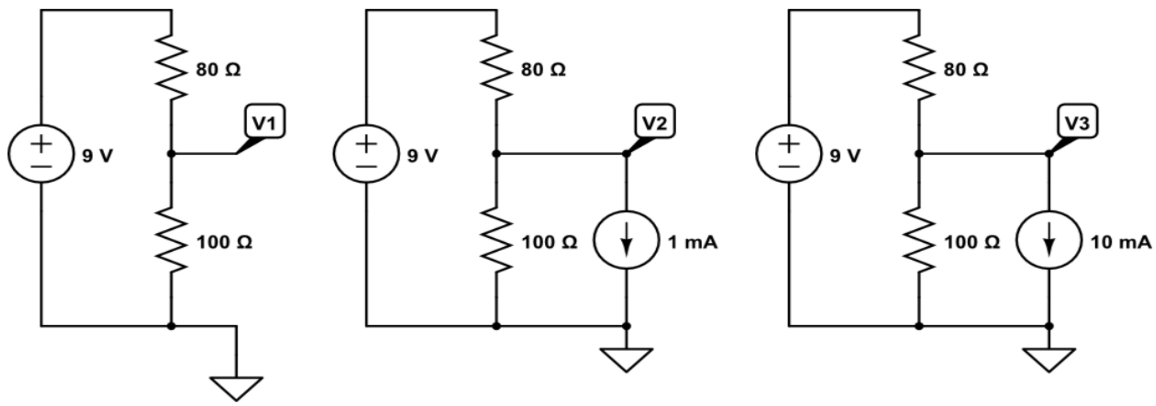

Figure 1: Three sample simple circuits to demonstrate the unsteady nature of V_x

For V_1, the volage is simply equivalent to the ratio of resistance prior to the node, as seen in Eq. 1.

$$V_1 = V_{in} - \frac{80}{80+100} \cdot V_{in} = 9 - \frac{80}{180} \cdot 9 = 5V \tag{1}$$

For V_2, two currents are added for investigation, i_1 across the 80 Ω resistor, and i_2 across the 100 Ω resistor. Hence, we can determine a relation of the input and output currents at the node between the resistors, (Eq. 2), and ultimately solve for the voltage drop across the first resistor.

$$i_1 - i_2 - .001 = 0 \tag{2}$$

Further, the currents are simply equal to the voltage drop across their respective resistor, divided by the resistance. Substituting this into Eq. 2, defining ground as the bottom most wire, we obtain:

$$\frac{V_{in} - V_2}{80} - \frac{V_2}{100} - .001 = 0 \tag{3}$$

and find V_2 to be 4.956 V. Following a similar procedure to the previous example, simply substituting

10 mA in for 1 mA into Eq. 2, we find V_3 to be 4.556 V.

Next, the initial schematic we will use is presented below, in Fig. 2.

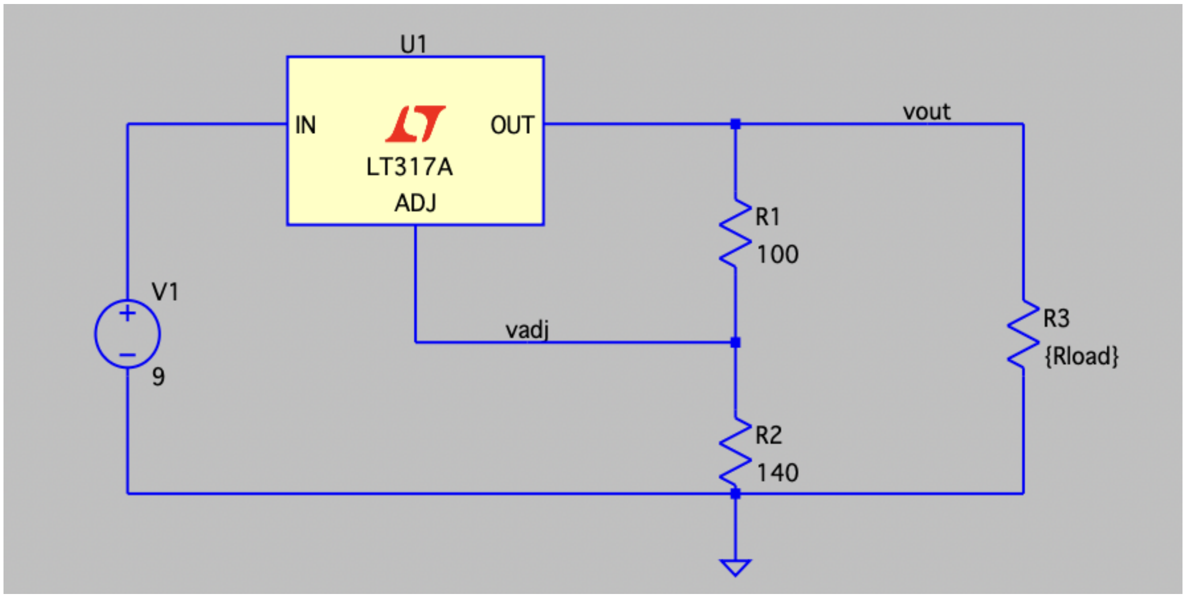

Figure 2: Schematic of circuit we will be utilizing

The equation to determine the output voltage of this circuit is:

$$V_{out} = V_{ref} \cdot \left(1 + \frac{R_2}{R_1}\right) + I_{adj} \cdot R_1 \tag{4}$$

although I_{adj} is negligible, and is thus ignored. We will fix R_1 to be 100 Ω, and R_2 is given as:

$$R_2 = R_1 \cdot \left(\frac{V_{out}}{V_{ref}} - 1\right). \tag{5}$$

3 Procedure

For this lab, we carried out three different trials all of which follow the same schematic given by 2. For the first trial, we maintained a constant output voltage across the load resistor by varying the resistance $R2$. For the second trial, we determined the regulator efficiency via a ratio of the power emitted by the load resistor, or output power, to the input power. For the third and final trial, we determined the drop-off voltage for the LM317 voltage regulator by varying the input voltage from 1 - to 60 V to determine the input voltage range where the regulator is operational.

First, to obtain constant output voltages of 3 - and 6 V, we used Eq. 5 to find the required resistance for R_2 to impose the aforementioned output voltages. For output voltages of 3 - and 6 V, we did the following calculations:

$$R_{2,3V} = R_1 \cdot \left(\frac{V_{out}}{V_ref} - 1 \right) = 100\Omega \cdot \left(\frac{3V}{1.25V} - 1 \right) = 140\Omega \tag{6}$$

$$R_{2,6V} = R_1 \cdot \left(\frac{V_{out}}{V_ref} - 1 \right) = 100\Omega \cdot \left(\frac{6V}{1.25V} - 1 \right) = 380\Omega \tag{7}$$

and found the resistance in R_2 required to maintain a constant output voltage of 3 V to be 140 Ω and a constant output voltage of 6 V to be 380 Ω. With the aforecalculated values of $R2$, we were then able to run LTspice with the schematic given in Fig. 2 with the resistance R_2 being both 140 Ω for 3 V and 380 Ω for 6 V.

Next, to determine the efficiency of the regulator, we set R_2 to 300 Ω and the load resistance to 500 Ω. We then ran a steady-state simulation to determine the current across load resistor and the voltage source. We then found the efficiency of the voltage regulator with the use of the following equation:

$$\epsilon_{reg} = \frac{V_{out} \cdot i_{LR}}{V_{in} \cdot i_V} \tag{8}$$

where i_{LR} and i_V are the currents across the load resistor and the voltage source, respectively. It should be noted that Eq. 8 is merely a ratio of the power dissipated by the load resistor to the total power inputted into the system by the voltage source.

Finally, to simulate the drop-off voltage, we utilized the same parameters as used to determine the efficiency, but used a varying voltage generated by the voltage source. We varied this voltage from 1 - to 60 V. From this simulation, we found the output voltage, the difference between the input and output voltage, and the output current all as a function of input voltage.

4 Observation and Data

To begin, we ran the schematic presented in Fig. 2 with a variant load resistance, a constant input voltage of 9 V, and R_1 with a resistance of 100 Ω. R_2 had a resistance of 140 Ω for an output voltage of 3 V, and 380 Ω for an output voltage of 6 V. The output voltage as a function of the load resistance for both desired cases are presented below.

Next, we set R_2 to 300 Ω to reach a desired output voltage of 5 V, and R_3 to 500 Ω. To determine the efficiency of the regulator, the LT317A, we divided the power dissipated in the load resistor, R_3, by the power dissipated in the voltage source, V_1; as shown in Eq. 8.

We found i_{LR} and i_V to be 10.1963 mA and -22.9536 mA, respectively. Thus, we found the regulator efficiency, ϵ_{reg}, to be -0.251629697617, or roughly 25.2%.

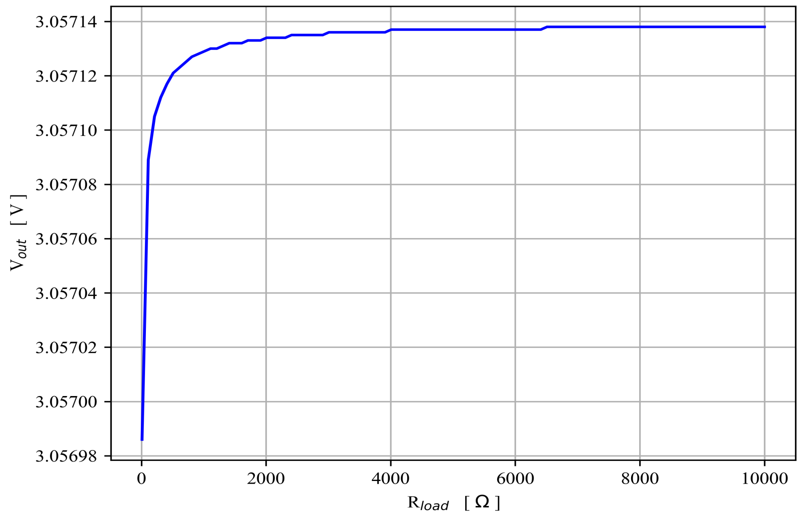

Figure 3: Output voltage as a function of load resistance, R_2 of 140 Ω

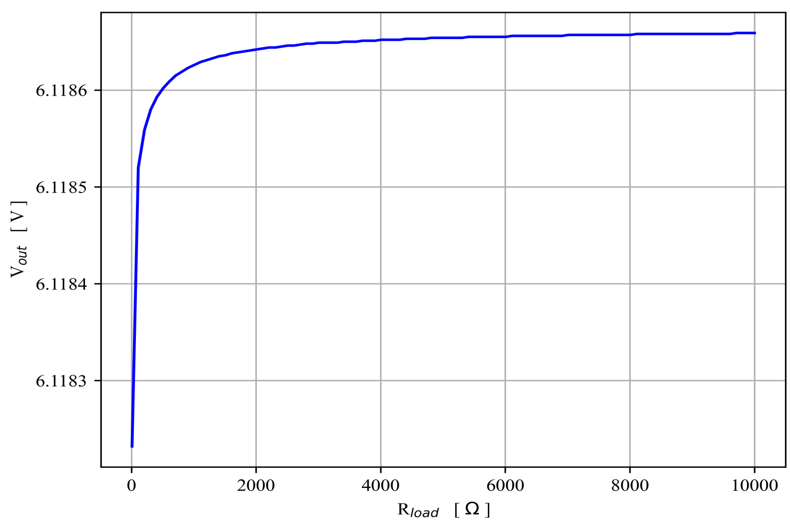

Figure 4: Output voltage as a function of load resistance, R_2 of 380 Ω

Proximally, through simulation of the aforementioned schematic, we determine our drop-off voltage to be 2 V. We determined this value by setting R_2 to be 300 Ω, so as to return an output voltage of 5 V, and had a variant input voltage. This is shown in Fig. 5. Although we determined a drop-off voltage of 2 V, the provided data sheet lists the drop-off voltage as 3 V. Finally, we determined the maximum current to be about 10.2 mA. As observed in the Fig. 5, once exceeding this maximum current, the regulator no-longer behaves as expected.

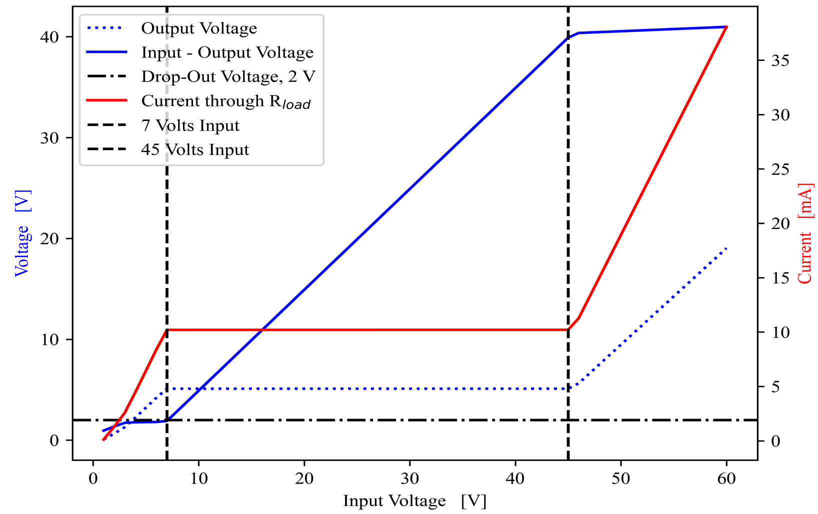

Figure 5: Drop-off voltage and maximum current of regulator

5 Analysis

Although our simulated output voltages are not precisely constant across all resistivities simulated, because the range of fluctuations in the output voltages is on the order of 10s of μV, we can state the voltage is constant. These observed fluctuations are much more constant than that of the naive solution of the circuits presented in Fig. 1. Further, we determined our regulator efficiency to be roughly 25%. Thus, at an output voltage of 5 V, an input voltage of 9 V, and a load resistor of 500 Ω, the load resistor is dissipating 25% of the power input by the voltage source. Finally, our observed domains of effective operation disagreed slightly with those presented in the data-sheet, however are near enough each other for the error to be simply attributed to the data-sheet being written for a different make and model.

6 Conclusion

In conclusion, when operating within the recommended conditions, the regulator performs as expected, effectively maintaining an essentially constant output voltage. Further, our simulated results of the effective domain of operation are within an order of magnitude of those listed in the provided data-sheet.

7 Appendix

All output files are in this google folder. The .docx is the output of the efficiency trial, as we could not figure out how to export that data into a .txt file.