Lab 6: Power Supply Design Project

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ECE 311-03
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1 Introduction

The purpose of this lab is to build a power supply that is able to convert 120V AC to 12V DC with the lowest amount of ripple. The scope of this experiment does not involve the use of a function generator for the AC supply. Instead, the electricity supplied by ComEd's distribution network will be utilized via the wall outlet. Furthermore, this power supply will be designed using only operational amplifiers, transistors, a voltage regulator, and a transformer.

2 Theory

To understand the fundamentals behind a power supply, a block diagram can be constructed to demonstrate its components. This is shown in Figure 1. Because in the United States electricity supplied to common wall outlets is 120V AC at 60 Hz, it is necessary that all power supplies, and all devices designed for use with a wall outlet, are designed to accommodate this restriction. Electronics do not generally use this voltage, so it is necessary to step it down. In the case of the power supply, alternating current must be converted into direct current. This is done by using a rectifier, generally implemented through the use of diodes. Looking back to Figure 1 it is clear that after the voltage is stepped down, it is then immediately rectified into DC. The next component is called the filter capacitor. If this were to be removed, the voltage v_c would be a half-wave or full-wave rectified sinusoid. This capacitor forces the output of the rectifier circuit to have a larger DC value, and when this capacitance has a large value, a very small ripple. The regulator then lowers the ripple even more, however this component tends to lower the DC voltage.

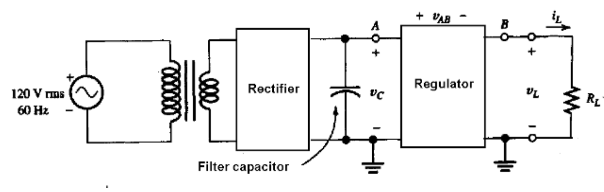

Figure 1: Block Digram Power Supply

The full implementation of the power supply circuit is shown in Figure 2.

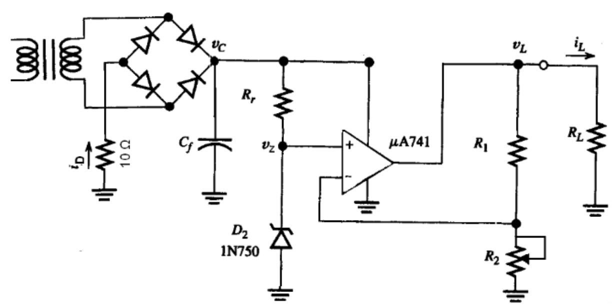

Figure 2: Power Supply Circuit Schematic

3 Procedure

The equipment used in the lab was:

- Breadboard
- Step Down Transformer

- IC Regulator
- LM 317 chip
- $47\mu F$ and $4.7\mu F$ Capacitors
- Resistors
- Diodes
- Operational amplifier
- Wire
- Multimeter

The first step of this experiment was to observe the open circuit voltage of the step-down transformer being used in the lab. This was done by constructing the circuit shown in Figure 3. Using the oscilloscope, the secondary voltage could easily be found. First the load had to be matched so that the secondary voltage equated to 12Vrms. This circuit is shown in Figure 4.

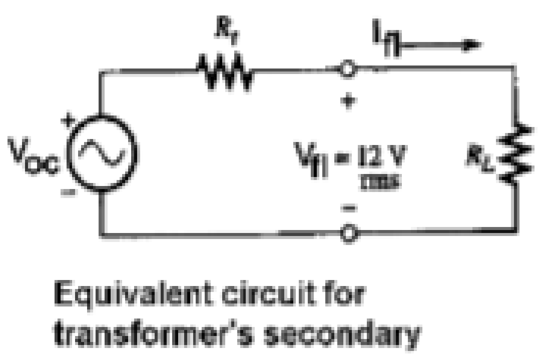

Figure 3: Basic Transformer Circuit

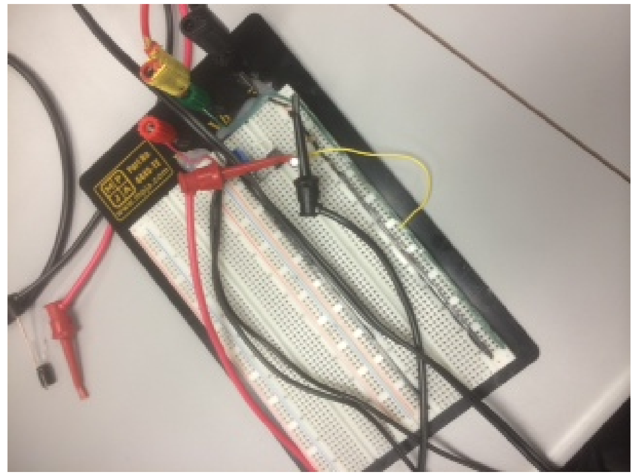

Figure 4: Basic Transformer Circuit Implementation

After this, the signal had to be rectified. This was done by capturing the load voltage along with the current of the diode. Using the schematic from Figure 5, the input and output ripple were captured using the oscilloscope.

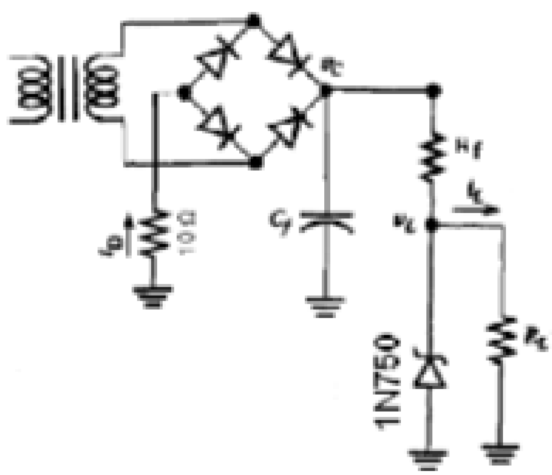

Figure 5: Rectifier Circuit diagram

After building this stage of the circuit, the input and output voltages were then captured using the Schematic of Figure 2. The implementation of this circuit is shown in Figure 6. For the capacitance, a value of $47\mu F$ was used. From here, the load was increased experimentally until the circuit stopped regulating.

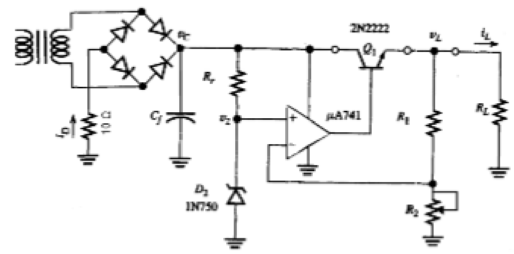

Figure 7: Power Supply Schematic with BJT

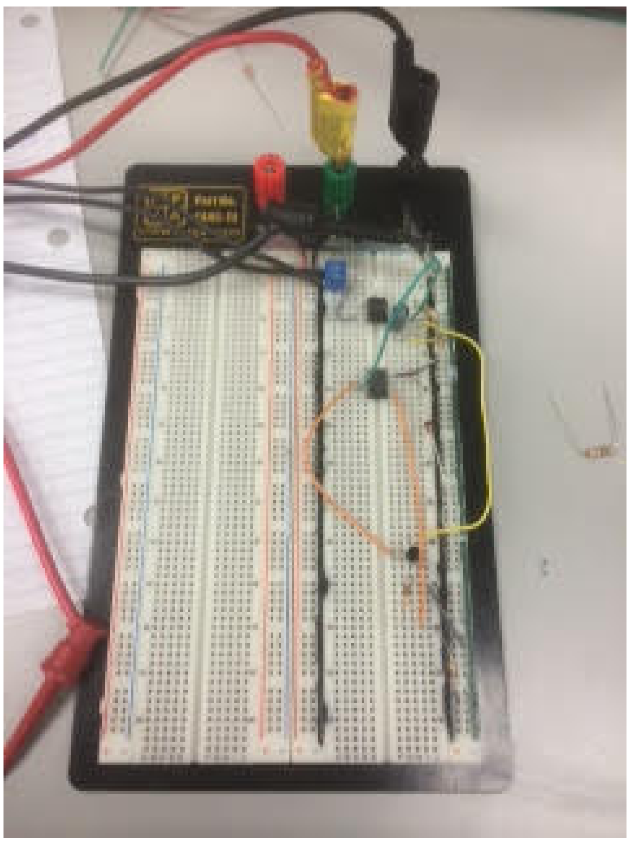

Figure 6: Power Supply Implementation

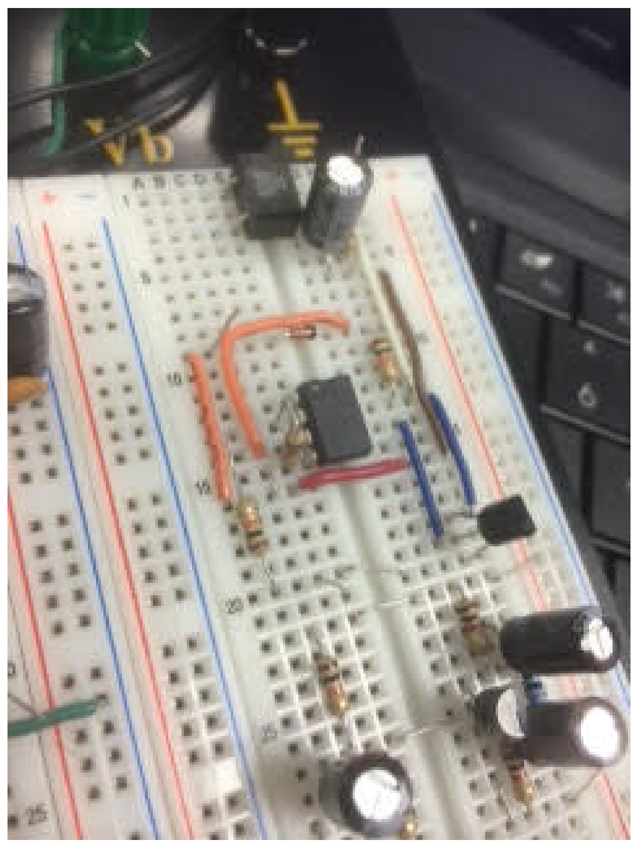

Figure 8: Power Supply Implementation with BJT

After this, the circuit in Figure 7 was built. The implementation is shown in Figure 8. The load was also experimentally incremented until the circuit stopped regulating.

4 Interpretation

Figure 9 shows the secondary voltage obtained during lab. It was experimentally determined that the load needed to obtain 12Vrms was around 40Ω. When testing the circuit in Figure 5, the load voltage along with the diode current was measured. This is shown in Figures 10 and 11. After this, the output and input voltage of Figure 2 was measured. This is shown in Figures 13 and 12. For this circuit, the capacitance value used was $47\mu F$ and the load used was 510Ω. After this, we compared these circuit values with the same circuit using a capacitance of $4.7\mu F$ and an open circuit voltage for the load. These results are shown in Figures 14 and 15. From here, the input and output voltage changed when the load was increased so that the circuit stopped regulating. This is shown in Figures 16 and 17. The load was then increased. This is shown in Figure 18.

The same results were captured for the power supply utilizing the BJT. The results are shown in Figures 19 through 22. After this the last circuit constructed utilized a capacitance of $C = 47\mu F$ and a load resistance of 510Ω. V_{in} vs V_{out} is shown in Figure 23.

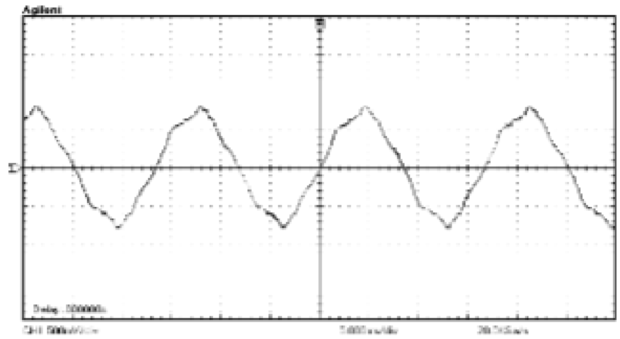

Figure 9: Transformer Secondary Voltage

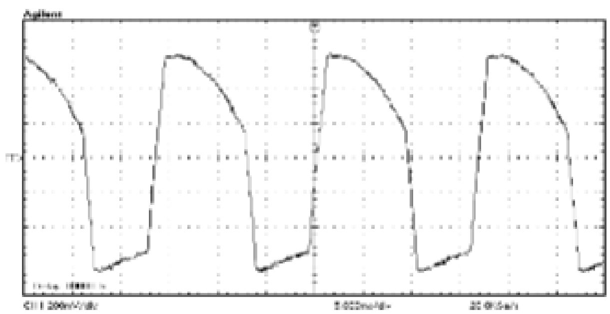

Figure 10: Load Voltage

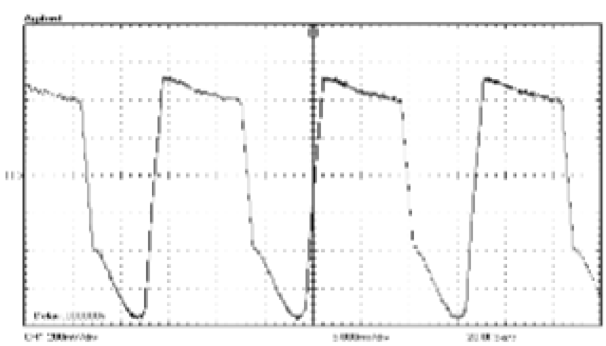

Figure 11: Diode Current

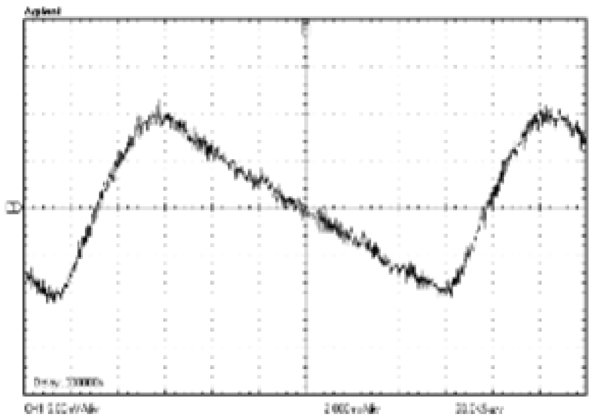

Figure 12: Input Voltage

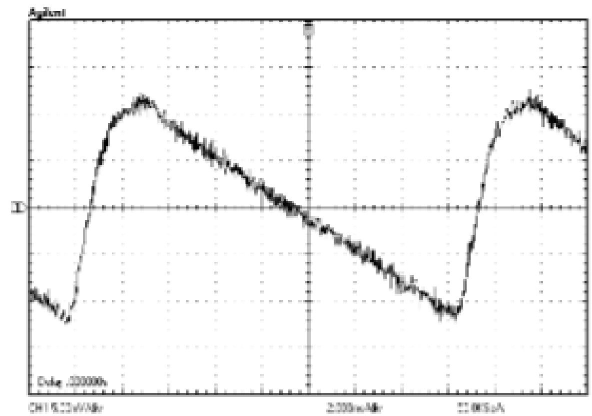

Figure 14: Input Voltage

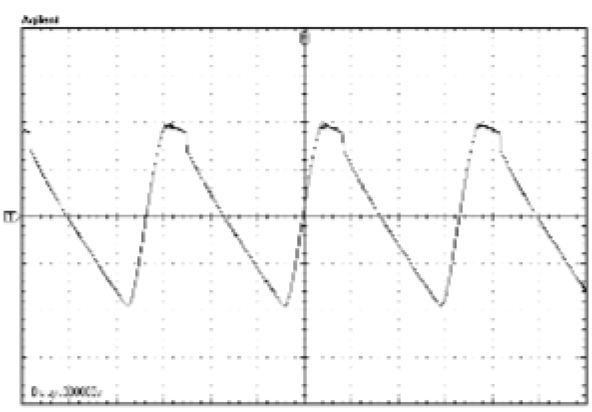

Figure 13: Output Voltage

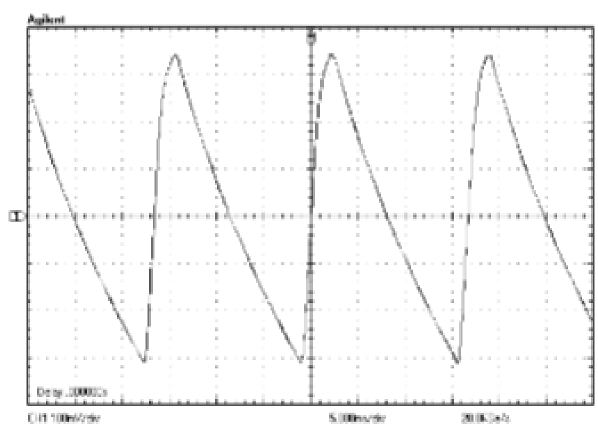

Figure 15: Output Voltage

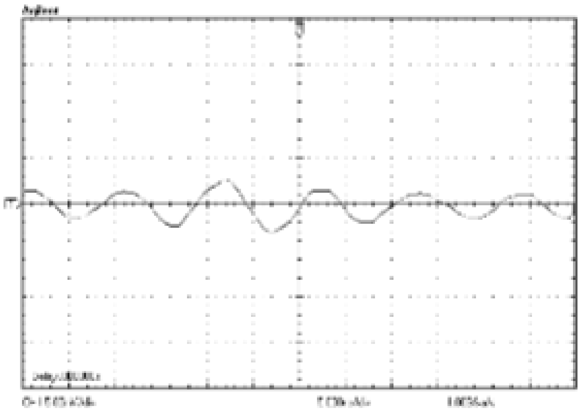

Figure 16: Input Voltage

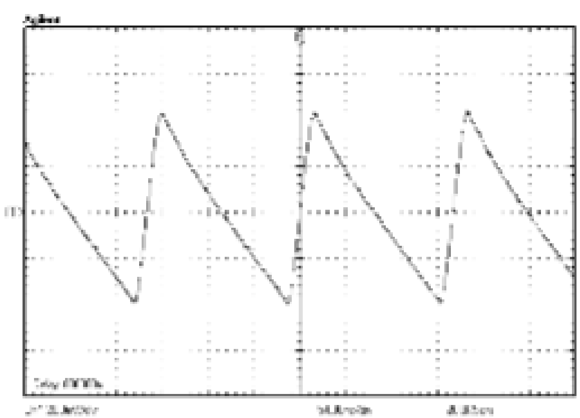

Figure 17: Output Voltage

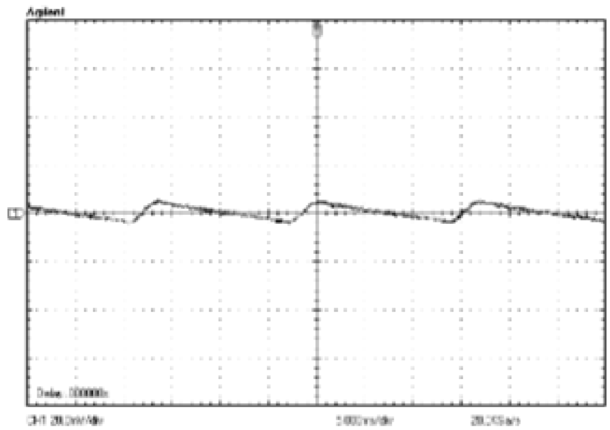

Figure 18: Output Voltage

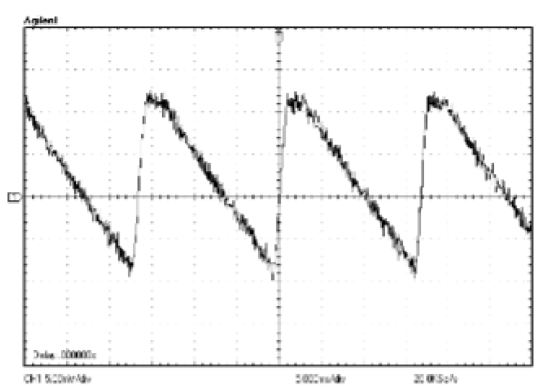

Figure 19: Input Voltage

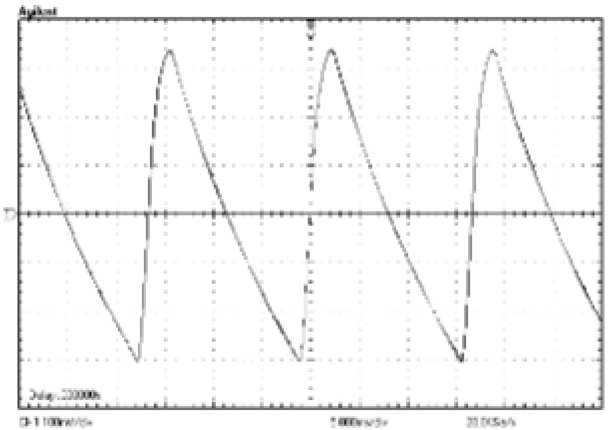

Figure 20: Output Voltage

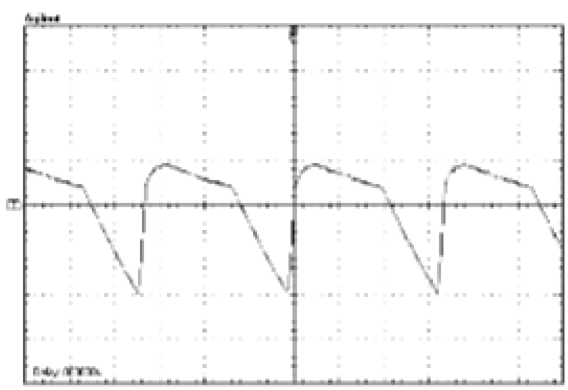

Figure 21: Input Voltage

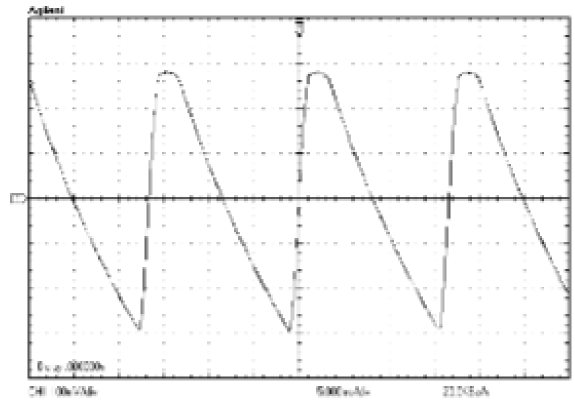

Figure 22: Output Voltage

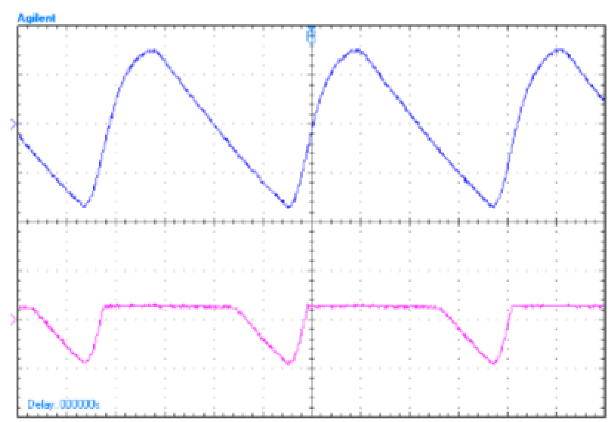

Figure 23: V_{in} vs V_{out}

Upon inspection of all the data gathered, it is clear that the experimental data obtained in lab was successfully verified by the preliminary calculations. This verified the authenticity of the results.

5 Conclusion

Overall, this lab can be considered a success. Each sub circuit was able to be constructed and individually tested to build up to a working power supply implementation. The results obtained in lab matched up with the preliminary results, thus ensuring that our data is correct. Further experimentation can be done by trying to obtain different DC voltage values or potentially creating an adjustable power supply.