Fall 2019

California State University of Northridge
Department of Electrical & Computer Engineering

Experiment 4
Power Supply Circuits

ECE 340L
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Introduction:

The purpose of this experiment is to analyze and verify the design of power supplies used in the course. In this lab, the power supply design is constructed of Rectifiers, Filters, and Voltage Regulators. Both half-wave and full-wave rectifiers are used in this experiment. The design also covers the use of transformer rather than a function generator as the input to the circuit.

Equipment:

Type	Model
Oscilloscope	Agilent Technologies DSO1002A
Transformer	N/A

Parts used:

QTY	Component	Value	Type
1	Resistor	1 kΩ	Carbon +/- 5%
1	Resistor	510 Ω	Carbon +/- 5%
1	Resistor	470 Ω	Carbon +/- 5%
1	Resistor	10Ω	Carbon +/- 5%
1	Diode	1N4002	Silicon +/- 5%
1	Zener Diode	1N957A	Silicon +/- 5%
1	Capacitor	470 µF	Aluminum +/- 5%
1	Capacitor	100 µF	Aluminum +/- 5%
1	Capacitor	10 µF	Polypropylene film +/- 5%

Software:

Pspice
Microsoft Word
Microsoft Excel

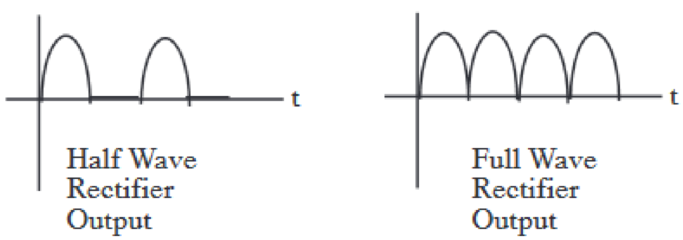
Background:
A DC power supply consists of a rectifier, a filter, and a regulator shown in Figure 1.

Figure 1. Top level design of Power Supply circuit

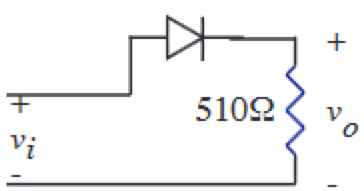
There are two types of rectifiers. The Half wave rectifier in Figure 2b consists of a Diode followed by a load resistor in series in which the output voltage is measured about the resistor. The full wave rectifier of Figure 2c consists of 4 diodes. Two diodes in series facing inwards each other that is parallel with two other diodes in a series facing outwards from each other. At the center of these diodes is the load resistor with output voltage. The outputs of these two circuits are modeled in Figure 2a. Underneath is their respective circuits.

Figure 2. Output graphs of a Half Wave and Full Wave Rectifier

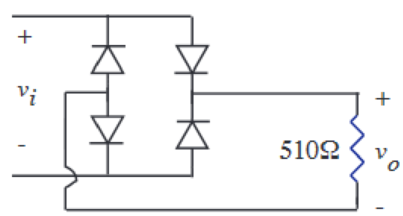
a.)



b.)



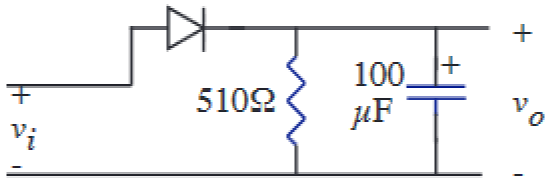
c.)



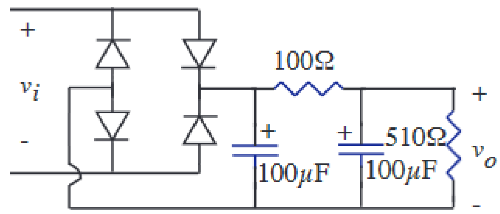
Each Rectifier has its own type of Filter. For the Half-wave rectifier, the filter of Figure 3a consists of capacitor in series of a small resistor. This filter is placed in series with the load resistor. For the Full wave rectifier, the filter of Figure 3.b consists of the load resistor being placed in parallel with the capacitor of a low pass filter. This setup is then placed in parallel with another capacitor. The filtering effect can be seen in Figure 3.c.

Figure 3. Filters of each Rectifier.

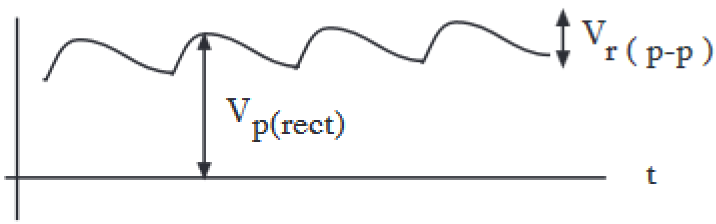
a.) Filtered Half wave



b.) Filtered Full wave



c.) Filtering effect

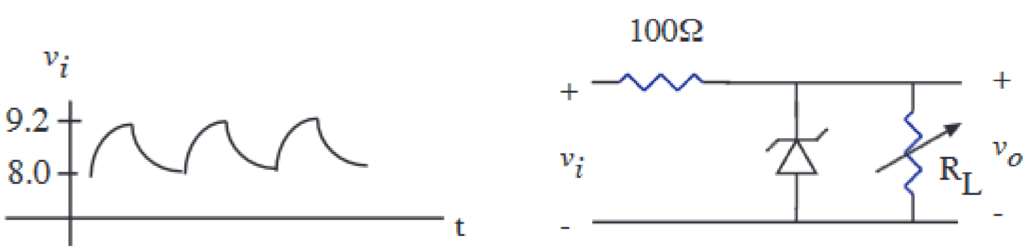


Looking closer at Figure 3c, the voltage output is getting closer to a DC level voltage. From this a percent ripple is calculated as follows.

$$\frac{V_{r(p-p)}}{V_{p,rect}} \times 100 \qquad \text{Equation 1}$$

To further reduce the ripple and get closer to a DC voltage, a voltage regulator is used. For the voltage regulator, a Zener diode replaces the capacitor of the low pass filter as seen in Figure 4. The input of this regulator is the output of the filtered rectifier.

Figure 4. Zener diode voltage regulator



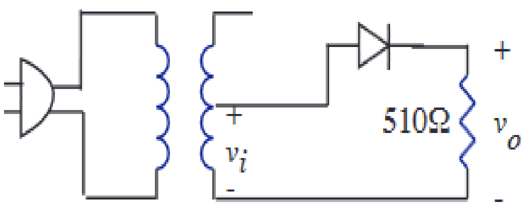
Procedure & Results:

A digital multimeter was used to measure the output voltage of the transformer which was 7.86 VAC-RMS. The following equation was used to calculate the peak voltage.

$$V_{pk} = V_{rms\sqrt{2}} = 07.86\sqrt{2} = 11.16 \text{ v} \qquad \text{Equation 2}$$

The Halfwave rectifier of Figure 5 was constructed. An oscillator was used to measure the voltage on the output seen in Graph 1. The output voltage was measured to be 10.4 v

Figure 5. Half Wave rectifier

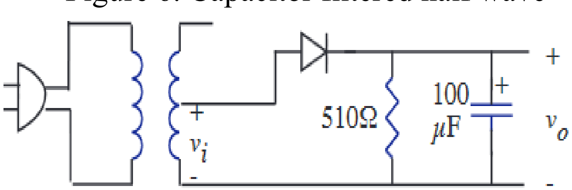


Graph 1. Half Wave peaks

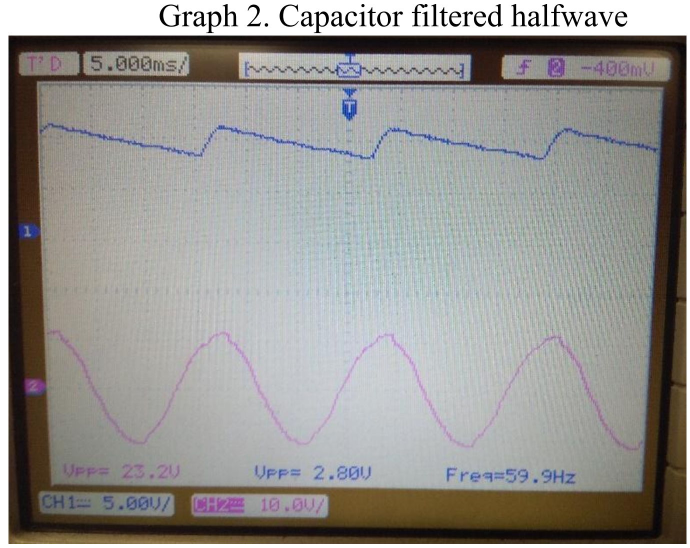
A capacitor was then added in parallel to the load resistor as seen in Figure 6. A ripple was recorded from the oscilloscope seen in graph 1. The peak to peak voltage was recorded to be 2.80 v. The percent ripple was recorded using Equation 1.

$$\frac{V_{r(p-p)}}{V_{p,rect}} \times 100 = \frac{2.80\, v}{10.4\, v} \times 100 = 26.9\ \%$$

Figure 6. Capacitor filtered half wave



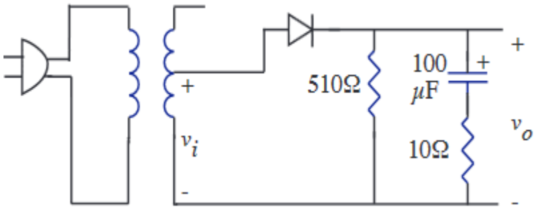
Graph 2. Capacitor filtered halfwave



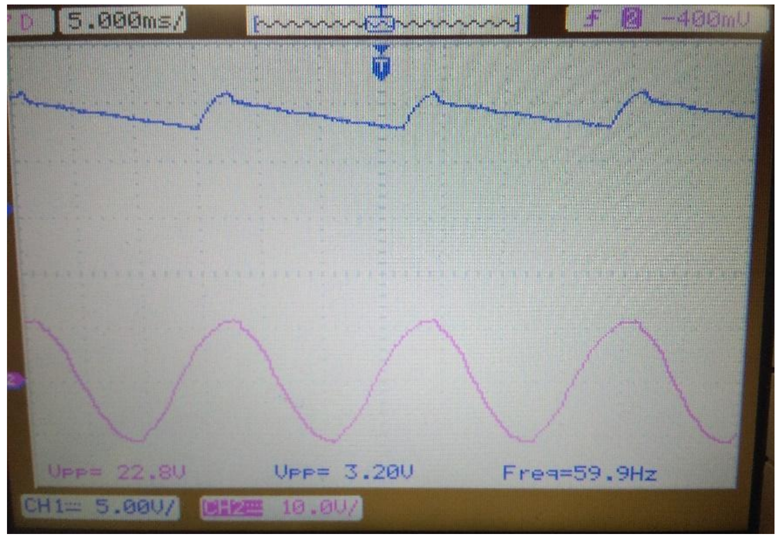
A resistor was added to the filter as seen in Figure 7. Another ripple output was recorded as seen in Graph 3. By adding the 10 Ω resistor, the output increased to 3.20 v.

$$\frac{V_{r(p-p)}}{V_{p,rect}} \times 100 = \frac{3.20\ v}{10.4\ v} \times 100 = 30.8\ \%$$

Figure 7. RC filtered half wave



Graph 3. RC filtered halfwave output

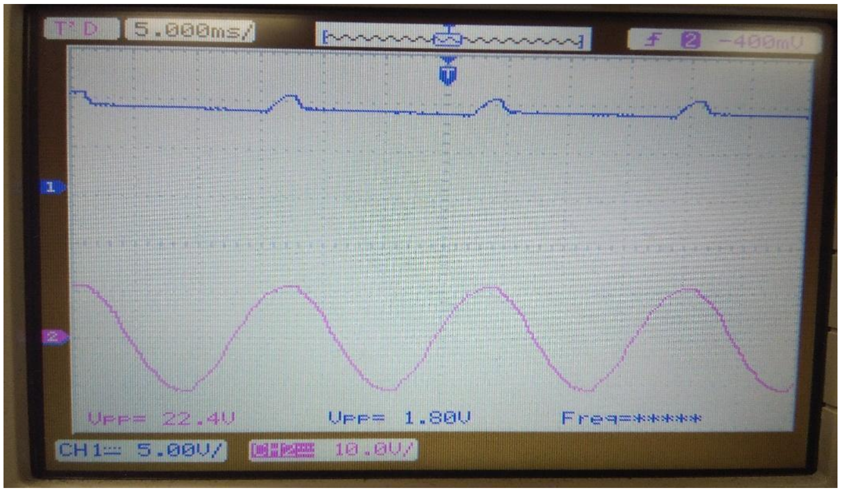


The 100 µF capacitor in Figure 7 was replaced with a 470 µF capacitor. The oscilloscope was used to measure the output voltage again. By increasing the capacitance, the output decreased to 1.80 v as seen in Graph 4.

$$= \frac{V_{r(p-p)}}{V_{p,rect}} \times 100 \quad \frac{1.80\ v}{10.4\ v} \times 100 = 17.3\ \%$$

The equation for impedance of a capacitor is $Z_c = \frac{1}{j\omega C}$ Equation 3

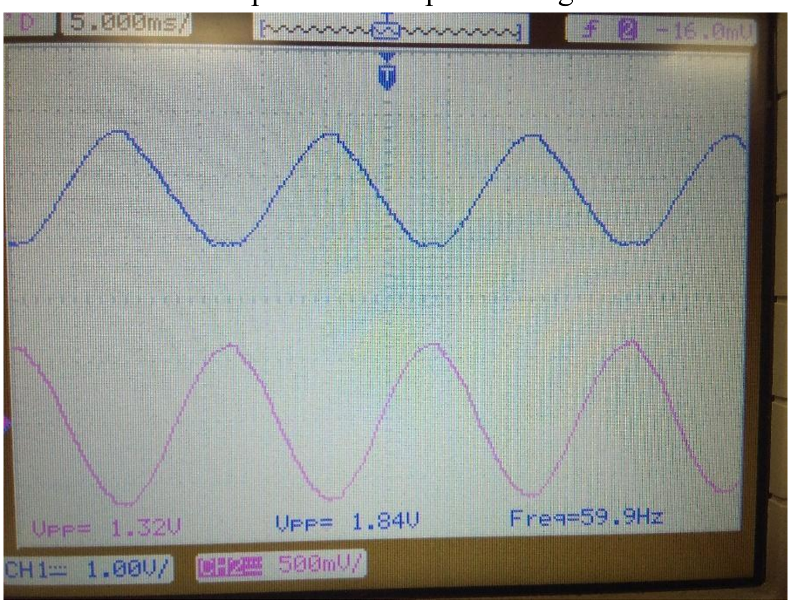
Increasing the capacitance causes the overall impedance of the filter to decrease, and therefore the output voltage also decreases.



Graph 4. RC filtered half wave rectifier with increased capacitance output

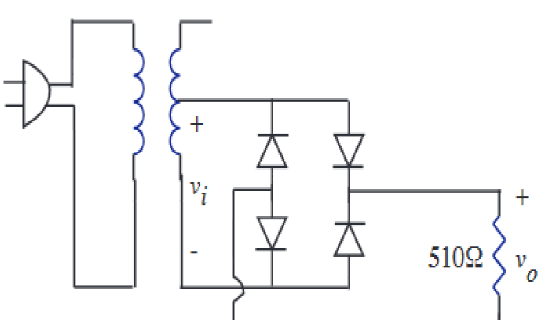
The oscilloscope was used to measure the voltage across the diode in the reverse direction. The measurement of V_{pp} = 1.84 v was recorded in Graph 5. This is the inverse peak voltage. When a diode is reverse biased, the terminals can be treated as an open circuit. The inverse peak voltage is the maximum voltage across the diode when the input is in the negative half of its alternating cycle.

Graph 5. Inverse peak voltage

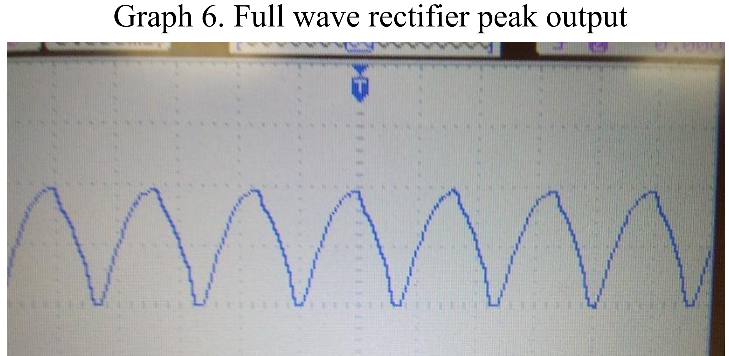


The circuit in Figure 8 was constructed. The output voltage was measured to be 10.0 v and plotted in Graph 6.

Figure 8. Full wave rectifier



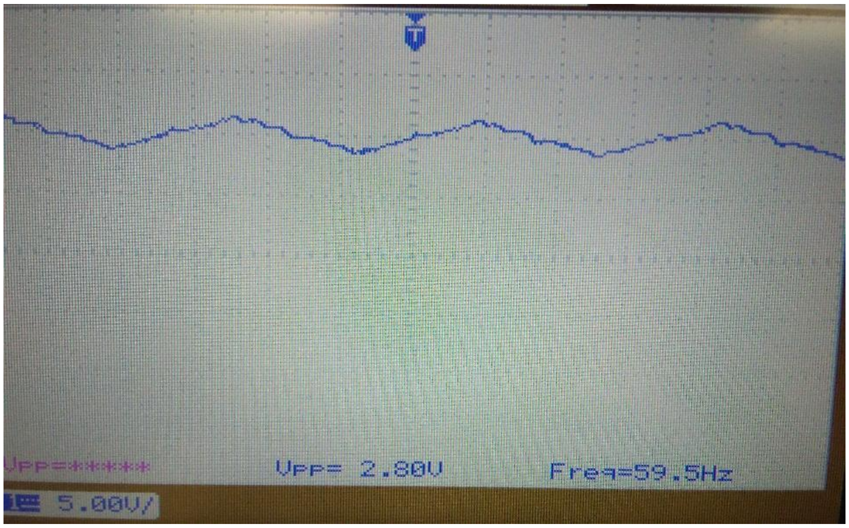
Graph 6. Full wave rectifier peak output



A 100 μF capacitor was placed in series with the 510 Ω load resistor of Figure 8. The oscilloscope measured a peak to peak voltage of 2.80 v and was plotted in Graph 7.

$$\frac{V_{r(p-p)}}{V_{p,rect}}\times 100 \quad = \frac{2.80\ v}{10.0\ v}\times 100 = 28.0\ \%$$

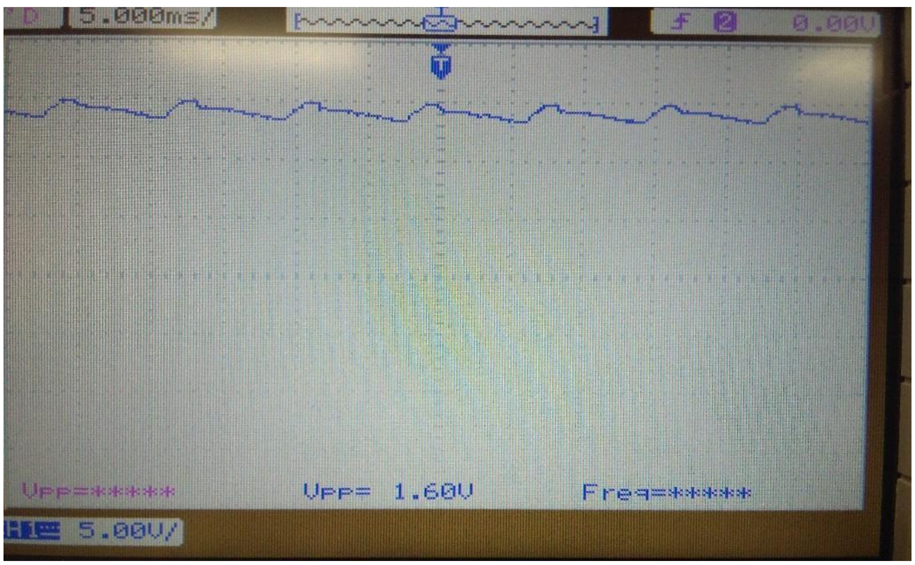
Graph 7. Capacitor filtered full wave rectifier output



A 10 Ω resistor was added in series to the 100 μF capacitor. The oscilloscope measured a peak to peak voltage of 1.60 v and was plotted in Graph 8.

$$= \quad \frac{V_{r(p-p)}}{V_{p,rect}}\times 100 \quad \frac{1.60\ v}{10.0\ v}\times 100 = 16.0\ \%$$

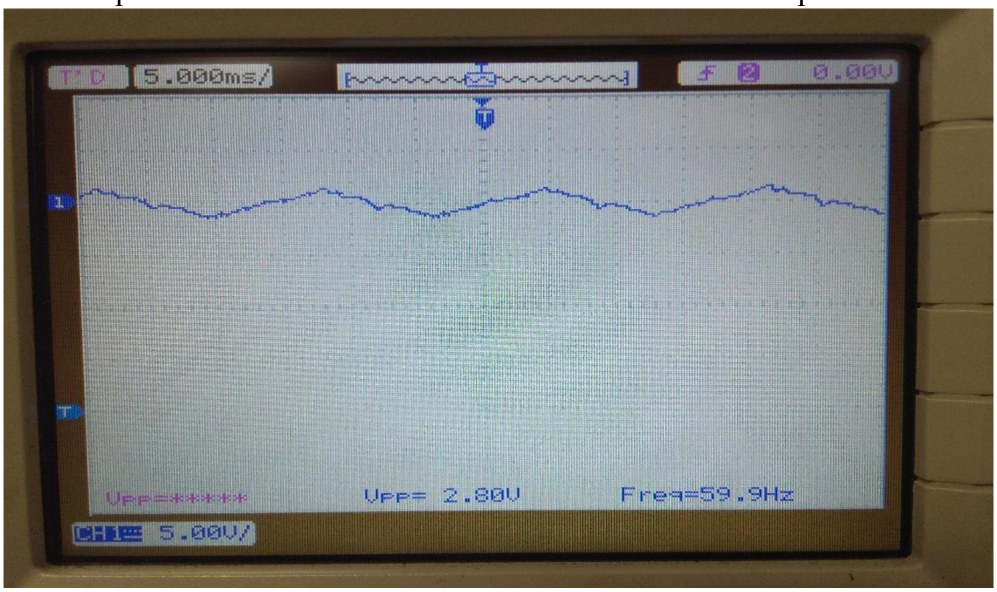
Graph 8. RC filtered full wave rectifier output



The 100 µF capacitor was replaced with a 470 µF capacitor. The oscilloscope measured a peak to peak voltage of 2.80 v and was plotted in Graph 9.

$$= \quad \frac{V_{r(p-p)}}{V_{p,rect}}\times 100 \quad \frac{2.80\ v}{10.0\ v}\times 100 = 28.0\ \%$$

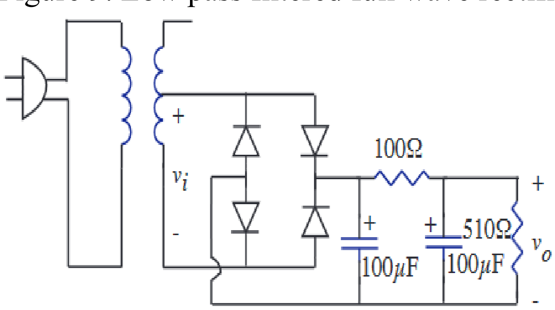
Graph 9. RC filtered full wave rectifier with increased capacitance



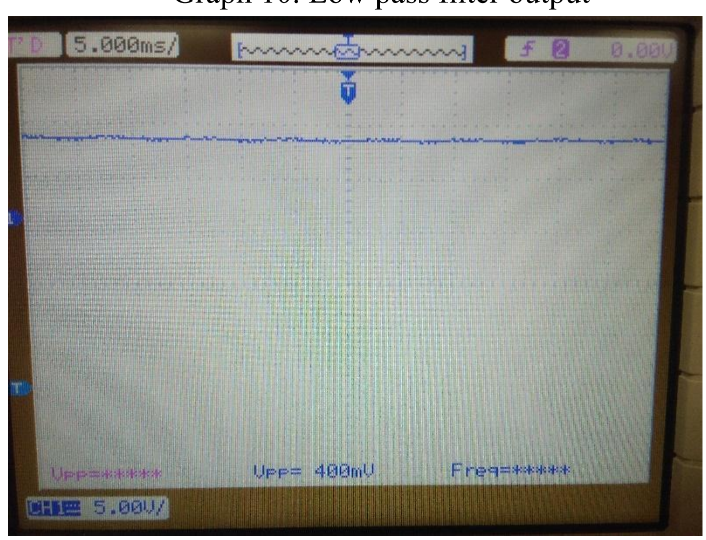
The 470 µF capacitor was removed and the circuit of Figure 9 was constructed. The output peak to peak voltage was measured as 1.00 v and the oscilloscope was plotted in Graph 10.

$$= \quad \frac{V_{r(p-p)}}{V_{p,rect}}\times 100 \quad \frac{400\ mv}{10.0\ v}\times 100 = 04.0\ \%$$

Figure 9. Low pass filtered full wave rectifier



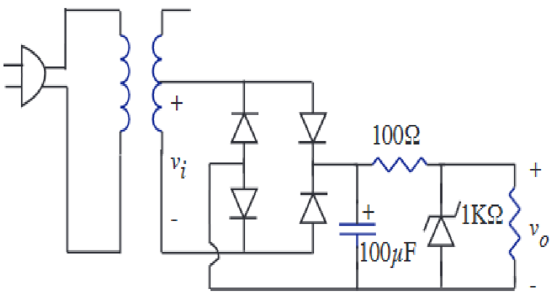
Graph 10. Low pass filter output



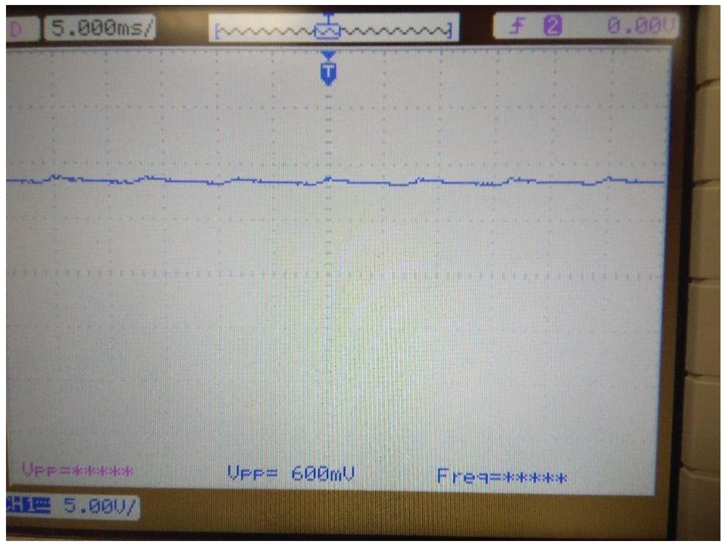
The Zener voltage regulator in Figure 10 was constructed. The output peak to peak voltage was measured to be 600 mv. The oscilloscope was plotted in Graph 11.

$$= \quad \frac{V_{r(p-p)}}{V_{p,rect}}\times 100 \quad \frac{600\ mv}{10.0\ v}\times 100 = 06.0\ \%$$

Figure 10. Voltage regulated Rectifier



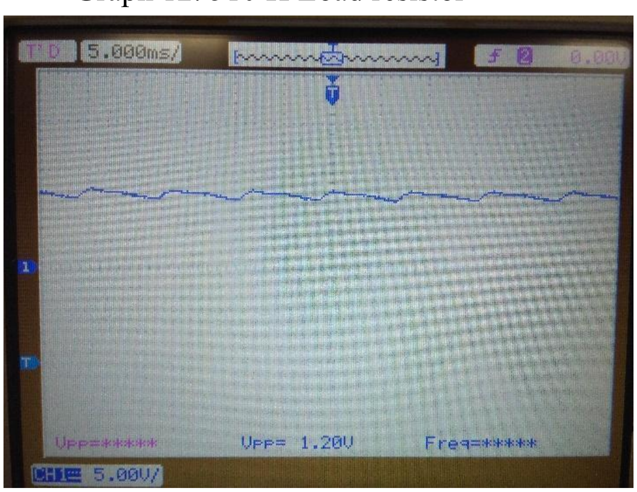
Graph 11. Voltage regulated output



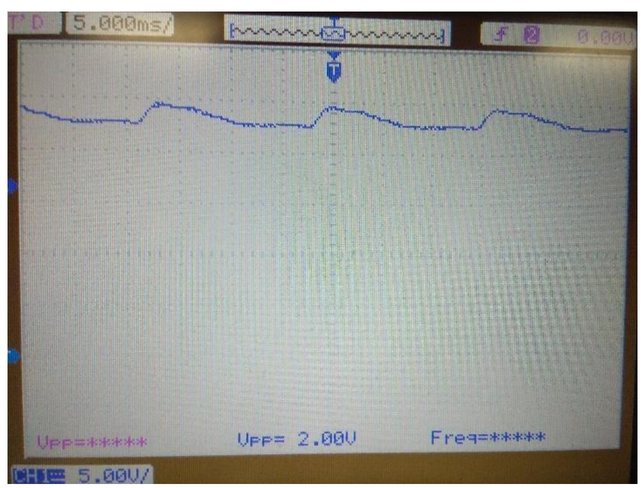
The 1kΩ resistor was removed and lower value resistors were checked until a negative ripple effect could be seen on the oscilloscope. The resistor values where ripples can be seen start at 510 Ω to 470 Ω resistors. The ripple increases to 1.2 v at 510 Ω and then drastically increases around 2.0 at 470 Ω.

In the Pre-Lab, the minimum theoretical value calculated for 6.8 v to be regulated is 480 Ω. This value is very close to our measured values.

Graph 12. 510 Ω Load resistor

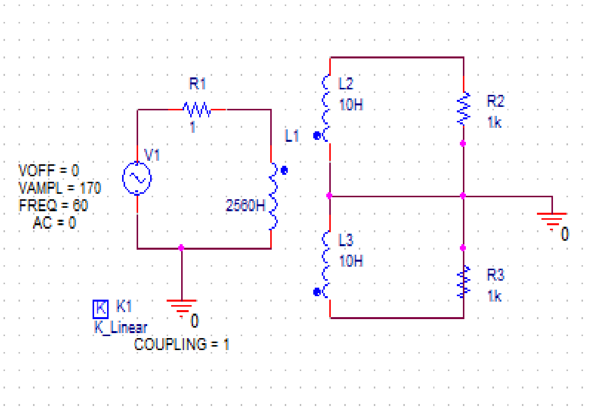


Graph 13. 470 Ω Load resistor



A half transformer was designed in Pspice 1. A transient analysis was run on the circuit and was graphed in Plot 1. The simulation shows the transformer outputs a 10.6 peak voltage. This is equal to the value of 7.5 v rms.

Pspice 1. Half secondary transformer



Plot 1. Transformer Peak voltage

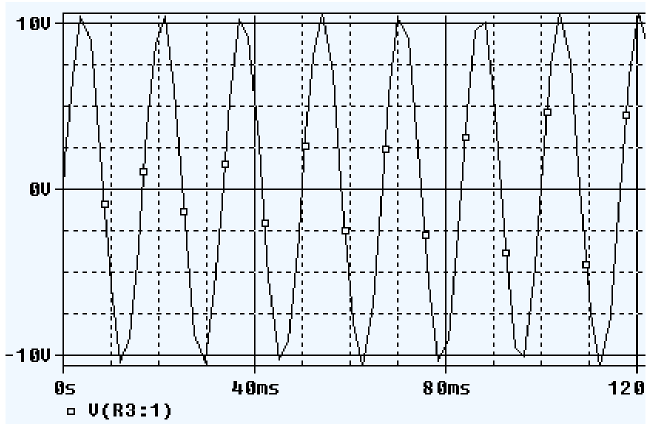
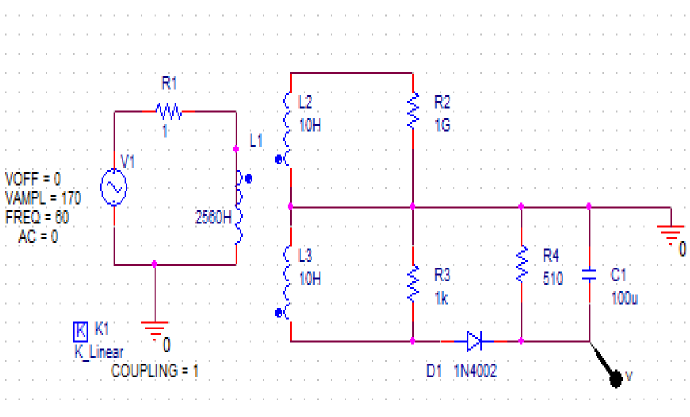
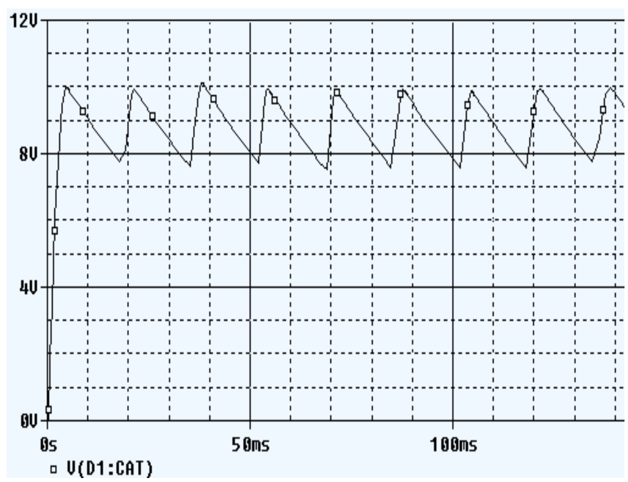


Figure 6 was simulated in Pspice 2. The simulation results are graphed in Plot 2. Looking closer at Plot 2, the peak to peak voltage is about 2.5 v. In Graph 2, the measured value of peak to peak voltage is 2.8 v. These results are significantly close, and their differences can be explained through differences in resistor values, capacitance, and input.



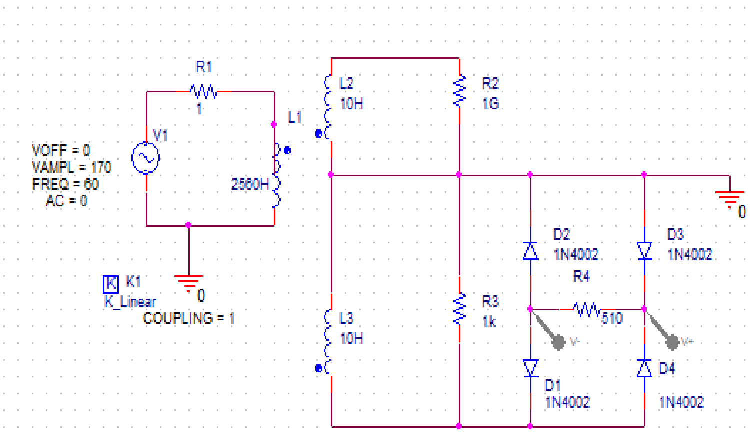
Pspice 2. Half wave rectifier design



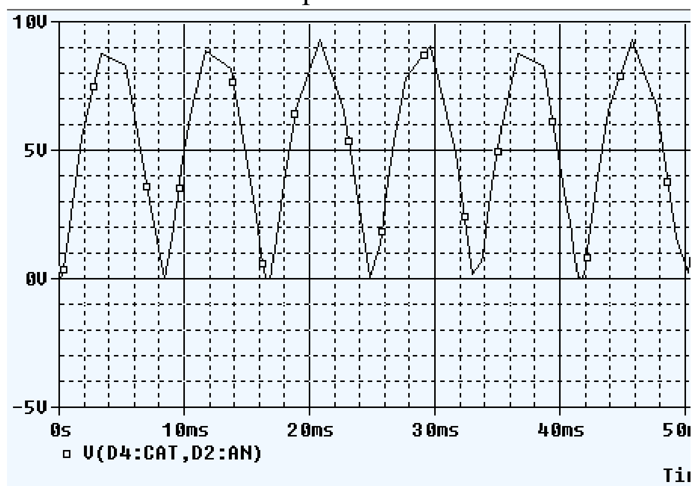
Plot 2. Capacitor filtered Half wave output

Figure 4.8 was simulated in Pspice 3. The simulation results are graphed in Plot 3. Pspice 3. The simulation returns the output of a full wave rectifier. The peak voltage is around 9.2 v. The peak voltage found in Graph 3 was 10.0 v. The difference in these results can be explained by the differences in the initial input voltage and the difference in nominal resistance.

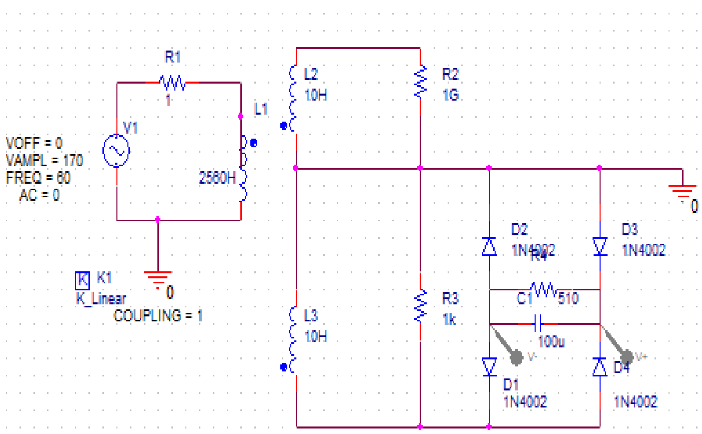
Pspice 3. Full wave rectifier design

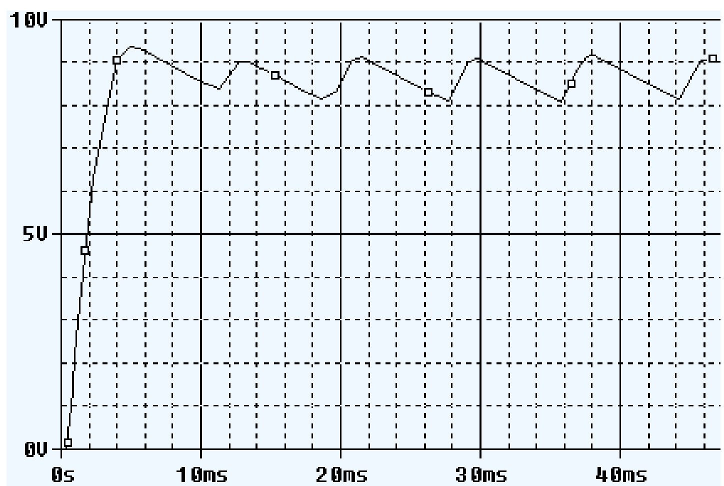


Plot 3. Full wave output



A capacitor was added across the load resistor of Figure 4.8 and then simulated in Pspice 4. The simulation is graphed in Plot 4. The simulation shows a filtered waveform with a peak to peak voltage of 1.0 v.



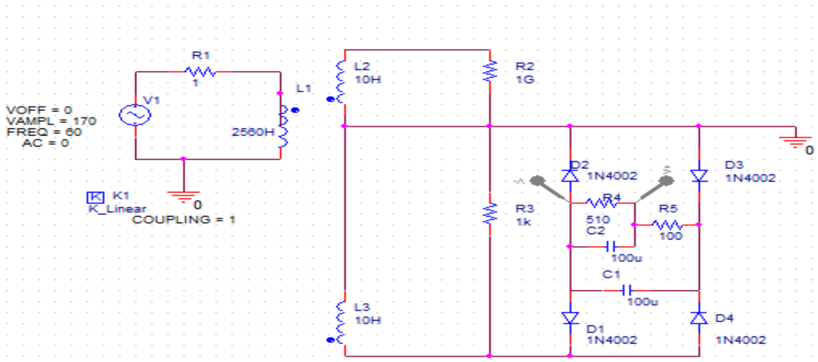


Pspice 4. RC filtered full wave rectifier

Plot 4. RC filter simulation

Figure 4.9 was simulated in Pspice 5. The simulation was graphed in Plot 5. The simulation shows about 300 mv peak to peak. The voltage difference is very minimal and the closest we get to a DC level signal. Compared to the measured value in Graph 10, the data is significantly close.

Pspice 5. Low pass filtered full wave rectifier design



Plot 5. Low pass filter simulated output

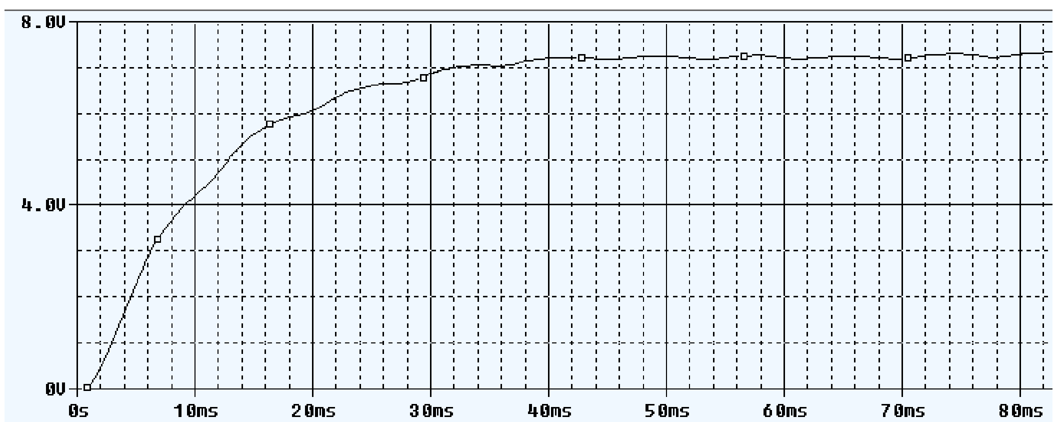
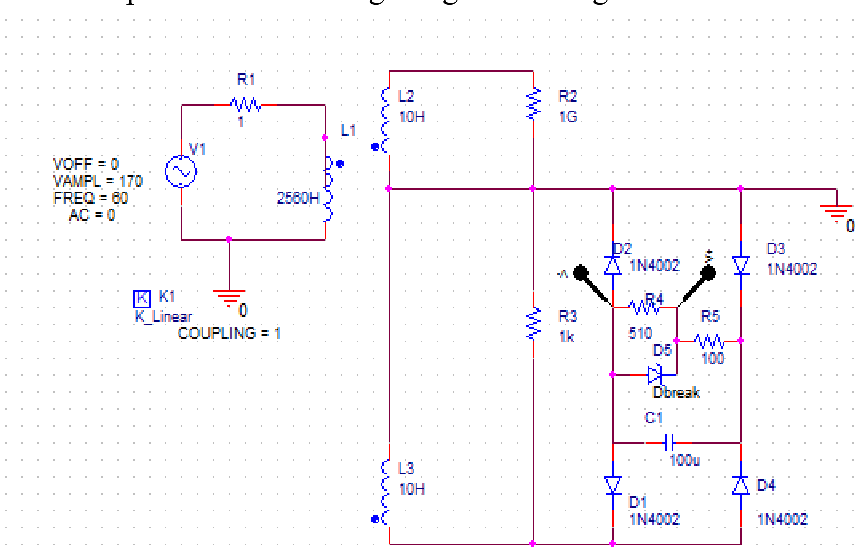


Figure 4.10 was simulated in Pspice 6. The simulation was graphed in Plot 6. The simulation shows a peak to peak voltage of about 600 mv. This simulated value is the exact same to the measured value in the lab.

Pspice 6. Zener Voltage Regulator design



Plot 6. Zener voltage regulator simulation

Conclusion

Throughout the experiment, the circuits were properly constructed, and readable graphs were recorded on the oscilloscope. Each filter was analyzed and verified in their function of producing a DC level signal. Eventually, a percent ripple of about 4% was constructed. The experiment was a success in the analysis of capacitor filters, low pass filters, and Zener voltage regulators.

The experiment was also a success in simulating each circuit in Pspice. Almost all simulations were close to the real-life measured values. And if there were any discrepancies, they could be explained by the nominal values of the resistors and capacitors.