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CE 3101
Lab 3
3/22/18

CE 3101 Lab Experiment 3

Abstract

When building power components that use the main line power provided by local utility companies, AC power often needs to be converted to DC power, reduced to a level that will not damage the component. This provides a unique challenge to designers which is further complicated by the fact that AC voltage and current alternates bipolarly; a power component will typically expect that a voltage source is held at a single polarity. Additionally, a typical power component expects that voltage levels remain at nearly constant magnitudes. Both characteristics just described as not characteristic of an AC voltage source. While this creates a significant engineering problem, a solution leveraging the switching characteristics of diodes, and the voltage characteristics of capacitors can be designed which provides near-direct current which can then be made almost perfectly DC using a regulator (the regulator eliminates the “ripple voltage effect”.

The goal of this experiment was to explore and implement the rectifier and filter aspects of a AC-to-DC converter. To do this, a half wave rectifier was simulated in PSPICE and then implemented on a breadboard to observe its characteristics and its differences between simulation and experiment. After this, the next step of the experiment was to perform the same procedure, but with a full wave rectifier rather than a half-wave rectifier. When the experiment was performed, a standalone rectifier diode was used to create the half wave rectifier, and when the full wave rectifier was built, an integrated chip was used rather than 4 independent diodes. Additionally, when the physical circuits were built, components were used that were as close to the ideal components as the EECS tech department could provide. The experiment was performed with large amounts of success; not only was the rectifiers implemented successfully on PSPICE, but the half wave rectifier performed very close to simulated prediction. It should be noted that time ran out before the full wave rectifier could be performed, so experimental results of the full wave rectifier weren’t compared against simulation.

Experiments

Part 1 – Half Wave Rectifier Circuit with Filter

PSPICE Simulation

The first step in simulating the half wave rectifier circuit in PSPICE was theorizing and designing the circuit based on its requirements.

Circuit Requirements

V2:	$10V_p$	$V_{r:}$	15%
RL:	4.7 kΩ		

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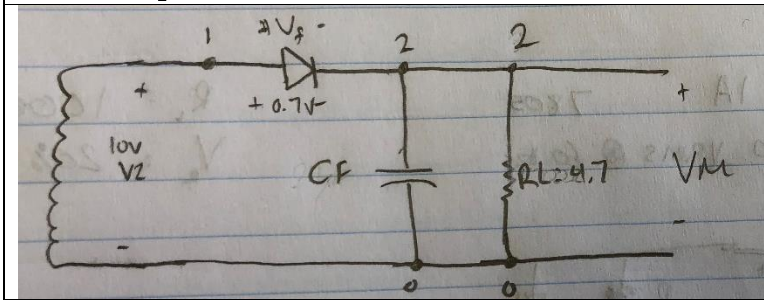
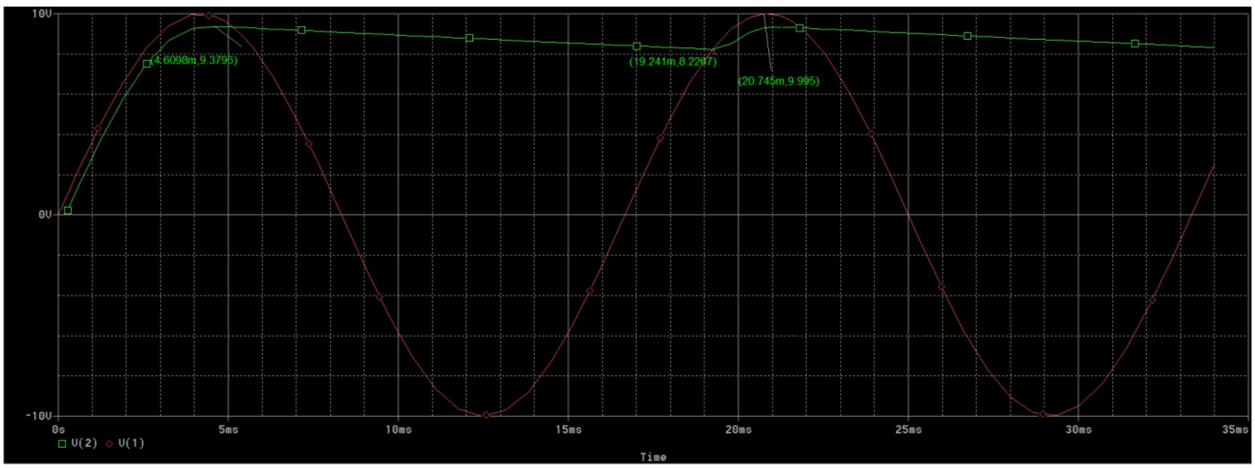
Circuit Design


Derived Values					
V_M =	$V2 - V_f = 10V - 0.7V = 9.3V$			CF =	$\frac{V_M}{f * R_L * V_R}$
V_R =	V_M*0.15 = 1.395 V			=	23.6µF

This circuit was then simulated in PSPICE and a trace of V2 and V_M were added to a plot. This yielded the following:



From the data points labeled on the traces, the derived values for ripple voltage and V_M can be verified:

V_R = 9.3796 – 8.2267 = 1.1529V

Worth noting is that the simulation results differed slightly for V_M (9.3796V compared to 9.3V) and for V_R (1.1529V vs 1.395V). This is likely a result of low precision used for the voltage drop across the diode when designing a theoretical circuit, and also a result of PSPICE using approximations of components. What is important is that the behavior showed in the simulation confirms the design and yields an almost DC voltage which gets refreshed at every peak.

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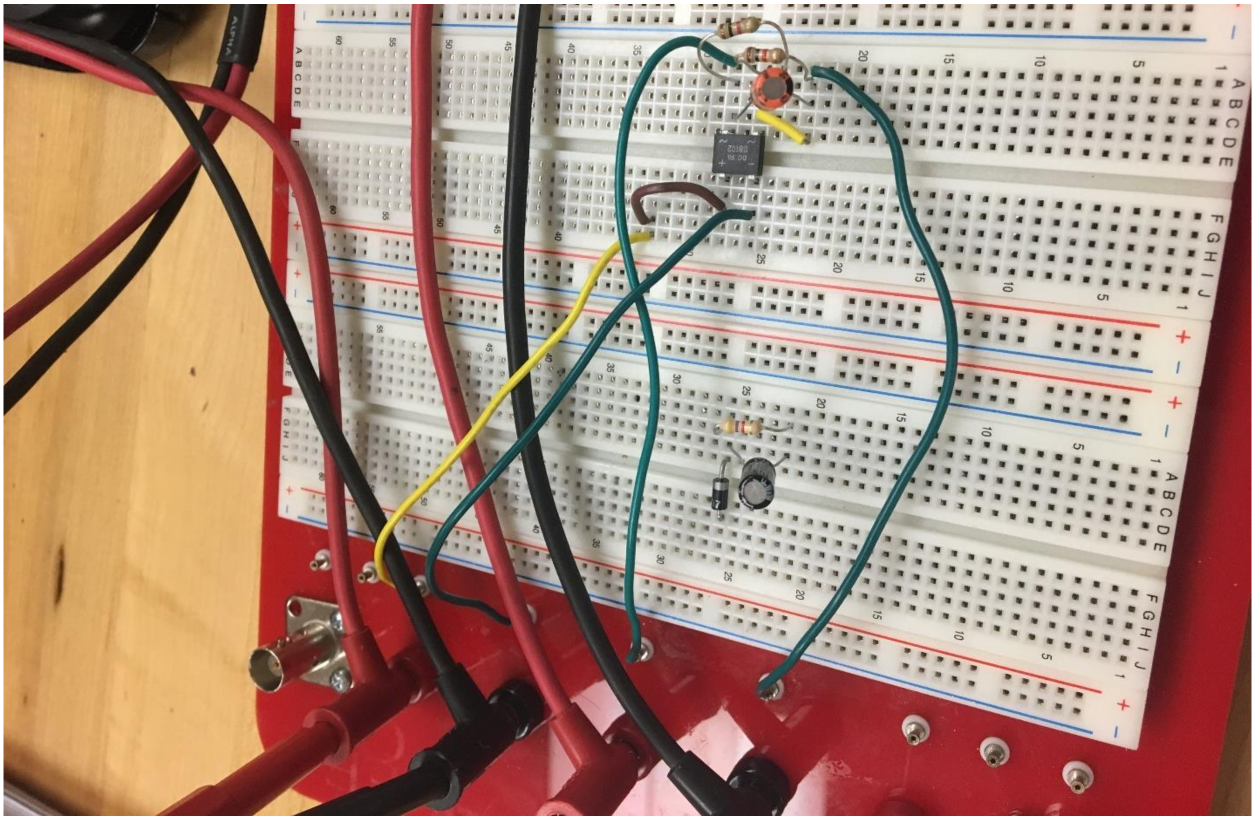
Half Wave Rectifier Implemented

The next step was to physically build the designed and simulated half-wave rectifying circuit with a filter and compare the results to the simulation. The circuit was built using the closest available components, and the lab bench waveform generator was used to generate the input sinusoidal wave (simulating voltage stepped down from main line). The circuit built took the following form:



The circuit was then observed with an oscilloscope monitoring input voltage V2 and voltage V_M. A picture was taken depicting the results and is shown below:

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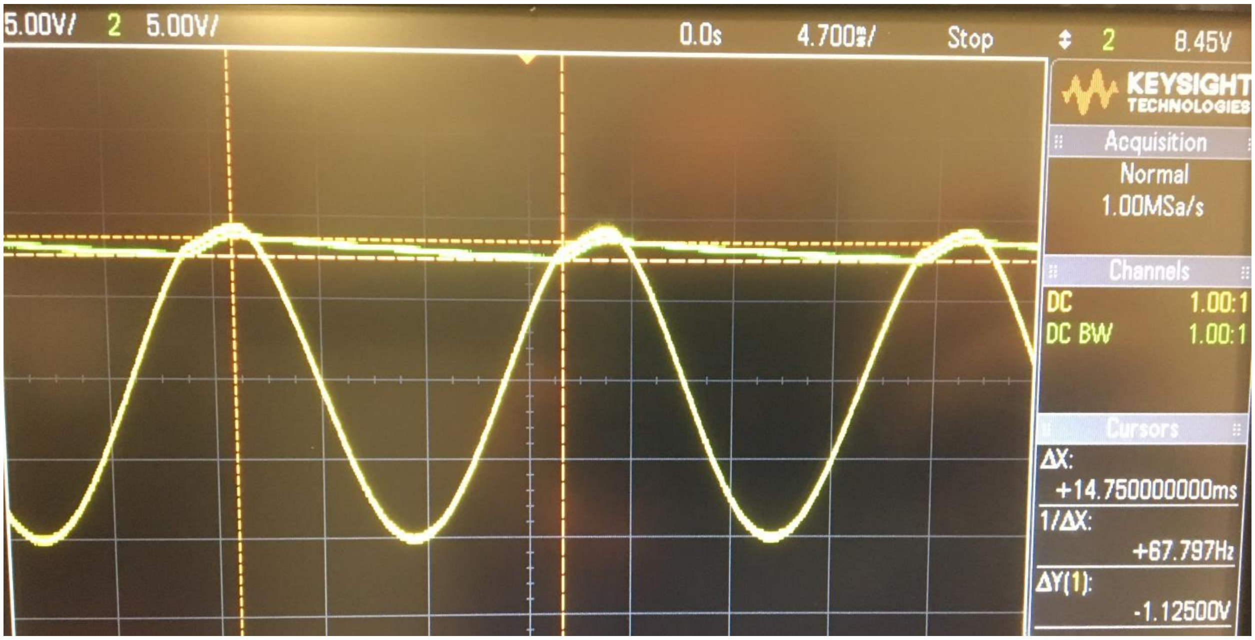

The oscilloscope showed results that were very similar to the simulation results. The rectified voltage took on characteristics close to DC voltage, with small ripples that had their value "refreshed" at every peak of the sinusoidal voltage. Cursors were used to measure the ripple voltage, and this came out to approximately 1.13 V. Cursors also helped determine that the peak sinusoidal voltage and peak V_M difference by an amount very close to 0.7V as expected. This was under both the theoretical and simulated ripple voltage, but still very close. This small discrepancy was expected since the components used in the circuit were not the same exact components as the ideal ones used in both simulation and theoretical design.

Time ran out to measure the circuit using the oscilloscope without the filter capacitor in place, but its still possible to imagine what the plot would look like. Rather than having a ripple voltage which holds near the peak of the sinusoid, V_M would instead follow the sinusoidal voltage closely, and then flatline to 0V when the sinusoid went negative. Additionally, there would be a lagtime from when V_M switched from 0 to following the sinusoid due to the turn on voltage of the diode. This would also result in the diode turning back to 0 (at the turn on voltage of 0.7V) before the input sinusoid reached 0V. This is a result of the half-wave rectifier only allowing current to flow in a single direction.

Part 2 – Full Wave Rectifier Circuit with Filter

PSPICE Simulation

Next, the Full Wave Rectifier was to be built. This began with a PSPICE simulation, and the first step for this was theorizing and designing the circuit based on its requirements.

Circuit Requirements

V2: $5V_p$ $V_{r:}$ 5%

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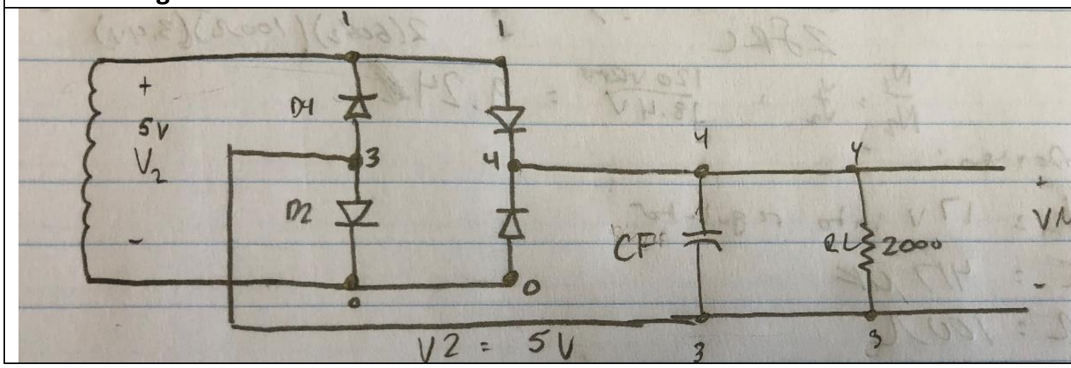
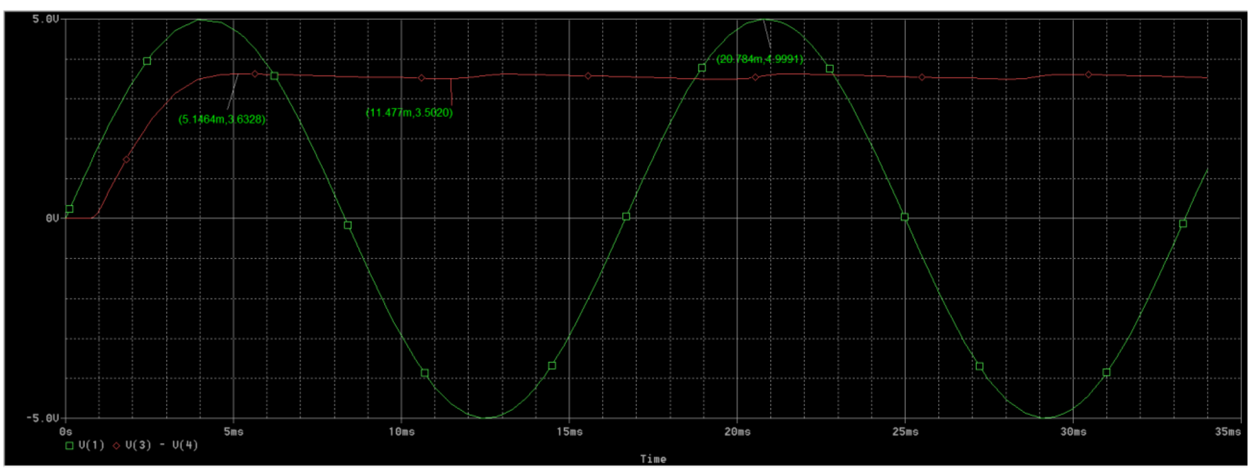
RL: 2 kΩ

Circuit Design


Derived Values					
V_M =	V2 – V_f – V_f = 5V – 0.7V – 0.7V= 3.6V			CF =	$\frac{V_M}{2f * R_L * V_R}$
V_R =	V_M*0.15 = 0.18 V			=	83µF

This circuit was then simulated in PSPICE and a trace of V2 and V_M were added to a plot. This yielded the following:



From the data points labeled on the traces, the derived values for ripple voltage and V_M can be verified:

V_R = 3.6328 – 3.5020 = 0.1308V

Again, just like what was seen with the half-wave rectifier, the simulation results differed slightly from the theoretical values. The reasoning behind this is the same – low precision used for V_f when making calculations, and PSPICE using approximations for components that were different from the linear approximations used in designing the circuit. The ripple voltage values (0.18V-theory, 0.13-simulated) and V_M (3.6-thoery, 3.63-simulated) were close enough however to verify the design, and the behavior seen in the traces were consistent with expectations. In the simulation, V_M ripples are very small, and rather than "refreshing" at every peak of the sinusoidal voltage source like the half-wave rectifier, the V_M voltage is "refreshed" at every peak and valley. This is characteristic of a full-wave rectifier and it demonstrates both polarities of the input voltage sine wave being used.

Full Wave Rectifier Implemented

Time ran out before the full-wave rectifier could be implemented but results would have appeared similar to the simulation while the filter capacitor was in place. As always, there would have been slight deviation in ripple voltage and V_M because the ideal components were not available.

Without the filter capacitor in place, behavior would have been similar to the behavior seen in the half-wave rectifier with 2 major differences. First, the lag between the voltages would have been twice as large, at 1.4V, due to current traveling through 2 diodes in series. This would have caused V_M to reach 0V 1.4V before the input sinusoid voltage too. Additionally, rather than V_M being flat at 0V for the entire time that the input sinusoid was negative, V_M would have been able to full advantage of both the negative and positive parts of the input sinusoid.

Conclusion

This laboratory experiment was great in reinforcing understanding of concepts taught in class. During the past week, the concept of a half and full wave rectifier was taught in class. While this information was valuable and very helpful, the completion of this laboratory experiment helped illustrate these ideas in a real environment and provide the hands-on learning that helps reinforce memorization of concepts. The results of the experiment agreed with all the concepts taught in class, and helped link theory, simulation, and implementation together. Its because of this that the experiment could be concluded with confidence to be a success.