Lab 5. AC-to-DC Rectifier

The goal of this lab is to investigate the behavior of a diode-bridge AC-DC rectifier, which is used in all power supplies taking energy from AC sources, like grid utility. First, we review the principle of operation of a diode-bridge AC-DC rectifier. Next, we simulate the rectifier to analyze the effects of its parameters on voltage and current waveforms. Finally, we perform lab experiments to observe the voltages and currents of a real AC-DC rectifier under different operating conditions.

Learning Objectives

After completing this lab, you will be able to:

1. Understand the operation of a full-wave rectifier
2. Learn how a capacitor can be used to more effectively convert AC to DC
3. Generate simulation results showing rectifier behavior
4. Validate simulation results by comparing with measured data

Required Tools and Technology

Platform: NI ELVIS II/II+ Instruments used in this lab: ● Instrument 1: Function Generator ● Instrument 2: Oscilloscope ● Instrument 3: Variable Power Supply **Note:** The NI ELVIS Cables and Accessories Kit (purchased separately) is required for using the instruments.	View User Manual: https://bit.ly/36DFFrv https://bit.ly/36CnQZH (Credit to Clemson University) View Tutorials: https://bit.ly/35Ae9Kc (Credit to Colorado State University) Install Soft Front Panel support: https://bit.ly/2NbhTv6
Hardware: NI ELVIS II/II+ Default Prototyping Board	View Breadboard Tutorial: http://www.ni.com/tutorial/54749/en
Hardware: Electronics Kit	• Various values of resistors • Various values of capacitors • Diodes (4 or more), 1N4148 or similar
Software: NI Multisim Live	Access online http://multisim.com View Help http://multisim.com/help/

1. Background Information

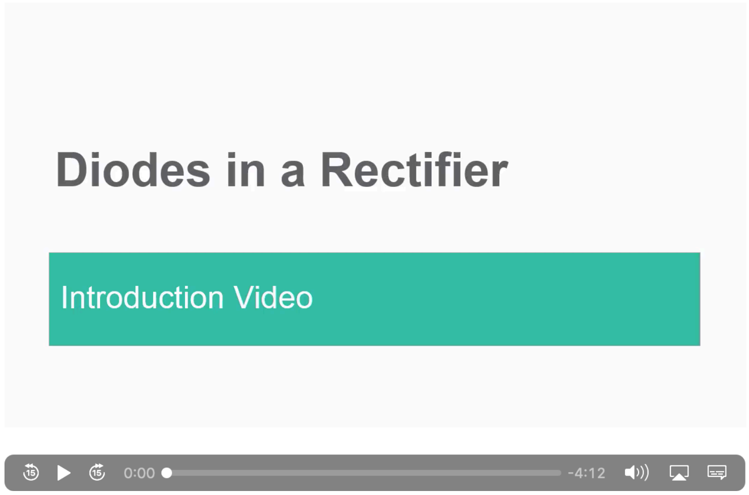

Figure 1. Video Screenshot View the video here: https://www.youtube.com/watch?v=KRa1uMfliu0

Video Summary
A rectifier is an electrical device that converts **alternating current** to **direct current.** As we saw in the previous lab, a half-wave rectifier will only allow one half of a sine wave to pass through.

The primary application of a rectifier is to obtain DC power from an AC source. The electricity coming from the wall is AC, but a lot of electronic devices require DC. Therefore, these devices typically have their own power supply which uses a rectifier to convert from AC to DC.

A rectifier is a diode circuit that converts an alternating current (AC) waveform into a waveform that has constant polarity (also sometimes called a direct current or DC waveform), either always negative or always positive depending on the direction of the diodes. There are two major classifications of rectifiers, half-wave and full-wave rectifiers. Half-wave rectifiers are so called because they only pass through one polarity of the circuit while the opposite polarity is removed.

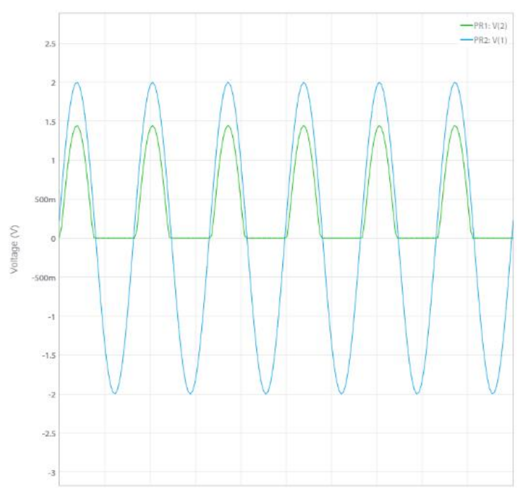

Figure 2: Half-wave rectified waveform. Note how the negative half of the input waveform is discarded in the output waveform

Full-wave rectifiers reproduce the whole waveform, but with one of the polarities inverted. You can think of full- wave rectification as putting an AC waveform through an absolute value function.

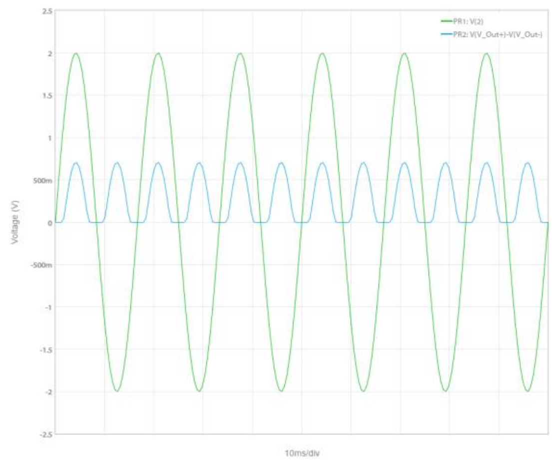

Figure 3: Full-wave rectified waveform. Note how the negative half of the input waveform is flipped into a positive waveform

In this lab we will simulate, build, and explore the bridge rectifier – a type of full-wave rectifier constructed using diodes.

2. Exercise

2.1. Simulation

The bridge rectifier consists of four diodes laid out in a bridge pattern. Using the forward-biased behavior of diodes, we can force current to flow in the same direction through a load. This allows us to convert an AC waveform into a DC waveform. Many circuits require the use of DC waveforms and the rectifier circuit is an important part of a power supply circuit.

Before building the circuit, we will first simulate it using Multisim as shown below.

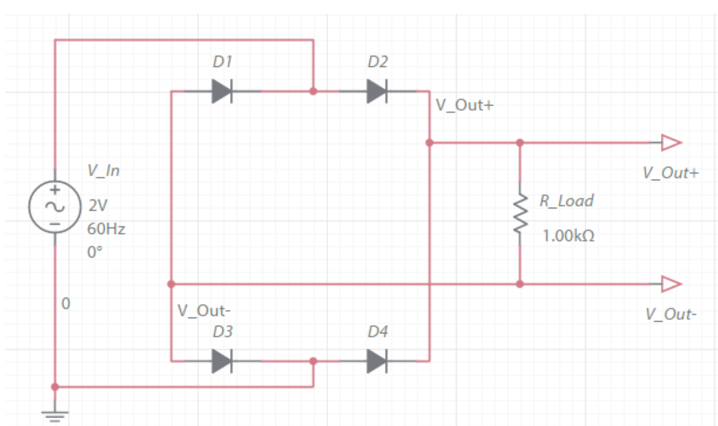

Figure 4: Full-wave Bridge Rectifier Circuit built in Multisim

The circuit above shows a typical configuration for a bridge rectifier. You can see that Diodes D1 – D4 are laid out in a bridge pattern with their anodes on the left and the cathodes on the right and the load is connected across the joint cathodes and the joint anodes.

- Using the circuit component names (D1, D2, D3, D4, R_Load), describe the path that current flows through during the positive half cycle of the AC input and the path that current flows through during the negative half cycle.

2.2. Experiments

In this activity, we will move to actually building the circuit so that we can compare our simulated results against an actual circuit.

1. Use the NI ELVIS II/II+ to construct the half wave rectifier circuit below.
    - Connect AI 0+ and AI 0- across the resistor, as shown.
    - Connect AI 1+ and AI 1- to the Function Generator and ground, as shown.

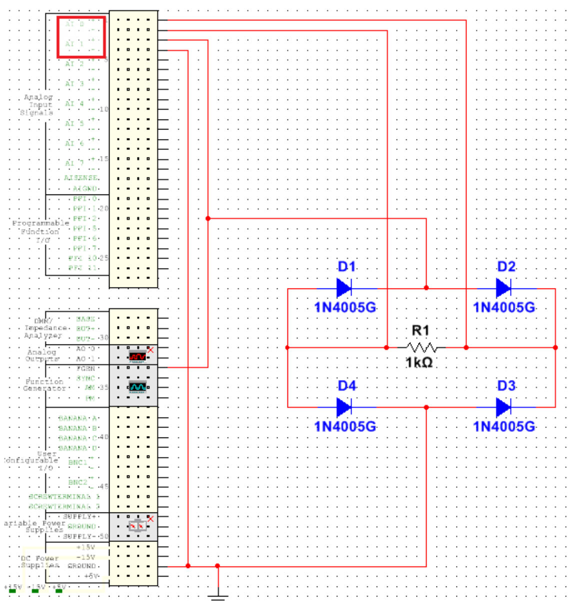

Figure 4. A full-wave bridge rectifier circuit

2. In the Function Generator window, set the Frequency to 60Hz and the Amplitude to 10Vpp.
3. Click the Run button.
4. Start the oscilloscope
    - Set the Channel 0 Source to AI 0.
    - Enable Channel 1.
    - Set the Channel 1 Source to AI 1.
    - Set the Trigger Type to Edge.
    - Leave the Slope as Increasing and the Level as 0V.

The full-wave rectifier outputs voltage in just one direction. This results in a voltage that is pulsating. In this section, we will use a capacitor to smooth the output of the rectifier.

1. Make sure the NI ELVIS II is turned on.
2. If they're not already open from part 2, open the Function Generator and Oscilloscope.
3. Add a 10µF capacitor in series to the resistor in the circuit from part 2 to build the following circuit.

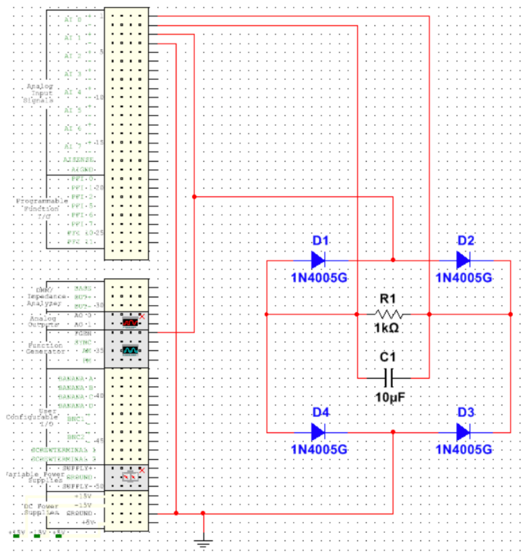

Figure 5. A full-wave bridge rectifier circuit with a filtering capacitor

4. Configure the Oscilloscope:
   - Set the Channel 0 Source to AI 0.
   - Enable Channel 1.
   - Set the Channel 1 Source to AI 1.
   - Set the Trigger Type to Edge.
   - Leave the Slope as Increasing and the Level as 0V.
5. Click the Run button.
6. Configure the Scale Volts/Div and Time/Div so that 2 or 3 cycles of the sine wave are visible on the graph.
7. Observe the graph that is generated:
   - Notice that the capacitor is maintaining a charge, and causing the voltage across the resistor to never reach 0.
   - The resulting signal is closer to a steady DC voltage, but there is still an AC "ripple" voltage component.
   - Measure the amplitude of the ripple voltage using the Vp-p from CH0 in the Oscilloscope window.
8. Replace the 10µF capacitor with a 100µF capacitor.
9. Run the Function Generator and Oscilloscope again.
10. Observe the signal and record the ripple voltage with this capacitor.
11. Stop the Function Generator and Oscilloscope.
12. Replace the 100µF capacitor with a 500µF capacitor.
13. Run the Function Generator and Oscilloscope again.
14. Observe the signal and record the ripple voltage with this capacitor.

1kΩ resistor	10µF	100µF	500µF
Ripple Voltage			

15. Complete the following table based on your ripple voltage measurements.
16. Replace the 1kΩ resistor with a 10kΩ resistor and replicate the voltage measurements.

10kΩ resistor	10μF	100μF	500μF
Ripple Voltage			

3. Analysis

These questions will help you review and interpret the concepts learned in this lab.

- Does this graph match the one in the simulation in Part 1?
- Is the amplitude of voltage across the resistor higher or lower than in the simulation?
- Why might the voltage be different? (**Hint:** Consider the difference between the circuits)
- What is the ripple voltage?
- How does the voltage change with an increase in the capacitance?
- How does the voltage change with an increase in the impedance?
- How does the current travel between the positive and the negative halves of the sinewave?
- Explain the effect of increasing the capacitance on the output of the rectifier.
- Explain the effect of increasing the resistance of the resistor on the output of the rectifier.

APPENDIX

The following is the template of the ECE 3313 report. Note that the report must be typed using Microsoft Words/Excel. Please download the template from the Canvas website.

ECE 3313 Lab X Report Your Name

<u>Title:</u> Lab 1: Observation, Modeling, and Communication

NAME: **Partner:**

General Objective: One or two sentences that describe the objective of this specific lab.

1.0 Prelab Activities: If there is any

2.0 Background Activities: Read background information and summarize important theory, equation, etc.

3.0 Procedure: Describe step-by-step procedure, including circuit schematic, calculation, and etc.

4.0 Results: A lab often includes questions. Please include your answer under the result sections.

- **4.1 Simulation Results:** Make sure to fully discuss about the results, figure, etc.
- **4.2 Experimental Results:** Make sure to fully discuss about the results, figure, etc.

5.0 Conclusions

Remark: Your lab report should include ALL relevant calculations, pictures and work needed for completion of the experiment. Circuit output validation using Multisim is also required. Detailed explanations for decisions made throughout the lab need to be included in the Discussion section of your report as outlined in the Report Guidelines.