THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2115: ENGINEERING ELECTRONICS LABORATORY

Experiment #2:
Solid State Diodes – Applications I

COMPONENTS

Type	*Value*	*Symbol Name*	*Multisim Part*	*Description*
Resistor	16kΩ	R_1	Basic/Resistor	---
Resistor	--- Ω	R_L	Basic/Resistor	---
Capacitor	--- F	$C_1 – C_2$	Basic/Capacitor	---
Diode	1N4002	$D_1 – D_4$	Diodes/1N4002G	Series Silicon Diode
Transformer	166K18		Basic/Transformer/1P2S	$115V_{RMS}$–$18V_{RMS}$ C.T.

Table 1 – Component List

OBJECTIVES

· To measure the output characteristics of your transformer
· To build and safely test a half wave rectifier
· To build and safely test a full wave rectifier
· To build and safely test a bridge rectifier
· To design, build, and test a voltage doubler

Introduction

In this lab, you will need to know how to use your AD2, and in particular the oscilloscope functionality of the AD2, in order to successfully do all the tasks. If you need a refresher on how to do this, go to Lab 2 of ECE 2110 (Circuit Theory) since this gives you all you need to know!

Introduction to the Oscilloscope

An oscilloscope is an electronic measurement instrument that unobtrusively monitors input signals and then graphically displays these signals in a simple voltage versus time format [1].

The Basics:

• An oscilloscope measures and displays voltage as it changes with time.
• It consists of a **display** screen with an X & Y-axis and **control panel** seen on the right-hand side.
• The X-axis of the display represents time.
• The Y-axis represents voltage.
• Each input channel has its own separate controls.

Setting the Scales for the Oscilloscope's X & Y-Axes

Let us begin by first getting acquainted with the most important controls on the oscilloscope. On the right-hand side of the oscilloscope are the two main controls for each input Channel, shown in Figure 5. These drop downs allow you to set the "Offset" and the "Range". The Offset moves the waveforms up and down along the Y Axis. This is useful for when we need to separate the waveforms on screen. The Range adjusts the scaling of the Y Axis, and is labeled V/div, volts per division. You will find that as you increase the V/div value, the "size" of the wave will shrink. The actual value of the wave is not changing, but you are increasing the scale of the Y Axis, so the graph will adjust accordingly. If you lower the V/div value, the wave will appear to grow. Again, the value of the actual wave is not changing, you are now decreasing the scale and the graph adjusts accordingly. The Range should be set at a value where you can see both peaks of each wave.

Another useful tool within the Oscilloscope is the "Time" feature, which can be found directly above the Channel controls. With this, we can jump to a specific point in time with the "position" feature. This is useful because it not only allows us to see the start of our circuit, but we can jump to a specific point where maybe something went wrong within the circuit, allowing us to troubleshoot. This number can be adjusted with the drop-down bar with set time values, by typing in your own value, or by clicking and dragging the white down arrow at the top of the oscilloscope screen. This value can also be changed by clicking on the graph and dragging either left or right. You will see the position value adjust accordingly. The other value is the "Base". Like V/div adjusted the scale of the Y Axis, the base adjusts the scale of the X Axis, but for both channels. The X Axis is measured in seconds per division, or sec/div. This is useful because it can help us home in on one specific cycle or see multiple cycles. This value can also be adjusted by scrolling in or out with the mouse pad or scroll wheel. It is worth noting that the green arrow below the Base value will allow you to change more features along the X Axis. Unless otherwise specified in the lab, you can just leave these values as is.

Key Points:

• The value of the X-axis scale is set using the Time feature, and is measured insec/div. • The value of the Y-axis scale is set under each channel, and is measured in Volts/div. • Both the X and Y Axis can also be adjusted with the mouse.
• Pressing the check button next to each channel will turn on/off the display of that individual channel.

More Important Features

There are many tabs above the Oscilloscope screen, starting with "Export" on the left, all the way to "Measurements" on the right. While you can watch this video to get a full explanation of each of these tabs, the two most important ones are the "Measurements" tab and the "X Cursors" tab. THE MEASUREMENTS TABS DO NOT CREATE THE SAME MENU. To get all the Measurements you will need for this lab and all other labs, it is best to use the Measurements tab that is closer to middle, NOT the one on the far right. The Measurements tab opens a new menu that appears to the left of the Channel controls. By clicking the "Add" button that appears within this menu, we can have the Oscilloscope display very useful data about our waves, on both channels. If we accidentally add a measurement that we do not need, we can simply press the red minus button that is directly right to the Add button. The other important tab is the X cursors tab. This will bring up a menu directly below the Oscilloscope screen. We can add either "Normal" cursors or "Delta" cursors. In this lab, we will use both cursors and see what they do.

A quick note on the AD2's internal wiring: It should be mentioned that the Wavegen and both Channels of the Oscilloscope are internally grounded, meaning that when you go to build the circuits in this class, only the positive ends of these devices are needed when measuring with respect to ground. If you are not measuring with respect to ground, and you want to measure across one specific component, you must use the negative ends of the Oscilloscope Channels (Wires 1- and 2-). These wires will have a white line on them, indicating that they are the negative ends.

Key Points:

• There are many different features available to us with this Oscilloscope, but not all are needed for our purposes.
• It is important to know which "Measurements" tab you are using. The one on the far right will not give you all the measurements you need to display.
• If you ever need to remove a measurement of the cursor, there will be a red minus button that will delete them.
• You can also remove both menus from your screen by simply pressing the "x" button at the top right-hand corner of both.

Multiple Channels

• The oscilloscope only has two separate input channels, allowing two different signals to be displayed on the screen simultaneously (**Figure 10** shows an example with two signals).

• The Offset values allow each signal to be shifted up and down independently of one another. This can be done to separate overlapping signals and to position the signals to make it easier to estimate their amplitudes. In **Figure 10**, the blue (channel-2) has been shifted slightly lower than channel-1.

Waveform Math

• Oscilloscopes ***cannot*** directly measure the voltage across a component unless one end of the component is grounded. Instead, oscilloscope measurements are limited to node-voltage measurements (node voltages are measured with respect to ground by definition).
• For an oscilloscope to measure the voltage across a component, the node voltage waveforms on each side of the component must be acquired and then subtracted.
• The oscilloscope can perform the following math functions:
  - **Add**, **Subtract**, **Multiply**, **Divide, RMS, ATan, AC, and offset.**
• Waveform Math is turned on and the Math menu is accessed by pressing the **Add Channel** button above channel 1 and 2, and then by pressing "Simple" on the drop-down menu.

Set Up and Using

Set up the desired measurements to be displayed. In the oscilloscope you will see a “Measurements" section on the right-hand side. Press the "Add" button then Click "Defined Measurement". After this, click "Channel 1" then Click "Vertical". Now you may Add the "Maximum", "Minimum", and "DC RMS" measurements, along with a few others. After this, you can also Click Horizontal and Add the "Frequency" measurement. Now you Click "Close". To Configure the digital oscilloscope, you can Adjust the vertical Volts/div until the entire signal is visible. You may also Adjust the horizontal sec/div until the desired waveform is seen on the display. You can use either the drop down or the scroll wheel on a mouse

PRELAB

Part I – Generate Equipment List

1. Read through the lab manual and generate an equipment list.

Part II – Specification Sheet Values

1. **Download** and **print** the specification sheet for the transformer in your kit: Hammond #166K18 *(See the lab website for links to spec sheet downloads and ensure this part number matches the transformer in your ECE 2115 parts kit)*
a. From the spec sheet, find the transformer with your model number and populate the following table for each characteristic of the transformer.

Note: *C.T. on the spec sheet means Center-Tapped.*

Characteristic	***Value***	***Convert RMS Values to V_P and V_{PP}***
Primary Voltage		V_P = V_{PP} =
Frequency		
Secondary Voltage		V_P = V_{PP} =
Secondary Current Limit		
Calculate Power Limit		
Calculate Turn Ratio (N_P/N_S)		

Table P.1 – Spec Sheet Values

Part III – Transformer Simulations

1. **Read** "*Tutorial #2 – Simulating Transformers in Multisim*" on the lab website.

2. **Use** the tutorial and values from **Table P.1** to construct a center-tapped transformer with a turn ratio that matches the transformer in your kit.

3. **Run a transient analysis** in Multisim to plot 10 cycles of the primary and secondary voltage.

4. **Use** the transformer you have built in step 2 to construct the three different rectifying circuits in **Figures P.1, P.2, and P.3**. For the circuits that use a "non-center tapped" transformer, simply use the top-half of the secondary coil of your center-tapped transformer. **Include** the **plots** of the voltage across R1 in your prelab. If you are unfamiliar with what each rectifier does, read sections 3.5 – 3.5.3 (in Sedra) to understand them further.

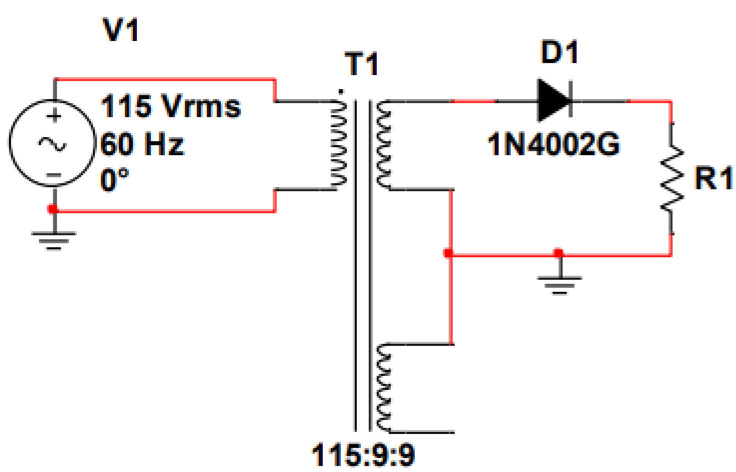


Figure P.1 – Half Wave Rectifier

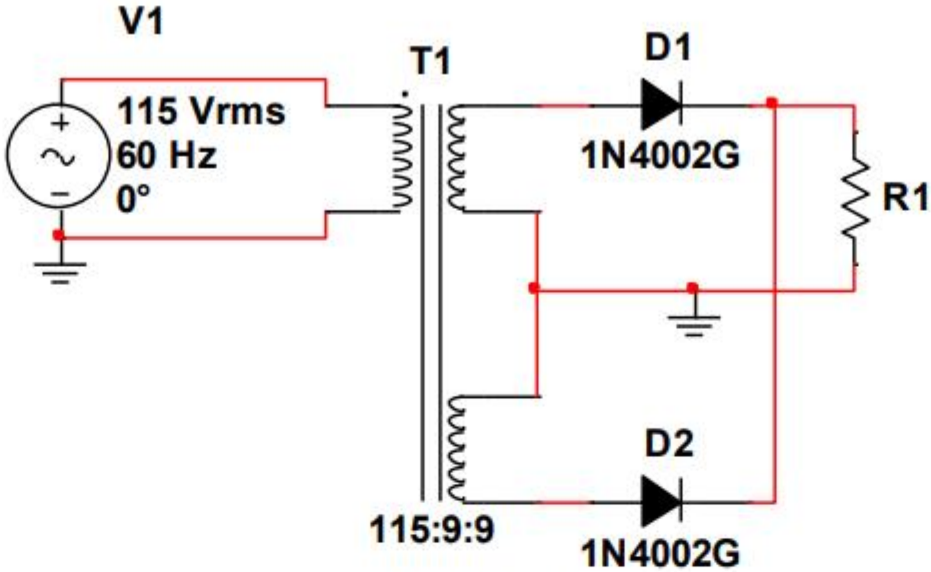


Figure P.2 – Full Wave Rectifier

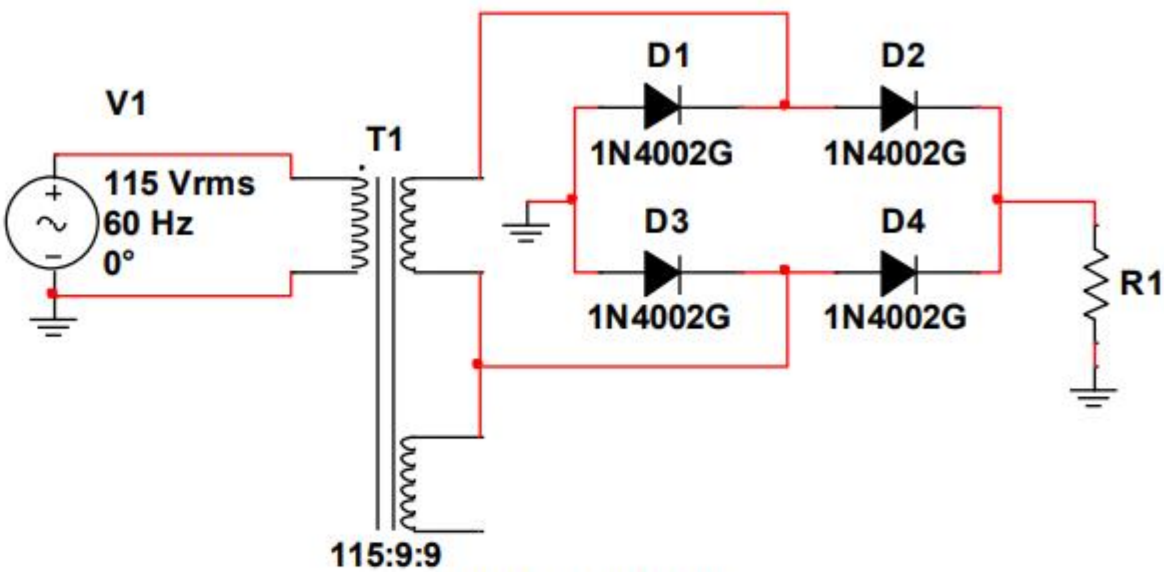


Figure P.3 – Bridge Rectifier

5. In the event of a prelab quiz, be prepared to draw the three waveforms that would result from each of the rectifier circuits.

Part IV – Voltage Doubler

1. **Design** and **build** a Voltage Doubler Circuit that meets the following specifications:

· **Input**: 12V_P (output of the top half of your transformer's secondary)
· **Output**: -24V +/- 5%
· **Type of Load**: Resistor
· **Max power** dissipated by load resistor: **100mW**

2. **Using Multisim** and section 3.6.3 of your textbook (p 189 in 5th edition Sedra), design, build, and simulate a voltage doubler circuit. For the AC voltage source in the textbook, you will use the **top half of the secondary coil of the center-tapped transformer** you have been simulating with thus far. Experiment with the various size capacitors available in your ECE 2115 kit to reduce the time the circuit requires to reach its steady state.

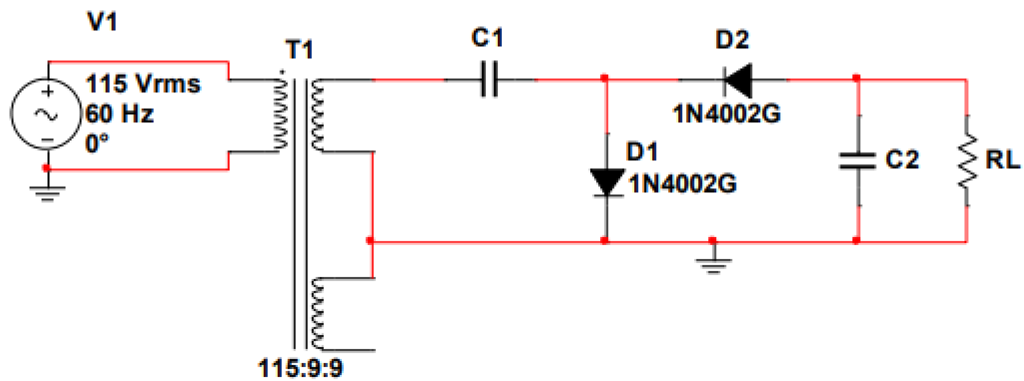


Figure P.4 – Sample Voltage Doubler Circuit Using a Center-Tapped Transformer

3. **Figure P.5** shows a successful doubling of a V_{source} = 9V_{RMS} (12.586V_P) source. The red trace shows a nearly doubled value of -23.88V, which is nearly |2V_P|. Notice steady state for the circuit is not reached for roughly 6 cycles.

Note: *The red trace is nearly a DC signal, which is the purpose of a voltage doubler.*

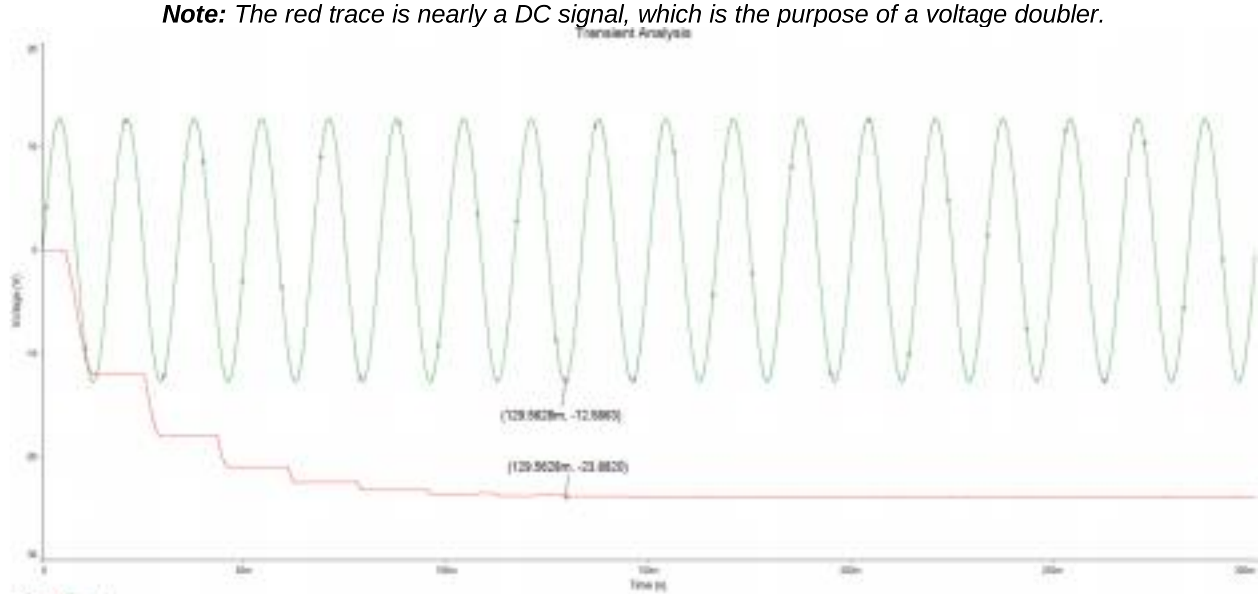


Figure P.5 – Secondary Coil Voltage and Output Voltage Across Load Resistor

4. **Figure P.6** shows the power dissipated by the load resistor P_L is roughly 100mW. You must choose an appropriately sized load resistor for your voltage doubler so that it dissipates no more than 100mW of power.

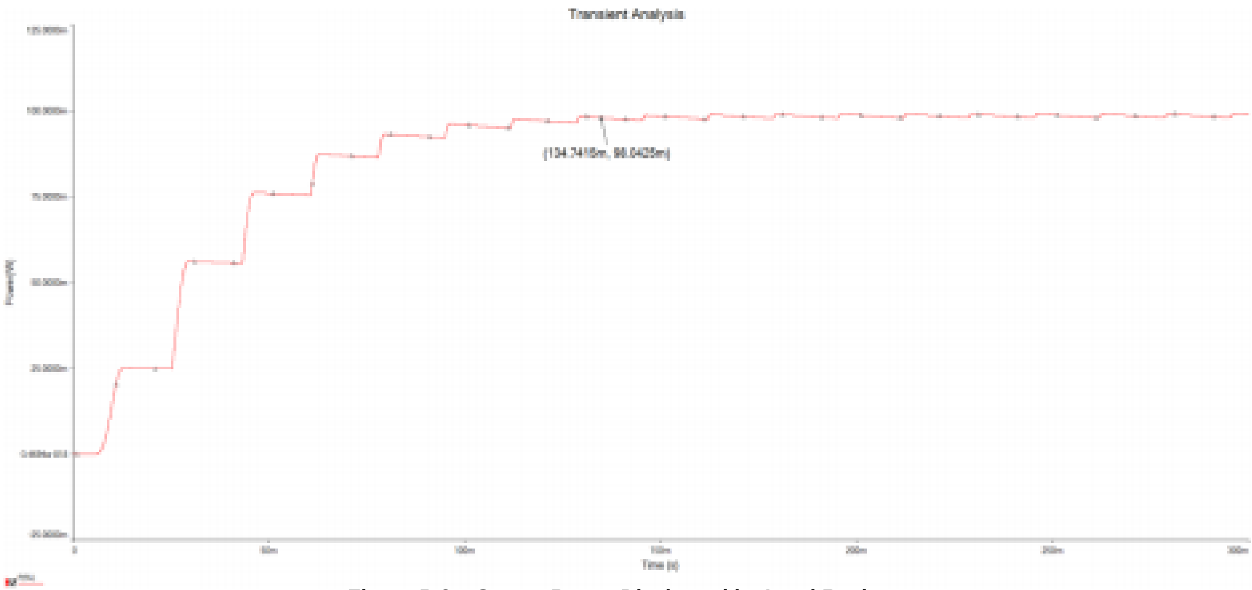


Figure P.6 – Output Power Dissipated by Load Resistor

Caution!

- **Be very careful during this experiment!**
- **Hazardous voltages will be present when you perform your measurements!**
- **The transformer in this lab has a primary voltage of roughly 120V_{RMS}.**
- **If not handled properly, injury can occur from your transformer.**

Part I – Determining the Turn Ratio of the Transformer

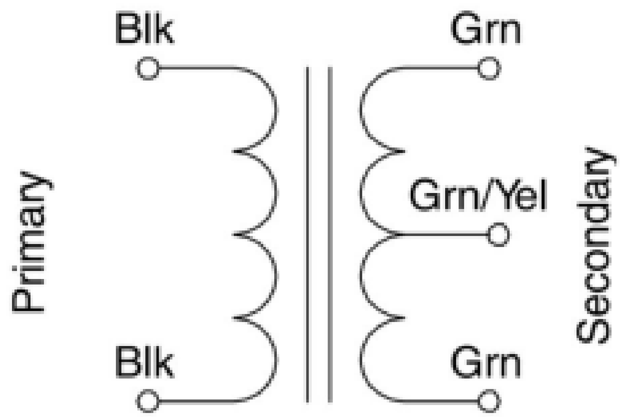


Figure 1.1 – Center-Tapped Transformer Schematic

1. **Plug** all of the output wires coming from the secondary coil of the transformer into a breadboard before connecting it to the AC outlet.

2. **Plug** the transformer into an AC outlet located on your bench.

3. Your **GTA** will measure the ***primary*** coil's voltage and announce it to the lab.

a. **Record** it as **$V1_{RMS}$**.
b. **Calculate** $V1_P$ and $V1_{PP}$ for the primary coil and record your results in a table.
4. **Use** the **DMM** to measure the voltage across the **TOP HALF** of the ***secondary*** coil.
 a. **Record** the voltage as **$V2_{TOP\_RMS}$**, **calculate** V_P and V_{PP}, and record this in the table.
5. **Use** the **DMM** to measure the voltage across the **BOTTOM HALF** of the ***secondary*** coil.
a. **Record** the voltage as **$V2_{BOTTOM\_RMS}$**, **calculate** V_P and V_{PP} and record this in the table.
6. **Use** the **DMM** to measure the voltage across the **ENTIRE** ***secondary*** coil (green to green wire).
a. **Record** the voltage as **$V2_{RMS}$**, **calculate** V_P and V_{PP}, and record this in the table. 7. **Determine** the **turns ratio** $(\frac{V1_{RMS}}{V2_{RMS}})$ and record this in the table.
8. **Connect** the **oscilloscope (in this case, you will be using the AD2 as your oscilloscope)** only to the secondary. ***Never*** connect the scope to the primary! The negative lead on the scope probe is ground. If you connect this lead to the primary, you will cause **120V_{RMS} at 20A** to short through your probe to ground!

a. **Use** the scope to measure the voltages across the TOP HALF, BOTTOM HALF, and across the ENTIRE secondary coil. You should have **three** different waveforms.

b. **Save** each waveform on a USB and include in the lab report. Be sure to measure the **frequency**, **V_{RMS}**, and **V_P** of each waveform you record.

c. **Label** the plots appropriately in the lab report.

9. **Disconnect** the transformer from the AC outlet!

10. **Calculate** $V1_{PP}$, and $V2_{PP}$ from the V_P measured by the oscilloscope and record in a table.

Part II – Testing the Half Wave Rectifier

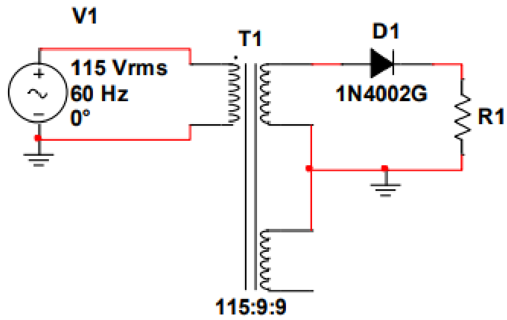
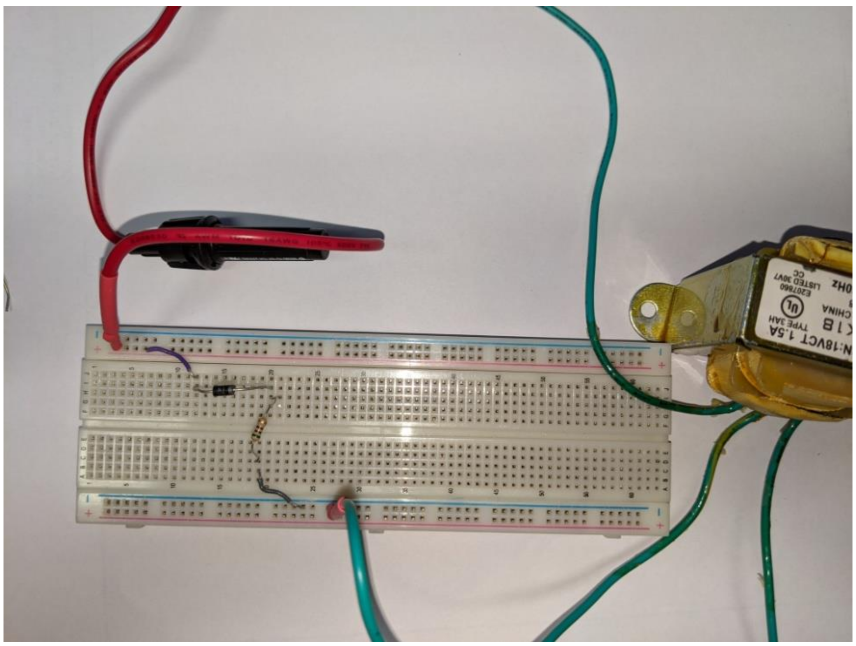


Figure 2.1 – Half Wave Rectifier



1. Construct the half wave rectifier circuit shown above in **Figure 2.1**

Note: *Even though the bottom half of the secondary is not used in this circuit, be sure to plug the lead into an empty spot on the breadboard so that it is not dangerously hanging out of the circuit.*

2. **Test** the circuit for a possible short to ground with an Ohmmeter. **Correct** any wiring errors and test again.
3. **Connect** the transformer to an AC outlet.
4. **Measure** and **record** the waveform across R_1 using the oscilloscope. Include any relevant measurements.
5. **Disconnect** the transformer from the AC outlet!

Part III – Testing the Full Wave Rectifier

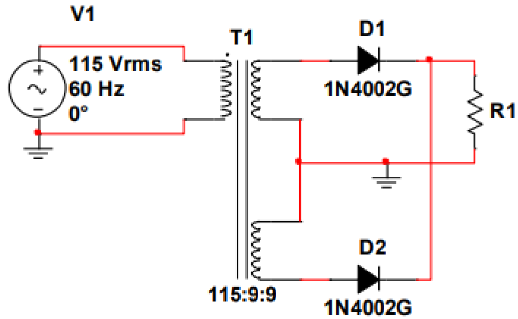
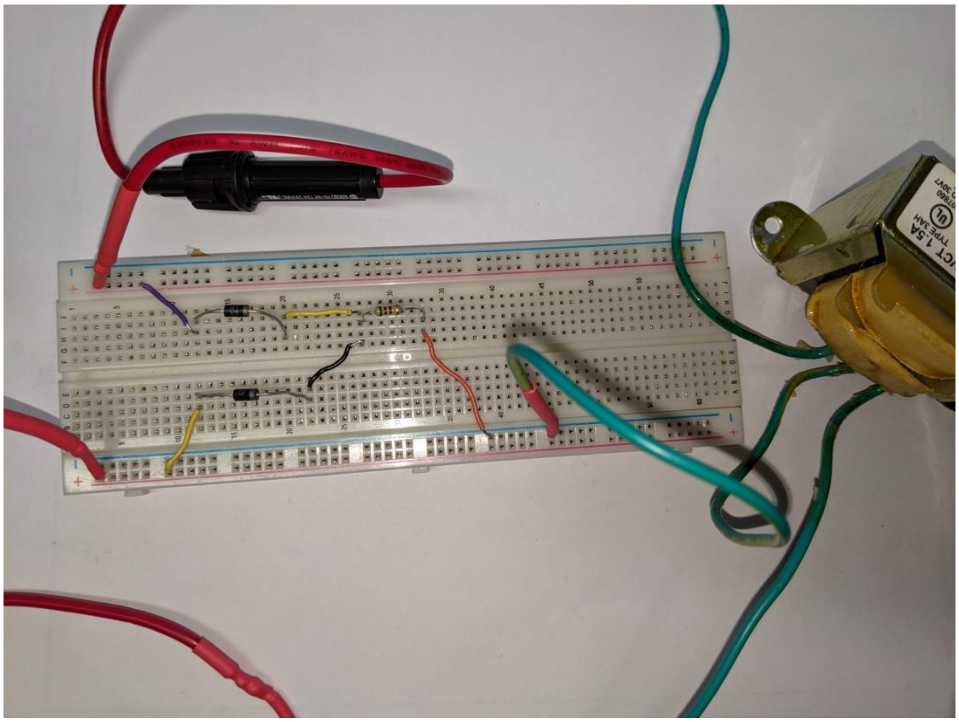


Figure 3.1 – Full Wave Rectifier



1. **Construct** the full wave rectifier circuit shown above in Figure 3.1.
2. **Test** the circuit for a possible short to ground with an Ohmmeter. **Correct** any wiring errors and test again
3. **Connect** the transformer to an AC outlet.
4. **Measure** and **record** the waveform across R1 using the oscilloscope. Include any relevant measurements.
5. **Disconnect** the transformer from the AC outlet!

Part IV – Testing the Bridge Rectifier

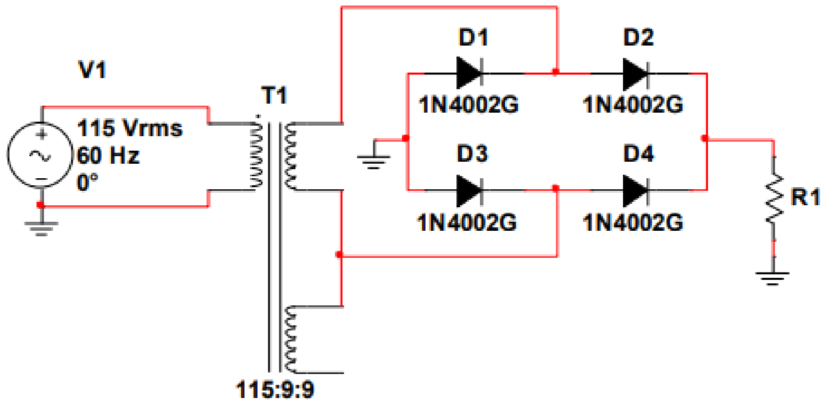
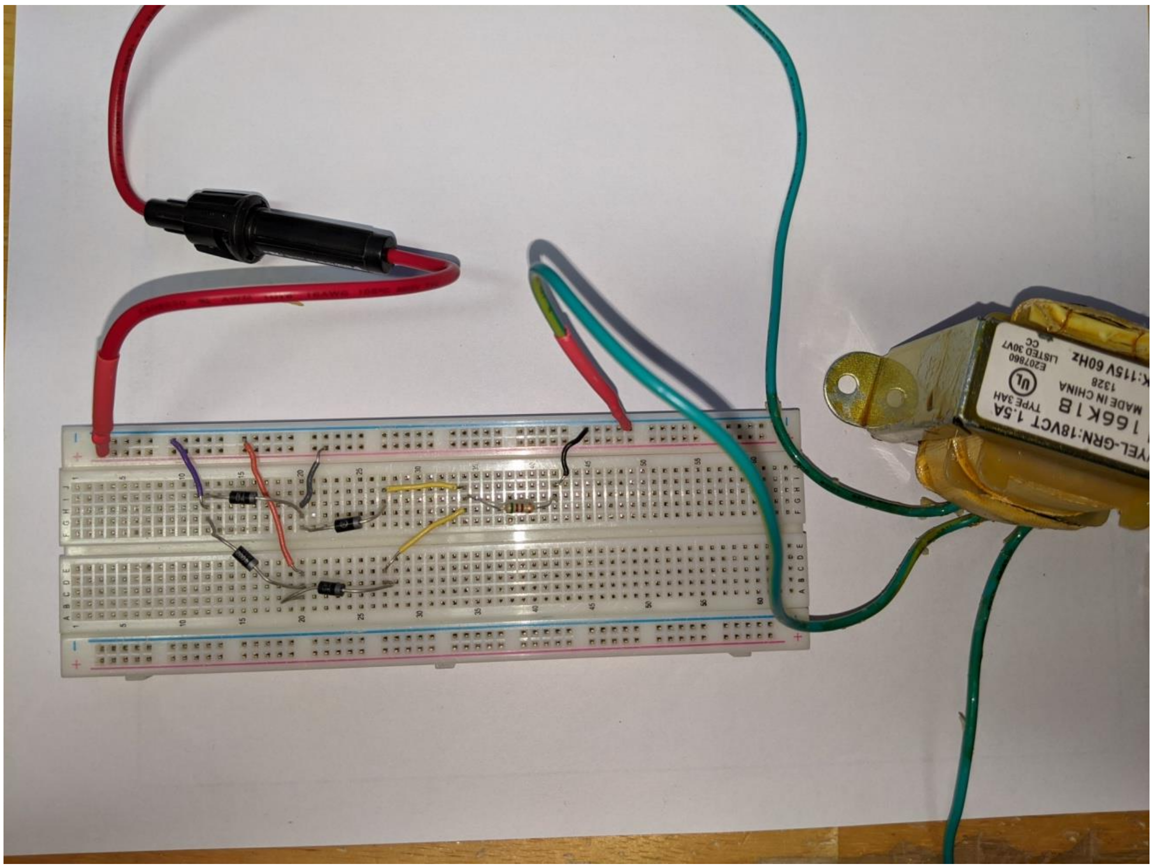


Figure 4.1 – Bridge Rectifier



1. **Construct** the bridge rectifier circuit shown above in **Figure 4.1**.

Note: *Even though the bottom half of the secondary is not used in this circuit, be sure to plug the lead into an empty spot on the breadboard so that it is not dangerously hanging out of the circuit.*

2. **Test** the circuit for a possible short to ground with an Ohmmeter. **Correct** any wiring errors and test again.
3. **Connect** the transformer to an AC outlet.
4. **Measure** and **record** the waveform across R_1 using the oscilloscope. Include any relevant measurements.
5. **Disconnect** the transformer from the AC outlet!

Part V – Testing the Voltage Doubler

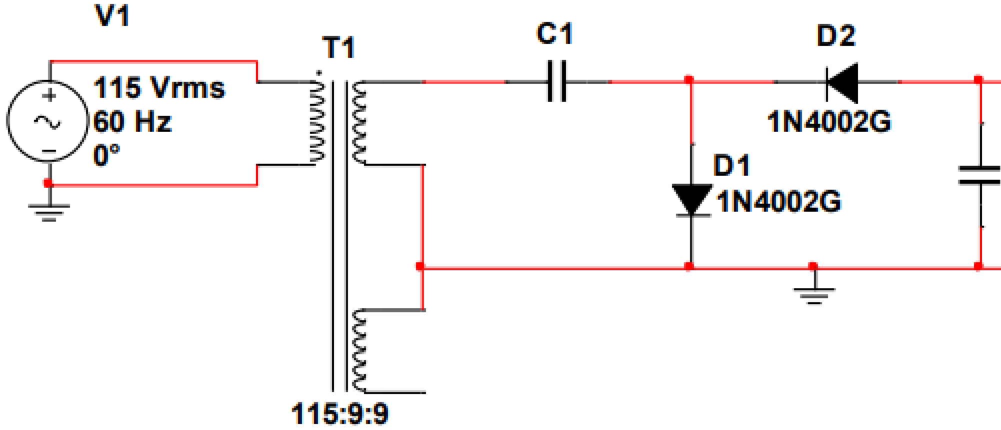
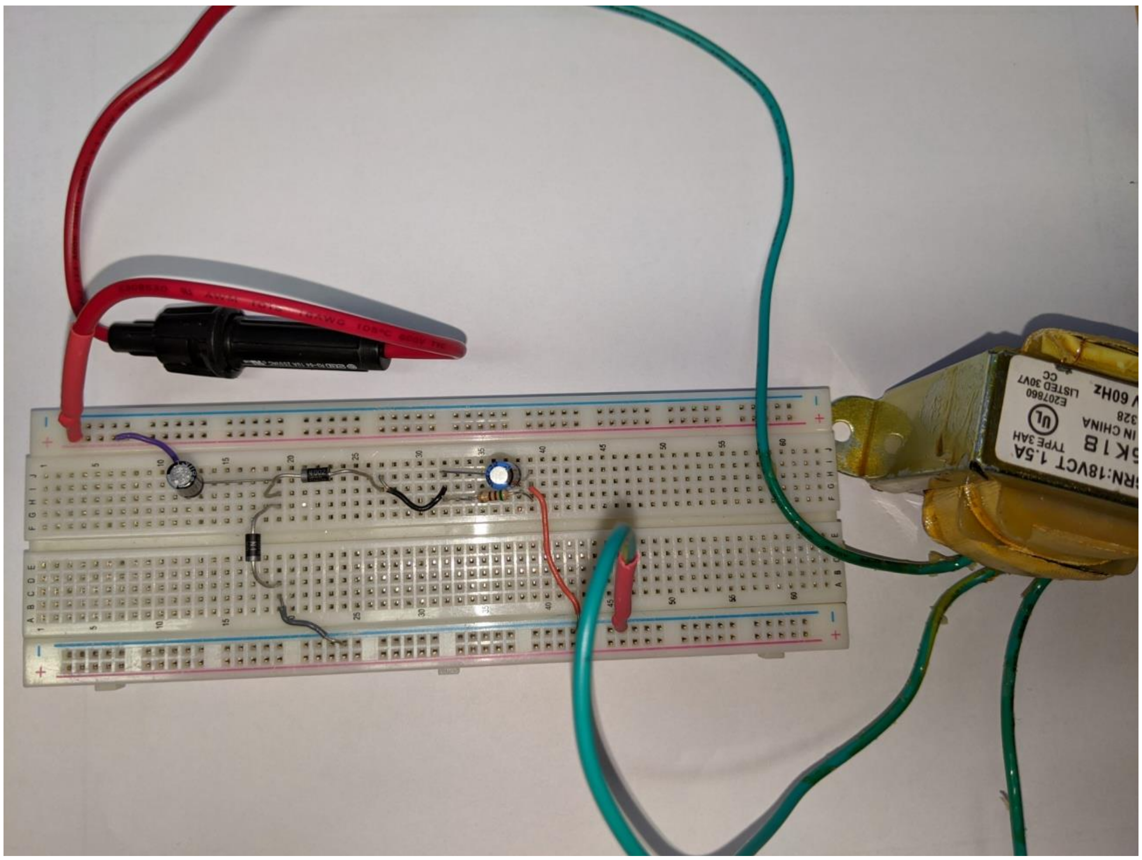


Figure 5.1 – Sample Voltage Doubler Circuit Using a Center-Tapped Transformer



1. **Build** the voltage doubler designed in the prelab.

Note: *The load resistor should* ***NOT*** *be 16kΩ. Instead, it should be the value you calculated based on the desired 100mW power dissipation goal of the design.*

2. **Use** the **oscilloscope** to **measure** the voltages found during simulation.

3. **Save** the output waveform from the oscilloscope to a USB.

POST-LAB ANALYSIS

1. **Compare** the measured results of the output of your transformer to those obtained using Multisim. **Include** in your comparison all waveforms and the details of what you measured.

2. **Compare** the measured results of each type of positive rectifier to those obtained using Multisim. **Include** in your comparison all waveforms and details of what you measured. 3. For each rectifier plot, **indicate** what is occurring in each region. As an example, **explain** which diodes are on and off in each region.

4. **Why** would one use a bridge rectifier over a full wave rectifier?

5. **Explain** the theory behind the **voltage doubler** you designed. **Show all** waveforms and **explain** what each component does.