EE 2010 Circuit Analysis
Lab 04: Single-Diode Rectifier

Lab Section: **Printed Name (Last, First):**

Learning Objectives:

- Understand the operation of a diode - *a one-way current valve*
- Understand the concept of *rectification*
- Understand the utility of capacitors in conditioning waveforms
- Be able to simulate a half-wave rectifier
- Be able to capture and display input-output waveforms of a rectifier

1 Before coming to lab:

1.1 What is a rectifier?

Definition (from Wikipedia): A *rectifier* is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The reverse operation is performed by the inverter.

The process is known as rectification, since it "straightens" the direction of current. Physically, rectifiers take a number of forms, including vacuum tube diodes, wet chemical cells, mercury-arc valves, stacks of copper and selenium oxide plates, **semiconductor diodes**, silicon-controlled rectifiers and other silicon-based semiconductor switches. Historically, even synchronous electromechanical switches and motor-generator sets have been used. Early radio receivers, called crystal radios, used a "cat's whisker" of fine wire pressing on a crystal of galena (lead sulfide) to serve as a point-contact rectifier or "crystal detector".

1.1.1 Read this Wikipedia Article on *Diodes*. See especially the section "Current-voltage characteristic."

1.1.2 Note that diodes act as one-way current valves. Though these are *non-linear* devices, they often appear in applications of otherwise linear circuits.

1.1.3 Read this Wikipedia Article on *Rectifiers*. Note that rectifiers are very commonly used in AC-DC power supplies. Power supplies like the one shown for a desktop computer are a critical component of every electronic device on the planet!

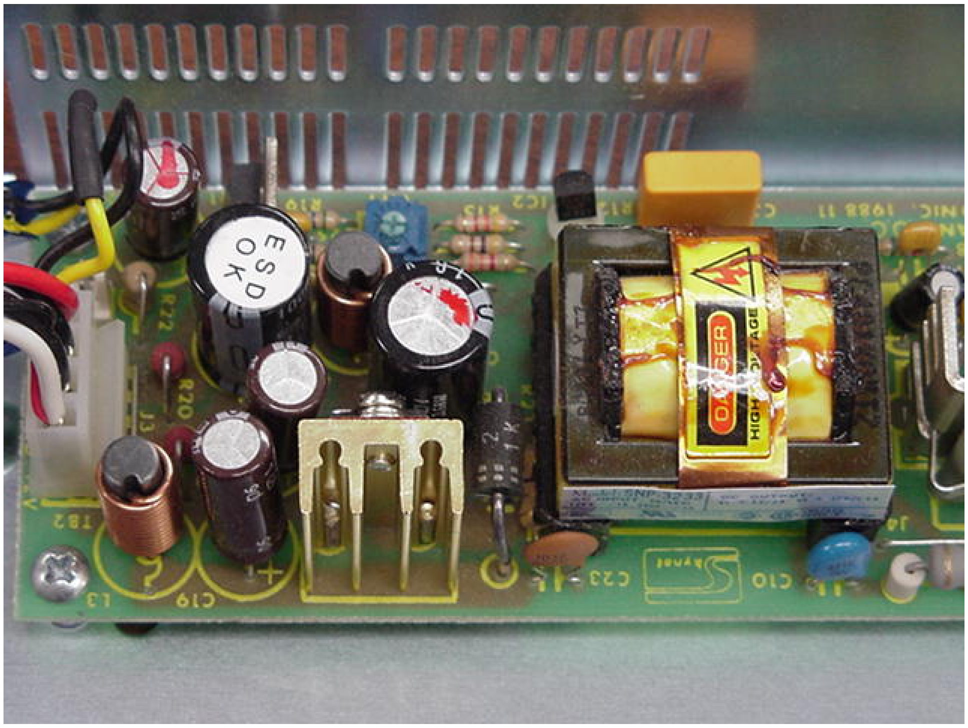


Figure 1: Desktop Computer Power Supply

1.1.4 For additional information, see this Wikipedia article concerning power supplies.

1.2 Simulation Procedures: Build a half-wave rectifier in Multisim

1.2.1 Build the circuit shown below:

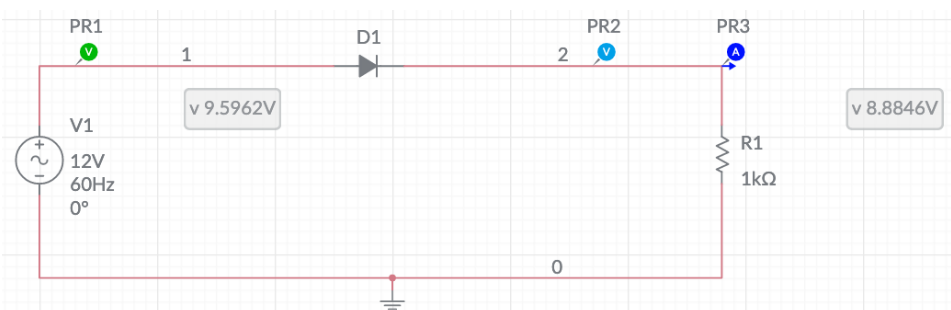


Figure 2: Diode-Resistor circuit schematic diagram

1.2.2 Employ an AC voltage source with an amplitude of 12V and a frequency of 60Hz

1.2.3 Run the simulation for a short time and capture the results.

1.2.4 Display the graphical result.
NOTE 1: The time duration of the graphical display should be on the order of 60mS.

NOTE 2: The Voltage and Current MIN and MAX should be adjusted to observe the entire waveforms.

1.2.5 The properly-constructed circuit should yield probe graphs like those shown below.

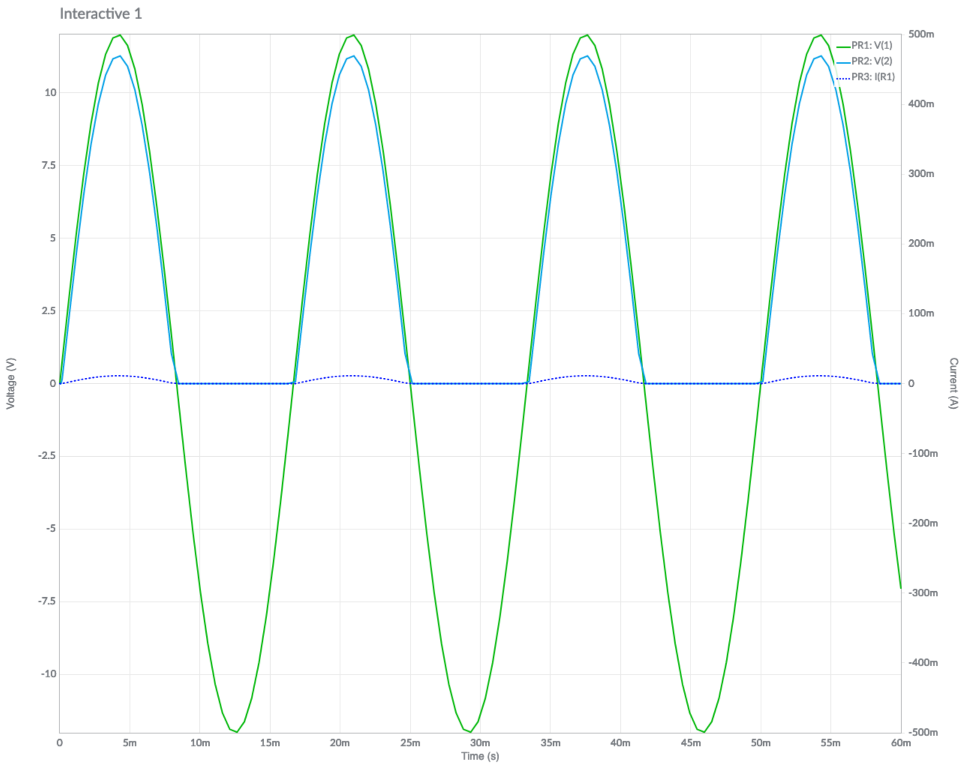


Figure 3: Diode-Resistor Response Waveforms

1.2.6 Note especially the voltage waveform at the load = R1

1.2.7 Observe the diode acts as a "one-way current valve" allowing current to flow in *only one direction* through the resistor - hence we observe only clockwise current flow and positive voltages.

1.2.8 Export the schematic of your circuit and probe waveform graph and upload it to Pilot under the appropriate **Dropbox** folder.

1.3 Observations

1.3.1 Notice that the single-diode rectifier rectifies only one-half of the voltage waveform.

1.3.2 This is inefficient by nature since only one-half the supply waveform is used.

1.3.3 The small difference between the supply voltage and resistor voltage is due to the *forward-bias voltage drop* of the diode. (This is typically about 0.7V.)

1.4 Simulation Procedures: Build a half-wave rectifier with capacitative charge storage

1.4.1 Build the circuit shown below which adds a capacitor to store and release energy so as to smooth the voltage as seen by the load resistor:

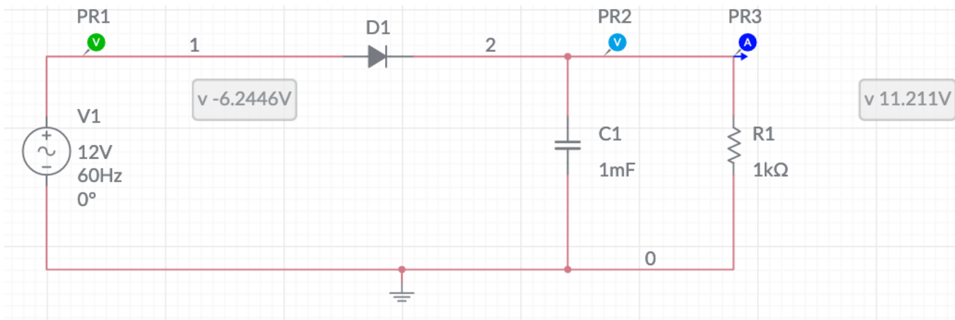


Figure 4: Half-Wave Rectifier circuit schematic diagram

1.4.2 Run the simulation for a short time and capture the results.

1.4.3 Display the graphical result.
NOTE 1: The time duration of the graphical display should be on the order of 60mS.
NOTE 2: The Voltage and Current MIN and MAX should be adjusted to observe the entire waveforms.

1.4.4 You will observe the capacitor acts to "smooth" the voltage waveform.

1.4.5 The goal is to approximate a constant voltage under the designed loading conditions.

1.4.6 You might experiment with different capacitor values to observe the effects of capacitor value.

1.4.7 The properly-constructed circuit should yield probe reading graphs like those shown below.

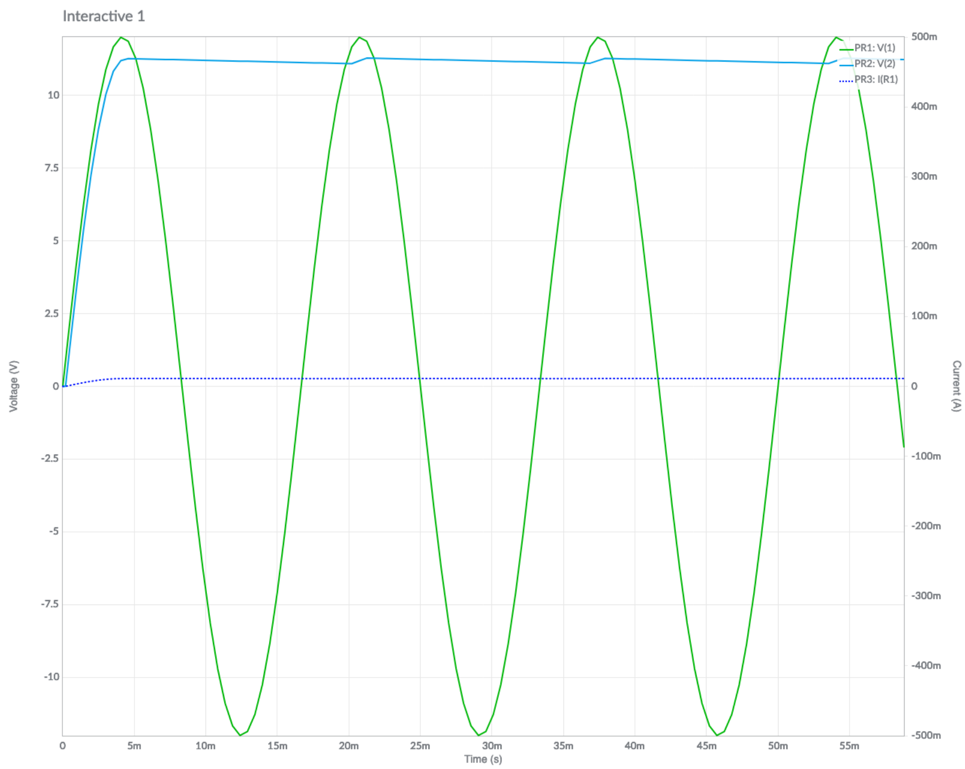


Figure 5: Diode-Resistor Response Waveforms

1.4.8 Note especially the voltage waveform at the load = R1

1.4.9 Export the schematic and waveform graph of your circuit and upload it to Pilot under the appropriate **Dropbox** folder.

1.5 Observations

1.5.1 Notice that the addition of a capacitor produces a reasonably-smooth "almost DC" waveform under minimal loading conditions.

1.5.2 Explore the effects of *increasing* the load-current by decreasing the value of the 1K Ω load resistor.

1.5.3 Explore the effects of *increasing* the capacitor value on the smoothness of the output voltage.

1.6 IMPORTANT LAB PREP!

1.6.1 You will be using a *Function Generator* as an AC power supply and an *Oscilloscope* in the place of Probe 2 to measure the time-varying voltage

1.6.2 Do lab prep by watching this video demonstrating the generation and measurement of an AC (sinusoidal) waveform.

2 In Lab Procedures

In this lab session you will construct and test a single-diode rectifier.

2.1 Realization Procedures: Build a half-wave rectifier

2.1.1 Build the circuit shown below:

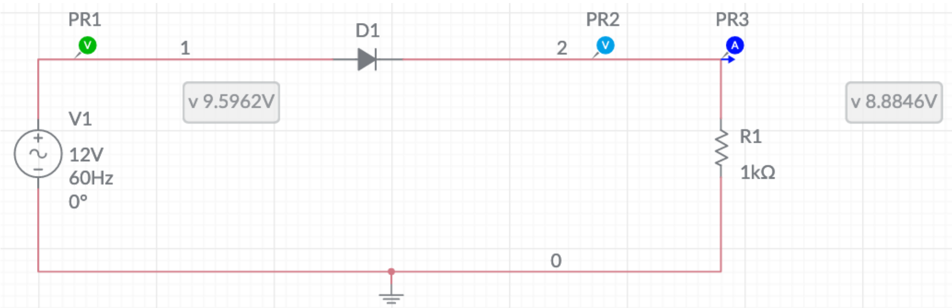
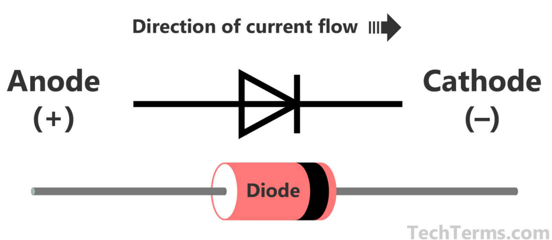


Figure 6: Diode-Resistor circuit schematic diagram

2.1.2 The polarities for diodes (current flow direction) and electrolytic capacitors (voltage polarity direction) are depicted below



(a) Diode current flow polarity

(b) Capacitor voltage polarity

Figure 7: Component polarity designations

2.1.3 Set the function generator for an amplitude of 5V and a frequency of 60Hz

2.1.4 Connect the function generator directly to the oscilloscope and verify the generation of a sine wave

2.1.5 Connect the function generator to be the source voltage and connect the oscilloscope to measure the voltage across R1

2.1.6 The oscilloscope should display a rectified waveform approximating the waveform observed in the simulation.

2.1.7 Verify with your TA that the circuit works properly. Have your TA sign below.

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TA Signature: ______________________

2.2 Realization Procedures: Build a half-wave rectifier with capacitative charge storage

2.2.1 Build the circuit shown below which adds a capacitor to store and release energy so as to smooth the voltage as seen by the load resistor:

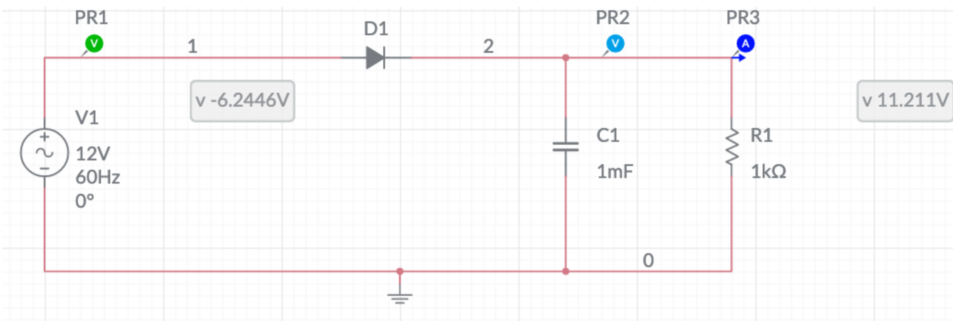

Figure 8: Half-Wave Rectifier circuit schematic diagram

2.2.2 Again set the function generator for an amplitude of 5V and a frequency of 60Hz

2.2.3 Connect the function generator to be the source voltage and connect the oscilloscope to measure the voltage across R1 2.18V

2.2.4 The oscilloscope should display a rectified and smoothed waveform approximating the waveform observed in the simulation.

2.2.5 Again, the goal is to approximate a constant voltage under the designed loading conditions.

2.2.6 You might experiment with different capacitor values to observe the effects of capacitor value.

2.2.7 Verify with your TA that the circuit works properly. Have your TA sign below.

TA Signature: ______________________

2.3 Observations

2.3.1 Notice that the addition of a capacitor produces a reasonably-smooth "almost DC" waveform under minimal loading conditions.

2.3.2 Explore the effects of *increasing* the load-current by decreasing the value of the 1K Ω load resistor.

2.3.3 Explore the effects of *increasing* the capacitor value on the smoothness of the output voltage.

3 Takeaways:

4.1 Rectifiers are fundamental to the operation of AC-DC power supplies.

4.2 The efficiency and the waveform quality *(minimizing "ripple")* of a rectifier are major design considerations for the vast majority of electronic devices (more on this later).

4.3 Useful rectifiers are enabled by the charge-storage characteristic of capacitors manifest as "voltage smoothers" through their operation as "current integrators"