

Diodes, Power Supplies, Voltage Regulators Cornerstone Electronics Technology and Robotics II

- Administration:
 - Prayer
- Electricity and Electronics, **Sections 17.2, 17.3, 17.4**, Diodes, Power Supplies, Voltage Regulators:
 - **Semiconductor Diodes:**
 - Semiconductor Diode Symbol: The cathode contains the N-type material and the anode contains the P-type material.



Figure 1

- Voltage vs. Current Graph for a Silicon Diode:

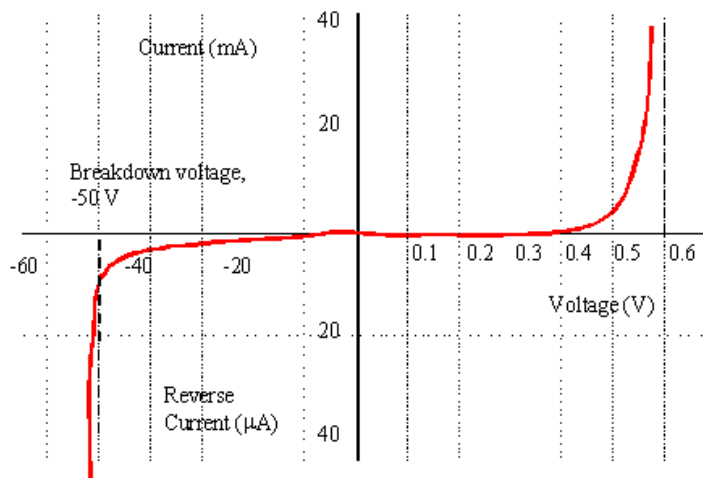


Figure 2 Voltage vs Current for Forward and Reverse Biased Diode

From http://www.antonine-education.co.uk/Electronics_AS/Electronics_Module_1/Topic_4/Topic_4_diodes.htm

- Notice that voltage must exceed 0.7 volts before the silicon diode will conduct; this voltage is called the barrier potential or barrier voltage. This creates a 0.7 voltage drop across the silicon diode and the energy lost due to this voltage drop is in the form of heat. The barrier voltage for a germanium diode is 0.3V.
- Also note that the diode will conduct if the voltage polarity is reversed and the reverse bias exceeds the breakdown voltage.
- See applet: <http://www.falstad.com/circuit/e-diodevar.html>
- Forward Biased: In Figure 3, once a small potential (approximately 0.7 V) is overcome in the diode, current will flow through the diode. This drawing is for illustration purposes only; a load must be in the circuit for a forward biased diode otherwise it may be considered a short circuit. Remember that the direction of electron flow is opposite that of conventional flow.

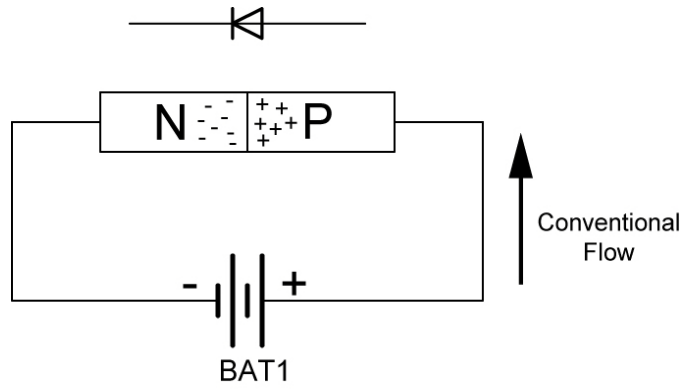


Figure 3 Forward Biased Diode

- Reversed Biased: Current will not flow through the diode until it is raised past to the breakdown voltage.

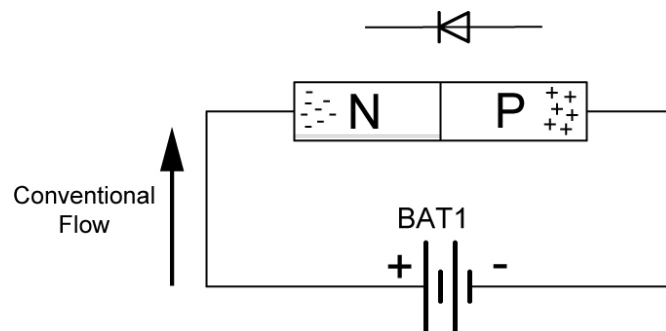


Figure 4 Reversed Biased Diode

- Voltage Dropper:
 - Since a diode typically has a 0.7 V drop, it may be used as a voltage dropper.
 - Perform Diodes, Power Supplies, Voltage Regulators Lab 1 – Voltage Dropper

○ **Power Supplies:**

- Power supplies convert ac power into dc power where it is required in an electronic circuit.
- Components of a power supply:

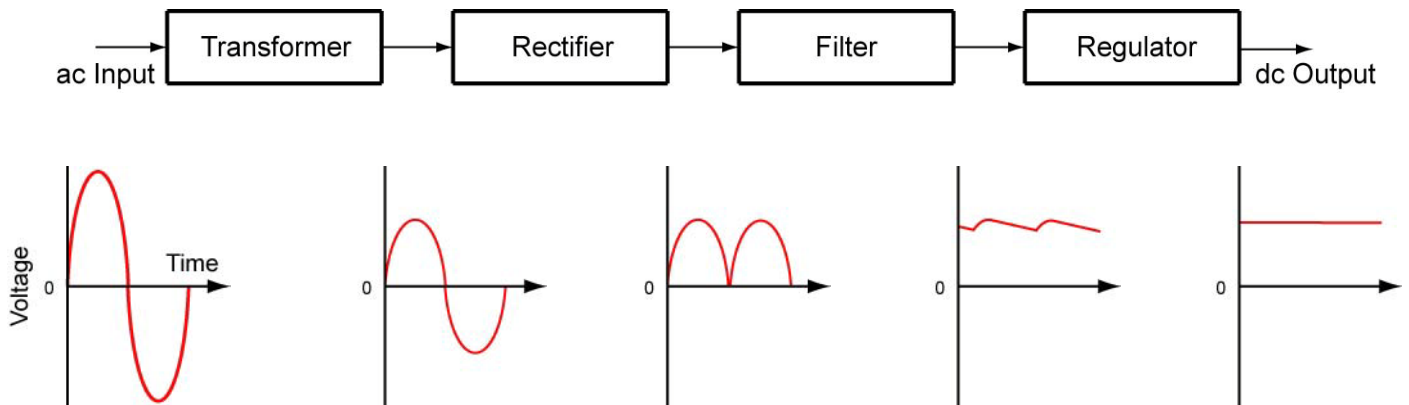


Figure 5 Power Supply Block Diagram with Input and Output Waveforms for Each Stage

- Transformer: Increases or decreases the ac line voltage to a desired value. In our example, the ac line voltage is decreased.
- Rectifier: Converts input ac voltage from the transformer into pulsating dc voltage.
- Filter: Smooths out the pulsating dc voltage.
- Regulator: Maintains a constant output dc voltage when the input ac voltage fluctuates or the load current changes.

- **Rectifiers:**

- Definition: Rectification is the process of converting alternating current to pulsating direct current.
- Half-Wave Rectifier:
 - A half-wave rectifier is a simple circuit where ac is applied to a diode and a resistor connected in series such that current flows through the resistor only when the diode is forward biased.
 - A half-wave rectifier is a rectifier that yields dc output only during the positive half-cycle of the ac input.
 - Operation:

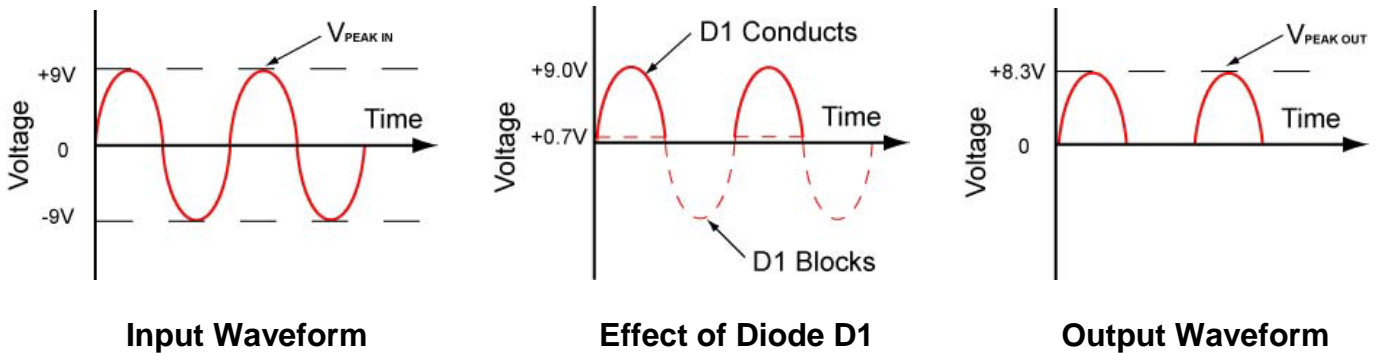
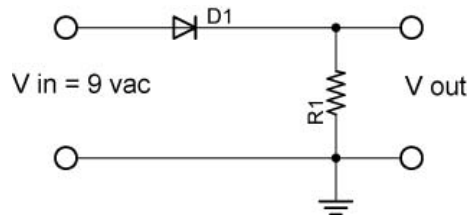


Figure 6 Input and Output Waveforms of a Half-wave Rectifier

- When the ac input voltage is between 0 and 0.7 V, the diode is forward-biased but the diode only conducts a minute current through the load resistor.
- When the ac input voltage is greater than 0.7 V, the diode is forward-biased and conducts usable current through the load resistor.
- When the ac input voltage is 0 V or less, the diode is reversed-biased and will block current through the load resistor.
- During the positive portion of the cycle, there is a 0.7 V to 0.7 V drop across the diode so:

$$\begin{aligned}
 V_{\text{peak out}} &= V_{\text{peak in}} - 0.7 \text{ V} \\
 V_{\text{peak out}} &= 9 \text{ v} - 0.7 \text{ V} \\
 V_{\text{peak out}} &= 8.3 \text{ V}
 \end{aligned}$$

- See applet: <http://www.falstad.com/circuit/e-rectify.html>

- Perform Diodes, Power Supplies, Voltage Regulators Lab 2 – Half-Wave Rectifier
- Full-Wave Rectifiers:
 - A full-wave rectifier is a rectifier that yields dc output during both the positive and negative half-cycles of the ac input.
 - Types:
 - Center-tapped rectifier: A rectifier that uses the center-tap of a transformer to produce full-wave rectification. This topic will not be covered in this lesson.
 - Bridge rectifier: A rectifier that uses four diodes in series-parallel to produce full-wave rectification.
 - Bridge Rectifier Schematic:

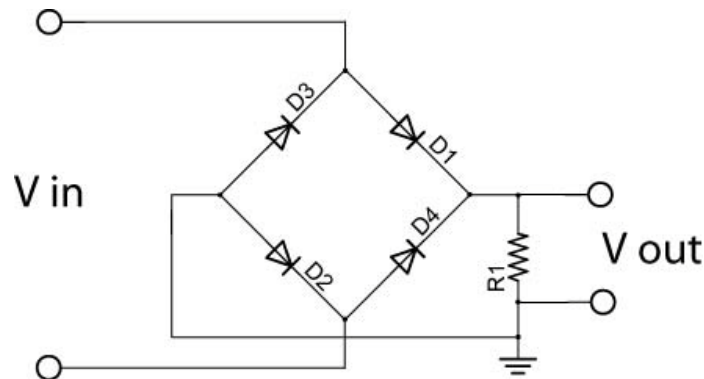


Figure 7 Full-Wave Bridge Rectifier

- How a full-wave bridge rectifier works:
 - Review Figures 8 – 11. Notice that two diodes D1 and D2 are forward biased during the positive half-cycle of the input ac voltage and the other two diodes D3 and D4 are forward biased during the negative half-cycle of the input ac voltage. Thus the full-wave bridge rectifier produces dc output during both the positive and negative half-cycles of the ac input waveform.
- See applet:
 - <http://www.falstad.com/circuit/e-fullrect.html>
- During the cycle, the voltage must pass through two diodes, therefore there is a 1.4 V (2 x 0.7 V) voltage drop across the diode.

$$\begin{aligned}
 P_{\text{peak out}} &= P_{\text{peak in}} - 1.4 \text{ V} \\
 P_{\text{peak out}} &= 9 \text{ v} - 1.4 \text{ V} \\
 P_{\text{peak out}} &= 7.6 \text{ V}
 \end{aligned}$$

- Perform Diodes, Power Supplies, Voltage Regulators Lab 3 – Full-Wave Bridge Rectifier

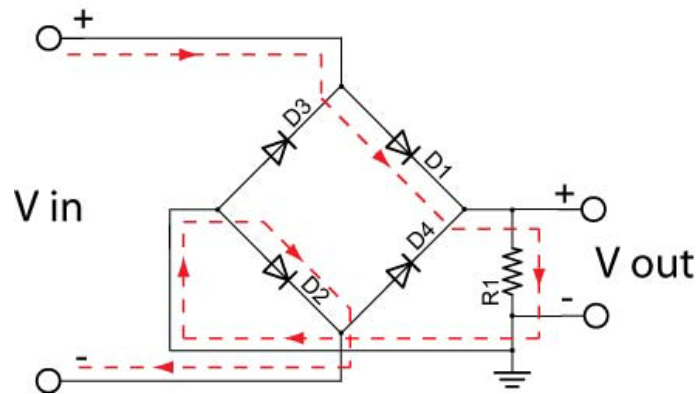


Figure 8, Conductive Diodes during the Positive Half-Cycle

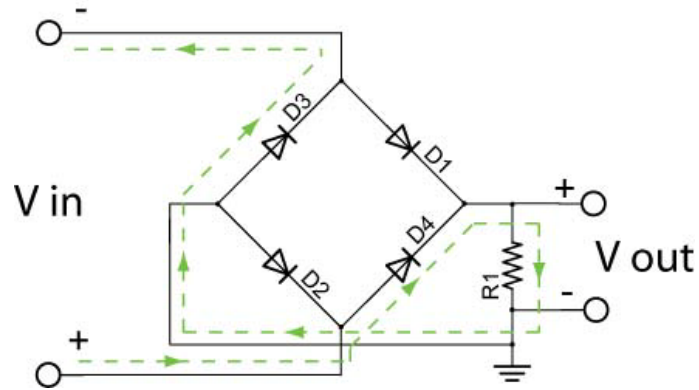


Figure 9, Conductive Diodes during the Negative Half-Cycle

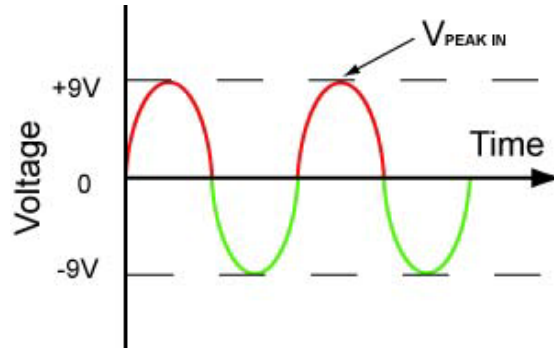


Figure 10, Full-Wave Bridge Rectifier AC Input

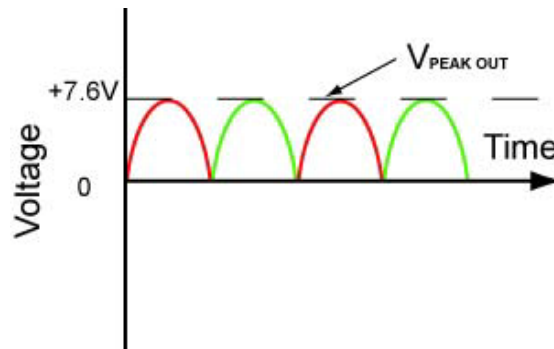


Figure 11, Full-Wave Bridge Rectifier Pulsating DC Output

- Capacitive Filter:
 - A capacitive filter is a capacitor that is added to a rectifier circuit to smooth out the pulsating dc output.
 - Schematic of Capacitive Filter in a Half-Wave Rectifier:

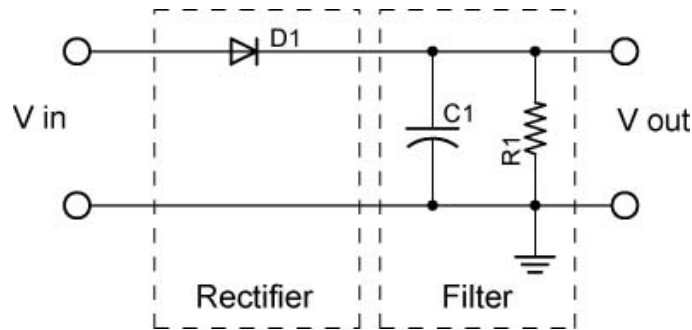


Figure 12 Half-Wave Rectifier with a Capacitive Filter

- A capacitive filter works by charging the capacitor $C1$ when the voltage applied to the capacitor is higher than the voltage stored in the capacitor and discharging the capacitor $C1$ when the voltage applied to the capacitor falls below the voltage stored in the capacitor. See Figure 13. The action of the capacitor smooths out the valleys of the filter input waveform.
- In most rectifiers, the value of the filter capacitor is between 470 μF and 2200 μF .

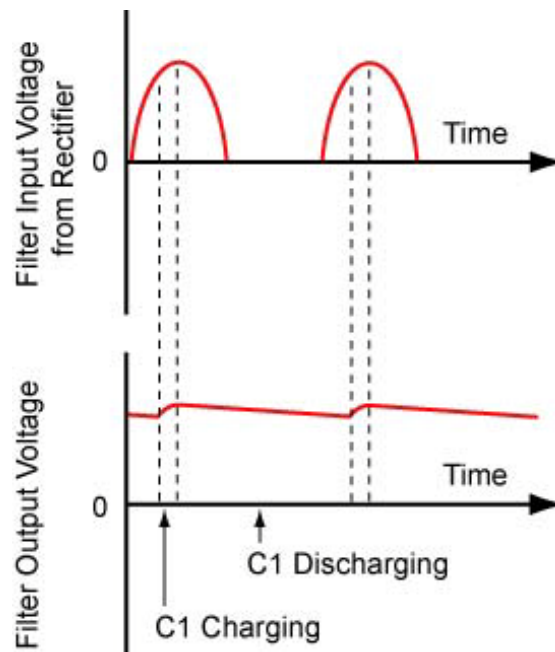


Figure 13 Input and Output Waveforms of a Capacitive Filter on a Half-Wave Rectifier

- See applet: <http://www.falstad.com/circuit/e-fullrectf.html>
- Perform Diodes, Power Supplies, Voltage Regulators Lab 4 – Capacitive Filter

- Voltage Regulators:
 - A voltage regulator provides a constant dc output voltage that is nearly independent of the input voltage, output load current, and temperature.
 - The 7800 series voltage regulators are integrated circuits (IC) that provide a positive voltage output. The 7900 series supplies a negative voltage output.
 - The supply voltage to a voltage regulator must be 2 - 3 volts above the regulator rating. For example, a 78L05 must have at least 7 to 8 volts as a supply to work properly.
 - 7800 Series Chart:

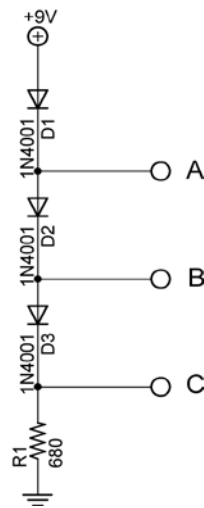
7800 Series Voltage Regulators	
Type Number	Output Voltage
7833	+3.3 V
7805	+5.0 V
7806	+6.0 V
7808	+8.0 V
7809	+9.0 V
7810	+10.0 V
7812	+12.0 V
7815	+15.0 V
7818	+18.0 V
7820	+20.0 V
7824	+24.0 V

Table 1 7800 Series Voltage Regulators

- Perform Diodes, Power Supplies, Voltage Regulators Lab 5 – Voltage Regulators.
 - Perform Diodes, Power Supplies, Voltage Regulators Lab 6 – Voltage Regulators with Two Output Voltages.
- **Continue Working on Robotic Car**

Cornerstone Electronics Technology and Robotics II
Diodes, Power Supplies, Voltage Regulators
Lab 1 – Voltage Dropper

- **Purpose:** The purpose of this lab is to demonstrate that how a diode may be used as a voltage dropper.
- **Apparatus and Materials:**
 - 1 – Solderless Breadboard with 9 V Power Supply
 - 1 – Digital Multimeter
 - 3 – 1N4001 Diodes
 - 1 – 680 Ω Resistor
- **Procedure:**
 - Since a diode typically has a 0.7 V drop, it may be used to drop a voltage.
 - Build the following circuit:



Voltage Dropper

- Measure the voltages at points A, B, and C with respect to ground and record your results.
- Measure the voltage drop across each 1N4001 diode and record your results.
- **Results:**
 - V_A , V_B , and V_C :

Point	Voltage (V)
A	
B	
C	

- Voltage across 1N4001:

Voltage Drop across 1N4001	
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Cornerstone Electronics Technology and Robotics II
Diodes, Power Supplies, Voltage Regulators
Lab 2 – Half-Wave Rectifier

- **Purpose:** The purpose of this lab is for the student to see the input and output waveforms when ac is applied to a half-wave rectifier.

- **Apparatus and Materials:**

- 1 – Solderless Breadboard with 9 VAC Power Supply
- 1 – Oscilloscope
- 1 – 1K Ω Resistor
- 1 – 1N4001 Diode

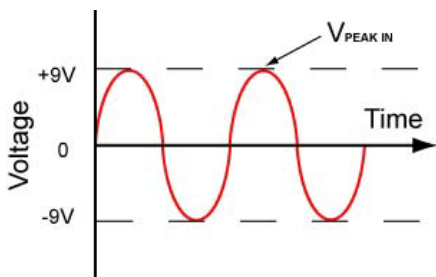
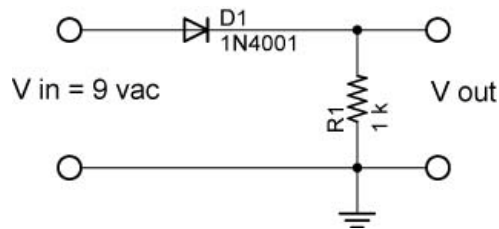
- **Procedure:**

- Build the half-wave rectifier circuit below:
 - Connect Channel 1 of the oscilloscope across the input and Channel 2 across the output load resistor, R1.
 - Use a 9 V, 500 mA transformer as your ac source. Set the oscilloscope to dc operation.
 - Observe:
 - Input sinusoid wave form on Channel 1
 - The output half-wave rectified waveform on Channel 2
 - Notice that the peak of the half-wave output is about 0.7 V lower than the peak of the input sinusoid.

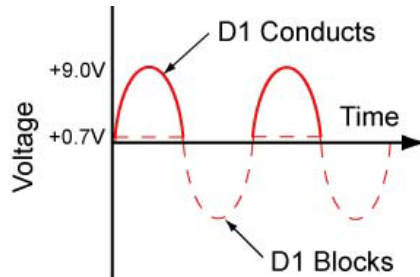
$$V_{\text{peak out}} = V_{\text{peak in}} - 0.7 \text{ V}$$

$$V_{\text{peak out}} = 9 \text{ v} - 0.7 \text{ V}$$

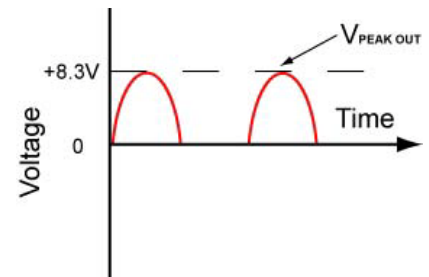
$$V_{\text{peak out}} = 8.3 \text{ V}$$



Input Waveform



Effect of Diode D1

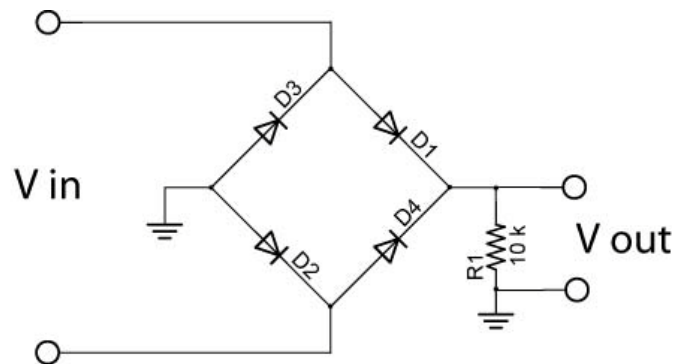


Output Waveform

Cornerstone Electronics Technology and Robotics II
Diodes, Power Supplies, Voltage Regulators
Lab 3 – Full-Wave Bridge Rectifier

- **Purpose:** The purpose of this lab is for the student to observe the input and output waveforms when ac is applied to a full-wave bridge rectifier.
- **Apparatus and Materials:**
 - 1 – Solderless Breadboard with 9 VAC Power Supply
 - 1 – Oscilloscope
 - 1 – 10K Ω Resistor
 - 4 – 1N4001 Diodes
- **Procedure:**
 - Build the full-wave bridge rectifier circuit below.
 - Connect the oscilloscope Channel 1 to the input and Channel 2 to the output:
 - Observe:
 - Input sinusoid waveform on Channel 1
 - The output full-wave rectified waveform on Channel 2
 - Notice that the peak of the full-wave output is about 1.4 V less than the peak of the ac input sinusoid.

$$\begin{aligned}V_{\text{peak out}} &= V_{\text{peak in}} - 1.4 \text{ V} \\V_{\text{peak out}} &= 9 \text{ v} - 1.4 \text{ V} \\V_{\text{peak out}} &= 7.6 \text{ V}\end{aligned}$$

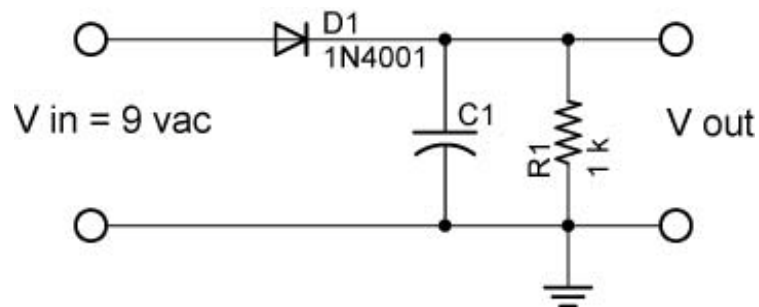


Note: All diodes are 1N4001

Full-Wave Bridge Rectifier

Cornerstone Electronics Technology and Robotics II
Diodes, Power Supplies, Voltage Regulators
Lab 4 – Capacitive Filter

- **Purpose:** The purpose of this lab is for the student to observe the input and output waveforms when ac is applied to a full-wave bridge rectifier.
- **Apparatus and Materials:**
 - 1 – Solderless Breadboard with 9 VAC Power Supply
 - Safety Goggles
 - 1 – Oscilloscope
 - 1 – 1K Ω Resistor
 - 1 – 1N4001 Diode
 - 1 – 10 μ F Capacitor
 - 1 – 100 μ F Capacitor
 - 1 – 1000 μ F Capacitor
- **Procedure:**
 - Build the half-wave rectifier with a capacitive filter circuit below.
 - Be certain that the capacitor is installed with the proper polarity.
 - Connect the oscilloscope Channel 1 to the input and Channel 2 to the output:
 - Use a 10 μ F, a 100 μ F, and then a 1000 μ F capacitor for filter capacitor, C1.
 - Note the changes in the output waveform across the load resistor R1 as the value of C1 increases.



Cornerstone Electronics Technology and Robotics II
Diodes, Power Supplies, Voltage Regulators
Lab 5 – Voltage Regulators

- **Purpose:** The purpose of this lab is for the student to verify that the input voltage into a voltage regulator must be 2 – 3 volts above its rating.
- **Apparatus and Materials:**
 - 1 – Solderless Breadboard with 9 VDC Power Supply
 - 2 – Digital Multimeters
 - 1 – 78L05 Voltage Regulator
 - 1 – 0.1 uF Capacitor
 - 1 – 10K Potentiometer
- **Procedure:**
 - Wire the following voltage regulator circuit:
 - The capacitor acts as a surge suppressor. When a heavy load is connected to the voltage source, there may be a mild power spike to your circuit. The voltage regulator will suppress most of this power spike and the capacitor helps suppress it even more.
 - Use two DMMs to measure the input and output voltages of the voltage regulator.
 - Change input voltages and record the output voltages

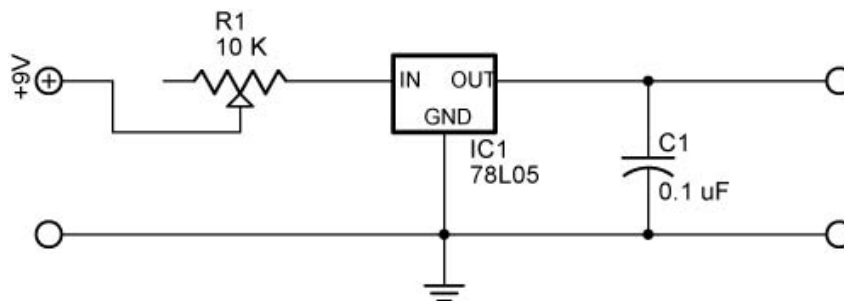


Figure 12, Voltage Regulator Circuit

• **Results:**

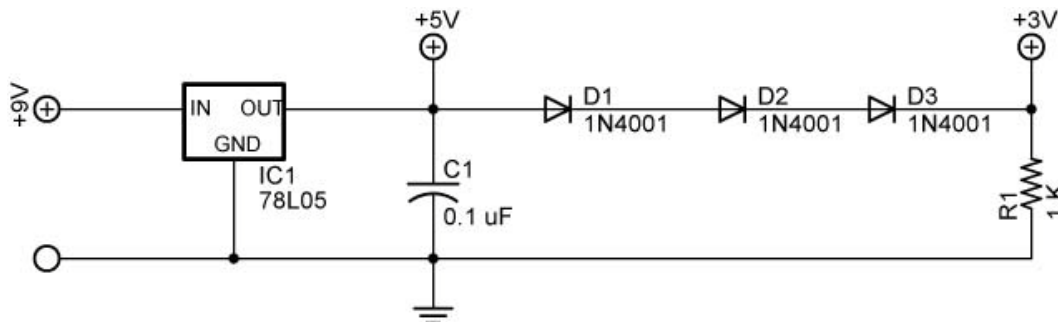
V_{in}	V_{out}
9.0 V	
8.5 V	
8.0 V	
7.5 V	
7.0 V	
6.5 V	
6.0 V	
5.5 V	
5.0 V	

• **Conclusions:**

- At what input voltage did the voltage regulator stop working properly?

Cornerstone Electronics Technology and Robotics II
Diodes, Power Supplies, Voltage Regulators
Lab 6– Voltage Regulator with Two Output Voltages

- **Purpose:** The purpose of this lab is to demonstrate that diodes may be used to drop output voltages in a voltage regulator circuit.
- **Apparatus and Materials:**
 - 1 – Solderless Breadboard with 9 VAC Power Supply
 - 1 – Digital Multimeter
 - 1 – 78L05 Voltage Regulator
 - 1 – 0.1 uF Capacitor
 - 1 – 10K Potentiometer
 - 3 – 1N4001 Diodes
- **Procedure:**
 - Wire the following voltage regulator circuit and verify the +5V and +3V output voltages:
 - Diodes D1, D2, and D3 have a voltage drop of approximately 0.7 V each.



Voltage Regulator with Two Voltage Outputs

- **Results:**

Nominal Value	Measured Value
+5V	
+3V	