Lab 6: Diodes (version 1.6)

WARNING: Use electrical test equipment with care! Always double-check connections before applying power. Look for short circuits, which can quickly destroy expensive equipment.

Summary
Investigation/study of the working principle of diodes and their use in rectifiers.

Learning Outcomes
• Understand the basics of a diode; AC rectification; and filtering.

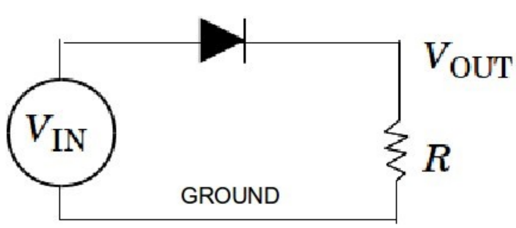
Lab Goals
Measure the current vs voltage relationship of a diode. Build a half wave rectifier with low-pass filtering. Build a full wave rectifier. Analyze the results.

Equipment needed:
DC Power Supply
Digital oscilloscope
Function generator
Circuit breadboard and components/cables/probes: Diodes, Resistors, and Capacitors.

Experiment/Procedure
In this Lab, we will investigate the working principle of diodes, study the relation of current through the diode vs applied voltage, and their use to build rectifiers to convert AC to DC voltages.

Input-output relationship of a diode
An ideal diode will perfectly conduct current when voltage is applied in one direction and completely block it the voltage is reversed. On the other hand, real diodes have non-ideal characteristics caused by their physical properties. These characteristics can be investigated from the dependence of the output current (I) vs the applied voltage (V) to a diode.

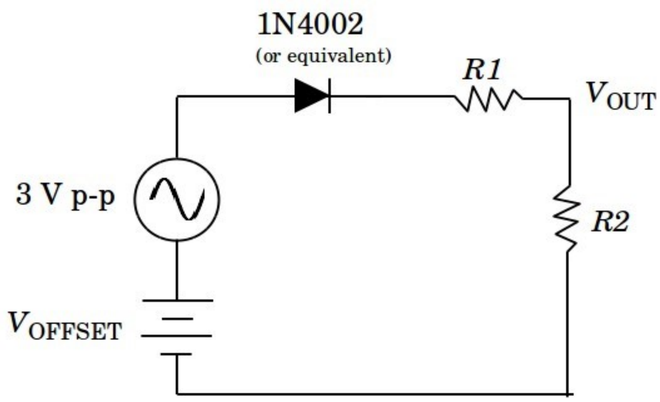
Construct the following circuit with a 1N4002 or equivalent diode. In the circuit below, the cathode of the diode is connected to R = 10 kΩ. The value of this "Limiting Resistor" is not critical, but it is critical to have it. This resistor limits the current that flows through the circuit. Measure the values of the components before you assemble any circuit. (**Note**: Unlike resistors and most capacitors, diodes cannot be placed into a circuit arbitrarily. Semiconductor diodes will be marked with an obvious band placed near the cathode.)



Apply V_{IN} with an adjustable DC power supply and measure I across R with a multimeter vs V_{IN} from -2 V to 2 V. Plot the current I through the diode vs V relation to investigate the diode properties. You should see an obvious threshold voltage where the diode turns on, which is important interpret the following experiments.

Half-wave rectifier

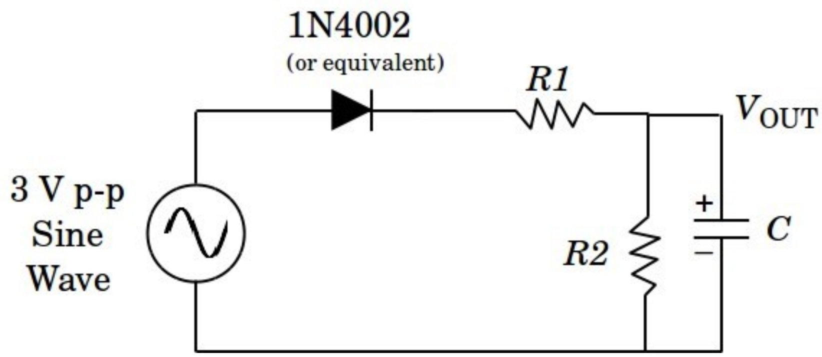
We will attempt to generate a DC signal from a sinusoidal AC signal by combining the diode-based rectifier with a low-pass filter. Change the circuit to add a second 10 kΩ resistor (see below). The output is read across R_2. The sinusoidal wave and DC offset can be generated by the function generator as $V(t) = (Vpp/2)*\sin(f\,t) + V_{OFFSET}$. Set the offset voltage to zero and confirm half-wave rectification. Increase V_{OFFSET} until rectification disappears. Report your observations (pictures/drawings & plots) and explain the operation in your lab notebook.



Half-wave rectifier with filter

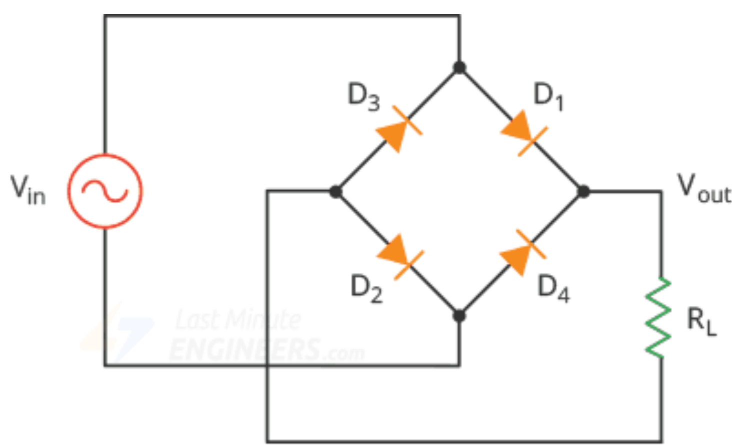
A capacitor (with the correct polarity) placed across the output of the rectifier can be used to damp time-dependent voltage fluctuations. This is because a capacitor has an infinite impedance to DC (ω=0) and decreasing impedance as the frequency increases ($Z_C = 1/j\omega C$).

Modify your circuit to add a capacitor **with the correct polarity** as shown below. Using an AC Vin with frequency ~1 kHz, study filtering action of the capacitor as it is changed. The filtering action of the capacitor can be characterized in terms of the observed ripple of the rectified signal (we define ripple as the maximum percentage voltage drop from the peak that occurs each period.) Set the offset to zero and determine a capacitor(s) value that gives ~25% and ~10% ripple. Report and discuss in your lab notebook.



Full wave rectifier with filter

Build the full-wave rectifier shown below. Input a sinusoidal AC signal in Vin and study the output V_{out} as a function of V_{in}. VOUT is the voltage across R_L. Record the results and discuss your observations in the lab book: what do you observe? Why do you observe this? how this circuit works to provide this observed V_{out}? Note that since the oscilloscope ground leads are grounded, to measure the voltage V_{OUT} across R_L you will have to make two measurements, each one at each side of R_L, and have the scope show the difference in voltage.



Analysis.

The required elements of the analysis for the different circuits are already discussed in each part. Below are some pointers to the analysis to be realized.

For the diode:

Plot the I-V plot. Discuss the observations and characterize the diode in terms of the diode parameters (current, threshold voltage, etc.), and dependence of current with respect to voltage. Compare your observations with different models of the diode (e.g. Shockley diode model, linearized model, ideal model) by plotting the expected behavior together with your data.

Half wave rectified:
Report on your observations and your findings. Discuss and analyze your measurements for the filtering action of the capacitor, and the ripple to quantify the amount of filtering. Discuss and analyze your observations with different $V_{offsets}$.

Full wave rectifier:
Report the results on your lab work and discuss the realization of your circuit. Discuss how your circuit works to provide full amplification. Discuss your measurements and observations.