MAE 60 Lab Project 6: Half-wave rectifier and Diode clipper

This lab session consists of two different parts dealing with applications of diodes. In Part 1, you will build a half-wave rectifier, and in Part 2, you will build a diode clipper.

As usual, each part will have 2 sections, one in TinkerCAD in which you will only wire the circuit and take a snapshot to add to the report, and one in Multisim Live in which you will make all the necessary measurements and export the data for postprocessing results to be included in the report.

> Questions to be presented in the lab report are found in blue boxes throughout this handout.

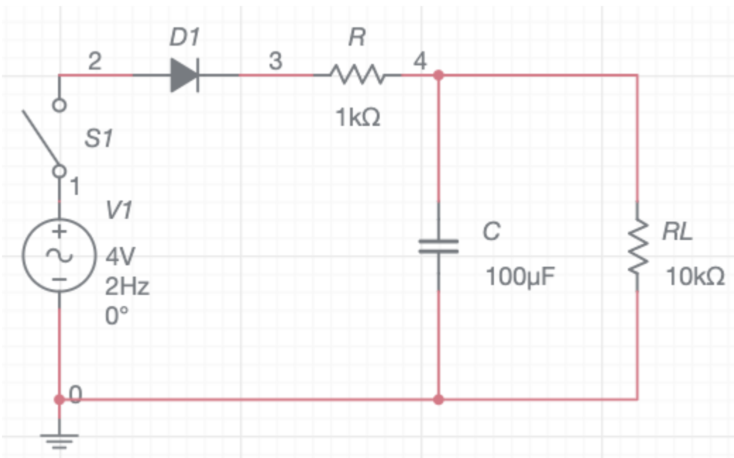
Part 1: Half-wave rectifier

When analyzing the half-wave rectifier circuit in class, we saw that, depending on capacitance, load resistance, and input resistance, the capacitor's charge asymptotically reaches a steady state value, and the voltage across the load exhibits a predictable ripple.

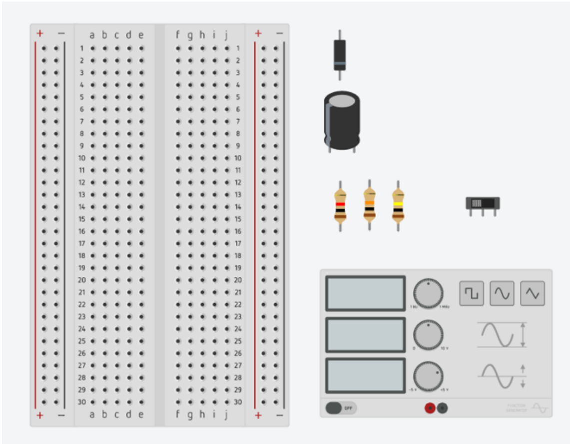
The goal of this experiment is to implement the circuit described in class with simulation software and characterize the behavior of the circuit for different values of the circuit parameters.

TinkerCAD

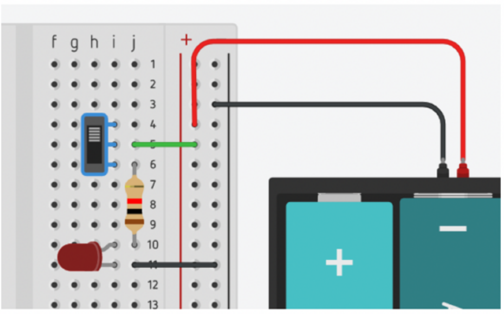
1. Build the following circuit:

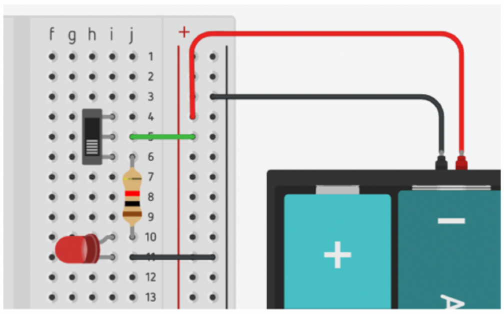


2. Copy the circuit materials that you need for this experiment from the link on Canvas: a breadboard, 3 resistors (1kΩ, 10kΩ, 100kΩ), a capacitor (100μF), a diode, a switch and a function generator. Wire it.



3. Make sure to connect the diode with the right orientation: the diode's perpendicular line in the schematic corresponds to the horizontal gray line in TinkerCAD element.
4. The capacitor is polarized, so make sure to orient it correctly: the pin on the side with a gray line must be connected to the lower potential node.
5. A switch has three ports: Terminal 1, Common and Terminal 2. It connects Common to either Terminal 1 or 2. See the example below: connect Common to node 5, Terminal 1 to node 6, and Terminal 2 unconnected from the rest of your circuit, to node 4. See how the LED illuminates when the switch connects nodes 5 and 6.

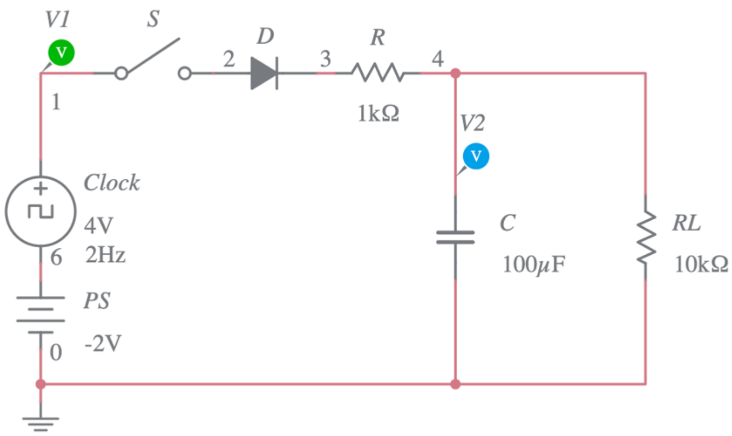




1. Once your circuit is wired, take a snapshot and add it to the lab report.

Multisim Live

1. Build the circuit in the schematic below. Note that in this case, we are using a combination of clock and (negative) power supply to generate a square wave, with 4V peak to peak (-2V to 2V) and a frequency of 2Hz.
   In the TinkerCAD setup you would only need to change the function generator from sinusoidal to square.



2. Set probes at nodes 1 and 4 (V1 and V2) to record data at those points.
3. With the switch closed, start the simulation. Observe (in Grapher tab) the evolution of V1 and V2. You should see how it takes a few seconds for the capacitor to reach its final potential. The ripple of V2 should be obvious (the ripple is the difference between the maximum and the minimum of the output signal, once it reaches a steady, periodic state).
4. Open the switch and observe how V2 decays slowly. Stop recording once V2 has reached an asymptotic value, close to zero.
5. Export the data for postprocessing and repeat the simulation using 100kΩ for RL.

2. Plot V1 and V2 for both values of the RL resistor. Describe the initial charging of the capacitor, the ripple voltage and the exponential decay.

3. For RL = 10kΩ, measure the voltage of the capacitor at one half of the period (take the origin as the time at the start of first positive swing of the input signal; it is usually zero because it is a simulation).

4. Find an analytical expression for V2 that is valid during the first period of the input voltage signal. Compare the analytical value for V2 at one half of the period with your measurement in 3.

5. Calculate the voltage ripple for both values of RL from your measurements.

Part 2: Diode clipper

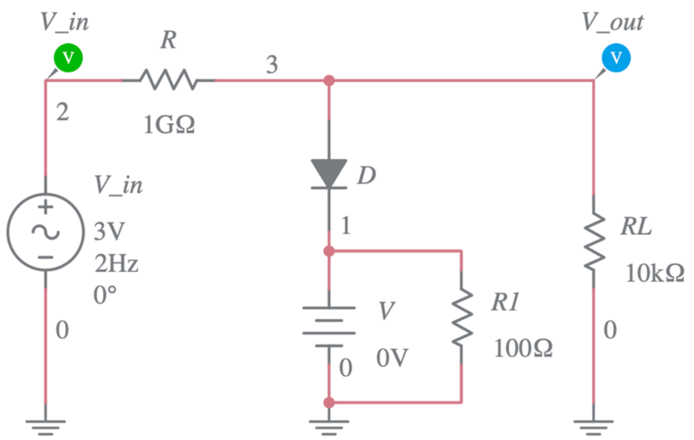
In this experiment you need to design a diode clipper that keeps its output voltage below a given maximum (2 Volts).

The input signal must be a sinusoid with a period of 0.5 s, an amplitude of 3 V, and zero offset. The load of the circuit is 10 kΩ. When you are using Multisim, you need to choose a resistor R (**1GΩ is a placeholder**) and a value V (using the adjustable voltage source) so that V_out does not exceed 2 Volts, and otherwise follows V_in as closely as possible. For now, place any resistor you want.

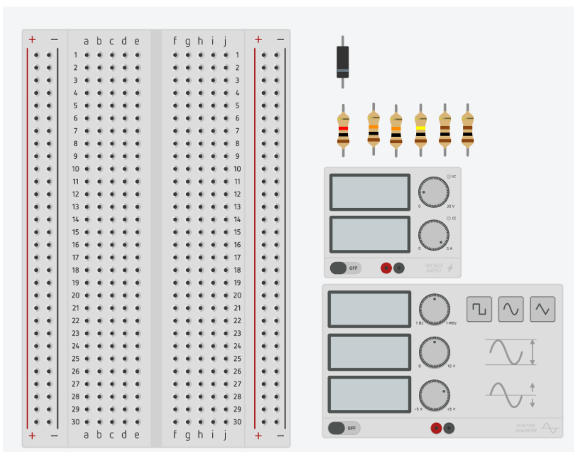
Note: the 100 Ω resistor across the adjustable source is not part of the standard diode clipper circuit; this resistor is needed for the particular voltage source used in the lab, which is designed to source positive current (instead of sink current). The resistor eliminates this problem.

TinkerCAD

1. Build the following circuit:



2. Copy the circuit materials that you need for this experiment from the link on Canvas: a breadboard, 6 resistors (two 100Ω, 1kΩ, two 10kΩ, 100kΩ), a diode, a power supply and a function generator. Wire it. Use Any value for R.



3. Make sure to orient the diode correctly: the perpendicular line of the diode in the schematic corresponds to the gray line in TinkerCAD element.

6. Once your circuit is wired, take a snapshot and add it to the lab report.

Multisim Live

1. Build the circuit in the schematic.
2. Set probes at nodes 2 and 3 (V_in and V_out) to visualize and record data at those points.
3. Play with values for the resistor R and set the voltage of the power supply so that you see V_out does not surpass 2V, but still follows V_in everywhere else (i.e., you see a 3V amplitude sine wave with the top chopped at 2V).

7. Derive an expression for the signal V_out as a function of V_in.

8. Provide the values of R and V that were chosen.

9. Plot V_in(t) and V_out(t) in the same graph.

Checklist for report plots

Effective plots, graphs, and figures should be included in your reports. For MAE 60 lab reports, plots must have:

- A title descriptive of what data is represented.
- Labeled axes with appropriate magnitude and units (e.g., 1.2 μs or $1.2 \cdot 10^{-6}$s instead of 0.0000012s).
- Axis limits set to proper visualization of the plot. Do not cut off the top/bottom of the signal or have much empty space at the top/bottom of the plot.
- A legend to distinguish between datasets (whenever 2 or more datasets are plotted).
- Colors that make visualization easy. Do not use dark backgrounds or shiny colors for data points over a white background.

Check Canvas for examples of best practices.