Lab 4: Diodes and Transistors

Physics 327

Spring 2025

Goals

Work with two semiconductor devices — diodes and transistors — by constructing two circuits related to power supplies: a rectifier circuit and a voltage and current source.

Pre-Laboratory Exercises

To prepare for this laboratory:

1. Read about solid state electronics in Part 6 of the textbook, rectifiers on page 325, and the chapter on transformers.
2. Construct the circuit shown in Figure 1a in a SPICE simulation program such as `LTspice`.[1] Complete the measurements described in Section A Part 1 using the simulation and include the results in your report.
3. Construct a SPICE simulation of the circuit shown in Figure 2a, choosing the 2N3904 transistor. Follow the steps in Section B Part 1.2 to calculate the output impedance, and report your findings in the lab report.

Note: This lab involves several measurements and new components. Be sure to thoroughly read this manual and complete the simulations prior to your lab meeting.

A Diodes

Diodes have the useful property of allowing current to flow in only one direction. This can be used to change an AC voltage into DC, as in these two *rectifier* circuits.

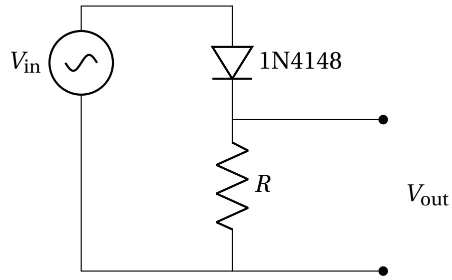
Part 1 Half-wave Rectifier

A half-wave rectifier circuit is shown in Figure 1a. Construct this circuit *in a SPICE simulation only*, as part of the pre-lab exercises, and include your results in your report. You do not need to build this circuit on a breadboard, but are welcome to do so if you have extra time.

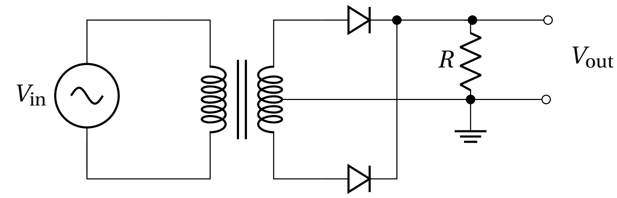
For the simulation, use $R = 1$ kΩ and a **1N4148** diode. The datasheet for the 1N4148 is available on Canvas in the Datasheets folder. Use a sine wave voltage with a 1 kHz frequency as the voltage source. Adjust the input signal amplitude between 0.25 and 4 V_p (0.5 to 8 V_{pp}) and measure V_{out}, taking several data points below 2 V_p. Include a picture or drawing of a complete period of the output waveform as a function of time.

Question 1: How is the output signal related to the input?

[1] Place a generic diode, then right click and choose "Pick New Diode" to select the 1N4148.



(a) Half-wave rectifier.



(b) Full-wave rectifier. Note that the transformer midtap is *not* connected to the wire between the two diode terminals.

Figure 1: Rectifier schematics.

Part 2 Full-wave rectifier

Next, consider the full-wave rectifier circuit shown in Figure 1b, which uses two 1N4148 diodes and a TC016 transformer. This is a symmetric transformer, where the impedance of the primary is equal to the impedance of the secondary winding. It also has a center tap, which is a line connected to the center of the coil.

First, characterize the transformer with an AC V_{in} by measuring voltages of various taps with a AC voltmeter and comparing the (rms) voltage of the input and output. Note your observations in the report.

Construct the circuit, using $R = 20$ kΩ, and again use a sine wave input with a frequency of 1 kHz. Describe the output and include a picture or drawing of a complete period of the output waveform.

Next, add a 5000 pF capacitor in parallel with the resistor, and note the effect. Repeat this with a 0.1 μF capacitor. In your lab report, estimate the size of capacitor needed to keep the variation in the output voltage around the average value below 1%.

B Transistors

Transistors are among the most important components in modern electronics. Complex integrated circuits are composed of thousands, or even billions, of miniaturized transistors. Here, you will construct two circuits using single transistors to understand these important devices.

Part 1 Voltage Source

Transistors can transform a poor voltage source into a relatively good one — much better than the voltage dividers you explored in Lab 1, which will serve as a starting point.

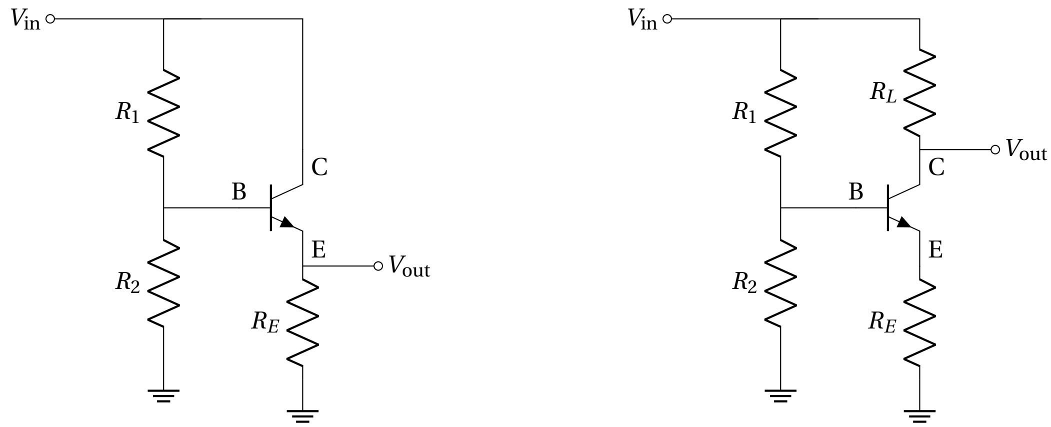
Part 1.1 DC Voltage Divider

First, set up a voltage divider with $R_1 = R_2 = 1$ kΩ and a DC input voltage of +12 V. Measure the input voltage and the voltage across R_2, V_{out}. Now, add a 510 Ω load resistor in parallel with R_2 and again measure the voltages. Plot the output voltage as a function of load resistor current. The relationship is linear, so these two points are sufficient to measure the slope. Once you have finished these measurements, remove the 510 Ω resistor.

> **Question 2:** What is the output impedance of the voltage divider, given by the slope $-dV_{\text{out}}/dI_{\text{out}}$?

Part 1.2 Transistor Voltage Source

Build the circuit shown in Figure 2a by connecting the node between R_1 and R_2 to the base of the **2N3904** npn transistor. Use $R_1 = R_2 = R_E = 1$ kΩ and $V_{\text{in}} = 12$ V DC. Measure the output voltage V_{out} across R_E.



(a) Transistor voltage source. (b) Transistor current source.

Figure 2: Transistor circuit schematics.

Next, add a 510 Ω load resistor in parallel with R_E and again measure the output voltage. Plot V_{out} vs. I_{out} on the same graph as the voltage divider (Part 1.1), again connecting the two data points. Explain your observations in the lab report, and compare to your findings from the simulation.

Question 3: Calculate the output impedance of the circuit, from the slope $-dV_{out}/dI_{out}$.

Part 2 Current Source

Finally, construct the *current source* circuit shown in Figure 2b, keeping the resistors and V_{in} the same as in the previous step. For the load resistance R_L, use values of 510, 1000, 2000, 2700, and 5400 Ω. Note that Figure 2a corresponds to $R_L = 0$ Ω. In each case, measure V_{out} and estimate the current I_L through R_L, and also directly measure this current using an ammeter. Plot the measured and estimated I_L vs. R_L.

Question 4: Explain your measurements. Why does the current through the load resistor depend on R_L the way it does?