Diodes

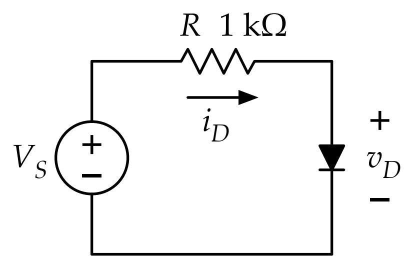
This week, we look at switching diodes, LEDs, and diode rectification. Be sure to bring a flash drive for recording oscilloscope traces.

1. Basic diode characteristics

Build the circuit shown in Fig. 1 using a 1N4006 diode from your kit. (Be sure to measure the resistor value beforehand.) Apply the various DC voltages for the source listed in the table below. For each source voltage, measure the corresponding diode voltage and resistor voltage. Calculate the diode current.

Use the collected data to make a graph of the diode *i-v* characteristics. (You might consider using Excel to help make the plot.)

Figure 1.



V_S (V)	v_R	v_D	i_D	V_S (V)	v_R	v_D	i_D
-10				+3			
-8				+4			
-6				+5			
-4				+6			
-2				+7			
0				+8			
+1				+9			
+2				+10			

2. Simple diode circuits

Calculate the expected resistor voltages and diode current for each of the circuits below, using the simple "on-off" model of the diode. Then build each of the circuits and measure the resistor voltages and currents. In your report, be sure to compare the measurements and calculations.

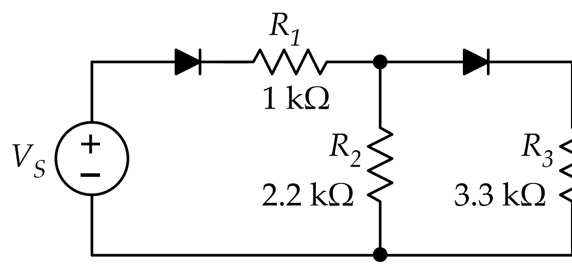


Figure 2. Do this first with V_S = + 1.0 V. Then repeat with V_S = +5 V.

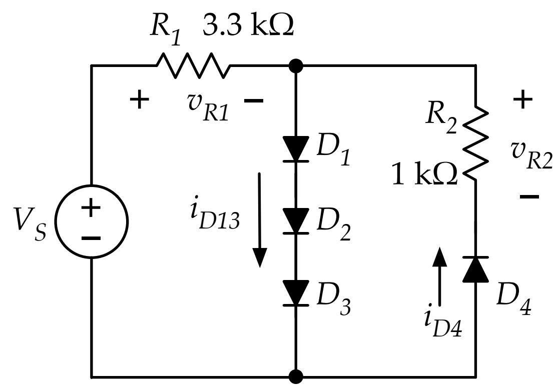


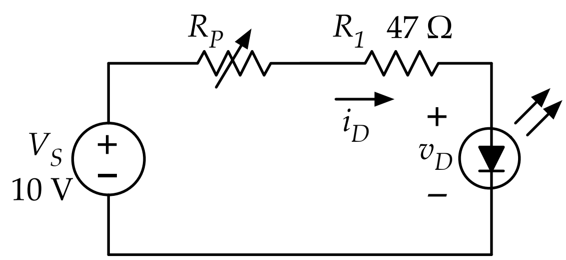
Figure 3. Do this first with V_S = + 10 V. Then repeat with V_S = –10 V.

3. Fun with light-emitting diodes

Build the circuit below using an LED. (Pick your favorite color.) R_p is a 1-kΩ potentiometer. R_1 is a "safety" resistor. Use the potentiometer to vary the diode current. Adjust the potentiometer through about 10 steps from the minimum setting to the maximum setting. (The steps don't have to be particularly well-defined.) At each step, measure the current (using R_1) and the diode voltage. Use your data to make a graph of the forward *i-v* characteristic of your LED. Note the change in the LED brightness as you change the current.

From your data, what would be a good "on" voltage to use for a simple "on-off" model of the LED? (Since the LED is not made with silicon, the "on" voltage is probably different that 0.7 V — most likely it is bigger.)

Figure 4. R_P is a 1-kΩ potentiometer.



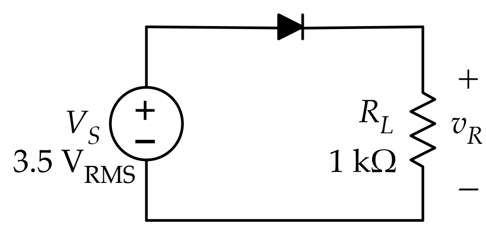
Replace the DC source with a square wave source, with the low-level value at 0 V and the high-level value at 10 V. Set the frequency at 1 Hz initially, so that the LED is clearly blinking on and off. Increase the frequency in 2-Hz steps. At what frequency can you no longer see that the LED is blinking?

Switch the function of the generator from square wave to pulse. Set the frequency at 200 Hz – fast enough so that you cannot see the switching. Vary the *duty cycle* of the pulse from 10% (high 10% of the time and low 90% of time) to 90% (high 90% of the time and low 10% of time) in 10% increments. (To change duty cycle, push the pulse parameter button and then choose "Duty" from the soft keys on the side.) As you change the duty cycle of the pulse, note qualitatively the apparent change in LED intensity as the duty is varied. This is known as *pulse width modulation* (PWM), and is another means for varying the average power being delivered to an electrical device. Congratulations — you have just made a modern light dimmer.

4. Rectifiers

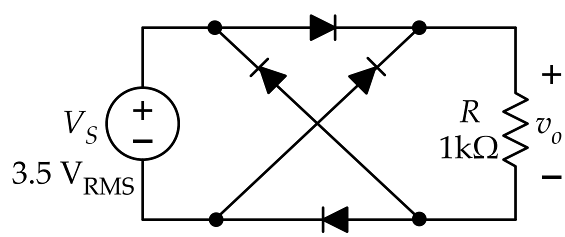
Build the simple single-diode rectifier circuit shown below. The source is the function generator set to a sinusoid with amplitude of 3.5 V_{RMS} (approximately 5 V peak) and frequency of 100 Hz. Use the oscilloscope to observe the source and the resistor voltages simultaneously. Record a clear trace that has at least two periods and clearly shows the rectification. Then zoom in on the area near where the diode turns on so that you can clearly see the slight time delay in the turn-on due to the offset voltage of the diode. Record this oscilloscope trace, also. Finally, switch the waveform type to square-wave and then triangle wave. (The amplitude and frequency can stay the same.) Note the changes in the resistor voltage.

Figure 5. Half-wave rectifier.



Now use four diodes to build the full-wave rectifier shown in Fig. 6. The source is the same as used for the half-wave rectifier (3.5 V_{RMS}, 100 Hz). Observe the resistor voltage using the oscilloscope. (Note that you cannot observe both the source and resistor voltages simultaneously because you cannot have a common ground for the two.) Record a clear trace of the full-wave rectified waveform for your report.

Figure 6. Full-wave rectifier.

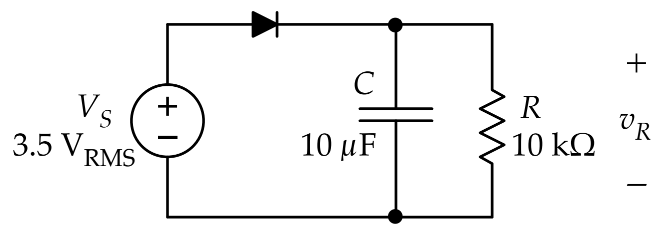


Now go back to the half-wave rectifier. Switch the resistor to a 10 kΩ. Make it into a peak rectifier by adding a 10-μF capacitor in parallel with the resistor, as shown in Fig. 7. (Be sure to insert the electrolytic capacitor with the correct polarity.) Observe and record the source and capacitor voltages together using the oscilloscope. The resistor voltage should flatten out to something approximating DC. Measure the DC value use the voltmeter. However, if you zoom in on the oscilloscope trace and look carefully, you will see that the DC is not perfectly flat, but "ripples" a little bit. From the oscilloscope trace, determine the extent of the ripple (difference between the peak voltage and the minimum voltage) of the output waveform.

Repeat the above measurements using resistor values of 4.7 kΩ and 22 kΩ. The changes in the resistor value cause both the DC value and the size of the ripple voltage to change.

For your report, calculate the expected ripple voltage for each of the three different load resistors.

Figure 7. Peak rectifier circuit.



Reporting

Prepare a report describing your measurements and results. Be sure to to include all your calculations, measurements, and oscilloscope traces, along with enough discussion to completely describe the work done in this lab. The report is due in one week at your next lab meeting.