

PHYS 1P92 Experiment 07

Electronics: Circuits and DC components

Notes

- Words in [blue](#) are links to additional reading or videos.
- Text in [gray](#) boxes are hints and things to take note of.
- Text in [red](#) boxes are important instructions or prompts that guide you to DISCUSS some of the key RESULTS and CONCEPTS learned in the lab. These prompts may not be the only items that need to be included in your report.

IMPORTANT: This lab requires error propagation - do not forget you MUST include your scanned error propagation pdf.

1 Objectives

- Create circuits with multiple different electronic components.
- Learn about the effect different components have on I-V curves of circuits and how they can be used in the real world.

2 Introduction

In lab 5 we created circuits with resistors, devices which (based on ohms law) can be used to restrict the amount of current or reduce the voltage in a segment of a circuit.

A [diode](#) is an electrical component that conducts current primarily in one direction (asymmetric conductance). It has low resistance to current in one direction, and high resistance in the other, thus its I-V curve is more complicated than Ohm's Law.

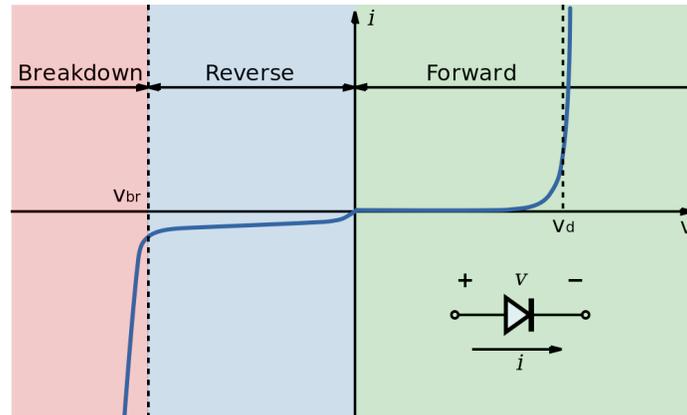


Figure 1: Ideal I-V curve of a diode.

Diodes are important for the control of current in circuits, and their asymmetry is the basis of electrical computation. Connecting more than one diode together allows for construction of [logic circuits](#), whose voltage output models basic algebra. More sophisticated diode devices called [transistors](#) can amplify voltages, and switch electronic signals on and off, allowing for more complex logic and computation.

[Capacitors](#) are electrical components used to store energy. Since charge builds up on a capacitor rather than flowing through it, charge can build up until the point that the voltage on the capacitor balances out the external voltage pushing charge onto the capacitor. Since the current stops at this point, an I-V curve for a capacitor only makes sense when V is changing in time.

The charge on a capacitor cannot change instantaneously; it takes time. Thus a simple [RC circuit](#) can produce a voltage that varies with a very specific characteristic [time constant](#) as seen in equation 1

$$\tau = R \times C \quad (1)$$

This allows circuit designs to have alternating currents (AC) with a specific and known time frequency.

3 Procedure

For this experiment you will need:

- 1 Ω resistor R_s (see Figure 2)
- 100 k Ω resistor R_1 (see Figure 2)

- capacitor (see Figure 3)
- Zener diode (see Figure 3)

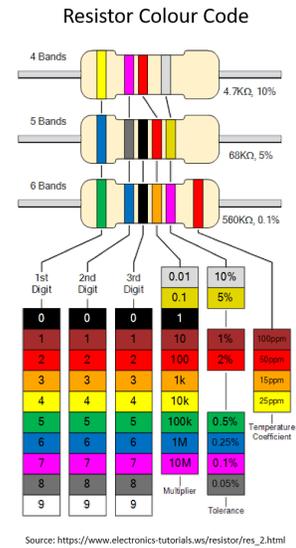


Figure 2: Resistors found in the 1P92 accessory kit

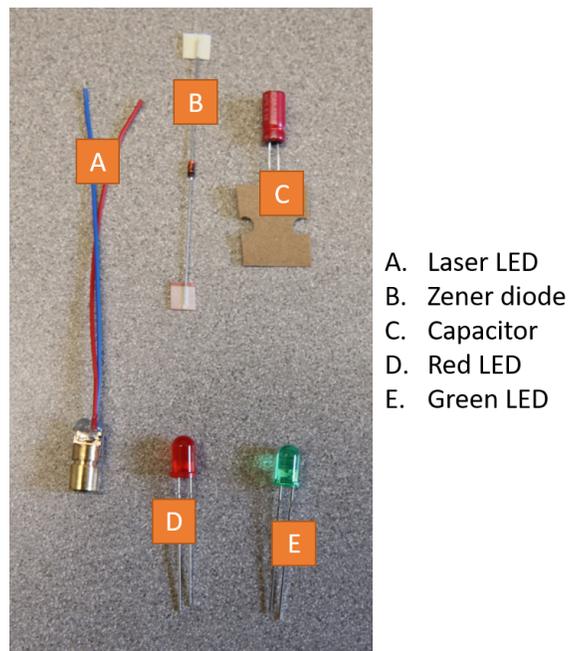


Figure 3: Electrical components found in the 1P92 accessory kit

3.1 Calibrating the High Gain Sensor

Similar to Lab 05, we will be creating our own ammeter to be able to calculate the current through the $1\ \Omega$ Resistor R_s . Since we will be using the same resistor for R_s the ‘conversion factor’ to determine the current from the voltage output of the gain sensor is the same from Lab 05. *i.e.* it’s your answer to the question "If we measure the voltage across the sensor resistor R_s as $1.2\ \mu\text{V}$, and given its resistance value of $1\ \text{Ohm}$, what is the current flowing in the circuit?"

HINT: you may want to check TA feedback from Lab 05 to make sure you did these conversions correctly in that lab first!

To calibrate the gain sensor we will create the circuit seen in Figure 4b

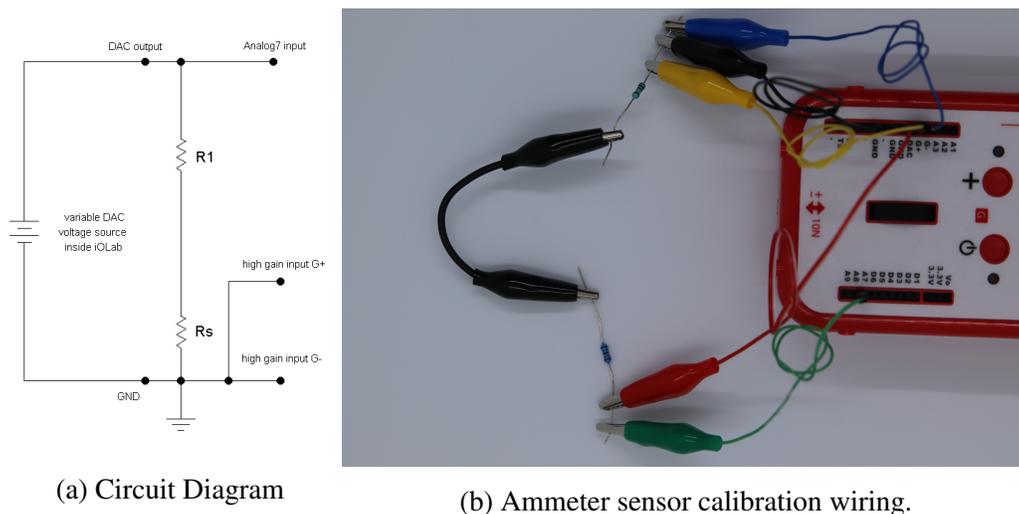


Figure 4: Ammeter sensor **calibration set-up**. The blue wire to G+ is connected to GND through the black wire, so that the high gain sensor can be calibrated. Do not forget to move this wire to the other side of R_s after.

To create the circuit:

- Connect one pin-to-alligator clip into the DAC (RED), then clip the other end to one side of the $100\ \text{k}\Omega$ resistor R_1 .
- connect one pin to alligator clip (GREEN) to the A7 sensor and attach it to the DAC side of R_1

- connect another pin-to-alligator clip (BLACK) into one of the GND slots and connect the clip side to one side of the $1\ \Omega$ R_s resistor.
- connect two more pin-to-alligator (YELLOW and BLUE) connectors to the G+ and G- terminals respectively and clip the alligator sections to the GND side of R_s
- with an alligator-to-alligator clip (BLACK DOUBLE ENDED ALLIGATOR) connect the open ends of R_s and R_1

Check off the DAC box in iOLab online.

Select High Gain Input sensor and acquire a couple seconds of data.

Open up the Settings section of iOLab online and delete your current calibration under High Gain null.

Take a few seconds of data.

Enter the value in the High Gain null box under the Settings section of iOLab Online.

Verify the G+ value is now closer to zero by taking another few seconds of data. (There may be some drift, but that's okay.)

Once calibrated move the alligator clip connected to the G+ terminal (YELLOW) to the other side of the R_s resistor as seen in Figure 5b. You may recognize this exact setup from Lab 05.

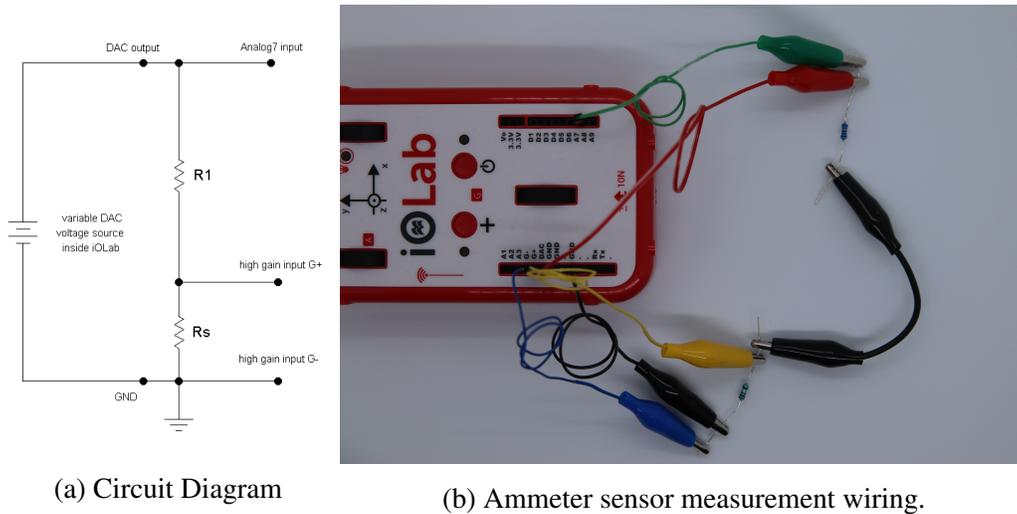


Figure 5: Ammeter sensor **measurement set-up**, for a single resistor. The R_s resistor is an important part of the new ammeter sensor. A7 will measure the voltage drop across R_1 , while the high gain input will help measure the current I through it.

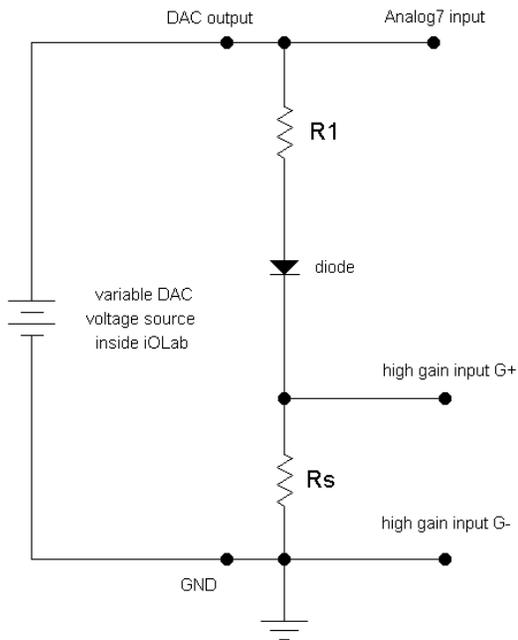
3.2 Diodes

Now that we can measure the I-V curves for different configurations of electronics components, let's measure the asymmetric I-V curve of a diode.

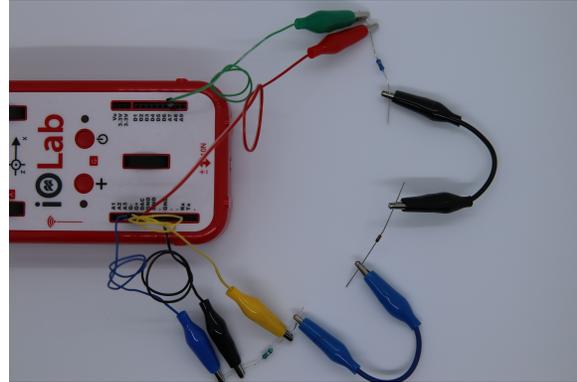
We will start by recording the I-V response in the forward bias direction. This configuration allows the current to flow easily through the diode (seen in the green section of Figure 1). Remember, *current* flows from the positive terminal to ground, but it's really the electrons flowing the *other way*.

We will create the circuit in Figure 6b. From the circuit you currently have, do the following:

- disconnect the double-ended alligator clip (BLACK) from the R_s diode but leave it clipped onto the R_1 side
- connect the open end of the double-ended BLACK alligator clip to the **red** side of the Zener diode.
- complete the circuit by connecting the R_s resistor to the open end of the diode using a double-ended alligator clip (BLUE).



(a) Forward bias diode schematic.



(b) Forward bias diode wiring.

Figure 6: A resistor and diode in series, where the diode is forward biased. The diode arrow points to the black band painted on the actual diode, and indicates the direction current is allowed to flow.

Record the I-V curve for the forward biased diode circuit.
For 6 data values of increasing V_{DAC} , **starting near 0 V**, record the:

- Voltage on the +, DAC side of the resistor (A7)
- Voltage across R_s (High Gain Input)

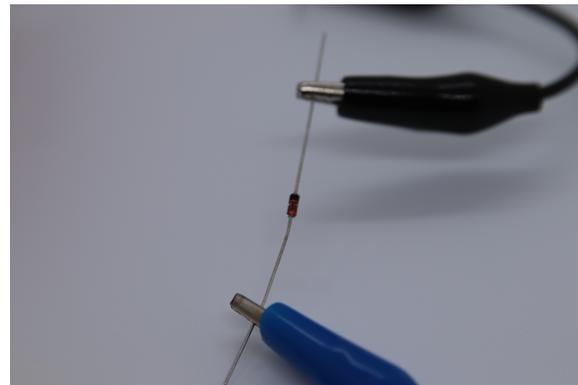
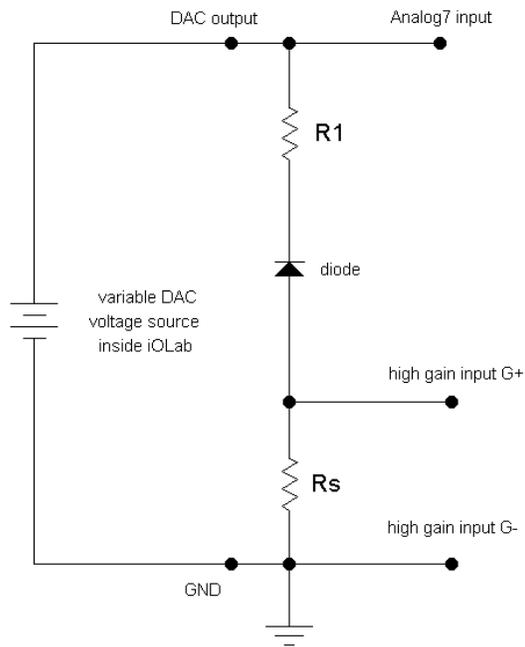
From the voltage output of the High Gain Input sensor you can use your conversion factor to calculate the current I .

Save your data for the second part below.

Now we will reverse the direction of the diode to the “reverse bias” direction as seen in Figure 7b. To do this:

- un-clip both sides of the diode

- flip the diode so that the black line on the diode is now facing the (BLACK) double-ended alligator clip
- clip the diode into the circuit in this orientation.



(b) Reverse bias diode wiring.

(a) Reverse bias diode schematic.

Figure 7: A resistor and diode in series, where the diode is reversed biased. Because we are now connected in reverse to the normal flow of current, what will happen?

Record the I-V curve for the reverse biased diode circuit as shown in Figure 7: For 6 data values of increasing V_{DAC} , **starting near 0 V**, record the:

- Voltage on the +, DAC side of the resistor (A7)
- Voltage across R_s (High Gain Input)

From the voltage output of the High Gain Input sensor you can use your conversion factor to calculate the current I .

We want to analyze the diode data together. To do this, we will combine the diode data (see bullets below) and plot the twelve total points with V on the x -axis, and I on the y axis

1. For the forward bias data, enter the values of V_{DAC} as + (positive) values.
2. For the reverse bias data, enter the values of V_{DAC} as - (negative) values [don't forget the current for these values should also be negative].

There is no need to fit a line to the data.

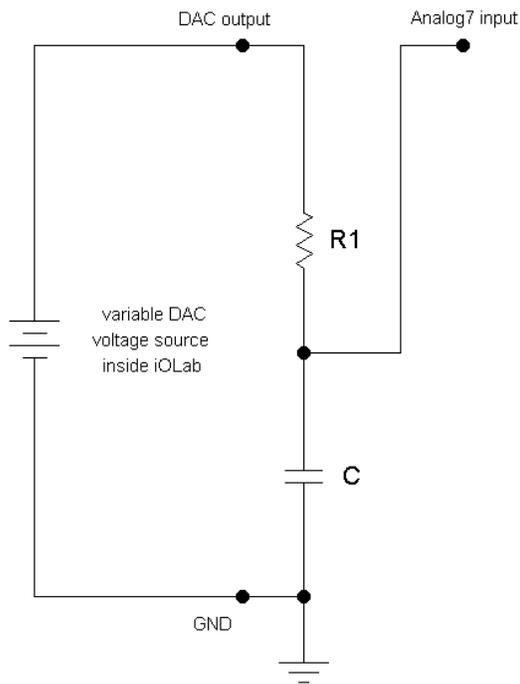
Describe the resulting graph.

3.3 RC circuits

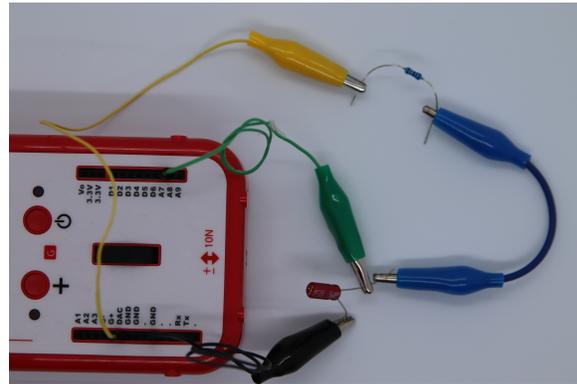
In this section, we will measure the *time response* τ of an RC circuit, which is determined by the time it takes to charge up an energy storing capacitor.

Build the circuit shown in Figure 8:

- Remove all connections to the iOLab.
- Connect one alligator-to-pin connector and put it in the GND input (BLACK)
- Take the capacitor C and connect the lead labelled with a white stripe and (-) sign to GND (BLACK) **The exact value (capacitance) of the capacitor is written on the side.**
- Connect the open side of the capacitor C and R_1 using a double-ended alligator clip (BLUE)
- Connect a pin-to-alligator connector to A7 and then clip it onto the capacitor lead connected to R_1 *i.e.* on the same side as the (BLUE) double-ended alligator clip
- Connect the open end of R_1 to DAC using a pin-to-alligator clip (YELLOW)



(a) RC circuit schematic.



(b) RC circuit wiring.

Figure 8: A simple RC circuit. The A7 sensor will measure the charging and discharging of the capacitor.

We will be starting with DAC on; the capacitor will be fully charged when we start the experiment. During the experiment you will turn off the DAC and let the capacitor discharge, then turn the DAC voltage back on to recharge it.

In IOLab Online, enable the DAC output and set DAC to 1.81 V. Select A7 and enter a collection time of 40 sec.

Collect one discharge and charge curve of the capacitor:

1. Click Start. Data near 1.81 V should appear on the graph display. If this voltage is changing, stop, and repeat until V is settled.
2. With a steady voltage, after a few of seconds **un-check** DAC; the DAC output goes to 0 V and the capacitor discharges.
3. Wait 10 to 12 seconds until the capacitor has fully discharged, and **re-check** DAC;

the DAC output goes to near 1.81 V, and capacitor re-charges.

4. Download and save your data!

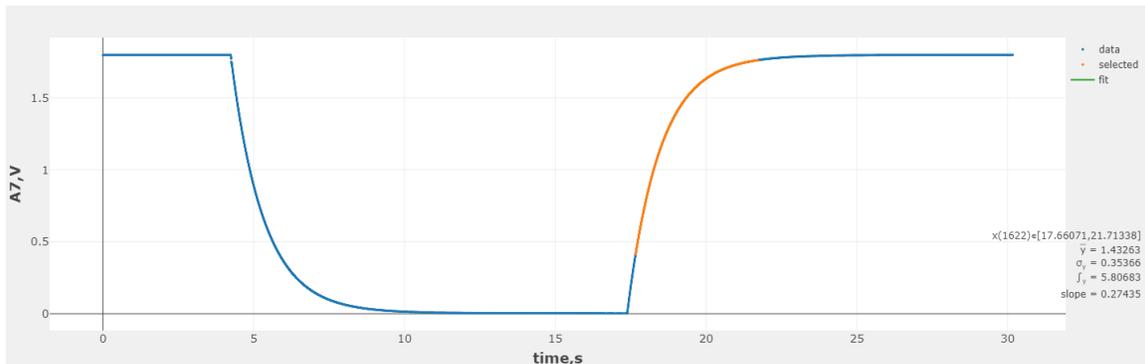


Figure 9: Example data of the capacitor discharging then charging. The DAC output was on at the beginning, turned off around 4.7 seconds, and turned back on at about 17.5 seconds. Some data showing the exponential recharge of the capacitor is selected for fitting. The fit is so good, it is impossible to see the data behind the fit.

Select a data range within the exponential decay of the discharge curve, use the iOlab Fit pull-down menu to select

$$A \cdot \exp(-(x-C)/B)$$

where $B = \tau$ the time constant from equation 1.

Start the fit with an initial value of fitting variable C that is the time of the first selected data point.

What is the circuit's discharge RC time constant?

Select a data range within the exponential growth of the charge curve, delete the current fitting equation and then from the pull-down menu select

$$A \cdot (1 - \exp(-(x-C)/B))$$

where $B = \tau$ the time constant from equation 1.

Start the fit with an initial value of C that is the time of the first selected data point.

What is the circuit's RC time constant, and its uncertainty from the fit?

Using equation 1 determine the theoretical value of τ the RC time constant for the circuit.

NOTE FOR UNCERTAINTY The “tolerance”, or uncertainty, of the actual capacitor value is 10% of its value ($1\mu\text{F}$). The tolerance of the resistor is 1% of its value ($1\text{k}\Omega$). Work out the expected RC constant and its uncertainty.

Do either of the RC constants measured this way agree with the known values of the resistor and capacitor that you used?

What do you think would happen to the capacitor charge and discharge graphs if we changed the initial DAC voltage?

Would there be an impact on τ the RC time constant for the circuit. Explain your thinking.

Finishing Up

Now that you have completed the lab, be sure you filled out all portions of the data tables (templates found in the Resources Tool on [Sakai](#)), include figures, and develop a robust discussion using prompts found throughout the manual.

Ensure to give yourself enough time to complete the report and to hand it in by the due date as late lab reports will not be accepted! If you have any questions please attend a live lab session to get help from one of the course lab demonstrators, or email Phys1P92@brocku.ca.