Lab 2: Testing Simple Circuits and Soldering

1. Objective:

(1). Investigate the current versus voltage (aka IV) characteristic curves of two different devices: resistors and LED's. These are devices that we expect to have different IV curves. You will also have a chance to observe how devices that are rated to be nominally the same may have different IV characteristics.

(2) Experimentally verify Kirchoff's Voltage and Current Laws (not simply solve them in problem sets). You will study and verify the superposition of sources in electrical circuits. Then, you will investigate the effect of different loads on the voltage and current supplied to the load. Hopefully, the concepts we have been analyzing in lecture will 'come alive' for you in this lab.

(3) Learn how to solder properly and safely.

This lab has very sparse instructions. You are going to build on the measurements and instruments you learned to use in last week's lab, and also apply some of the analysis you learned in lecture. If you cannot figure out how to do something or what your results mean after thinking about it, ask your TF for help.

2. Pre-lab questions

Thinking about and answering the following questions may help you prepare for the lab:

Feel free to use any resource available to you to help you find the answer, including book, material on the course web site, google search, your friends, TFs, course instructors, etc.

a. *Read Lab 2 handout* prior to coming to the lab. Write "READ" in your pre-lab when done.

b. *Watch* this video (https://www.youtube.com/watch?v=IpkkfK937mU) about good soldering practices. If you have done so, write "WATCHED" on your pre-lab :).

c. Draw qualitative plots of what you think the I-V curves of the resistor and of the LED might look like, and discuss how they might differ.

We have dealt with resistors in lectures, but not with LEDs (although you have made them light up in lab). Remember that all diodes (light emitting or not) conduct current only when voltage of appropriate polarity is applied across them.

d. What do you think might happen if you (inadvertently) applied a large positive or negative voltage to both LED and resistors, say 10 V or -10 V?
Think carefully about what is going on, how much power you are delivering to the devices, what might happen to the device, would they heat up, cease to function?

3. IV Characteristic Curves of Resisters and LEDs

(a) Obtain a ”mystery” resistor, with an unknown resistance RX , from your TF. Measure its IV characteristic curve resistor in 0.5 V increments, with three positive voltages, three negative voltages, and at 0 V. Record your results and plot the curve. Finally, draw a best fit curve and show it to your TF. Based on your measurement, determine the value of the resistance RX ? To check your answer, measure this resistance using digital multimeter, and write down your observations.

(b) Besides the points you used for your curve in part (a), measure the current for a much larger positive and negative voltage. Do those data points follow the curve that you drew in part (a)?

(c) Repeat part (a) with an LED instead of a resistor. Again, show your best fit curve to your TF. For the LED, go up to voltages at least as high as 2.5V.
Note that the longer lead on LED’s is the positive side.

(d) Besides the points you used for your curve in part (c), measure the current for a much larger positive and negative voltage (say +6v or -6v). Do those data points follow the curve that you drew in part (c)?

4. KVL, KCL, and Superposition

Construct the circuit in Figure 1 on a solderless breadboard. Choose resistances between 400 Ω and 6 kΩ for R1, R2, and R3. Choose a voltage between 5V and 10V for V1 that will be supplied by the DC Power Supply. Finally, use a battery pack (3V) for V2.

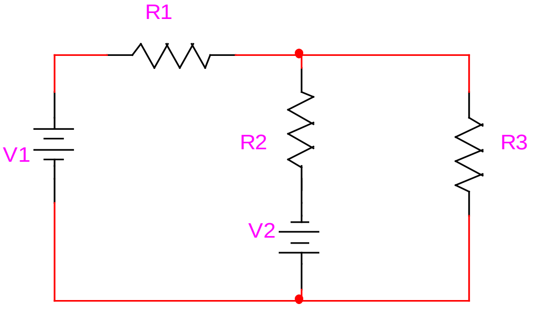

Figure 1: Circuit for Verifying KVL

(c) Verify Kirchoff's Voltage Law (KVL) for all three loops in this circuit measuring the voltages clockwise (as viewed in Figure 1). Pick one loop and measure the voltages again but in the counterclockwise direction. Does it matter which direction you measure the voltages? Record all of your measurements in your write-up.

(d) In Figure 1, pick (and indicate on the schematic) the reference direction for current I_2 flowing through resistor R2. Then measure the current with respect to this direction. What does your measurement tell you about your I_2 reference choice? For fun, measure the current through R2 using the opposite reference direction. What value do you get now?

(e) Verify Kirchoff's Current Law (KCL) for one of the nodes using the handheld multimeters to measure current. Remember, multimeters need to be reconfigured to measure the currents.

5. Voltage Divider

Now look at the circuit shown in Figure 2; This so called "voltage divider", it is very useful as it can be used to step-down the voltage from a voltage source to any smaller value, as defined by R1 and R2. Often, the circuit is designed to deliver power to a 'load' or device.

a) Pick values for R1 and R2 that are between 500 Ω and 2 kΩ. Measure the voltage across the load with load resistance, R_L, in each of the following cases:

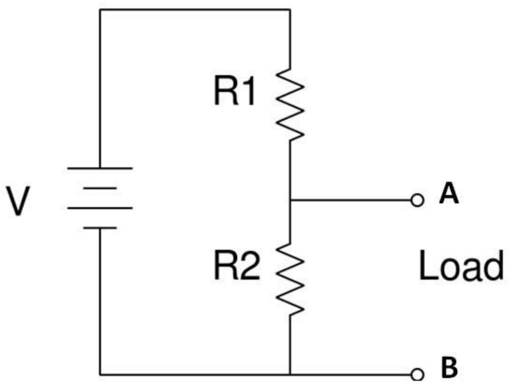

Figure 2: Circuit for Testing Loads

- without the load resistor R_L
- with R_L close in value to R2;
- with $R_L = 0\Omega$;
- with R_L much larger than R2;

In what cases does voltage divider behave as an ideal source that is its output (V_{AB}) does not depend on the load R_L?

Summarize your measurements in a table, and compare the results with the values of V_{AB} that theory predicts (equation for voltage divider). Are there any differences? Why?

b) Using a potentiometer (you played with these in Lab 1) and a DC power supply with its output voltage set to 10V, construct a circuit that can deliver arbitrary voltages between 0V and 10V. (You can build a separate circuit for this). The circuit will be similar to that shown in Figure 2, with a potentiometer replacing R1 and R2. Measure V_{AB} while twisting the potentiometer knob. Does the circuit do what you expect it to? Discuss the pros and cons of using 1kΩ, 10kΩ and 100kΩ potentiometers to construct the voltage divider. You can either try this in practice, or think about it and write your conclusions.

Hint: Make sure that you consider the power borne on the divider as well as the dependence of V_{AB} on the load.

c) Now return to the circuit you used in part (a) (before the potentiometer). Use a large capacitor (>= 100 μF) as a load. Turn the power supply off before connecting your capacitor and make sure the **polarity** of the capacitor is correct (+ side goes to the higher voltage potential side). **Show the circuit to your TF before turning the power on**. Measure the voltage across the load as you turn on the power supply and see if the voltage changes over time. Describe your results.

While still measuring the voltage on the load, turn the power supply off and observe the voltage over time. Describe your results.

Repeat both of these experiments to see if you observe the same behavior.

6. Soldering

In this part of the lab, you will do something very cool and build your first real circuit, by soldering various components on the printed circuit board (PCB).

Soldering is the act of using a molten metal alloy to form an electrical connection between two components. The metal 'alloy' melts at a temperature lower than that of a pure metal. The connection formed by the metal alloy is known as a "joint." This connection is the "next step up" from breadboarding in that the electrical connections made are more permanent and often more stable. Indeed, if we look at the Arduino's circuit board, almost everything on it is soldered to the board. The solidified metal alloy can be found on the bottom of the circuit board. We can accomplish the same thing by soldering by hand.

There are three main components necessary for soldering:

a) A soldering iron: the actual heating element that liquifies the metal alloy.

b) Solder: the actual metal alloy that is to be melted. This generally comes in the form of a wire. The wire itself actually consists of two parts: an outside shell of solder (metal alloy) and an inner core of "flux." "Flux" (in most cases a mixture predominantly composed of a kind of tree resin) is a component that, when melted, dissolves and removes any metal oxide that may be present either on the solder or on the electrical component. This prevents metal oxide from getting stuck in our solder joint and eventually destructively continuing to oxidize/rust and eventually break the solder joint.

c) Electrical components: the actual components that will define the circuit and do useful things.

Important: The electrical components have heat tolerances and prolonged exposure to high heat can permanently damage them. Resistors and, of course, wires, tend to be heat resistant and can withstand extended (on the order of seconds) contact with a soldering iron. LEDs are also somewhat heat resistant. However, capacitors, integrated circuits (ICs - those black chips you see everywhere), and many other components tend to be much more heat sensitive and cannot be exposed to the heat for long time. To avoid soldering-related damage to ICs, often we do not solder them to the board directly. Instead, we solder IC sockets to the board, and insert ICs into them. You will do this in amplifier lab as well as for your final projects!

You might also notice a sponge next to your soldering iron. The sponge is there to clean the soldering iron tip.

To practice soldering:
We will be soldering LEDs to a circuit board to form your favorite letter - "H." Before you start, inspect your "H" PCB –There are two main traces which act as a power rail and a ground rail to which the LEDS are connected in parallel.

The Steps.

1. First heat up your soldering iron by plugging it in to the wall and letting it sit until it is hot enough to melt solder (this generally takes around 5 minutes).

2. Clean your soldering iron by wiping it on a wet sponge.

3. Touch the iron to the connection (pad) you want to solder and then touch the wire of solder to the connection. Then bring the lead of the electrical component you want to solder to the pad. Eventually, there should be no hesitation between the two touches (the rhythm should just be touch with the iron and then immediately touch with the soldering wire).

   Make sure that you are using the tip, both of the soldering iron and of the solder wire. This ensures that the flux is melted as soon as or even before the solder starts melting so that it has an opportunity to clean the joint site before the joint is formed.

   Use just enough solder until the entire pad is covered. Then first remove your solder wire and then remove your iron. If you remove the iron first, you run the risk of the solder wire cooling and fusing with your joint. This is not a big deal. Simply touch the soldering iron to the wire and melt it again.

   Eventually, after some practice, this procedure will become very smooth, without any hesitation between the touches. For now it is okay to have a little pause between the touches.

   After you are done soldering, examine your soldering joint. It should look like a broad mountain that covers the entire pad. If it looks more like a large sphere-like blob, this probably means you've either used too much solder, or the solder is too high up and doesn't actually touch much of the pad. If the entire pad is not covered, this means that you have not used enough solder.
   You can also try to shake the component gently and see if the leads move – they shouldn't! If they do, you need to redo the procedure, since this joint would be unreliable (sometimes work and sometimes does not). Bad solder joints are one of the most common failure mechanisms of ES 50 final projects – so practice now ☺!

4. *Continue* the procedure outlined above and solder all components.

5. *Clean* up by your soldering tip when done soldering everything.

6. ***UNPLUG*** your soldering iron when done.

Before you embark on the soldering adventure, make sure to remind your TF to demonstrate the procedure to everyone in your section ☺.

Remark-1: At present, the Arduino's board is most likely soldered by a machine, but the basic principles and purpose are just the same as if the soldering were done by hand.

Remark-2: If you accidently solder things you weren't supposed to or used too much solder, there are ways of fixing this. Ask your TF about these. As it might appear from all the points above, soldering is an art and skill that may take a bit of practice to learn.

This video goes over good soldering practices. Watch it if you have spare time. Regardless of whether or not you watch the video, your TF will demonstrate how to solder in person. The video will go over some things that we won't, such as using the metal wool pad (that sponge made of metal fibers) to clean the soldering iron tip and cleaning off excess flux. For our purposes, neither is extremely important.

Remark-3: What we are learning is known as "padded through hole" soldering. As its name implies, this kind of soldering relies on having a hole through which we can thread the connections of the electrical component we want to solder. This is the easiest form of soldering by hand.

If we go back to the Arduino, you might notice some components on the board don't look like they have any corresponding solder on the back of the board. These components are soldered to the surface of the board. Hence this kind of soldering is known as "surface mount" soldering. It is generally more difficult to do by hand than through hole soldering; the vast majority of soldering by hand is limited to through hole components.