University of Colorado Boulder
ECEE Department

ECEN 2250 - Introduction to circuits and electronics - Fall 2023
Location: Engineering Center, ECCR 1B40, MWF 2:30PM - 3:20PM
Instructor: Professor Eric Bogatin, Dr. Mona ElHelbawy
Lab #1
Lab Title: Week intro, life at DC V-R circuits-1
Date of Experiments: September 13th, 2023
Names: Connor Sorrell

Experiment 1

Introduction:

The overarching purpose of this lab is to check out the several circuit kits and circuit equipment that will be put to use during this course. It is also important to start the process of thinking about measurement practices, circuit design strategies, proper ways to test and debug, and documenting work. Overall, this lab will be important in understanding the procedures needed to complete future labs, whether that is tangible or mental work. These exercises will assist in bridging the gap between theoretical based knowledge and practical application in real world scenarios.

Discussion:

1) It is necessary to do every lab because these labs are how one can learn how to problem solve. These labs mean more than just learning how to plug things in, make things turn on, and submit. These are built to teach how to hypothesize, test work, find issues, and solve issues. More importantly, these labs are so important because they provide real practice when it comes to analyzing and truly thinking outside the box and outside what the brain thinks it's capable of.
2) Rule #9 is the practice of preemptively thinking about the anticipated outcome before experimentation. It is a crucial rule because it shifts the brain away from solely focusing on assembly without comprehension. It is important to practice rule #9 and emphasize it throughout each and every lab because it serves as a basis of understanding, as well as evidence after experimentation is complete.
3) Situational awareness is not only being able to understand things on paper or in a math problem, but also the physical circuits and equipment themselves. It is important to recognize everything around you, not just the ideal model that is in your head. Likewise, it is just as important to analyze the situation, whether it be the circuit or other problems that may be encountered. All of this falls into having strong situational awareness, and being able to determine a real physical model from an ideal one that is so ingrained in so many of our heads.
4) Figures of merit comprise a set of specifications that quantity and describe a device.. Some figures of merit are gain, resistance, and impedance, but there are many more like bandwidth, amplitude, etc. Overall, figures of merit are just terms that are used to quantify a characteristic..
5) Reverse engineering an instrument means to observe the outcome and then retracing the steps backward in time in order to fully comprehend the processes that led to the outcome. Reading numerical values is straightforward, but grasping the mechanisms and the underlying principles and procedures is much more difficult yet important.

6) There are many things that could be reasons why the LED is not on at all. One possible solution is that the diode and anode of the LED are plugged in backward. Another possible cause is that the power connection or ground connection are not fully plugged in, or they are plugged into the wrong ports.

Experiment 2

Introduction:

- The purpose of this lab is to explore best practices using the solderless breadboard and learn how to reverse engineer and verify its connections. This lab will also help one understand how to use the DMM to test values and conductivity, and help ingrain the practice of using the correct technical terms to describe experiments.

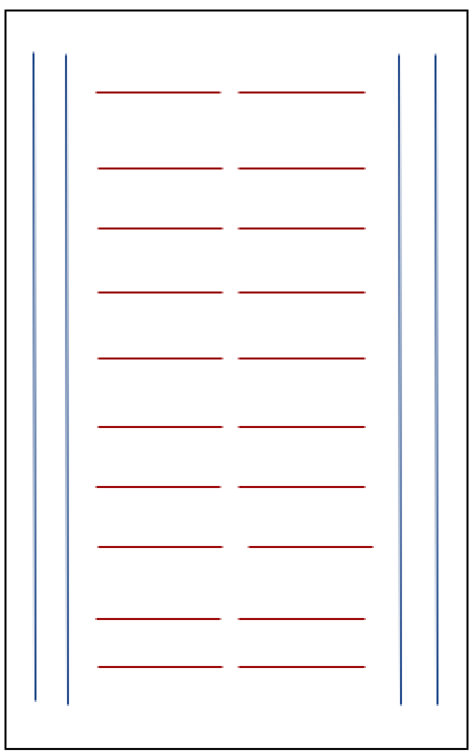
1) 

Figure 1.2.0. Illustrates the connectivity in the SBB. The red lines connect together and the blue lines connect together.

2) Procedure:

To test the conductivity on the breadboard, I utilized two stripped wires and linked them to the alligator clips of the DMM. One wire was connected to the input terminal, while the other was connected to the COM terminal.

3) <u>Experimenting & Discussion:</u>

The breadboard emits an audible signal when it encounters resistance below a threshold of one tenth of an ohm. This is because the DMM is very sensitive, and is capable of measuring resistance down to that value. Because of this, when the multimeter beeps, it is a sign that the circuit is wired correctly, because an ideal circuit has nearly zero resistance. If I incorrectly placed any wires on the breadboard, the DMM would remain silent, indicating no connection.

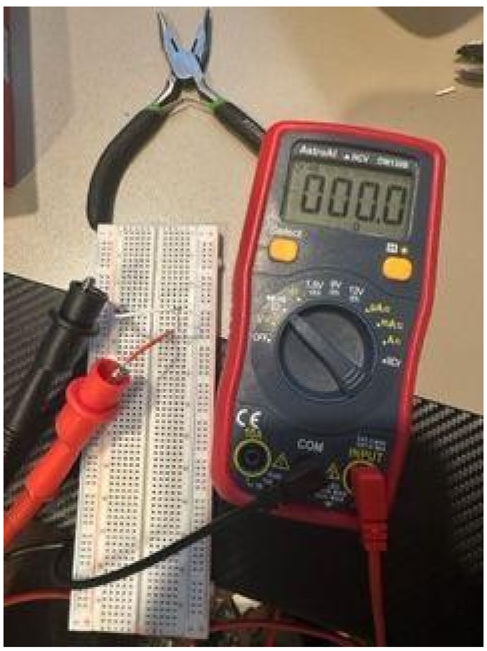
4) 

Figure 1.2.1: This is a picture of my breadboard connected to the DMM. The red wire represents power, while the black wire represents ground. The white wire is a signal wire which is used to connect terminals to each other on the SBB. With both the alligator clips connected, the DMM shows a resistance of zero, implying the simple circuit is correctly connected.

Experiment 3

Introduction:

- This experiment is to get comfortable with the DMM and learn how to use it to measure voltages, current, and the resistance of resistors.

Discussion:

1) Procedure:
   To measure the five voltage sources, connect the ground end of the DMM to the ground port on the Arduino. Then connect the power end of the DMM to the 3.3V port and the 5V port. To read the other two voltage sources, connect the red power end of the DMM to the V_{in} port, doing this once with the 5V adapter plugged into arduino from the wall, and again with the 9V adapter.

2) Experimental Data & Discussion:
   Before each measurement, we expected a voltage value extremely close to the voltage source itself. After doing each measurement, our prediction was correct. A 5V source typically measured between 4.8V and 5.1V for example. The measurement read by the multimeter was typically around 5% off due to imperfections in the board and the multimeter, but each reading was extremely accurate relative to the actual voltage value.

3) The three different resistor measurements used for testing were 100 ohm, 1k ohm, and 1M ohm. The 100 ohm was expected to provide a larger current, compared to the mega ohm, which should provide a very small number of amps. Before testing, we mentioned to each other that we find it extremely cool and intriguing that even though each resistor looks so similar, and is installed the exact same, the difference in their resistance properties is night and day. The voltage in each measurement using different resistors stayed the same, which conforms with our previous knowledge. When measuring the resistance of each resistor, they all displayed their indicated value with a ~2% error. It makes sense that the voltage would stay the same regardless of the resistor used due to the 5V source being independent and not having to do with resistance.

4) Prior to the experiment, we expected the current measurements to be slightly off, because the resistors and DMM are only rated to 5% accuracy. The three different resistor measurements for testing were 100 ohm, 1k ohm, and 1M ohm. All three

resistors measured ~5V, with around 2-3% percent error, which is expected because of the small errors within the board and the resistors. The 100 ohm resistor measured 49.84 mA (~50 mA), the 1k ohm resistor measured 4.79mA (~5mA), and the mega ohm resistor measured 0.51 µA (~0.5 µA). When measuring the mega ohm resistor, the DMM had to be changed to microamps in order to read the extremely low amperage level caused by the huge resistance. Once again, the true values read from the DMM were all slightly off, but not to a significant level which could raise alarm.

5) To test the 5% rating, we measured two of the same 1k ohm resistors, one from the top of the package and one from the bottom. The first one measured 982 ohm, the second was closer to 1k ohms at 994 ohms. We then did the same thing with a 330 ohm resistor, where one measured 361 ohms and the other measured 354. We repeated this with the 570 ohm resistor, where one measured 556 ohms and the other read 544 ohms. Then again with the 220 ohm resistor, where one read 205 ohms and the other read 217 ohms. Clearly, the resistors aren't perfect, but to our measurements, they are typically even more accurate than 5% error.

Experiment 4

<u>Introduction:</u>

- The purpose of this lab is to not only build a circuit, but be able to identify what it means to work, test it, debug it, and analyze it.

1) <u>Procedure:</u>
   This circuit was powered via an Arduino which was powered through a 5V wall adapter. There is a wire that bridges power over to the breadboard, coming from the 5V regulated pin in the Arduino. The resistor is then connected to the power, leading into the anode of the LED, which is the longer leg, or the positive side of the diode. Then, there is another wire that connects the cathode (negative side) of the LED to ground, which is then bridged back to the ground port on the Arduino board.

2) <u>Discussion & Experimental Data</u>
   This circuit was very simple and hence relatively easy to make, especially considering I have made almost this exact circuit many times throughout the past few years. Something that made this lab a little challenging was finding the right resistor needed to produce a 10 mA current through the diode. We tested four different resistors, all of

which produced a different amount of current. After testing a few, we were able to infer what resistance our resistor needed to be around. We then found that out of all the resistors in our packets, the 470 ohm resistor gave us the closest current to 10mA through the LED. However, the exact measurement was ~10.7 mA, but this was as close as we could get.

We also measured the DC forward voltage drop across the LED, resistor, and loop. We expected a 3V drop over the resistor and a 2V drop over the LED. This was obviously not exactly correct, as the true values were 3.12V and 1.88V. Surprisingly, the complete loop had a perfect 5V drop, which I anticipate is because of the Arduinos regulated 5V pin.

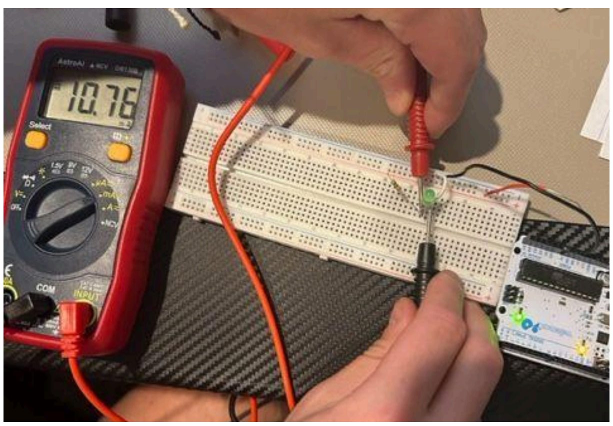


Figure 1.4.0: This picture shows the circuit as well as the current value that was provided by the 5V input and 470 ohm resistor.
(10.76 mA)

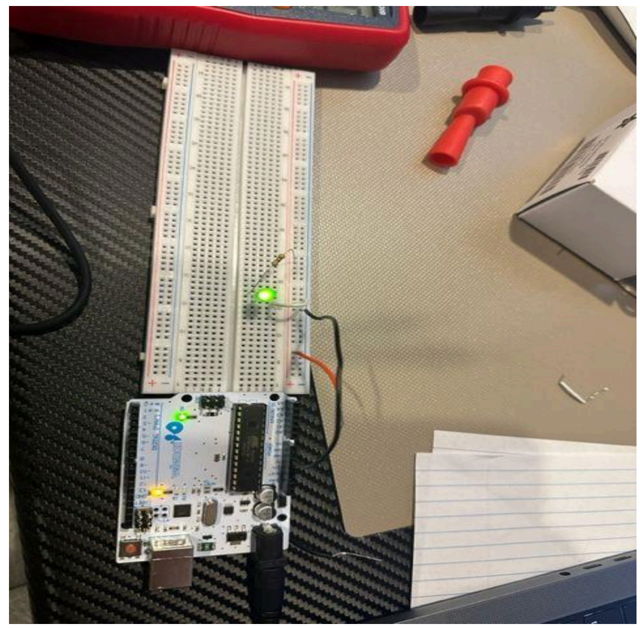


Figure 1.4.1: This picture shows the entire circuit. Arduino’s power is bridged to the breadboard which is then connected to a resistor and turns on an LED.

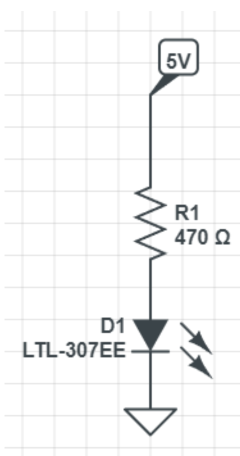


Figure 1.4.2: schematic of circuit. 5V source leads into a 470 ohm resistor, which connects to an LED. In this configuration, ~20mA of current runs through the diode.