On the following pages is an example report for Lab 1. I wrote this up after doing all of the lab exercises. (I did not read the tutorials — at this point, they are probably not necessary for me.) I offer this example writeup as a guide to (what I think is) a good report.

Here is how to use the example:

1. You can use this as the starting point for your own Lab 1 report. (Microsoft Word, pdf, and Apple Pages versions are available. Also, you should be able to import one of these into Google docs, if that is your preference.) I give everyone permission to plagiarize this report ruthlessly — you can re-use all of my text if you want. What you should change are: the data that you measured, the calculations that you did, and any photos that you took during lab. In that sense you can use it as a cut-and-paste template for presenting your own work — just take out my details and put in your details. But to be clear, while you can use my words, you cannot use my data, calculations, or figures in your report. If you did not take any photos during lab, that's OK — photos aren't absolutely necessary, and your report won't have any. (Perhaps you will want to include photos in future reports.) I expect that most of the Lab 1 reports that are submitted will be very similar, and everyone will get similarly good grades.
2. Alternatively, you can use my example simply as a guide for writing your Lab 1 report. You can do everything from scratch, writing your own text in your own voice and arranging everything with your own format. There is no requirement that all EE 201 reports be clones of mine. If you are confident in your report-writing skills and have developed your own style, then feel free to do your own thing.
3. For future labs, there will be no template or example reports. You will need to generate those reports from scratch, providing all of your own words in addition to the measurements and calculations. Of course, the Lab 1 example report can serve as a guide for how to proceed with those future reports — follow the general outline and you should be successful.

Why am I doing this? The short answer is for efficiency. In the past, I would provide a template for the the first lab report. Students would use the template to write crappy reports. (Mainly by trying to do the absolute minimum in filling out the template.) My head would explode while reading the bad reports. Everyone would get bad grades with lots of red marks. Then we would have an unpleasant class discussion about lousy report writing. After repeating the cycle a few times, most people would start writing better reports.

This time, I'm hoping that it will be more efficient to show you (what I think is) a good report at the outset and skip the other rigamarole. (You may disagree about my example being a good report, but for now we will use my standards.) Everyone will have access to a "good" example, and everyone should a get good score on the first report. And then moving ahead, everyone should be able make good reports for the remaining labs. We will see how it goes.

Basic DC circuit tools and measurements

G. Tuttle (Section 0. Work completed on Feb.12, 2021)

Introduction

The main purpose of this lab was to gain an introduction to some of the tools and techniques used in a circuits lab and to get some initial experience in using these tools. Most of of the time used in working on these exercises was spent in reading introductions and tutorials. In particular, we learned about

- using the breadboard to build circuits
- the resistor color code
- how a potentiometer (variable resistor) works
- operation of the digital multimeter: voltmeter, ammeter, and ohmmeter
- operation of the DC triple-output power supply.

For some of the tools, the introductions were somewhat cursory. Presumably, we will have opportunities for more in-depth use in future labs.

After being introduced the basic tools, we performed several different types of measurements, most of which were fairly straight-forward.

The lab work took about 3 hours[1], with additional time for writing the report.

Resistor measurements and tolerance

We selected 20 resistors at random from the supplied lab kit, trimmed the leads to better fit in the breadboard, and inserted them into the breadboard, as shown in Fig. 1.

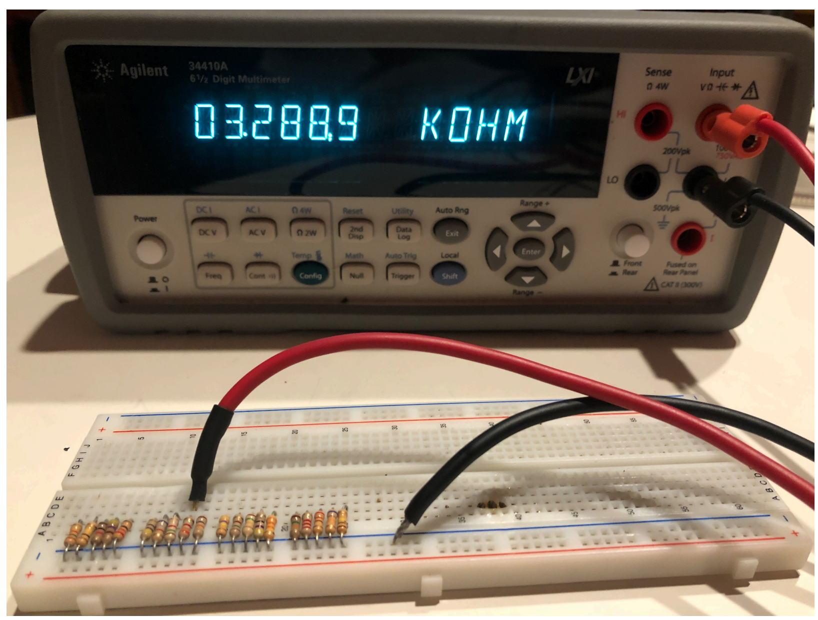


Figure 1. Measuring 20 resistors. The set-up makes for speedy measurements — we simply had to move the red probe across the top connections to measure each resistor.

[1]I am trying to pretend that I am EE 201 n00b. In reality, it took me about 30 minutes for all measurements. -G.T.

We read the color codes for each of the resistors, translated those to resistor values, and then measured the resistances using the ohm-meter. For each we calculated the variance of the measured value from the nominal value. The calculation for relative difference is 100 x (measured – nominal) / nominal. The results are shown in Table 1 below.

Table 1. Summary of resistance measurements.

color code	nominal value (Ω)	measured value (Ω)	relative difference(%)
brown - green - red	1500	1482.3	-1.18
brown - black - yellow	100,000	99,316	-0.684
brown - black - red	1000	979.6	-2.04
yellow - purple - brown	470	464.9	-1.09
red - red - black	22	22.5	2.27
yellow - violet - black	47	46.84	-0.34
blue - grey - red	6800	6709	-1.34
brown - green - red	1500	1478	-1.47
orange - orange - red	3300	3289	-0.33
brown - black - orange	10,000	9864	-1.36
yellow - violet - yellow	470,000	468,200	-0.38
brown - green - brown	150	151.8	1.20
brown - green - orange	15,000	14,940	-0.40
yellow - violet - black	47	46.36	-1.36
orange - orange - orange	33,000	32,890	-0.33
brown - green - orange	15,000	14,730	-1.80
red - red - red	2200	2179.8	-0.92
red - red - brown	220	218.1	-0.86
blue - gray - orange	68,000	67,400	-0.88
brown - black - yellow	100,000	99,980	-0.02

All resistors were well within the expected 5% tolerance. Most (but not all) measured values were below the nominal. The "average difference" (average of the absolute value of the relative differences) was 1.013%.

Resistor power rating

We took a 100-Ω resistor from the kit (measured value of 99.4 Ω) and inserted it into the breadboard with the variable 25-V source connected across it. The resistor is rated at 0.25 W, meaning that it should be able to dissipate 0.25 W — converting it to heat — indefinitely. For a 100-Ω resistor, 0.25 W correspond to 5 V and 50 mA.

We started with the power supply set at 1 V, and then began the incrementing the source in 1-V steps while observing the resistor to see what would happen. The table below gives a running commentary of the experiment. We waited about 30 seconds at each step before incrementing.

Table 2. Burning a resistor at the stake.

voltage (V)	current (mA)	power (W)	comment
1	10	0.01	
2	20	0.04	
3	30	0.09	
4	40	0.16	
5	50	0.25	
6	60	0.36	Noticeably warm
7	70	0.49	Definitely getting hot
8	80	0.64	
9	90	0.81	Ouch! Starting to smell.
10	100	1	
11	110	1.21	
12	120	1.44	Definite dead fish smell.
13	130	1.69	
14	140	1.96	Starting to discolor.
15	150	2.25	Smell is very bad now.
16	160	2.56	Smoke!
17	170	2.89	Outer surface is completely charcoaled.
18	180	3.24	Glowing red!
19	190	3.61	Flames! Board is melting! Power down!!

There were no obvious heating issues until the resistor was well past the rated power. (That's the idea. The resistor should be fine at the rated power, and probably well above that.) The resistor did become noticeably hot at about 1.5 times the rated power. Not surprisingly, the resistor suffered as the power was increased to higher levels. It was smelling noticeably at about 1 W. The plastic coating started to discolor at about 2 W. The magic smoke appeared at 2.5 W. The resistor started to glow at about 3 W, and momentarily caught fire. At that point, the plastic breadboard was melting badly. However, the plucky little resistor never gave up — it continued to conduct current until we decided it would be a good idea to pull the plug. The photographs below bear witness to the experiment.

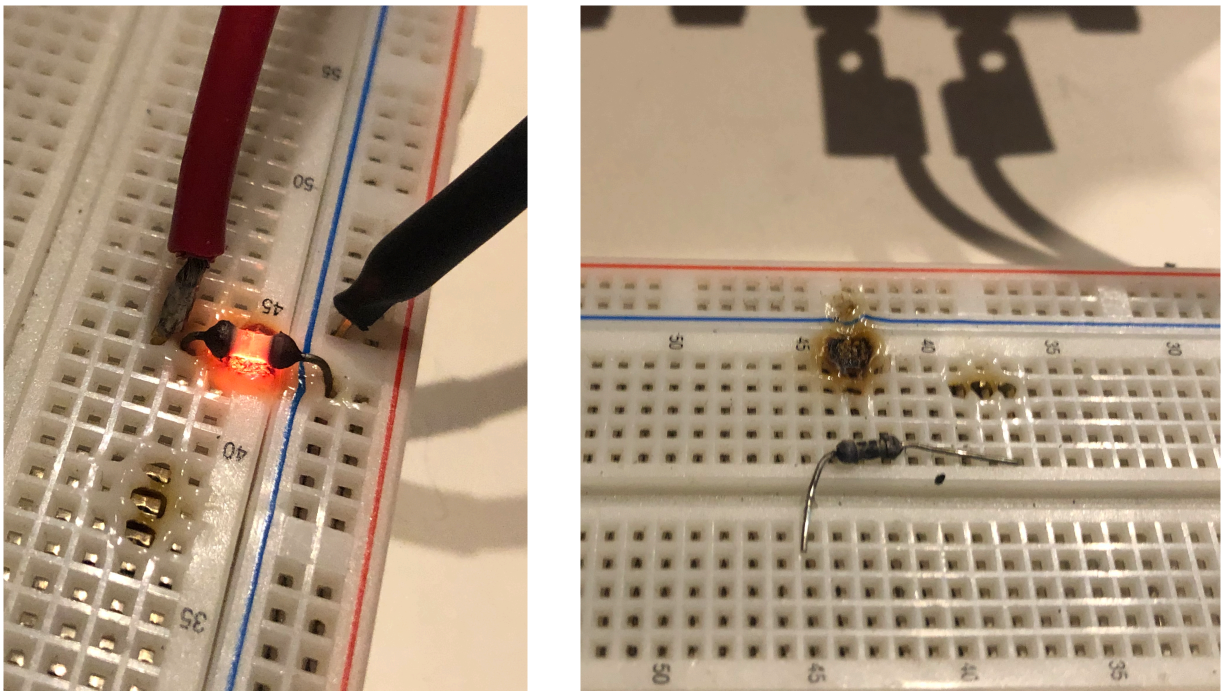


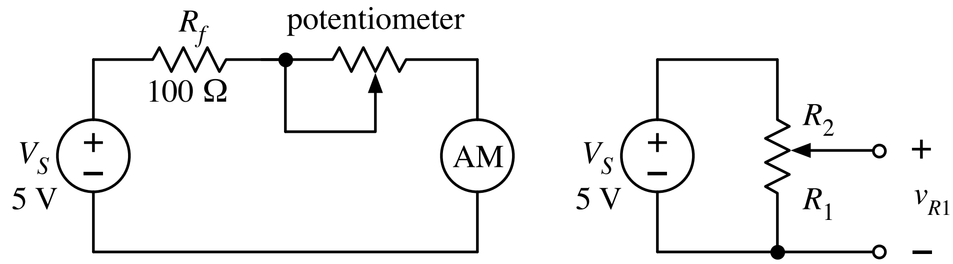
Figure 3. Photographs from the resistor power rating experiments: On the left is the glowing resistor. On the right are the carcass of the toasted resistor and the resulting board damage.[2] (Note that this board had witnessed an earlier, somewhat less severe, thermal event.)

[2] It might have been wise to leave longer leads for this resistor so that it was not be touching the board. ☹️

Potentiometers

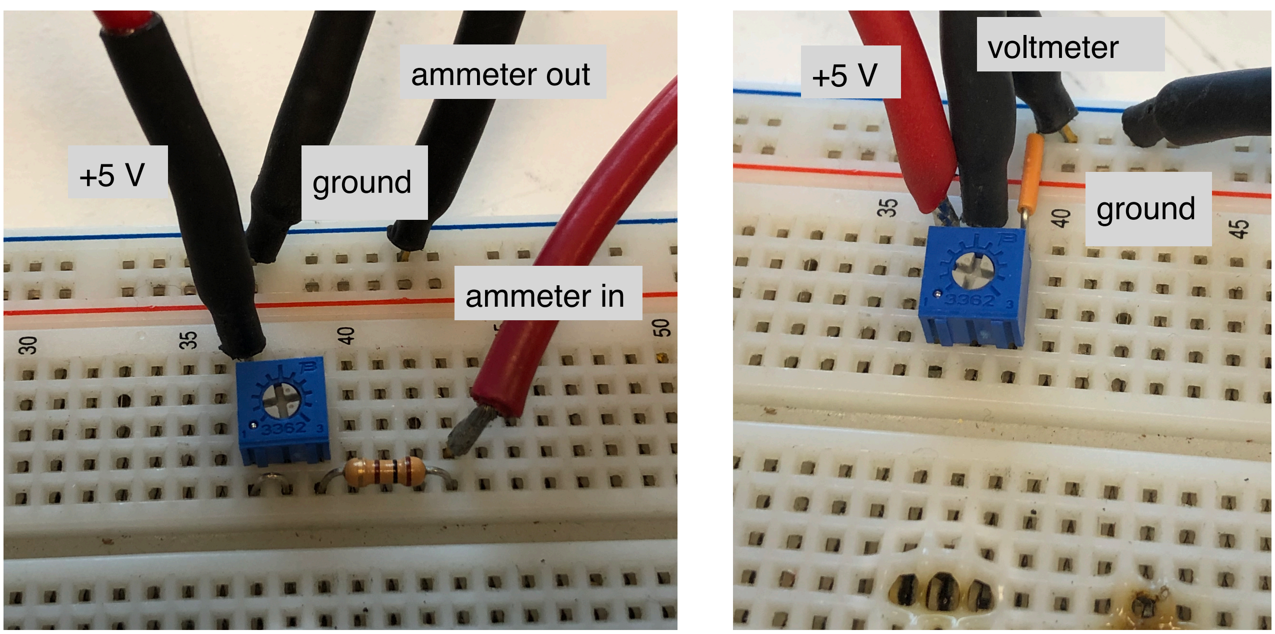
Next, we performed two simple exercises with a 10-kΩ potentiometer (actual value 9.286 kΩ). In the first, the potentiometer was connected as a variable resistor (rheostat) to control the current flowing from a voltage source, as shown in Fig. 4(a) below. In the second exercise, shown in Fig. 4(b), the potentiometer was connected as a variable voltage divider, like a volume control in an audio circuit.

Figure 4.



(*a*) (*b*)

Figure 5. Potentiometer configurations.

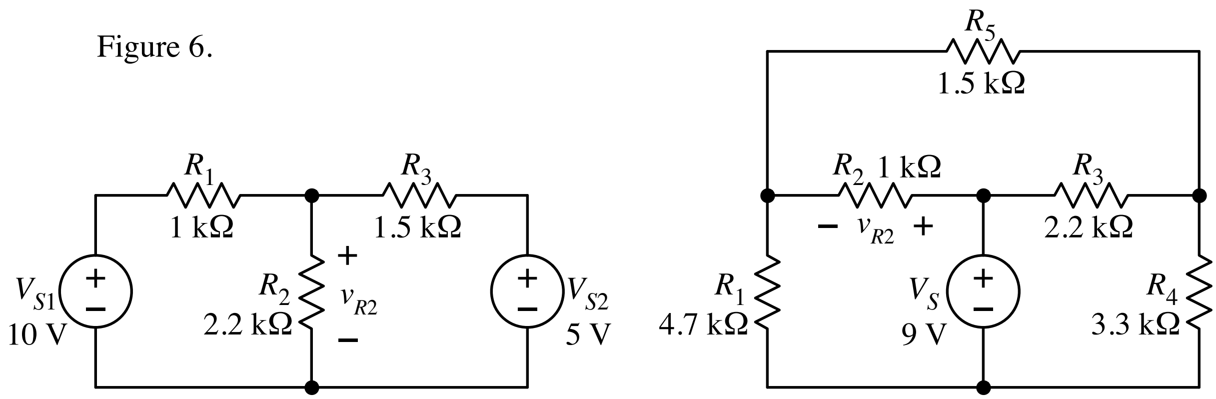


In the variable resistor application, varying the potentiometer through its full range changed the current from 0.53 mA (full resistance) to 47.1 mA (potentiometer turned to zero). These numbers matched the expected values within the resistor tolerances. For the voltage divider the application, the voltage on the "wiper" with respect to ground varied smoothly from 0 to 5 V, as expected.

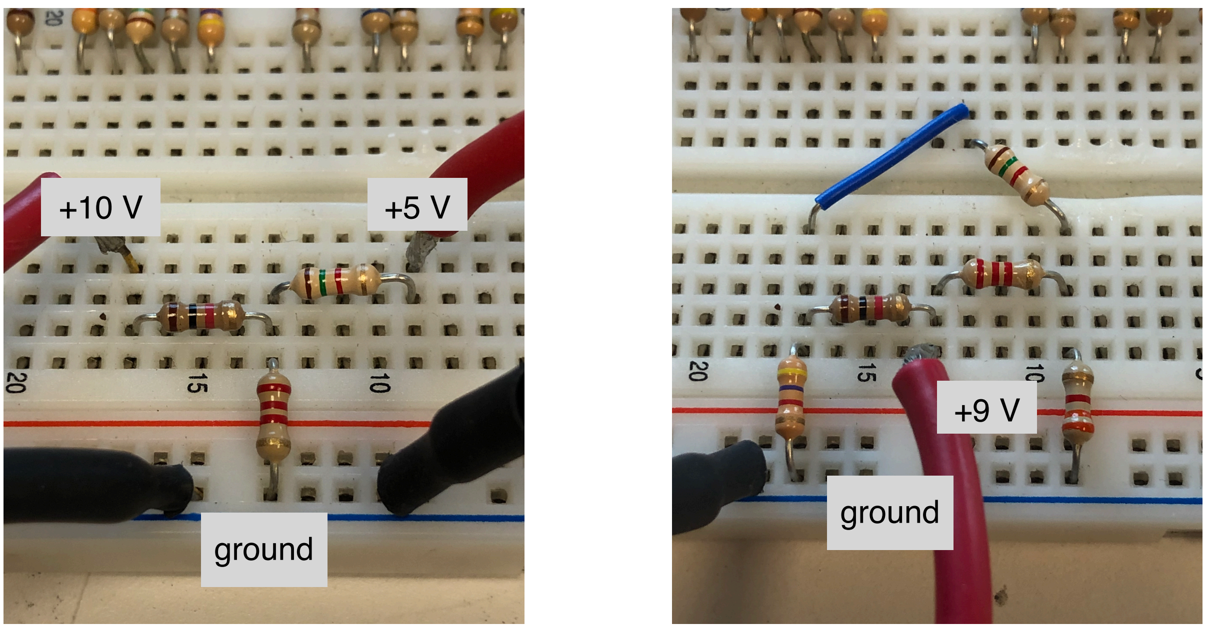
Kirchoff's Laws

The two circuits in Fig. 6 below are identical to examples from the Kirchoff's Laws practice problems. Now we do them in lab.

Figure 6.



(*a*) (*b*)



For circuit (a), the voltage v_{R2} was measured to be 6.302 V. Then we can calculate the other values.

Using KVL, we calculate that $v_{R1} = V_{S1} - v_{R2} = 3.698$ V and $v_{R2} = V_{S2} - v_{R2} = -1.302$ V. Using Ohm's law, the corresponding currents are: $i_{VS1} = i_{R1} = v_{R1} / R_1 = 3.698$ mA, $i_{R2} = v_{R2} / R_2 = 2.86$ mA, and $i_{VS2} = i_{R3} = v_{R3} / R_3 = -0.868$ mA.

Measurements give $v_{R1} = 3.696$ V and $v_{R3} = -1.300$ V. Everything checks to within the resistor tolerances.

For circuit (b), v_{R2} was measured to be 2.02 V.

Using KVL, we can calculate $v_{R1} = V_S - v_{R2}$ = 6.98 V. Then from Ohm's law, $i_{R1} = v_{R1} / R_1$ = 1.49 mA and $i_{R2} = v_{R2} / R_2$ = 2.02 mA. Using KCL, we can calculate that $i_{R5} = i_{R2} - i_{R1}$ = 0.53 mA. Then back to Ohm's law: $v_{R5} = i_{R5} R_5$ = 0.800 V. Using KVL twice in succession gives, $v_{R3} = v_{R5} + v_{R2}$ = 2.82 V and $v_{R4} = V_S - v_{R3}$ = 6.18. Then find Ohm's law to find i_{R3} = 1.28 mA. Finally, $i_{VS} = i_{R2} + i_{R3}$ = 3.30 mA.

Then we measured to see how we did with the calculations. Using the voltmeter, v_{R1} = 6.97 V, v_{R3} = 2.85 V, v_{R4} = 6.15 V and v_{R3} = 0.83 V. Using the ammeter, we measured i_{VS} = 3.38 mA. It all checks.

Conclusion

In these exercises, we learned about a using the multimeter and the DC power supply along with methods for doing DC measurements. In addition, we learned about using the breadboard and wires to make clean and efficient circuit layouts, and we learned the color code for labeling resistor values. The multimeter and DC supply were straight-forward to use, and we expect to make good use of those in future labs.

Using the instruments:

- We measured a collection of resistors and learned about component tolerance.
- We tortured a hapless resistor to learn about power ratings and the perils of heat in a circuit.
- We performed some simple experiments with potentiometers to learn how they might used in future circuits.
- We did lab versions of two Kirchoff's-law practice problems and confirmed that Kirchoff's Laws are still working after 150 years of use.

We managed to do all these things without starting any major fires[3] or being electrocuted. (And hopefully, we did not contract the corona virus.) Taken altogether, these seem like significant accomplishments.

[3] Only minor fires were encountered.