Lab 3: Introduction to Laboratory Equipment

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Introduction

Now we are on to physical electronics. With a multi-meter, resistors, capacitors, inductors, transistors, and all other sorts of electronic components, many circuits can be experimented with like some are here. The resistor band patterns are incredibly important for differentiating resistors. Waveforms is likewise a very important piece of software for testing circuits. Working with these tools and components will increase theoretical and practical understanding.

Exercise 1

The circuit schematics are in the order they appear in the instructions. The 1 V power supply is arbitrary.

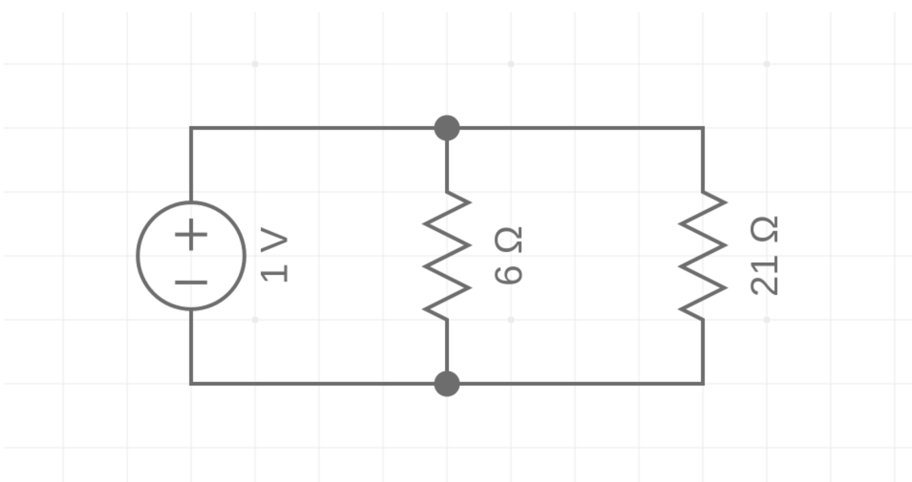

Figure 1: Circuit 1

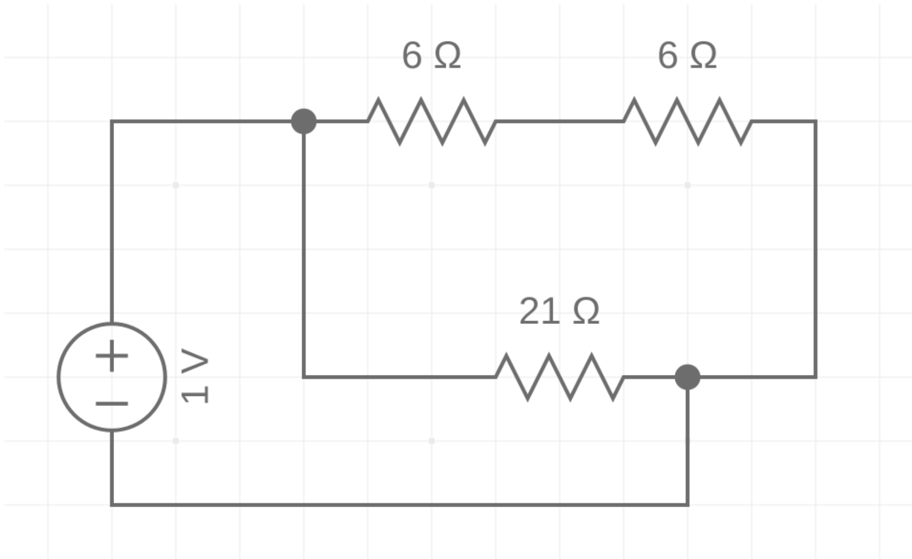

Figure 2: Circuit 2

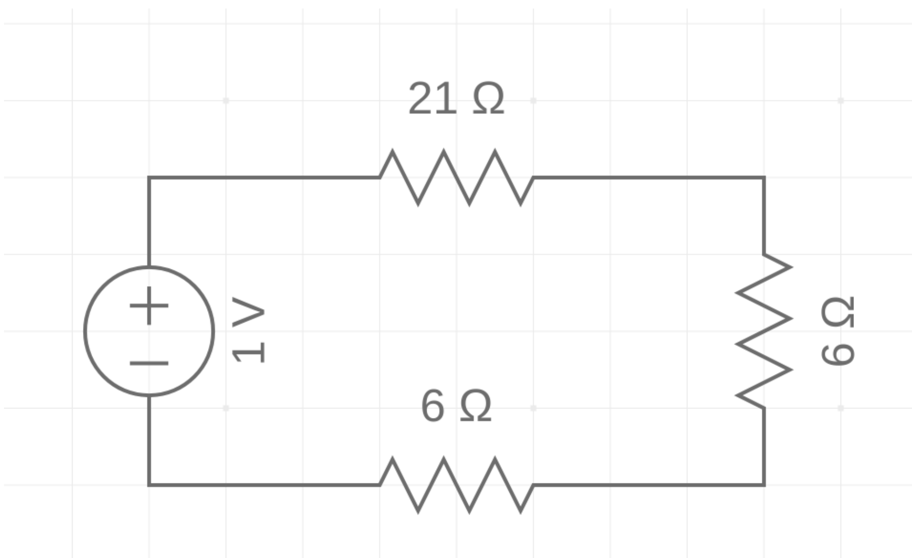

Figure 3: Circuit 3

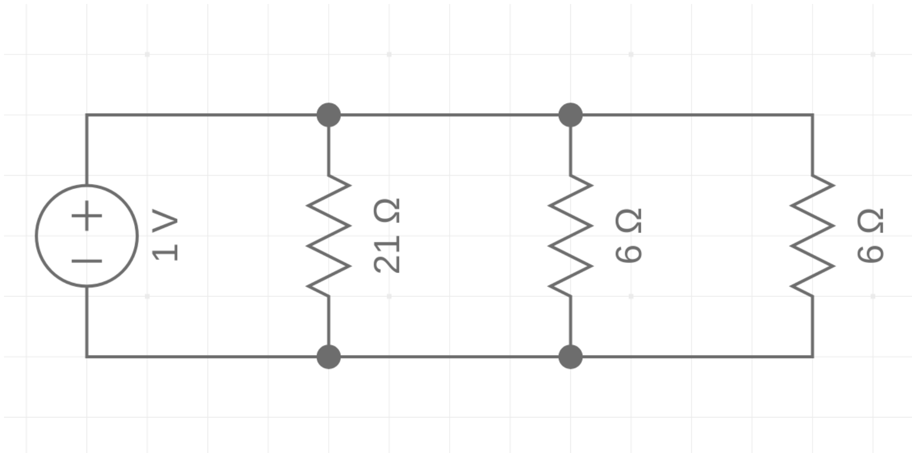

Figure 4: Circuit 4

Exercise 2

Part 1

1st band	2nd band	3rd band	4th band	Resistance ± Tolerance
Orange	Orange	Red	Silver	3300 ohm ± 10%
Green	Blue	Red	No band	5600 ohm
Brown	Black	Orange	Gold	10000 ohm ± 5%
Black	Brown	Brown	No band	10 ohm

Part 2

Resistor	1	2	3
Nominal	100	100	470
Measured	98.1	99.7	465

How much of a difference is there between the ideal and true resistance values? Not much.

Does this fit in the acceptable tolerance limits? Yes.

Part 3

	Resistance (Ohm)	Case (Imperial)	Tolerance (%)	Price (USD) for 10 pcs
#1	12M	0201	1%	2.67×10^{-6}
#2	0	0201	1%	0.021
#3	10k	0603	0.01%	14.1
#4	500G	2512	20%	97.9
#5	50	0603	1%	0.001

Exercise 3

The experimental setup:

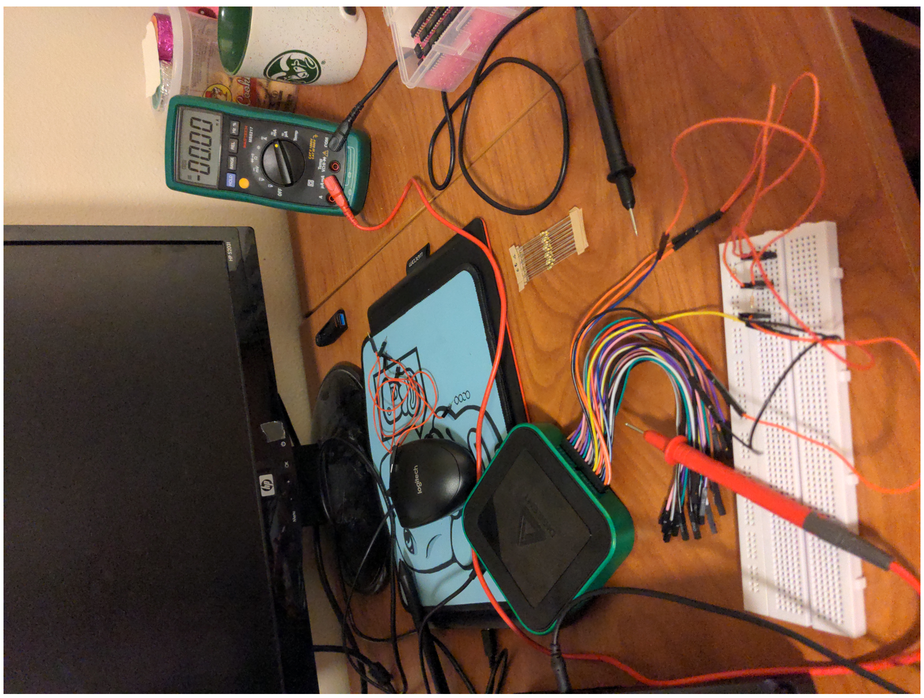

Figure 5: Setup

The resistors values chosen are:

$$R_1 = 470\Omega$$

$$R_2 = 100\Omega$$

V_S (V)	V_1 (V)	V_2 (V)	I (mA)	$V_1 + V_2$ (V)	V_1/R_1 (mA)	V_2/R_2 (mA)
-5	-4.08	-0.84	-10.65	-4.92	-8.6	-8.4
-4	-3.25	-0.66	-8.51	-3.91	-6.9	-6.6
-3	-2.44	-0.48	-6.38	-2.92	-5.1	-4.8
-2	-1.61	-0.31	-4.24	-1.92	-3.4	-3.1
-1	-0.79	-0.14	-2.11	-0.93	-1.6	-1.4
1	0.86	0.21	2.13	1.07	1.8	2.1
2	1.68	0.38	4.25	2.06	3.5	3.8
3	2.51	0.55	6.38	3.06	5.3	5.5
4	3.33	0.73	8.52	4.06	7.0	7.3
5	4.15	0.91	10.66	5.06	8.8	9.1

Exercise 4

a) Since the resistors are in series, they all have the same current, which is the voltage drop across the resistor divided by the resistance, Ohms' Law:

$$I = \frac{V}{R}$$

b) Yes. The loop which goes from the positive terminal and ends at the negative terminal of the voltage source (ground) has a voltage sum equal to zero.

c) The sign of the voltage would swap, since the voltage across the two wires would be swapped.

d) The sign switched for the *calculated* current, but, physically, no.

e) The absolute value of the measured voltages still fufill KVL, although the measured voltages are contray to the sign convention.

Exercise 5

Code in Python; I can easily do MATLAB (I took CBE 160), but Python is significantly more readable, which works better for a lab report:

```
import numpy as np
import matplotlib.pyplot as plt

v1 = np.array([-4.08, -3.25, -2.44, -1.61, -0.79, 0.86, 1.68, 2.51, 3.33, 4.15])
v2 = np.array([-0.84, -0.66, -0.48, -0.31, -0.14, 0.21, 0.38, 0.55, 0.73, 0.91])

i = np.array([-10.65, -8.51, -6.38, -4.24, -2.11, 2.13, 4.25, 6.38, 8.52, 10.66])

m1, b1 = np.polyfit(i, v1, 1)
```

```
m2, b2 = np.polyfit(i, v2, 1)

plt.title("Resistor Voltage vs Measured Current")
plt.xlabel("Current [mA]")
plt.ylabel("Voltage [V]")
plt.grid()
plt.scatter(i, v1)
plt.scatter(i, v2)
plt.plot(i, m1 * i + b1)
plt.plot(i, m2 * i + b2)
plt.legend(
    [
        "R1",
        "R2",
        f"{round(m1, 3)}i + {round(b1, 3)}",
        f"{round(m2, 3)}i + {round(b2, 3)}",
    ]
)
```

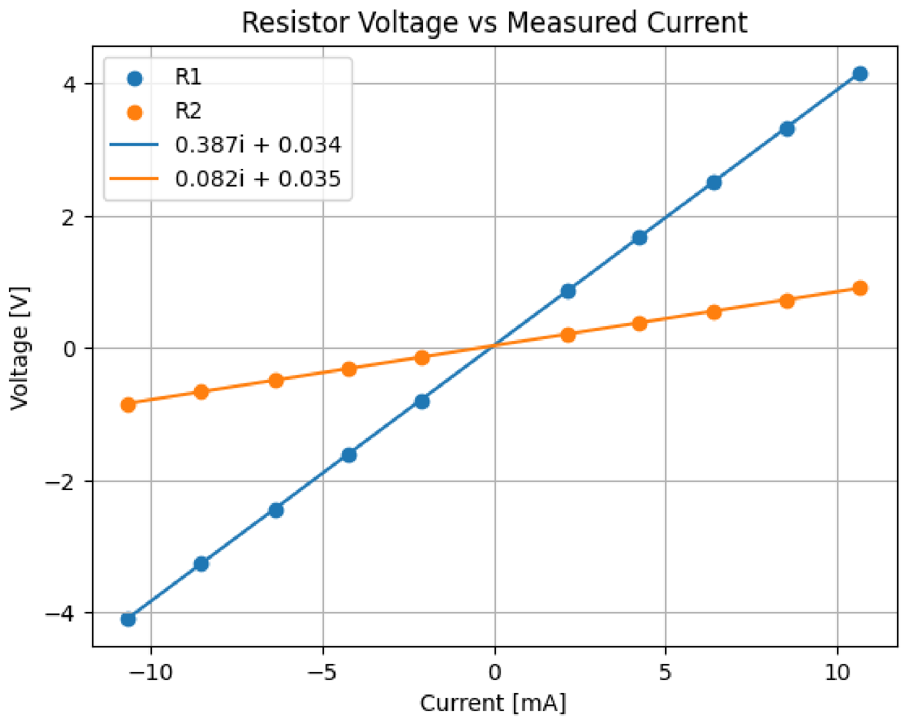

Figure 6: Graph

Converting the slope valuse (resistance) from milli-ohms to ohms yields:

	R1	R2
Measured	387	82
Nominal	470	100

The values from the lines of best fit are similar to the real values, but are still off by 83 for R1 and 18 for R2. This error is within reason for the magnitudes of the resistors.

Exercise 6

Another 100 ohm resistor (R3) was added in parrellel with the other 100 ohm resistor (R2).

V_S (V)	V_1 (V)	V_2 (V)	I (mA)	$V_1 + V_2$ (V)	V_1/R_1 (mA)	V_2/R_2 (mA)	V_3/R_3 (mA)
-5	-4.48	-0.44	-10.57	-4.92	-9.5	-4.4	-4.4
-3	-2.95	0.02	-6.3	-2.93	-6.2	0.2	0.2
-1	-0.94	0.2	-2.09	-0.74	-2.0	2.0	2.0
1	1.03	0.04	2.09	1.07	2.0	0.4	0.4
3	3.03	0.04	6.31	3.07	6.4	0.4	0.4
5	5.01	0.05	10.54	5.06	10.0	0.5	0.5

a) Unlike the first circuit, there is a current divider across the two resistors (R2, R3) which are in parrelel. The current across each is given by:

$$I_x = \frac{R_T}{R_x + R_T} I_T$$

where I_x is the current across the desired resistor, I_T is the total current entering all the resistors in parallel, R_x is the resistor in question, and R_T is the equivalent resistance of all the other resistors.

Or, if the voltage between the nodes is known, Ohms' Law can be used for each resistor separately.

b) Yes. Same explanation as exercise 4.

c) Yes. The current across R1 is equal to the sum of the currents across R2 and R2, for the most part (some issue arose when measuring the voltage drops for a positive source).

d) Explained in exercise 4, (c).

e) No, but current follows the passive sign convention, so there is a change in the current's sign, assuming the direction of current is set by convention.

Conclusion

After finishing all the exercises, I realized how finicky some of the electronics were. Regardless, I learned how to identify resistors and use a breadboard. Using the Waveforms software also helped me understand how to interact with electronics through a computer interface, which allows for more complex circuits. These skills will be essential for future labs and other practical applications.