Lab 2 - Kirchhoff's Circuit Rules

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Overview

In Labs 2 you studied Ohm's Law and learned how different combinations of resistors in series or parallel resulted in an equivalent resistor. It turns out there are rules that define how these equivalent resistances work. They are Kirchhoff's Circuit Rules. There are two rules. The first rule is the junction rule. The sum of the currents flowing into a junction is equal to the sum of the current flowing out of a junction.

$$\Sigma I_{in} = \Sigma I_{out} \tag{1}$$

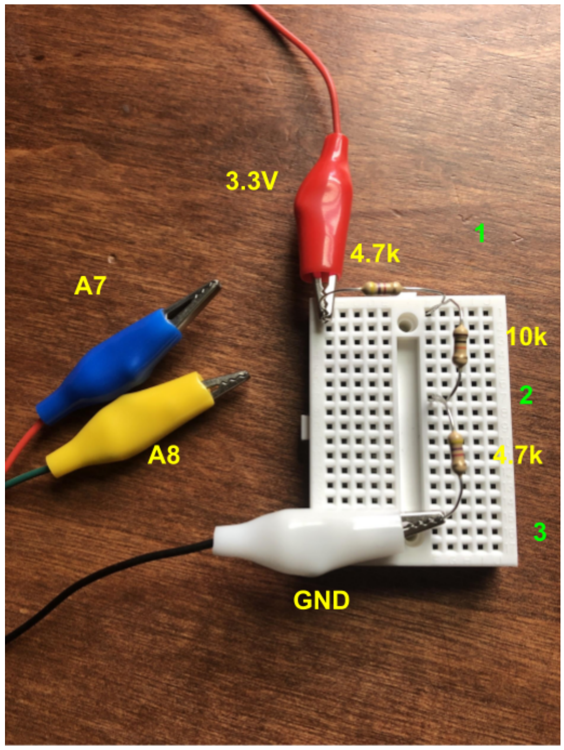
The foundation for this rule is that electric charge is conserved. The second rule is the loop rule. The sum of the voltages around a loop is zero.

$$\Sigma V = 0 \tag{2}$$

The foundation for the loop rule is that energy is conserved. In this lab you are going to construct circuits to test these rules.

Part 1 - Kirchhoff's Loop Rule

Construct a circuit with a 10kΩ (brown, black, orange, gold) and two 4.7kΩ (yellow, purple, red, gold) resistors in *series*. The three resistors along with the 3.3V supplied by the iOlab make a loop circuit. Your circuit should look like this:



- Red alligator clip is connected to 3.3V.
- Blue alligator clip is connected to A7.
- Yellow alligator clip is connected to A8.
- White alligator clip is connected to GND.

The blue and yellow alligator clips are intentionally not connected to the circuit because you will move the clips to three positions around the circuit loop and measure the voltage.

Think back to Lab 2 - Ohm's Law when you constructed a circuit with resistors in series. The two resistors in series had an equivalent resistance of R_s equal to the sum of the individual resistor:

$$R_s = R_1 + R_2$$

1. If two or more resistors are in series, what must be true about the *current* through each resistor? Explain your answer.

With 2 or more resistors in series, the current through each resistor is reduced, the total reduction in current through resistors must be equal to the original current.

2. Using Ohm's Law $V = IR$ and Kirchhoff's Loop Rule, derive the equation for the equivalent resistance for resistors in series. Show your work.

$$V_1 + V_2 + V_3 = \emptyset$$

$$V = IR$$

$$I = \text{constant}$$

$$\cancel{I}(R_1) + \cancel{I}(R_2) + \cancel{I}(R_3) = 0$$

$$R_1 + R_2 + R_3 = 0$$

$$+R_1 + {}^{-}R_2 + R_3 \leftarrow$$ To make equal to 0, at least one must be negative

$$R_1 = R_2 + R_3$$

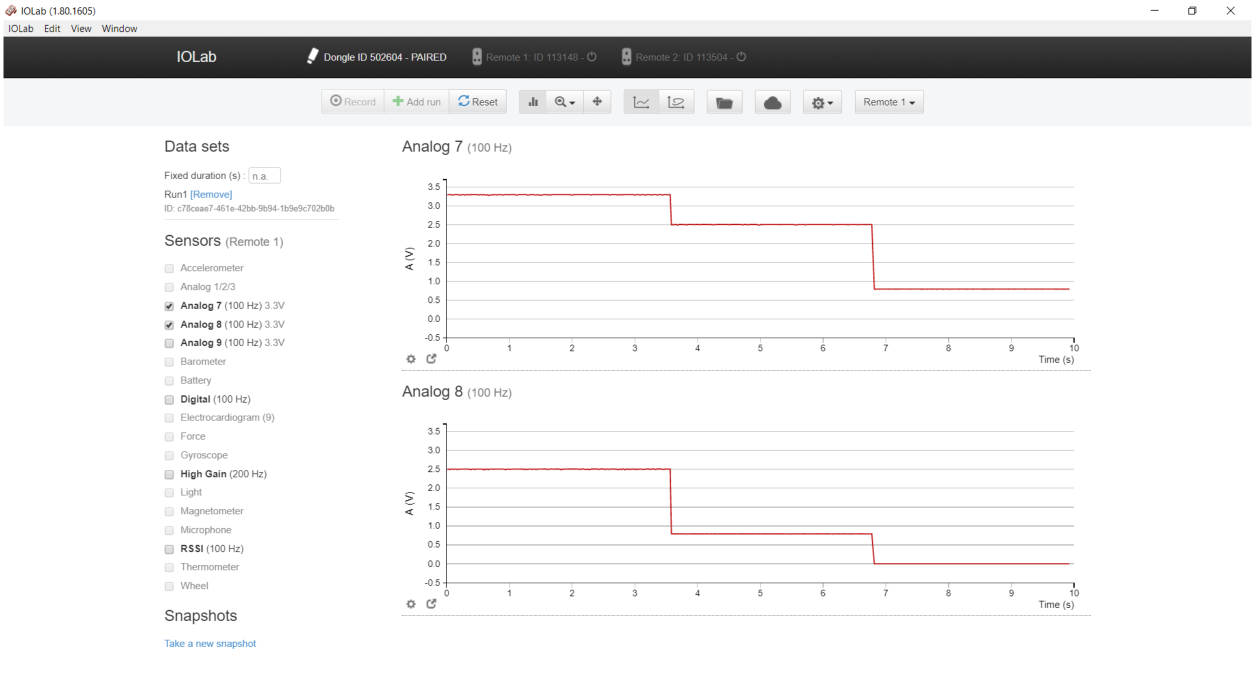
Setup the iOLab and application:

- Launch the iOlab application on your computer.
- Make sure the dongle is connected to the USB port of your computer and the iOLab is turned on.
- Check the A7 and A8 sensors.

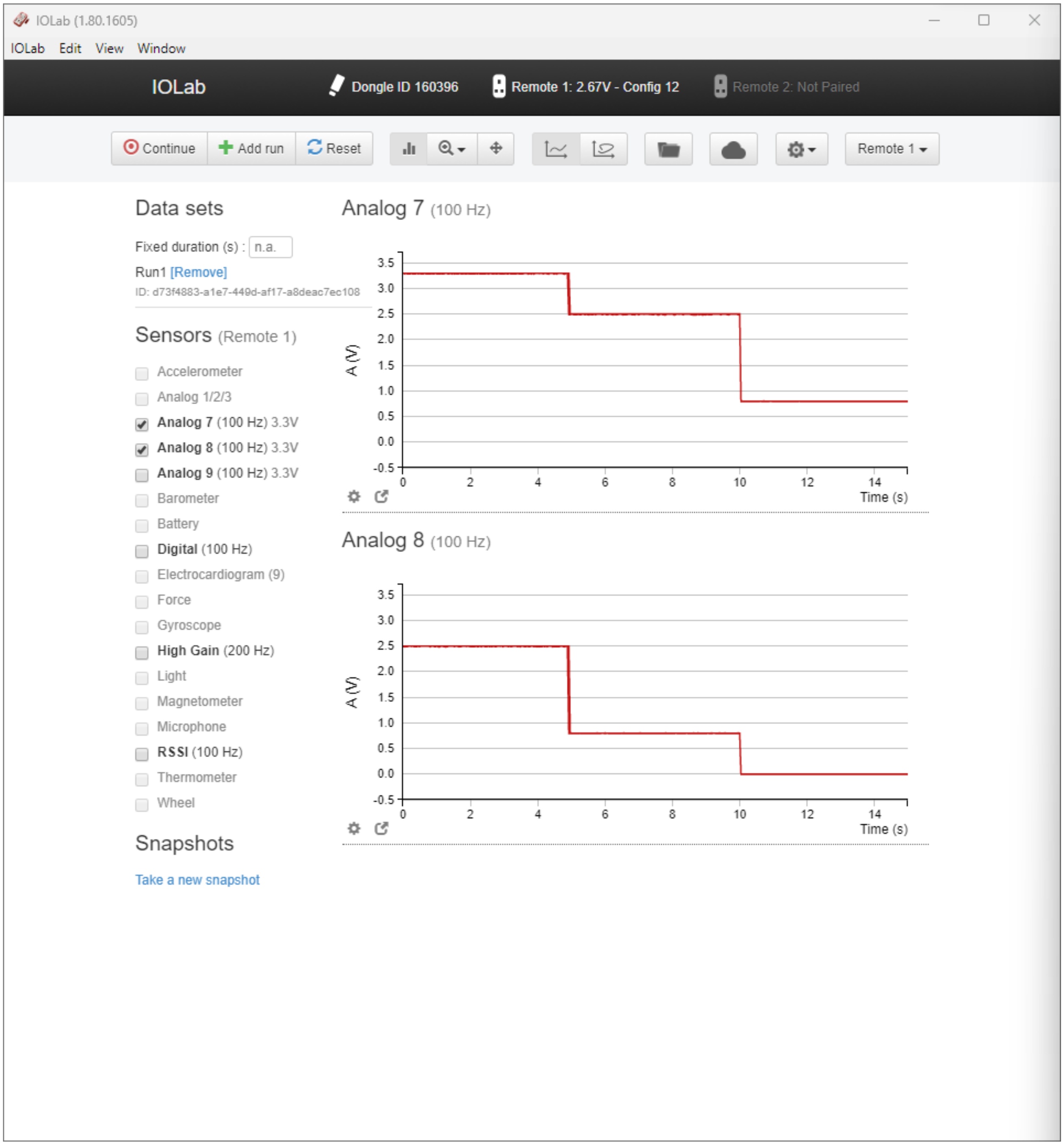
Now it’s time to take some data:

- Across the first resistor, connect the blue clip to the red clip position and connect the yellow clip to position 1.
- Click and record for about 5 seconds then stop.
- Across the second resistor, connect the blue clip to position 1 and move the yellow clip to position 2.
- Click continue and record data for 5 seconds then stop.
- Across the third resistor, connect the blue clip to position 2 and the yellow clip to position 3.
- Click continue and record data for 5 seconds then stop.

When you are done your data should look something like this:



3. Take a screenshot of your iOLab application with the data and paste here:



4. Notice that the voltage measured by A8 is *lower* than A7. Does that mean the voltage across a resistor rises or drops? Explain your answer.

The voltage across a resistor drops, this is because the measured voltage before the resistor is higher than after the resistor. According to ohms law, voltage drops across the resistor.

Now record the values of voltage of A7 and A8 for the three positions. You can record your measurements in this spreadsheet:

Kirchhoff's Circuit Rules - Student Data

You need to make a copy of the spreadsheet first. In the spreadsheet click the menu File>make a copy.

5. Use the Analysis Mode in the iOLab application and record the voltages measured by sensors A7 and A8 in the spreadsheet for the three positions.

6. For each position, calculate the difference A8 - A7. This is the voltage across each of the three resistors.

7. Calculate the *sum* of the voltages across the three resistors. Record the sum in the table below:

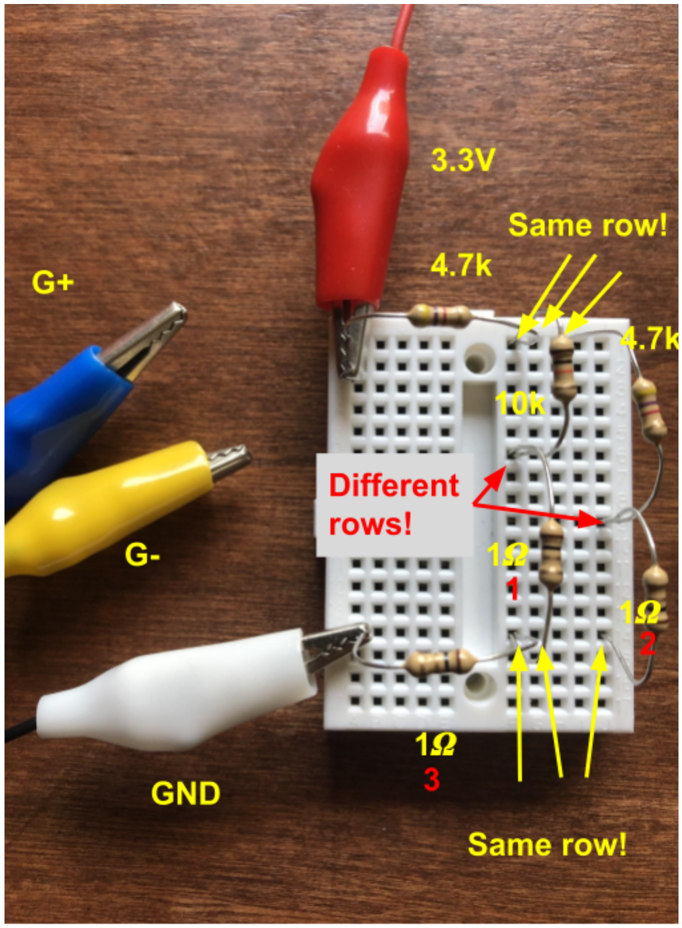
Sum of Voltage across Three Resistors (V)
-3.3 V

8. How does the sum of voltages across the three resistors compare to the 3.3V supplied by the iOLab? Explain your answer in terms of the loop rule in Eq. (2).

The sum of the voltages across the 3 resistors is exactly the same as the supplied voltage. This follows the loop rule, because in that rule it states that all voltages must add to 0, therefore the resistances must cancel out the original voltage.

Part 2 - Kirchhoff's Junction Rule

Now you are going to construct a circuit with a junction in it using the same three resistors. You will also need three 1Ω resistors. They will be the ammeters to measure the current in the circuit. Construct a circuit like this:



- The 10k and two 4.7k resistors are connected along the same row at top of the breadboard. This makes a junction
- The three 1Ω (brown, black, gold, gold) resistors are also connected along the same row. This is the junction we will measure the current through.
- Important: The 10k and second 4.7k resistors are in parallel, BUT do not connect the low potentials to the same row. The low potentials should be DIFFERENT rows of the breadboard.
- Red alligator clip connected to 3.3V.
- Blue alligator clips connected to G+.
- Yellow alligator clip connected to G-.
- White alligator clip connected to GND.

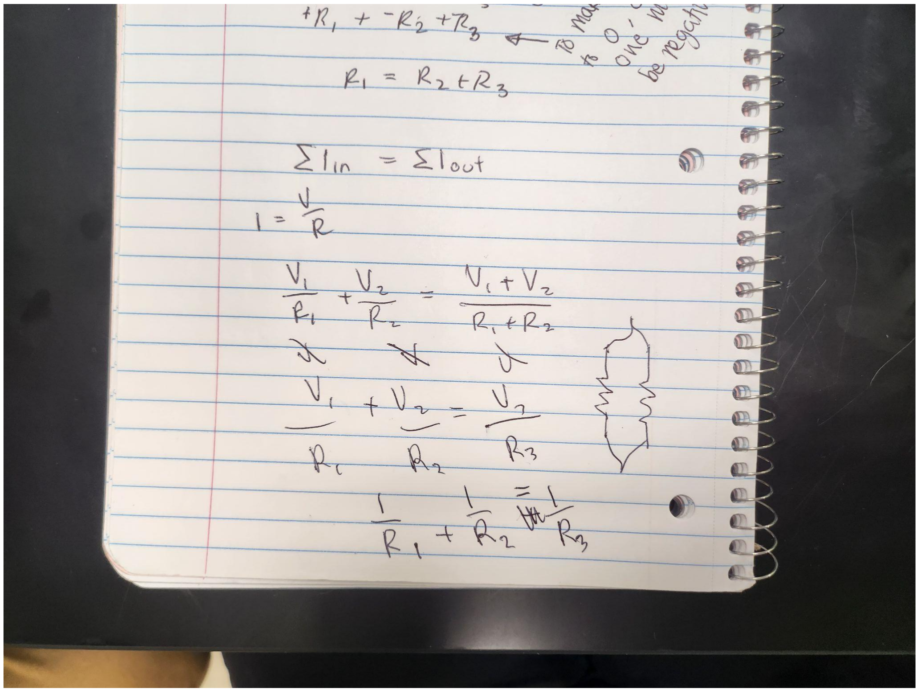
Think back to Lab 2 - Ohm's Law when you constructed a circuit with resistors in parallel. The two resistors in parallel had an equivalent resistance of R_p equal to:

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

9. If two or more resistors are in parallel, what must be true about the *voltage* across each resistor? Explain your answer.

The voltage across the 2 resistors must be equal because the current travels through them at the exact same time.

10. Using Ohm's Law $I = V/R$ and Kirchhoff's Junction Rule, derive the equation for the equivalent resistance for resistors in parallel. Show your work.



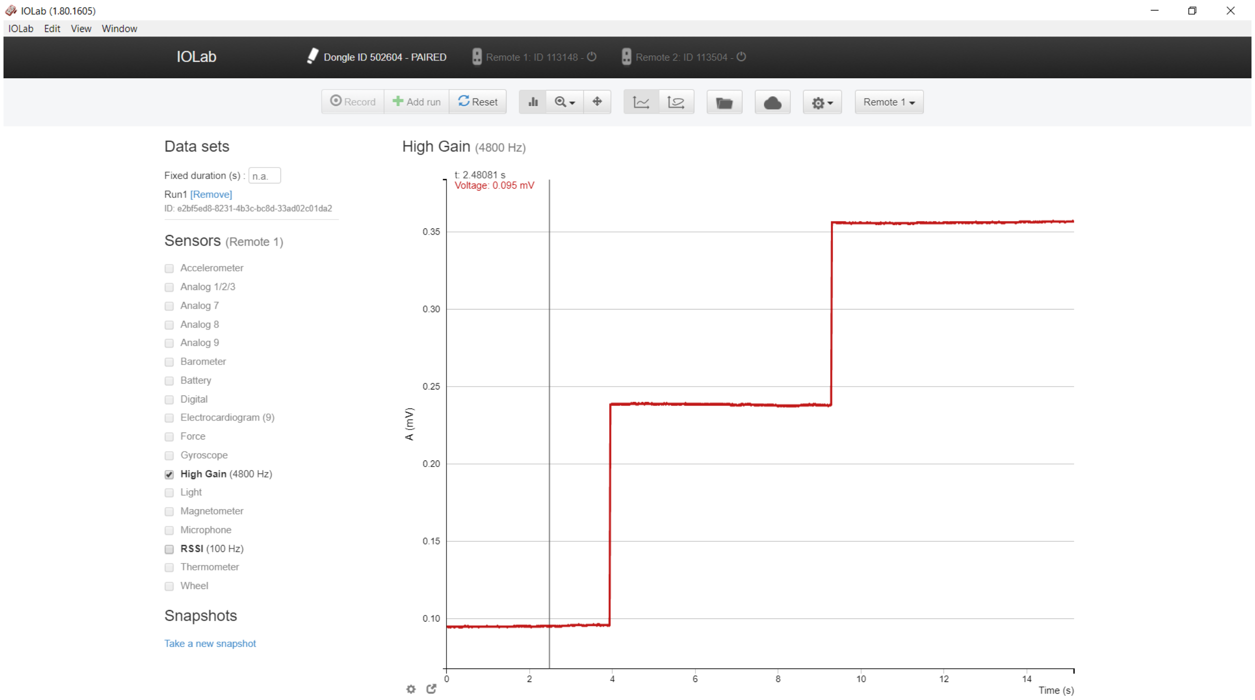
Setup the iOLab and application:

- Launch the iOlab application on your computer.
- Make sure the dongle is connected to the USB port of your computer and the iOLab is turned on.
- Uncheck the A7 and A8 sensors.
- Check the High Gain sensor.

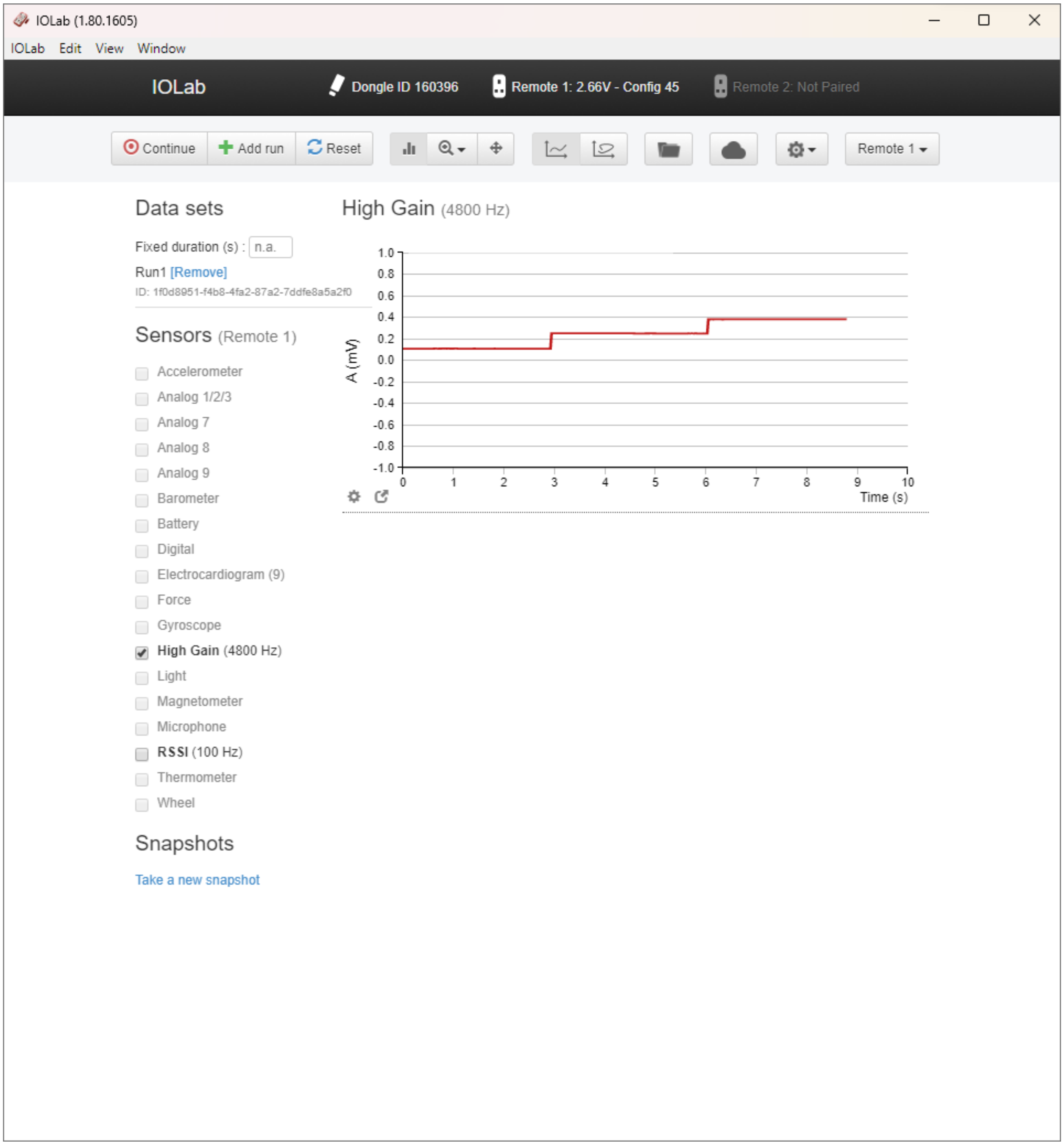
Now it's time to take some data:

- Across the 1Ω resistor #1, connect the blue and yellow clip.
- Click and record for about 5 seconds then stop.
- Across the 1Ω resistor #2, connect the blue and yellow clip.
- Click continue and record data for 5 seconds then stop.
- Across the 1Ω resistor #3, connect the blue and yellow clip.
- Click continue and record data for 5 seconds then stop.

When you are done your data should look something like this:



11. Take a screenshot of your iOLab application with the data and paste here:



Remember the three 1Ω resistors are all connected to the same row on the breadboard. That means that all share the same junction! If there is a junction, then current is flowing through that junction from each of the 1Ω resistors. How much current is flowing? Remember in Lab 2 - Ohm's Law you used a 1Ω resistor as an ammeter by measuring the voltage across the resistor, then divide by 1Ω.

In the spreadsheet Kirchhoff Circuit Rule, click the tab at the bottom that is labeled "Junction Rule."

12. Use the Analysis Mode in the iOLab application and record the current measured by the High Gain sensor for each of the three 1Ω resistors.

13. Which of the 1Ω resistors does current flow INTO the junction? Which of the 1Ω resistors, does current flow OUT the junction?
    The 2 resistors that are just before the last 1 ohm resistor flow INTO the junction, meanwhile the last 1 ohm resistor flows OUT of the junction
14. Add the currents that flow into the junction. Add the currents that flow out of the junction. Record your results in the table below:

ΣI_{in} (mA)	ΣI_{out} (mA)
.35	.38

15. How does ΣI_{in} compare to ΣI_{out}? Explain your answer in terms of the junction rule in Eq. (1).

Current in is less than current out but very close, the junction rule states that current in cancels out current out. So in theory the currents should be the same, but in reality there are some rounding errors that change the real output.