Abstract:
In this experiment we built a Wheatstone Bridge by using four resistors, a power source, and ground source. This allowed us to see how a balanced bridge and unbalanced bridge compared in terms of voltage. We also used a potentiometer which allowed us to adjust the resistance and gave us an output voltage as close to zero as possible. We eventually ended the lab by using a thermistor in place of one of the resistors, this allowed us to see that thermistors have an inverse relationship with resistance. We were able to see that the voltage was affected by the heating of the thermistor, it caused the output voltage to decrease.

Intro:

The Wheatstone Bridge is a circuit named Charles Wheatstone, which is used to measure unknown resistor values. The circuit is often in a diamond orientation and consists of four resistors, a power source, and a voltage output, which can be seen in figure 1 (*Wheatstone bridge*).

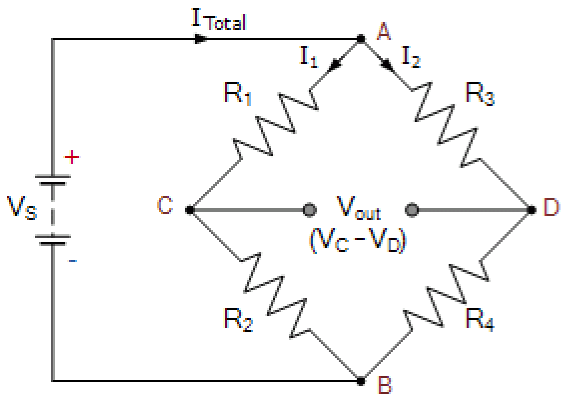

Figure 1

The Wheatstone Bridge is also known as a bridge circuit, which is known to be useful in measuring changes in resistance and to find the value of an unknown resistor, and is balanced when (R1/R2)=(R4/R3). To find the unknown value of a resistor we set up a voltage divider equation and then balance the equations to eventually calculate the unknown value (Stefanovic, F).

A potentiometer is also known as a resistor that can be manually adjusted. A potentiometer has three terminals, one terminal is known as a wiper which has the ability to be adjusted and act as a resistance divider. When the wiper is adjusted we see different values of resistance, which can be seen in figure 2 (Potentiometer).

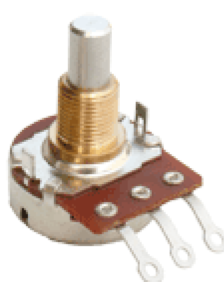

Figure 2

Thermistors are also known as a thermal resistor, which is used to measure temperature, as pictured below in figure 3. Thermistors are semiconductors, which have a decreased resistance as temperature increases, and an increased resistance as temperature decreases (Engineering, O).

Figure 3 (Ago, G.)

In this experiment, we use a Wheatstone Bridge, potentiometer, and a thermistor were used to measure the voltages, resistances, and temperatures of circuits. The Wheatstone Bridge allowed us to measure the unknown resistor values, while the thermistors were used to measure the temperature of the circuit.

Methods:

In the laboratory we performed two experiments, the first experiment only utilized a wheatstone bridge and the second experiment utilized both the wheatstone bridge and thermistor.

Experiment 1:

We start by gathering all of the needed materials: a breadboard, four equals resistors with

A value equal to or greater than 10K Ohms, Elvis Board, wires, and a laptop with the Elvis software. First, we plug the Elvis Board into a power source and we also connect it to the laptop with the Elvis software, this allows us to eventually measure different values for our circuit. Next, we first plug the red power source alligator wire into the V-Ohm-> socket in the Elvis board, and the black alligator wire plugs into the COM socket, allowing it to act as a ground eventually. We then connect one end of a red wire into the +5 input voltage and the other end is plugged into the (+) column, we then use another red wire going from the (+) column to where the first and second resistors meet in the breadboard. The first and second resistors are placed next to each other, both starting in the same row and ending in different locations. We also plug a blue wire at the end of resistor one and we plug a green wire at the end of resistor two, this eventually allows us to measure the output voltage of the circuit. The third and fourth resistors are placed in the same orientation as resistor one and two, except they are further away from the starting point of resistors one and two. We then plug one end of a black wire into the row where the third and fourth resistors end, the other end of the black wire is plugged into the (-) column. We use another black wire to connect the (-) column to the ground socket, which allows us to ground the resistor. We then use two additional circuits to measure the output voltage across the resistor. To do this, we add a wire at the ending point of resistor one and two, and then we connect the red power source alligator wire to the blue wire by resistor one, and the black grounding alligator wire is connected to the green wire by resistor two. The set up of the circuit can be seen below in figure 4. Figure 4 allows us to better visualize how the wires are connected in the breadboard and where the alligator wires are connected to the circuit to measure the output voltage.

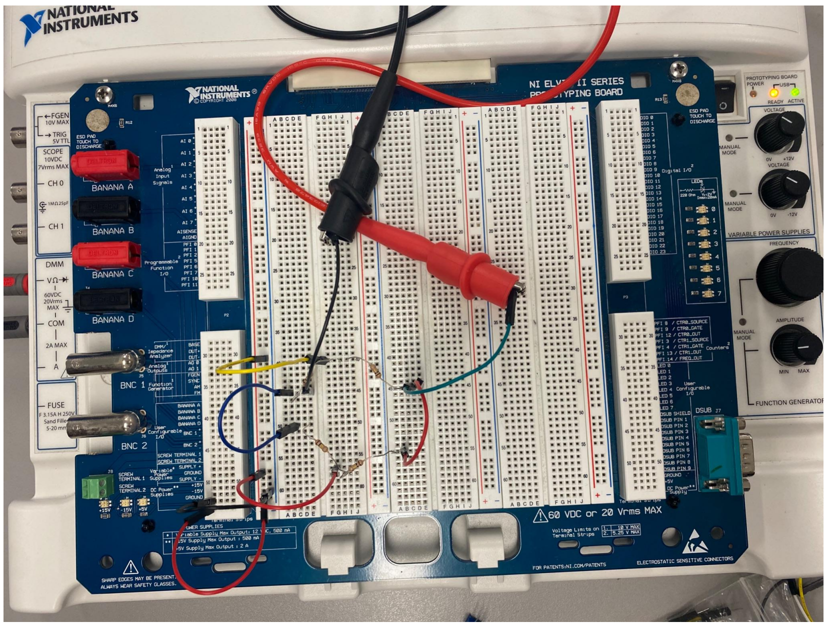

Figure 4

After connecting the 5V DC power source and ground wires, we use the DMM application in the Elvis software, allowing us to measure the output voltage. We then create a hand drawn schematic of the Wheatstone Bridge, which includes the resistor values, and then we calculate the theoretical output voltage of the circuit.
Next, we measure the actual resistance of each individual resistor by using the DMM resistance application within the Elvis software, we are then able to re-calculate the theoretical output voltage and compare that to the original theoretical value.
We then add a potentiometer right next to the resistor on the bottom right, also known as resistor two, as seen in figure 5. We have to adjust the potentiometer until we get a value that is as close to zero as possible. Next we draw another schematic of this new circuit, and we also create this circuit on TinkerCAD. This circuit is shown below in figure 5.

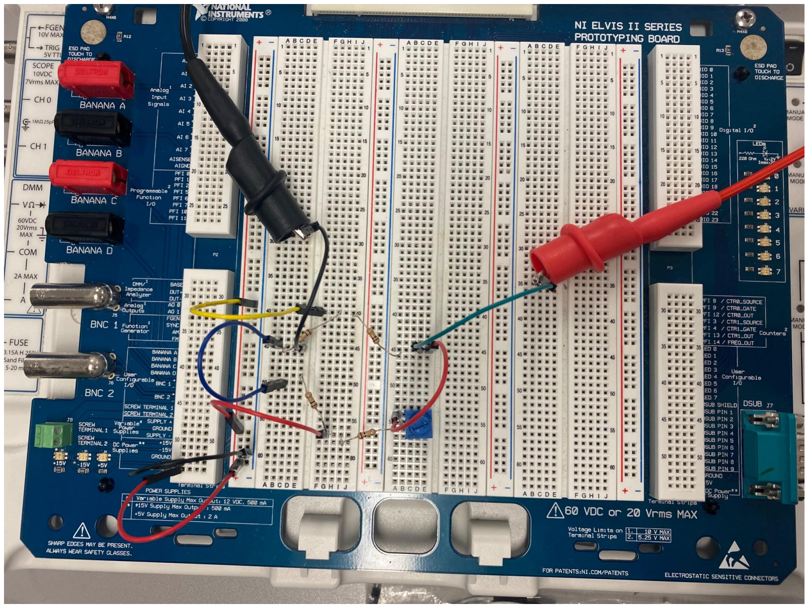

Figure 5

Experiment 2:

For experiment two we are able to keep the same breadboard set up, except we must switch out our current resistors and instead use resistors with a value of about 10K Ohms. We then remove resistor four and replace it with a thermistor. Next we measure the output voltage by utilizing the DMM multimeter function in the Elvis software, which is done by connecting probe one to the positive Bout and probe two to the negative Vout node and the difference is then calculated. We then removed the thermistor and held it in our hand for a few minutes, this allowed the thermistor to warm up. Next the thermistor must be re-inserted into the circuit and we measure the output voltage of the circuit. This set up of the circuit can be seen below, in figure 6.

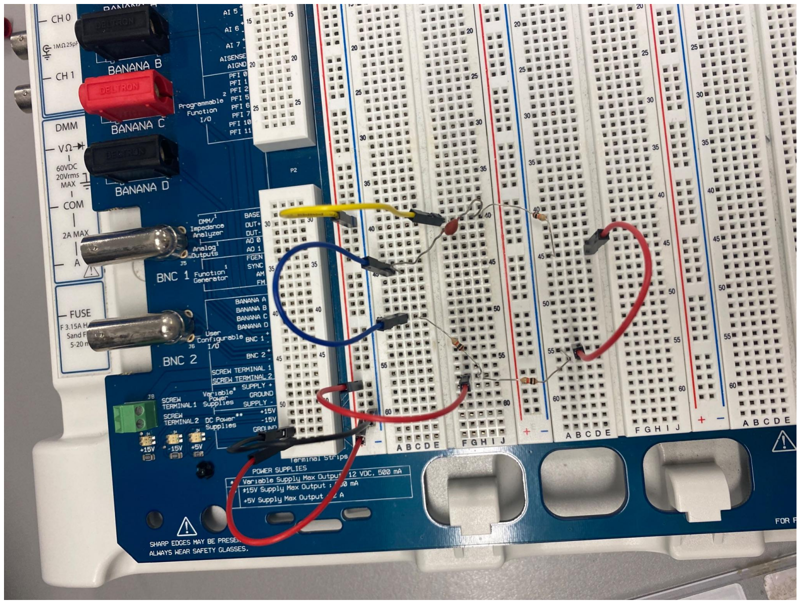

Figure 6

Results:

Experiment 1:

When setting up the Wheatstone Bridge circuit we had to measure the resistor values to make sure they were larger than 10K Ohms, our resistor values were: R1=99.2K Ohms, R2= 98.8K Ohms, R3=98.8K Ohms, and R4= 99.1K Ohms. We then used the 5V DC input voltage and measured the output voltage6 to be about 0.004mV DC. Before running the experiment we each created a hand drawn schematic of the Wheatstone Bridge circuit and we also calculated the theoretical output voltage to be zero since the circuit is balanced, which can be seen below in figure 7.

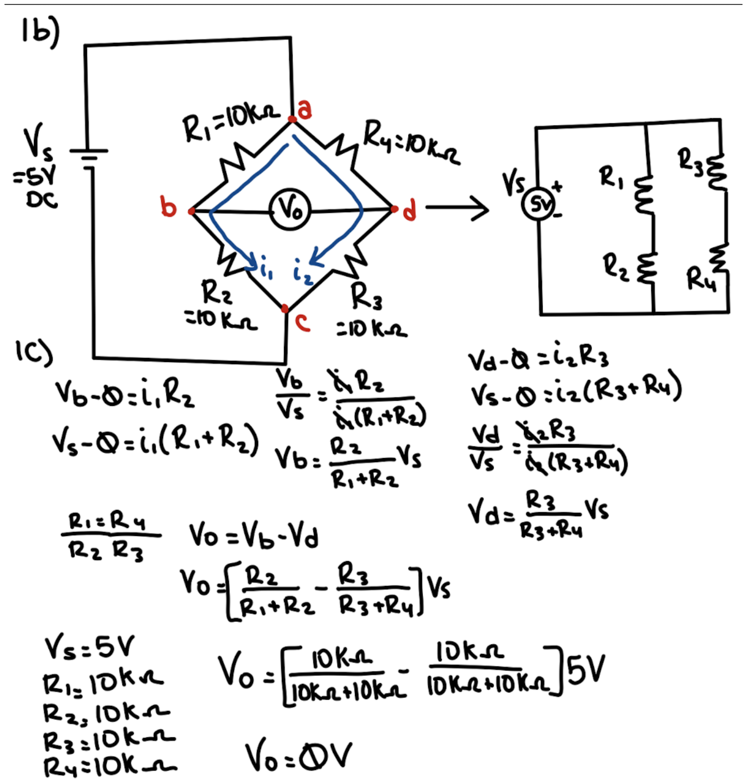

Figure 7

The theoretical and measured values did differ for the output voltages, 0V in comparison to 0.004mV, but the difference is extremely small. The circuit can also be seen below in figure 8 and the multimeter value shown was 0.004mV. The actual resistance values of each resistor can be seen below in table 1.

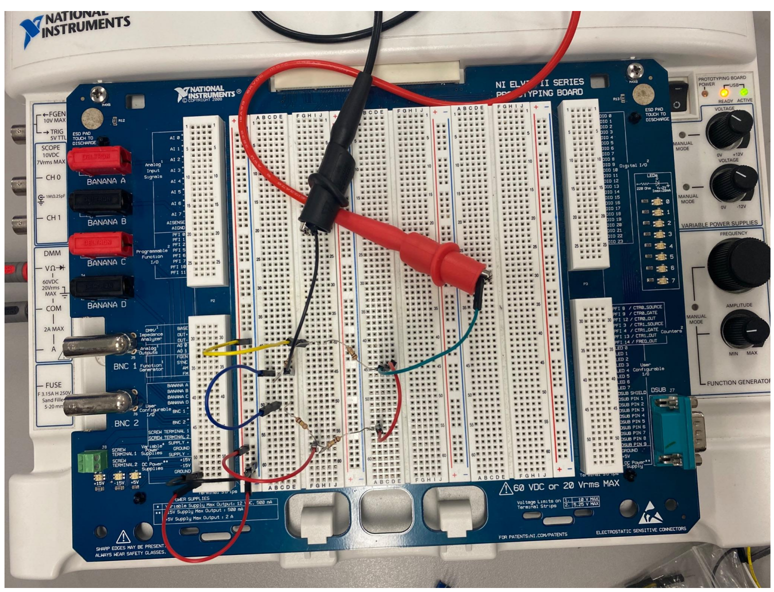

Figure 8

Resistor	Value
1	99.2K Ohm
2	98.8K Ohm
3	98.8K Ohm
4	99.1K Ohm

Table 1

We then re-calculated the theoretical output voltage using the measured resistor values, which can be seen below in figure 9.

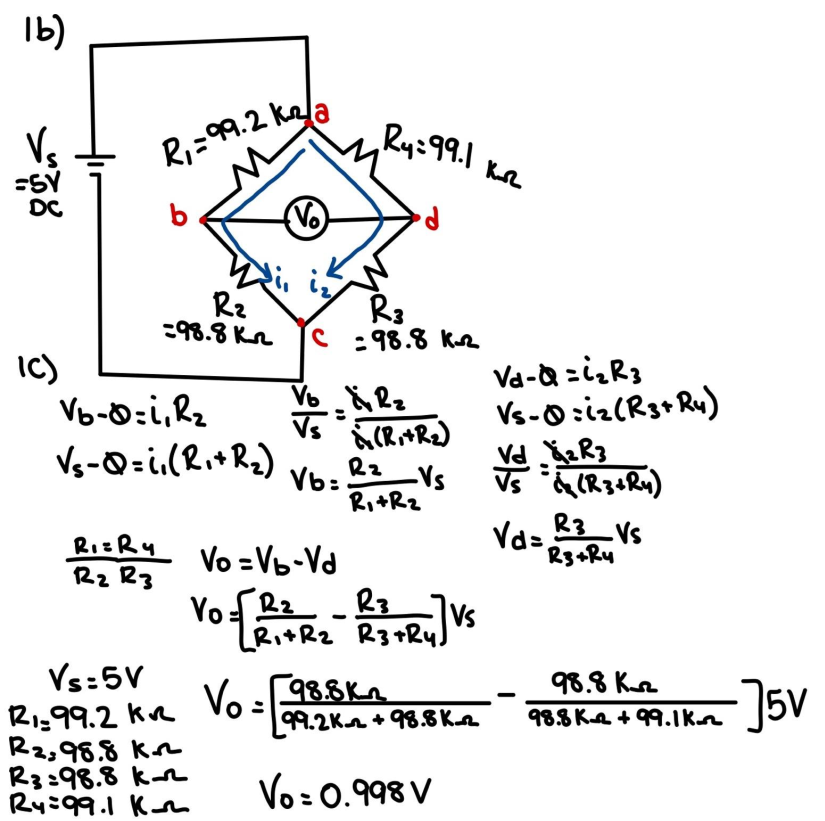

Figure 9

The derived equation I used for voltage was $Vo = [(R2/R1 + R2) - (R3/R3 + R4)]Vs$, I plugged in the measured resistor values for R1, R2, R3, and R4, and ended up getting a new output voltage of 0.998V. This output voltage is a little higher than our original calculated value because the Wheatstone Bridge was not balanced due to all of the resistor values being slightly different from each other. Resistor values vary because they are dependent on the other factors such as voltage and current. Resistors also have a margin of error so that the values fall within the same range for the same type of resistor, but that means they aren't always exactly the same accuracy. This means that our resistor values will be very similar in value, but will vary slightly. Resistors are also affected by heat which can cause a difference in values.

We then added a potentiometer into the circuit and adjusted the potentiometer until the output voltage was close to zero, which can be seen below in figure 10. We also made sure to use three resistors with the same resistance values as before, R1=99.2K Ohms, R2= ?, R3= 98.8K Ohms, R4=99.1K Ohms, and R2 is the potentiometer.

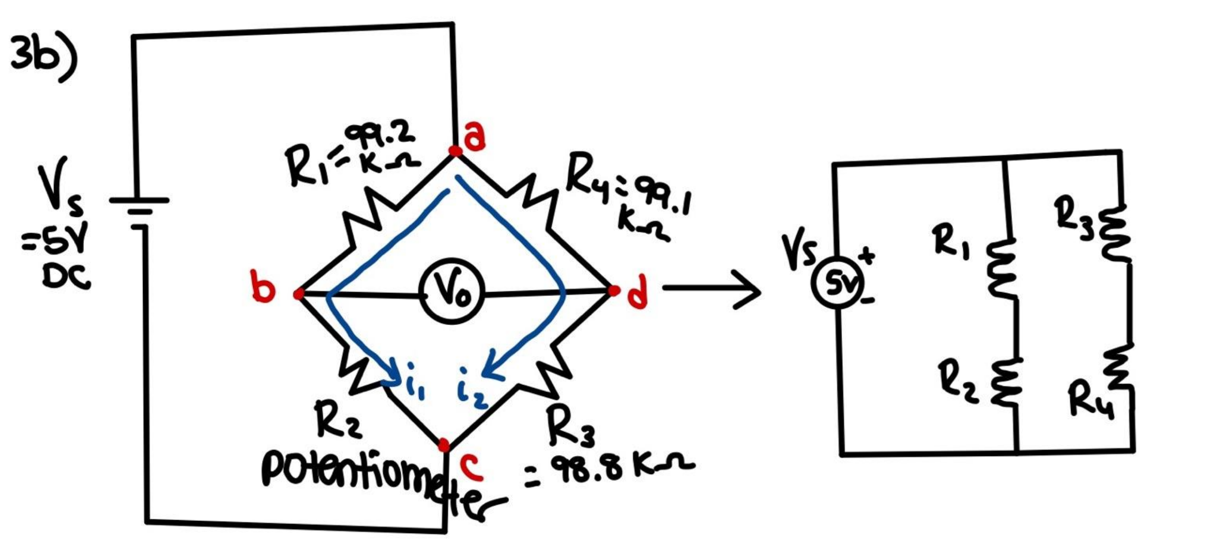

Figure 10

The new measured output voltage to be -0.007mV DC, this value varied from the prior output voltage because potentiometers are basically a resistor that can vary in resistance. Instead of having one set resistance like resistors 1, 3, and 4, the potentiometer could be adjusted and that causes the output voltage to be different. Output voltage is calculated by $V = iR$, meaning the resistance of the circuit affects the voltage. This circuit was created on TinkerCAD and can be seen below in figure 11, where the potentiometer was adjusted so the output voltage was as close to zero as possible.

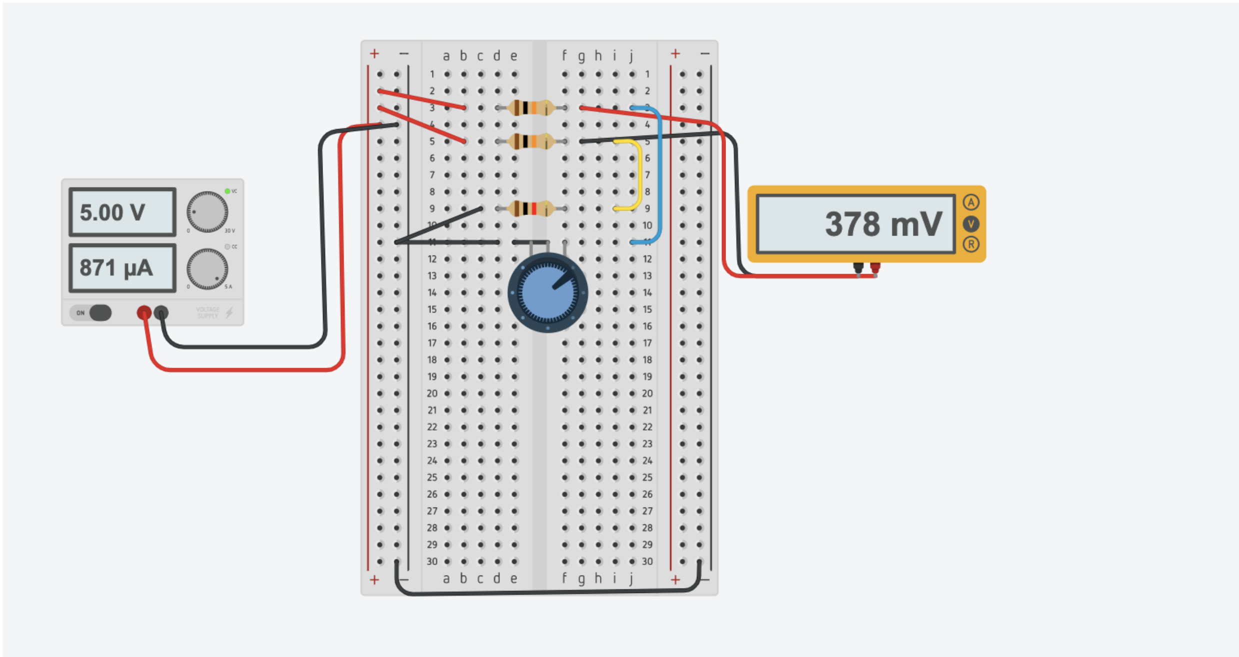

Figure 11

Experiment 2:
When setting up the Wheatstone Bridge circuit we had to measure the resistor values to make sure they were about 10K Ohms, our resistor values were: R1=9.8K Ohms, R2= 9.9K Ohms, R3=9.8K Ohms, and Rt= 12.57K Ohms. We removed resistor 4 and replaced it with a thermistor to demonstrate how heat will affect the circuit and the output voltage, which can be seen below in figure 12.

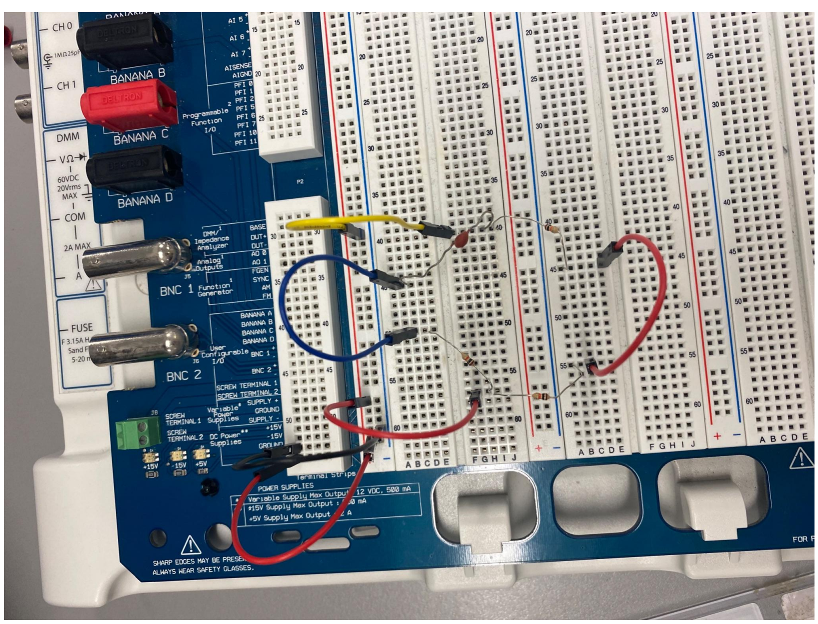

Figure 12

We then used the multimeter to measure the output voltage to be 0.394V. We then removed the thermistor from the circuit and allowed it to heat up in our hands for a few minutes, and then reinserted it back into the circuit. We then remeasured the output voltage and got the value of 0.152V. With thermistors, resistance decreases as temperature increases, and resistance increases as temperature decreases. Thermistors have an inverse relationship with the output voltage of the circuit. Since the temperature increased as we held the thermistor and then re-measured the output voltage, the resistance decreased. This means the output voltage of the circuit will decrease, which can be seen below in figure 13.

$$V = iR$$

$$\text{high } R: \; V = 2A(10\Omega)$$
$$V = 20V$$

$$\text{low } R: \; V = 2A(5\Omega)$$
$$V = 10V$$

Figure 13

Conclusion:

This experiment allowed us to build Wheatstone Bridge circuits and demonstrate how thermistors and potentiometers affect a circuit. We were better able to see that a potentiometer can be adjusted to get the output voltage as close to zero as possible. Meanwhile the thermistor could be heated using our body heat, which caused the resistance to decrease and caused the output voltage to to decrease from 0.394V to 0.152V. We were also better able to understand why resistor values are not exact and we can see how having an unbalanced Wheatstone Bridge affects the output voltage of the circuit.

Sources:

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