Multimeter Project

Kevin Downing,
Tyler Doyle,
John Lemieux,
Luke Morrison, and
Ryan Shaw

5/11/2018

Designing the Ammeter

Objectives:

- Build an ammeter that can measure 1mA, 10mA, and 100mA.
- Understand how to calculate the shunt with the deflection

Procedure:

Meter:

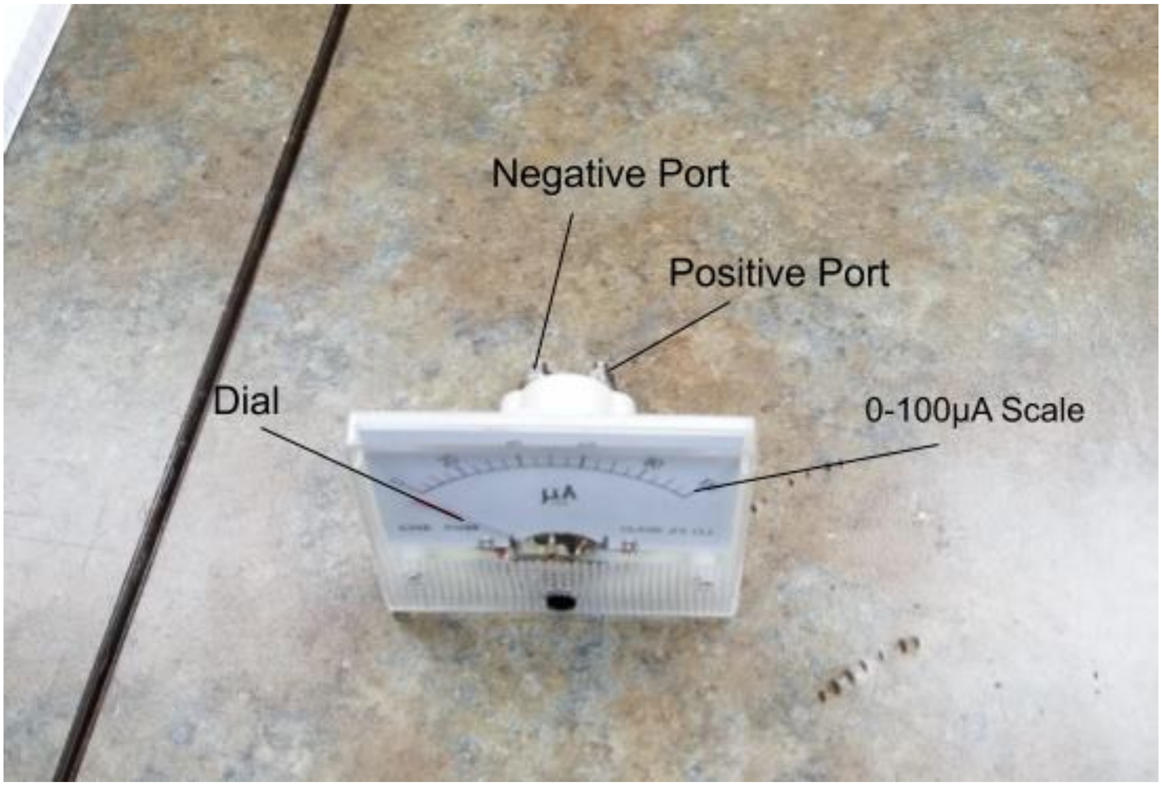

Figure 1-1

First, we collected a meter (Figure 1-1) then calculated the resistance by placing one lead from the ohmmeter to the positive port, with the other lead connected to the negative port. Polarity of the meter can be determined by seeing which port has the negative sign under it. The one with the negative sign is the negative port while the other port is positive. The internal resistance calculated by the ohmmeter is shown below in Table 1-1:

Resistance (Measured)	Resistance (Multisim)
2.158kΩ	2.15kΩ

Table 1-1

Next, we figured out the amount of current the meter can handle based on the scale. Since, the meter is on a 0-100μA scale, the total amount of current it can handle is 100μA.

Then we calculated the voltage drop of the meter by multiplying the maximum current that the meter can handle by its internal resistance. The calculated voltage drop is shown in Table 1-2:

Voltage Drop of Meter (Measured)	Voltage Drop of Meter (Multisim)
0.2158V	0.215V

Table 1-2

Since, the shunt and meter are in parallel, they have the same voltage drop. This means that the voltage drop according to Table 1-2, the voltage is 0.215V.

Next, the amount of current going through the shunt is calculated by subtracting the current deflection by the maximum current that the current can handle. This is done based on the current deflection being 1mA, 10mA, and 100mA. The results were recorded below in Table 1-3:

Current Deflection	Current of Shunt
1mA	0.9mA
10mA	9.9mA
100mA	99.9mA

Table 1-3

Next, we divided the voltage drop in Table 1-2 by the current of the shunt from Table 1-3 to find the resistance of the shunt. This was then recorded below in Table 1-4:

Current Deflection	Resistance of Shunt
1mA	238.89Ω
10mA	21.72Ω
100mA	2.15Ω

Table 1-4

The value of the resistor found in Table 1-3 was then connected to the meter in parallel to create an ammeter.

Next, a seperate circuit was made as shown below in Figure 1-2:

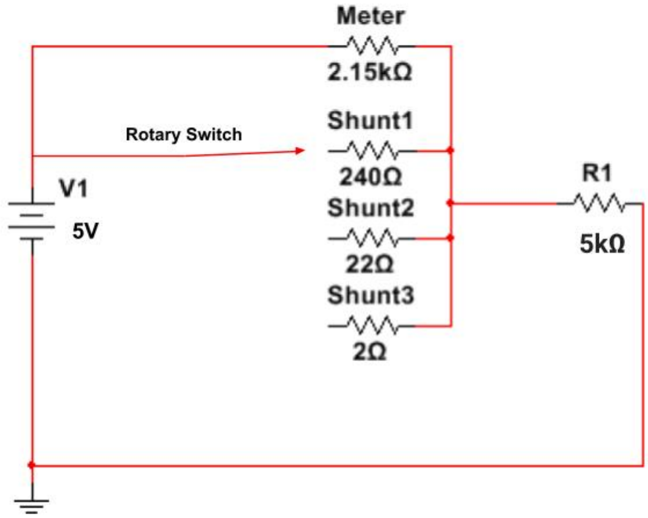

Figure 1-2

The rotary switch in Figure 1-2 was placed in all of the shunts to measure the current of the circuit. R1 for the first shunt, a 20kΩ resistor was measured, for the second shunt it was 200kΩ, and for the third shunt it was a 2MΩ resistor The current was then recorded below in Table 1-5:

Shunt	R1	Current Reading (Measured)	Current Reading (Calculated)
Shunt 1(240Ω)	5kΩ	0.9586mA	1mA
Shunt 2 (22Ω)	500Ω	9.58mA	10mA
Shunt 3 (2Ω)	50Ω	96.1mA	100mA

Table 1-5

Based on Table 1-5, the current measured was slightly lower than the calculated reading, and the more resistance in the circuit, the more accurate the reading was. This is because the ammeter adds resistance to the circuit.

Discussion:

During this lab, we easily figured out a lot of the information that we needed. With our knowledge on ammeters as a whole, it was easy to figure out how to find the correct shunt value depending on the input current and the meter's current limit. We had few problems and we compared our data with other groups to see if what we were doing was correct and accurate.

Conclusion:

The purpose of this experiment was to create an ammeter given a meter with specified current deflection, being 1mA, 10mA, and 100mA. Since, the ammeter's maximum current of the meter being only 100μA, there had to be a different shunt for each different current deflection. To measure a meter's resistance, an ohmmeter's leads are connected to the ports of the meter. In Figure 1-1, the ohmmeters reads 2.15kΩ, this is the internal resistance of the meter. The voltage drop of the meter is calculated by multiplying the maximum current that the meter can handle by its internal resistance. This is derived from ohm's law which states that voltage is proportional to resistance and current. In Table 1-1, multiping 100μA by 2.15kΩ equals to 0.215V. Since, the shut is parallel to the meter, the voltage drop will be the same. Using the new voltage and current going across the shunt, you can find the resistance value of this shunt using the formula R=V/I. which causes the current to go down.

In this example, R=0.215V/0.9mA, equals a resistance of 238.89Ω across the shunt (Table 1-4). Placing this shunt parallel to the meter would create a 1mA ammeter. Based on Table 1-5, the current measured than the calculated one because the ammeter adds resistance in the circuit,

Designing the Voltmeter

Objectives:

- Build a voltmeter that can measure 1V, 10V, and 30V.
- Understand how to calculate the multiplier with the deflection

Procedure:

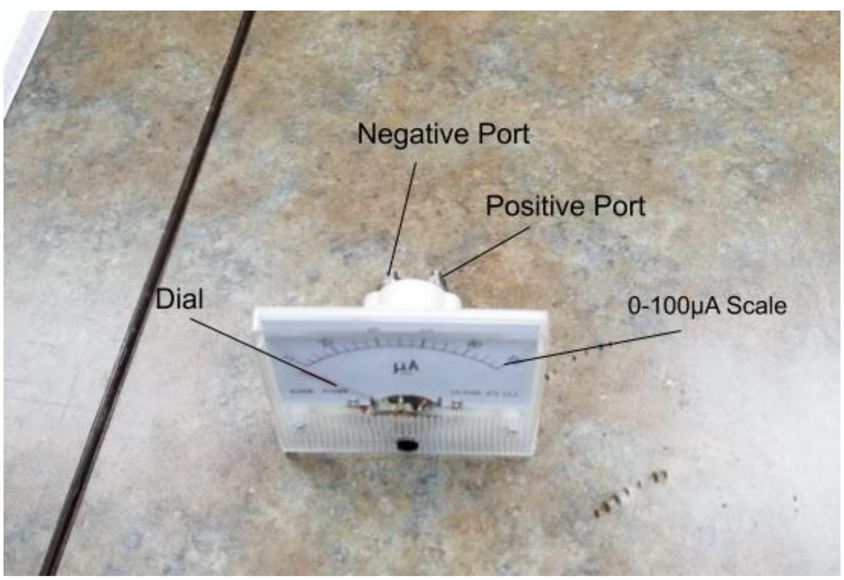

Figure 2-1

First, we collected a meter (Figure 2-1) then calculated the resistance by placing one lead from the ohmmeter to the positive port, with the other lead connected to the negative port. Polarity of the meter can be determined by seeing which port has the negative sign under it. The one with the negative sign is the negative port while the other port is positive. The internal resistance calculated by the ohmmeter is shown below in Table 2-1:

Resistance (Measured)	Resistance (Multisim)
2.158kΩ	2.15kΩ

Table 2-1

Next, we figured out the amount of current the meter can handle based on the scale. Since, the meter is on a 1-100μA scale, the total amount of current it can handle is 100μA.

Then, we calculated the voltage drop of the meter by multiplying the maximum current that the meter can handle by its internal resistance. The calculated voltage drop is shown below in Table 2-2:

Voltage Drop of Meter (Measured)	Voltage Drop of Meter (Multisim)
0.2158V	0.215V

Table 2-2

We then got the voltage drop and subtracted it by the deflection to get the multiplier, a resistor used to take in the excess. This was calculated for the deflections 1V, 10V, and 30V. We then recorded our results below in Table 2-3:

Deflection Voltage	Voltage Drop of Multiplier (Measured)	Voltage Drop of Multiplier (Multisim)
1V	0.7842V	0.7850V
10V	9.777V	9.785V
30V	29.7843	29.7850

Table 2-3

Next, the value of the multiplier is determined by dividing its voltage drop by the maximum current that the current can handle. This was done to each deflection voltage and the results were recorded below in Table 2-4:

Voltage Deflection	Multiplier Resistance (Measured)	Multiplier Resistance (Multisim)
1V	7.842kΩ	7.850kΩ
10V	97.77kΩ	97.850kΩ
30V	297.843kΩ	297.85kΩ

Table 2-4

Once, the value for the multiplier found in Table 2-4, a resistor of that value was gathered and connected to the meter in series to create a voltmeter, as shown below in Figure 2-2:

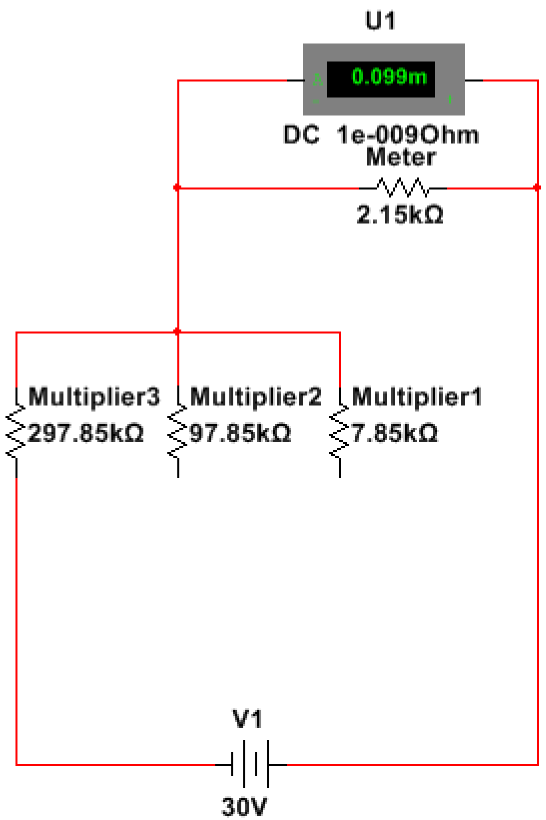

Figure 2-2

The rotary switch in Figure 2-2 was placed to switch between the multiplier to measure the voltage of the circuit. Multiplier1 was the shunt used to measure 1V, a 7.85kΩ resistor was measured, for the second multiplier it was 97.85kΩ, and for the third shunt it was a 297.85kΩ resistor. The current was then recorded below in Table 2-5:

Multiplier	V1	Current Reading (Measured)	Current Reading (Calculated)
Multiplier1 (7.85kΩ)	1V	.99V	1V
Multiplier2 (97.85kΩ)	10V	9.8V	10V
Multiplier3 (297.85kΩ)	30V	29.87V	30V

Table 2-5

Based on Table 1-5, the voltage measured was slightly lower than the calculated reading, and the reading became less accurate as it went to a larger voltage. This is because the more resistance in the component being measured for its voltage, the less accurate the reading was. This is because the voltmeter lowers the resistance in the circuit.

Discussion:

During this lab, some of our group members did not fully understand how to create a voltmeter with a multiplier. Because of this, we had to tutor them multiple times with multiple examples. Once this information was fully understood, the lab was easily completed and we had no problems at all.

Conclusion:

The purpose of this experiment was calculate the multiplier of a voltmeter, when given the values of 1V, 10V, and 30V. The meter's voltage drop was .215V, this is shown in Table 2-2. This meant that if there was more voltage going into the meter, then the meter would no longer work. If there was 1V, this is shown in Table 2-4, where the point was being measured and it was you full deflection, then you would use the *Formula 2-1:* $Vt=V1+V2+....+Vn$. The multiplier's voltage would be 0.785V, as shown in Table 2-3. Then, since the current is the same in the meter and in the multiplier, using the *Formula 2-2:* $R=V/I$, this would be used to calculate the resistance of the multiplier. The resistance would be 7.842kΩ, as shown in Table 2-4.

Designing the Ohmmeter

Objectives:

- Build an ohmmeter that can measure 500Ω, 5kΩ, and 50kΩ.
- Understand how to calculate the multiplier and shunt of an ohmmeter

Procedure:

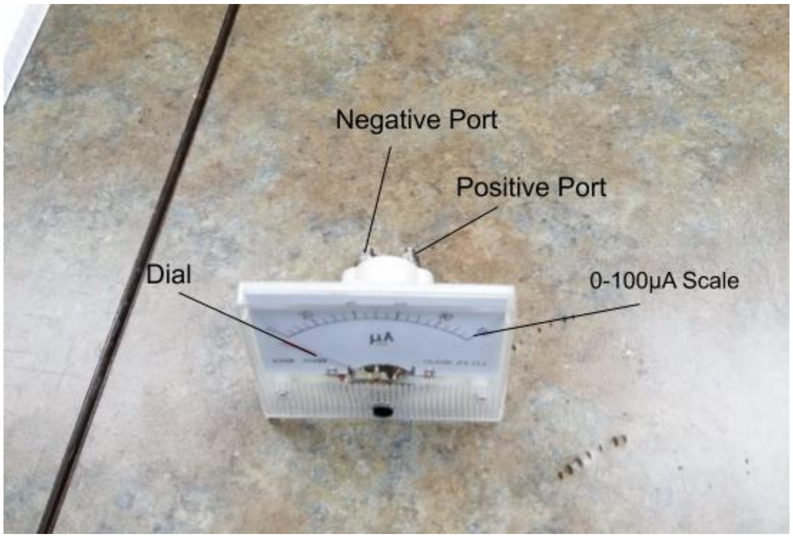

Figure 3-1

First, we got out meter, shown in Figure 3-1. We used a meter that can only take .215V and can take a current of .1mA. The resistance was 2.15kΩ. We then had to construct different circuits to figure out different values of multipliers and shunts. This is shown in Figures 3-2, 3-3, and 3-4.

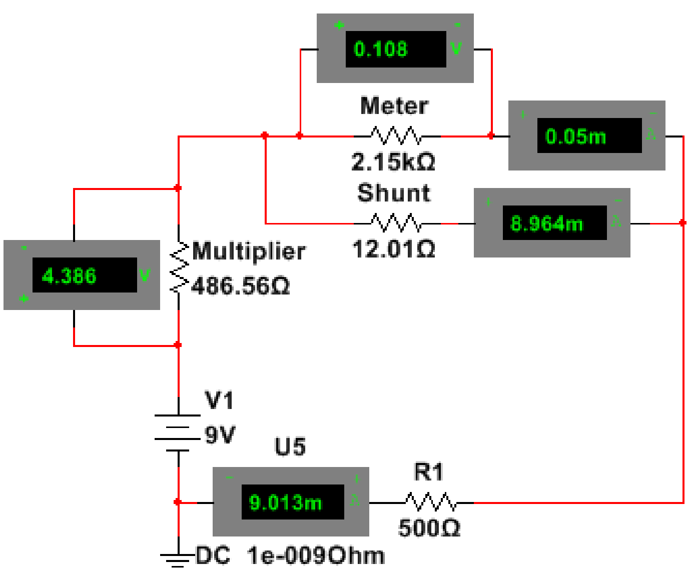

Figure 3-2

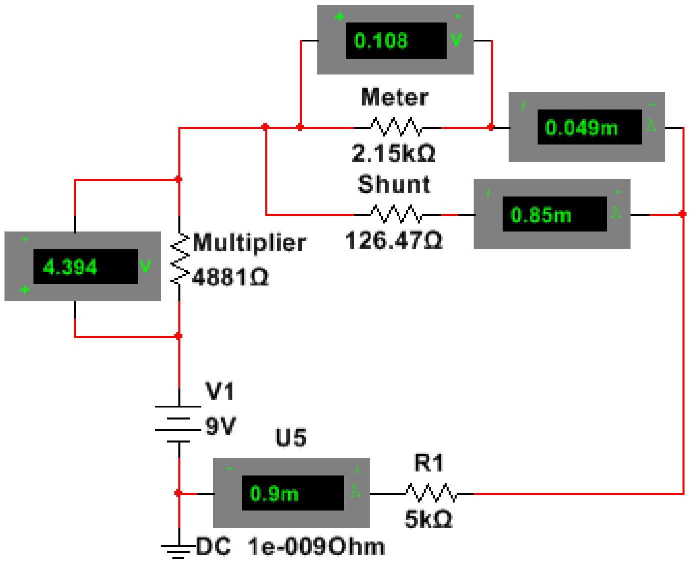

Figure 3-3

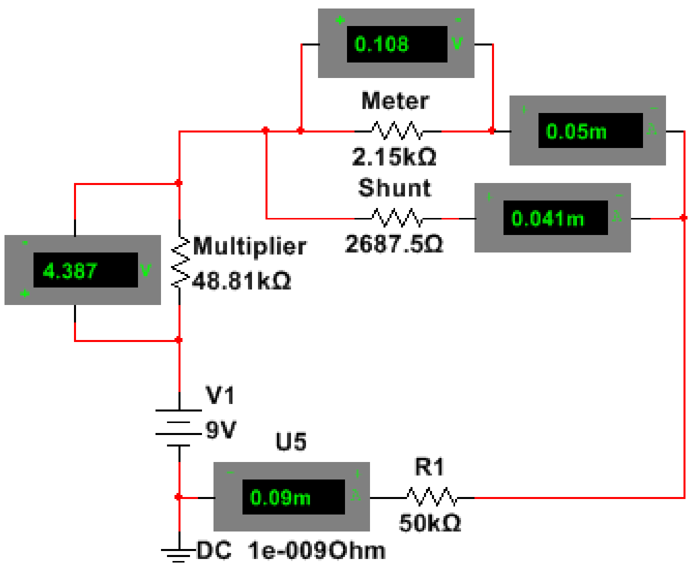

Figure 3-4

We calculated the values by making the resistor we are trying to measure a half deflection. We used a 9V battery and used a .1mA meter. We needed to find the total current going through the circuit by using *Formula 3-1: It=Vt/Rt*, where Vt is 9V and Rt is the half deflection. Theses values are recorded in Table 3-1.

Table 3-1

Half deflection	Current
500Ω	18mA

5kΩ	1.8mAdwa
50kΩ	.18mA

We then used *Formula 3-2: Vt=V1+V2+....+V#*, to calculate the voltage going through the multiplier. We then used Formula 3-1, to calculate the resistance of the multiplier. We recorded our values in Table 3-2.

Table 3-2

Multiplier Values	500Ω half deflection	5kΩ half deflection	50kΩ half deflection
Current	18mA	1.8mA	.18mA
Voltage	8.785V	8.785V	8.784V
Resistance	488.06Ω	4880.56Ω	48.8056kΩ

We then had to calculate the resistance of the shunt. We used *Formula 3-3: It=I1+I2+...+I#*, to find the current being diverted from the meter. Since the shunt is parallel to the meter, we can calculate the resistance of the shunt by using Formula 3-1. These values are recorded in Table 3-3.

Table 3-3

Shunt Values	500Ω half deflection	5kΩ half deflection	50kΩ half deflection
Current	17.9mA	1.7mA	.08mA
Voltage	.215V	.215V	.215V
Resistance	12.01Ω	126.47Ω	2687.5Ωk,

Discussion:

This lab was very easy for the people working on it on both Multisim and out in the lab area. It was not very complicated and every single person easily understood it. In the lab area, each time we tested the experiment, our expected results were shown.

Conclusion:

An ohmmeter is a specific type of meter required to measure the resistance of a component. This meter in particular has a combination of both the ammeter and the voltmeter, with both a shunt and a multiplier. Also, an ohmmeter has its own battery so that there is both a current and a voltage to base the resistance off of. First, you need to simplify the circuit for the total resistance and current. To do this, simplify all of the resistors to give a total resistance and divide the total voltage by that resistance to find the total current. Then, you must find the value of the multiplier. To do this, you must subtract the voltage in the meter from the total voltage to give the multiplier voltage. It will then have the same current as the total circuit and with the formula R=V/I, you can find the resistance of the multiplier. Then, to find the resistance of the shunt, the shunt will have the same voltage as the meter. From this, you subtract the amount of current that the meter can handle from the total current to acquire the current of the shunt. Then, again using the formula R=V/I, you can find the resistance of the shunt. When measuring a half deflection on an ohmmeter with a resistor that is the same as the total resistance in the ohmmeter, it will be read at 50% on the meter, and when there is no resistance being measured, the meter will read a full deflection because it is nonlinear to reading voltage and current.

Creating the Multimeter

Objectives:

- Understand how the schematic of a multimeter
- Learn how to design PCBs
- Use ultiboard to design PCBs
- Print out designed PCB
- Understand how to 3D print using makerbot and inventor

Procedure:

To begin this lab, we designed a schematic for the multimeter that would contain an ammeter, voltmeter, and ohmmeter. The one end of the shunts from both the ohm and ammeter were connected to the positive end of the meter and test lead as shown below in Figure 4-1.

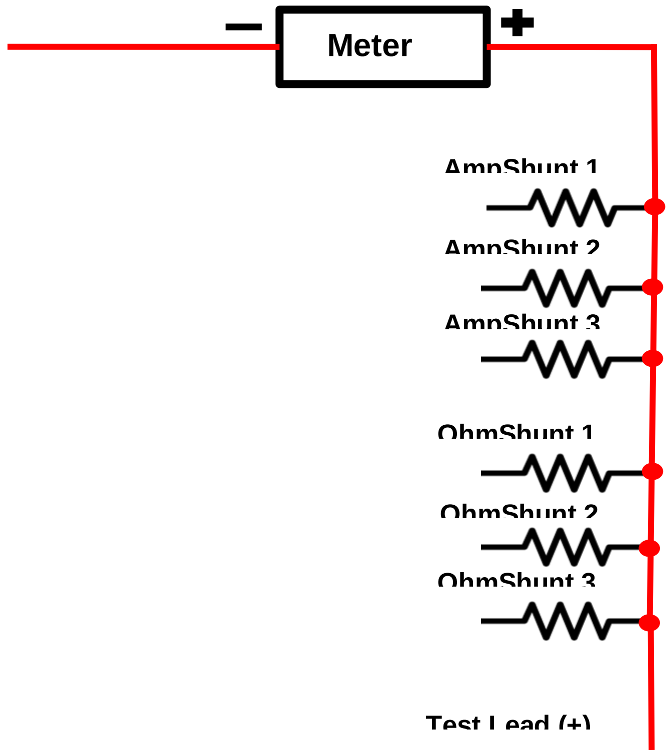

Figure 4-1

Next, the neutral pin from both rows of the rotary switch were connected to each other and to the negative side of the meter as shown below in Figure 4-2.

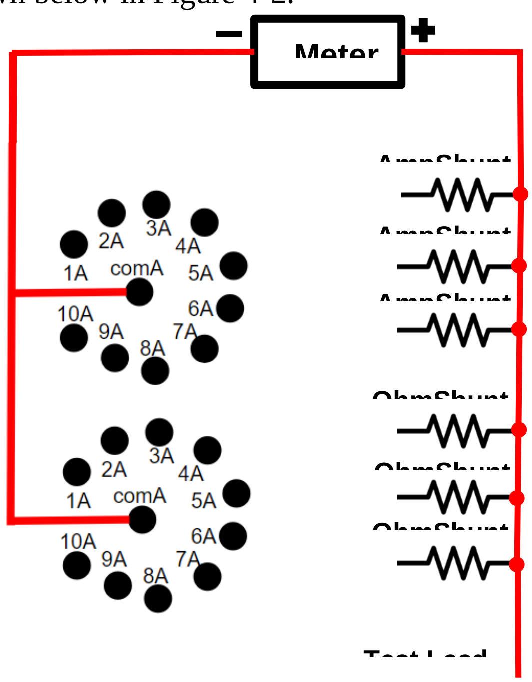

Figure 4-2

The other side of the shunts from the ammeter were connected from pins 1-3A and the other side of the shunts from the ohmmeter were connected from pins 7-10A as shown in Figure 4-3. This makes the shunts parallel to the meter.

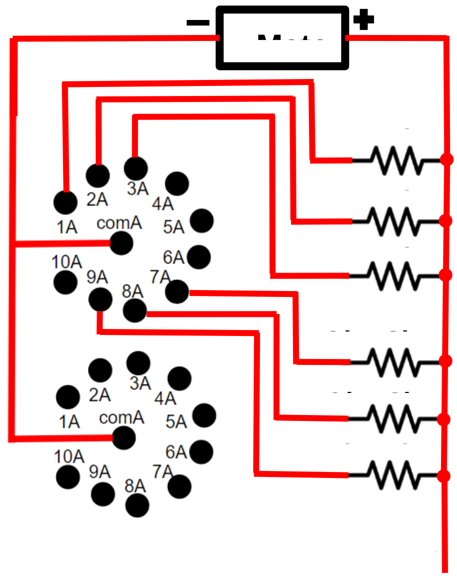

Figure 4-3

Next, we connected one end of multipliers from the voltmeter to the negative end of the test the connected the other end to the pins 4-6B (Figure 4-4). One end from the multipliers from the ohmmeter were connected to pins 7-9B with the other ends being connected together with the potentiometer and battery as shown in Figure 4-4.

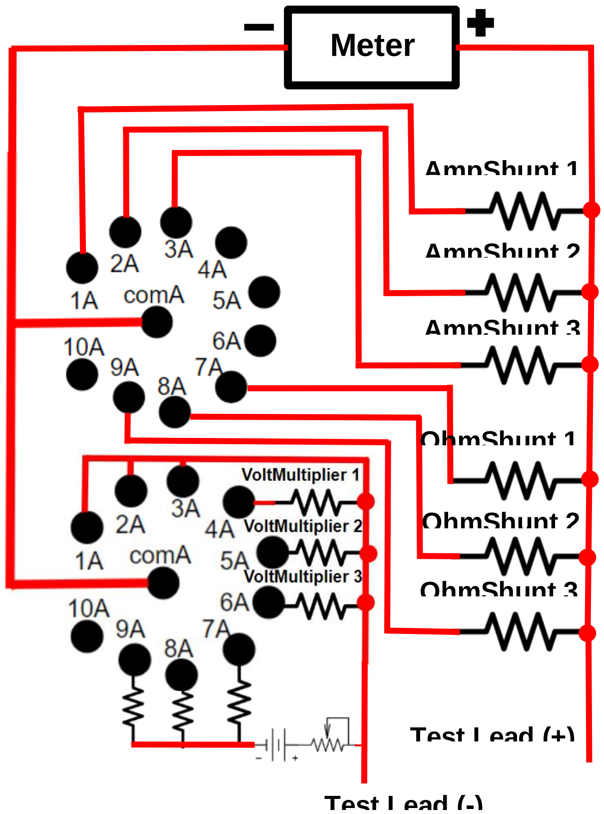

Figure 4-4

Then, using the schematic from Figure 4-4, we designed a PCB on Ultiboard. Twenty four holes were placed for the resistors, two for each. Then bottom copper trace was placed to connected the shunts together to the hole for the negative test lead and negative port of the multimeter as shown in Figure 4-5. Next, the multipliers from the voltmeter were connected together with the positive test lead, pins 1-3B, and the negative side of the battery. The multiplier from the ohmmeter were connected together and to pin 1 of the potentiometer. The holes of pin 2 and 3 of the potentiometer were connected together with the hole for the positive side of the battery (Figure 4-5). Three holes were made, connected to each other, for the positive side of the multimeter and the neutral pins from the rotary switch. The PCB that we created is shown below in Figure 4-5.

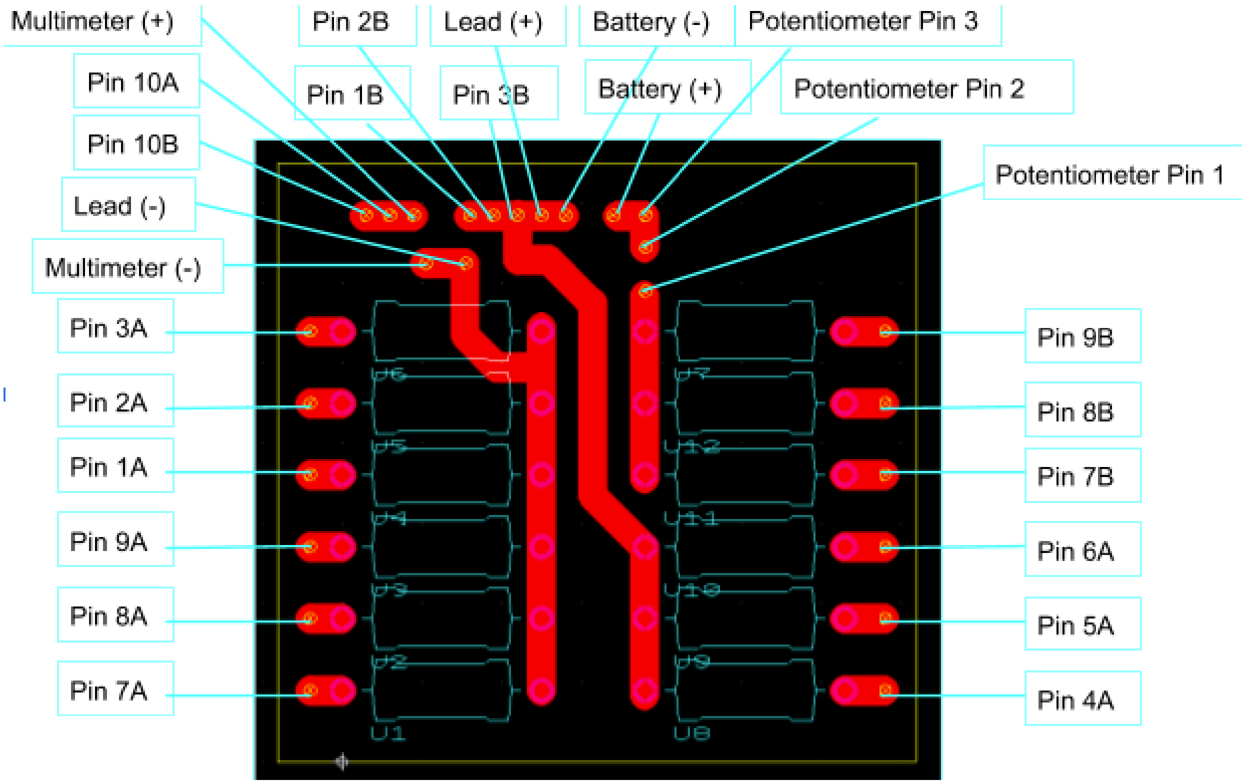

Figure 4-5

The PCB in Figure 4-5 was shown to be 1.5 x 1.5 inches. A board of fiber, 1.5 x 1.5 inches with a thin layer of copper was placed into the

After all of this was completed, we gathered our board and started to place the corresponding components onto it. We had to place the shunt resistors from table 1-4 in pins 7A, 8A, and 9A (Figure 4-3), to represent the ammeter. The multipliers from table 2-4 were placed in pins 4A, 5A, and 6A (Figure 4-3), to represent the voltmeter. We placed the multipliers for the ohmmeter in pins 7B, 8B, and 9B and we placed the shunts for the ohmmeter in pins 1A, 2A, and 3A (Figure 4-3). We also had another group member working on putting wires onto the rotary switch, to make sure that it could correctly be inputted into the board. Once both of these were finished, we soldered the components onto the board in the correct positions. We then tested each individual meter out, making sure that there was a correct reading on the meter across a component. We did this by creating a circuit, giving it voltage, and measuring across the resistor. Figure 4-7 shows the wires soldered together:

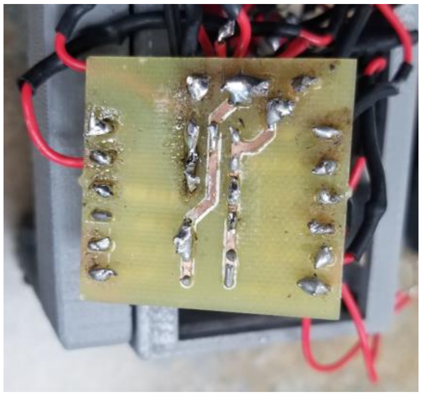

Figure 4-7

We then had to make a box to go with our multimeter in Inventor. First, a box, 5.5 x 2.25 x 3.25 inches was made with the walls having a thickness of .12 inches. Holes for the meter were created so that the meter could fit and the screws could create a tight fit. The dimensions of the holes are shown below in Table 4-1:

	Meter Hole	Screw Holes
Radius	60mm	4mm
Length from other hole	32mm	32mm
Height from other hole	17mm	17mm

Table 4-1

We had to make a box to go with our multimeter in Inventor, which is shown in Figure 5-1. First, we inserted the dimensions of the large circle of the meter along with the holes for the two screw on a box. This box was made to hold our entire board and meter, with holes for certain components. There is a hole for the meter, the potentiometer, the rotary switch, and two clips to measure. The dimensions of this box are: 80 mm in height, 144 mm in length, and 60 mm in width.

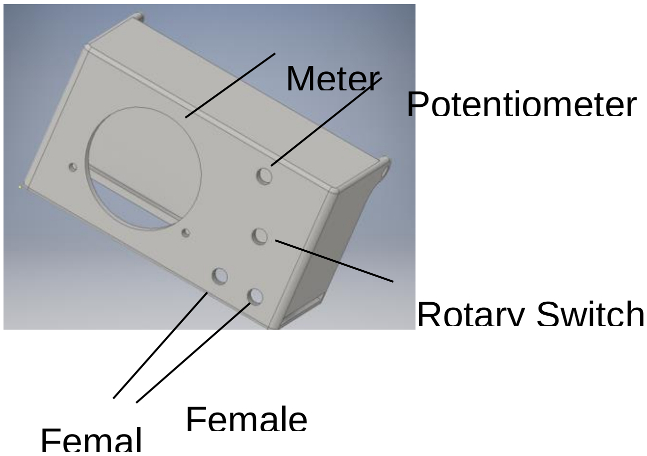

Figure 4-8

Once the box was fully printed out, we placed our components into it, making sure that each fit in perfectly. We then adjusted to the board, for it couldn't be connected to the board before it was placed in. We also had to put labels showing which setting the multimeter was on.

We then tested each individual meter out, making sure that there was a correct reading on the meter across a component. We did this by creating a circuit, giving it voltage, and measuring across the resistor.

After we made sure each setting worked, we added a label to show which setting was which on the box itself (Figure 4-8). We were also required to create our own test leads out of banana plugs, stranded wire, and 12 gauge wire. The stranded wire was placed into the banana plugs after they were unscrewed. The plugs were then screwed and the 12 gauge wire was heat-shrunk onto the stranded wire. The final product of this lab is shown in Figure 4-9.

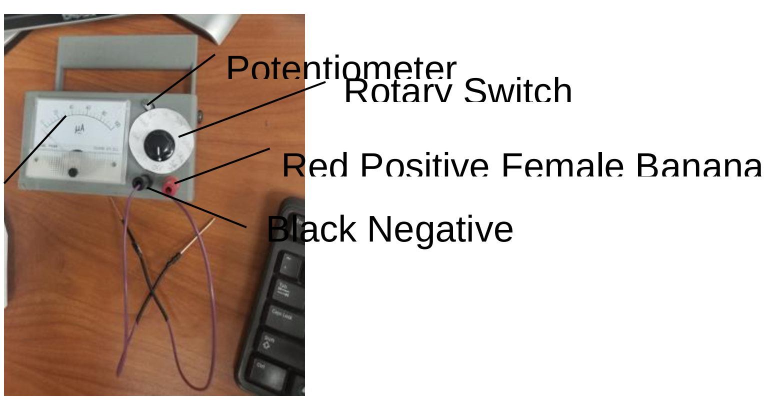

Figure 4-9

Discussion:

This lab was somewhat challenging for us to complete. Over the past few weeks, we have been gathering information leading up on how to finish this lab correctly, making it an easy and fast experiment to complete. Our Ultiboard had already been completed from the week before, and each group member understood the information on it. We had finished the box the week before, but we made it incorrectly, causing us to remake the box as a whole. Luckily, we did not print the first box. We did have a problem with the holes in our board not showing clearly and not going through the board the whole way, meaning that we had to manually put holes into the board using a drill. We also had been using the wrong wire for our rotary switch, causing us to desolder and solder a different wire on again. We had to file our box and components a little, but not that much for everything to fit in perfectly.

Conclusion:

The purpose of this lab was to create a multimeter that had ranges of 1mA, 10mA, 100mA, 1V, 10V, 30V, 500Ω, 5kΩ, and 50kΩ (Tables 1-1, 1-2, and 1-3). This lab included information from our previous 3 labs: building an ammeter, a voltmeter, and an ohmmeter. To make a multimeter, you need to have each of these meters connected to a rotary switch, which is a switch that has 2 layers, where when the switch is turned, it will turn to a pin on the top layer and a pin on the bottom layer (Figure 1-2). For example, if an ohmmeter was connected to pins 1, 2, and 3 on both layers, as the switch is moved from 1 to 2, it will move it from 1 to 2 on both layers. This is then connected to the board, with each pin having a wire to connect it to a certain hole in the board. The board also has different resistors, for when the rotary switch is turned, it can access a different part of the multimeter (the ammeter, voltmeter, or ohmmeter). These resistors will either be in parallel or in series with the meter, depending on what is being measured. If it is measuring ohms, it will be changed to the ohmmeter setting and will have resistors in series (multipliers) and in parallel (shunts) with the meter. The ohmmeter will have to have the component being measured taken out of the circuit in order to measure its resistance. If it is measuring amps, it will be changed to the ammeter setting and will have a resistor (shunt) in parallel with the meter. There will also have to be a break in the circuit to insert the ammeter in series. If it is measuring volts, it will be changed to the voltmeter setting and will have a resistor (multiplier) in series with the meter. The voltmeter will be placed in parallel with the component being measured. The multipliers are there to deflect the excess voltage from the meter and the shunts are there to direct the excess current from the meter (Figure 1-2). On both a voltmeter and an ammeter, the meter itself is linear and reads from 0-100, but on an ohmmeter, it reads from infinity to 0, with a half deflection being the same resistance as the total resistance of the meter.

The Multimeter Manual

Table of Contents

Section 1: Setting up multimeter

1. First, locate the red positive lead and black negative lead (Figure 5-1).

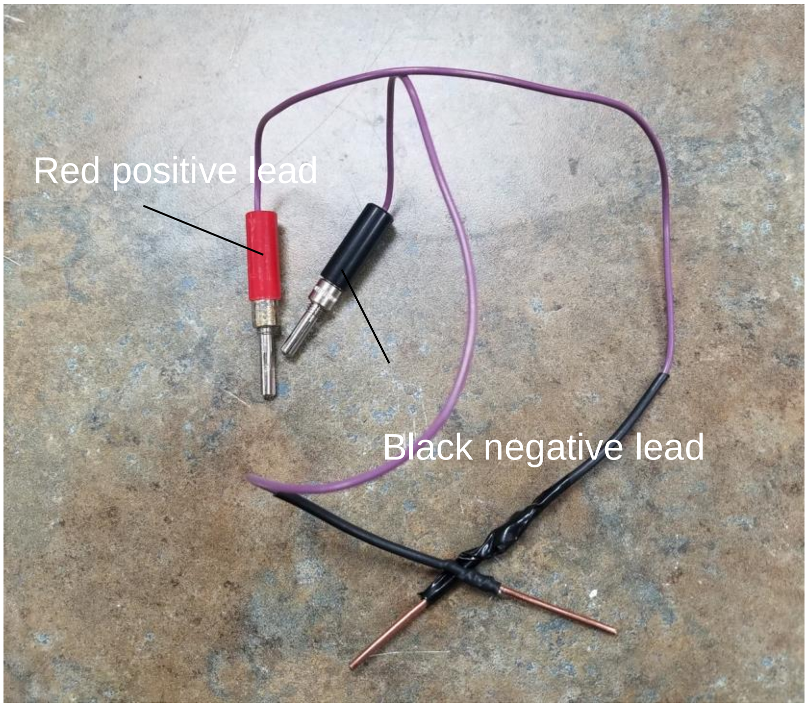

Figure 5-1

2. Next, insert the red positive lead to the red positive female banana port and the black negative lead to the black negative female banana port as shown in Figure 5-2.

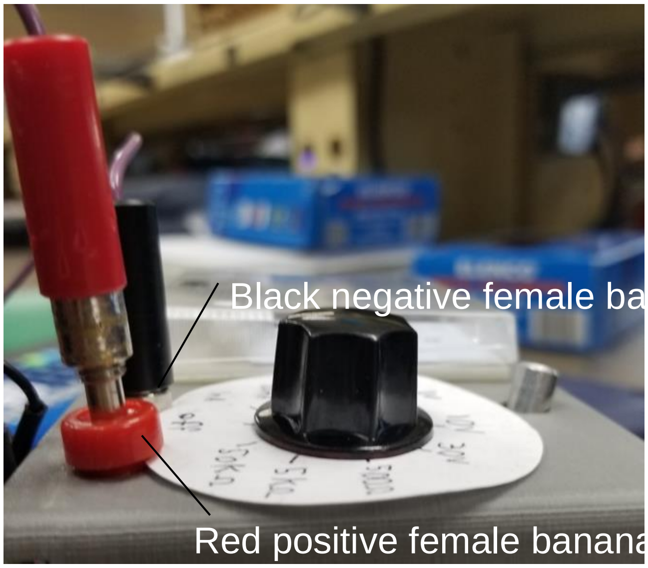

Figure 5-2

3. When not in use, remove the red positive lead and black negative lead from the multimeter and turn the r

Section 2: Measuring current

1. Turn the rotary switch clockwise until it reaches one of three ranges of current (Figure 5-3). These ranges indicate the maximum amount of current that the meter can handle. When at max, the dial from the meter will be at the end point.

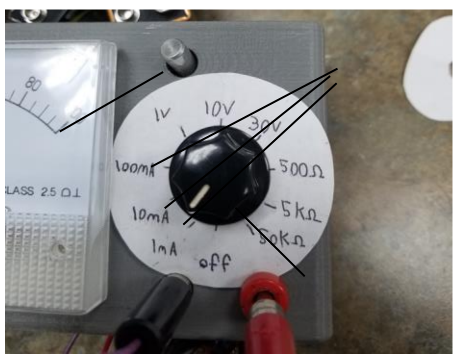

Figure 5-3

2. The current ranges and resolution are shown in table 5-1.

Ranges for Current

Pin #	Range	Resolution
1	1mA	.05mA
2	10mA	.5mA

3	100mA	5mA

Table 5-1

3. If the current value is known, choose the smallest current range that is over or equal to the current value being measured.
4. If the current value is unknown, select the maximum current range which is 100mA (Table 5-1).
5. After the range has been selected, create an open in the circuit then insert the black negative test lead to the side where current is flowing out from then put the red positive test lead to the opposite side so that the multimeter is in the circuit in series as shown in figure 5-4. Note: If the polarity has been switched, the reading will be negative.

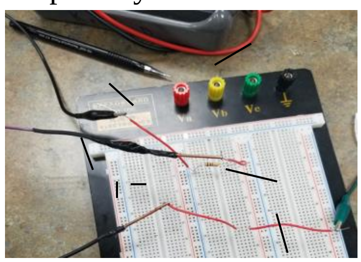

Figure 5-4

6. If you originally didn't know the value and want a more accurate reading, rotate the knob counterclockwise to a lower current range that is the smallest range that is over or equal to the current being measured.

Section 3: Measuring voltage

1. Turn the rotary switch clockwise until it reaches one of three ranges of voltage (Figure 5-5). These ranges indicate the maximum amount of voltage that the meter can handle. When at max, the dial from the meter will be at the end point.

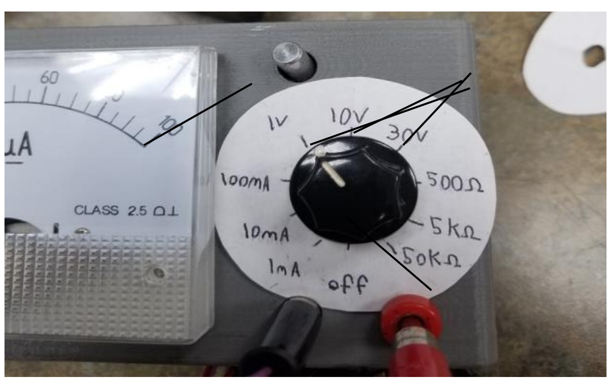

Figure 5-5

2. The voltage ranges and resolution are shown in table 5-2.

Ranges for Voltage

Pin #	Range	Resolution
4	1V	.05V
5	10V	.5V
6	30V	1.5V

Table 5-2

3. If the voltage value is known, choose the smallest voltage range that is over or equal to the voltage value being measured.
4. If the voltage value is unknown, select the maximum voltage range which is 30V (Table 5-2).
5. After the range has been selected, connect the black negative test lead to the side of a component where current is flowing out from then put the red positive test lead to the opposite side so that the multimeter is parallel to the component or circuit being measured as shown in figure 5-6. Note: If the polarity has been switched, the reading will be negative.

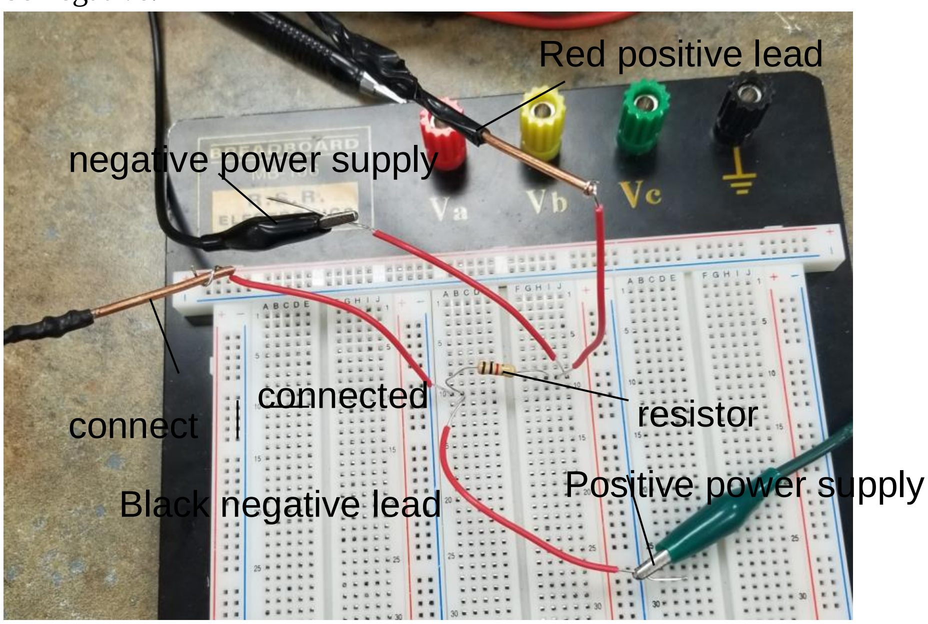

Figure 5-6

6. If you originally didn't know the value and want a more accurate reading, rotate the knob counterclockwise to a lower voltage range that is the smallest range that is over or equal to the voltage being measured.

Section 4: Measuring Resistance

1. Turn the rotary switch clockwise until it reaches one of three ranges of resistance (Figure 5-7). These ranges indicate the maximum amount of resistance that the meter can handle. When at max, the dial from the meter will be at the half point.

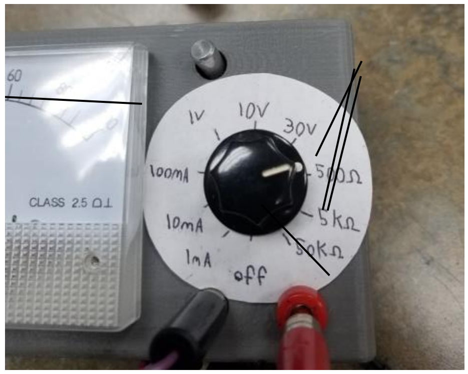

Figure 5-7

2. The resistance ranges and resolution are shown in table 5-3.

Ranges for Resistance

Pin #	Range	Resolution
7	500Ω	2.5Ω
8	5kΩ	25Ω
9	50kΩ	250Ω

Table 5-3

3. If the resistance value is known, choose the smallest resistance range that is over or equal to the resistance value being measured.
4. If the resistance value is unknown, select the maximum resistance range which is 50kΩ (Table 5-3).
5. After the range has been selected, remove the resistor or component being measured out of a circuit then connect the black negative test lead to one side of a component then put the red positive test lead to the opposite side so that the multimeter is parallel to the component or circuit being measured as shown in figure 5-8. Note: If the polarity has been switched, the reading will be the same.

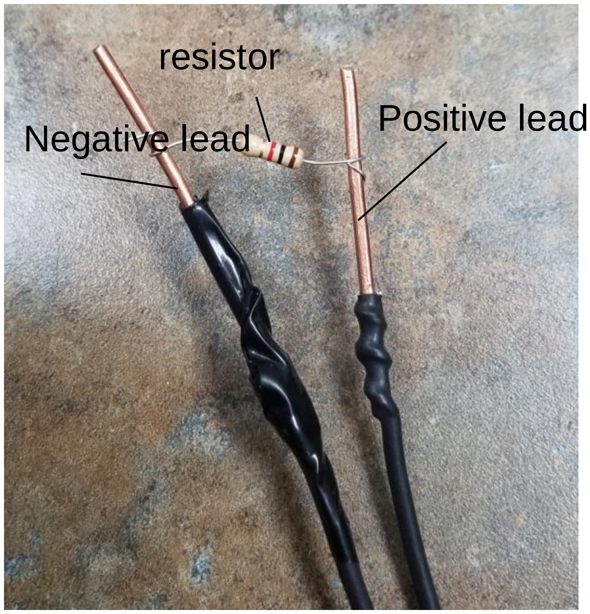

Figure 5-8

6. If you originally didn't know the value and want a more accurate reading, rotate the knob counterclockwise to a lower resistance range that is the smallest range that is over or equal to the resistance being measured.
7. Over time the battery will lose voltage, to adjust this, turn the potentiometer counterclockwise (Figure 5-9).

Figure 5-9