Lab 4 - The Diode

Your Name (First Last):

Overview

By now you have a sense of what kinds of materials can conduct electric currents. Metals like copper are very good conductors, which is why wires are often made of copper. On the other hand there are materials that do not conduct electrical currents at all. Wires are often coated with plastic which is a very poor conductor. Plastic is an insulator.

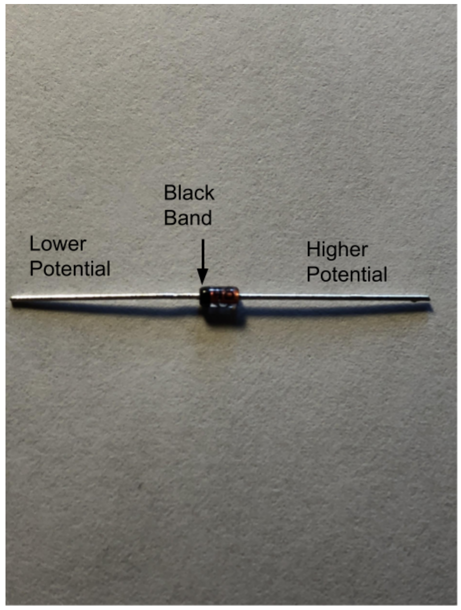
You also know that resistors conduct current depending on their resistance. A 1Ω resistor conducts much more current than a $10\text{k}\Omega$ resistor. Another feature about resistors and wires is it does not matter the orientation of the resistor or wire in the circuit. The same amount of current with flow in either direction.

In this lab you will study another kind of electrical element called a diode. Diodes are interesting because they can be a conductor or insulator. This means the diodes behave like a switch; they can turn “on” and “off.”

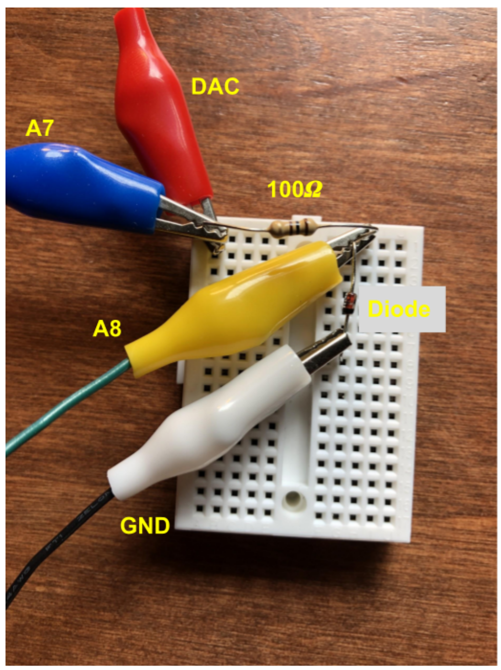
Part 1 - Silicon Diode

Let’s study a kind of diode called a silicon diode. this kind of diode behaves like a “switch.” Depending on the amount of voltage across it, it can turn *on* and allow a current to flow, or *off* and no current will flow.

Construct a circuit with a 100Ω resistor in series with a silicon diode. The diode is also polarized and has a high potential and low potential side. You can tell which side is the low potential side by the black band on one side of the diode.



Your circuit should look like this:



- Red alligator clip connected to DAC.
- Blue alligator clip connected to A7.
- Yellow alligator clip connected to A8.
- White alligator clip connected to GND.

Setup the iOlab app:

- On the toolbar click the settings button (cog) > Expert Mode > Output configuration.

- Make sure A7 and A8 are checked.
- At the bottom of the iOLab app window the DAC Output should appear.
- In the DAC Output menu select 0.0V then click On.

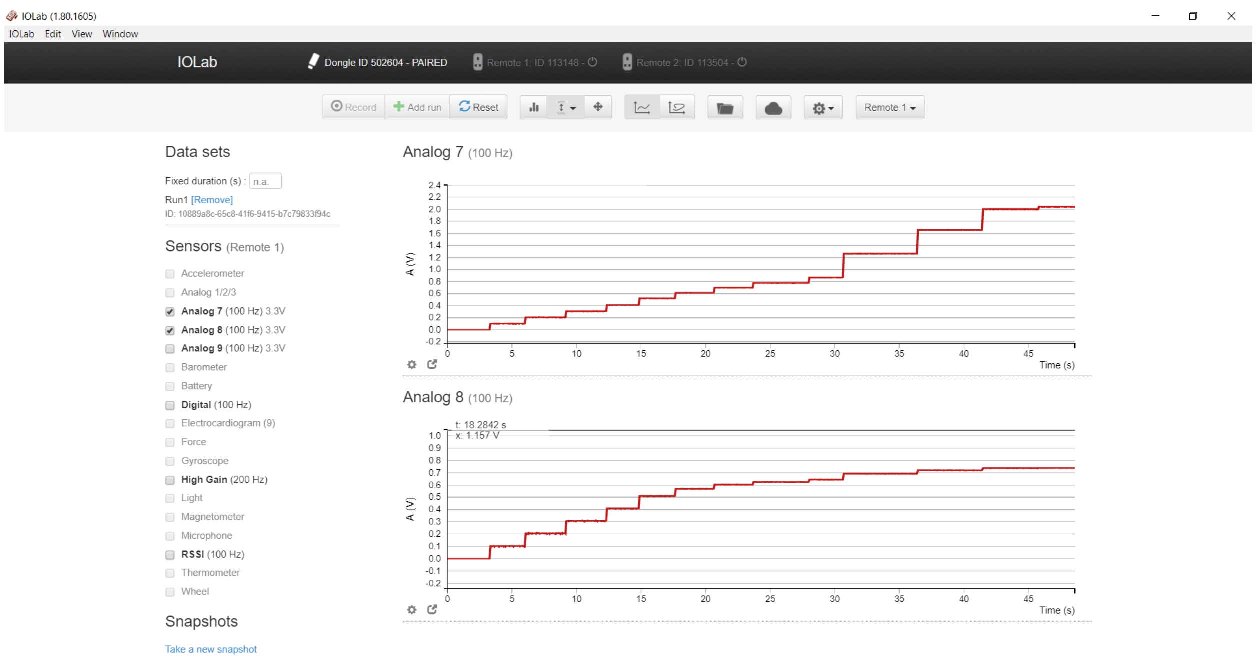
You will need to record the values of voltage of A7 and A8.You can record your measurements the spreadsheet The Diode - Student Date:

The Diode - Student Data

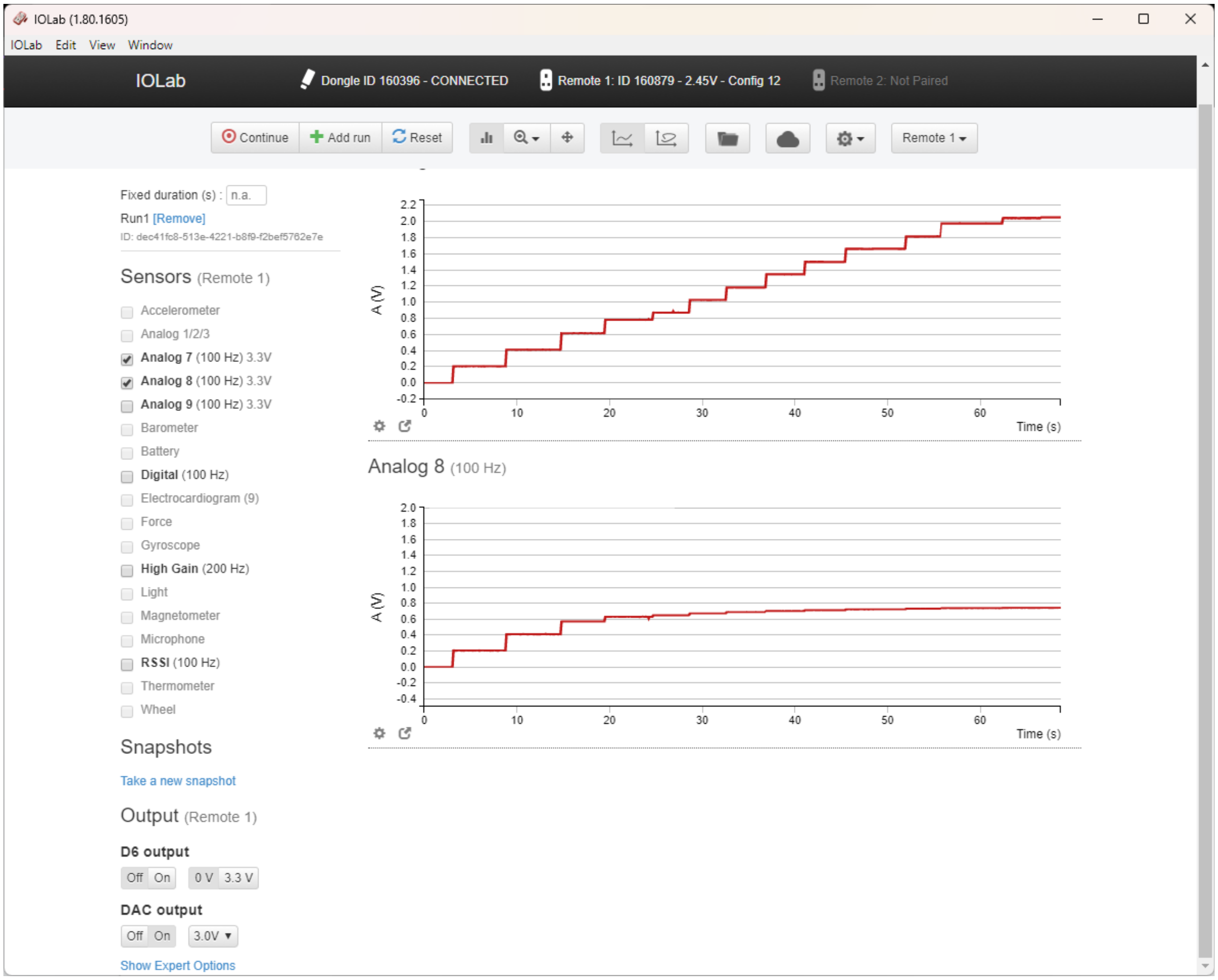
Now it’s time to take some data:

- Click the Record button and record the voltages for A7 and A8 for about 5 seconds.
- While still recording, change the DAC Output voltage menu to 0.2V. Record for 5 more seconds.
- Change the DAC Output voltage in 0.2V steps up to 3.0V. With each change in voltage record the A7 and A8 voltage for about 5 seconds. Then click Stop.

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



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



Now record the values of voltage of A7 and A8 for each step you changed the DAC Output voltage. You can record your measurements in the spreadsheet Diodes - Student Copy. Be sure to click the tab Silicon Diode at the bottom of the spreadsheet.

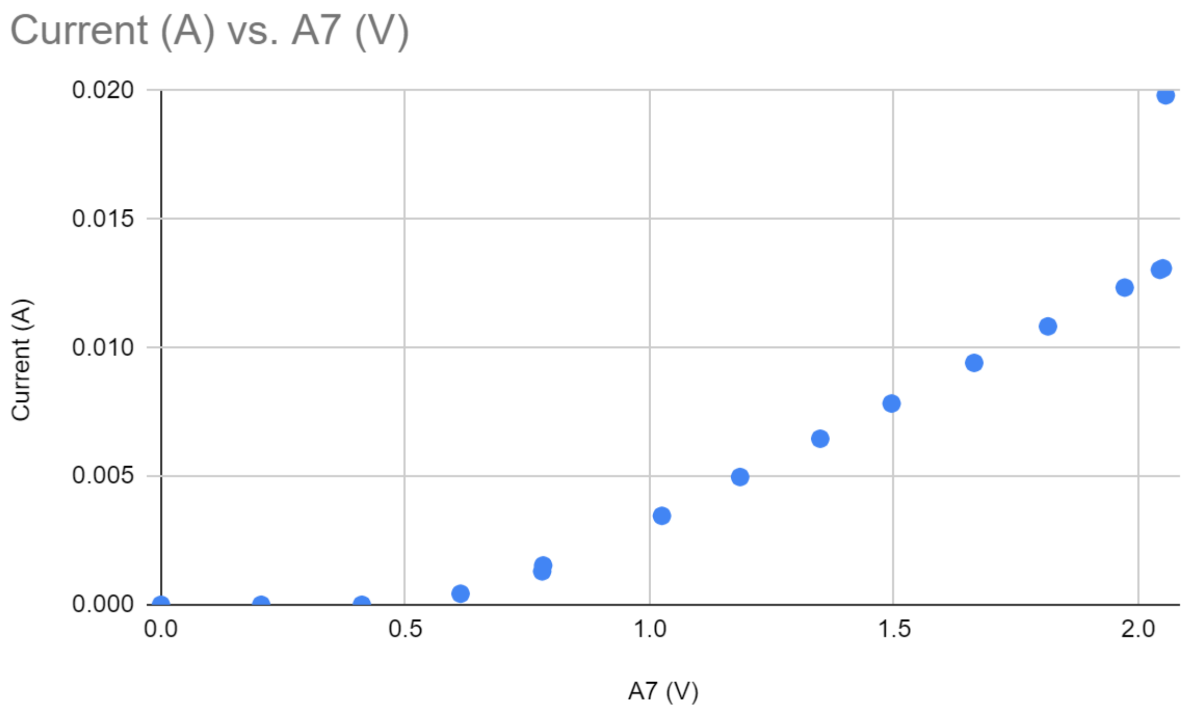
2. Use the Analysis Mode in the iOLab application and record the voltages measured by sensors A7 and A8 in the spreadsheet for each step you changed the DAC Output voltage.

3. For each measurement, calculate the voltage across the resistor V = A7 - A8.

4. For each measurement, calculate the current through the resistor I = V/R.

5. Make a scatter plot of diode Current vs. Voltage A7:
    a. Click on the top of the column with the values of A7 (V) (Column C).
    b. Press and hold the Ctrl key and click on the top of the column with the Current (A) values (Column E).
    c. Release Ctrl key and open the Insert menu and select Chart.
    d. The Charter Editor will open. In Setup choose Chart Type > Scatter Chart,

e. Make sure the X-axis indicates A7 (V).
f. Make sure the Series indicates Current (A). If A7 (V) is in the Series, remove it.
g. In Customize > Chart & axis titles add axes titles with units to your graph.
h. Copy and paste your plot into this document below here:



6. Look closely at your graph Current vs. Voltage. Is the relationship between current and voltage linear? Explain your answer.

The graph is linear, however its x-intercept is not at the origin, it is shifted over about half a volt in the positive direction.

7. From your graph, What range of voltages do you estimate the diode is “off”; i.e., no current flows? Explain your answer.

0 V - .5 V because the voltage across the resistor is 0, indicating that the current is not flowing

8. From your graph, What range of voltages do you estimate the diode is “on”; i.e., current does flow? Explain your answer.

From voltages above .5 V I would estimate that the current is flowing, this is because there is measurable voltage across the resistor.

Threshold Voltage

Based on your plot of Current vs. Voltage of the silicon diode, it should be clear that the diode does not work like a resistor. For some range of voltages no current flows, so the diode is like an insulator. In other ranges of voltages there is current flowing, so the diode is like a conductor. You can probably have guessed the silicon the diode is made of is a semiconducting material. But what makes the diode transition from insulator to conductor? The answer is there is a threshold voltage applied to the diode that is necessary to turn “on” the diode.

Look again at your plot of Current vs. Voltage and for the range of voltages where the diode is "on", it looks very linear. That is because the plot is the Current vs Voltage for the 100 Ω resistor and resistors are ohmic devices; the current through and voltage across a resistor is linearly proportional to each other. If that is true, then a linear fit to the portion of the data when the diode is "on" can be used to determine the threshold voltage.

9. Use the built in function LINEST to determine the best slope and intercept of Current vs. Voltage.
    a. In an empty cell enter =LINEST(range of y,range of x,1,1).
    b. The range of y should be the range of cells with the values of Current in Column E. USE ONLY THE VALUES WHEN THE DIODE IS "ON"!
    c. The range of x should be the range of cells with the values of Voltage A7(V) in Column B. USE ONLY THE VALUES WHEN THE DIODE IS "ON"!

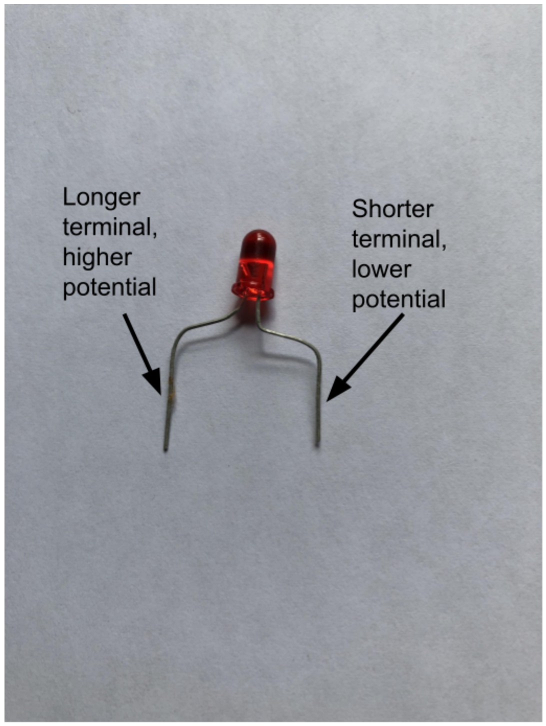
10. Using the best values of slope and intercept from LINEST to determine the threshold voltage. Hint: What would be the value of current flowing through the resistor at the threshold voltage?

Threshold Voltage (V)
.619 V

Part 2 - Light Emitting Diode.

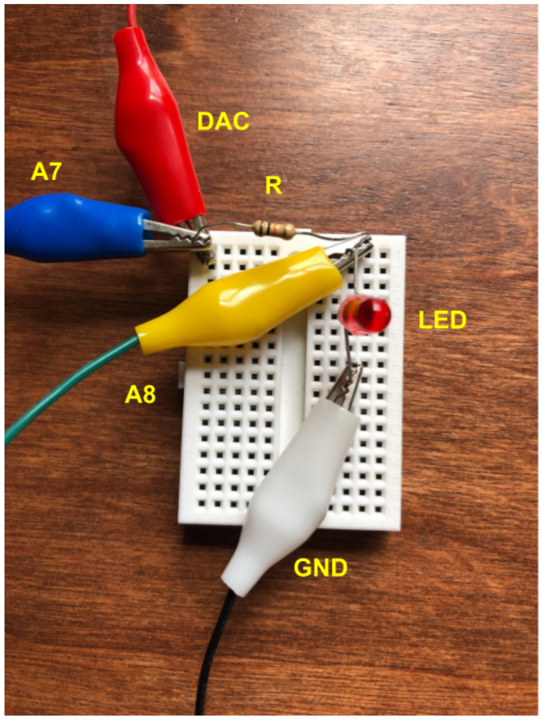
A really cool feature of some diodes is if a current flows through the diode it will emit light! Light emitting diodes have become widely used because they can emit lots of light without consuming much power.

Just like a capacitor, the LED has a preferred polarization when a voltage is applied. When the higher potential is applied to the longer terminal, the LED is *forward biased*, and a current will flow through it. If the higher potential is applied to the shorter terminal, the diode is *reverse biased*, and no current will flow.



For this part of the experiment, you will need to work with other students as a team. You will measure the current through and voltage across four different color LEDs and determine the threshold voltage for each of them; just like the silicon diode . You will share your measurements with the other pair of lab partners sitting across from you. One pair of partners will measure the red and yellow LEDs, and the other will measure the green and blue LEDs

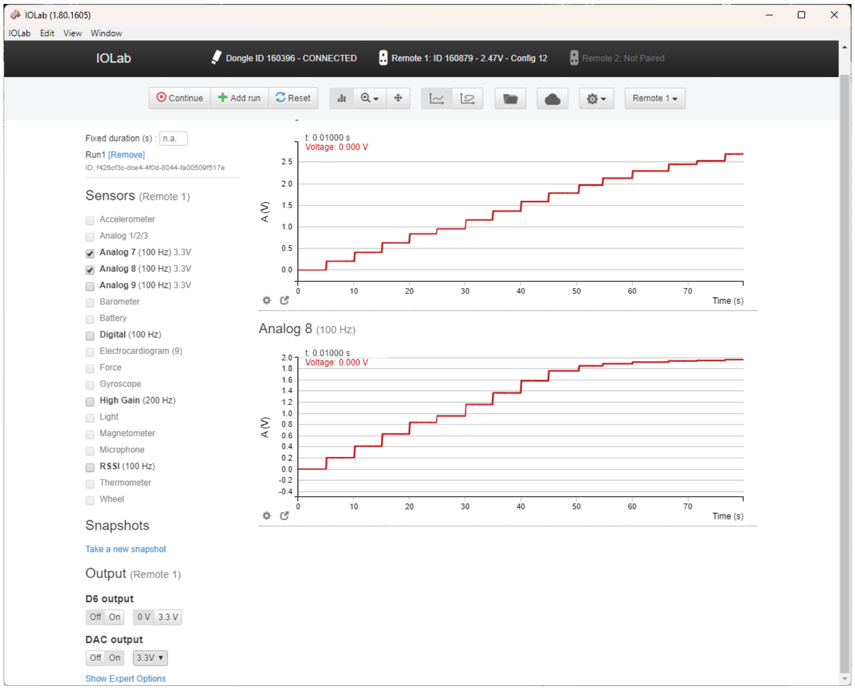
You will construct a circuit using a 100Ω resistor in series with one of the LEDs



- Red alligator clip connected to DAC.
- Blue alligator clip connected to A7.
- Yellow alligator clip connected to A8.
- White alligator clip connected to GND.

Now it's time to take some data:

- Click the Record button and record the voltages for A7 and A8 for about 5 seconds.
- While still recording, change the DAC Output voltage menu to 0.2V. Record for 5 more seconds.
- Change the DAC Output voltage in 0.2V steps up to 3.0V. With each change in voltage record the A7 and A8 voltage for about 5 seconds. Then click Stop.
- Swap the LED for a different color and repeat the measurements of A7 and A8 as you change the DAC Output voltage in 0.2V steps.

 yellow

11. Use the Analysis Mode in the iOLab application and record the voltages measured by sensors A7 and A8. Make sure you click the tab at bottom of the spreadsheet for the color LED you are measuring.

12. For each resistor, calculate the voltage across the resistor = A7 - A8.

13. For each resistor, calculate the current through the resistor I = V/R.

Now share the measurements of current and voltage for each LED with your team. You and your teams should all have data for four LEDs.

14. Make a scatter plot of LEDs Current vs. Voltage A7:
    a. Click on the top of the column with the values of A7 (V) (Column C).
    b. Press and hold the Ctrl key and click on the top of the column with the Current (A) values (Column E).
    c. Release Ctrl key and open the Insert menu and select Chart.
    d. The Charter Editor will open. In Setup choose Chart Type > Scatter Chart,
    e. Make sure the X-axis indicates A7 (V).
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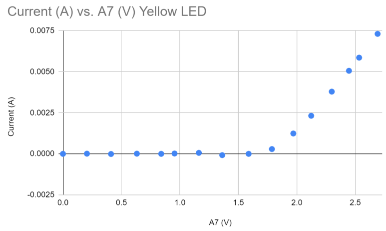
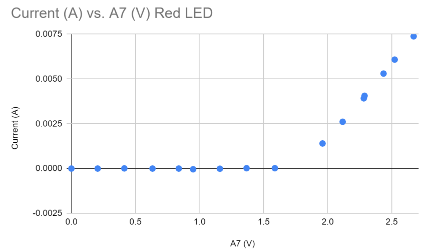
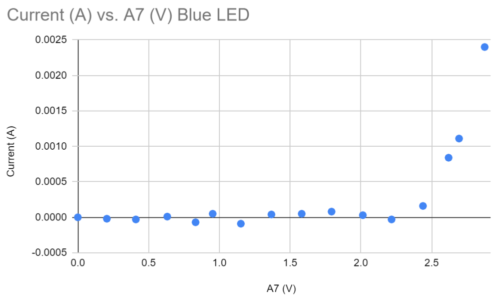
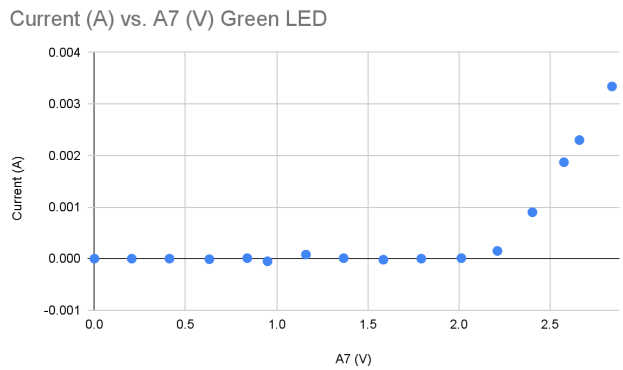
    h. Copy and paste your plot into this document below here:









15. Look closely at the plot of Current vs. Voltage. They all should look similar to the plot for the silicon diode, but there are some differences. Do the LEDs turn "on" at the same voltage?

The LEDs turn on at the same time in 2 different pairs, the red and yellow turn on at 1.8 V and blue and green turn on at 2.25 V

Now you are going to determine the threshold voltages for each of the LEDs. You will use the same method you used to find the threshold voltage of the silicon diode.

16. For each LED, use the built in function LINEST to determine the best slope and intercept of Current vs. Voltage.
    a. In an empty cell enter =LINEST(range of y,range of x,1,1).
    b. The range of y should be the range of cells with the values of Current in Column E. USE ONLY THE VALUES WHEN THE DIODE IS "ON"!
    c. The range of x should be the range of cells with the values of Voltage A7(V) in Column B. USE ONLY THE VALUES WHEN THE DIODE IS "ON"!

17. Using the best values of slope and intercept from LINEST to determine the threshold voltage. Hint: What would be the value of current flowing through the resistor at the threshold voltage?

LED	Threshold Voltage (V)
Red	1.806 V

Yellow	1.799 V
Green	2.247
Blue	2.444 V