Lesson #3: Build An Integrated Sensor System
A Teachers Guide

Outlook: Many students have no idea what a sensor does, let alone how to use two sensors together to collect data. Here is an opportunity for students to learn how to construct an apparatus that utilizes two basic sensors (light and voltage) to determine properties of different dilutions of conductive paint. Students may learn about the correlative relationship between light and voltage of different dilutions.

Purpose: Build your own integrated sensor system (potentiometer + light sensor) to determine relationship between variables. [or leave blank and have students fill in after conducting the lab]

Student Learning Objectives: By doing this exercise, students will:

1. Be able to correlate two quantities (conductivity and light values) to measure thickness of the conductive paint layer
2. Learn how to set up a complex experiment, collect data, and interpret the data in graph form.
3. Be able to use potentiometers and sensors to measure other physical characteristics of matter.

Topics Covered: Potentiometers, correlation of two variables to determine their relationship

CST:

Grade 8: 7c, 9a-g

Grade 9-12: Physics 5a-c

Materials: paper, tape, 400 ml beakers, various dilutions of conductive paint, paint brushes (2" foam is good), alligator clips, voltmeter, ManyLabs grove arduino setup, manylabs software, easy-set-up light box, light sensor, handouts

Time Needed:

Teacher Prep: It's easier if you prepare the paint for students to use to paint their own strips. Show students how your method for painting. There should be an evenly mixed dilution of paint, and the foam brush should have a

nice coat of the paint to paint an even stroke. Also have a reserve set of painted strips to show students how they should look. This should take about 20-30 minutes for mixing up dilutions and painting strips. Drying time will vary.

Students: Write 1st name and last initial on one side of each square, then paint the opposite sides with each dilution. Let set to dry in 10 minutes (so this could be done in one class period with explanation of lab, or in conjunction with other labs as a station with rotations)

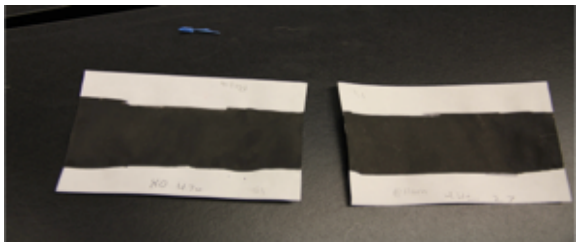
Grouping Ideas: For small classes, individual students conduct lab, for classes with 30+ kids, groups of 2-3 students would suffice (split tasks in procedure and make sure group members have same data)

Topics Covered: electrical circuits, real-time data collection, investigation and analysis, potentiometer.

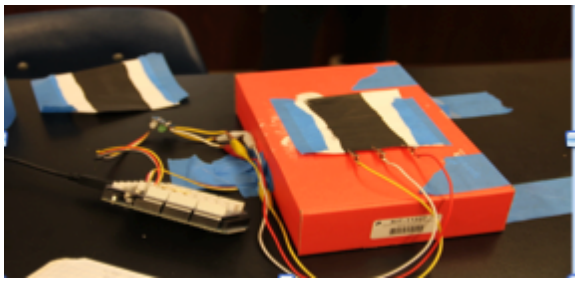
Procedures:

For Set Up

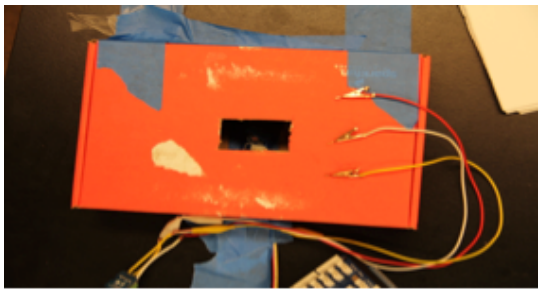
1. Collect 5 squares of paper, label one side of each square with your number and paint the opposite side of each with each diluted paint. Make sure to have students paint one continuous strip as carefully as possible. Let dry for 30 minutes to overnight. Note that very dilute solutions (1:5 and higher will take less time).



2. Make sure microcontroller, or voltmeter (if computer isn't working) is set up properly (check with teacher). Run in Mozilla Firefox, or Google Chrome.
3. Attach alligator clips according to diagram (Y=neg, R=pos, W=connection) to shaded circuit area, see below:



4. If computer is set up properly, open Manylabs “Exploring Graphite Potentiometers” and complete 1st step (making sure microcontroller is recognized and which com port is correct).
5. Prepare the light box for students but have them set it up. You can use any shoebox, small package box (I used a Sparkfun electronics package box). Set up your light box and put the “light sensor” under it. Make sure it is “centered” under the shaded-in area and tape it down. Here is an example:



6. NOTE: This depends on color of alligator clips. Y= yellow, R= red, and W= white. Pre-connect your 1st shade by clamping alligator clips (ex: Y=ground, R=5V, W=sensor) such that Y and R are opposite each other, and W is attached in the center.

For Running Sensor (If ManyLabs is working)

7. Run the plotter program in Mozilla Firefox to see what the initial value of light is without your shades (700+), and let it run. You will see “Light” and “Voltage” values that fluctuate. If it doesn’t do anything, check with teacher (this may mean restarting webpage, replugging in the microcontroller, or updating microcontroller.
8. While the program is running, tape down the shade and make sure the tape is not touching the paint. Attach the alligator clips in the manner as seen in step

#3 above.

9. Click “record 1:1” box and the values will show in the boxes to the side.
10. Detach the shade and attach the next dilution shade as said in #8 above.
11. Click “record 1:2” box and the values will show in the boxes to the side and a graph may show up.
12. Repeat Step #8 and click on the subsequent “record 1:x” boxes for the remainder of the shades.

SEE EXAMPLE BELOW:

Results: Students can write down the voltage and light values for each dilution in the chart below, as it is in their handout that they receive when the lab begins.

Dilution Factor	Light Value	Voltage
[undiluted]		
1:2		
1:3		
1:4		
1:10		

Conclusion: Answer the following discussion questions below.

1. Reattach the 1:4 dilution shade and try different positions for the W alligator clip (or whichever color you designate). What does the "voltage" sensor tell you specifically? What type of sensor is this? How can you tell?

The voltage sensor tells you the actual voltage read across a distance of conductive paint. The graphite paint is a potentiometer in this case because when you move the alligator clip you get different readings. If it is closer to the 5V clip, it will be higher, and if it is closer to the ground clip, it will be lower. (5 points)

2. While running the experiment on the computer, what differences did you notice with each square? Note the position of the "center" alligator clip and the voltage values for all dilutions.

Each square should have a successive increase in light values and decrease in voltage values. (2 points)

3. What does the change in light values actually mean? Explain.

Each successive dilution should have a greater light value because of the lighter shade of paint. This means the relative thickness of paint decreases with each dilution. And, since the paint is opaque to light, the thinner the paint, the less opaque it becomes and the more light is let through. (10 points)

4. What are some possible errors you encountered while doing this experiment? List at least three and explain them.

Accept any thought out answer. Answers can include messy painting giving bad readings, light box not set up properly, faulty leads on voltage sensor, incorrect placement of alligator clips. (15 points)

Extensions:

1. If you have some time, you could have students research and test different (nontoxic) spreadable materials that are conductive and they have at home (i.e., ketchup, mayonnaise, different types of mustards) and set up the same lab as above to see which substance has the greatest thickness (density?)
2. You could have students measure thickness (density?) of different fabrics by establishing the same conductivity using conductive tape, simple wire with alligator clips or other method.