Calibrate an Analog Sensor



Calibrating an electronic sensor is a basic skill that many scientists and engineers use when making precise measurements with data-collection tools. Essentially it means making hardware or software adjustments so that an electronic sensor reads correctly. Many analog sensors use a simple linear calibration, meaning the sensor reading varies in direct proportion to the voltage signal. This makes calibration relatively easy. Examples of these are the Vernier Dual-Range Force Sensor, pH Sensor, and Low-g Accelerometer. Other sensors use complex calibration equations making calibration somewhat harder. Examples of these are the Vernier Stainless Steel Temperature Sensor, Surface Temperature Sensor, Ion-Selective Electrodes, and Wide-Range Temperature Sensor.

This activity challenges you to perform a linear calibration using a Vernier sensor, and verify the accuracy of your model afterward.

DESIGN OBJECTIVES

- Calibrate an analog sensor.
- Check the accuracy of your sensor after calibration.

MATERIALS

Vernier computer interface (LabQuest, LabQuest Mini, LabPro, or Go!Link)
Logger *Pro* software
computer

One of these Vernier Sensors:
- Dual-Range Force Sensor
- pH Sensor
- Low-g Accelerometer

BACKGROUND

Analog sensors measure continuous signals. They can produce an unlimited number of values within a given range. Digital sensors, on the other hand, generate discrete signals. That means their data values increase or decrease in equal steps. Because their resolution is theoretically infinite, analog sensors make more precise measurements than digital sensors. However, analog sensors are prone to signal variation due to unwanted noise, such as static electricity. Many analog sensors have linear calibrations; that is, the voltage or electric potential from them varies in direct proportion with the sensor reading. Voltage can be converted into an appropriate measurement unit using the slope-intercept equation shown below:

(1) sensor reading = slope * voltage + intercept

where slope is the rate of change between the sensor reading and the voltage, and intercept is the offset or sensor value at zero volts.

If you know what the voltage will be for two different sensor values, you can determine the slope and intercept with a simple two-point calibration process. Consider the graph below.

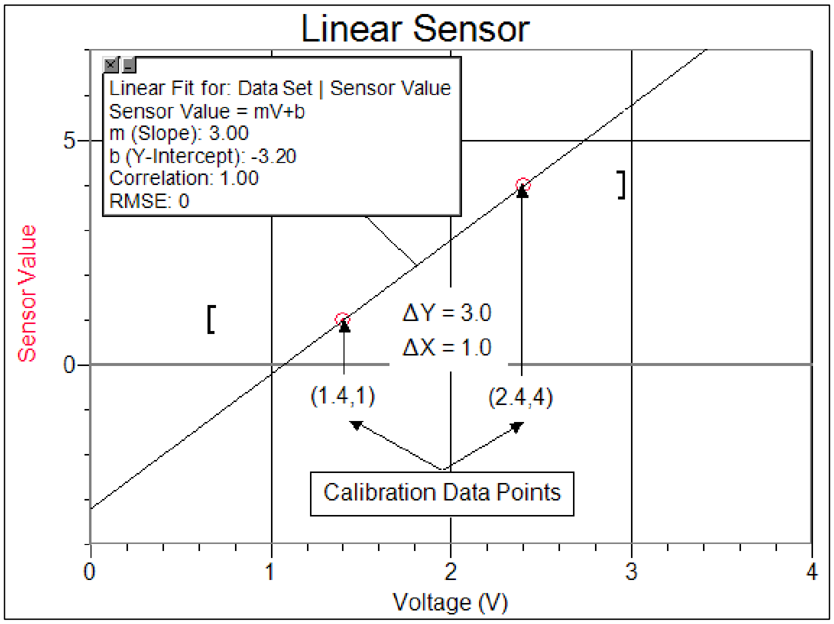

Figure 1 Two-point calibration

When the measured voltage is 1.4 V, the sensor value is 1 unit. Similarly, when the measured voltage is 2.4 V, the sensor value is 4 units. To calculate the slope, you divide the difference in the sensor values by the difference in the corresponding voltages, as shown in Equation 2. Using the data from our example yields a slope of 3.

(2) Slope = (Sensor Value 2–Sensor Value 1)/(V_2–V_1)

To find the intercept, you can either graphically determine it by drawing a line through the two data points until it crosses the y-axis, or you can mathematically calculate it using Equation 3. The mathematical method typically generates a more precise value. Using the data from our previous example yields an intercept of –3.2.

(3) Intercept = Sensor Value 2–slope * V_2

Once you have the slope and intercept constants determined for the sensor, you can specify them in Logger *Pro* and let the software convert voltages into proper sensor units.

PROCEDURE

Set up Logger *Pro* for Raw Voltage Readings

1. Connect a sensor to CH1on the Vernier interface.

2. Open Logger *Pro*.

3. Choose Set Up Sensors from the Experiment menu.

4. Click on the CH1 icon.

4. From the pull-down menu, select Choose Sensor ►Voltage ►Raw Voltage (0–5 V).

5. Close the Set Up Sensors configuration window.

Determine the Slope and Intercept of an Analog Sensor

1. You need to collect voltage readings for two different known situations. For the sensors recommended above, here are some possibilities:
   - Dual-Range Force Sensor: Hang no weight from the hook for the first reading (force = 0 N) and then hang a known weight for the second reading.
   - pH: Use a pH buffer solution of pH=4 for the first reading and a pH buffer solution of pH=10 for the second reading.
   - Low-g Accelerometer: Use gravity for both readings. If you point the arrow on the sensor horizontally, the value of the acceleration is zero. If you point the arrow vertically upward, then the value of the acceleration is $+9.8\ m/s^2$.

2. Record the voltage (electric potential) measured by Logger *Pro* for the two different situations below.

   Sensor Value 1 = ____________________ Potential 1 _____________V

   Sensor Value 2 = ____________________ Potential 2 _____________V

3. Calculate the slope and intercept using equations (2) and (3).

   Slope = ____________________________ Intercept = _______________

Convert Voltages to Sensor Readings

1. Choose New Calculated Column from the Data menu.

2. Enter an appropriate name and units for your sensor (e.g., Force in Newtons).

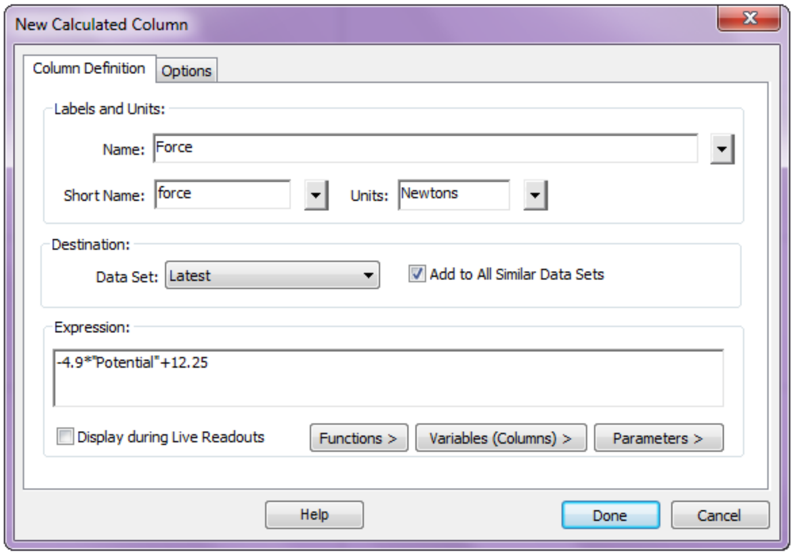

Figure 2 New Calculated Column configuration window

3. Enter Equation 1 into the Expression field. You can click on the Variables button to enter "Potential" into the expression.

4. Click Done.

Test Your Sensor

1. Click on the graph's y-axis label (Potential) and change it to the name of your new calculated column.

2. Start data collection.

3. Collect readings with your sensor for the two situations used during calibration. How accurate are your sensor readings?

4. Now try a different situation from the ones used in calibration. For example, if you are doing a pH calibration, insert the sensor into a third buffer solution. Is the sensor reading accurate?