Skill Builder: Dial Potentiometer

Overview:

In this lesson, students will learn how to build a simple device and calibrate it. The simple dial device is built from a Potentiometer with Knob, and protractor. The calibration process uses TI-Basic code from Skill Builder 4 to measure analog output from several different dial positions as measured by degree of clockwise rotation. After collecting several ordered pairs of data, students analyze the data to find a linear model between analog output and angular position of the dial. A TI-Basic program is written using the linear model to predict and display angular position of the Potentiometer with Knob based on the analog input value. Students will then evaluate their model for accuracy.

Goals:

1. Design and construct a device with a physical input and a voltage output.
2. Apply the skill of analog input (Unit 4) to collect data of dial position and analog output value.
3. Synthesize a linear model to predict dial position from analog input value.
4. Author a program that utilizes a best-fit linear model to display the dial position in degrees on the calculator.
5. Test and evaluate predicted dial position.

Background:

The world around us is observed with our five senses. We describe those observations as: “hot” or “cold”; “bright” or “dim”; “loud” or “quiet”. We might also observe the world around us using a machine or an instrument such as a thermometer to measure temperature, or a light meter to measure brightness, or a sound meter to measure loudness.

An added benefit of using an instrument to make measurements is they are quantitative that is they measure with numbers. When you put your finger in a hot pot of water on the stove you might say “that’s hot!”; when you put a thermometer in the pot it reports a numeric temperature, perhaps 78˚C.

Quantitative measurements, ones with numbers, are more useful in science and everyday life because they are more objective and without opinion. When engineers build an instrument, they must first find a phenomenon in nature that responds to the desired observation. For example, the liquid metal mercury, Hg, expands when it gets hot and contracts when cold. This phenomenon of metal expansion may be used to build a thermometer. When mercury is placed in a tube that has uniform marks and numbers on the outside, the device may be used to measure temperature.

The problem with building a device like the mercury thermometer is how does it know what 22˚C or 100˚C is? The answer is… the device must be calibrated to some standard. In other words, the engineers must find a mathematical equation that relates the one parameter to another. In the case of the mercury thermometer, this relationship is between the height of the mercury and its temperature.

In order to calibrate an instrument’s measurement, it must be compared with a standard. A standard is an agreed-on value for some measurement. For example, 0˚C is defined as the temperature water freezes while 100˚C is defined as the temperature water boils. These two constant phenomena can be used as standards to calibrate the mercury thermometer marks and evaluate its accuracy.

In this activity, students will calibrate the rotational position of the Potentiometer with Knob, as measured in degrees, with the analog output value displayed on their handheld.

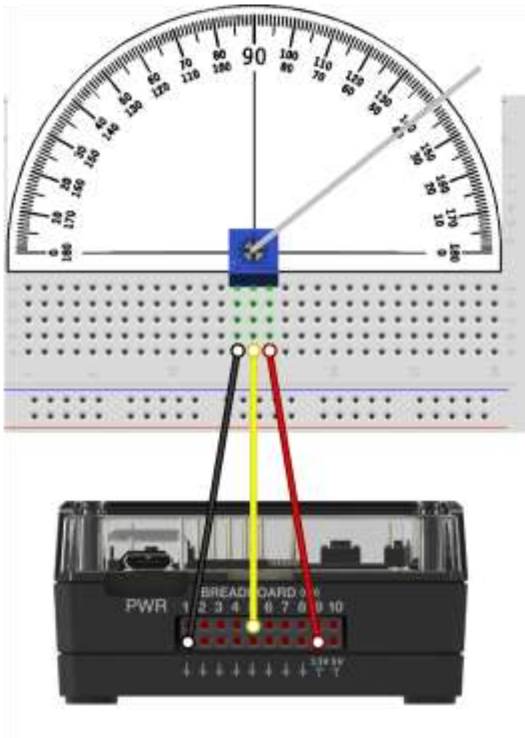
Materials and Tools:

- TI-84 Plus CE
- TI-Innovator™ Hub with USB Cable
- TI-Innovator Breadboard Pack:
  - Breadboard
  - Male to Male Jumper Cable
  - Potentiometer with Knob
- Printed protractor
- Scissors
- Breadboard
- Hot glue or tape
- Needle nose pliers (optional)

Build the Hardware:

Assemble the circuit in the diagram on the right by completing the following steps:

1. Print protractor and cutout to fit the breadboard.
2. Tape or glue protractor to the breadboard.
3. Insert the Potentiometer with Knob into the breadboard so that each leg is in a separate column and not electrically connected and that the shaft of the Potentiometer with Knob is centered over the origin of the protractor.
4. Insert a red Male to Male Jumper Cable from the red power bus to either outer leg of the Potentiometer with Knob.
5. Insert a black Male to Male Jumper Cable from the blue ground bus to the opposite outer leg on the Potentiometer with Knob.
6. Insert a yellow Male to Male Jumper Cable from the BB5 pin to the center leg of the Potentiometer with Knob.
7. Insert a red Male to Male Jumper Cable from the TI-Innovator Hub 3.3V to the red power bus on the breadboard.
8. Insert a black Male to Male Jumper Cable from any ground on the TI-Innovator Hub to the blue ground bus on the breadboard.
9. Plug the "B" end of the unit-to-unit USB cable into the TI-Innovator Hub and then the "A" end into the handheld device.



Tech Tip: It is important to print the protractor with a width of about 3 inches to match the width of the breadboard. Lightly glue the protractor onto the breadboard so the protractor does not move. Be sure the pointer is attached rigidly to the shaft of the Potentiometer with Knob. Be sure to insert the Potentiometer with Knob so the shaft is aligned over the origin of the protractor.

Write the Software for the TI-84 Plus CE:

Example Code for the TI-84 Plus CE:

```
Send("CONNECT ANALOG.IN 1 TO BB 5 ")
Send("READ ANALOG.IN 1")
Get(A)
Disp "ANALOG IN = ",A
```

Program 1 Description: Write a program that…

1. connects ANALOG.IN 1 to BB5.
2. reads the input voltage value from ANALOG.IN 1.
3. displays the "raw" value on the calculator with an appropriate message.

Task:

1. Rotate the pointer to the 0 degree position and then run the program to read the ANALOG.IN value from the TI-Innovator Hub. Record the value in table on right.
2. Rotate pointer to the 20-degree mark and again run your program and record the value in the table.
3. Repeat Step 2 until the table is complete.
4. From the STAT menu, choose EDIT to enter data into table. Enter analog input value into the column L1, and enter Dial position into column L2.
5. From the STAT PLOT menu, graph L1 (analog input) on the horizontal and L2 (dial position) on the vertical.
6. Press the Zoom menu key and ZoomStat (9) to plot the scatterplot.
7. Choose two representative points from the data table, and calculate the slope and intercept form (y=mx+b) of a line.
8. Press the y= key and enter the equation into Y= prompt.
9. Press the Graph key to plot the function.
10. Adjust the slope and intercept values so the function line fits the data best as judged by your eye.
11. Record the values of **m** (slope) and **b** (*y*-intercept) in data table; these will be used when writing the TI-Basic program in next section.
12. Alternatively, students can use the linear regression feature of the calculator to find best-fit equation.

Data Table:

Analog output (bit value)	Dial position (degrees)
	0
	20
	40
	60
	80
	100
	120
	140
	160
	180
Slope (m)	Y-intercept (b)

<u>**Sample Answer:**</u> **See Graphics Below for Results**

Write the Software for the TI-84 Plus CE:

Example Code for the TI-84 Plus CE:

```
Send("CONNECT ANALOG.IN 1 TO BB 5")
For(N,1,200)
Send("READ ANALOG.IN 1")
Get(A)
-.015*A+205→P
Disp "DIAL POSITION= ",P
Wait .1
End
```

Program 2 Description: Write a program that…

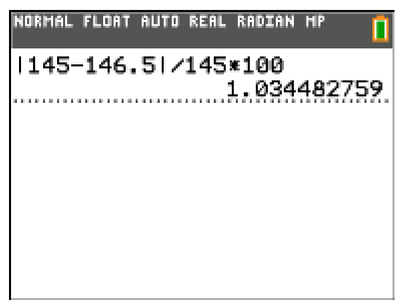
1. connects ANALOG.IN 1 to BB 5.
2. reads the analog value every .1 second.
3. incorporates the slope and intercept equation from the prior data analysis to calculate the position of the dial.
4. displays the position value in degrees with an appropriate message on the calculator.

Evaluate:

The accuracy of a measurement can be evaluated by comparing the actual value with the predicted value from the device. In this activity, the actual is the real position of the dial as measured by the protractor while the predicted is the calculated position that is displayed on the calculator by the program.

$$\%Error = \frac{|Actual - Predicted|}{Actual} \cdot 100$$

For example, the dial could be set to 145 degrees and the program running on the calculator reports 146.5 degrees. The two do not agree because the instrument is not extremely accurate. To evaluate the accuracy of the device, the percent error shown on the right would be calculated.



Task:

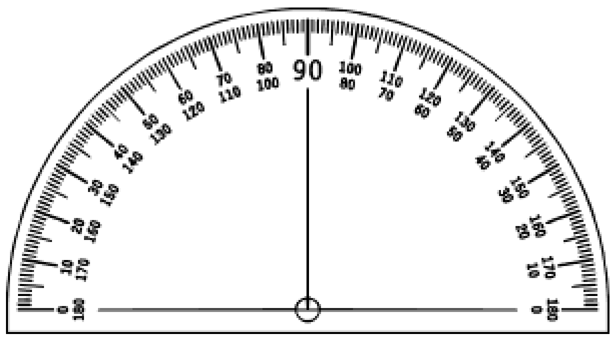
1. Set the dial of your Potentiometer with Knob to some number of your choosing that is NOT in the original data table.
2. Run your program that displays the dial position in degrees.
3. Record the actual dial position and also the predicted value.
4. Calculate the percent error of your instrument.
5. Write a paragraph interpreting the percent error you calculated and an evaluation of the accuracy of your dial.

Actual Value	Predicted Value
Percent Error	

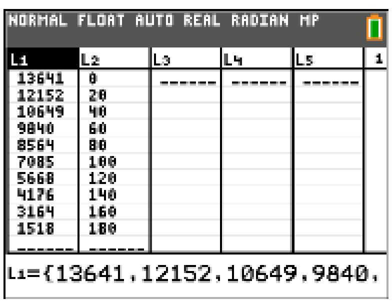
<u>**Sample Answer:**</u> **Answers will vary depending on how carefully the task is done. An example calculation is above and example data is below.**

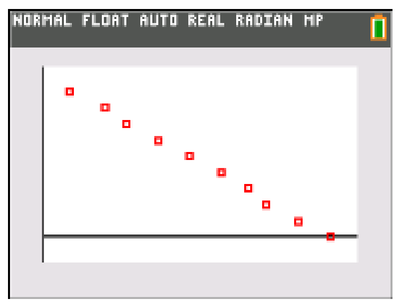
Extra for Experts:

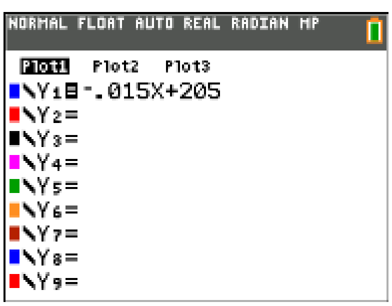
Modify the program to play a tone on the speaker that changes pitch as the dial is turned.

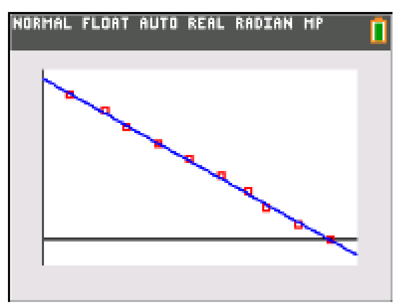


Example Calibration Results









Teacher Tip: Swapping the 3.3V and Gnd connections to the outer legs of the Potentiometer with Knob will reverse the sign of the slope of the data.

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