Sichuan University - Pittsburgh Institute

ME 1042

Mechatronics Lab

Angular Displacement

Revised March

2021

Mechanical Engineering Department

Lab 1: Angular Displacement

Figure 0: Accurate measurement of angular displacement is essential in many robotic applications

This lab explores angular displacement measurements using a potentiometer and an incremental encoder. Both sensors will be calibrated prior to measuring angular displacements. Different decoding algorithms for the encoders will be examined.

Learning Objectives

After completing this lab, you should be able to complete the following activities:

1. Understand the voltage dividing properties of a potentiometer
2. Calibrate the output of a potentiometer in terms of angular displacement
3. Determine an encoder's pulses-per-revolution
4. Examine non-quadrature, X2, and X4 decoding
5. Calibrate the output of an encoder in terms of angular displacement
6. Observe the effect of low sampling on the accuracy of measured data

Required Tools and Technology

Platform: NI ELVIS III	✓ View User Manual http://www.ni.com/en-us/support/model.ni-elvis-iii.html
Hardware: Quanser Mechatronic Sensors Board	✓ View User Manual http://www.ni.com/en-us/support/model.quanser-mechatronic-sensors-board-for-ni-elvis-iii.html
Software: LabVIEW Version 18.0 or Later Toolkits and Modules: • LabVIEW Real-Time Module • NI ELVIS III Toolkit	✓ Before downloading and installing software, refer to your professor or lab manager for information on your lab's software licenses and infrastructure ✓ Download & Install for NI ELVIS III ✓ http://www.ni.com/academic/download ✓ View Tutorials ✓ http://www.ni.com/academic/students/learn-labview/

Expected Deliverables

In this lab, you will collect the following deliverables:

- ✓ Record raw potentiometer output
- ✓ Screenshot of the potentiometer calibration graph showing fitted calibration curve
- ✓ Record potentiometer calibration coefficients
- ✓ Calculate potentiometer sensitivity in mV/deg
- ✓ Observe encoder signal edge counts using non-quadrature, X2, and X4 decoding
- ✓ Calculate encoder PPR
- ✓ Calculate encoder angular resolution
- ✓ Screenshot of encoder signal response

1 Experrimental Procedure

1.1 Measuring Angular Displacement using a Potentiometer

The Virtual Instrument (VI) used to collect data from and calibrate the potentiometer is shown in Figure 1.

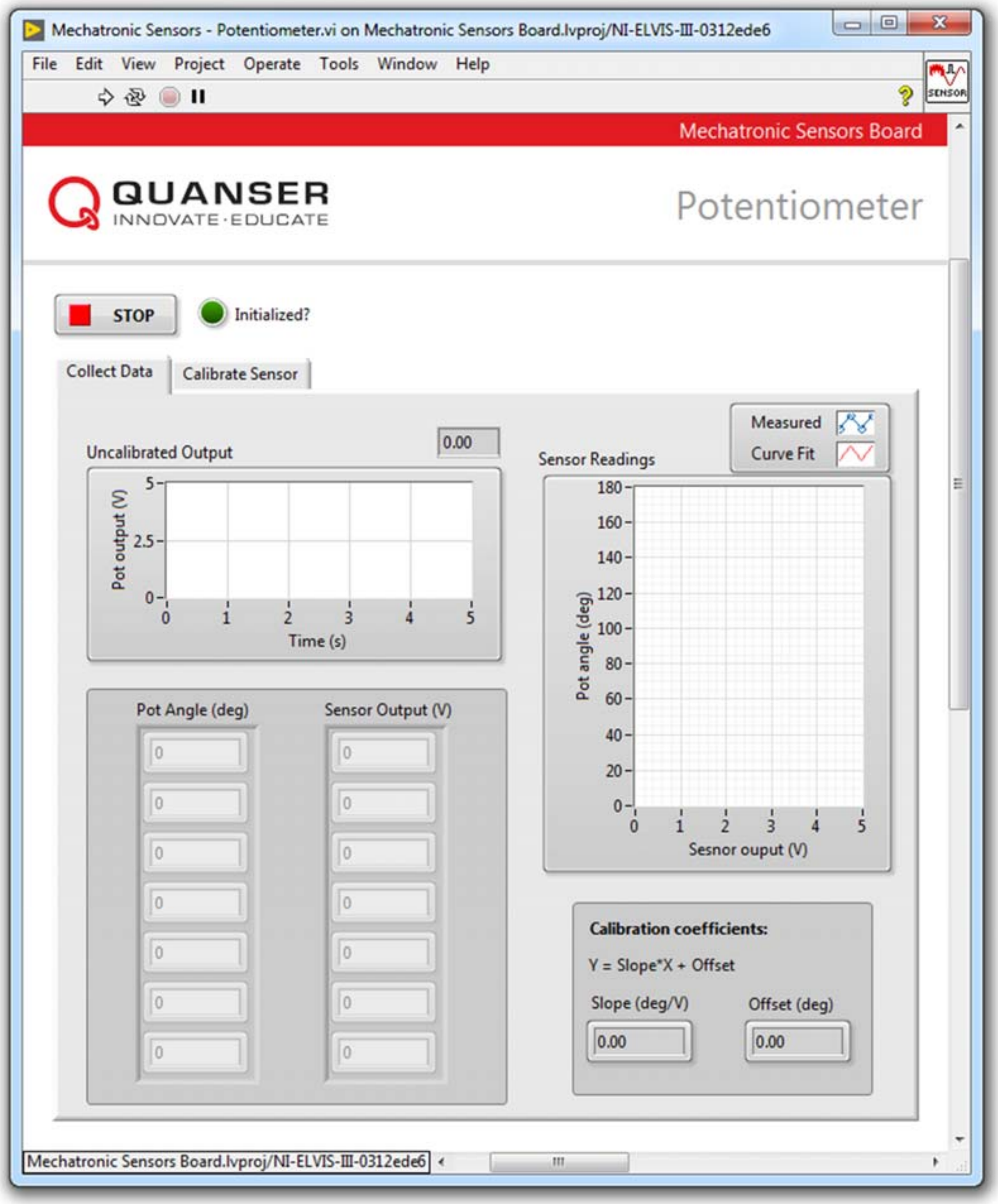

Figure 1: VI for collecting data from the potentiometer

1.1.1 Collect Data

1. Open **Mechatronic Sensors Board.lvproj**
2. From the **Project Explorer** window, open **Mechatronic Sensors - Potentiometer.vi**
3. Click on the **Collect Data** tab.
4. Run the VI.
5. Wait for the **Initialized?** LED indicator to turn on.
6. Set the potentiometer knob to the 0° mark.
7. Enter 0 in the **Pot Angle (deg)** array.
8. Using the **Uncalibrated Output** waveform chart, read the corresponding sensor output and enter the value in the **Sensor Output (V)** array.
9. Continue taking measurements by rotating the potentiometer at 30° intervals. Enter the angular position and measured sensor outputs in the **Pot Angle (deg)** and **Sensor Output (V)** arrays respectively. Take a screenshot of your results.

   Note: Once all of the measured data have been entered, a linear curve is automatically generated to fit the data. The curve is shown in the **Sensor Readings** waveform graph. This curve represents the calibration curve of the sensor.

10. The slope and offset of the calibration curve are automatically calculated by the VI and displayed in the **Slope (deg/V)** and **Offset (deg)** indicators. Make a note of these values.
11. Record the collected data in Table 1.
12. Take a screenshot of the **Sensor Readings** graph.
13. Continue to the next section.

Table 1: Recorded potentiometer measurements

Angle (deg)	Output (V)
0°	
30°	
60°	
90°	
120°	
150°	
180°	

1.1.2 Calibrate the Potentiometer

14. Click on the **Calibrate Sensor** tab to calibrate the output of the potentiometer in terms of angular position (in degrees).
15. Use the **Slope (deg/V)** and **Offset (deg)** numeric controls to enter the slope and offset values you obtained during the data collection step.
16. Test the accuracy of your calibration. To do this, set the potentiometer knob to different angles and verify that the correct angular position is displayed in the **Calibrated Output** waveform chart as well as the **Pot Angle (deg)** meter indicator.
17. Press the **Stop** button.

1.2 Measuring Angular Displacement using an Encoder

The Virtual Instrument (VI) used to collect data from and calibrate the encoder is shown in Figure 2.

Figure 2: VI for collecting data from the encoder

1.2.1 Non-quadrature Decoding

1. Open **Mechatronic Sensors Board.lvproj**
2. From the **Project Explorer** window, open **Mechatronic Sensors - Incremental Encoder.vi**
3. From the **Decoder** drop-down menu, select **non-quad**.
4. Run the VI.

5. Wait for the **Initialized?** LED indicator to turn on.
6. In non-quadrature decoding only signal A is used. Rotate the encoder knob in the clockwise direction. How does the **Edge (count)** numeric display change?
7. Rotate the knob in the counter-clockwise directions. How does the **Edge (count)** numeric display change?

   Note: At any time you can press the *Reset* button to reset the counter. This will rest the **Edge (count)** and **Angle (deg)** numeric displays to zero.

8. Using the **Edge (count)** numeric display, determine the number of pulses the encoder generates per each full revolution (PPR).

   Note: PPR is determined in non-quadrature mode. It refers to the total number of pulses generated by *Signal A* when the encoder makes one full revolution. The value of PPR will be used to calibrate the encoder pulses in terms of angular displacement in degrees.

9. Continue to the next section.

1.2.2 Calibrate the Encoder

10. Calibrate the pulses of the encoder in terms of angular displacement. To do this, enter the PPR value which was calculated in the previous section in the **PPR** numeric control and press the **Enter** key.
11. Verify the accuracy of your calibration. To do this, first press the **Reset** button then rotate the encoder knob and verify that the correct angular position is displayed in the **Angle (deg)** numeric indicator.
12. Continue to the next section.

1.2.3 X2 Decoding

13. From the **Decoder** drop-down menu, select **X2**.
14. Press the **Reset** button.
15. In X2 decoding both signals A and B are used. Rotate the encoder knob in the clockwise direction. How do the **Edge (count)** and **Angle (deg)** numeric displays change?

    Note: An encoder will have a fixed PPR value regardless of the decoding algorithm that is used.

16. Rotate the knob in the counter-clockwise direction. How do the **Edge (count)** and **Angle (deg)** numeric displays change?
17. Examine the behavior of signal A and signal B.
18. What is the resolution of the measured angular displacement?
19. Continue to the next section.

1.2.4 X4 Decoding

20. From the **Decoder** drop-down menu, select **X4**.
21. Press the **Reset** button.
22. Rotate the knob in the clockwise and counter-clockwise directions. How do the **Edge (counts)** and **Angle (deg)** numeric displays change?
23. What is the resolution of the measured angular displacement?
24. Examine the behavior of signal A and signal B as you slowly rotate the encoder knob in the clockwise direction. In particular, compare the behavior of signals A and B and you rotate the encoder in the clockwise direction with the state machine diagram shown in Figure 2-4. Take a screenshot of your results.
25. Press the **Stop** button.

3 For the Repot

The report format will be a **MEMO**. Be sure to include:

Potentiometer

1. The results you recorded in Table 1.
2. The calibration equation that you obtained.
3. The sensitivity of the sensor in mV/deg.

Encoder

1. What is the PPR of the sensor?
2. What is the angular resolution of sensor when using non-quadrature/X1, X2 and X4 decoders?
3. Using the screenshot you captured, compare the behavior of signals A and B and you rotate the encoder in the clockwise direction with the state machine diagram for X4 decoding algorithm. Do your results match the state machine sequence?

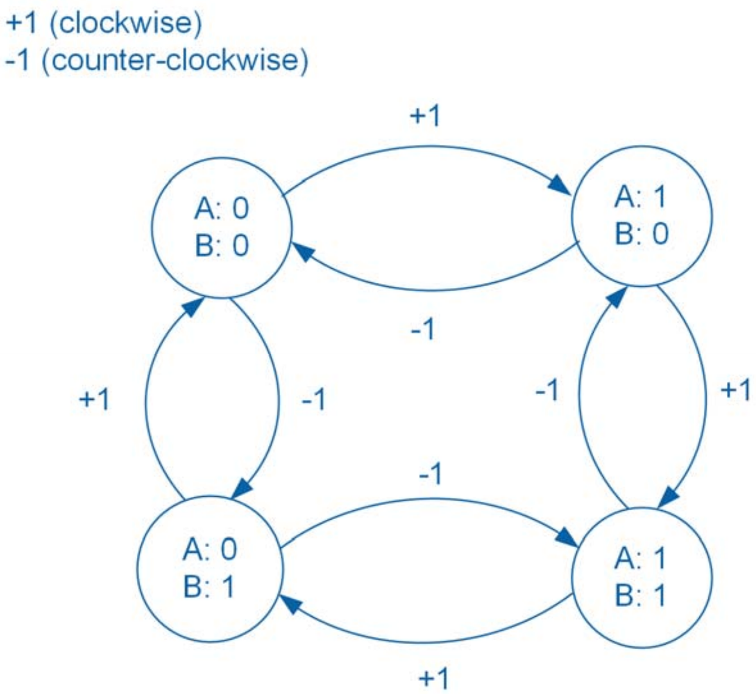

Figure 3: State machine representation of the X4 decoding algorithm