**Department of Electrical Engineering**

|  |  |
| --- | --- |
| **Faculty Member:\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Dated: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **Semester:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Section: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** |

**EE-383**-**Instrumentation and Measurements**

**Experiment # 9**

**QNET Mechatronic Sensors**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **PLO4/**  **CLO3** | | **PLO4/ CLO4** | **PLO8/ CLO5** | **PLO9/ CLO6** |
| **Name** | **Reg. No** | **Viva / Quiz / Lab Performance** | **Analysis of data in Lab Report** | **Modern Tool Usage** | **Ethics and Safety** | **Individual and Teamwork** |
|  |  | **5 Marks** | **5 Marks** | **5 Marks** | **5 Marks** | **5 Marks** |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

**Lab no. 9**

**QNET Mechatronic Sensors**

# OBJECTIVE

In this lab, you will be introduced to QNET Mechatronics Sensor board; and you will learn:

* QNET Mechatronic Sensor Board and its salient features
* Encoder, working principle , uses and application
* Potentiometer, its working principle, uses and application.

# Introduction to QNET Mechatronics Sensors

# The QNET Mechatronic Sensors, pictured in Figure 1, is an engineering trainer board designed for teaching and demonstrating the fundamentals of common sensors used in mechatronic applications. It provides students hands-on experience measuring calibrating and analyzing the following physical properties/phenomenon: temperature, angular position, short and long distances, vibration, pressure, strain, switch debouncing, and natural frequency. The system is operated using a PC running LabVIEW, and the NI ELVIS II.

# Main QNET Mechatronic Sensors features:

# ● Thermistor

# ● Quadrature encoder

# ● Potentiometer

# ● Infrared (IR) range sensor

# ● Ultrasonic range sensor

# ● Magnetic field sensor

# ● Reflective optical sensor

# ● Piezo vibration sensor

# ● Absolute pressure transducer

# ● Strain gage (quarter-bridge type II)

# ● Snap action/micro switch

# Hardware Components:

# The main components comprising the QNET Mechatronic Sensors are labeled in Figure 1 and are listed in Table below.

# Table Description automatically generated

# 

# *Figure 1: QNET Mechatronic Sensors and its components.*

# Part (a): Encoder

# What is an Encoder?

# An incremental optical encoder, shown in Figure 2, is a relative angular displacement sensor which measures angular displacement relative to a previously known position. Unlike an absolute encoder, an incremental encoder does not retain its position information upon power loss. An incremental encoder outputs a series of pulses which correlate to relative change in angular position. Encoders are commonly used to measure angular displacement of rotating load shafts. Information extracted from an incremental encoder can also be used to derive instantaneous rotational velocities.

# 

# *Figure 2: US Digital incremental rotary optical shaft encoder.*

# An incremental optical encoder typically consists of a coded disk, an Infrared (IR) LED, and two photo sensors. The disk is coded with an alternating light and dark radial pattern causing it to act as a shutter. As shown schematically in Figure 3, the light emitted by the IR LED is interrupted by the coding as the disk rotates around its axis.

# 

# *Figure 3: Output of an incremental encoder showing signals A and B when rotating in a clockwise manner*

# The two photo sensors (A and B) positioned behind the coded disk sense the infrared light emitted by the IR LED, which results in A and B signals/pulses, in four distinct states:

# 1. A off, B on

# 2. A off, B off

# 3. A on, B off

# 4. A on, B on

# Encoders which output A and B signals are often referred to as quadrature encoders since

# the signals are separated in phase by 90° and result in four distinct states. Non-quadrature encoders have only one output signal and thus are unable to detect direction. The resolution of an encoder corresponds to the number of light or dark patterns on the disk and is given in terms of pulses per revolution , or PPR.

# Some encoders utilize an index pulse (Z channel), which is triggered once for every full rotation of the disk (see Figure 4). The index pulse can be used for calibration or so-called homing of a system, as well as a revolution counter. Depending on the encoder, the width of the index plus may be aligned with any of the four quadrature states. For example, the index pulse may have a width that spans a full cycle (4 states), a half cycle (2 states), or a quarter cycle (1 state). In the example shown in Figure 4, the width of the index pulse is aligned with a full cycle of the B signal.

# 

# *Figure 4: Output of a quadrature encoder with an index pulse.*

# Procedure

# The Virtual Instrument (VI) used to collect data from and calibrate the encoder is shown in Figure 5.

# 

# *Figure 5: VI used to collect data from and calibrate the encoder.*

# Analysis of Non-quadrature Decoding

# 1. Open QNET Mechatronic Sensors.lvproj .

# 2. From the Project Explorer window, open QNET Sensors Encoder.vi .

# 3. From the Device drop-down menu, select the device name.

# 4. From the Decoding Algorithm drop-down menu, select non-quadrature (no index) .

# 5. Run the VI.

# 6. In non-quadrature decoding only A signal is used. Rotate the encoder knob in the clockwise direction. How does the Edge (counts) numeric display change?

# Note : The index pulse is not used in non-quadrature decoding.

# 7. Rotate the knob in the counterclockwise direction. How does the Edge (counts) numeric display change?

# Note: At any time, you can press the Reset button to reset the counter. This will rest the

# Edge (counts) and Angle (deg) numeric displays to zero.

# 8. Using the Edge (counts) numeric display, measure 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 the A signal 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.

# Calibrate the Encoder

# 1.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 Pulses per revolution (PPR) numeric control and press the Enter key.

# 2. Verify the accuracy of your calibration. To do this, rotate the encoder knob and verify that the correct angular position is displayed in the Angle (deg) numeric indicator.

# 3. Calculate the expected angular resolution using Equation 2 in the Concept Review . Rotate the encoder knob and verify if you measure the same resolution?

# 4. Continue to the next section.

# Analysis of X2 Decoding

# 1. From the Decoding Algorithm drop-down menu, select X2 .

# 2. Press the Reset button.

# 3. In X2 decoding both A and B signals are used. Rotate the encoder knob in the clockwise direction. How do the Edge (counts) and Angle (deg) numeric displays change?

# Note : The PPR value remains constant regardless of the decoding algorithm used.

# 4. Rotate the knob in the counterclockwise direction. How do the Edge (counts) and Angle (deg) numeric displays change?

# 5. Examine the response of the A and B signals.

# 6. What is the resolution of the measured angular displacement?

# 7. Continue to the next section.

# 2. Analysis of X4 Decoding

# 1. From the Decoding Algorithm drop-down menu, select X4 .

# 2. Press the Reset button.

# 3. Rotate the knob in the clockwise and counterclockwise directions. How do the Edge (counts) and Angle (deg) numeric displays change?

# 4. What is the resolution of the measured angular displacement?

# 5. Continue to the next section.

# Analysis of the Index Pulse

# 1. Before using the index pulse, you must first determine the unique combination of signal A and signal B that occurs only once during the width of the index pulse. It is preferred to select a unique state that occurs closer to middle of the index pulse.

# 2. Slowly turn the encoder until you see a full index pulse. Immediately stop the VI using the Stop button.

# 

# *Figure 6: Response of the index pulse.*

# 3. Figure 6 shows a typical response. If needed, use the Graph Palette to zoom into the waveform chart. In this example, several unique combinations of signal A and signal B occur during the width 3 of the index pulse. For example, one combination is when both signal A and signal B are high. Determine the unique state based on your results.

# 4. Re-run the VI.

# 5. Press the Reset button.

# 6. Enable the Enable Index button.

# 7. Set the A Polarity and B Polarity buttons based on your analysis of the index pulse. For example, to select a high state for both signal A and B, enable both A Polarity and B Polarity buttons.

# 8. Rotate the encoder knob a few full revolutions. How does enabling the index to affect the readings? What can this be used for?

# Note: To observe the effect of the index pulse, you must rotate the encoder knob at least one full revolution.

# 9. If no further experiments are required, press the Stop button and power down the experiment.

# Part 2: Potentiometer

# What is a Potentiometer?

# A rotary potentiometer, or pot, is a manually controlled variable resistor. As shown in Figure 1, it typically consists of an exposed shaft, three terminals (A, W, and B), an encased internal resistive element shaped in a circular pattern, and a sliding contact known as a wiper. By rotating the shaft, the internal wiper contacts the resistive element at different positions, causing a change in resistance when measured between the center terminal (W) and either of the side terminals (A or B). The total resistance of the potentiometer can be measured by clamping a multimeter to terminals A and B.

# 

# *Figure: A typical rotary potentiometer*

# A schematic diagram of the voltage dividing characteristic of a potentiometer is illustrated in Figure 3. By applying a known voltage between terminals, A and B ( ), voltage is divided between terminals AW and WB such that:

# VAB =VAW +VWB

# When connected to an external shaft, a rotary potentiometer can measure absolute angular displacement. In this application, by applying a known voltage to the outside terminals of the pot, we can determine the position of the sensor based on the output voltage or which will be directly proportional to the position of the shaft. One of the advantages of using a potentiometer as an absolute position sensor is that after power loss, position information is retained since the resistance of the pot remains unchanged.

# 

# *Figure : Schematic diagram of the voltage dividing characteristic of a rotary potentiometer.*

# The typical lifespan of a pot is a few thousand rotations. This is because the wiper makes physical contact with the resistive element inside the pot, eventually wearing it out. This physical contact and the presence of dust also causes both mechanical and electrical noise. While the mechanical noise is rather inaudible in modern pots, electrical noise causes variations in the measured output. In audio applications where pots are used for volume and tone control, the electrical noise manifests itself in the form of audible pops and crackles.

# Procedure

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

# 

# 

# *Figure 1: VI used to collect data from and calibrate the potentiometer*.

# Collect Data

# 1. Open QNET Mechatronic Sensors.lvproj .

# 2. From the Project Explorer window, open QNET Sensors Potentiometer.vi .

# 3. Click on the Collect Data tab.

# 4. From the Device drop-down menu, select the device name.

# 5. Run the VI.

# 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.

# Note: As the measured readings are 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.

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

# 

# Table 1: Recorded potentiometer measurements.

# 12. Export a copy of the Sensor Readings graph. To do this, right-click on the graph and select Export .Export Simplified Image .

# 13. Continue to the next section.

# Calibrate the Potentiometer

# 1. Click on the Calibrate Sensor tab to calibrate the output of the potentiometer in terms of angular position (in degrees).

# 2. Use the Slope (deg/V) and Offset (deg) numeric controls to enter the slope and offset values you obtained during the data collection step.

# 3. 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.

# 4. If no further experiments are required, press the Stop button and power down the experiment.

# Conclusion: