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QNET Mechatronic Sensors Trainer for NI ELVIS

Developed by Quanser

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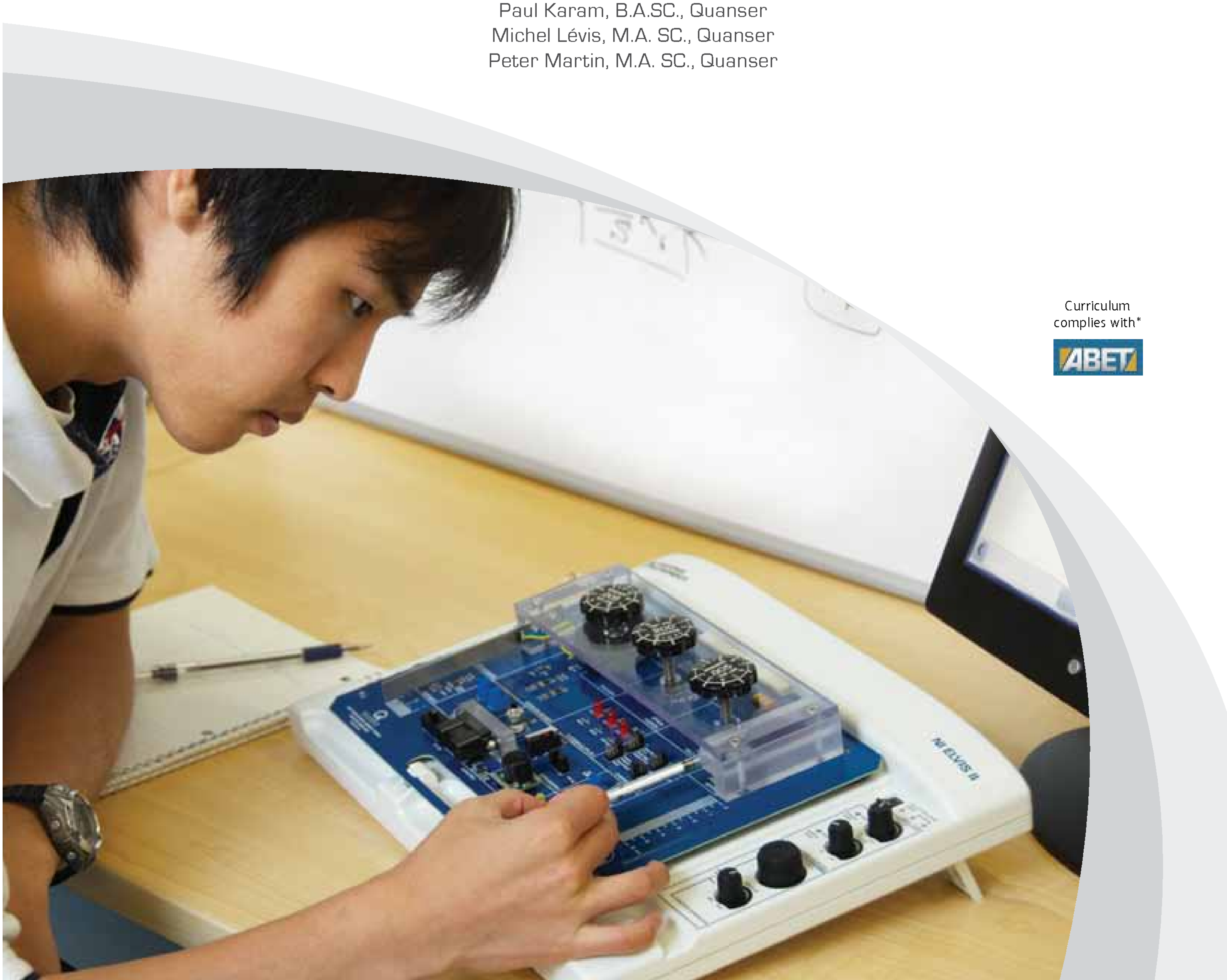

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Contents

1 INTRODUCTION

Mechatronics engineering is a cross-disciplinary field that combines mechanical and electronic design in control systems architecture though the application of computer programming. One of the most useful topics that can be covered in an introductory mechatronics course is the understanding and application of sensors. Various sensors are used in all types of industries. For example, in the automotive industry magnetic field transducers are used for throttle, pedal, suspension, and valve position sensing. In assembly line and machine automation, optical sensors are used for non-contact position sensing and safety. Piezo film sensors are installed in packages to log vibration history of a shipment.

The QNET mechatronics sensors (MECHKIT) trainer is shown in Figure 1.1. It has ten types of sensors, two types of switches, a push button, and two LEDS. This QNET module can be used to teach the physical properties of most sensors used today, and the techniques and limitations of their application.

Figure 1.1: QNET Mechatronic Sensors Trainer (MECHKIT)

There are 12 experiments: strain gage with flexible link, pressure sensor, piezo sensor, potentiometer, infrared, sonar, optical position, magnetic field, encoder, temperature sensor, switches and LEDs, and switch debounce analysis. The experiments can be performed independently.

Topics Covered

- Strain gauge to measure deflection
- Piezo film sensor to measure vibration
- Rotary potentiometer to measure position
- Pressure and thermistor sensors
- Long range sensors: sonar and infrared
- Short range sensors: magnetic field and optical
- Micro switch, push button, and optical switch
- Light emitting diodes (LEDs)
- Encoders
- Switch debouncing

Prerequisites
In order to successfully carry out this laboratory, the user should be familiar with the following:

- Using LabVIEW®to run VIs.

2 SENSOR PROPERTIES

This section discusses various sensor properties that are often found in technical specifications.

2.1 Resolution

The resolution of a sensor is the minimum change that can be detected in the quantity that is being measured. For instance a sensor that measures angular position of a motor shaft may only be able to detect a 1 degree change. Thus if the motor moves 0.5 degrees, it will not be detected by the sensor. Depending on the precision needed for the application, this may be adequate.

2.2 Range

Range sensors can only take measurements of a target within a certain operating range. The operating range specifies a maximum, and sometimes also a minimum, distance where the target can be from the sensor in order to obtain an accurate measurement. Sensors with a small range are the magnetic field and optical position sensors. Sensor with a relatively larger range are infrared and sonar.

2.3 Absolute and Incremental

Absolute sensors detect a unique position. Incremental sensors measure a relative position that depends on a prior position or last power on/off. For example, if an incremental rotary encoder is used to measure the position of wheel, the encoder will measure zero every time its power is reset. If an absolute sensor such as a rotary potentiometer is used, then it will detect the same angle regardless if it has just been powered.

2.4 Analog Sensor Measurement

Analog sensors output a signal that correlates to the quantity it is measuring. The relationship between the output signal of the sensor and the actual measurement varies depending on the type of sensor. For example, the voltage measured by a potentiometer is directly proportional to the angle it is measuring. However, the resistance of a thermistor decreases exponentially as the temperature increases.

Some of the different ways to characterize analog sensors is illustrated in Figure 2.1.

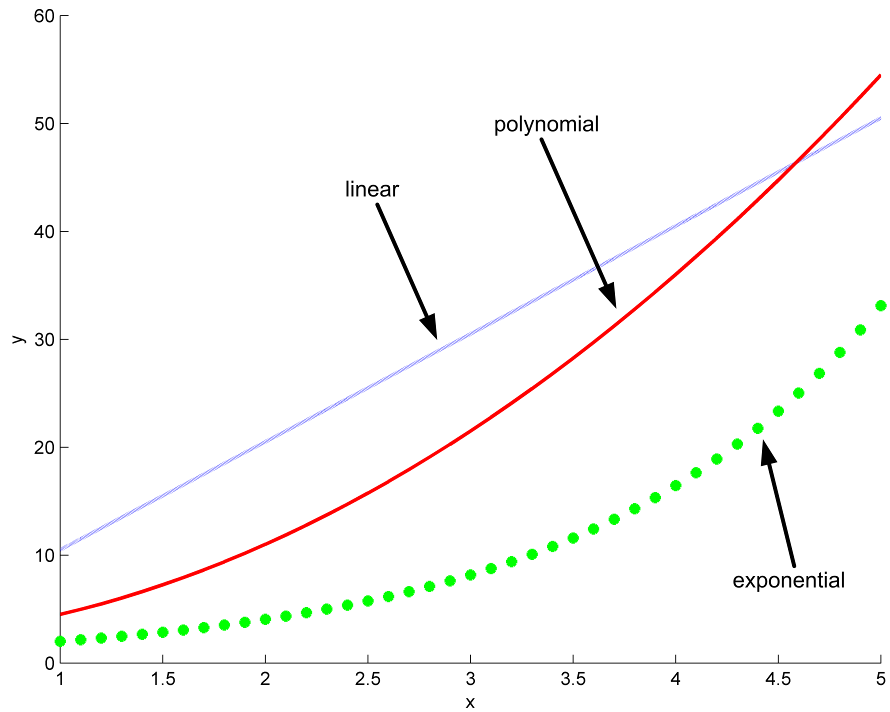

Figure 2.1: Different sensor responses

Linear sensors can be modeled using the equation

$$y = ax + b \tag{2.1}$$

where a is the rate of change and b is the offset. Variable x is the sensor output signal and y is the measurement, e.g. for the potentiometer x would be the voltage measured by the sensor and y would be the angular measurement (in either degrees or radians). Other types of sensors need to be characterized by more complex relationship such as polynomial

$$y = ax^2 + bx + c \tag{2.2}$$

or exponential

$$y = ae^{bx} \tag{2.3}$$

3 STRAIN GAGE WITH FLEXIBLE LINK

3.1 Background

A strain gage measures strain, or deflection, of an object. As shown in Figure 3.1, in the QNET mechatronic sensors trainer a strain gage is used to measure the deflection of a flexible link. As the link bends, the resistance of the strain gage changes.

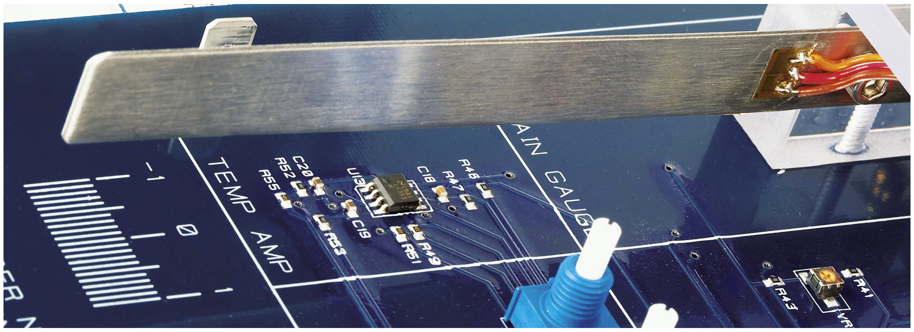

Figure 3.1: Strain gage measuring deflection of flexible link on QNET mechatronic sensors trainer

deflection of flexible link on QNET mechatronic sensors trainer.

3.2 Strain Virtual Instrument

The virtual instrument used to collect data using the strain gage is shown in Figure 3.2. The virtual instrument used to calibrate strain data is shown in Figure 3.3. The virtual instrument used to determine the natural frequency of the flexible link is shown in Figure 3.4.

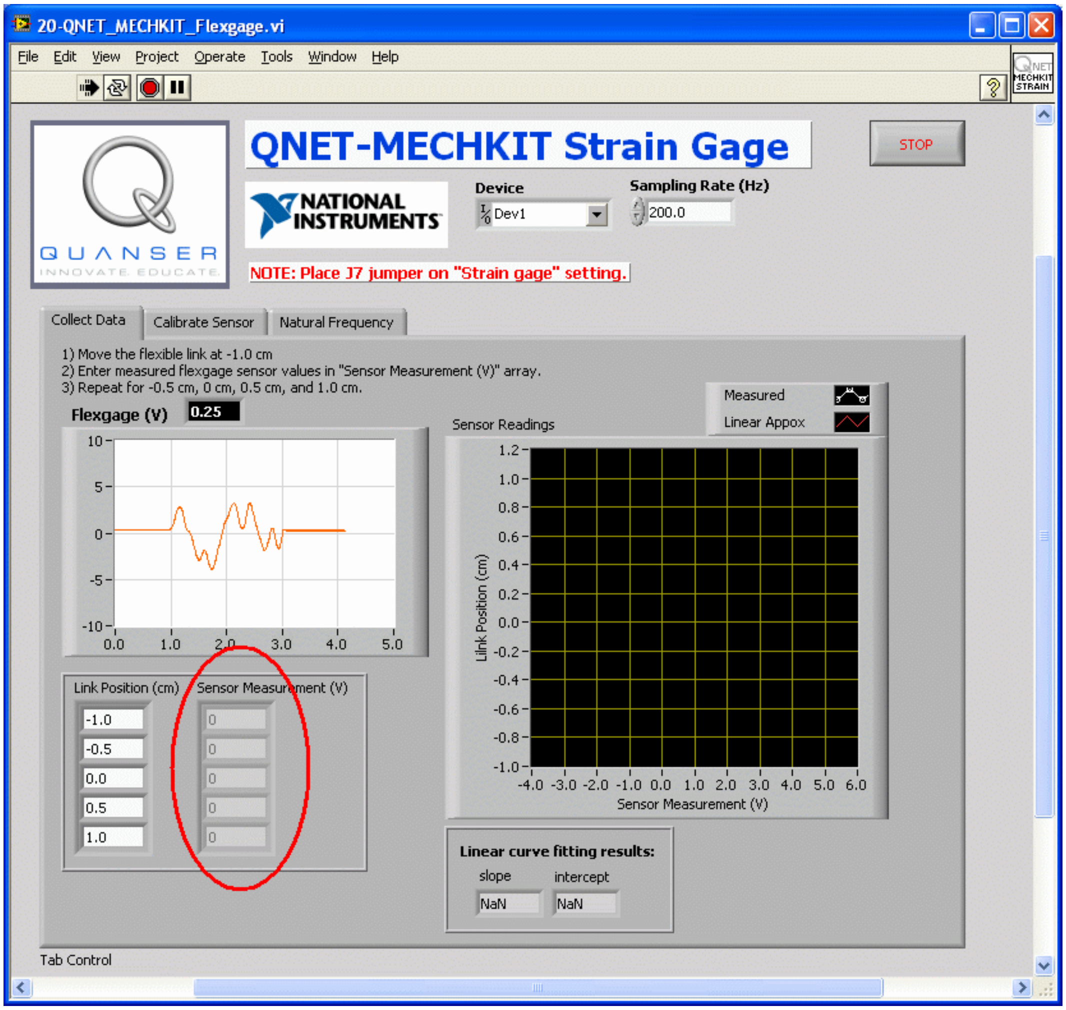

Figure 3.2: Collecting flexgage data

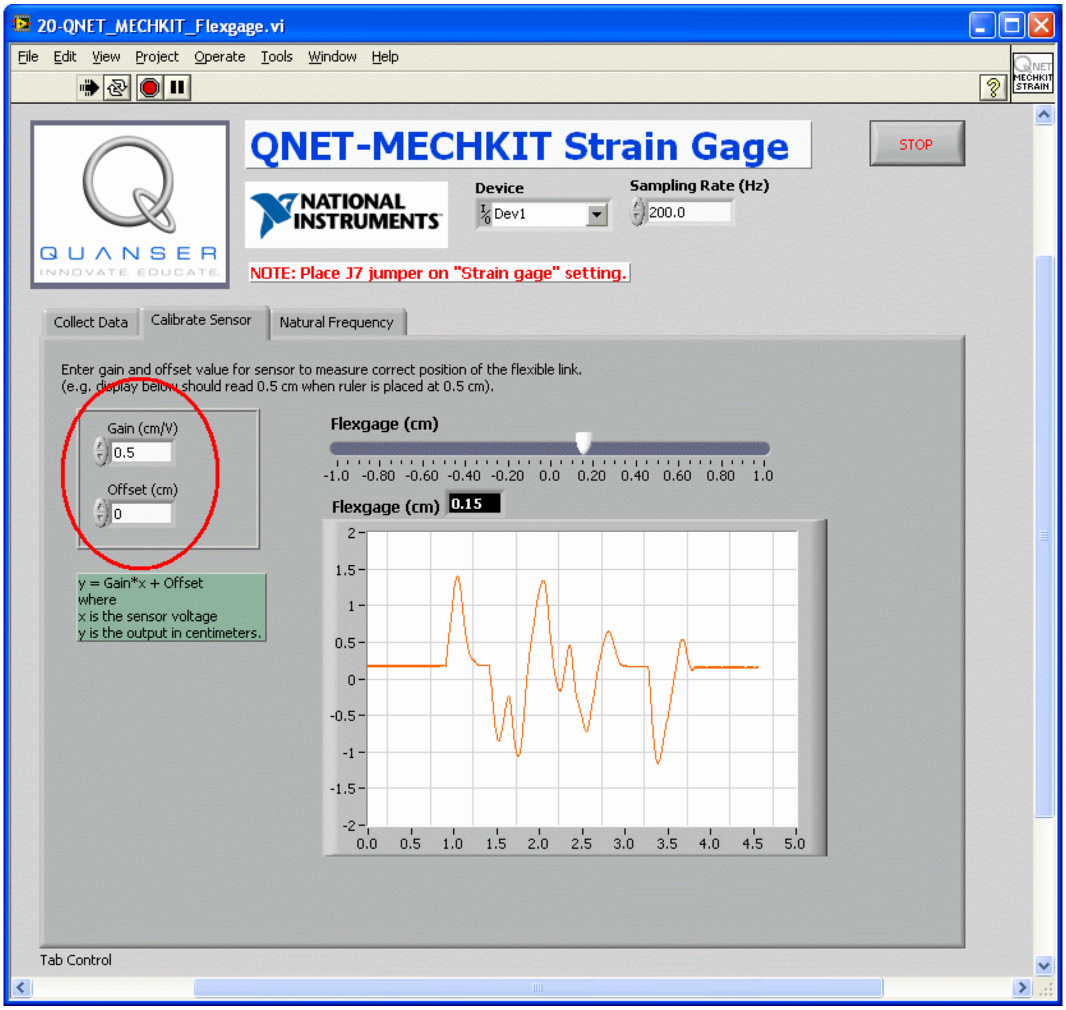

Figure 3.3: Calibrating the strain gage sensor

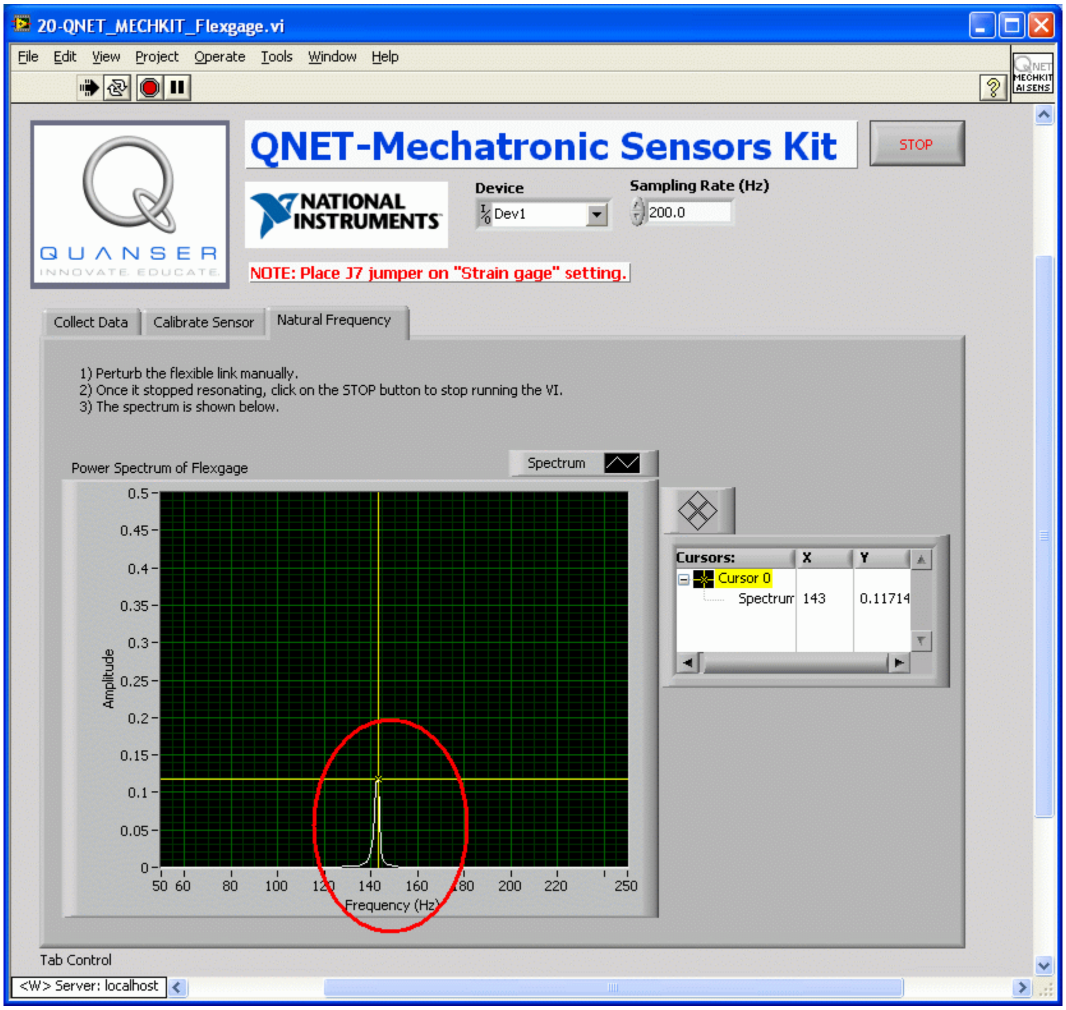

Figure 3.4: Finding natural frequency of flexible link

3.3 Lab 1: Collect Data

1. **Ensure *J7* is set to *Strain Gage*.**
2. Open and configure the QNET MECHKIT Flexgage VI as described in Section 15.2. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Flexgage.vi
4. Move the flexible link to -1 cm.
5. Enter the strain gage voltage reading in the *Sensor Measurement (V)* array (indicated in Figure 3.2).
6. Repeat for -0.5 cm, 0 cm, 0.5 cm, and 1.0 cm. A linear curve is automatically fitted to the data being entered and its slope and intercept are generated.
7. Enter the measured voltages and capture the *Sensor Readings* scope.

Parameter	Value	Units	Notes
Sensor Measurement: at -1.0 cm		V	
Sensor Measurement: at -0.5 cm		V	
Sensor Measurement: at 0 cm		V	
Sensor Measurement: at 0.5 cm		V	
Sensor Measurement: at 1.0 cm		V	
Gain		cm/V	
Offset		cm	

Table 3.1: Strain gage results

8. Click on *Stop* button to stop the VI.

3.4 Lab 2: Calibrate Sensor

1. Run the QNET_MECHKIT_Flexgage.vi
2. Select the *Calibrate Sensor* tab and enter the slope and intercept obtained in Section 3.3 into the *Calibration Gain and Offset* controls shown in Figure 3.3, below. When the link is moved, the slider indicator in the VI should match up with the actual location of the flexible link on the QNET module.
3. Enter the gain and offset obtained.
4. Click on *Stop* button to stop the VI.

3.5 Lab 3: Natural Frequency

1. Run the QNET_MECHKIT_Flexgage.vi
2. Select the Natural Frequency tab.
3. Manually perturb the flexible link and stop the VI when it stops resonating (after about 5 seconds). The spectrum should then load in the chart, as shown in Figure 3.4 (the value shown is incorrect).
4. Enter natural frequency found and capture the resulting power spectrum response. Hint: You can use the cursor to take measurements off the graph.
5. Click on *Stop* button to stop the VI.

3.6 Results

Parameter	Value	Units	Notes
Gain		cm/V	
Offset		cm	
Natural Frequency		Hz	

Table 3.2: Strain gage results summary

4 PRESSURE SENSOR

4.1 Background

A pressure sensor is attached to the plunger on the QNET mechatronic board shown in Figure 4.1. This is a gage pressure sensor and its measurements are relative to the atmospheric pressure. The voltage signal generated is proportional to the amount of pressure in the vessel of the plunger. So as the plunger is pushed further, the air inside the vessel becomes more compressed and the reading increases.

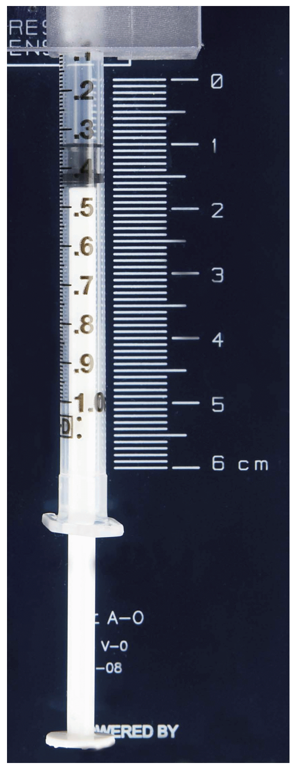

Figure 4.1: Pressure sensor on QNET mechatronic sensors trainer

Pressure sensors can also be used to indirectly measure other values. For example, in the QNET mechatronics board the position of the plunger head is measured. It can also be used to measure the amount of volume in a reservoir or the altitude of an aerial vehicle.

4.2 Pressure Virtual Instrument

The virtual instrument used to collect data using the strain gage is shown in Figure 3.2. The virtual instrument used to calibrate strain data is shown in Figure 3.3. The virtual instrument used to determine the natural frequency of the flexible link is shown in Figure 3.4.

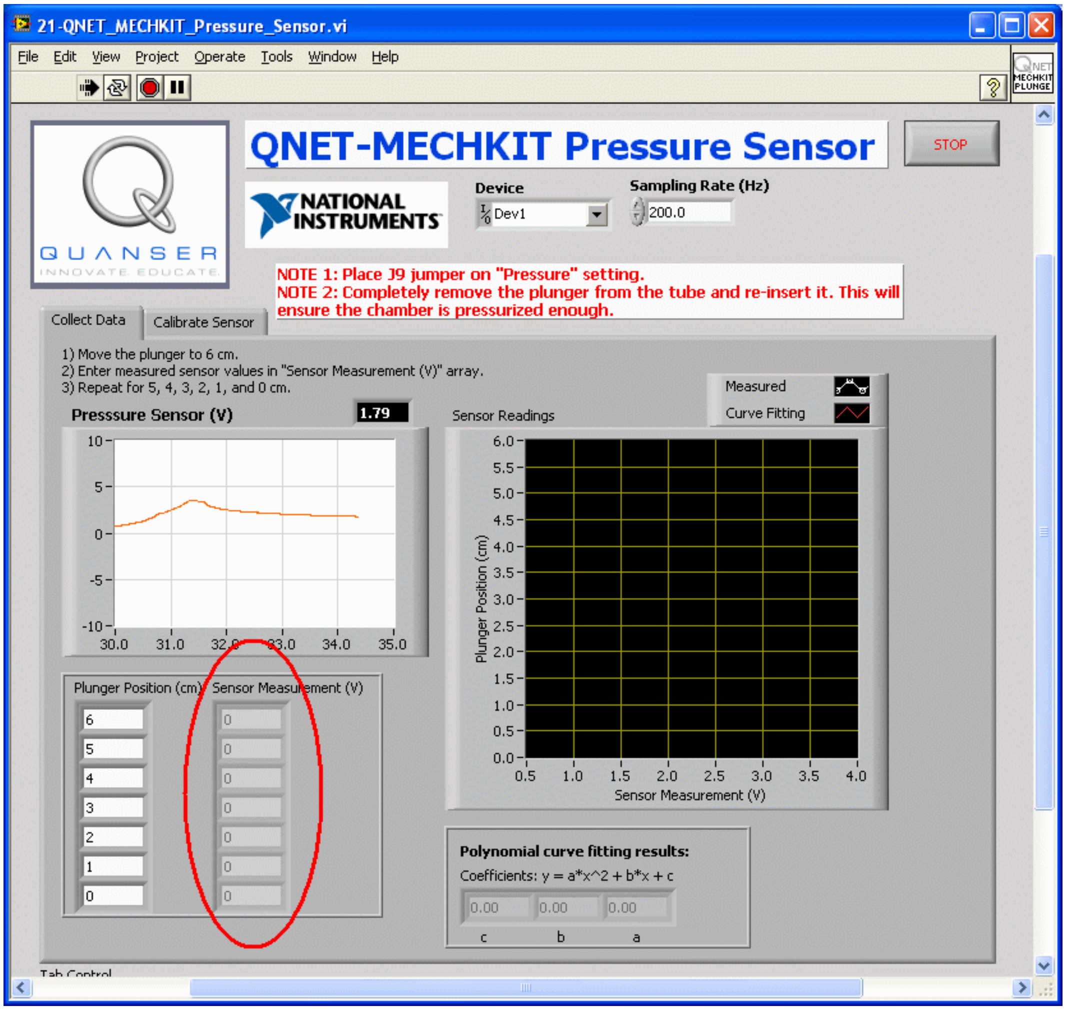

Figure 4.2: Collecting pressure data

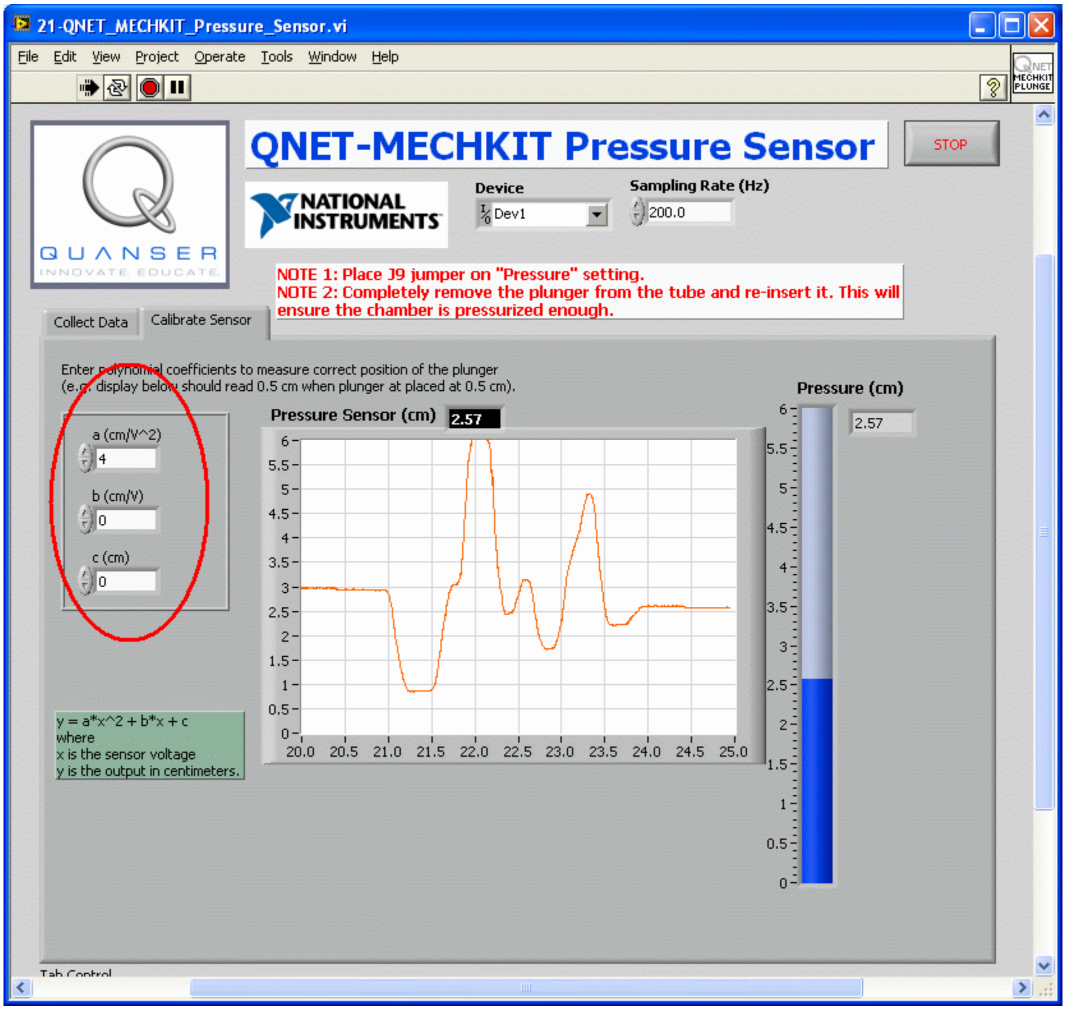

Figure 4.3: Calibrating the pressure sensor

4.3 Lab 1: Collect Data

1. **Ensure *J9* is set to *Pressure*.**
2. Open and configure the QNET MECHKIT Pressure VI as described in Section 15.3. **Make sure the correct *Device* is chosen.**
   ■ **Important:** Completely remove the plunger from the tube and re-insert it. This will ensure the chamber is pressurized enough.
3. Run QNET_MECHKIT_Pressure_Sensor.vi
4. Push the plunger up to the 6 cm marked on the MECHKIT board and measure the resulting voltage using the *Pressure (V)* scope (or the digital display).
5. Enter the result in the *Sensor Measurement (V)* array, as indicated in Figure 4.2.
6. Repeat for when the plunger is at 5.0 cm, 4.0 cm, 3.0 cm, 2.0 cm, 1.0 cm, and 0 cm. The pressure sensor is quadratic. The coefficients for the second-order polynomial are generated and the fitted curve is automatically plotted.
7. Enter collected results and capture the *Sensor Readings* scope.

Parameter	Value	Units	Notes
Sensor Measurement: at 6.0 cm		V	
Sensor Measurement: at 5.0 cm		V	
Sensor Measurement: at 4.0 cm		V	
Sensor Measurement: at 3.0 cm		V	
Sensor Measurement: at 2.0 cm		V	
Sensor Measurement: at 1.0 cm		V	
Sensor Measurement: at 0.0 cm		V	

Table 4.1: Pressure sensor results

8. Click on *Stop* button to stop the VI.

4.4 Lab 2: Calibrate Sensor

1. Run the QNET_MECHKIT_Pressure_Sensor.vi
2. In the *Calibrate Sensor* tab, enter the polynomial coefficients, as illustrated in Figure 4.3, to measure correct position of the plunger. Verify that the sensor is reading properly, e.g. display should read 0.5 cm when plunger is placed at 0.5 cm.
3. Enter the a, b, and c, parameters used.
4. Click on *Stop* button to stop the VI.

4.5 Results

Parameter	Value	Units	Notes
a		cm/V^2	
b		cm/V	
c		cm	

Table 4.2: Pressure sensor results summary

5 PIEZO SENSOR

5.1 Background

Piezo sensors measure vibration. The piezo sensor on the QNET-MECHKIT trainer, shown in Figure 5.1, is connected to a plastic band that has a brass disc weight at the end.

Figure 5.1: Piezo sensor on the QNET mechatronic sensors trainer

5.2 Lab 1: Data Analysis

1. **Ensure *J8* is set to *Piezo*.**
2. Open and configure the QNET MECHKIT Piezo VI as described in Section 15.4. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Piezo.vi
4. Manually perturb the plastic band that is attached to the piezo sensor by flicking it and examine the response in the *Piezo (V)* scope.
5. Grab the end of the plastic band and move it slowly up and down. Examine the response.
6. Based on these two tests, what does the Piezo sensor measure? How is this different then a strain gage measurement? Capture a sample *Piezo (V)* scope response after it has been perturbed (by flicking it).
7. Click on *Stop* button to stop the VI.

5.3 Lab 2: Natural Frequency

1. Run the QNET_MECHKIT_Piezo.vi
2. Manually perturb the piezo sensor.
3. Capture the resulting power spectrum response and give the measured natural frequency. **Hint:** You can use the cursor to take measurements off the graph.
4. Click on *Stop* button to stop the VI.

6 POTENTIOMETER

6.1 Background

Rotary potentiometers are absolute analog sensors used to measure angular position, such as a load shaft of a motor. They are great to obtain a unique position measurement. However, caution must be used as their signal is discontinuous. That is, after a few revolutions potentiometers will reset their signal back to zero. The potentiometer on the QNET MECHKIT board is shown in Figure 6.1.

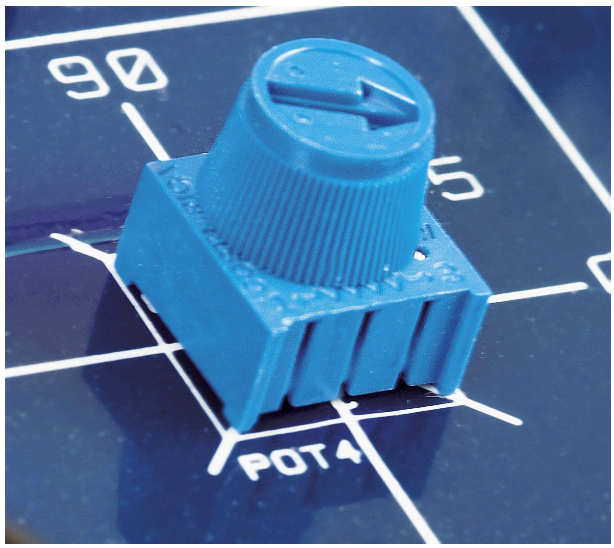

Figure 6.1: Potentiometer knob on QNET mechatronic sensors trainer

6.2 Potentiometer Virtual Instrument

The virtual instrument used to collect data using the potentiometer is shown in Figure 6.2. The virtual instrument used to calibrate potentiometer data is shown in Figure 6.3.

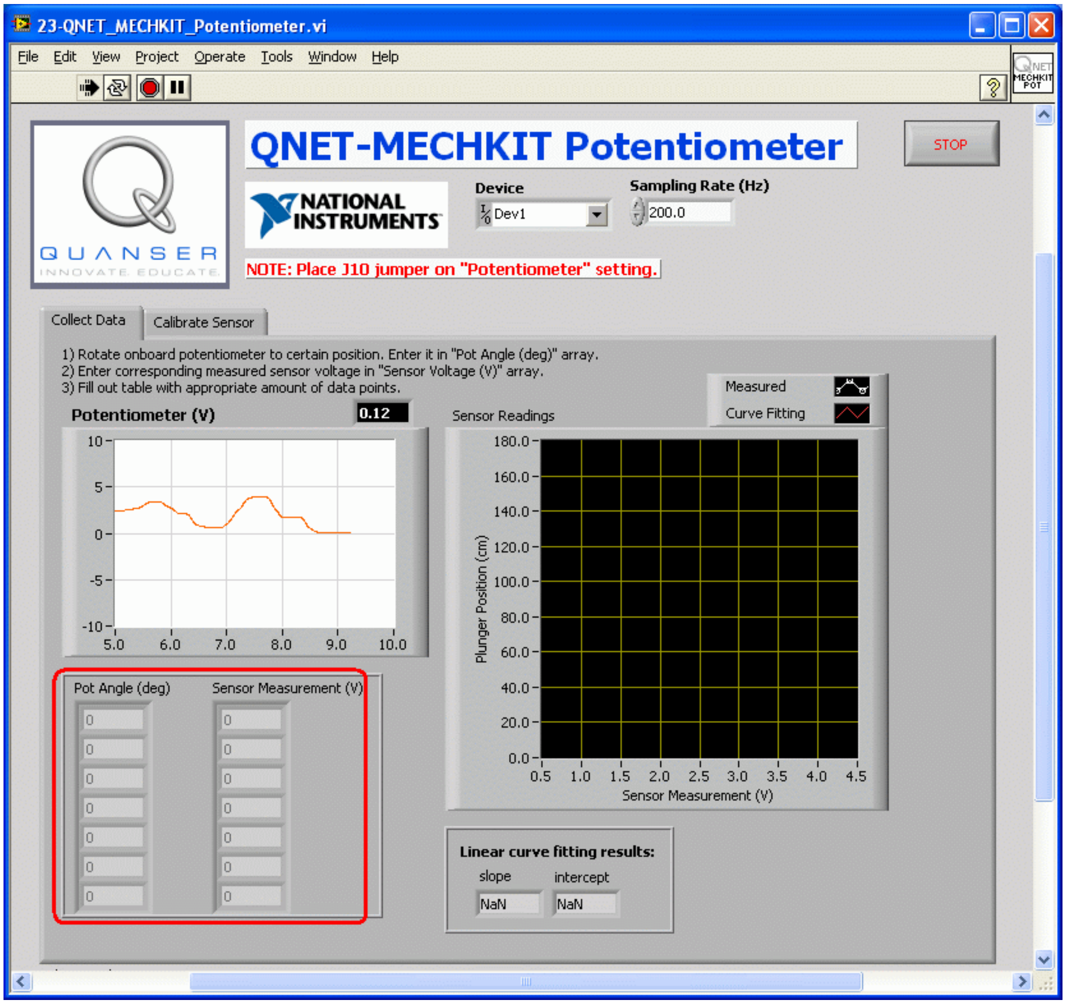

Figure 6.2: Collecting potentiometer data

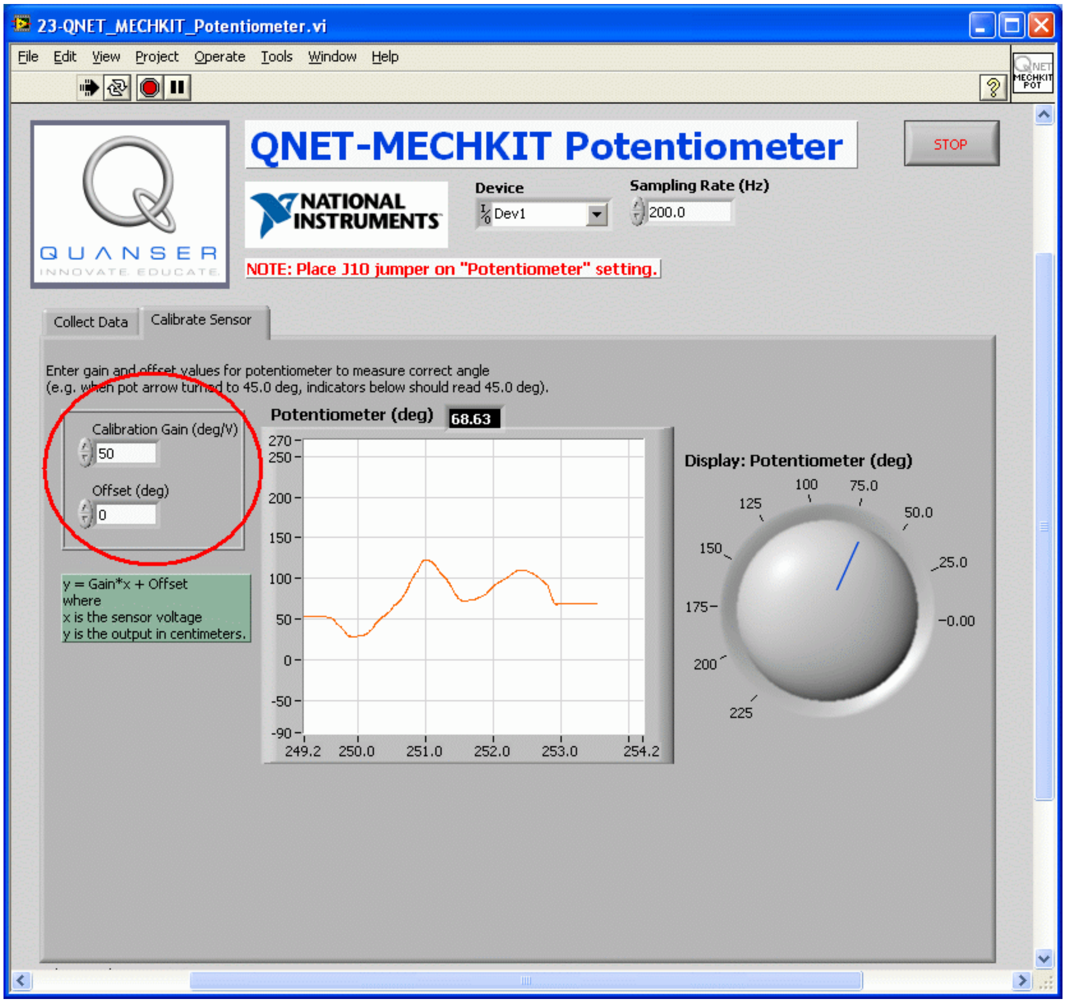

Figure 6.3: Calibrating the potentiometer

6.3 Lab 1: Collect Data

1. **Ensure *J10* is set to *POT*.**
2. Open and configure the QNET MECHKIT Potentiometer VI as described in Section 15.5. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Potentiometer.vi
4. Rotate the arrowhead of the potentiometer to a certain position, e.g. 45 degrees.
5. Enter the position in the *Pot Angle (deg)* array, as indicated in Figure 6.2.
6. Enter corresponding measured sensor voltage in *Sensor Measurement (V)* array (shown in Figure 6.2).
7. Fill out table with an appropriate amount of data points. Notice that as the measured potentiometer readings are entered, a curve is automatically generated to fit the data. The slope and intercept of this line is generated as well.
8. Enter the collected data and capture the *Sensor Reading* chart.

Parameter	Value	Units	Notes
Sensor Measurement: at 0 deg		V	
Sensor Measurement: at 45 deg		V	
Sensor Measurement: at 90 deg		V	
Sensor Measurement: at 135 deg		V	
Sensor Measurement: at 180 deg		V	
Gain		deg/V	
Offset		deg	

Table 6.1: Potentiometer sensor results

9. Click on *Stop* button to stop the VI.

6.4 Lab 2: Calibrate Sensor

1. Run QNET_MECHKIT_Potentiometer.vi
2. In the *Calibrate Sensor* tab, set the *Gain* and *Offset* controls, as indicated in Figure 6.3, to values such that the potentiometer measures the correct angle. Verify that the sensor is reading properly, e.g. when pot arrow is turned to 45.0 deg, the *Display: Potentiometer (deg)* knob indicator should read 45.0 degrees.
3. Enter *Gain* and *Offset* values used.
4. Click on *Stop* button to stop the VI.

6.5 Results

Parameter	Value	Units	Notes
Gain		deg/V	
Offset		deg	

Table 6.2: Potentiometer sensor results summary

7 INFRARED

7.1 Background

Infrared (IR) sensors are widely used in robots, automotive systems, and various other applications that require an accurate, medium-range non-contact position measurement. An IR sensor is typically composed of an infrared emitting diode (IRED), a position sensing detector (PSD), and a signal processing circuit. It outputs a voltage the correlates to the distance of the remote target. The infrared distance measuring sensor on the QNET MECHKIT board is shown in Figure 7.1.

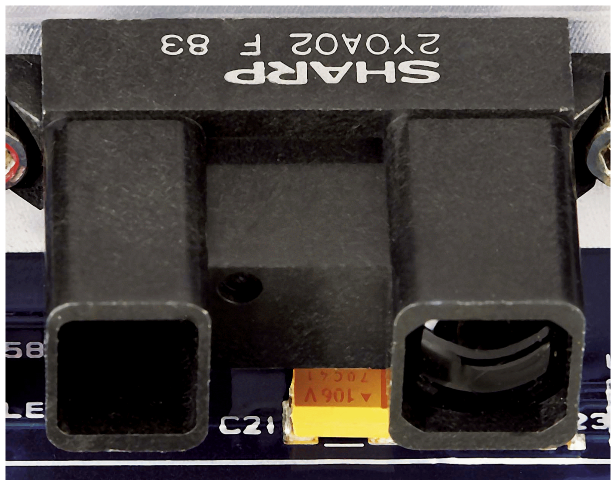

Figure 7.1: IR sensor on QNET mechatronic sensors trainer

Infrared-based distance sensors typically have a smaller maximum range than sonar but the resolution is better.

7.2 Potentiometer Virtual Instrument

The virtual instrument used to collect data using the IR sensor is shown in Figure 7.2. The virtual instrument used to calibrate IR range data is shown in Figure 7.3.

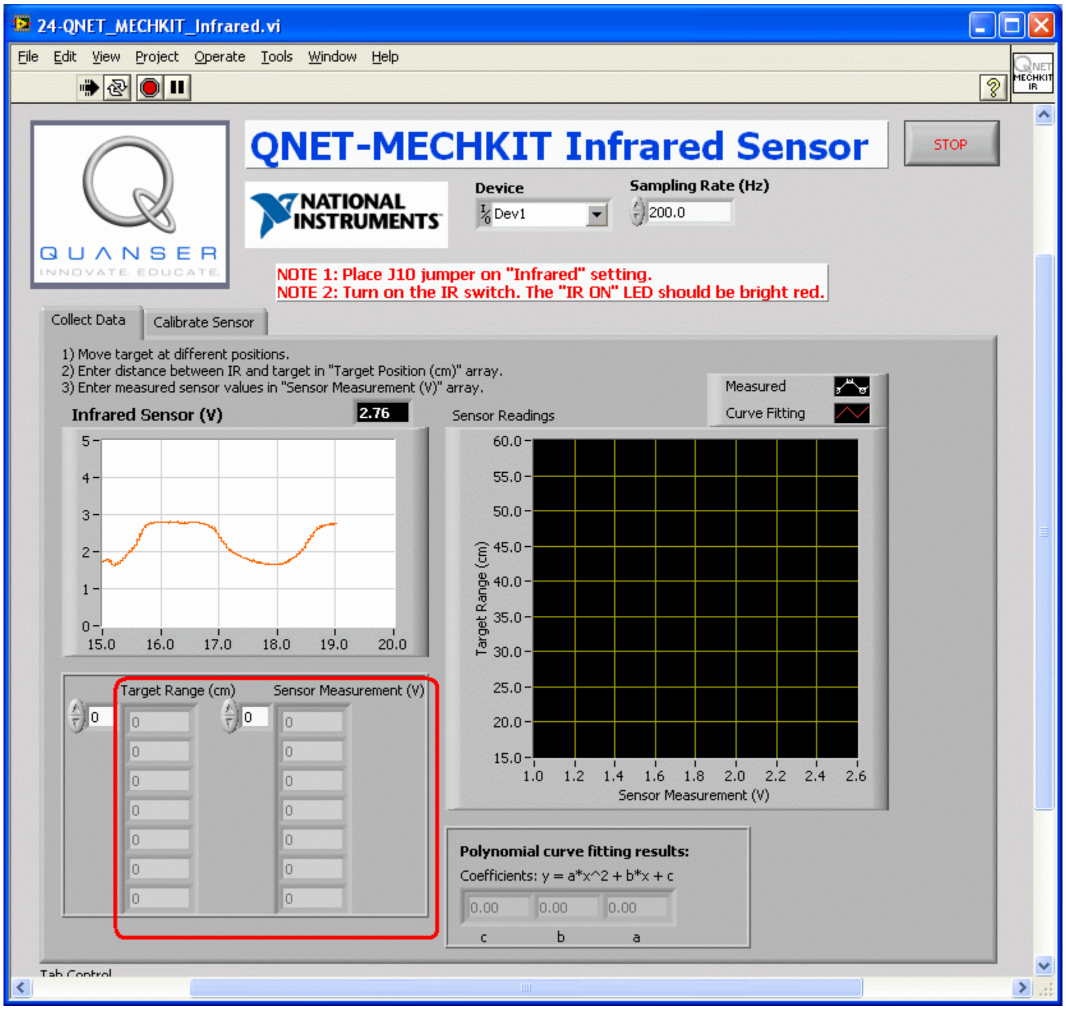

Figure 7.2: Collecting IR data

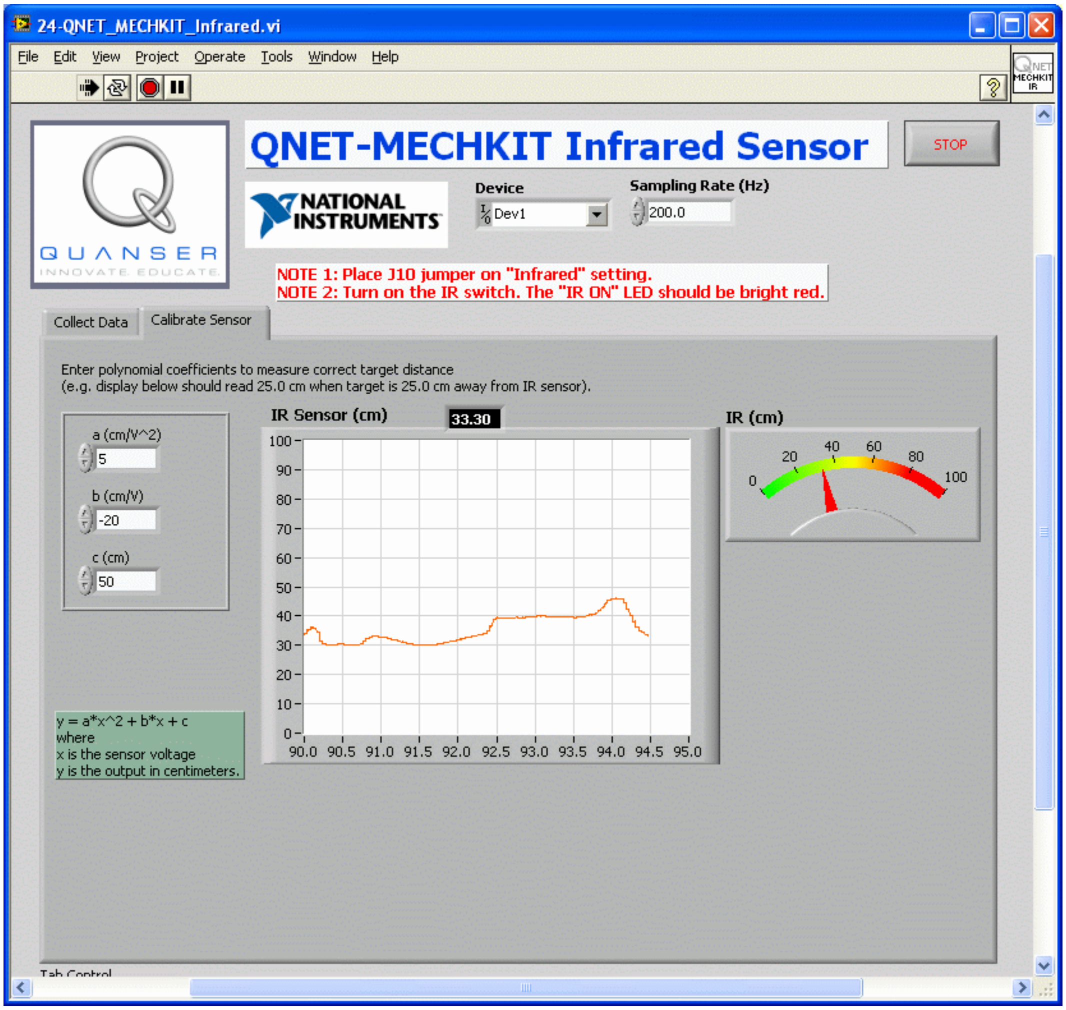

Figure 7.3: Calibrating the IR sensor

7.3 Lab 1: Collect Data

1. **Ensure *J10* is set to *Infrared*.**
2. Open and configure the QNET MECHKIT Infrared VI as described in Section 15.6. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Infrared.vi
4. Turn *ON* the IR switch to enable the Infrared sensor. The *IR ON LED* should be lit bright red. ■ **Important:** Make sure you turn OFF the IR switch when the experiment is over. When active, the infrared sensor tends to generate noise in other sensor measurements.
5. Get a target, such as a sturdy piece of cardboard, that is at least 10 by 10 cm^2 with a reflective colour like white or yellow.
6. Begin with the target close to the IR sensor and slowly move it away.
7. Once its range of operation is found, enter the distance between the target and the IR sensor in the *Target Range (cm)* array, as shown in Figure 7.2.
8. Enter the corresponding measured voltage from the IR sensor in the *Sensor Measurement (V)* array, as shown in Figure 7.2.

9. Repeat for different target positions. The IR sensor is quadratic. As the measurements are entered, the coefficients for the second-order polynomial are generated and the fitted curve is automatically plotted.

10. Record your distance and voltage observations and capture the corresponding *Sensor Readings* scope.

Parameter	Value	Units	Notes
Sensor Measurement: at 17cm		V	
Sensor Measurement: at 22 cm		V	
Sensor Measurement: at 27 cm		V	
Sensor Measurement: at 32 cm		V	
Sensor Measurement: at 37 cm		V	
Sensor Measurement: at 42 cm		V	
Sensor Measurement: at 47 cm		V	
Sensor Measurement: at 52 cm		V	
Sensor Measurement: at 57 cm		V	

Table 7.1: IR sensor results

11. What did you notice when the target is close to the IR sensor? That is, did the behaviour of the sensor change when the target was in close proximity as opposed to being further away?

12. Click on *Stop* button to stop the VI.

7.4 Lab 2: Calibrate Sensor

1. Run QNET_MECHKIT_Infrared.vi

2. In the *Calibrate Sensor* tab, enter the polynomial coefficients to correctly measure the distance of the target. Check that it is measuring correctly, e.g. when target is 25.0 cm away, the display should read 25.0 cm.

3. Enter the a, b and c values used in Table 7.2.

4. Click on *Stop* button to stop the VI.

7.5 Results

Parameter	Value	Units	Notes
a		cm/V^2	
b		cm/V	
c		cm	

Table 7.2: IR sensor results summary

8 SONAR

8.1 Background

Often used in mobile robotics, sonar sensors are fitted with an emitter that generates ultrasonic waves and a receiver that captures them after hitting a target. A timer calculates how long it takes for the signal to return and, given the speed of sound in air, the distance of the remote target is measured. The sonar ranger on the mechatronic trainer is pictured in Figure 8.1.

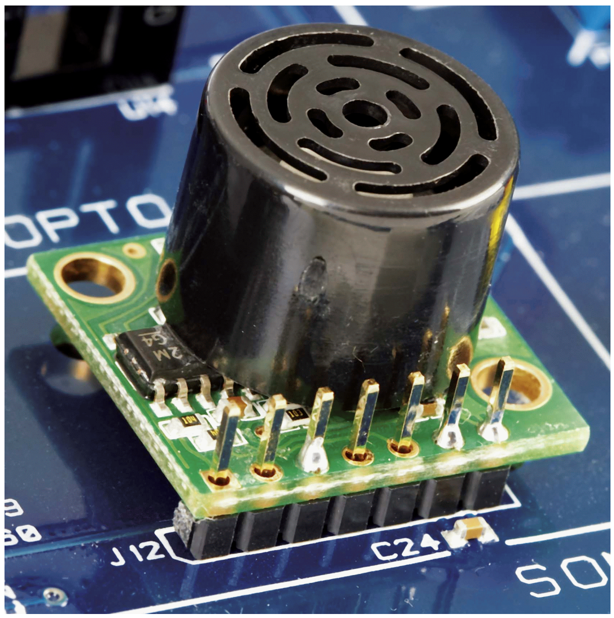

Figure 8.1: Sonar sensor on QNET mechatronic sensors trainer

Sonar sensors are great for long-distance measurements. For example, the one mounted on mechatronic board can go up to 21 feet. However, in general, these devices do not have good close-range measurements and their resolution can be relatively coarse.

8.2 Sonar Virtual Instrument

The virtual instrument used to collect data using the sonar sensor is shown in Figure 8.2. The virtual instrument used to calibrate sonar range data is shown in Figure 8.3.

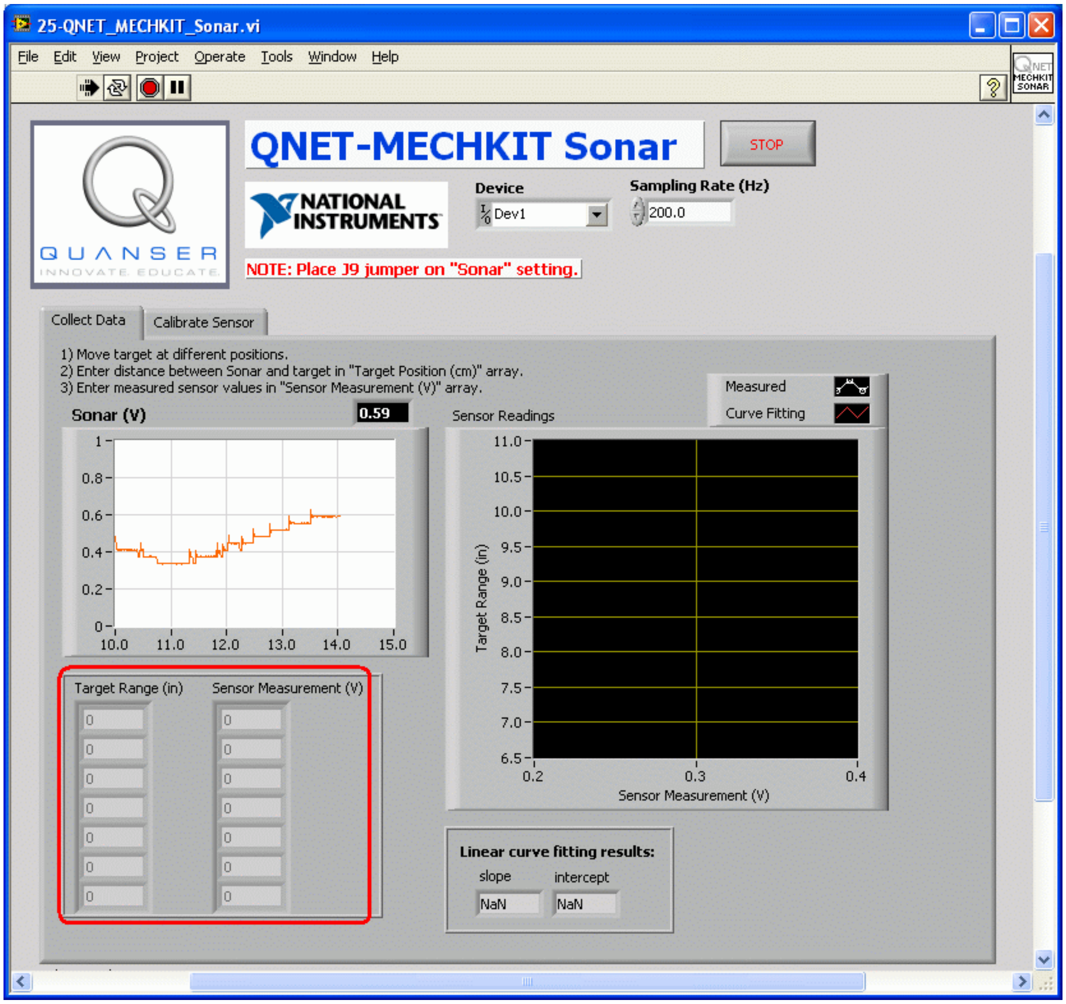

Figure 8.2: Collecting sonar data

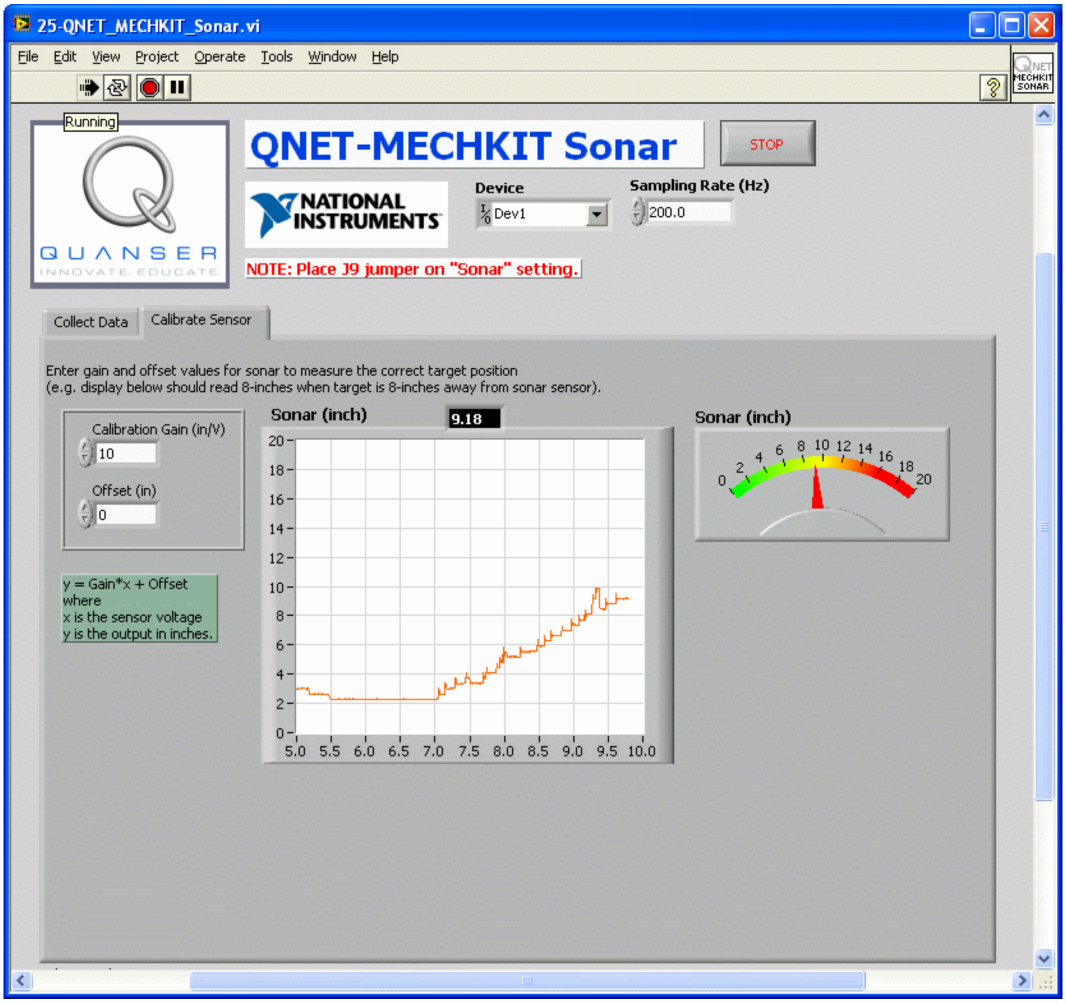

Figure 8.3: Calibrating the sonar sensor

8.3 Lab 1: Collect Data

1. **Ensure *J9* is set to *Sonar*.**
2. Open and configure the QNET MECHKIT Sonar VI as described in Section 15.7. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Sonar.vi
4. Get a target, such as a sturdy piece of cardboard, that is at least 10 by 10 cm^2 with a reflective colour like white or yellow.
5. Begin with the target close to the sonar sensor and slowly move it upwards.
6. Once its range of operation is found, enter the distance between the target and the sonar sensor in the *Target Range (cm)* array, as shown in Figure 8.2.
7. Enter the corresponding measured voltage from the sonar sensor in the *Sensor Measurement (V)* array, as shown in Figure 8.2.
8. Repeat for different target positions. The sonar sensor is linear. The slope and intercept are generated and the fitted curve is automatically plotted.

9. Enter your collected target distances and voltages. Capture the *Sensor Readings* scope as well.

Parameter	Value	Units	Notes
Sensor Measurement: at 7 cm		V	
Sensor Measurement: at 8 cm		V	
Sensor Measurement: at 9 cm		V	
Sensor Measurement: at 10 cm		V	
Sensor Measurement: at 11 cm		V	

Table 8.1: Sonar sensor results

10. What is the resolution and operating range of the sonar sensor? How does the resolution and range compare with the IR sensor?
11. Click on *Stop* button to stop the VI.

8.4 Lab 2: Calibrate Sensor

1. Run QNET_MECHKIT_Sonar.vi
2. Select the *Calibrate Sensor* tab and enter *Gain* and *Offset* coefficients to correctly measure the distance of the target. Make sure the coefficients are correct, e.g. when the target is 10.0 inches away then the *Sonar (inch)* display should read 10.0 inches.
3. Enter *Gain* and *Offset* values used in Table 8.2.
4. Click on *Stop* button to stop the VI.

8.5 Results

Parameter	Value	Units	Notes
Range		cm	
Resolution		cm	
Gain		cm/V	
Offset		cm	

Table 8.2: Sonar sensor results summary

9 OPTICAL POSITION

9.1 Background

Optical position sensors are used in applications such as assembly lines, machine automation, and even edge detection in robots. The optical position sensor on the QNET mechatronic sensors board is the black plastic housing located at the bottom of Figure 9.1. An infrared emitting diode and an NPN silicon phototransistor are mounted side-by-side and are used to measure the position of a target. This sensor has a range of 0.25 inches.

Figure 9.1: Optical position sensor (bottom) and target position knob (top) on QNET mechatronic sensors trainer

9.2 Optical Virtual Instrument

The virtual instrument used to collect data using the optical position sensor is shown in Figure 9.2. The virtual instrument used to calibrate optical position data is shown in Figure 9.3.

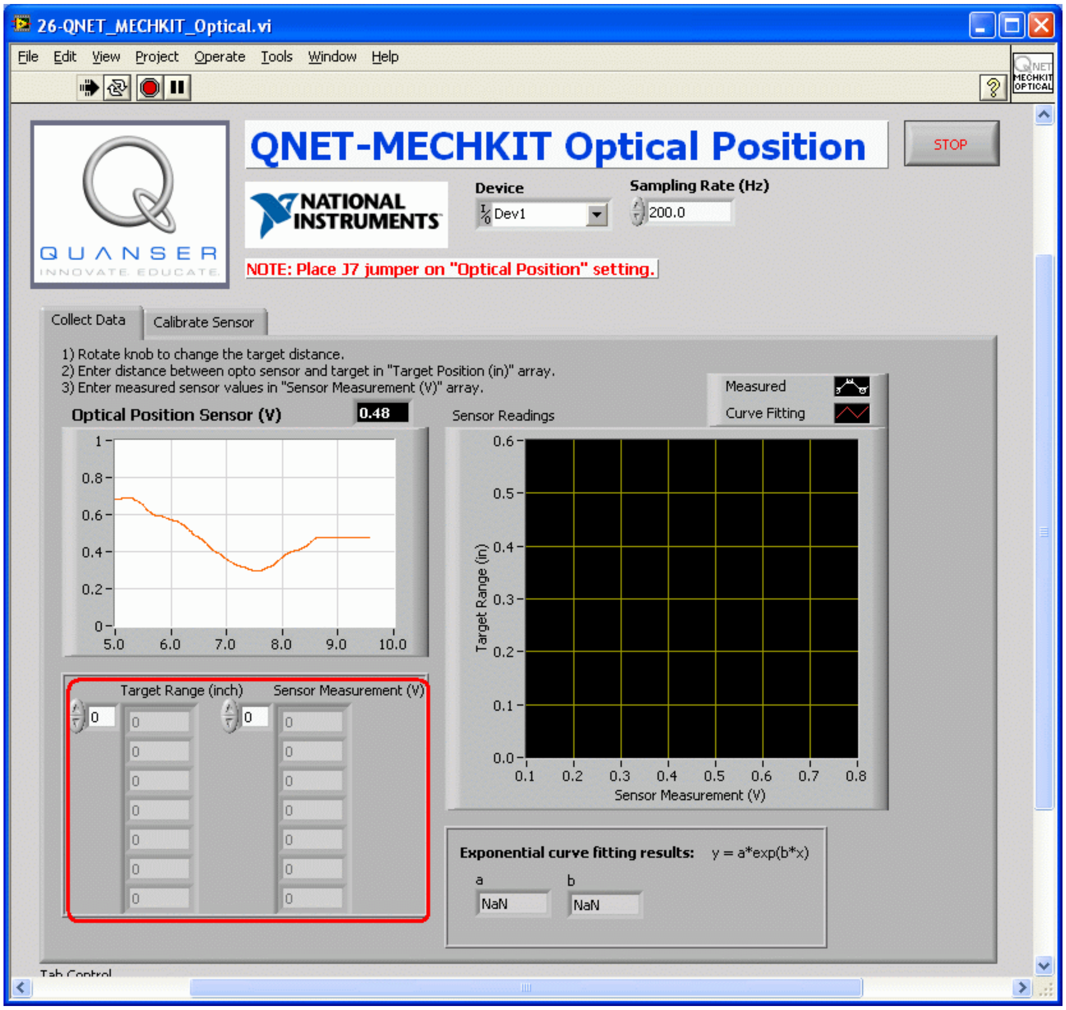

Figure 9.2: Collecting optical position data

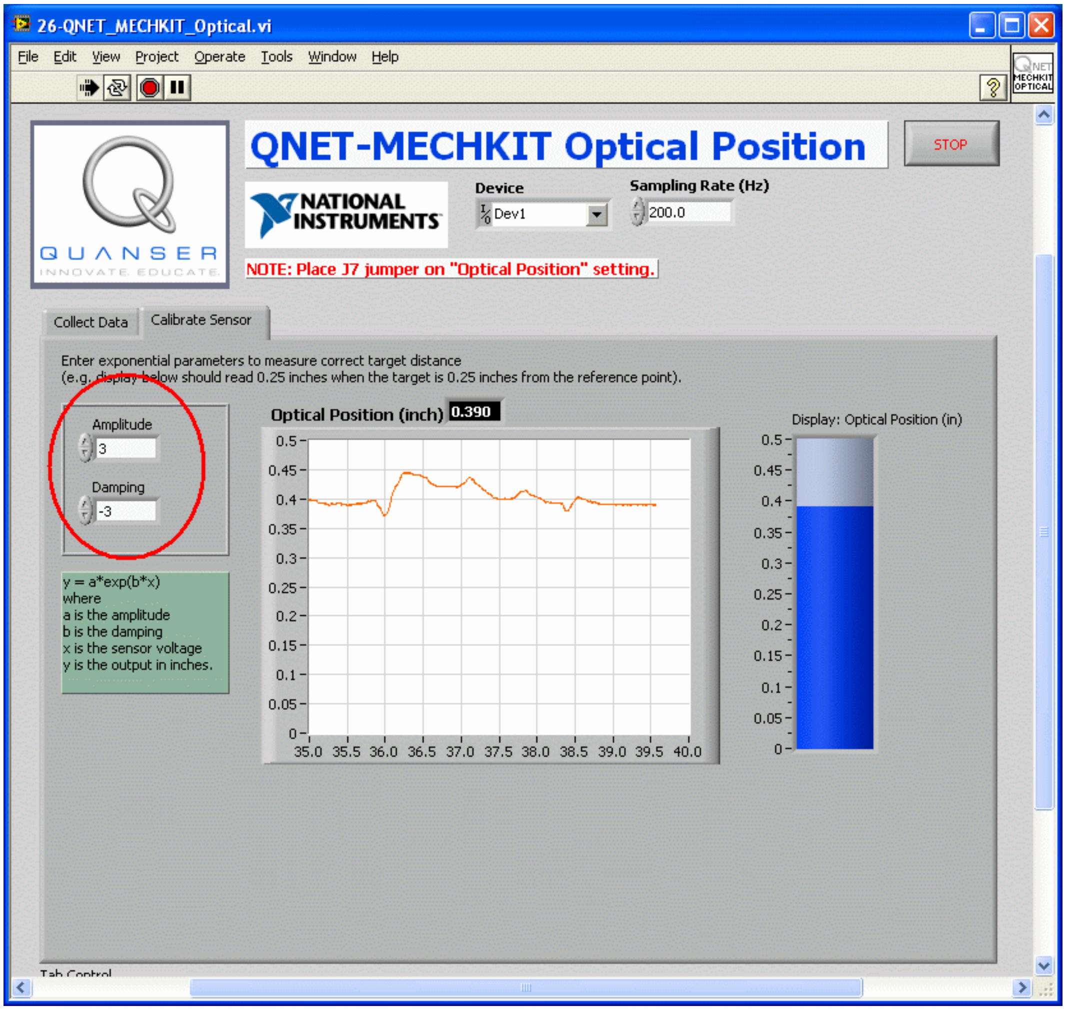

Figure 9.3: Calibrating the optical position sensor

9.3 Lab 1: Collect Data

1. **Ensure *J7* is set to *Optical Position*.**
2. Open and configure the QNET MECHKIT Optical Position VI as described in Section 15.8. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Optical.vi
4. Gently turn the knob of the optical position sensor clockwise until the flat metal surface gently rests on top of the tube. Then, rotate the knob slightly counter-clockwise so the 0 mark on the knob faces up. At this point, the reflective target is very close to the optical sensor and will be the reference 0 inch position. Enter the 0 position in the first element of the *Target Range (inch)* array, shown in Figure 9.2.
5. Enter the voltage measured by the optical position sensor, when the target is 0 inches away, in the *Sensor Measurement (V)* array, as indicated in Figure 9.2.
6. Turn the knob counter-clockwise one rotation to move the target further from the sensor. The target moves 1-inch for every 20 turns. Enter the position the target has moved from the reference in the *Target Range (inch)* array, which is shown in Figure 9.2.
7. Record the measured sensor voltage in the *Sensor Measurement (V)* array.

8. Take samples for the entire range of the target (i.e. until the knob cannot be rotated CCW anymore). Remark that the optical position sensor is exponential. As data is being entered, the exponential parameters are generated and the fitted curve is automatically plotted.

9. Enter the measured sensor data and capture the *Sensor Readings* response.

Parameter	Value	Units	Notes
Sensor Measurement: at 0 in.		V	
Sensor Measurement: at 0.025 in.		V	
Sensor Measurement: at 0.050 in.		V	
Sensor Measurement: at 0.075 in.		V	
Sensor Measurement: at 0.100 in.		V	
Sensor Measurement: at 0.125 in.		V	
Sensor Measurement: at 0.150 in.		V	
Sensor Measurement: at 0.175 in.		V	
Sensor Measurement: at 0.200 in.		V	
Sensor Measurement: at 0.225 in.		V	
Sensor Measurement: at 0.250 in.		V	
Sensor Measurement: at 0.28 in.		V	

Table 9.1: Optical position sensor results

10. Click on *Stop* button to stop the VI.

9.4 Lab 2: Calibrate Sensor

1. Run QNET_MECHKIT_Optical.vi

2. Select the *Calibrate Sensor* tab, enter values for the *Gain* and *Damping* exponential function parameters, as shown in Figure 9.3, to correctly measure the distance of the target, e.g. when target is 0.10 inches away then display should read 0.10 inches.

3. Enter the *Gain* and *Damping* parameters used into Table 9.2.

4. Click on *Stop* button to stop the VI.

9.5 Results

Parameter	Value	Units	Notes
Gain		in	
Damping			

Table 9.2: Optical position sensor results

10 MAGNETIC FIELD

10.1 Background

A magnetic field transducer outputs a voltage proportional to the magnetic field that is applied to the target. The magnetic field sensor is the chip located on the bottom of Figure 10.1. It applies a magnetic field perpendicular to the flat screw head. The position of the screw head is changed by rotating the knob. This magnetic field transducer has a similar range to the optical position sensor.

Figure 10.1: Magnetic field transducer on QNET mechatronic sensors trainer

10.2 Magnetic Field Virtual Instrument

The virtual instrument used to collect data using the magnetic field transducer is shown in Figure 10.2. The virtual instrument used to calibrate magnetic field data is shown in Figure 10.3.

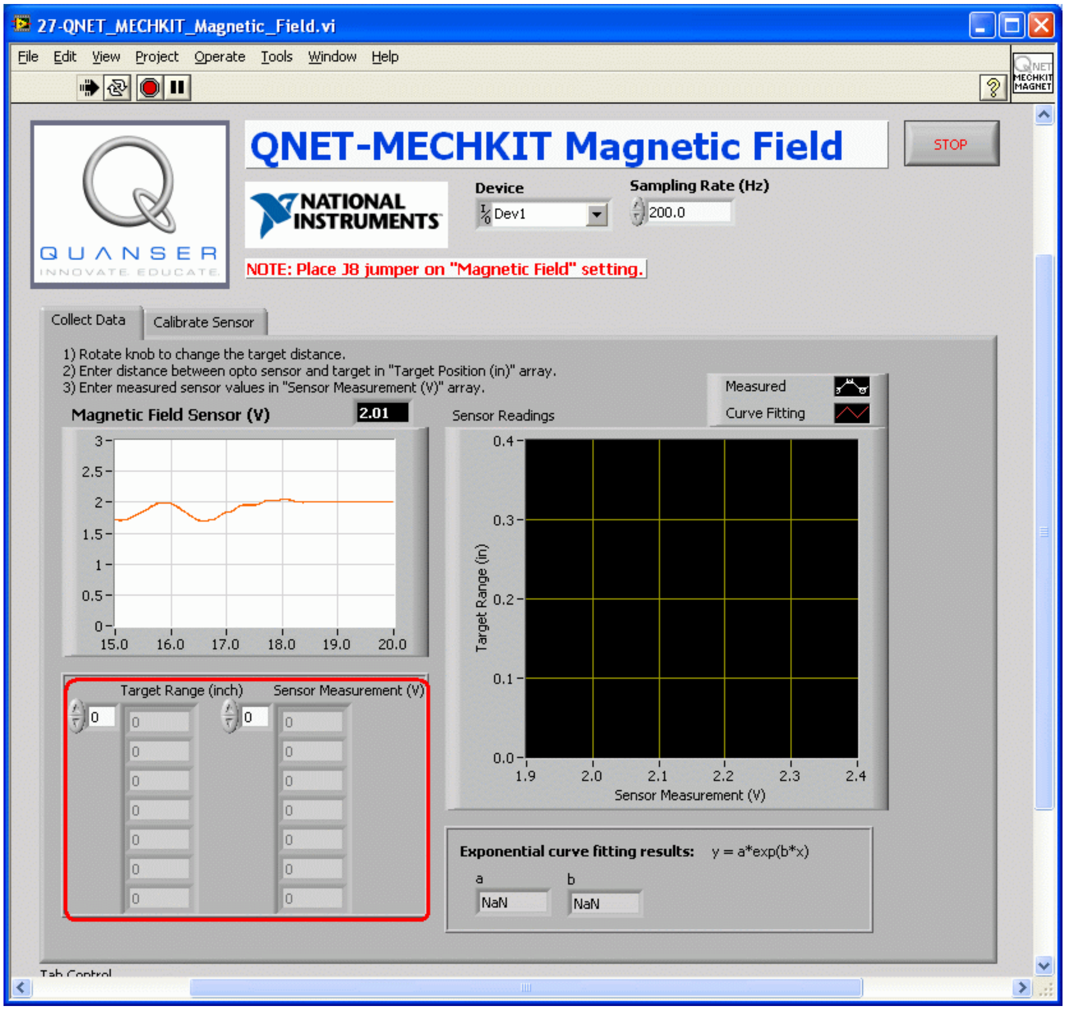

Figure 10.2: Collecting magnetic field data

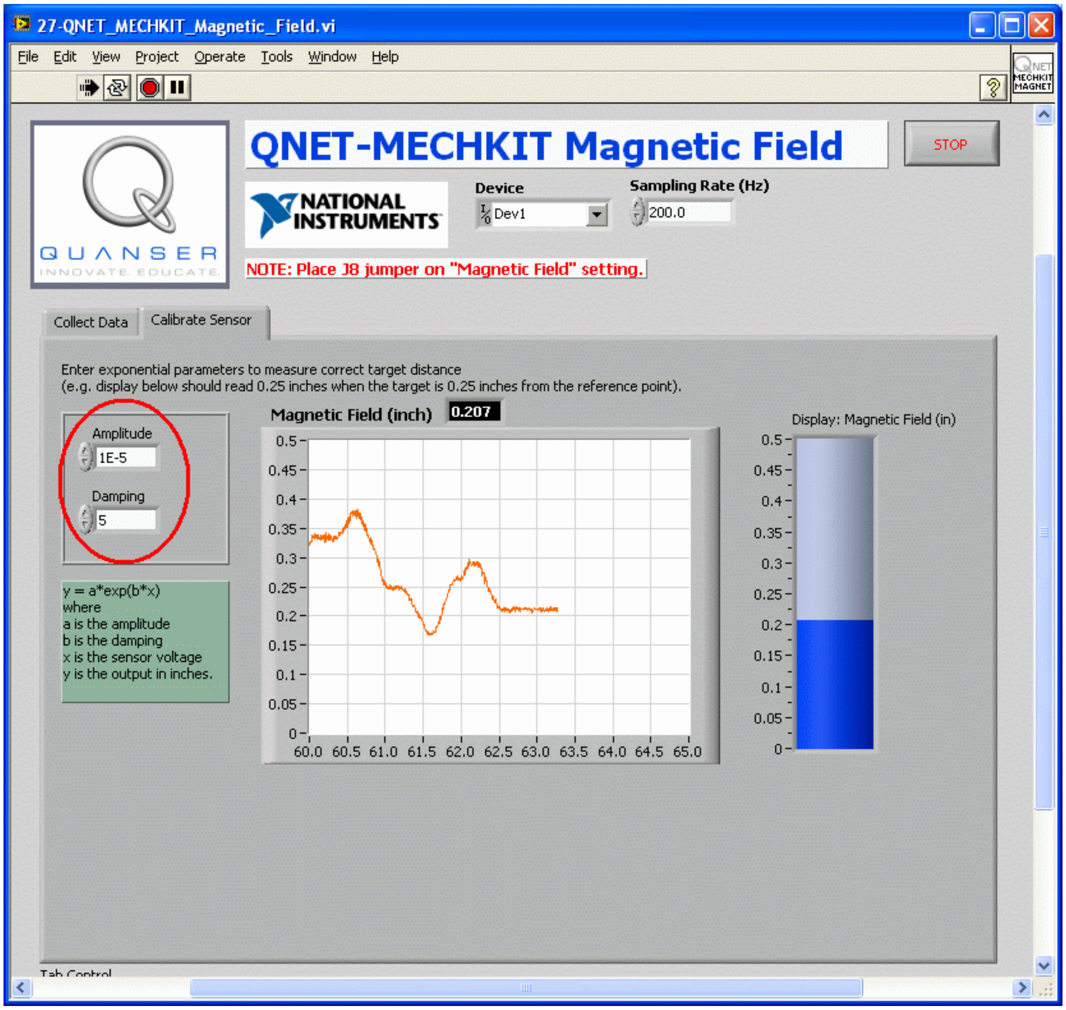

Figure 10.3: Calibrating the magnetic field transducer

10.3 Lab 1: Collect Data

1. **Ensure *J8* is set to *Magnetic Field*.**
2. Open and configure the QNET MECHKIT Magnetic Field VI as described in Section 15.9. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Magnetic_Field.vi
4. Gently turn the knob of the magnetic field sensor clockwise until it is at its limit. Then, rotate the knob slightly counter-clockwise so the 0 mark on the knob faces up. This will be reference 0 cm target position. Enter this in the *Target Range (cm)* array, shown in Figure 10.2.
5. Enter the voltage measured from the magnetic field position sensor for the reference 0 cm position in the *Sensor Measurement (V)* array. The array is indicated in Figure 10.2.
6. Turn the knob counter-clockwise one rotation to move the target further from the sensor. The target moves 1-inch for every 20 turns. Enter the position the target has moved from the reference in the *Target Range (cm)* array.
7. Record the measured sensor voltage in the *Sensor Measurement (V)* array.

8. Take samples for the entire range of the target (i.e. until the knob cannot be rotated CCW anymore). The magnetic field sensor is exponential. The parameters of the exponential function are outputted and the fitted curve is automatically plotted as data is entered.

9. Enter the range and measured sensor voltages and capture the *Sensor Readings* scope.

Parameter	Value	Units	Notes
Sensor Measurement: at 0 in.		V	
Sensor Measurement: at 0.025 in.		V	
Sensor Measurement: at 0.050 in.		V	
Sensor Measurement: at 0.075 in.		V	
Sensor Measurement: at 0.100 in.		V	
Sensor Measurement: at 0.125 in.		V	
Sensor Measurement: at 0.150 in.		V	
Sensor Measurement: at 0.175 in.		V	
Sensor Measurement: at 0.200 in.		V	

Table 10.1: Magnetic field transducer results

10. Click on *Stop* button to stop the VI.

10.4 Lab 2: Calibrate Sensor

1. Run QNET_MECHKIT_Magnetic_Field.vi

2. Enter *Gain* and *Damping* exponential function parameters to correctly measure the distance of the target. For instance, when target is at 0.10 inches from the reference, then the display should read 0.10 inches.

3. Record *Gain* and *Damping* parameters used for correct measurement.

4. Click on *Stop* button to stop the VI.

10.5 Results

Parameter	Value	Units	Notes
Gain		in/V	
Damping			

Table 10.2: Magnetic field transducer results summary

11 ENCODER

11.1 Background

Similar to rotary potentiometers, encoders can also be used to measure angular position. There are many types of encoders but one of the most common is the rotary incremental optical encoder, shown in Figure 11.1. Unlike potentiometers, encoders are relative. The angle they measure depends on the last position and when it was last powered. It should be noted, however, that absolute encoders are available.

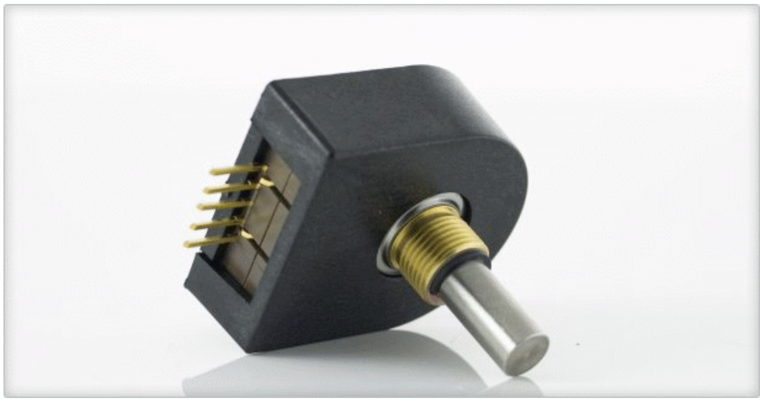

Figure 11.1: US Digital incremental rotary optical shaft encoder

The encoder has a coded disk that is marked with a radial pattern. As the disk rotates (with the shaft), the light from an LED shines through the pattern and is picked up by a photo sensor. This effectively generates the A and B signals shown in Figure 11.2. An index pulse is triggered once for every full rotation of the disk, which can be used for calibration or “homing” a system.

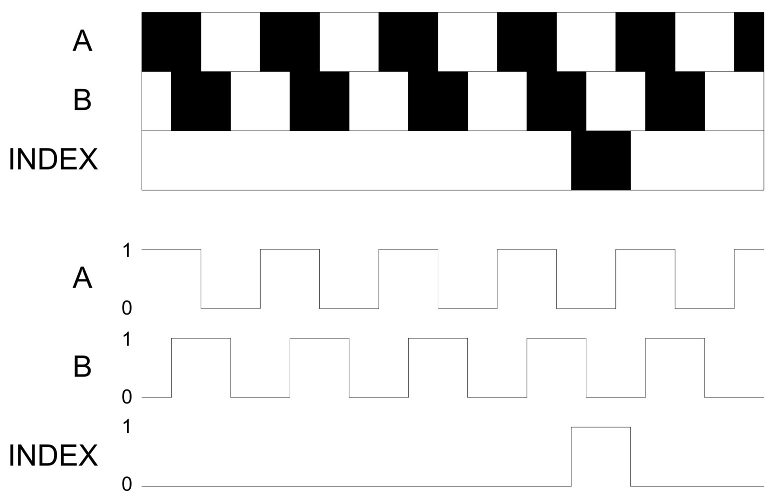

Figure 11.2: Optical incremental encoder signals

The A and B signals that are generated as the shaft rotates are used in a decoder algorithm to generate a count. The resolution of the encoder depends on the coding of the disk and the decoder. For example, an encoder with 1024 lines on the disk can generate a total of 1024 counts for every rotation of the encoder shaft. However, in a quadrature decoder the number of counts quadruples, therefore the encoder would generate 4098 counts per revolution.

The encoder knob on the QNET mechatronic sensors trainer is pictured in Figure 11.3 and the corresponding A, B, and Index signals are displayed on the LEDs shown in Figure 11.4.

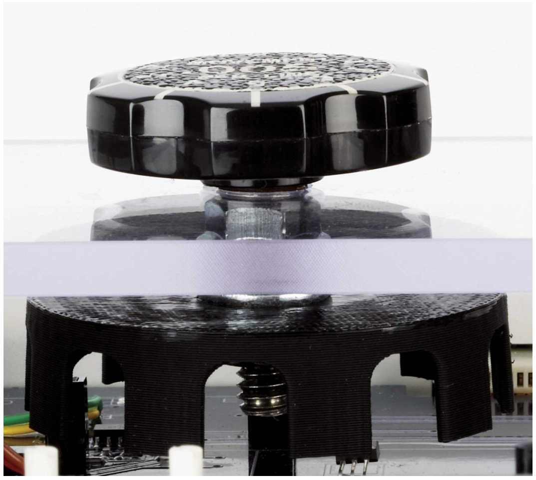

Figure 11.3: Encoder wheel on QNET mechatronic sensor trainer

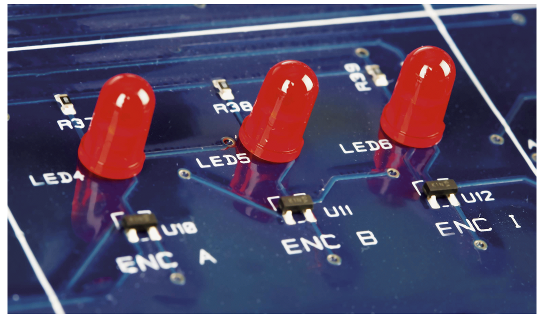

Figure 11.4: Encoder LEDs on QNET mechatronic sensor trainer

11.2 Encoder Virtual Instrument

The virtual instrument used to collect and calibrate encoder data is shown in Figure 11.5.

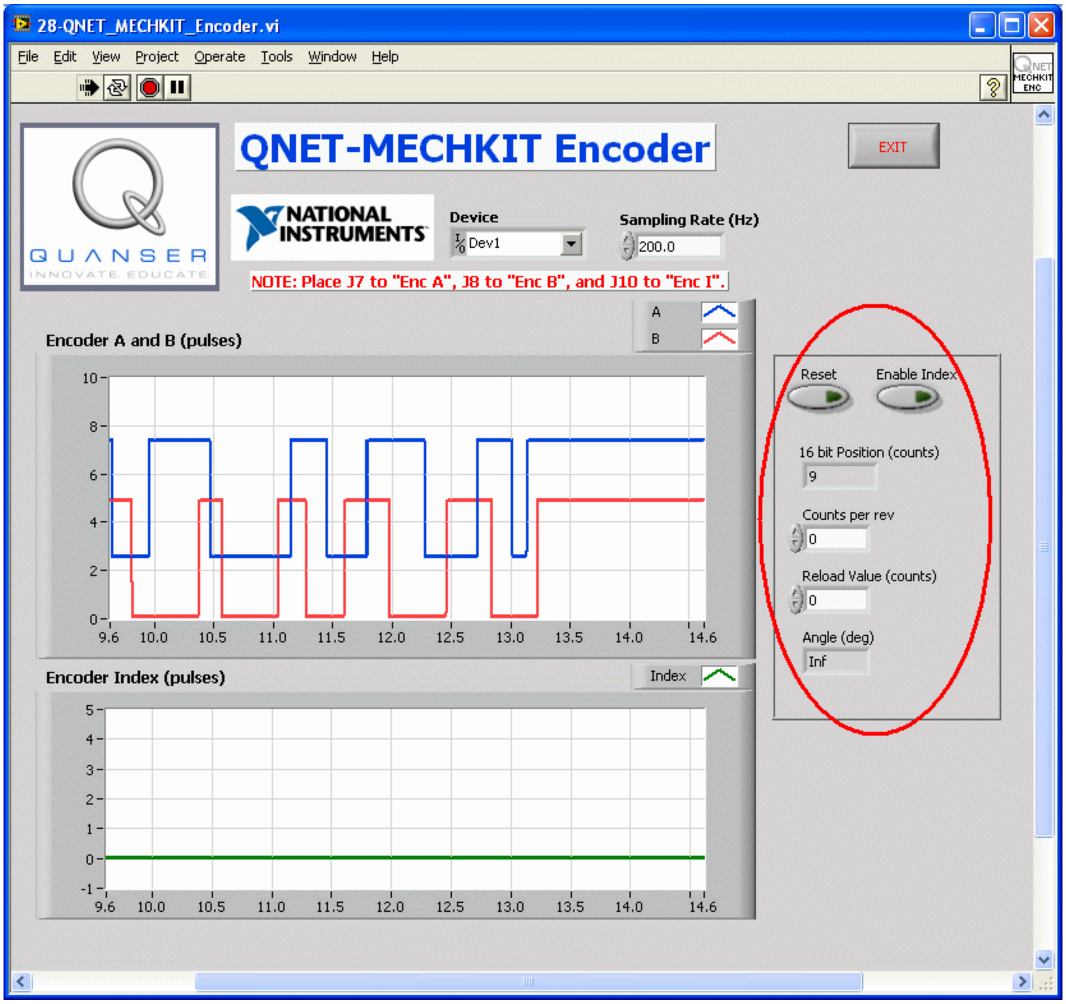

Figure 11.5: Running the encoder VI

11.3 Lab 1: Analysis of A, B, and I Signals

1. **Ensure *J7* is set to *Enc A*, *J8* is set to *Enc B*, and *J10* is set to *Enc I*.**
2. Open and configure the QNET MECHKIT Encoder VI as described in Section 15.10. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Encoder.vi
4. Turn the encoder knob clockwise and examine the response of the A and B signals. Note that the signals are offset by 2.5 V for display purposes. Similarly, turn the encoder knob counter-clockwise and enter your observation.
5. When is the index pulse triggered? What can this be used for?
6. Click on *Stop* button to stop the VI.

11.4 Lab 2: Encoder Calibration

1. Run QNET_MECHKIT_Encoder.vi
2. Using the *16-bit Position (counts)* indicator on the VI, as shown in Figure 11.5, rotate the knob and determine how how many counts there are per revolution. Enter your result in the *Counts per rev* box in the VI. Rotate the knob and confirm that the *Angle (deg)* indicator is displaying an accurate angle.
3. Turn the knob such that the 0 is in the upward position and reset the counter by clicking on the *Reset* button.
4. Enable the index by clicking on the *Enable Index* button.
5. Rotate the knob a full CW turn until the index is triggered. Keep turning the knob until the 0 mark on the knob is pointing upwards. What do you notice about the *16-bit Position (counts)* and the *Angle (deg)* indicator values?
6. Adjust the *Reload Value* such that *Angle (deg)* measures 0 degrees when the 0 mark of the knob is pointing up. Confirm this by moving the knob CW.
7. Enter the *Count per rev* and the *Reload Value* values used for a calibrated measurement.
8. Position the knob such that its 0 label is pointing upwards again. The *Counts per rev and Angle (deg)* should both be reading 0. Rotate the knob in the CCW fashion one full rotation. Is *Angle (deg)* reading 0 degrees? Discuss why or why not.
9. Click on *Stop* button to stop the VI.

11.5 Results

Encoder Knob Rotation	A or B Signal Leads?
Clockwise	
Counter-clockwise	

Table 11.1: A and B signals and encoder rotation

Parameter	Value	Units	Notes
Counts per rev		counts/rev	
Reload Value		counts	

Table 11.2: Encoder calibration

12 TEMPERATURE SENSOR

12.1 Background

As described in [3], there are several different types of transducers available to measure temperature: the thermocouple, the resistance temperature detector (RTD), the thermistor, and the integrated circuit (IC). Each have their own advantages and disadvantages. The Thermocouple has a wide temperature range and is easy to use but is the least stable and sensitive. The RTD, on the other hand, is most stable and accurate of the sensors but is slow and relatively more expensive. The IC is the only linear transducer, has the highest output, but is slow. The thermistor responds very quickly but has a limited temperature range. The thermistor on the mechatronic sensors board is shown in Figure 12.1.

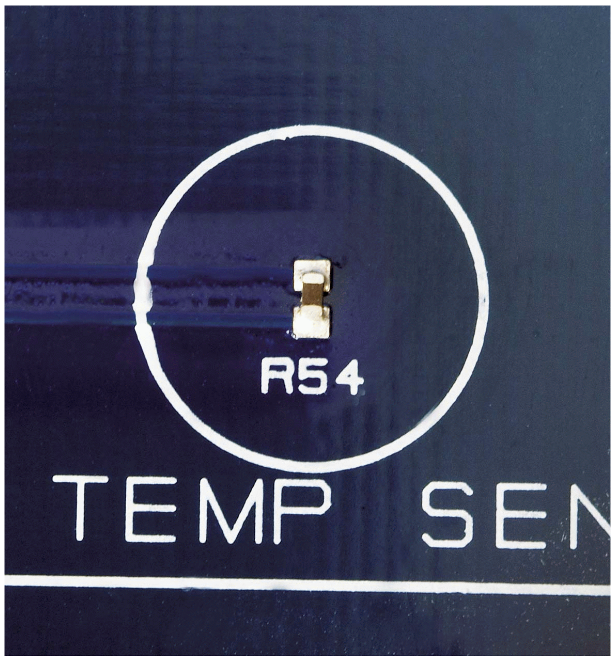

Figure 12.1: Temperature sensor on QNET mechatronic sensors trainer

The thermistor is a resistor that changes value according to the temperature. As given in [4], the relationship between the resistance of the thermistor and the temperature, T, can be described using the B-parameter equation

$$R = R_0 e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)} \tag{12.1}$$

The resistance is R_0 when the temperature is at T_0. For the thermistor on the mechatronic sensors trainer, the sensor resistance is

$$R_0 = 47000\,\Omega \tag{12.2}$$

when the temperature is at 25 degrees Celsius, or

$$T_0 = 298.15\,K \tag{12.3}$$

Thermistors are typically part of a circuit. In the QNET mechatronic sensors trainer, the thermistor is in the circuit shown in Figure 12.2 and labeled by R.

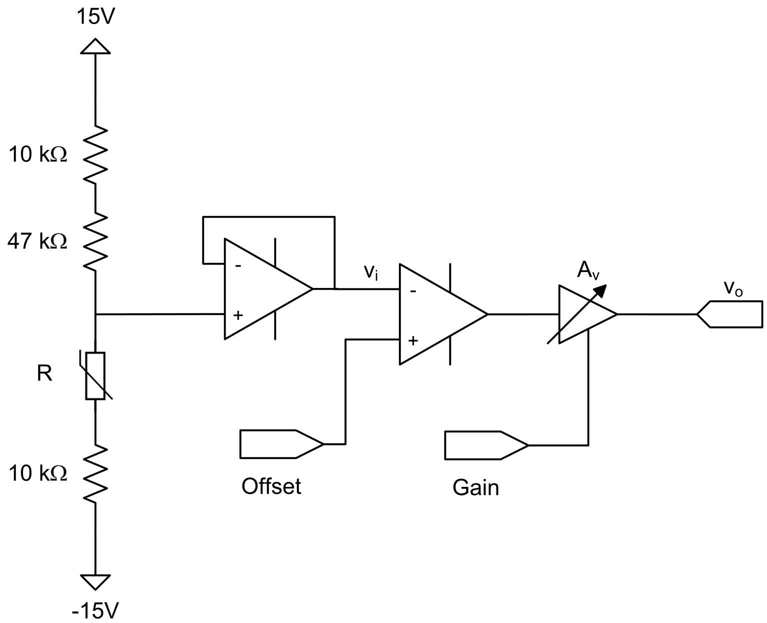

Figure 12.2: Thermistor circuit on QNET mechatronic sensors module

Using the voltage divider rule, the voltage entering the negative terminal of the second operation amplifier, i.e. the offset op amp, is

$$v_i = \frac{30(R + 10000)}{67000 + R} - 15 \quad (12.4)$$

The output voltage of the circuit is

$$v_o = A_v(v_{\text{off}} - v_i) \quad (12.5)$$

where v_off is the voltage adjusted using the *Offset* potentiometer and A_v is the amplifier gain that can be changed externally using the *Gain* potentiometer. The *Gain* and *Offset* potentiometers are on the QNET mechatronic sensor trainer and shown in Figure 12.3.

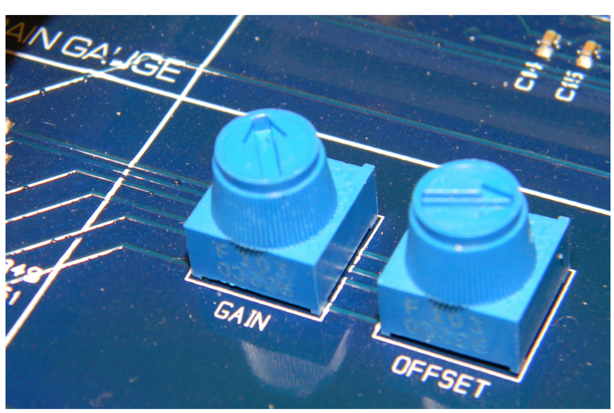

Figure 12.3: Thermistor Gain and Offset potentiometers on QNET mechatronic sensors trainer

12.2 Temperature Virtual Instrument

The virtual instrument used to collect temperature data is shown in Figure 12.4. The virtual instrument used to calibrate temperature data is shown in Figure 12.5.

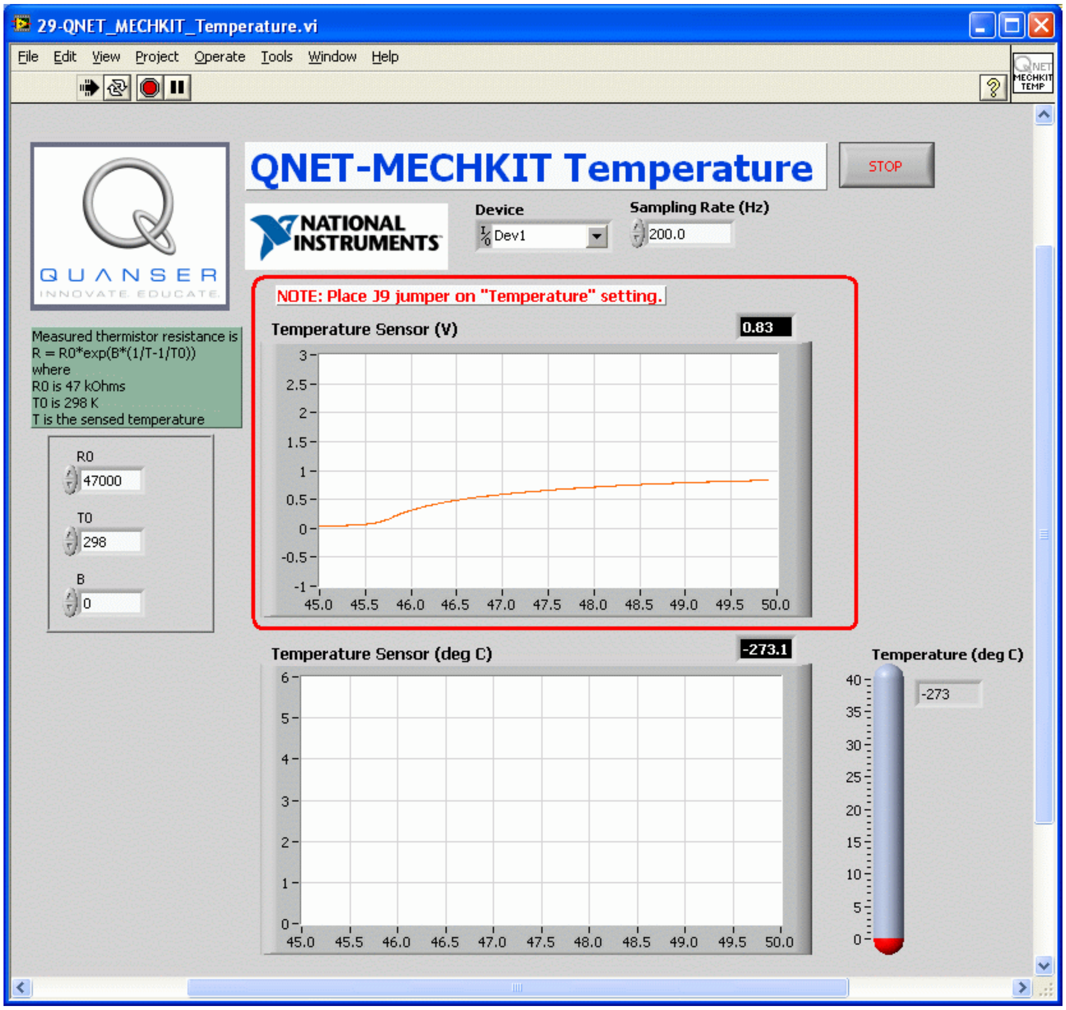

Figure 12.4: Collecting temperature sensor data

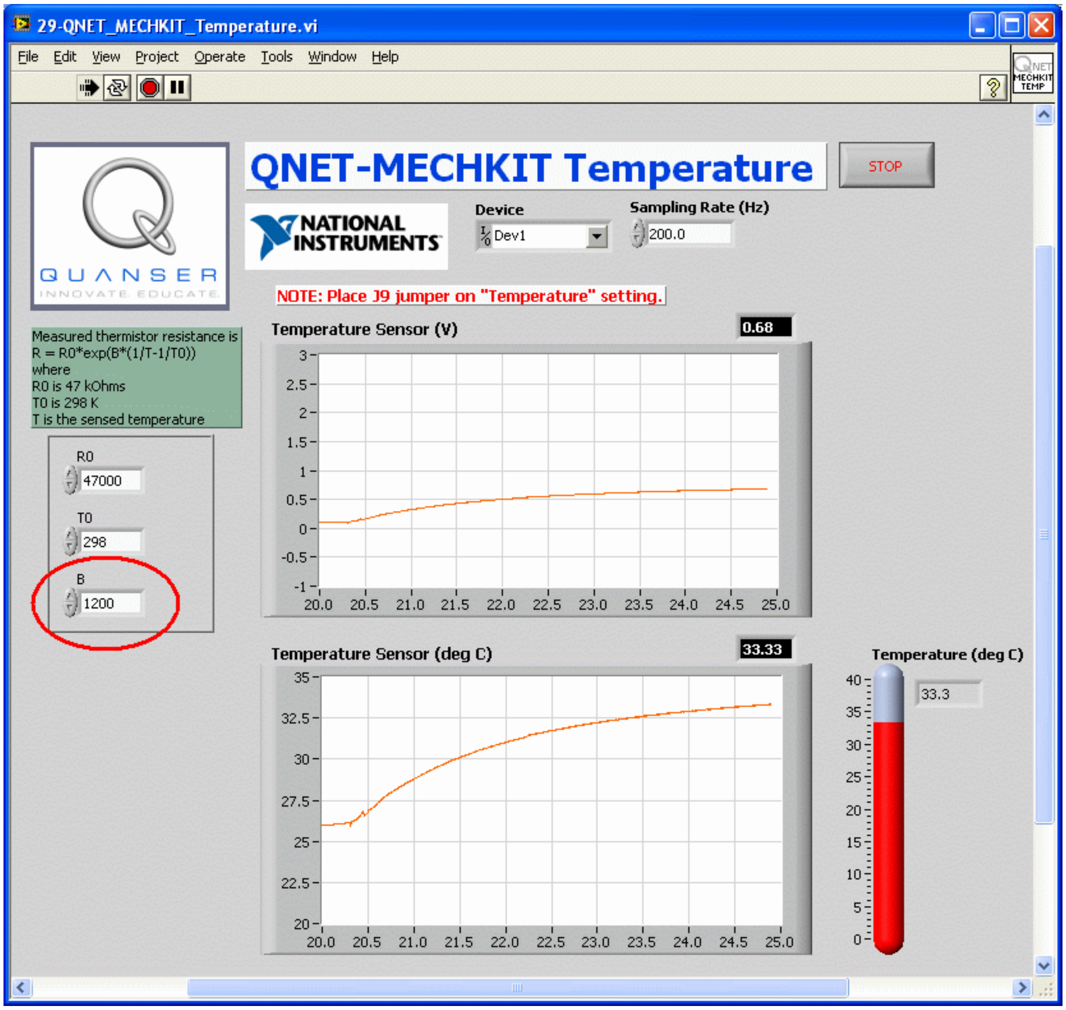

Figure 12.5: Calibrating the temperature sensor

12.3 Lab 1: Collect Data

1. **Ensure *J9* is set to *Temperature*.**
2. Open and configure the QNET MECHKIT Temperature VI as described in Section 15.11. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Temperature.vi
4. As discussed in Section 12.1, the thermistor is part of a circuit and the output voltage can be varied using the *Gain* and *Offset* potentiometers on the QNET mechatronic sensors board. Rotate the *Gain* knob on the counter-clockwise until it hits its limit.
5. Adjust the *Offset* knob such that the *Temperature Sensor (V)* scope reads 0 V. This is the voltage measured at room temperature, T_0 = 298 K. **Note:** For this step, assume your room is at 25.0 degrees Celsius (°C) even though it's probably warmer or cooler.
6. Gently place your fingertip on the temperature sensor and examine the response in the *Temperature Sensor (V)* scope. The surface temperature of the fingertip is approximately 32.0°C. Enter the voltage read at room temperature and with the fingertip.
   Note: The thermistor is very sensitive. Do not press down too hard on the sensor with your finger when taking

measurements. Otherwise, the measurement will not be consistent.
Note: After releasing the sensor it takes a a while for the temperature reading to settle back to 0 V. You can bring the temperature down faster by gently blowing on the sensor.

7. Click on *Stop* button to stop the VI.

12.4 Lab 2: Calibrate Sensor

12.4.1 Pre-Lab Exercises

1. The voltage being measured on the QNET MECHKIT is the output voltage, v_o, of the circuit discussed Section 12.1. Using the circuit and its corresponding equations, derive the formula that can be used to find the thermistor resistance from the output voltage of the circuit, R.

2. Find the thermistor resistance at room temperature, R_0, and at the fingertip, R.

3. Derive the equation to find the exponential parameter, B, and compute it based on the obtained results.

12.4.2 In-Lab Experiment

1. Run the QNET_MECHKIT_Temperature.vi

2. Enter the B parameter that was found in Section 12.4.1 in the *Temperature Sensor VI*, as shown in Figure 12.5. Place your fingertip on the sensor and capture the obtained response in *Temperature Sensor (deg C)* scope.

3. Based on the measured response in Step 2, is the temperature sensor reading correctly?

4. Click on *Stop* button to stop the VI.

12.5 Results

Temperature (°C)	Temperature (K)	Measured Voltage (V)	Units	Notes
25	298		V	Voltage at room temp, T_0
32	305		V	Voltage with finger, T

Table 12.1: Measured thermistor readings summary

Temperature (°C)	Temperature (K)	Measured Resistance (Ω)	Units	Notes
25	298		Ω	Resistance at room temp, R_0
32	305		Ω	Resistance with finger, R

Table 12.2: Measured thermistor resistances summary

13 SWITCHES AND LEDS

13.1 Background

13.1.1 Switches

Different applications call for different types of switches. For example, a micro switch may be used to detect mobile robot hitting a wall whereas an optical switch could be used to detect an edge. The push button is the most common type of switch mechanism. A switch that is active high means the output is high, e.g. 5.0 V, when the switch is triggered (e.g. pressed down). Active low means the signal is high, e.g. 5.0 V, when the switch is not engaged (e.g. not pressed down).

The different switches on the QNET mechatronic sensors trainer are introduced in this section followed by a discussion about *debouncing*.

Micro Switch

The micro switch is an active low device and is shown in Figure 13.1.

Figure 13.1: Micro switch on QNET mechatronic sensors

Push Button

The push button on the QNET MECHKIT is pictured in Figure 13.2 and is active high.

Figure 13.2: Push button on QNET mechatronic sensors trainer

Optical Switch

The optical switch, shown in Figure 13.3, is a photo-microsensor that includes transmissive and reflective components. As opposed to the push button and micro switch, this is a non-contact triggering solution. It is triggered when the reflective sensor does not detect any light, i.e. when an object is placed between the components. It goes low when no object is detected.

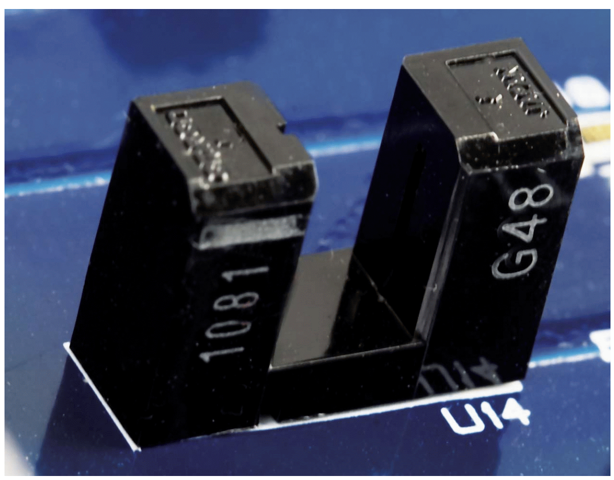

Figure 13.3: Optical switch on QNET mechatronic sensors trainer

Light Emitting Diodes (LEDs)

A light-emitting diode, or LED, is a low-energy and robust indicator that is used in many applications. The LEDs on the mechatronic sensors trainer, labeled *LED7* and *LED8*, are pictured in Figure 13.4. They are connected to digital output lines from which they can be turned on and off. As with switches, LEDs can be wired to be active high or active low.

Figure 13.4: LEDs on QNET mechatronic sensors trainer

13.2 Switches and LEDs Virtual Instrument

The virtual instrument used to collect optical switch data is shown in Figure 13.5. The virtual instruments used to calibrate the micro switch, and push button are shown in Figure 13.6, and Figure 13.7 respectively. The virtual instrument used to control the LEDs is shown in Figure 13.8.

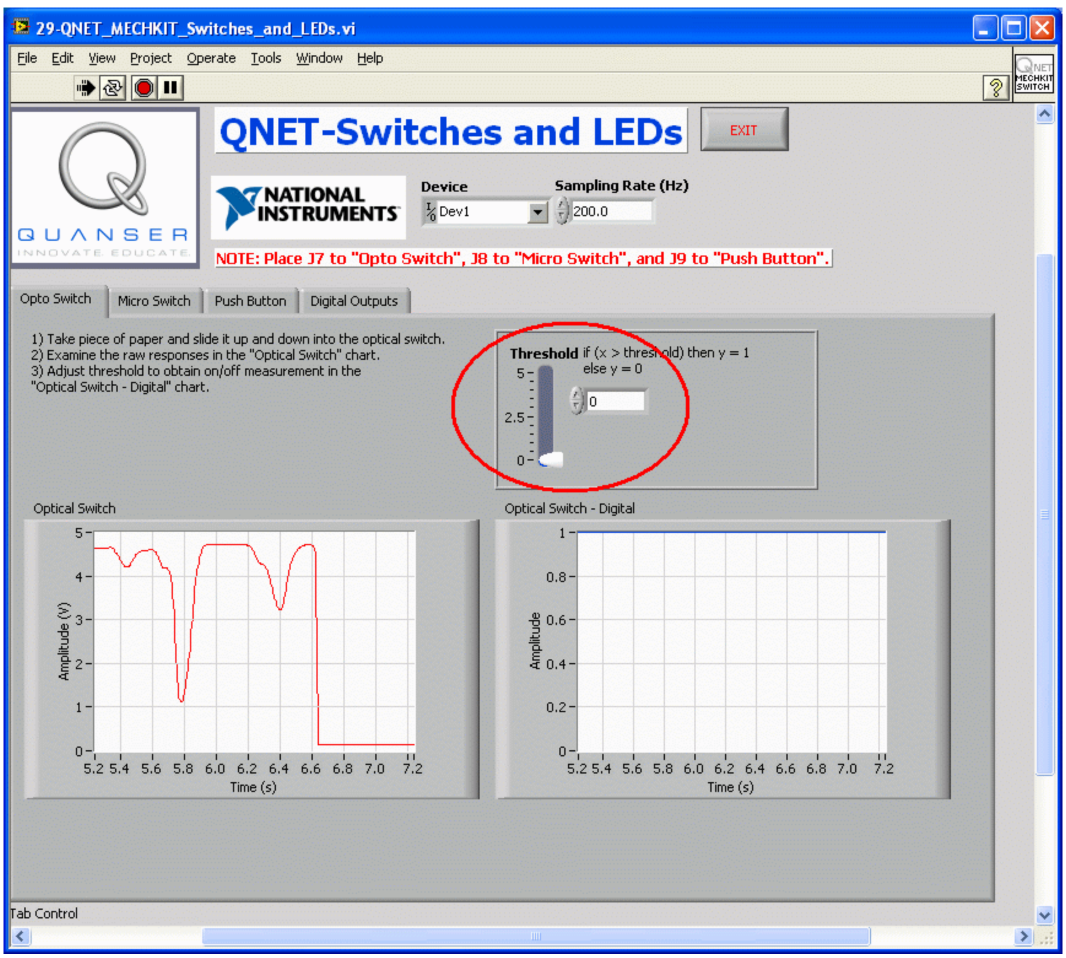

Figure 13.5: Optical switch VI

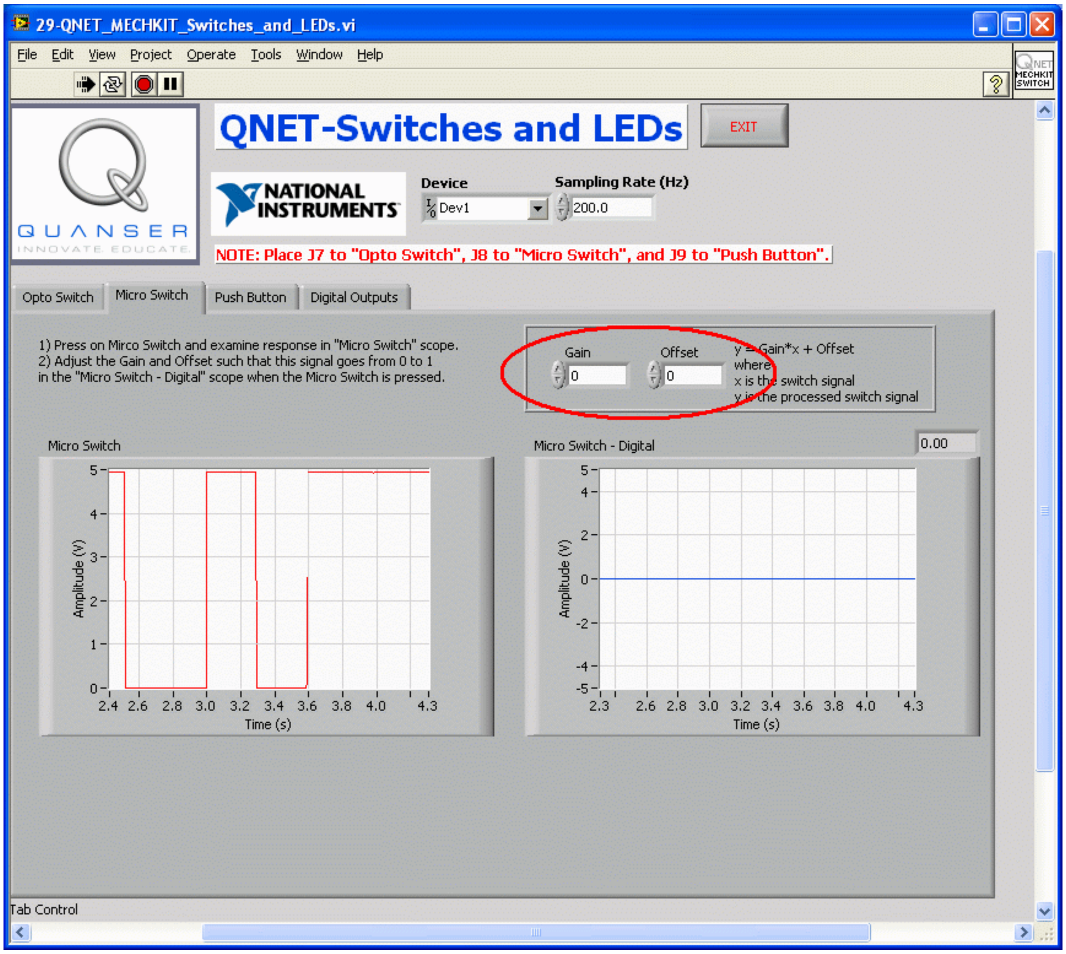

Figure 13.6: Calibrating micro switch

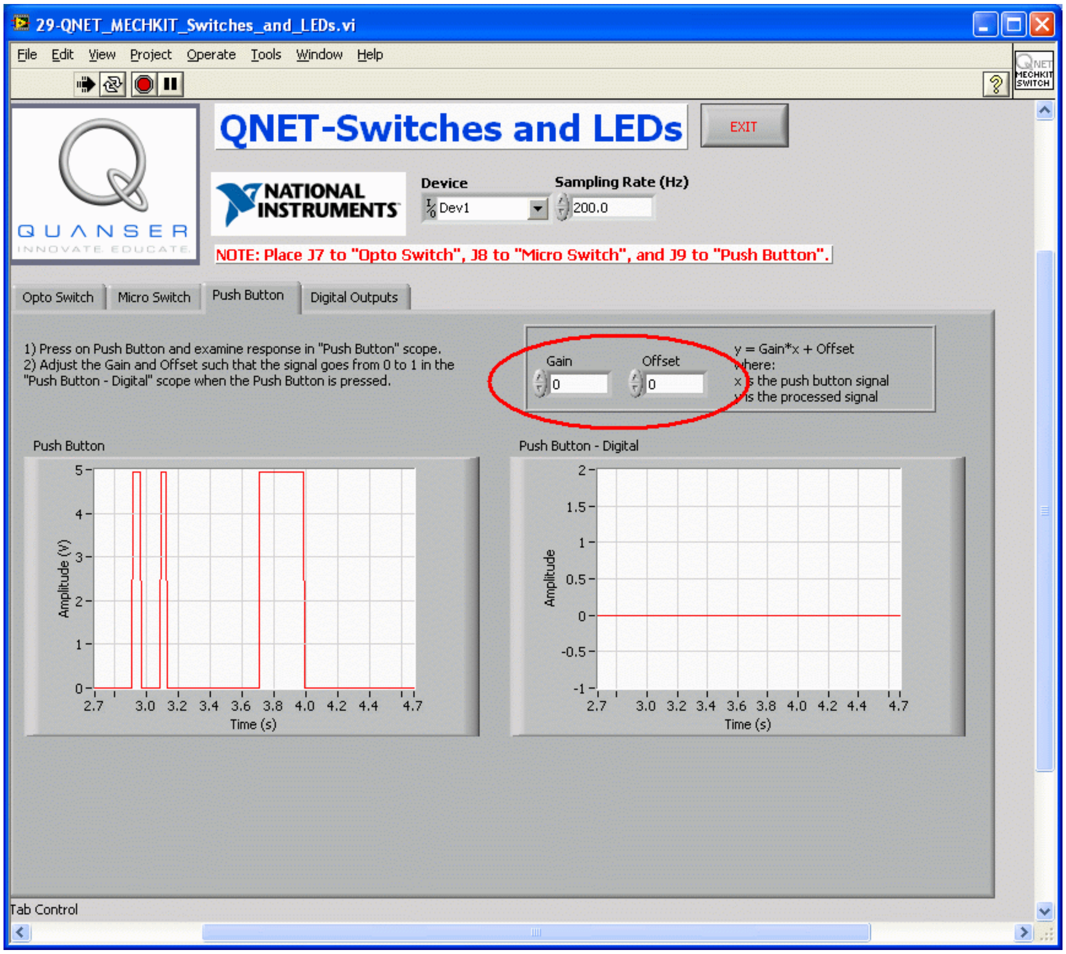

Figure 13.7: Calibrating the push button

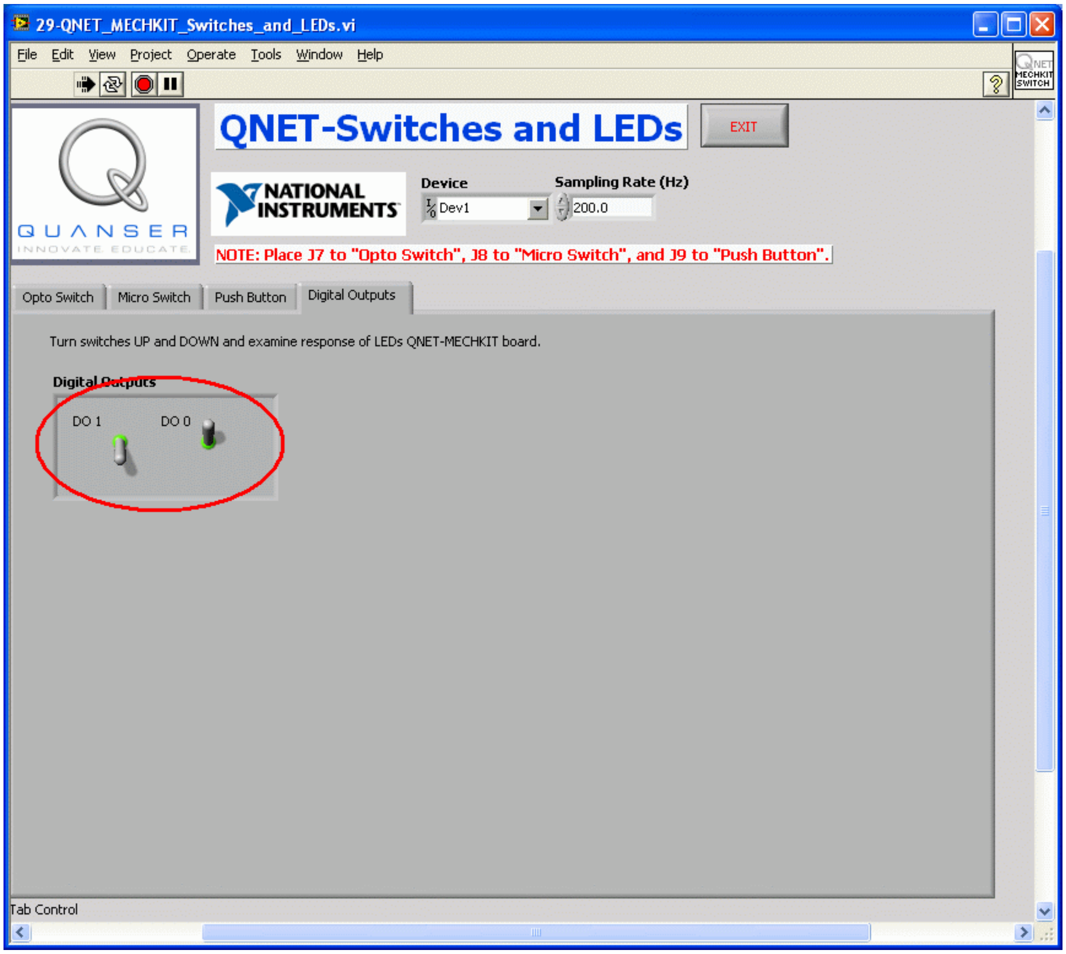

Figure 13.8: Setting the digital outputs

13.3 Lab 1: Optical Switch

1. **Ensure *J7* is set to *Opto Switch*.**
2. Open and configure the QNET MECHKIT Switches and LEDs VI as described in Section 15.12. **Make sure the correct *Device* is chosen.**
3. Run QNET_MECHKIT_Switches_and_LEDs.vi
4. Select the *Opto Switch* tab.
5. Take piece of paper and slide it up and down into the optical switch. Examine the raw responses in the *Optical Switch* scope.
6. Adjust threshold, indicated in Figure 13.5, to obtain an on/off or 0/1 digital measurement in the *Optical Switch - Digital* scope.
7. Record threshold used to get on/off measurement and paste the response of the *Optical Switch and Optical Switch - Digital* scopes.
8. Click on *Stop* button to stop the VI.

13.4 Lab 2: Micro Switch

1. **Ensure *J8* is set to *Micro Switch*.**
2. Run QNET_MECHKIT_Switches_and_LEDs.vi
3. Select the *Micro Switch* tab.
4. Press on the micro switch and examine its raw response in *Micro Switch* scope.
5. Adjust the *Gain* and *Offset*, shown in Figure 13.6, such that this the signal goes from 0 to 1 in the *Micro Switch* □ *Digital* scope when the micro switch is pressed.
6. Record the *Gain* and *Offset* used and capture representative *Micro Switch* and *Micro Switch - Digital* responses.
7. Click on *Stop* button to stop the VI.

13.5 Lab 3: Push Button

1. **Ensure *J9* is set to *Push Button*.**
2. Run QNET_MECHKIT_Switches_and_LEDs.vi
3. Select the *Push Button* tab.
4. Press on the push button and examine its raw response in the *Push Button* scope.
5. Adjust the *Gain* and *Offset*, indicated in Figure 13.7, such that this signal goes from 0 to 1 in the *Push Button* □ *Digital* scope when the push button is pressed.
6. Record the *Gain* and *Offset* parameters used and capture representative *Push Button* and *Push Button - Digital* responses.
7. Explain how the micro switch and push button behave differently.
8. Click on *Stop* button to stop the VI.

13.6 Lab 4: LEDs

1. Run QNET_MECHKIT_Switches_and_LEDs.vi
2. Select the *Digital Outputs* tab.
3. As shown in Figure 13.8, switch *DO 1* and *DO 0* between the up/down positions and examine its effect on the on-board LEDs.
4. Record what position, i.e. up or down, the *DO 1* and *DO 0* switches have to be in such that the DO 1 and DO 0 LEDs are lit.
5. Click on *Stop* button to stop the VI.

13.7 Results

Parameter	Value	Units	Notes
Gain			
Offset			
Gain			
Offset			
DO 1 Switch position for DO 1 LED ON			
DO 1 Switch position for DO 1 LED OFF			

Table 13.1: Switch and LED results summary

14 SWITCH DEBOUNCE ANALYSIS

14.1 Background

14.1.1 Switch Debouncing

When implemented digitally, debounce is a type of signal conditioning algorithm that ensures the switch, button, or sensor does not trigger anything due to unexpected conditions.

For example, consider a high-powered cart that is mounted on a track. Proximity sensors are installed that detect when the cart goes beyond a safety limit, in which case the amplifier is deactivated. However due to the high-frequency switching in the motor leads, the proximity switches are sometimes unexpectedly triggered even when the cart is in the safe zone. The raw signal from the proximity sensor is shown in the top plot of Figure 14.1. To avoid this, the output signal from the sensor is passed though a debounce switch and the resulting signal is shown in the bottom plot of Figure 14.1.

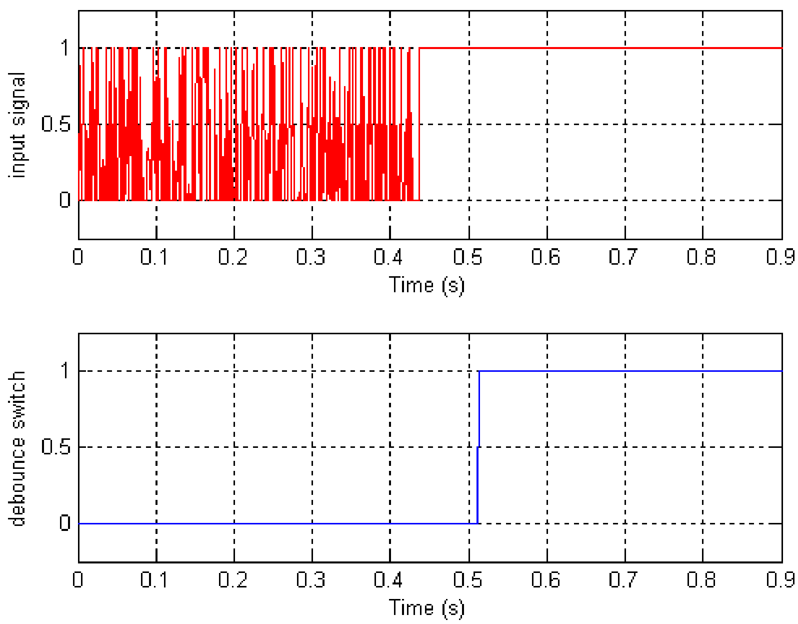

Figure 14.1: Sample debounce response

Note: This laboratory is for the ELVIS II only. The ELVIS I does not have the functionality to perform this experiment

14.2 Switches and LEDs Virtual Instrument

The NI ELVISmx Oscilloscope is shown in Figure 14.2. The virtual instrument used to analyze and debounce the micro switch, and push button is shown in Figure 14.3.

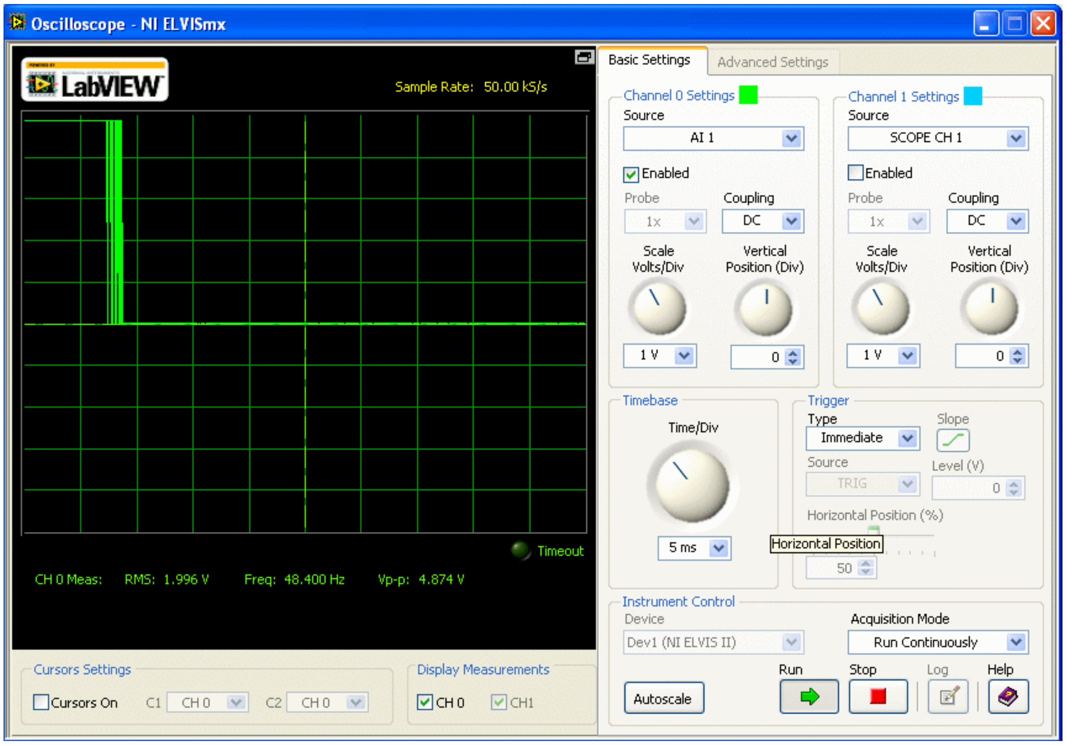

Figure 14.2: NI ELVISmx Oscilloscope instrument when pressing micro switch

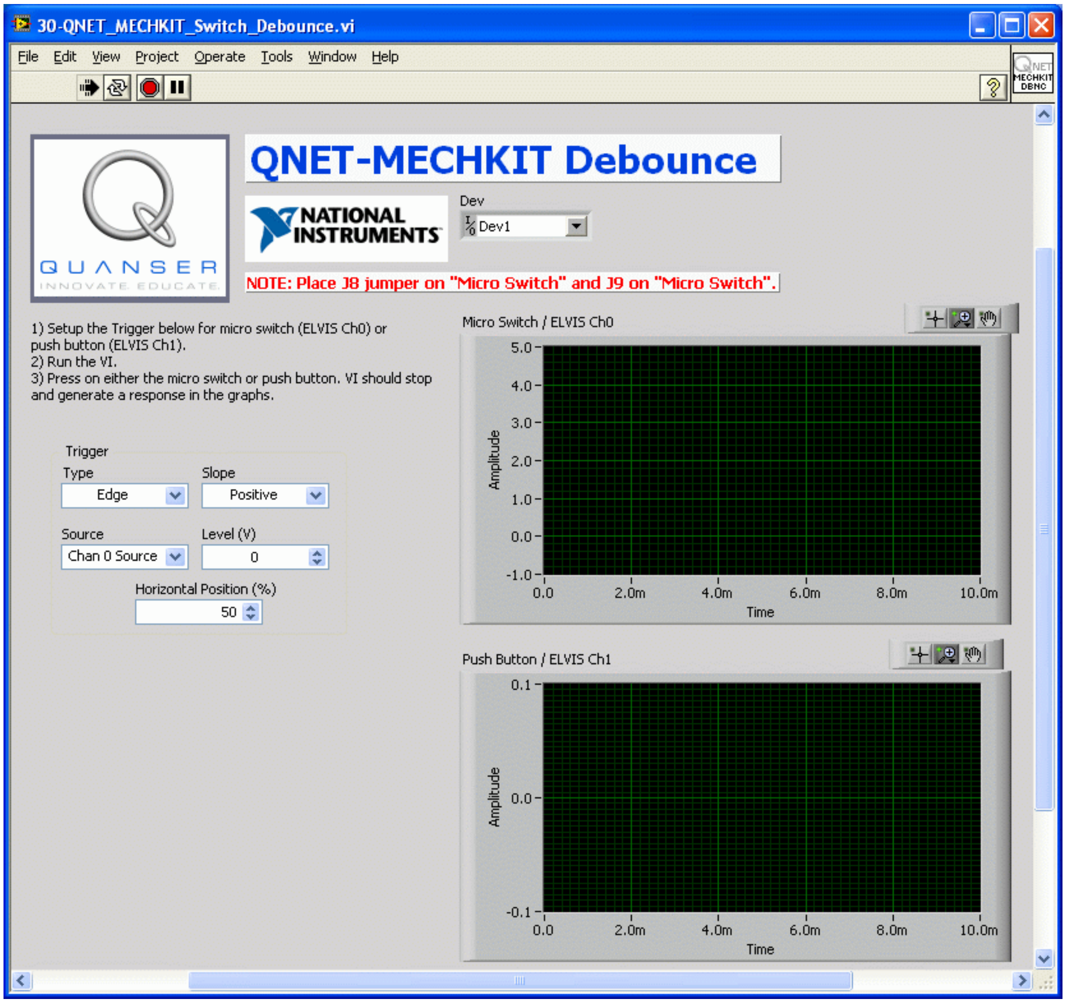

Figure 14.3: VI used to analyze debounce of micro switch and push button

14.3 Lab 1: Running the Oscilloscope

1. **Ensure *J8* is set to *Micro Switch* and *J9* to *Push Button*.**
2. Run the Oscilloscope NI ELVISmx instrument. By default, this is located under *Start \All Programs \National Instruments \NI ELVISmx \Instruments*.
3. Click on the green start arrow to run the Oscilloscope.
4. To read the micro switch, set the *Source* control in *Channel 0 Settings* to *AI 1* (i.e. analog input channel #1). The response obtained should be similar as shown in Figure 14.2.
5. Press on the micro switch and ensure you are getting the expected signal. Since the *Acquisition Mode* is set to continuous, the instrument keeps on running and the signal can be observed in real-time.
6. To examine the behaviour of the micro switch when it is engaged, configure the *Trigger* section to stop. **Note:** If preferred, you can change the *Acquisition Mode* to *Run Once* so the oscilloscope stops when the trigger is engaged.
7. If the trigger has been setup correctly, then the oscilloscope screen should capture a closeup view of the micro switch signal as it goes from 5 V to 0 V.

8. Try to setup the oscilloscope for the *Push Button*. This is on analog input channel #2 and you can choose to configure it on the Channel 1 of the oscilloscope (if you do, make sure you enable the channel). **Note:** To increase the sampling rate and obtain a more closeup view of the signal, decrease the *Time/Div* knob control.

9. When you are done, stop and close down the Oscilloscope instrument.

   ■ **Caution:** Make sure any ELVISmx instrument, e.g. the oscilloscope, is closed before running any ELVIS II based VIs. Otherwise the VI will not be able to run.

14.4 Lab 2: Micro Switch

1. **Ensure *J8* is set to *Micro Switch*.**
2. The QNET MECHKIT Debounce VI, which is shown in Figure 14.3, has the same functionality as the Oscilloscope tool used in Section 14.3. It is already setup with a trigger and does not run continuously as the oscilloscope instrument does. The Debounce VI is described in more detail in Section 15.13.
3. Run QNET_MECHKIT_Debounce.vi
4. Setup the *Trigger* for the Micro Switch (Ch #0).
5. Press the micro switch. The VI should stop and a response displayed on both graphs.
6. Capture the *Micro Switch* scope. What do you notice about the output signal from the micro switch?
7. Click on *Stop* button to stop the VI.

14.5 Lab 3: Push Button

1. **Ensure *J9* is set to *Push Button*.**
2. Run QNET_MECHKIT_Debounce.vi
3. Setup the *Trigger* for the Push Button (CH #1) and enter the settings in Table 14.1.
4. Press the push button. The VI should stop and a response displayed on both graphs.
5. Capture the *Push Button* scope. What do you notice about the push button signal?
6. Which control would require debounce more micro switch or push button? Explain.
7. When triggering on one channel, notice that there is a signal on the other channel (e.g. when pressing the micro switch observe the Ch1 scope). Capture representative plots and explain why this occurs.
8. Click on *Stop* button to stop the VI.

14.6 Results

Trigger Parameters Micro Switch	Value	Units	Notes
Type			
Slope			
Source			
Level		V	
Push Button			
Type			
Slope			
Source			
Level		V	

Table 14.1: Debouncing trigger parameters summary

15 SYSTEM REQUIREMENTS

Required Hardware

- NI ELVIS II (or NI ELVIS I)
- Quanser QNET Mechatronic Sensors Trainer. See QNET MECHKIT User Manual ([2]).

Required Software

- NI LabVIEW®2010 or later
- NI DAQmx
- NI LabVIEW Control Design and Simulation Module
- *ELVIS II Users*: ELVISmx installed from ELVIS II CD.
- *ELVIS I Users*: ELVIS CD 3.0.1 or later installed.

■ **Caution: If these are not all installed then the VI will not be able to run!** Please make sure all the software and hardware components are installed. If an issue arises, then see the troubleshooting section in the QNET VTOL User Manual ([2]).

15.1 Overview of Files

File Name	Description
QNET MECHKIT User Manual.pdf	This manual describes the hardware of the QNET Mechatronic Sensors trainer and how to setup the system on the ELVIS.
QNET MECHKIT Lab Manual (Student).pdf	This laboratory guide contains pre-lab questions and lab experiments demonstrating how to calibrate and use sensors on the QNET MECHKIT trainer LabVIEW®.
QNET_MECHKIT_Flexgage.vi	Control the current in the propeller motor
QNET_MECHKIT_Pressure Sensor.vi	Validate transfer function model and identify system parameters
QNET_MECHKIT_Piezo.vi	Control the pitch of the VTOL device using PID
QNET_MECHKIT_Potentiometer.vi	Calibrate potentiometer to get correct angle
QNET_MECHKIT_Infrared.vi	Calibrate infrared sensor to measure target distance
QNET_MECHKIT_Sonar.vi	Implement sonar sensor to measure target range
QNET_MECHKIT_Optical.vi	Calibrate optical sensor to measure the position of the flat screw head, which can be adjusted using the knob
QNET_MECHKIT_Magnetic_Field.vi	Implement magnetic field sensor to measure position of the screw head, which can be adjusted using its knob
QNET_MECHKIT_Encoder.vi	Used to teach the fundamentals of a rotary optical encoder
QNET_MECHKIT_Temperature.vi	Calibrate thermistor to measure correct temperature
QNET_MECHKIT_Switches_and_LEDs.vi	Change the on/off behaviour of the micro switch, push button, and optical switch and drive on-board LEDs
QNET_MECHKIT_Switch_Debounce.vi	High-frequency analysis of micro switch and push button

Table 15.1: Files supplied with the QNET MECHKIT Laboratory.

15.2 Strain Gage with Flexible Link VI

This VI can be used to view the strain gage measurements when moving the flexible link on the QNET mechatronic sensors trainer. Table 15.2 lists and describes the main elements of the QNET Flexgage VI and every element is uniquely identified by an ID number in Figure 15.1, Figure 15.2, and Figure 15.3.

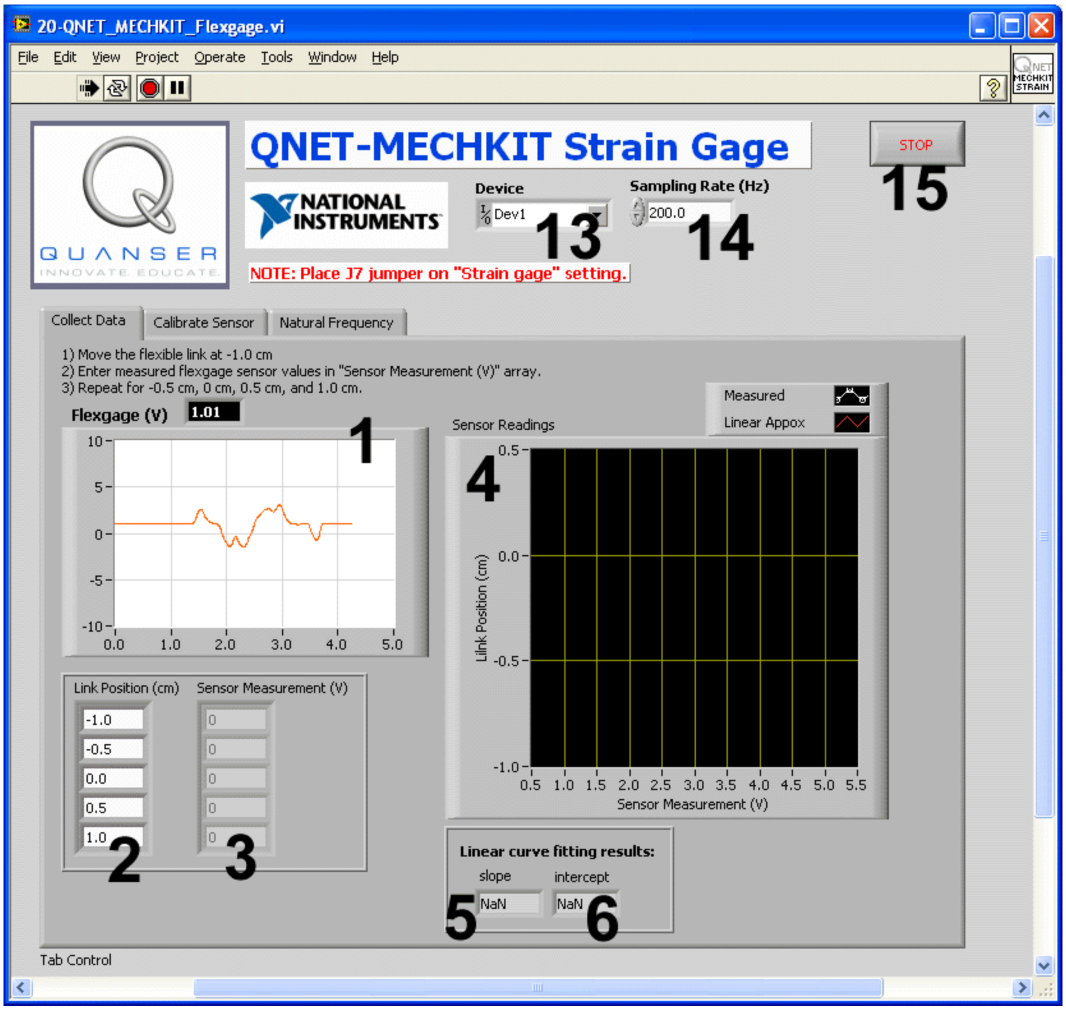

Figure 15.1: QNET-MECHKIT Flexgage VI: *Collect Data* tab selected

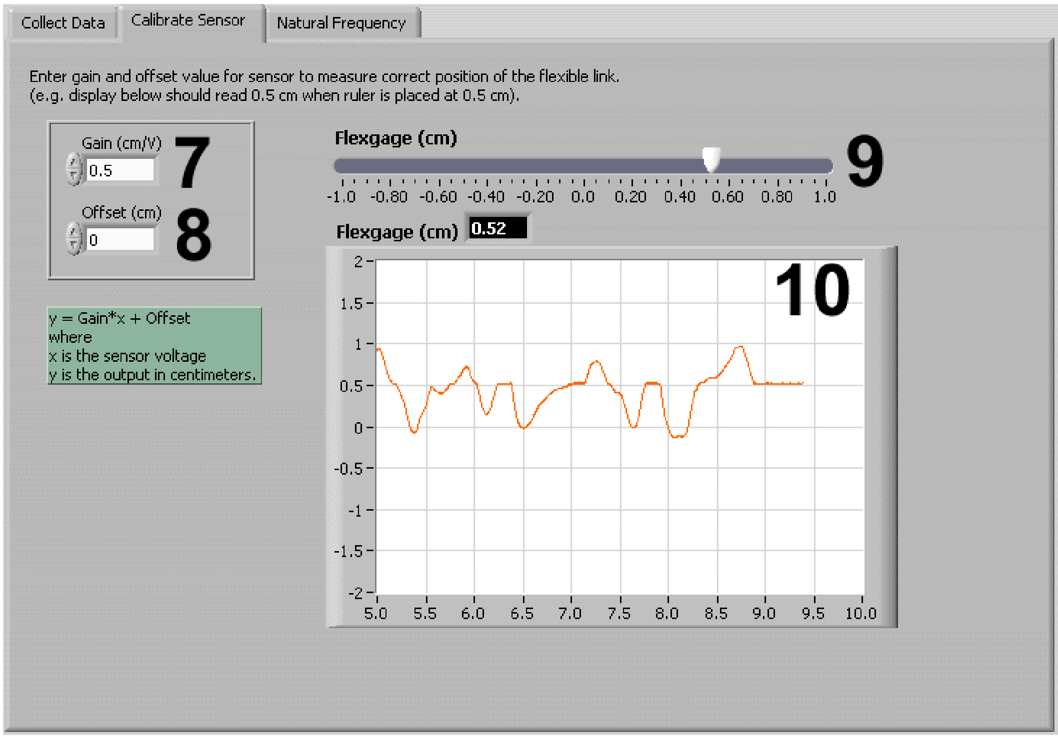

Figure 15.2: QNET-MECHKIT Flexgage VI: *Calibrate* tab

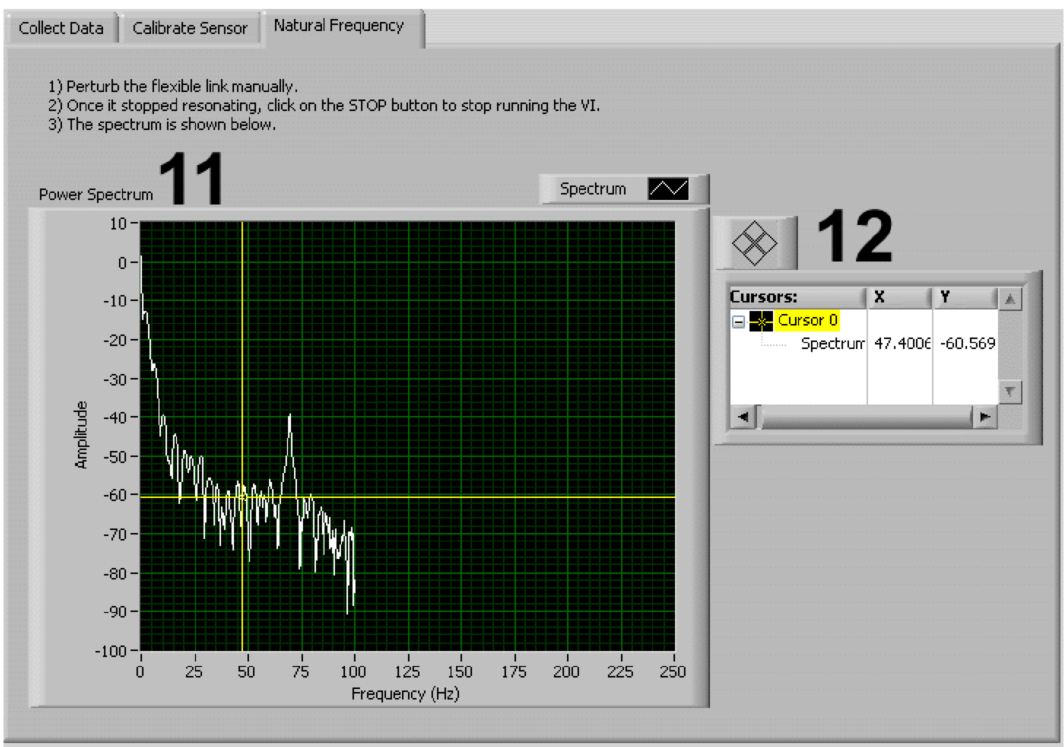

Figure 15.3: QNET MECHKIT Flexgage VI: *Natural Frequency* tab

ID #	Label	Description	Unit
1	Scope: Flexgage (V)	Scope showing raw voltage measured by strain gage	V
2	Link Position (cm)	Position of flexible link along printed graduated ruler on QNET board	cm
3	Sensor Measurement (V)	Recorded strain gage measurement for each link position	V
4	Sensor Readings	Graph showing measured and curve fitted data	
5	Slope	Slope computed by curve fitting algorithm	cm/V
6	Intercept	Intercept computed by curve fitting algorithm	cm
7	Gain (cm/V)	Sensor calibration gain (slope)	cm/V
8	Offset (cm)	Sensor calibration offset (intercept)	cm
9	Slider: Flexgage (cm)	Displays position of flexible link using *Gain* and *Offset* parameter	cm
10	Scope: Flexgage (cm)	Displays position of flexible link using *Gain* and *Offset* parameter	cm
11	Graph: Power Spectrum	Graph showing power spectrum of flexible link (after being perturbed)	
12	Cursor	Displays numerically the location of the cursor on the *Power Spectrum* graph	
13	Device	Selects the NI DAQ device	
14	Sampling Rate	Sets the sampling rate of the VI	Hz
15	Stop	Stops the LabVIEW VI from running	

Table 15.2: Nomenclature of QNET-MECHKIT Flexgage VI

15.3 Pressure Laboratory VI

This VI can be used to view the pressure sensor measurements as the plunger is moved at different locations within the syringe on the QNET mechatronic sensors trainer. Table 15.3 lists and describes the main components of the QNET Pressure Sensor VI and they are uniquely identified by an ID number in Figure 15.4 and Figure 15.5.

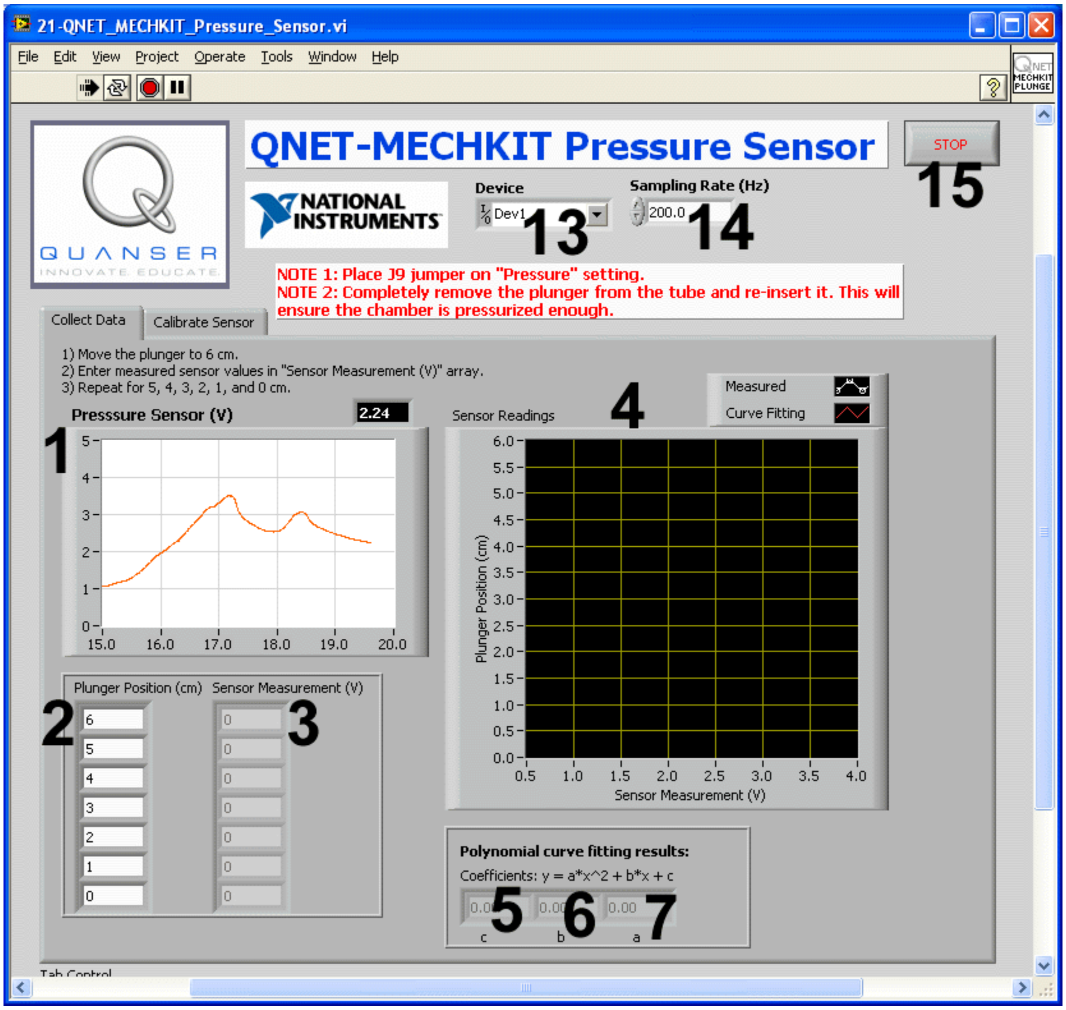

Figure 15.4: QNET MECHKIT Pressure Sensor: *Collect Data* tab

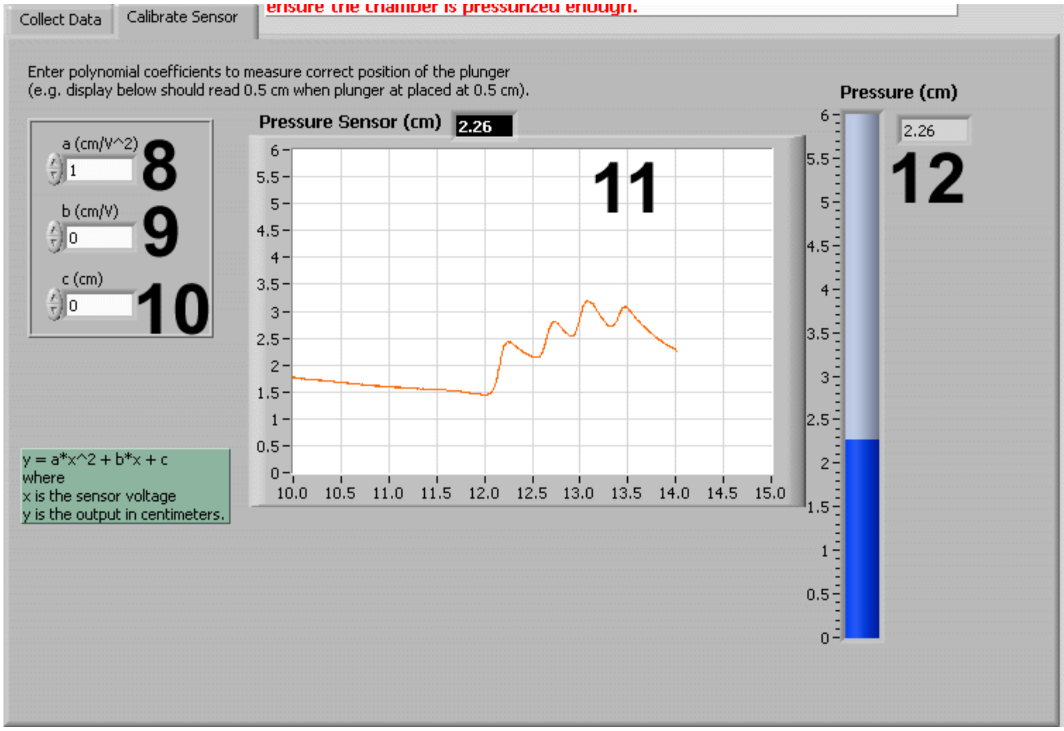

Figure 15.5: QNET MECHKIT Pressure Sensor VI: *Calibration* tab

ID #	Label	Description	Unit
1	Scope: Pressure Sensor (V)	Scope showing raw voltage measured by pressure sensor	V
2	Plunger Position (cm)	Position of syringe along printed graduated ruler on QNET board	cm
3	Sensor Measurement (V)	Recorded pressure sensor measurement for each plunger position	V
4	Graph: Sensor Readings	Graph showing measured and curve fitted data	
5	c (*Collect Data* tab)	Intercept computed by curve fitting algorithm	cm
6	b (*Collect Data* tab)	Slope computed by curve fitting algorithm	cm/V
7	a (*Collect Data* tab)	Rate of slope computed by curve fitting algorithm	cm/V^2
8	a (*Calibrate Sensor* tab)	Rate of slope computed by curve fitting algorithm	cm/V^2
9	b (*Calibrate Sensor* tab)	Slope computed by curve fitting algorithm	cm/V
10	c (*Calibrate Sensor* tab)	Intercept computed by curve fitting algorithm	cm
11	Scope: Pressure Sensor (cm)	Chart displays position of target using *a*, *b*, and *c* parameters	cm
12	Pressure (cm)	Slide indicator displays position of target using *a*, *b*, and *c* parameters	cm
13	Device	Selects the NI DAQ device	
14	Sampling Rate	Sets the sampling rate of the VI	Hz
15	Stop	Stops the LabVIEW VI from running	

Table 15.3: Nomenclature of QNET-MECHKIT Pressure Sensor VI

15.4 Piezo VI

The QNET Piezo VI is used to view the piezo sensor readings as the plastic strip on the QNET MECHKIT is perturbed. The components of the VI are listed in Table 15.4, and identified in Figure 15.6 and Figure 15.7.

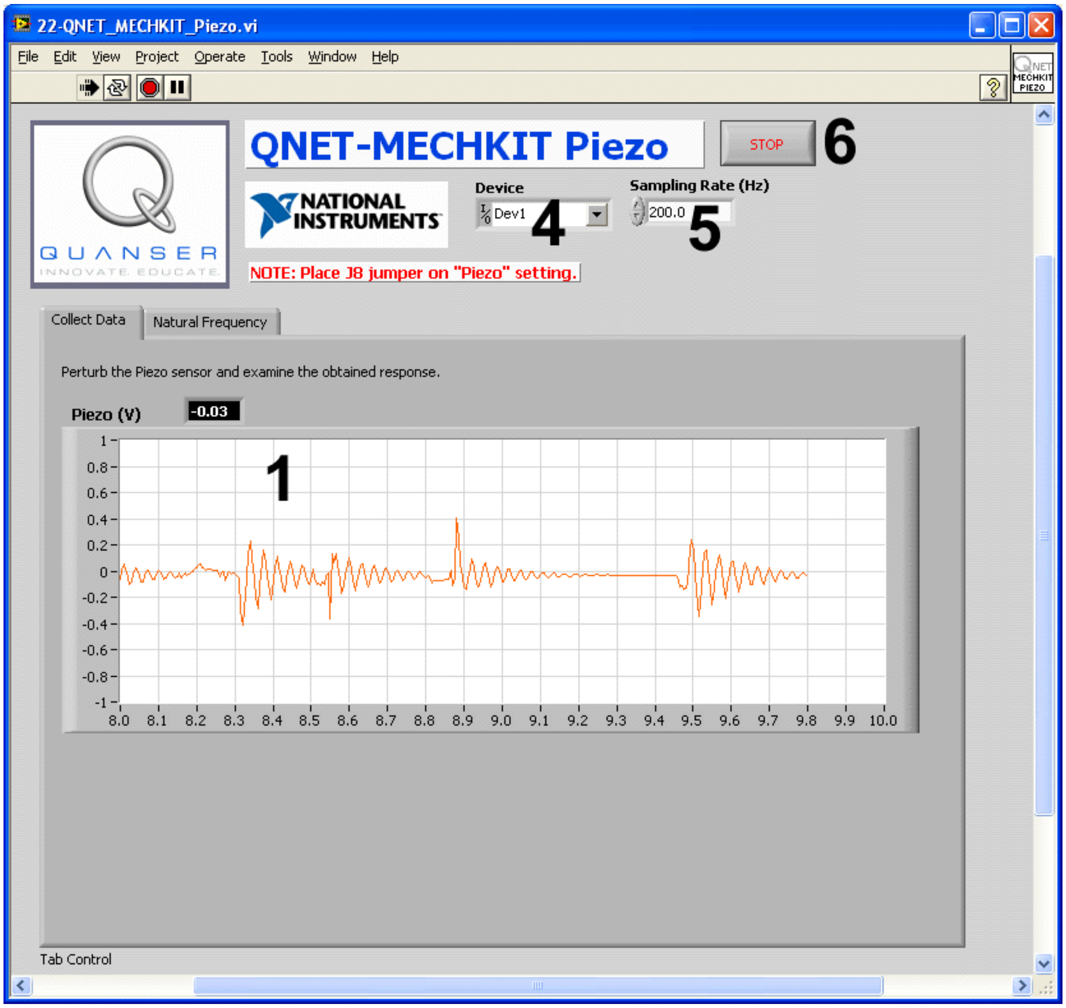

Figure 15.6: QNET MECHKIT Piezo Sensor VI: *Collect Data* tab

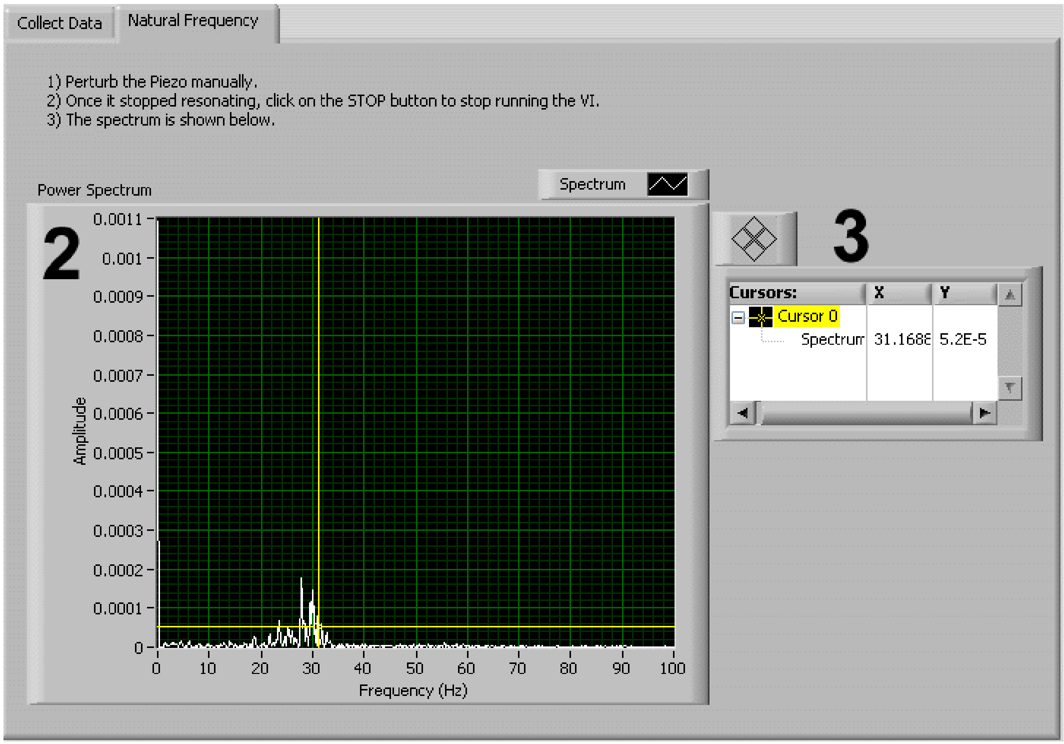

Figure 15.7: QNET MECHKIT Piezo Sensor VI: *Natural Frequency* tab

ID #	Label	Description	Unit
1	Scope: Piezo (V)	Scope showing raw voltage measured by piezo film sensor	V
2	Graph: Power Spectrum	Graph showing power spectrum of film (after being perturbed)	
3	Cursor	Displays numerically the location of the cursor on the Power Spectrum graph	
4	Device	Selects the NI DAQ device	
5	Sampling Rate	Sets the sampling rate of the VI	Hz
6	Stop	Stops the LabVIEW VI from running	

Table 15.4: Nomenclature of QNET-MECHKIT Piezo VI

15.5 Potetiometer VI

This VI can be used to view the potentiometer measurements when moving the potentiometer knob on the QNET mechatronic sensors trainer. Table 15.5 lists and describes the main elements of the QNET Potentiometer VI and every element is uniquely identified by an ID number in Figure 15.8 and Figure 15.9.

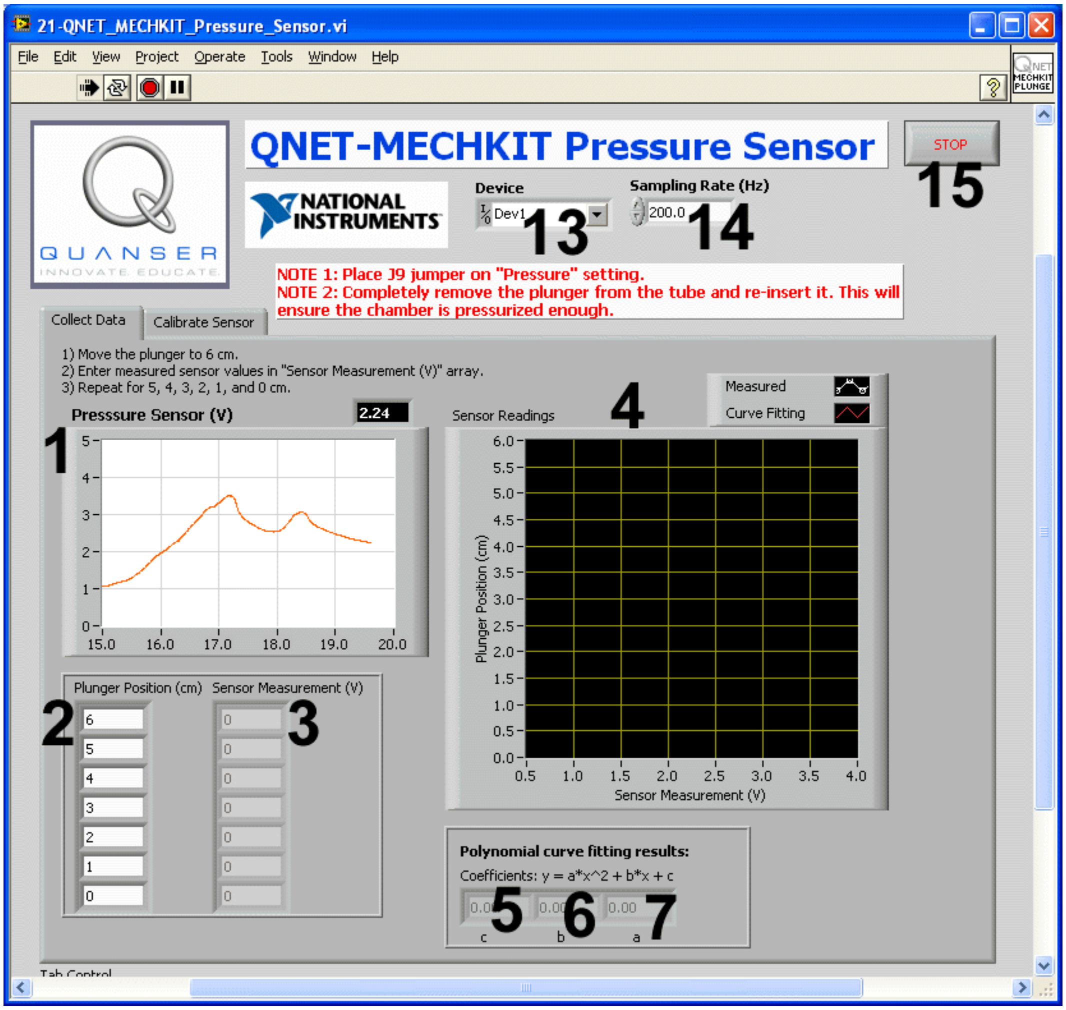

Figure 15.8: QNET MECHKIT Potentiometer VI: *Collect Data* tab

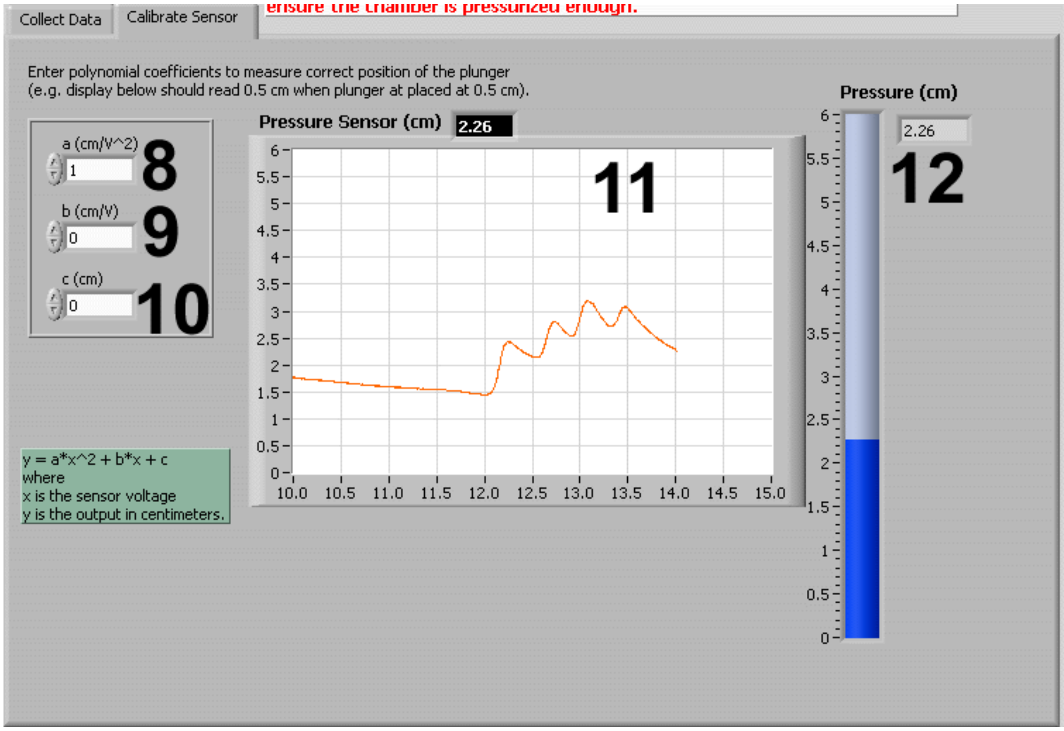

Figure 15.9: QNET MECHKIT Potentiometer VI: *Calibration* tab

ID #	Label	Description	Unit
1	Scope: Potentiometer (V)	Scope showing raw voltage measured by potentiometer	V
2	Pot Angle (deg)	Angle of top arrow on the potentiometer knob	deg
3	Sensor Measurement (V)	Recorded potentiometer measurement for each angle	V
4	Sensor Readings	Graph showing measured and curve fitted data	
5	Slope	Slope computed by curve fitting algorithm	deg/V
6	Intercept	Intercept computed by curve fitting algorithm	deg
7	Gain (deg/V)	Sensor calibration gain (slope)	deg/V
8	Offset (deg)	Sensor calibration offset (intercept)	deg
9	Scope: Potentiometer (deg)	Displays angular position of potentiometer according to the *Gain* and *Offset* parameters	deg
10	Knob: Potentiometer (deg)	Displays position of potentiometer according to the *Gain* and *Offset* parameters	deg
11	Device	Selects the NI DAQ device	
12	Sampling Rate	Sets the sampling rate of the VI	Hz
13	Stop	Stops the LabVIEW VI from running	

Table 15.5: Nomenclature of QNET-MECHKIT Potentiometer VI

15.6 Infrared Sensor Laboratory VI

Use the QNET Infrared VI to view and calibrate the readings of the infrared sensor on the MECHKIT as the target distance is changed. The components of the VI are listed in Table 15.6 and identified in Figure 15.10 and Figure 15.11.

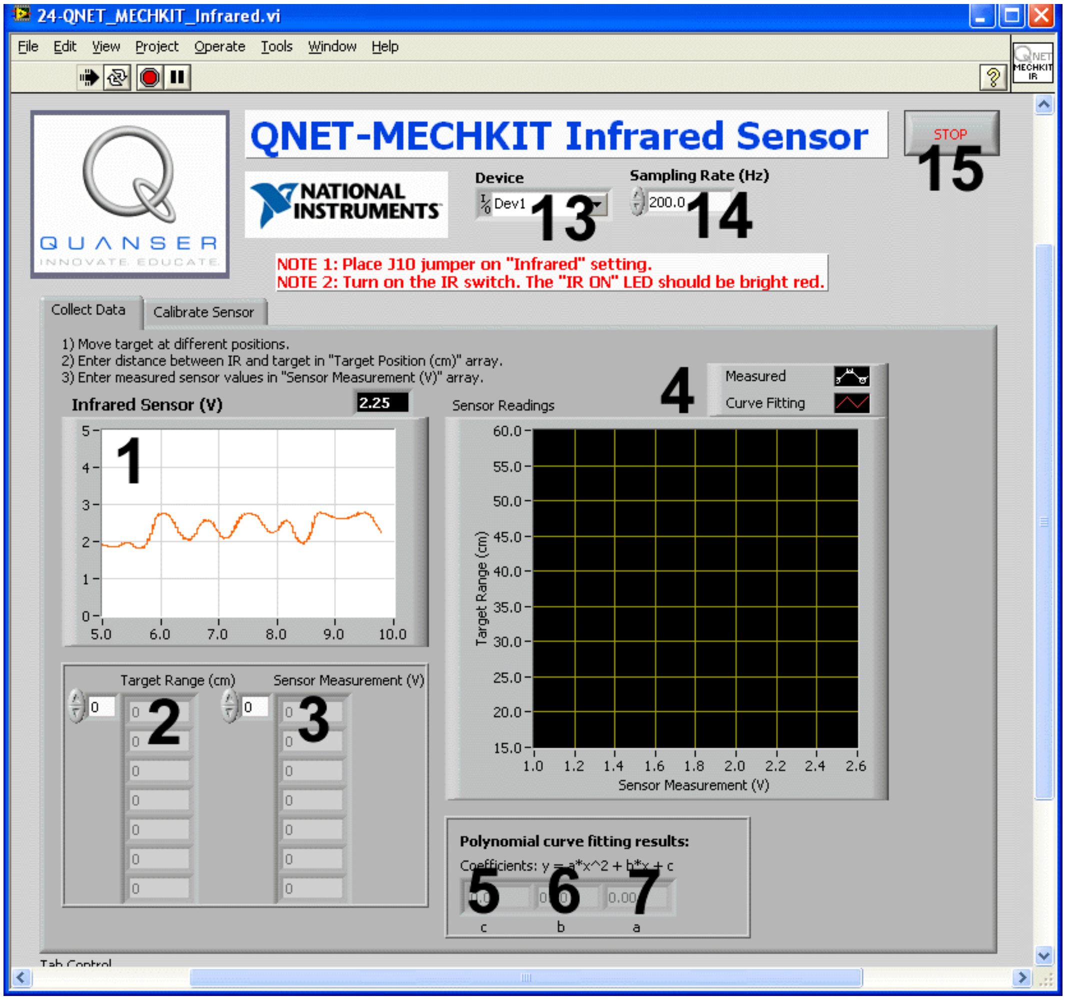

Figure 15.10: QNET MECHKIT Infrared Sensor VI: *Collect Data* tab

Figure 15.11: QNET MECHKIT Infrared Sensor VI: *Calibration* tab

ID #	Label	Description	Unit
1	Scope: Infrared Sensor (V)	Scope showing raw voltage measured by infrared sensor	V
2	Target Range (cm)	Distance between the target and IR sensor	cm
3	Sensor Measurement (V)	Recorded IR measurement for each target position	V
4	Graph: Sensor Readings	Graph showing measured and curve fitted data	
5	c (*Collect Data* tab)	Intercept computed by curve fitting algorithm	cm
6	b (*Collect Data* tab)	Slope computed by curve fitting algorithm	cm/V
7	a (*Collect Data* tab)	Rate of slope computed by curve fitting algorithm	cm/V^2
8	a (*Calibrate Sensor* tab)	Rate of slope computed by curve fitting algorithm	cm/V^2
9	b (*Calibrate Sensor* tab)	Slope computed by curve fitting algorithm	cm/V
10	c (*Calibrate Sensor* tab)	Intercept computed by curve fitting algorithm	cm
11	IR Sensor (cm)	Displays target distance using *a*, *b*, and *c* parameters	cm
12	IR (cm)	Knob displays position of target using *a*, *b*, and *c* parameters	cm
13	Device	Selects the NI DAQ device	
14	Sampling Rate	Sets the sampling rate of the VI	Hz
15	Stop	Stops the LabVIEW VI from running	

Table 15.6: Nomenclature of QNET-MECHKIT Infrared VI

15.7 Sonar Sensor VI

Use this VI to view the sonar measurements as a target is moved at different distances away from the sensor. Table 15.7 lists and describes the main components of the QNET Sonar VI and they are uniquely identified by an ID number in Figure 15.12 and Figure 15.13.

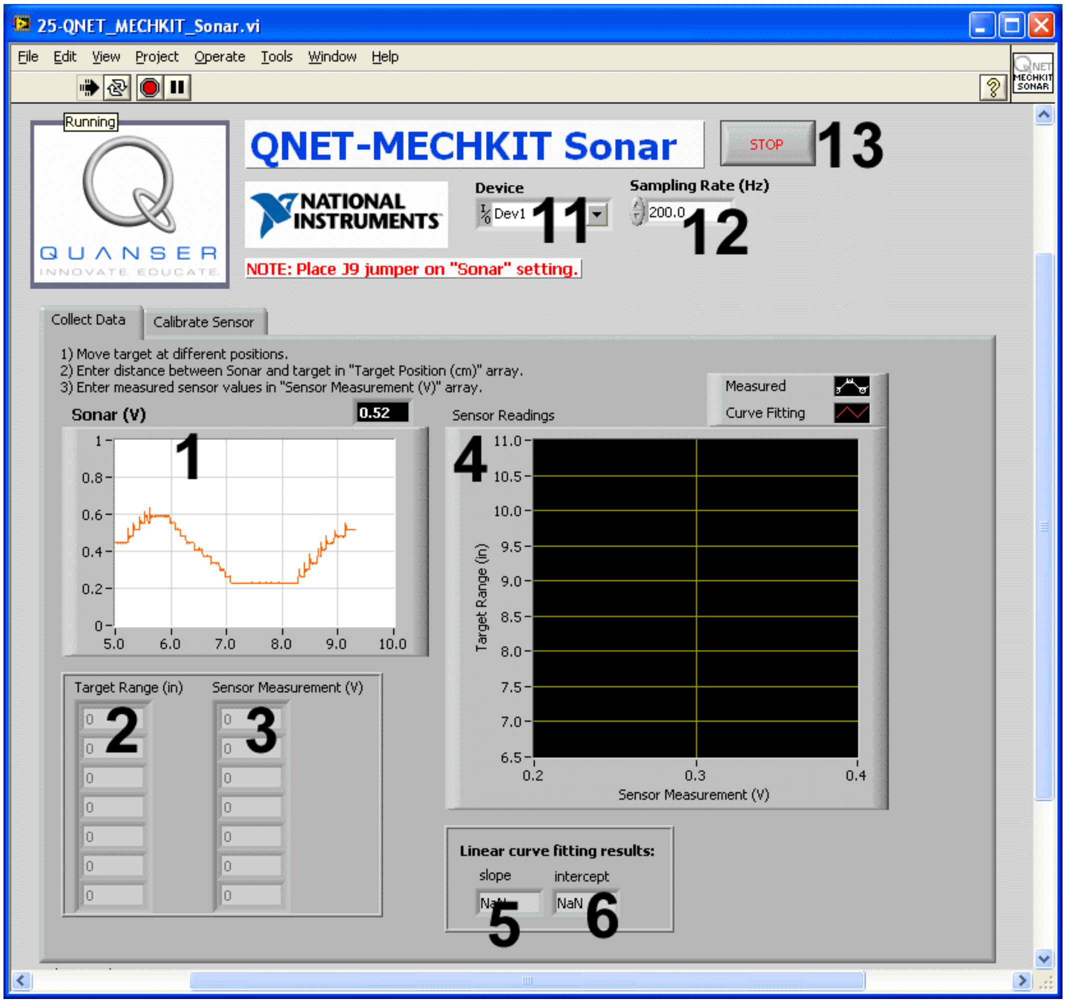

Figure 15.12: QNET MECHKIT Sonar VI: *Collect Data* tab

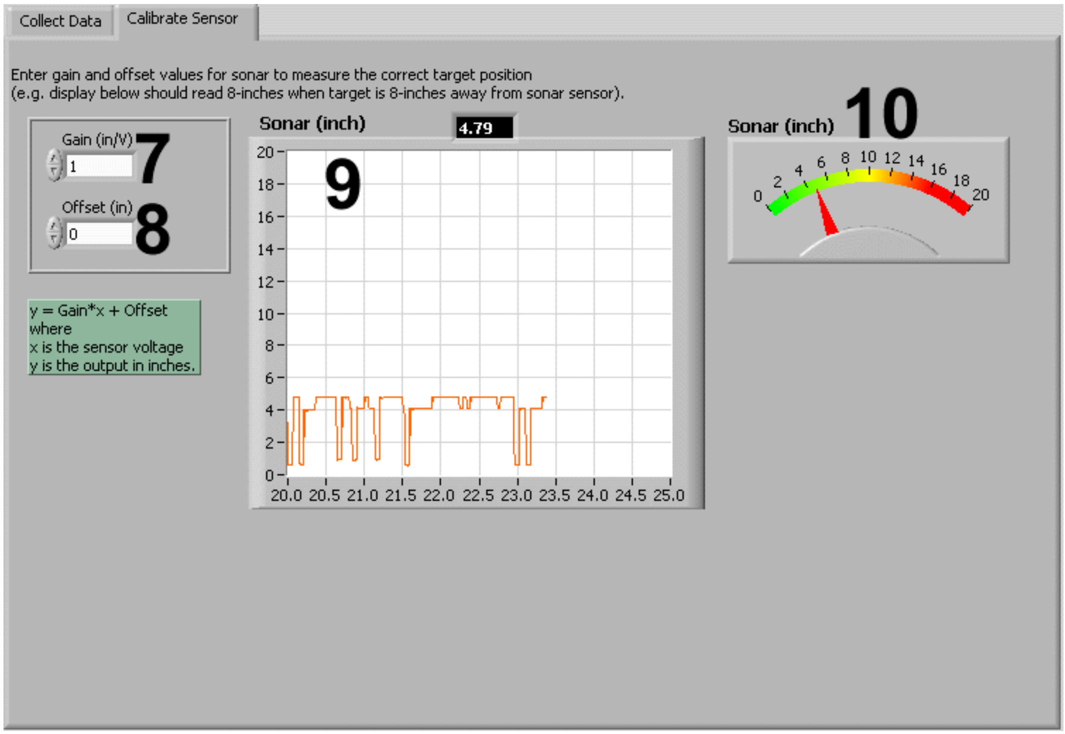

Figure 15.13: QNET MECHKIT Sonar VI: *Calibration* tab

ID #	Label	Description	Unit
1	Scope: Sonar (V)	Scope showing raw voltage measured by sonar	V
2	Target Range (in)	Distance between target and sonar sensor	in
3	Sensor Measurement (V)	Recorded sonar measurement for each target position	V
4	Sensor Readings	Graph showing measured and curve fitted data	
5	Slope	Slope computed by curve fitting algorithm	in/V
6	Intercept	Intercept computed by curve fitting algorithm	in
7	Gain (deg/V)	Sensor calibration gain (slope)	in/V
8	Offset (deg)	Sensor calibration offset (intercept)	in
9	Scope: Sonar (in)	Displays target position according to the *Gain* and *Offset* parameters	in
10	Meter: Sonar (in)	Displays target position according to the *Gain* and *Offset* parameters	in
11	Device	Selects the NI DAQ device	
12	Sampling Rate	Sets the sampling rate of the VI	Hz
13	Stop	Stops the LabVIEW VI from running	

Table 15.7: Nomenclature of QNET-MECHKIT Sonar Sensor VI

15.8 Optical Position Laboratory VI

The QNET-MECHKIT Optical VI is used to view the measurements of the optical position sensor as the target is moved at different locations using the knob. The components of the VI are described in Table 15.8 and identified in Figure 15.14 and Figure 15.15.

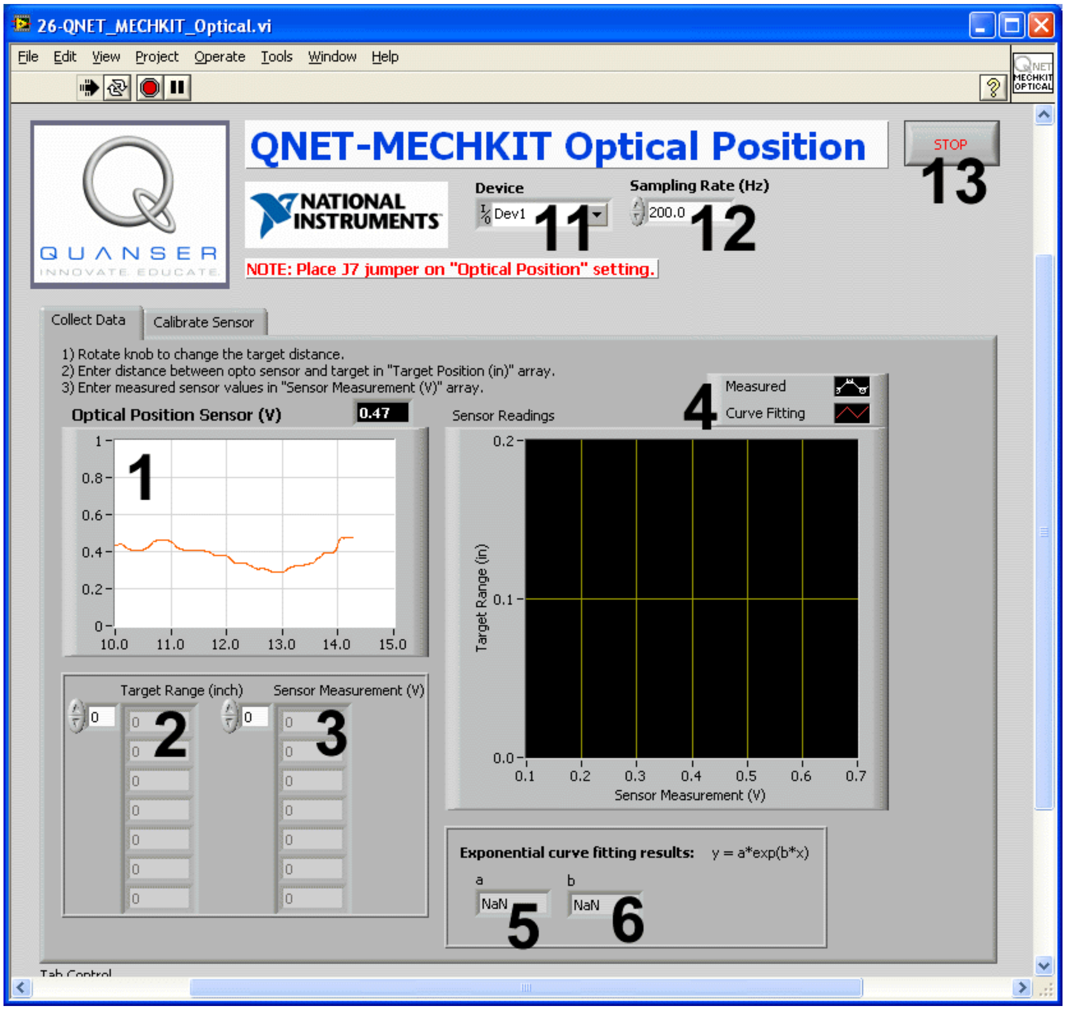

Figure 15.14: QNET MECHKIT Optical VI: *Collect Data* tab

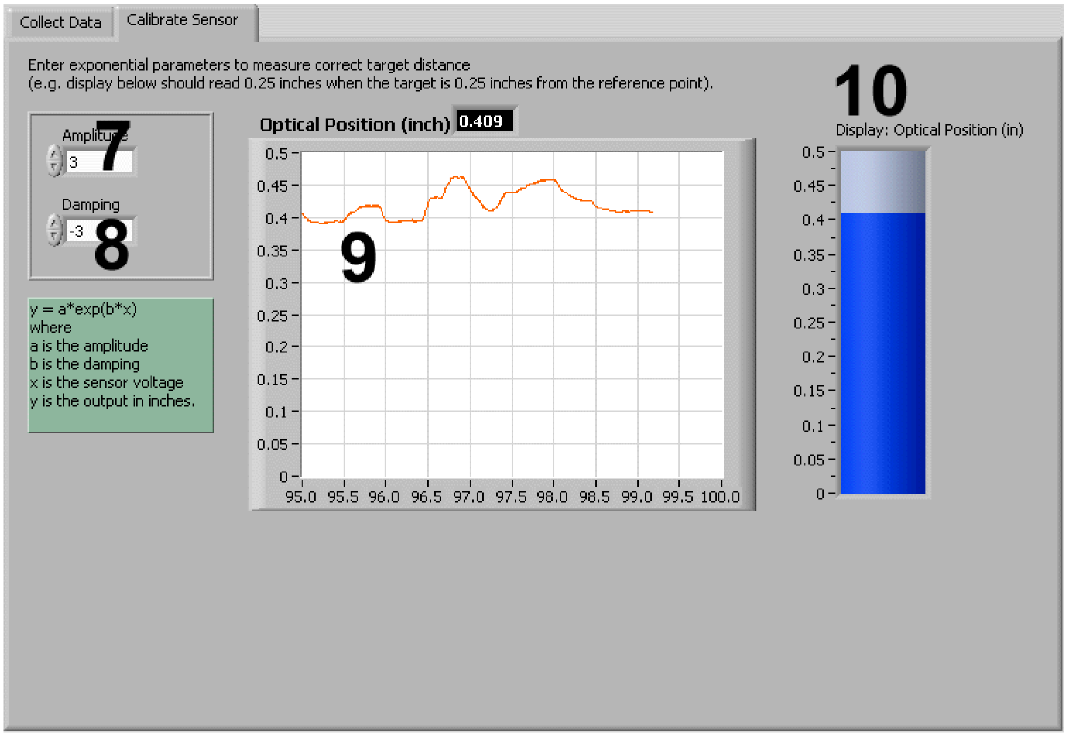

Figure 15.15: QNET MECHKIT Optical VI: *Calibration* tab

ID #	Label	Description	Unit
1	Scope: Optical Position Sensor (V)	Scope showing raw voltage measured by optical position sensor	V
2	Target Range (in)	Distance between the target and optical sensor	in
3	Sensor Measurement (V)	Recorded optical sensor measurement for each target position	V
4	Graph: Sensor Readings	Graph showing measured and curve fitted data	
5	a	Exponential function amplitude parameter computed by curve fitting algorithm	
6	b	Exponential function decay/growth parameter computed by curve fitting algorithm	
7	Amplitude	Gain of exponential function	
8	Damping	Exponential decay/growth factor of exponential function	
9	Scope: Optical Position (in)	Scope that shows position of target based on entered *Amplitude* and *Damping* parameters	in
10	Display: Optical Position (in)	Slider indicator displays position of target based on entered *Amplitude* and *Damping* parameters	in
11	Device	Selects the NI DAQ device	
12	Sampling Rate	Sets the sampling rate of the VI	Hz
13	Stop	Stops the LabVIEW VI from running	

Table 15.8: Nomenclature of QNET-MECHKIT Optical VI

15.9 Magnetic Field Laboratory VI

Using this VI, the magnetic field measurements can be read as the target is moved at different locations using the knob on the QNET mechatronic sensors trainer. The components of the QNET Magnetic Field VI are summarized in Table 15.9 and identified in Figure 15.16 and Figure 15.17.

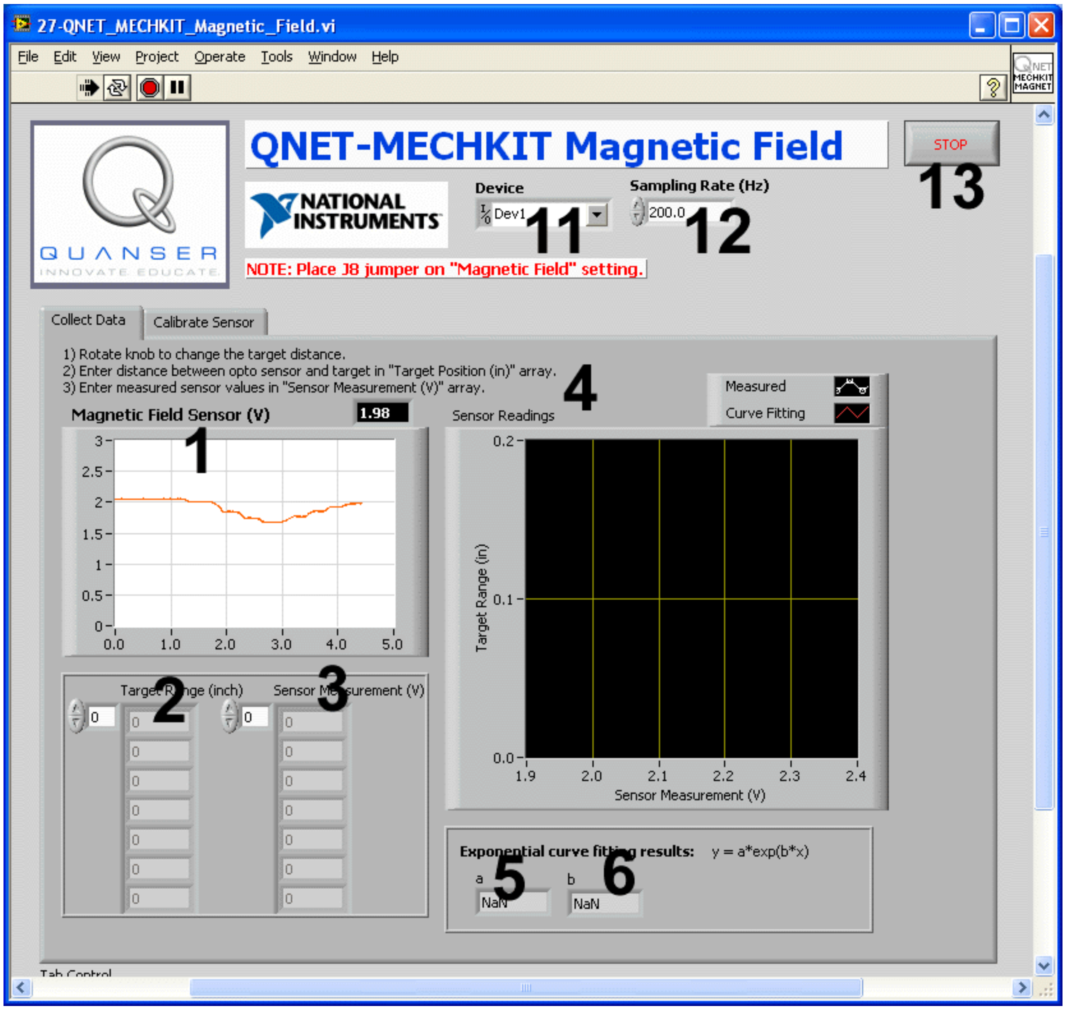

Figure 15.16: QNET MECHKIT Magnetic Field VI: *Collect Data* tab

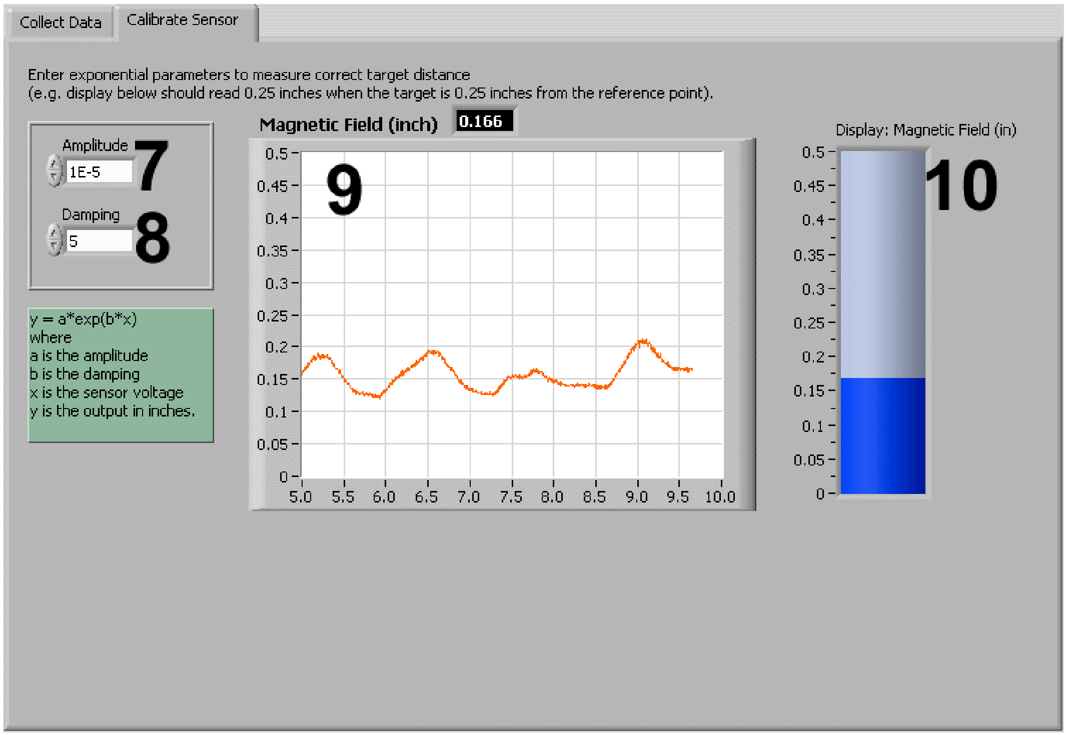

Figure 15.17: QNET MECHKIT Magnetic Field VI: *Calibration* tab

ID #	Label	Description	Unit
1	Scope: Magnetic Field Sensor (V)	Scope showing raw voltage measured by magnetic field sensor	V
2	Target Range (in)	Distance between the target and magnetic field sensor	in
3	Sensor Measurement (V)	Recorded sensor measurement for each target position	V
4	Graph: Sensor Readings	Graph showing measured and curve fitted data	
5	a	Exponential function amplitude parameter computed by curve fitting algorithm	
6	b	Exponential function decay/growth parameter computed by curve fitting algorithm	
7	Amplitude	Gain of exponential function	
8	Damping	Exponential decay/growth factor of exponential function	
9	Scope: Magnetic Field (in)	Scope that shows position of target based on entered *Amplitude* and *Damping* parameters	in
10	Display: Magnetic Field (in)	Slider indicator displays position of target based on entered *Amplitude* and *Damping* parameters	in
11	Device	Selects the NI DAQ device	
12	Sampling Rate	Sets the sampling rate of the VI	Hz
13	Stop	Stops the LabVIEW VI from running	

Table 15.9: Nomenclature of QNET-MECHKIT Magnetic Field VI

15.10 Encoder Laboratory VI

This VI shows the A, B, and Index signals generated by the rotary optical encoder on the QNET mechatronic sensors trainer as the knob is rotated. The components of the QNET Encoder VI are described in Table 15.10 and identified in Figure 15.18.

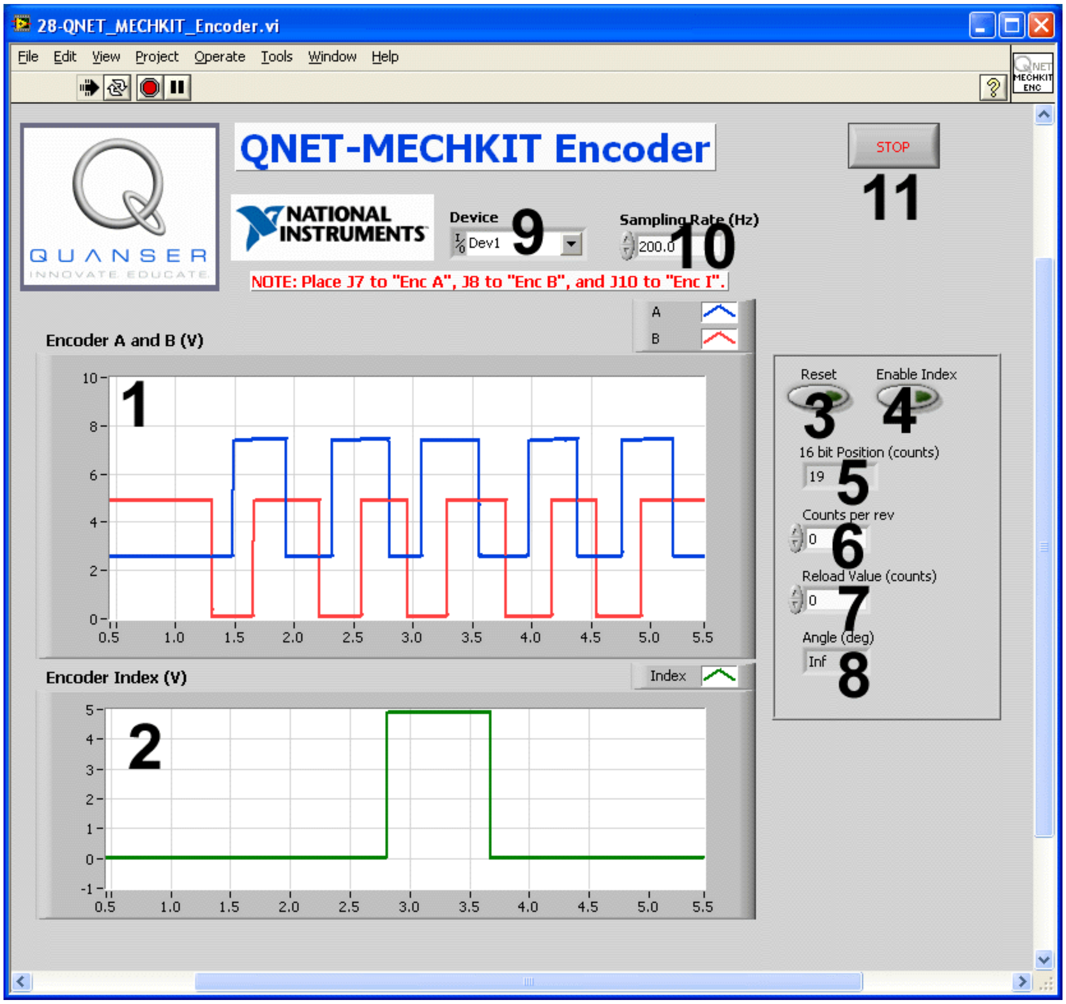

Figure 15.18: QNET MECHKIT Encoder VI

ID #	Label	Description	Unit
1	Scope: Encoder A and B (V)	Scope showing encoder A (blue) and B (red) voltage signals. Signals are offset by 2.5 V for viewing purposes	V
2	Scope: Encoder Index (V)	Scope displays the index trigger	V
3	Reset	Resets the encoder count	
4	Enable Index	When enabled, the encoder count is reset on an index pulse	
5	16-bit Position (counts)	Count generated by decoder	
6	Counts per rev	Number of counts for every full rotation	
7	Reload Value (counts)	Resets the count to this value	
8	Angle (deg)	Angle measured by encoder according to the *Counter per rev* parameter	
9	Device	Selects the NI DAQ device	
10	Sampling Rate	Sets the sampling rate of the VI	Hz
11	Stop	Stops the LabVIEW VI from running	

Table 15.10: Nomenclature of QNET-MECHKIT Encoder VI

15.11 Temperature Laboratory VI

The measured voltage output from the thermistor circuit is displayed on this VI as well as the calibrated temperature reading. The QNET MECHKIT Temperature VI components are given in Table 15.11 and identified in Figure 15.19.

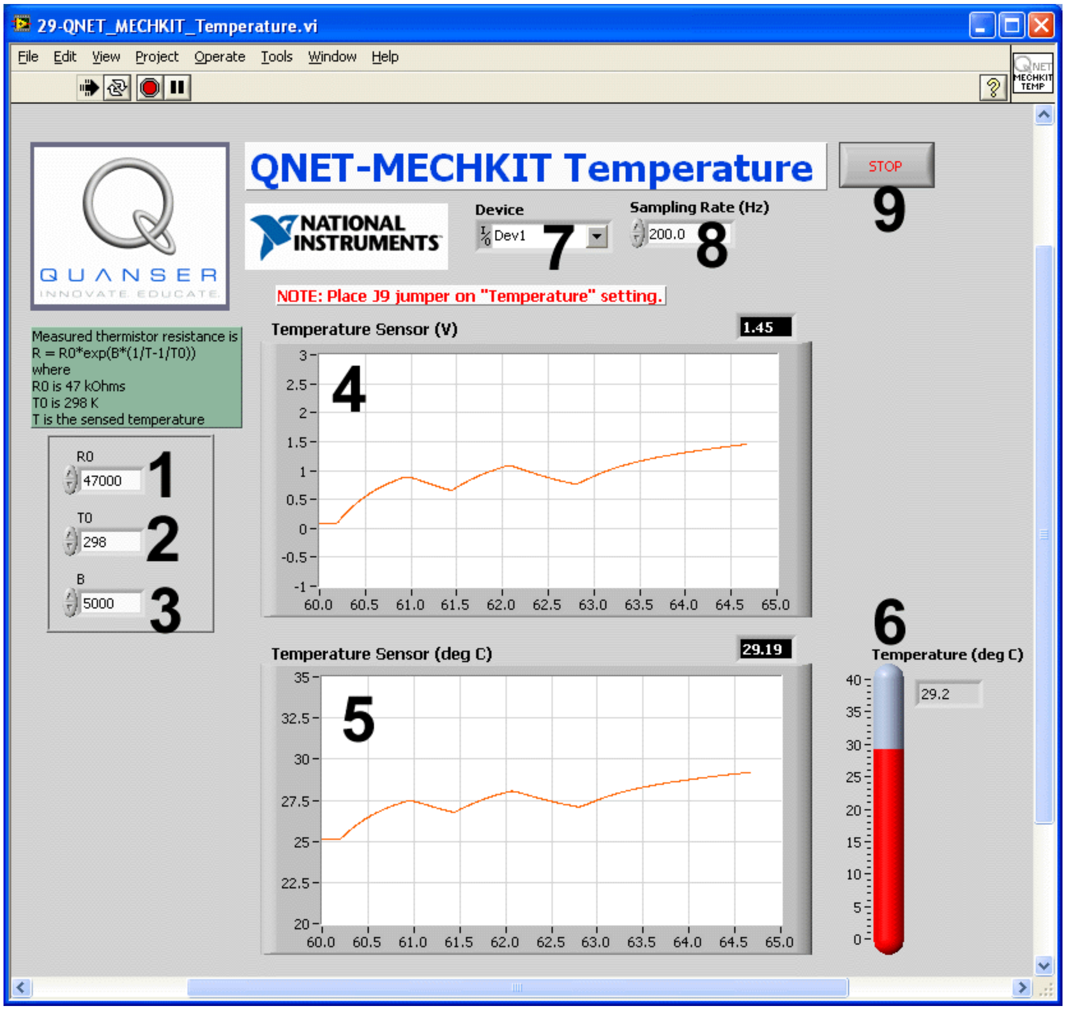

Figure 15.19: QNET MECHKIT Temperature VI

ID #	Label	Description	Unit
1	R0	Resistance of thermistor at temperature specified in T_0	
2	T0	Room temperature in Kelvin	
3	B	Thermistor equation exponential parameter	
4	Scope: Temperature Sensor (V)	Scope shows the output voltage of the thermistor circuit	V
5	Scope: Temperature Sensor (deg C)	Scope displays the measured temperature based on the T0 and B parameters entered	$^\circ$ C
6	Temperature (deg C)	Thermometer displays the measured temperature based on the T0 and B parameters entered	$^\circ$ C
7	Device	Selects the NI DAQ device	
8	Sampling Rate	Sets the sampling rate of the VI	Hz
9	Stop	Stops the LabVIEW VI from running	

Table 15.11: Nomenclature of QNET-MECHKIT Temperature VI

15.12 Switches and LEDs Laboratory VI

The QNET MECHKIT Switches and LEDs VI allows users to view the output of the optical switch, micro switch, and push button and calibrate them to obtain a desired on/off behaviour. This VI can also be used to drive the digital output lines #0 and #1 that are connected to the LEDs on the QNET mechatronics sensors trainer. The VI components are listed in Table 15.12 and identified in figures Figure 15.20, Figure 15.21, Figure 15.22, and Figure 15.23.

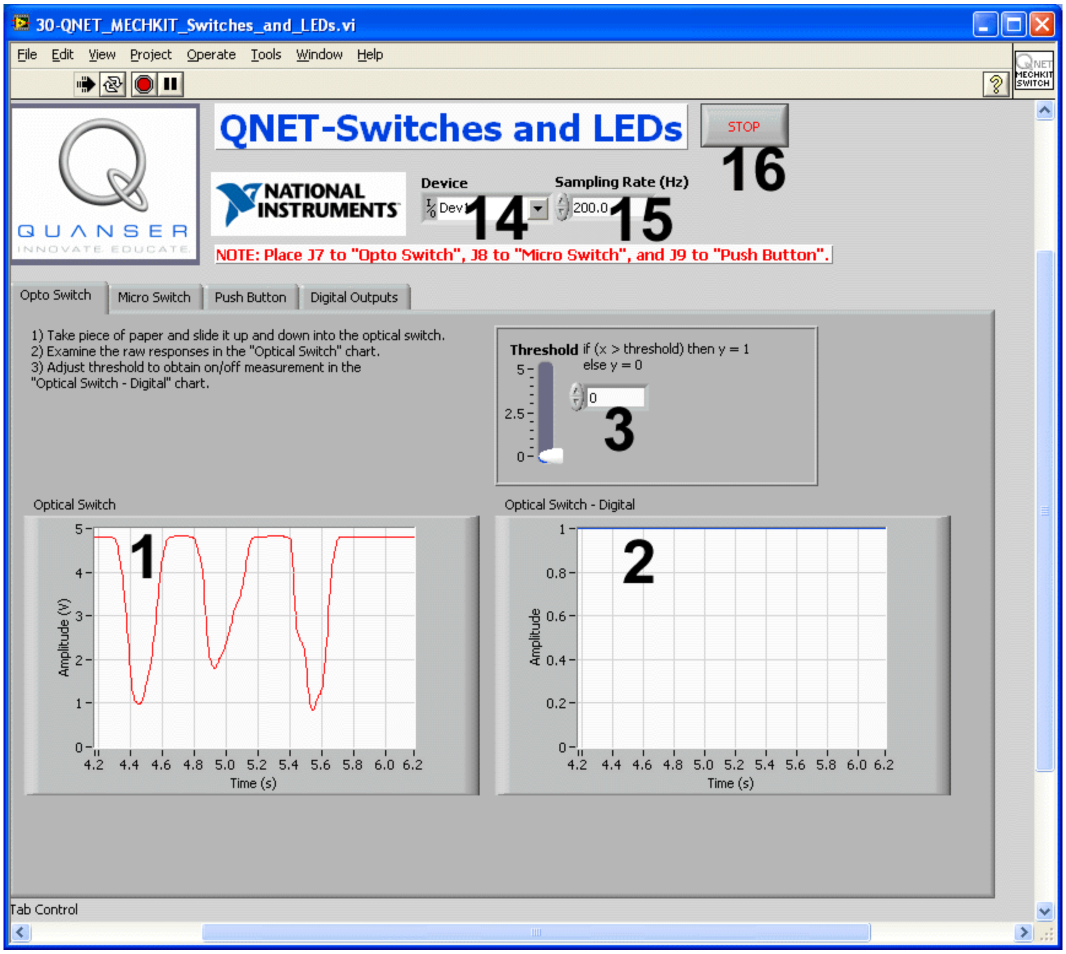

Figure 15.20: QNET MECHKIT Switches and LEDs VI: *Opto Switch* tab

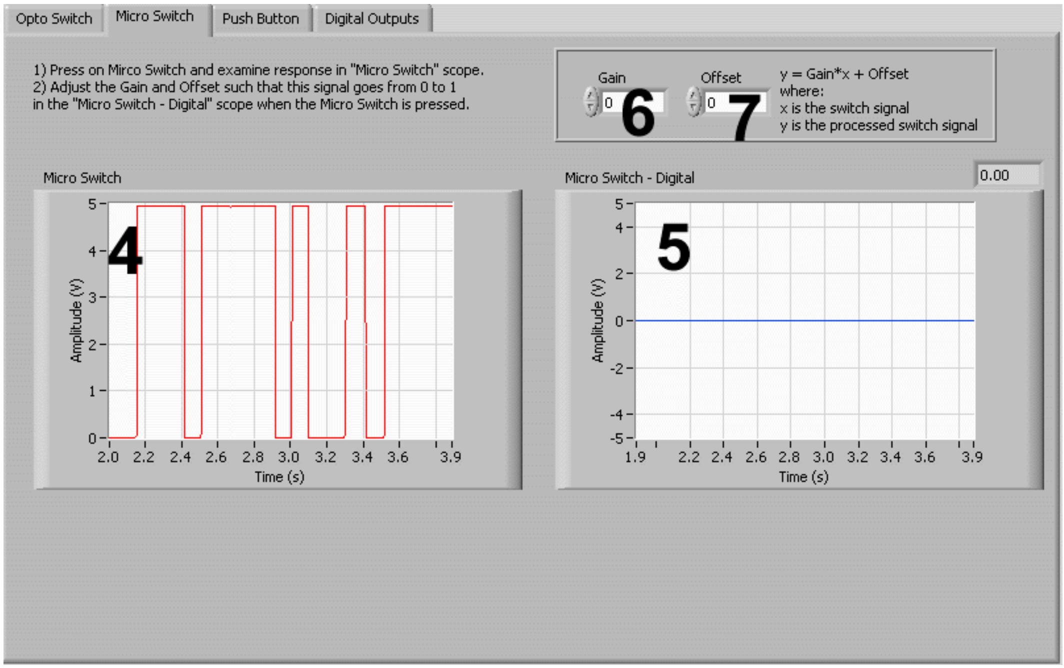

Figure 15.21: QNET MECHKIT Switches and LEDs VI: *Micro Switch* tab

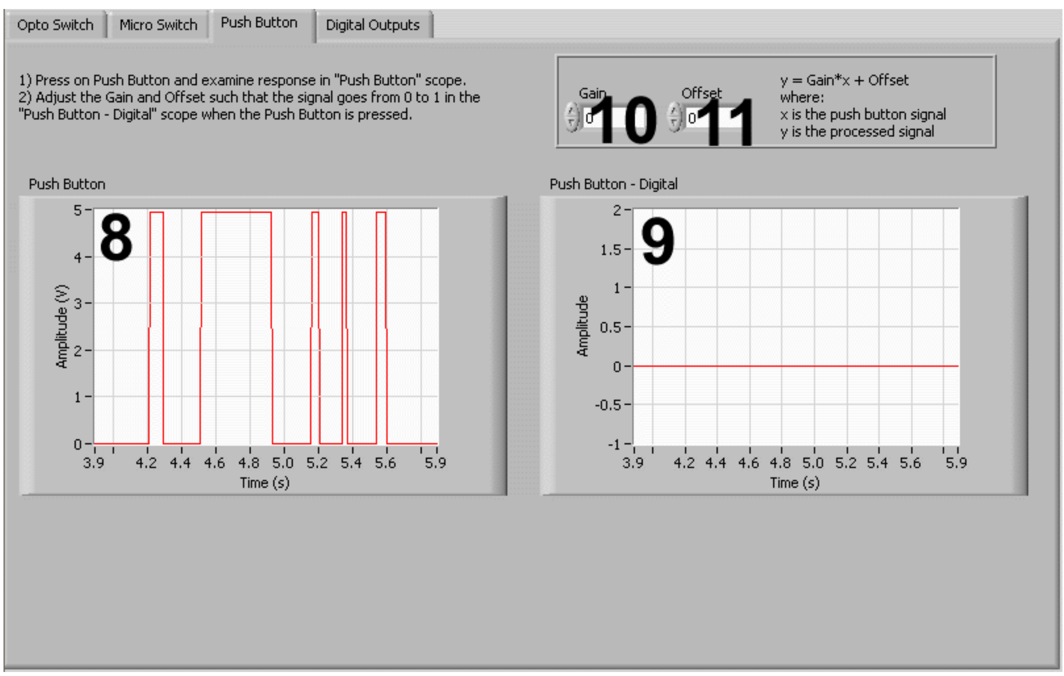

Figure 15.22: QNET MECHKIT Switches and LEDs VI: *Push Button* tab

Figure 15.23: QNET MECHKIT Switches and LEDs VI: *Digital Outputs* tab

ID #	Label	Description	Unit
1	Scope: Optical Switch	Scope shows the optical switch output voltage	V
2	Scope: Optical Switch - Digital	Scope displays readout of optical switch when passed through *Threshold* switch	
3	Threshold	Adjusts the threshold of the optical switch that determines when it is ON or OFF	V
4	Scope: Micro Switch	Scope shows the micro switch output voltage	V
5	Scope: Micro Switch - Digital	Scope displays calibrated micro switch output based on *Gain* and *Offset* parameters.	
6	Gain	Micro switch calibration gain	
7	Offset	Micro switch calibration offset	
8	Scope: Push Button	Scope shows the push button output voltage	V
9	Scope: Push Button - Digital	Scope displays calibrated push button output based on *Gain* and *Offset* parameters.	
10	Gain	Push button calibration gain	
11	Offset	Push button calibration offset	
12	DO 1	Digital output to channel #1 - connected to LED7 on QNET MECHKIT trainer	
13	DO 0	Digital output to channel #0 - connected to LED8 on QNET MECHKIT trainer	
14	Device	Selects the NI DAQ device	
15	Sampling Rate	Sets the sampling rate of the VI	Hz
16	Stop	Stops the LabVIEW VI from running	

Table 15.12: Nomenclature of QNET-MECHKIT Switches and LEDs VIs

15.13 Switch Debounce Laboratory VI

In this VI, the triggered output of the Micro Switch and the Push Button can be viewed. The ELVISmx Oscilloscope VI is setup to monitor either the Micro Switch or Push Button analog input lines at a sample rate 100 kHz. Once the signal is triggered, the VI automatically stops and outputs a 1k sample of the voltage output. In effect, this gives a a 10 ms sample of the signal. See Table 15.13 for a listing of the VI components that are shown in Figure 15.24.

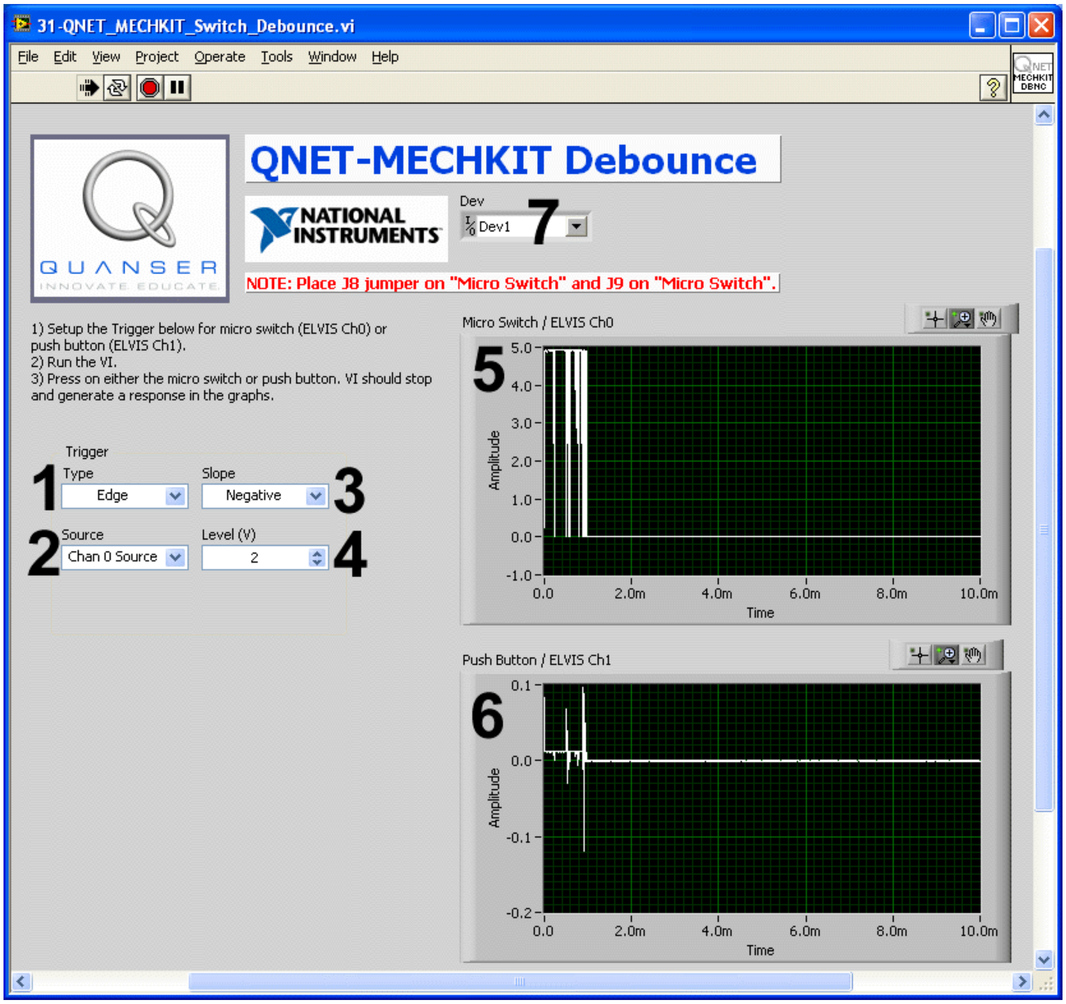

Figure 15.24: QNET MECHKIT Debounce VI

ID #	Label	Description	Unit
1	Type	Type of signal trigger	
2	Source	Select which *ELVIS* channel (0 or 1) to trigger	
3	Slope	Select whether the trigger is to occur when the edge is rising (positive) or decreasing (negative)	
6	Level (V)	Threshold of the trigger	V
4	Graph: Micro Switch/ELVIS Ch0	Graph displays the triggered micro switch output	
5	Graph: Push Button/ELVIS Ch1	Graph displays the triggered push button output	
7	Device	Selects the NI DAQ device	

Table 15.13: Nomenclature of QNET-MECHKIT Debouncing VI

16 LAB REPORT

This laboratory contains twelve groups of experiments, namely,

1. Flexgage,
2. Pressure Sensor,
3. Piezo Film Sensor,
4. Potentiometer,
5. Infrared Sensor,
6. Sonar Sensor,
7. Optical Position,
8. Magnetic Field,
9. Encoder,
10. Temperature,
11. Switches and LEDs, and
12. Switch Debouncing.

For each experiment, follow the outline corresponding to that experiment to build the *content* of your report. Also, in Section 16.13 you can find some basic tips for the *format* of your report.

16.1 Template for Content (Strain Gage with Flexible Link)

I. PROCEDURE

1. *Collect Data*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experimental procedure in Step 7 in Section 3.3.
2. *Calibrate Sensor*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experimental procedure in Step 3 in Section 3.4.
3. *Natural Frequency*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experimental procedure in Step 4 in Section 3.5.

II. RESULTS
Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor readings plot from Step 7 in Section 3.3.
2. Power spectrum response from Step 4 in Section 3.5.
3. Provide applicable data collected in this laboratory from Table 3.2.

III. ANALYSIS
Provide details of your calculations (methods used) for analysis for each of the following:

1. Natural frequency measurement in Step 4 of Section 3.5.

16.2 Template for Content (Pressure Sensor)

I. PROCEDURE

1. *Collect Data*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 7 in Section 4.3.
2. *Calibrate Sensor*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 3 in Section 4.4.

II. RESULTS
Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor readings from Step 7 in Section 4.3.
2. Provide applicable data collected in this laboratory from Table 4.2.

16.3 Template for Content (Piezo Film Sensor)

I. PROCEDURE

1. *Data Analysis*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 6 in Section 5.2.
2. *Natural Frequency*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 3 in Section 5.3.

II. RESULTS

Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor response from Step 6 in Section 5.2.
2. Power spectrum response from Step 3 in Section 5.3.

III. ANALYSIS

Provide details of your calculations (methods used) for analysis for each of the following:

1. Piezo sensor analysis in Step 6 in Section 5.2.
2. Natural frequency measurement from Step 3 in Section 5.3.

16.4 Template for Content (Potentiometer)

I. PROCEDURE

1. *Collect Data*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 8 in Section 6.3.
2. *Calibrate Sensor*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 3 in Section 6.4.

II. RESULTS
Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor response from Step 8 in Section 6.3.
2. Provide applicable data collected in this laboratory from Table 6.2.

16.5 Template for Content (Infrared Sensor)

I. PROCEDURE

1. *Collect Data*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experiment procedure in Step 10 in Section 7.3.
2. *Calibrate Sensor*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experiment procedure in Step 3 in Section 7.4.

II. RESULTS

Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor response from Step 10 in Section 7.3.
2. Provide applicable data collected in this laboratory from Table 7.2.

III. ANALYSIS

Provide details of your calculations (methods used) for analysis for each of the following:

1. Observations in Step 11 in Section 7.3.

16.6 Template for Content (Sonar Sensor)

I. PROCEDURE

1. *Collect Data*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 9 in Section 8.3.
2. *Calibrate Sensor*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 3 in Section 8.4.

II. RESULTS
Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor response from Step 9 in Section 8.3.
2. Provide applicable data collected in this laboratory from Table 8.2.

III. ANALYSIS
Provide details of your calculations (methods used) for analysis for each of the following:

1. Sonar sensor analysis in Step 10 of Section 8.3.

16.7 Template for Content (Optical Sensor)

I. PROCEDURE

1. *Collect Data*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experiment procedure in Step 9 in Section 9.3.
2. *Calibrate Sensor*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experiment procedure in Step 3 in Section 9.4.

II. RESULTS
Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor response from Step 9 in Section 9.3.
2. Provide applicable data collected in this laboratory from Table 9.2.

16.8 Template for Content (Magnetic Field Sensor)

I. PROCEDURE

1. *Collect Data*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experiment procedure in Step 9 in Section 10.3.
2. *Calibrate Sensor*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experiment procedure in Step 3 in Section 10.4.

II. RESULTS
Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor response from Step 9 in Section 10.3.
2. Provide applicable data collected in this laboratory from Table 10.2.

16.9 Template for Content (Encoder)

I. PROCEDURE

1. *Analysis of A, B, and I Signals*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 4 in Section 11.3.
2. *Encoder Calibration*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 7 in Section 11.4.

II. RESULTS
Do not interpret or analyze the data in this section. Just provide the results.

1. Provide applicable data collected in this laboratory from Table 11.1 and Table 11.2.

III. ANALYSIS
Provide details of your calculations (methods used) for analysis for each of the following:

1. Enocder signal observations from Step 4 in Section 11.3.
2. Identifying the transfer function in Step 5 in Section 11.3.
3. Index pulse analysis in Step 8 in Section 11.4.

16.10 Template for Content (Temperature Sensor)

I. PROCEDURE

1. *Collect Data*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 6 in Section 12.3.
2. *Calibrate Sensor*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 2 in Section 12.4.2.

II. RESULTS

Do not interpret or analyze the data in this section. Just provide the results.

1. Sensor response from Step 2 in Section 12.4.2.
2. Provide applicable data collected in this laboratory from Table 12.1.

IV. CONCLUSIONS

Interpret your results to arrive at logical conclusions for the following:

1. Sensor response from Step 3 in Section 12.4.2.

16.11 Template for Content (Switches and LEDs)

I. PROCEDURE

1. *Optical Switch*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 7 in Section 13.3.
2. *Micro Switch*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 6 in Section 13.4.
3. *Push Button*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 6 in Section 13.5.
4. *LEDs*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experiment procedure in Step 4 in Section 13.6.

II. RESULTS
Do not interpret or analyze the data in this section. Just provide the results.

1. Provide applicable data collected in this laboratory from Table 13.1.

III. ANALYSIS
Provide details of your calculations (methods used) for analysis for each of the following:

1. Optical switch response from Step 7 in Section 13.3.
2. Micro switch and digital response from Step 6 in Section 13.4.
3. Push button and digital response from Step 6 in Section 13.5.
4. Comparitive analysis in Step 7 in Section 13.5.
5. Observations in Step 4 in Section 13.6.

16.12 Template for Content (Switch Debounce Analysis)

I. PROCEDURE

1. *Running the Oscilloscope*
   - Briefly describe the main goal of the experiment.
2. *Micro Switch*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experimental procedure in Step 4 in Section 14.4.
3. *Push Button*
   - Briefly describe the main goal of the experiment.
   - Briefly describe the experimental setup in Step 3 in Section 14.5.

II. RESULTS

Do not interpret or analyze the data in this section. Just provide the results.

1. Optical switch response from Step 6 in Section 14.4.
2. Micro switch and digital response from Step 5 in Section 14.5.
3. Cross channel response from Step 7 in Section 14.5.

III. ANALYSIS

Provide details of your calculations (methods used) for analysis for each of the following:

1. Trigger settings in Step 4 in Section 14.4.
2. Trigger settings in Step 3 in Section 14.5.
3. Micro switch observations in Step 6 in Section 14.4.
4. Push button observations in Step 5 in Section 14.5.
5. Comparitive analysis in Step 6 in Section 14.5.
6. Cross talk analysis in Step 7 in Section 14.5.

16.13 Tips for Report Format

PROFESSIONAL APPEARANCE

- Has cover page with all necessary details (title, course, student name(s), etc.)
- Each of the required sections is completed (Procedure, Results, Analysis and Conclusions).
- Typed.
- All grammar/spelling correct.
- Report layout is neat.
- Does not exceed specified maximum page limit, if any.
- Pages are numbered.
- Equations are consecutively numbered.
- Figures are numbered, axes have labels, each figure has a descriptive caption.
- Tables are numbered, they include labels, each table has a descriptive caption.
- Data are presented in a useful format (graphs, numerical, table, charts, diagrams).
- No hand drawn sketches/diagrams.
- References are cited using correct format.

REFERENCES

[1] Quanser Inc. *QNET Mechatronic Sensors Trainer User Manual*, 2011.

[2] Agilent Technologies. *Practical Temperature Measurements (Application Note 290)*, 2008.

[3] Wikipedia. Thermistor. *http://en.wikipedia.org/wiki/Thermistor*.

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