SCUPI

Sichuan University - Pittsburgh Institute

ME 1042

Mechatronics Lab

Distance and Proximity

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Mechanical Engineering Department

Lab 2: Distance and Proximity

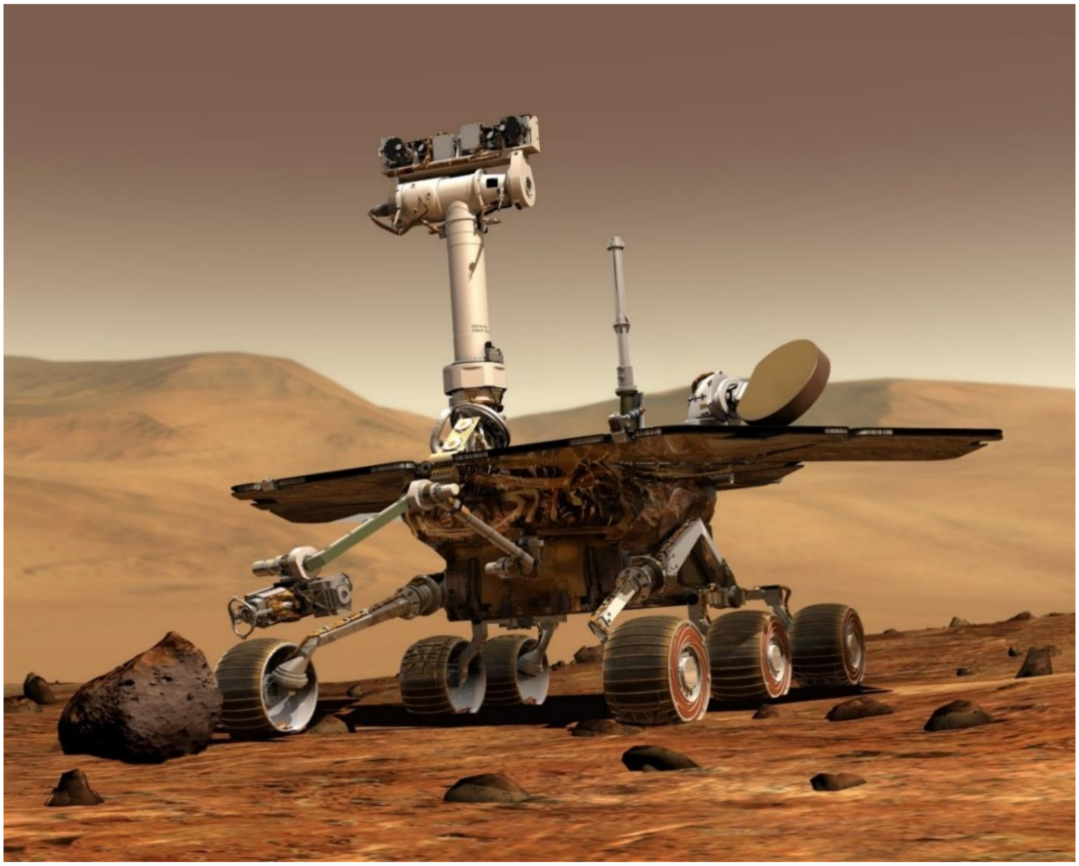

Figure 0: Distance measurement is an integral part of mobile robotic applications

This lab explores long-range distance measurement using a sonar, mid- to short-range distance measurement using a Time-of-Flight (ToF) sensor, as well proximity measurement using an infrared proximity sensor. Sensor calibration, measurement scatter, as well as the effect of target reflectivity, will be examined.

Learning Objectives

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

- Calibrate the output of a sonar in terms of distance
- Characterize Time-of-Flight sensor scatter
- Determine sensor resolution
- Measure target proximity using an infrared proximity sensor
- Examine the effect of target reflectivity on the sensor output

Required Tools and Technology

Platform: NI ELVIS III	✓ View User Manual http://www.ni.com/en-us/support/model.ni-elvis-iii.html
Hardware: Quanser Mechatronic Sensors Board	✓ View User Manual http://www.ni.com/en-us/support/model.quanser-mechatronic-sensors-board-for-ni-elvis-iii.html
Software: LabVIEW Version 18.0 or Later Toolkits and Modules: • LabVIEW Real-Time Module • NI ELVIS III Toolkit	✓ Before downloading and installing software, refer to your professor or lab manager for information on your lab's software licenses and infrastructure ✓ Download & Install for NI ELVIS III ✓ http://www.ni.com/academic/download ✓ View Tutorials ✓ http://www.ni.com/academic/students/learn-labview/
Accessories: • Sturdy 12 in by 12 in cardboard • Ruler	

Expected Deliverables

In this lab, you will collect the following deliverables:

- ✓ Record calibrated sonar data
- ✓ Screenshot of sonar calibration curve
- ✓ Record sonar calibration coefficients
- ✓ Calculate sonar resolution
- ✓ Calculate sonar sensitivity
- ✓ Record ToF sensor scatter data
- ✓ Screenshot of ToF scatter behavior
- ✓ Calculate the standard deviation of ToF sensor scatter data

- ✓ Record proximity sensor threshold data
- ✓ Plot curve relating proximity sensor pulse count to a proximity threshold

1 Experimental Procedure

1.1 Measuring Long-range Distance using a Sonar

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

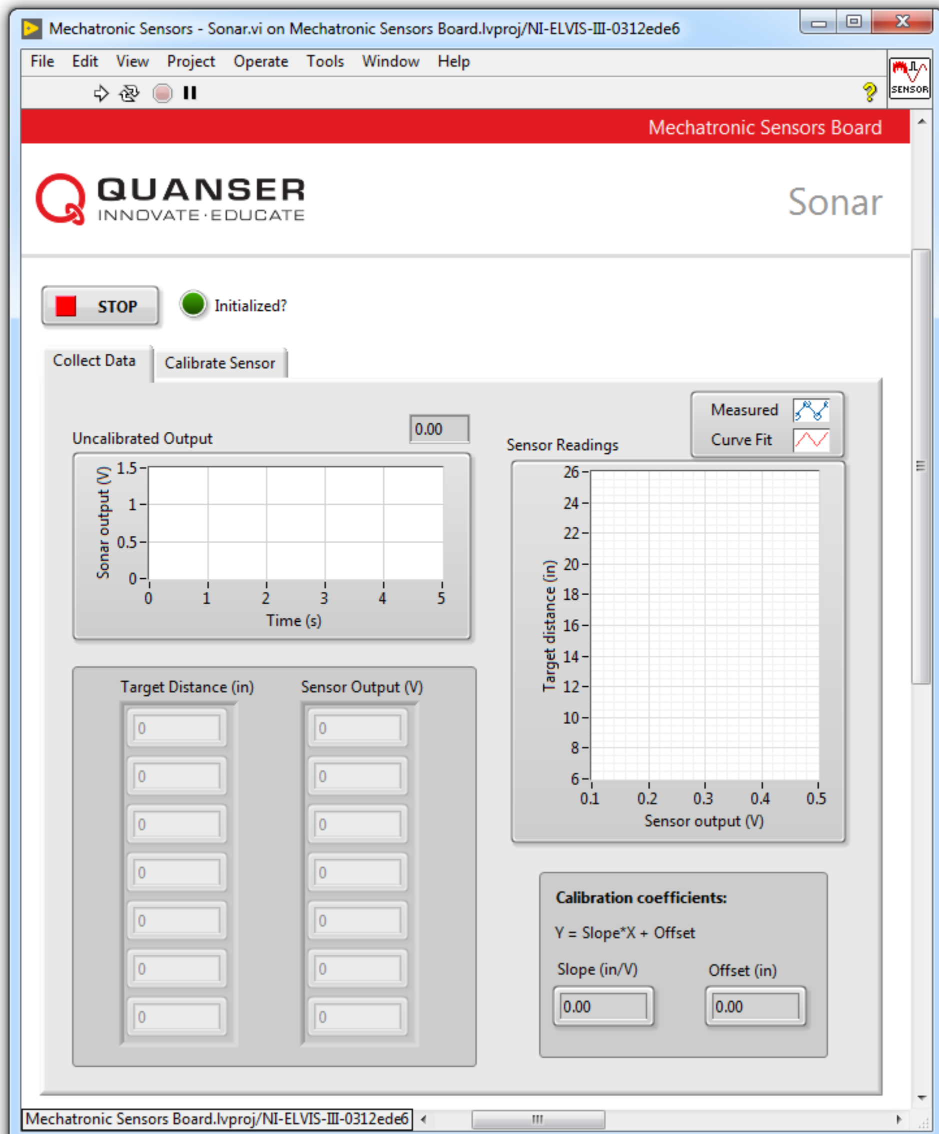

Figure 1 VI for collecting data from the sonar

1.1.1 Collect Data

1. Prior to conducting this lab, use the **Application Board Power** switch to cycle the Quanser Mechatronic Sensors Board power. The MaxBotix sonar sensor performs a self-calibration on power-up to compensate for ambient temperature and humidity. Ensure that there are no objects close to the sensor while cycling the power. Best sensitivity is obtained when the sensor's detection area is clear of any objects for 14 inches during power-up.
2. Open **Mechatronic Sensors Board.lvproj**
3. From the **Project Explorer** window, open **Mechatronic Sensors - Sonar.vi**
4. Click on the **Collect Data** tab.
5. Run the VI.
6. Wait for the **Initialized?** LED indicator to turn on.
7. Enter **7** in the **Target Distance (in)** array.
8. Hold a sturdy cardboard target that is sized 12 in by 12 in at a distance of 7 inches away from the surface of the application board. Using the **Uncalibrated Output** waveform chart, read the corresponding sensor output and enter the value in the **Sensor Output (V)** array.

   Note: Since the sensor generates a wide cone-shaped pulse, do not stand too close to the sensor while taking measurements. It will cause the sensor to detect your body which will interfere with your measurements. When measuring targets at longer distances, you will need to stand back and stretch out your arm while holding the target to get a valid measurement.

9. Continue taking measurements by moving the target in 3 inch intervals away from the sensor. Each time, enter the target distance and measured sensor outputs in the **Target Distance (in)** and **Sensor Output (V)** arrays respectively.

   Note: Once 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. Record the collected data in Table 1.
11. The slope and offset of the calibration curve are automatically calculated by the VI and displayed in the **Slope (in/V)** and **Offset (in)** indicators. Record these values in Table 2.
12. Take a screenshot of the **Sensor Readings** graph.
13. Continue to the next section.

Table 1 Recorded sonar measurements

Target Distance (in)	Sensor Output (V)
7	
10	
13	
16	
19	
22	
25	

Table 2: Calibration coefficients

Slope (in/V)	Offset (in)

1.1.2 Calibrate the Sonar

14. Click on the **Calibrate Sensor** tab to calibrate the output of the sonar in terms of linear displacement of the target (in inches).
15. Use the **Slope (in/V)** and **Offset (in)** numeric controls to enter the slope and offset values you obtained during the data collection process.
16. Test the accuracy of your calibration. To do this, place the target at different known positions within the calibrated range, and verify that the correct distance is displayed in the **Calibrated Output** waveform chart as well as the **Distance (in)** slider indicator.
17. Using the **Calibrated Output** waveform chart, approximate the resolution of the sensor (in inches). Start by holding the target 7 inches away from the sensor. At a steady rate, slowly move the target away from the sensor and observe its response. The calibrated output of the sensor will have a step-like response.

What is the smallest change in distance that it can detect? Take a screenshot of the response of the sensor.

18. Press the **Stop** button.

1.2 Measuring Short to Mid-range Distance using a Time-of-Flight Sensor

The Virtual Instrument (VI) used to collect data from the ToF sensor is shown in Figure 2.

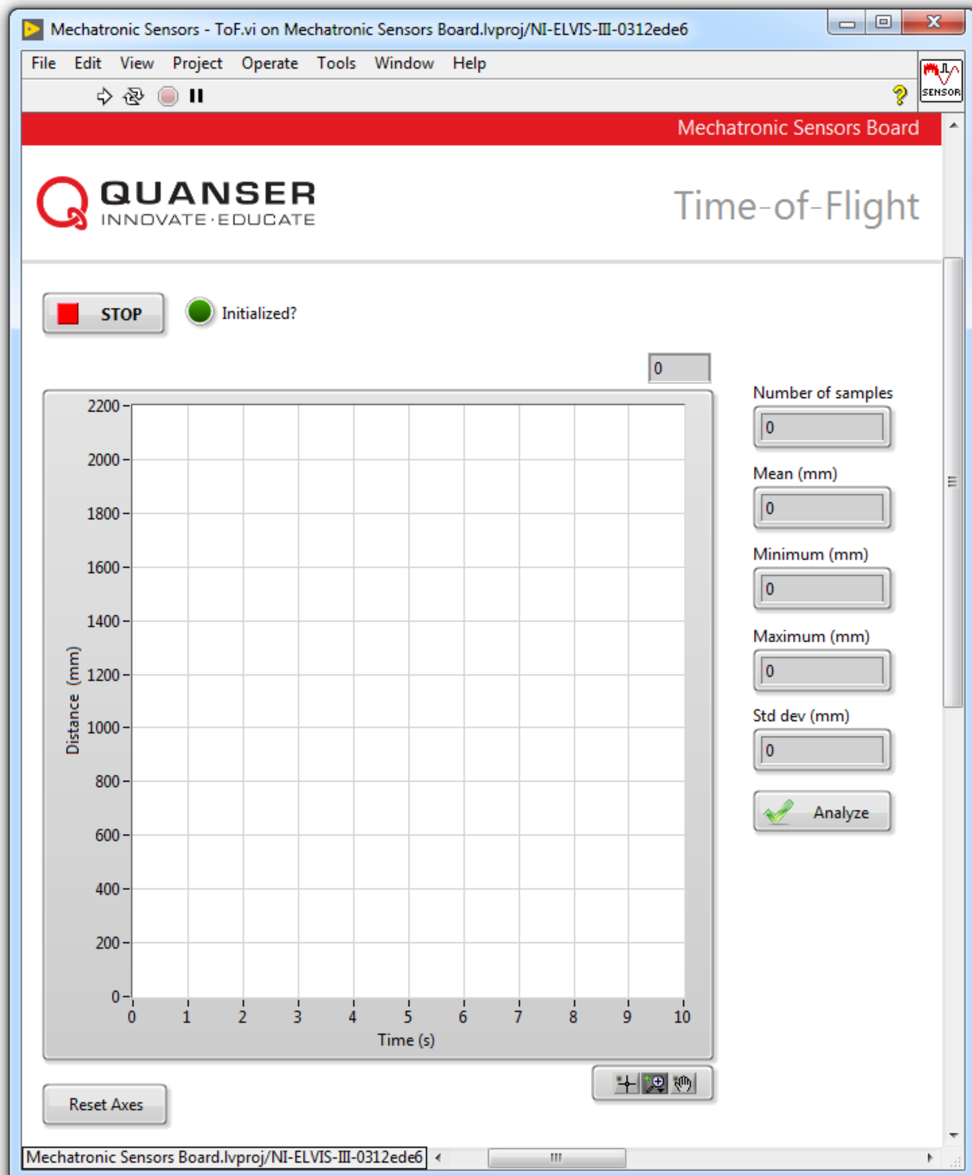

Figure 2: VI for collecting data from the ToF sensor

1.2.1 Observe Measurement Scatter

1. Open **Mechatronic Sensors Board.lvproj**
2. From the **Project Explorer** window, open **Mechatronic Sensors - ToF.vi**
3. Run the VI.
4. Wait for the **Initialized?** LED indicator to turn on.
5. The Quanser Mechatronic Sensors Board's digital ToF sensor outputs an 11-bit value ranging between 0 and 2048, which directly corresponds to the target distance in millimeters. As such, you do not need to calibrate the output of the sensor in terms of measured distance.

   However, the output of the ToF sensor exhibits random variation, or scatter, as shown in Figure 3. Observe this scatter by holding a sturdy cardboard target that is sized 12 in by 12 in at various random positions ranging between 100 mm and 1000 mm. Takes screenshots of your observations. Does the level of scatter change with target distance?

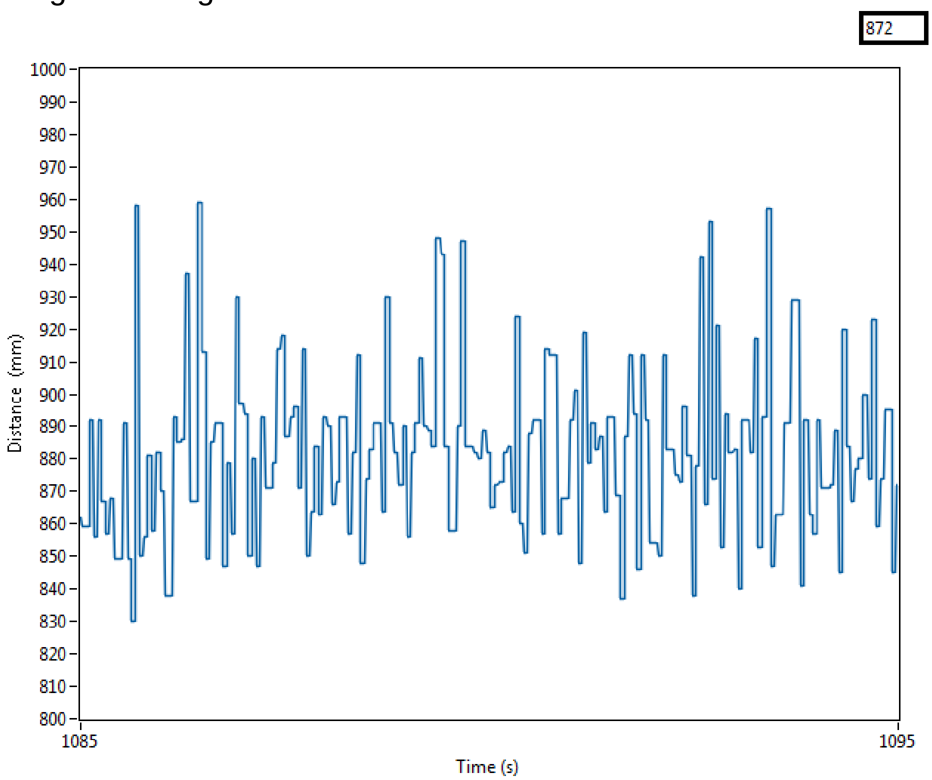

Figure 3 Measurement scatter associated with the output of the ToF sensor

1.2.2 Quantify Measurement Scatter

6. Quantify the level of measurement scatter. To do this, steadily hold the target at an approximate distance of 100 mm from the ToF sensor. Wait for the readings to stabilize for at least **3 seconds,** and then click the **Analyze** button. The VI is programmed to collect 300 data points at a rate of 100 Hz. When the *Analyze* button is pressed, the VI calculates and displays the mean, minimum, maximum, and standard deviation of the acquired data. Record these values as your first trial in Table 3. Repeat the measurement twice more and record the data in Table 3.
7. Now repeat the previous step but this time hold the target at a distance of approximately 1000 mm. Record your results in Table 3.
8. Press the **Stop** button.

Table 3: Scatter data

Approx. distance (mm)	Trial	Mean (mm)	Max (mm)	Min (mm)	Std Dev (mm)
100	1				
	2				
	3				
1000	1				
	2				
	3				

1.3 Measuring Proximity using an Infrared Proximity Sensor

The Virtual Instrument (VI) used to collect data from the IR proximity sensor is shown in Figure 4.

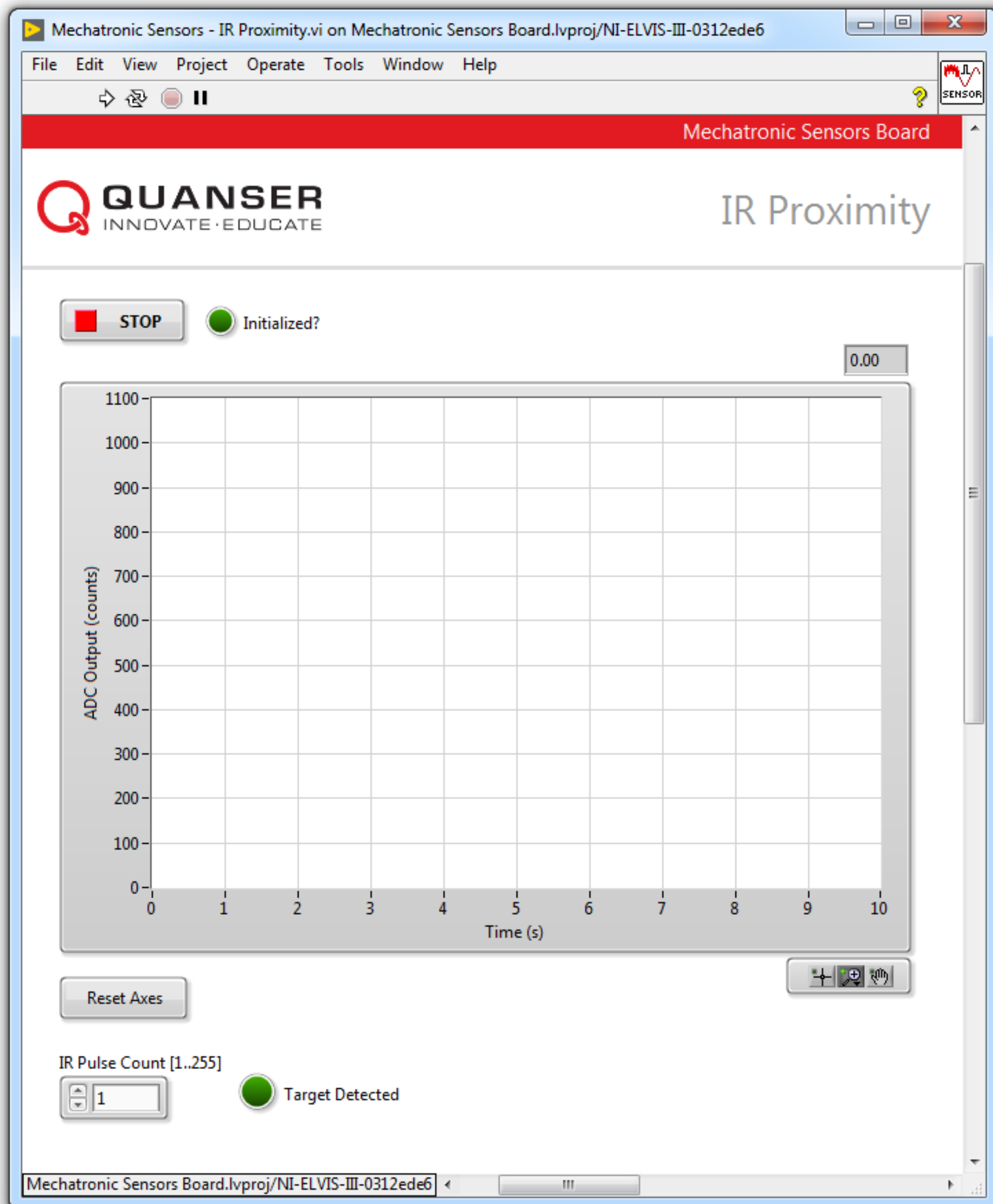

Figure 4: VI for collecting data from the IR proximity sensor

1.3.1 Observe Sensor Behavior

1. Open **Mechatronic Sensors Board.lvproj**
2. From the **Project Explorer** window, open **Mechatronic Sensors – IR Proximity.vi**
3. Run the VI.
4. Wait for the **Initialized?** LED indicator to turn on.
5. The waveform chart shows the raw count of the sensors analog-to-digital output.

6. Ensure the **IR Pulse Count [1..255]** numeric control is set to **1**. This setting causes the sensor to generate 1 IRED pulse during each cycle of operation.
7. Hold your hand at a distance of about 30 cm above the sensor. Slowly move your hand toward the sensor and observe the response of the sensor; in particular, observe how the number of output counts increases as well as any scatter in the sensor's output. Once your hand reaches the proximity threshold, the number of output counts will reach a maximum value of 1023. Using a ruler, estimate the threshold distance in terms of millimeters and record the value in Table 4. Take screenshots of your results.

Table 4: Sample recorded data

IR Pulse Count	Proximity Threshold (mm)
1	
10	
50	
100	
150	
255	

8. Stop the VI by pressing the **Stop** button.
9. As noted in section 3.1, a higher pulse count results in larger sensor sensitivity as well as a larger proximity threshold limit. To observe this, set **IR Pulse Count [1..255]** numeric control to **10** and re-run your VI and repeat step 7. Record your results in Table 4.
10. Repeat steps 8 through 9 for the remaining values of **IR Pulse Count** listed in Table 4.
    Note: Prior to entering a new pulse count value, you must stop the VI each time. Enter a new value and re-run the VI.

11. Press the **Stop** button.

2 For the Repot

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

<u>Sonar</u>

1 Present the results you recorded in Table 1.

2 Attach the screenshot of the Sensor Readings waveform graph showing the fitted calibration curve and the calibration coefficients.

3 What is the resolution of the sonar? Attach the screenshot of the step-like response of the sensor.

4 The Quanser Mechatronic Sensors Board implements the non-inverting amplifier circuit. Using the following equation

$$V_O = \left(1 + \frac{R_2}{R_1}\right) V_{in}$$

and the calibration coefficients, calculate the sensitivity of the sensor in terms of V/in? Assume $R_1 = R_2 = 10\ k\Omega$.

<u>ToF sensor</u>

1 Present the results you recorded in Table 3.

2 Standard deviation is a statistical measure of the amount of variation, or scatter, within a set of measured data points. A larger standard deviation implies larger scatter within the acquired data. In this lab, since measurements for a given target distance were repeated multiple times, you must apply pooled statistics to provide a single best statistical estimate of the measured data.

For each target distance, calculate the *pooled standard deviation* using the formula below:

$$S_{pooled} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} S_i}$$

where S_{pooled} is the pooled standard deviation for a given target distance, N is the number of trials, and S_i is the standard deviation of each trial. Compare the pooled standard deviations for the two different target positions. What do your results indicate about the scatter when the target is placed further away from the sensor?

IR proximity sensor

1 Present the results you recorded in Table 4.

2 Using the data recorded in Table 4, plot a curve that relates the sensor's IRED pulse count to its proximity threshold. What type of curve best fits the data? Using this curve estimate the number of pulse count required to result in a proximity threshold of 70 mm.