INTEGRATION GUIDE

This guide is meant to serve as an introduction to the capabilities and interfacing procedures for the Quanser QBot 2 Mobile Platform. The following topics will be covered:

Topics Covered

- Actuation and Commands
- Chassis Sensors
- Kinect RGB Data
- Kinect Depth Data

Prerequisites

- The QBot 2 has been setup and tested. See the QBot 2 Quick Start Guide for details.
- You have access to the QBot 2 User Manual.
- You are familiar with the basics of Matlab® and Simulink®.

1 Actuation and Commands

The Simulink model used in this section is called "QBot 2_Integration_Commands.mdl", shown in Figure 1.1.

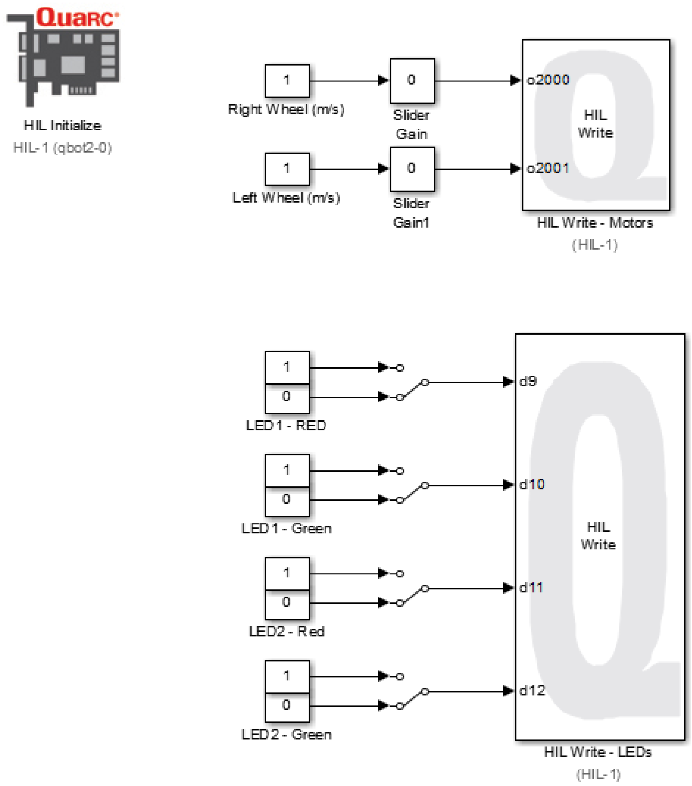

Figure 1.1: Snapshot of the model "QBot 2_Integration_Commands"

1.1 Motor Commands

The Quanser QBot 2 Mobile Platform is driven by two high-performance DC motors with encoders, located co-axially in a differential drive configuration. The two motors are commanded using the QUARC HIL Write block shown in Figure 1.1. Right wheel commands are sent on channel 2000, and left wheel commands on channel 2001. The maximum command that is recommended to each motor is 0.7 m/s.

Compile and run the Integration Commands model. Once the QBot 2 beeps, indicating that the initialization routine is complete, follow the procedures outlined below to familiarize yourself with the motor operation.

1. Gradually increase the left wheel velocity command to 0.5 m/s. The robot should begin to rotate about the left wheel.
2. Slowly decrease the right wheel velocity to -0.5 m/s, with the left wheel command set to 0.5 m/s. The QBot 2 should begin to spin in place.
3. Slowly increase the right wheel velocity to 0.2 m/s, the robot should now begin driving in a small circle.

For more information on mapping the rotational speed of the wheels to deterministic motion of the chassis, please refer to the Kinematics laboratory experiments and controllers.

1.2 LED Commands

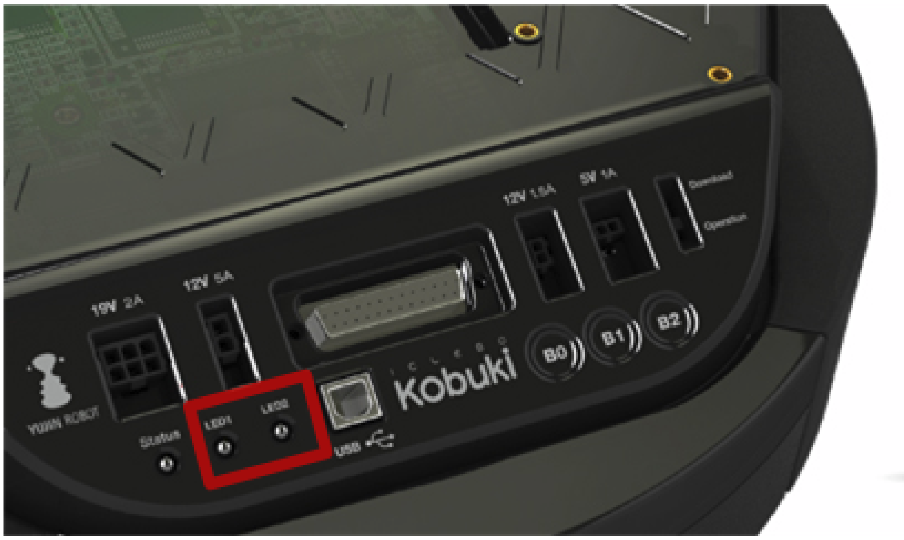

Figure 1.2: QBot 2 LEDs

There are two programmable LEDs on the top of the QBot 2 that can be illuminated as either green or red. The LEDs are commanded on digital lines 9 through 12 as outlined in the QBot 2 User Manual, and as demonstrated in the model shown in Figure 1.1.

Run the model and once the QBot 2 beeps, indicating that the initialization routine is complete, toggle the switches that control the commands sent to each LED to familiarize yourself with their operation.

1.3 Additional Actuators

For custom applications that require additional actuators, the QBot 2 has several additional PWM channels that are available using the custom DAQ interface on the front of the robot, shown in Figure 2.2. Detailed instructions for writing to these headers are provided in the QBot 2 User Manual.

2 Chassis Sensors

The Simulink model for this section is "QBot 2_Integration_Sensors.mdl", shown in Figure 2.1.

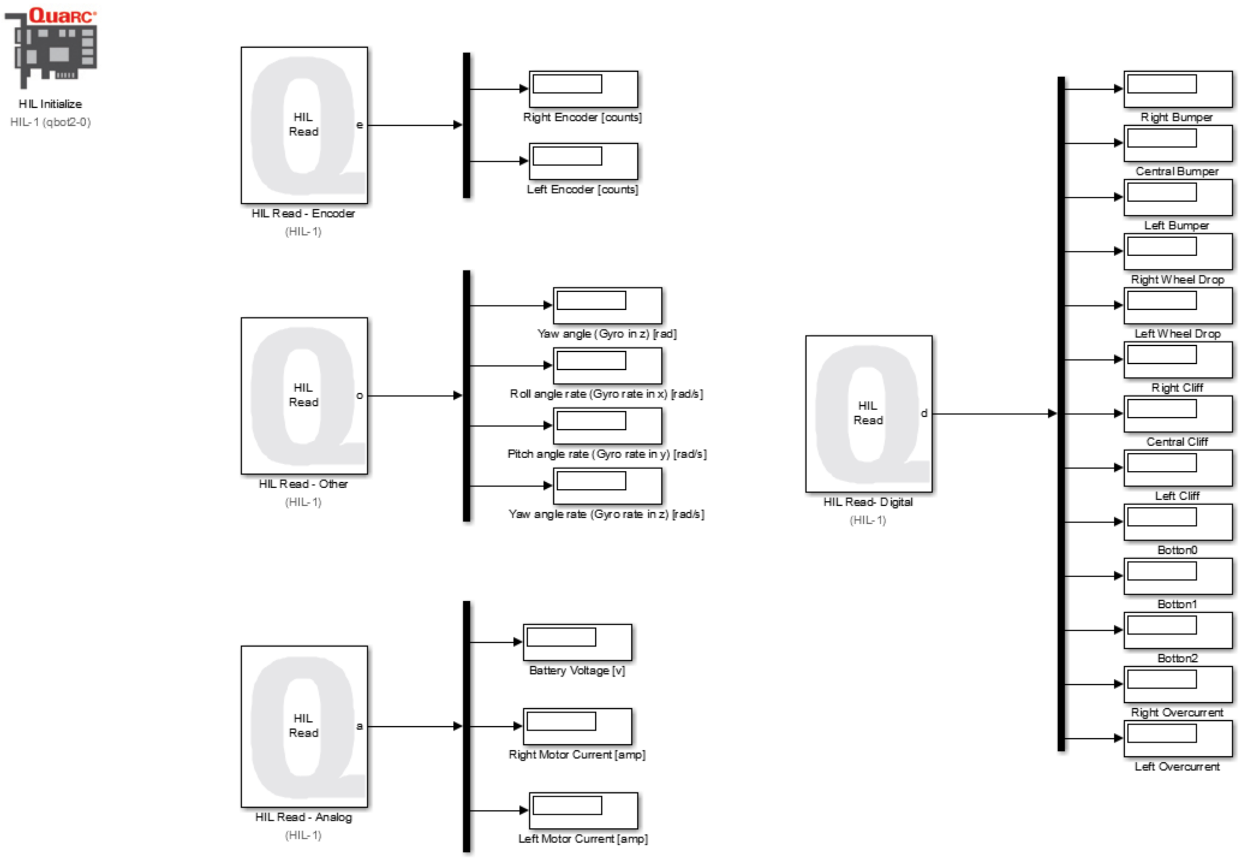

Figure 2.1: Snapshot of the model "QBot 2_Integration_Sensors"

2.1 Encoders

The QBot 2 is equipped with two high resolution wheel encoders to track the rotation of each wheel. The wheel encoder values for the right and left wheels are read using the QUARC HIL Read block on encoders channels 2 and 3 respectively, as shown in Figure 2.1.

Compile and run the Integration Sensors model. Once the QBot 2 beeps, indicating that the initialization routine is complete, follow the procedures outlined below to familiarize yourself with the encoders.

1. Slowly move the robot forward and backward and track the direction of each encoder. Then rotate the robot clockwise and counter-clockwise.
2. The encoders on the QBot 2 measure 52 counts per rotation at the motor, which when translated through the gearbox yields 2578 counts per rotation at the wheel. To convert the wheel rotation counts to wheel rotations in radian add a gain of 0.0024 to each measurement. You can also add a gain of 35 representing the wheel radius in mm to translate the rotation of the wheels to linear movement of the robot base in each wheel frame. Try adding these gains to check the rotation of each wheel against the movement of the robot base.

For more information on mapping the rotation of each wheel to deterministic motion of the chassis, and for recommended approaches to determining the speed of each wheel using the encoders, please refer to the Kinematics laboratory experiments and controllers.

2.2 Gyroscope

The QBot 2 is equipped with a three axis gyroscope that tracks the angular rate of the roll, pitch, and yaw of the robot. For simplicity, the yaw angle of the robot is output on channel 1002 using the QUARC HIL Read block, along with the roll, pitch, and yaw rates on channels 3000-3002. The proper configuration of these measurements is shown in Figure 2.1.

Compile and run the Integration Sensors model. Once the QBot 2 beeps, indicating that the initialization routine is complete, follow the procedures outlined below to familiarize yourself with the gyroscope.

1. Slowly rotate the robot clockwise, and counterclockwise and observe the changing gyroscopic values.
2. Pitch and roll the robot and observe the measured angular rates. If needed, take note of the conventions which all follow a conventional right-hand rule.

For more information on how the gyroscope measurements are used for deterministic motion of the chassis, please refer to the Kinematics, and Mapping laboratory experiments and controllers.

2.3 On/Off Sensors

The QBot 2 is equipped with several binary digital sensors including impact bumpers, wheel drop sensors, cliff sensors, and buttons. These sensors can be used for various custom applications including obstacle avoidance and path following. The digital sensors are measured using the QUARC HIL Read block, and are accessed on digital channels 8-18. The chassis also includes over-current sensors to ensure that the motors are not damaged due to improper use. These sensors can be measured on channels 19 and 20. The sensor mapping is outlined in the User Manual, and is shown in Figure 2.1.

Compile and run the Integration Sensors model. Once the QBot 2 beeps, indicating that the initialization routine is complete, trigger several of the sensors to familiarize yourself with their operation.

2.4 Power Sensors

To track the status of the QBot 2 battery, and for possible closed-loop motor control several power sensors are provided. The batter voltage can be measured using the QUARC HIL Read on Analog channel 4. The two motor current measurements can also be measured on Analog channels 8 and 9.

2.5 Additional Sensor Interface Board

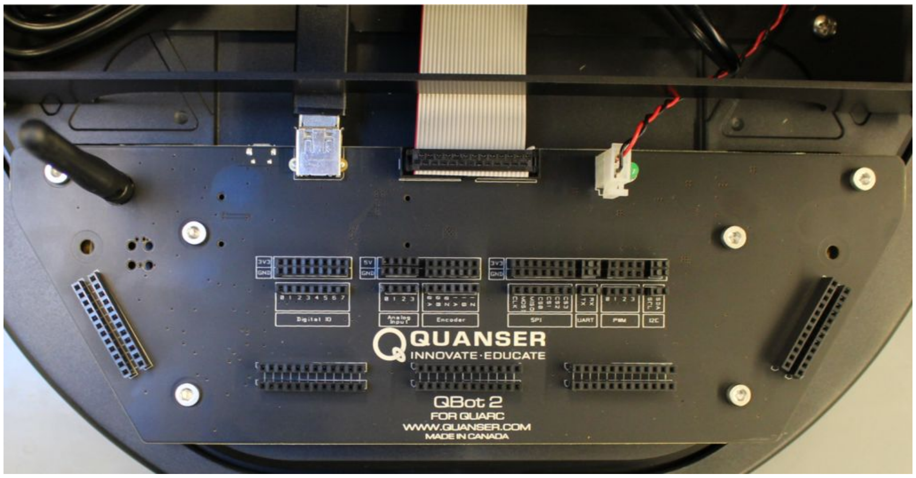

Figure 2.2: QBot 2 DAQ

To add additional custom capabilities to the QBot 2, the embedded DuoVero data acquisition system has been mapped to several headers on the front of the robot platform. These headers can be used to connect several custom sensors including two encoders and several analog and digital sensors. There are also interface channels for I^2C, SPI, and UART devices. Detailed instructions for reading from these headers are provided in the QBot 2 User Manual.

3 Kinect Vision Sensor

To enable the QBot 2 to easily perform classic mobile robotic algorithms and applications including visual servoing, mapping and localization, obstacle avoidance, and path following, the QBot 2 is equipped with a Microsoft Kinect which utilizes an infrared lazer projector and monochrome CMOS sensor for depth measurement, and an RGB camera for image processing. The camera provides image and depth capture at a frame rate of 30 fps and resolution of 640x480. The depth sensor has a range of 0.5 to 6 m. The sensor has a horizontal field of view (FOV) of 57 degrees, and vertical FOV of 43 degrees. The sensor can also be pivoted vertically by up to 21.5 degrees to allow the sensor to measure objects outside of the conventional horizontal field. The depth of objects are measured as a monochrome value depending on their distance from the sensor as illustrated in Figure 3.1.

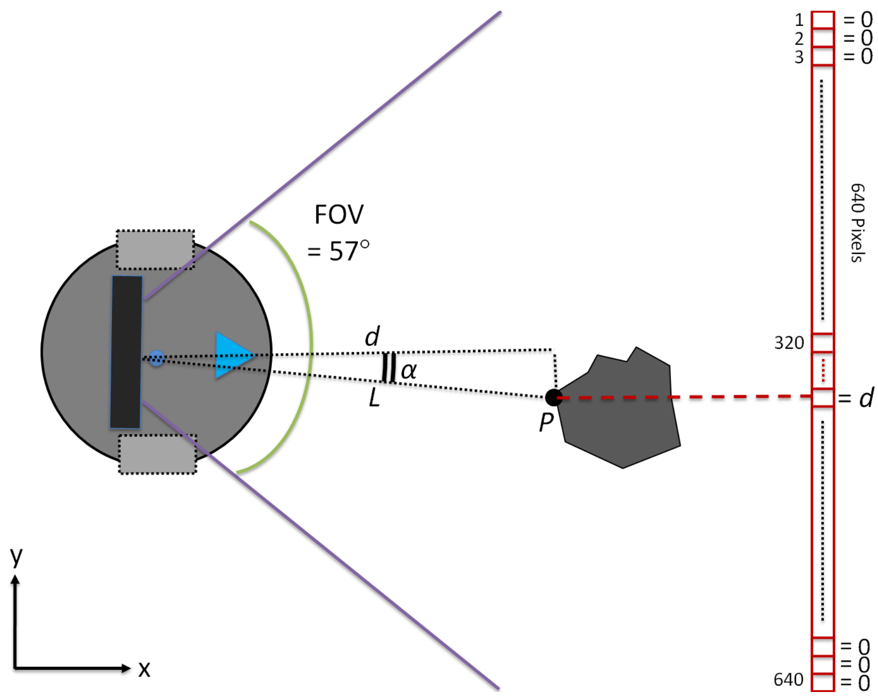

Figure 3.1: QBot 2 Depth Measurement

The Simulink model that is used to illustrate Kinect sensor measurement is "QBot 2_Integration_Vision.mdl", shown in Figure 3.2.

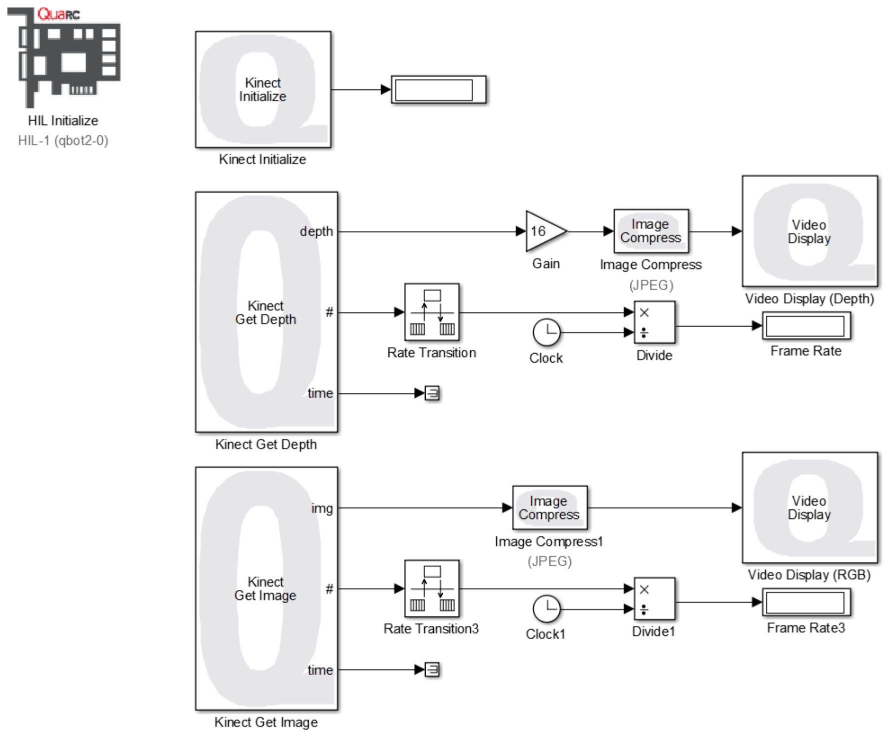

Figure 3.2: Snapshot of the model ”QBot 2_Integration_Vision”

Before running the vision model, there are several configuration settings that should be observed to ensure proper deterministic operation of the sensor. Begin by making sure that the trigger duration in the ”Signal and Triggering” sub-menu of the ”External Mode Control Panel” is set to **2**, as shown in Figure 3.3.

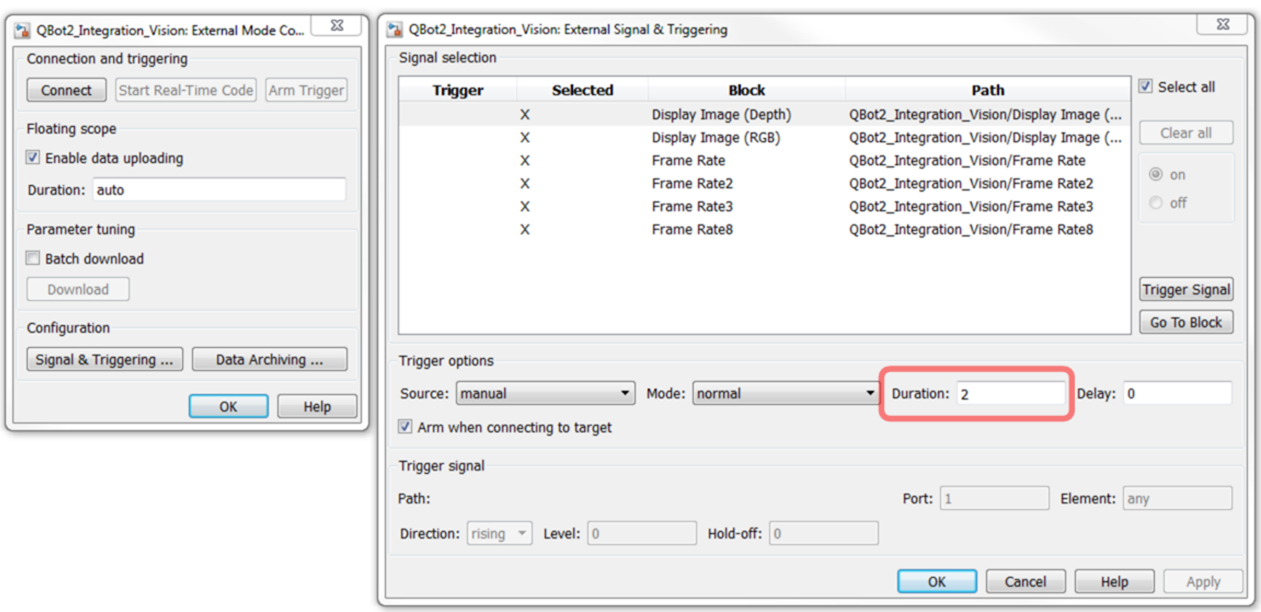

Figure 3.3: External Mode Triggering Duration settings

Next make sure that the ”Sample Time” parameter in the *Kinect Initialize*, *Kinect Get Depth*, and *Kinect Get Image* blocks are set to a multiple of **qc_get_step_size** (sample rate of the model). For example, if the sample time of the model is 0.005 s, then to achieve a frame rate of 10 fps (100 milliseconds per frame) the sample time should be set to **qc_get_step_size*20** = 100 milliseconds per frame.

Recommended configuration settings for the Kinect sensor blocks are presented in Table 3.1. These values are recommendations, and are not representative of the actual performance bounds of the sensor.

	30 fps	20 fps	10 fps	5 fps	1 fps
Capture and Processing* - RGB and Depth	480x640	480x640	480x640	480x640	480x640
Display on Host PC - RGB	24x32	48x64	96x128	120x160	240x320
Display on Host PC - Depth	24x32	48x64	96x128	120x160	240x320
Display on Host PC - Depth and RGB	N/A	N/A	N/A	48x64	96x128

Table 3.1: Kinect Sensor Recommended Configuration Settings

Compile and run the Integration Vision model. Once the QBot 2 beeps, indicating that the initialization routine is complete, make sure that the Display Image and Display Depth windows are visible. If they are not open, double click on each of the display blocks to open the viewers. With the model running, move the robot and place objects in front of the robot to familiarize yourself with the operation and capabilities of the vision sensor.

For more information on how using the Kinect sensor, several laboratory experiments will be provided including Mapping and Localization, and Image Processing. Please refer to these labs for examples of various scenarios and use-cases for the sensor system.

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