APPENDIX A: INTEGRATION GUIDE

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

Topics Covered

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

Prerequisites

- The QBot 2e has been setup and tested. See the QBot 2e Quick Start Guide for details.
- You have access to the QBot 2e 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 `QBot2e_Integration_Commands.mdl`, shown in Figure 1.1.

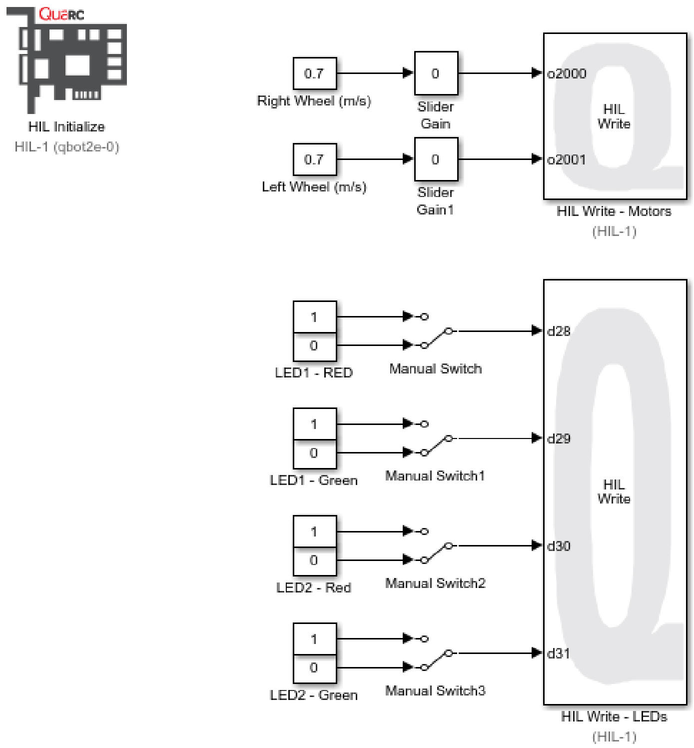

Figure 1.1: Snapshot of the model `QBot2e_Integration_Commands`

1.1 Motor Commands

The Quanser QBot 2e 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 2e 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 2e 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

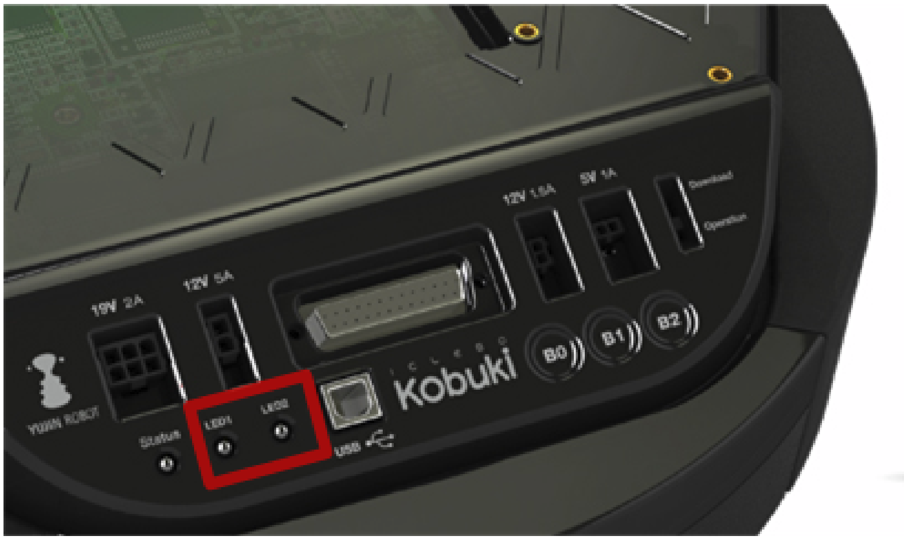

Figure 1.2: QBot 2e LEDs

There are two programmable LEDs on the top of the QBot 2e that can be illuminated as either green or red. The LEDs are commanded on digital lines 28 through 31 as outlined in the QBot 2e User Manual, and as demonstrated in the model shown in Figure 1.1.

Run the model and once the QBot 2e 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.

2 Chassis Sensors

The Simulink model for this section is `QBot2e_Integration_Sensors.mdl`, shown in Figure 2.1.

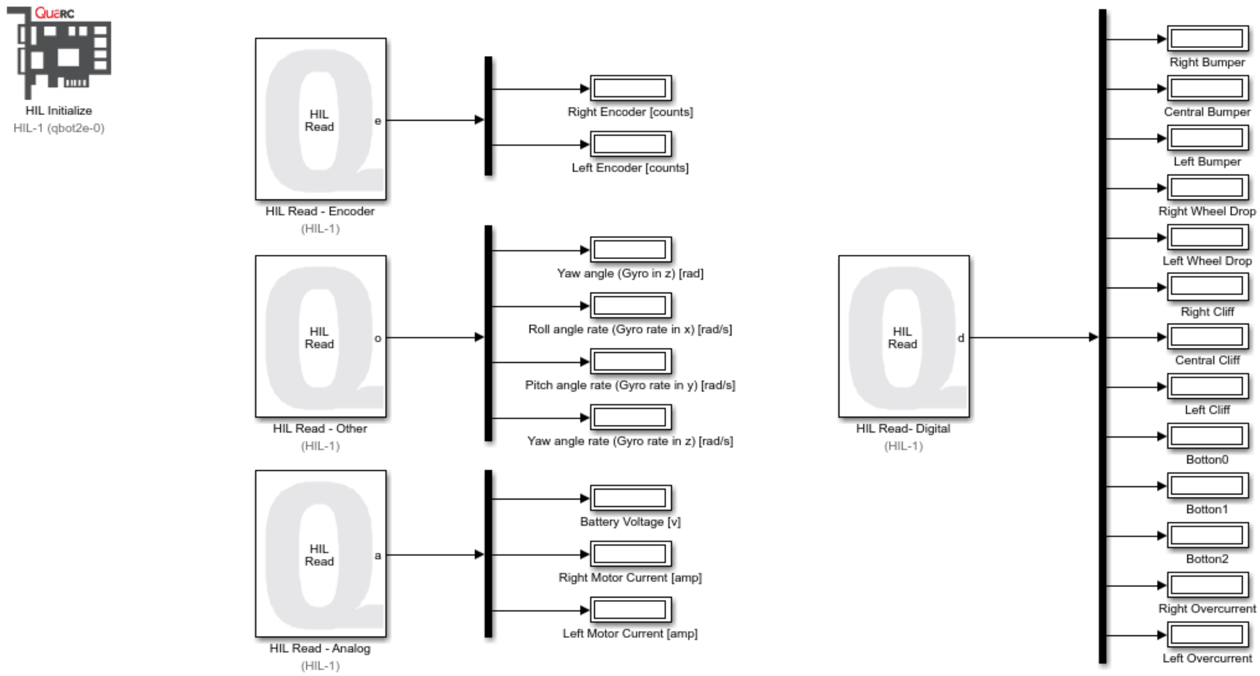

Figure 2.1: Snapshot of the model `QBot2e_Integration_Sensors.mdl`

2.1 Encoders

The QBot 2e 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 0 and 1 respectively, as shown in Figure 2.1.

Compile and run the Integration Sensors model. Once the QBot 2e 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 2e 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 2e 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 2e 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 2e 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 28-38. 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 39 and 40. 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 2e 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 2e 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 0. The two motor current measurements can also be measured on Analog channels 4 and 5.

3 Kinect Vision Sensor

To enable the QBot 2e to easily perform classic mobile robotic algorithms and applications including visual servoing, mapping and localization, obstacle avoidance, and path following, the QBot 2e is equipped with a Microsoft Kinect which utilizes an infrared laser 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 upto 30 fps and resolution of 640 x 480 pixels. 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.

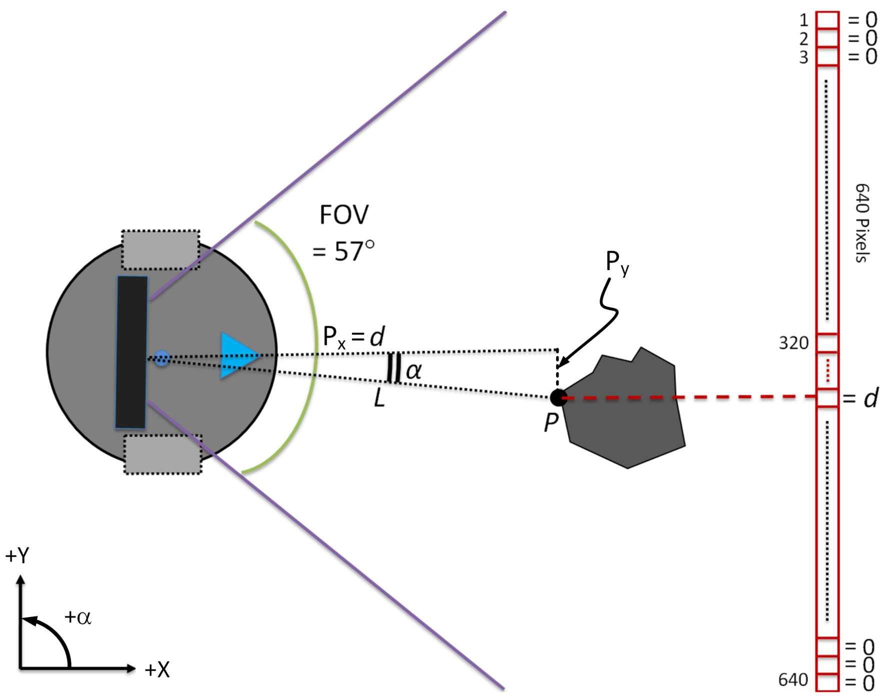

Figure 3.1: QBot 2e Depth Measurement

The Simulink model that is used to illustrate Kinect sensor measurement is `QBot2e_Integration_Vision.mdl`, shown in Figure 3.2.

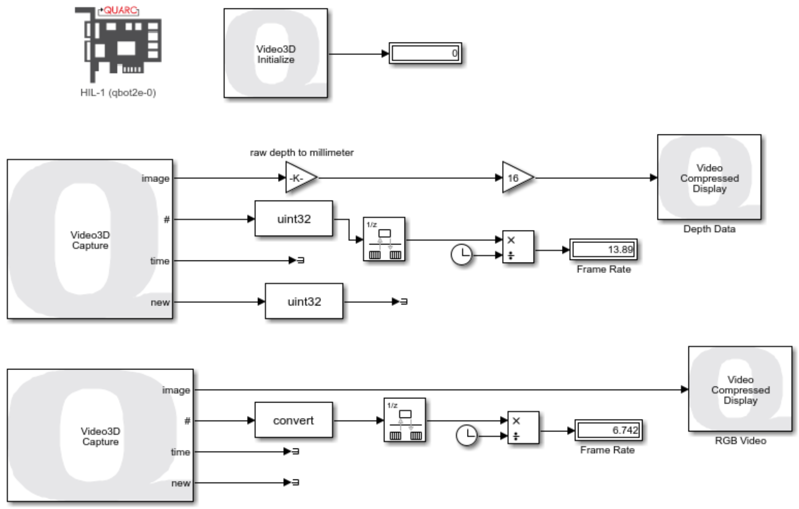

Figure 3.2: Snapshot of the model `QBot2e_Integration_Vision.mdl`

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.

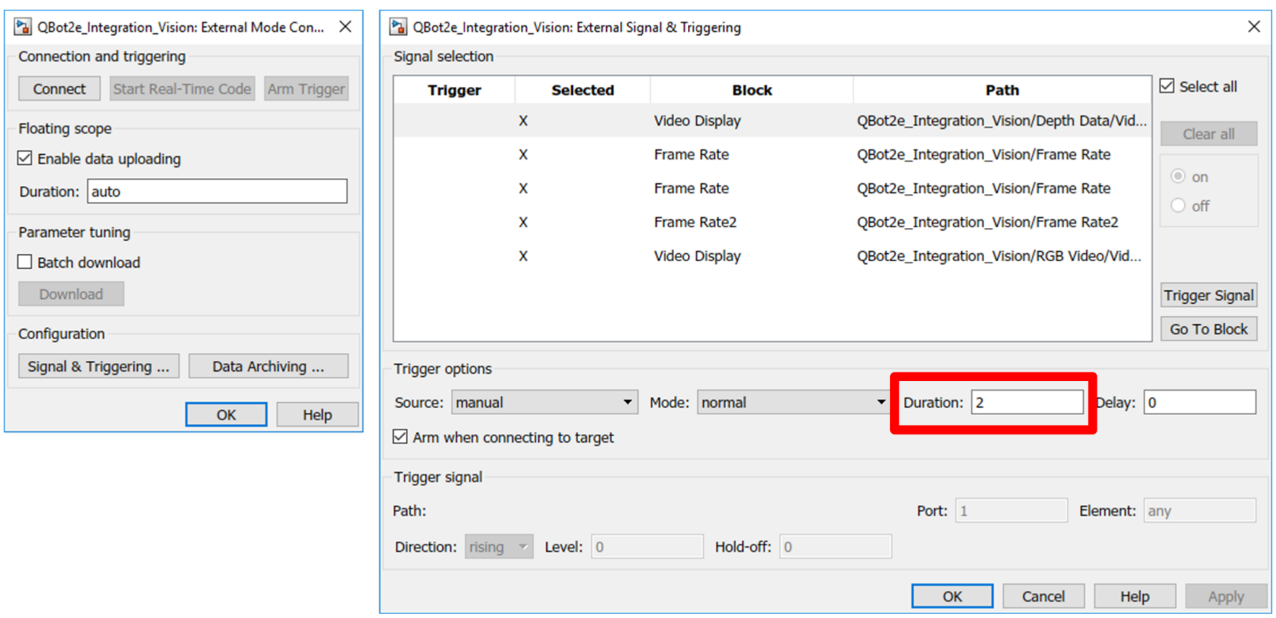

Figure 3.3: External mode triggering duration settings

You can use the Sample Time parameter in the Video3D Initialize and Video3D Capture blocks to achieve a desired frame rate by setting it 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), Sample Time should be set to **qc_get_step_size*20** = 100 milliseconds per frame. If the Sample Time parameter is set to **qc_get_step_size**, then the model attempts to acquire images at the maximum rate of 30 fps.

For improved image playback it is recommended to use the Video Compressed Display as shown in Figure 3.2. The Video Compressed Display block displays video in a window on the host. However, it uses image compression internally to minimize the bandwidth required to transmit the raw image from the target model to the host. It is designed for typical video frame rates. The video can be paused and resumed, and the current frame may be saved to disk as an image. This block has much higher performance than the Display Image block because it does not use MATLAB figure windows. However, as a result it cannot be used to drive axes in a MATLAB GUI.

Compile and run the Integration Vision model. Once the QBot 2e beeps, indicating that the initialization routine is complete, make sure that the Depth Data and RGB Video 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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