QUANSER
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Lab Procedure
Pendulum Interfacing & Inertia

Introduction

Ensure the following:

1. You have reviewed the Application Guide – Pendulum Interfacing and Inertia
2. The Qube-Servo 3 has been previously tested, is ON and connected to the PC.
3. Pendulum is attached and connected using the Encoder 1 connector to the Qube-Servo 3. If the pendulum is not centered on the Qube, you can turn it at the connection port to change its resting position.
4. Launch MATLAB and browse to the working directory that includes the Simulink models for this lab.

The **Hardware Interfacing** and **Filtering** labs explained the basic blocks to read and write from the Qube-Servo 3. For simplicity, all labs forward will use a Qube-Servo 3 block that sets up the system beforehand and outputs the available information from the Qube.

This lab will focus on understanding the pendulum attachment and will be separated in three sections. The first one will help you develop the pendulum conventions of movement. The last two will be focused on calculating and measuring the moment of inertia of the pendulum.

Developing the Pendulum Conventions

Using the gains found to convert tachometer counts/s into rads/s from the instrumentation labs, update the gains in the qs3_pendulum_interfacing.slx file. This model should read the base motor shaft and pendulum encoder positions of the Qube-Servo 3 and apply a small voltage to the motor. The model will then be modified to adhere to the conventions of the pendulum model, as laid out in the concept review.

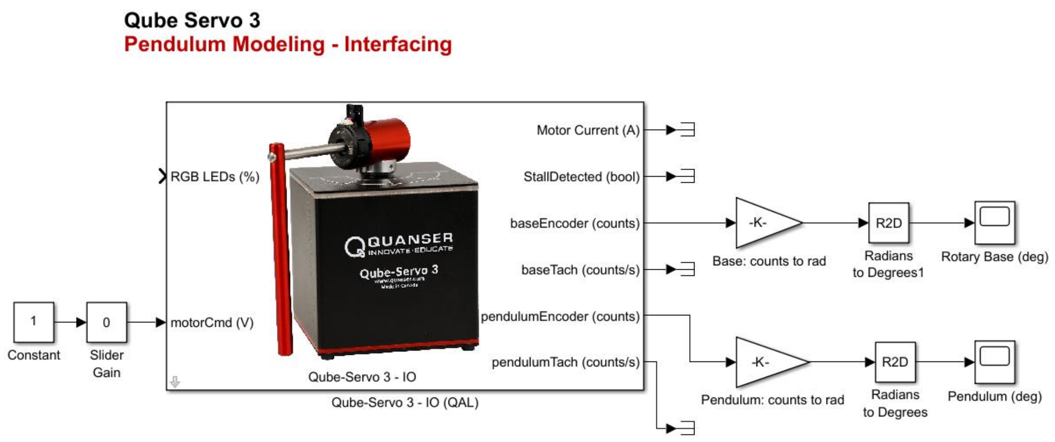

Figure 1: Simulink model used to interface with the Qube-Servo 3 using the pendulum module.

Setup the model as follows:

1. Setup the encoder gains on `baseEncoder` and `pendulumEncoder` to read the angles in radians.
2. Connect the measured angles to scopes but display them in degrees. You can do this adding the `Radians to Degrees` block into your model, by double clicking on an empty part of your model and typing the block name or through another `Gain` block.
3. Ensure the voltage sent to the Qube-Servo 3 can be adjusted. This can be done through a `Constant` block and a `Slider Gain` block. Make sure the voltage sent to the motor is limited to ±1V.
4. Ensure that the Rotary arm rod is aligned with 0 degrees marking on the Qube chassis by turning the plug that connects into the Qube.
5. Click `Monitor & Tune` in the `Hardware` or `QUARC` tab to deploy and run the model.
6. Rotate both the rotary base and pendulum counterclockwise. Examine the response in the scopes.
7. If the rotations performed in the previous step do not match the positive rotation conventions of the pendulum model, modify the Simulink model so that they do.
   Note: The Simulink model may need to be stopped and have `Gain` blocks added so that CCW is the positive direction.
8. Apply a small voltage (0.5V) to the motor by using the `Slider Gain` block or modifying the `Constant` block.
9. If the voltage applied does not adhere to the expected rotation from a positive voltage, modify the Simulink model so that it does.
10. Stop the Simulink model.
11. Add a `Modulus` and `Bias` block to the Simulink model so that the pendulum angle α is 0 rad in the upright position and is bounded by $\pm\pi$ rad. The model should look similar to Figure 2 below:

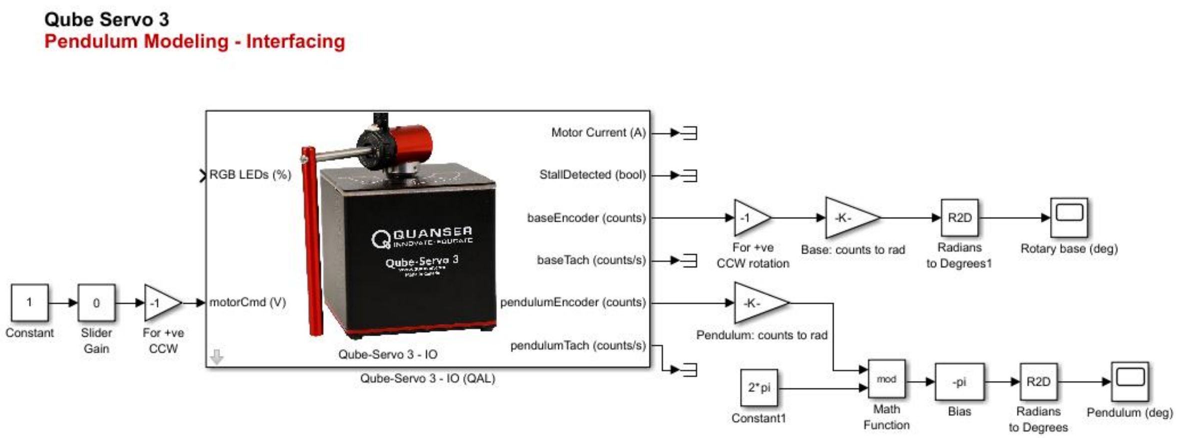

Figure 2: Simulink model that includes the modulus and bias blocks.

12. Build and run the QUARC controller using the `Monitor & Tune` button on the `Hardware` or `QUARC` tab.

13. Rotate the pendulum to the upright position to ensure the angle is 0 rad. Capture a screenshot of the Pendulum (deg) scope demonstrating the pendulum moving from the downright position to the upright position.

14. Once all conventions have been validated, stop the Simulink model.

15. Take a screenshot of the completed Simulink model with all the changes made.

16. Close your model. Ensure you save a copy of the files for review later.

Calculating the Moment of Inertia

The goal is to derive the moment of inertia of the pendulum module on the Qube-Servo 3 experimentally and analytically. The model qs3_moment_of_inertia.slx measures the pendulum angle using the encoder and converts from encoder counts to degrees.

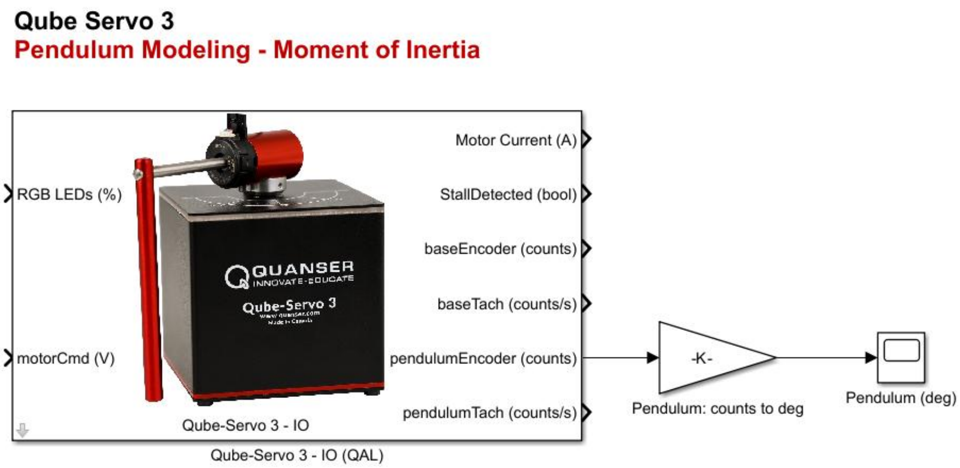

Figure 3: Simulink model that displays the measured pendulum angle.

17. Find the moment of inertia acting about the pendulum using the free-body diagram from the concept review. Use the parameters as defined in the Qube-Servo 3 User Manual. Use the file qs3_rotpen_param.m to fill out your values and do the calculations.
    Hint: For solid objects with uniform density, you can express the differential mass in terms of differential length.

Measuring the Moment of Inertia

18. Click `Monitor & Tune` in the `Hardware` or `QUARC` tab to deploy and run the model.

19. While holding the pendulum base in place, manually perturb the pendulum.
Tip: This may be easier if the rotary arm is held against the physical rotation limit. Ensure the pendulum swings freely without obstructing the cables connected to the back of the Qube-Servo 3.

20. Measure the number of cycles (n_{cyc}) and the duration of the cycles (Δt) from the pendulum position scope. Your response should look similar to Figure 4:

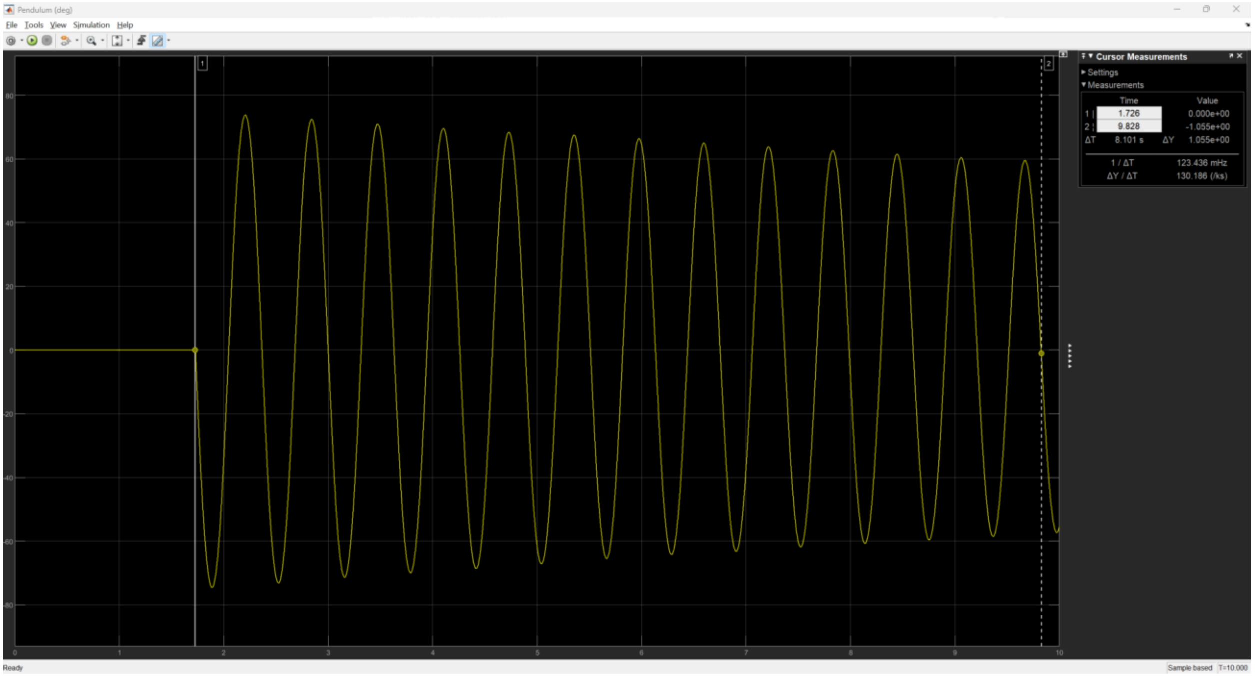

Figure 4: Sample response of perturbed pendulum.

21. Calculate the moment of inertia for the pendulum using n_{cyc} and Δt.

22. Once the calculations have been validated, close your model. ensure you save a copy of the files for review later.

23. Power OFF the Qube-Servo 3