Lab Procedure

Frequency Response Modeling Virtual

Introduction

Ensure the following:

1. You have reviewed Application Guide - Frequency Response Modeling
2. Make sure you have Quanser Interactive Labs open in the Qube 3 - DC Motor → Servo Workspace.
3. 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.

Using the gains found to convert tachometer counts/s into rads/s from the instrumentation labs, use the qs3_frequency_response.slx file to design a model that applies a sine wave and/or a constant voltage to the motor and measure the corresponding motor speed of the Qube-Servo 3 as shown in Figure 1. The second input of the `Mux`, as well as the `Time Delay Scope` will not be used until the third section of the lab.

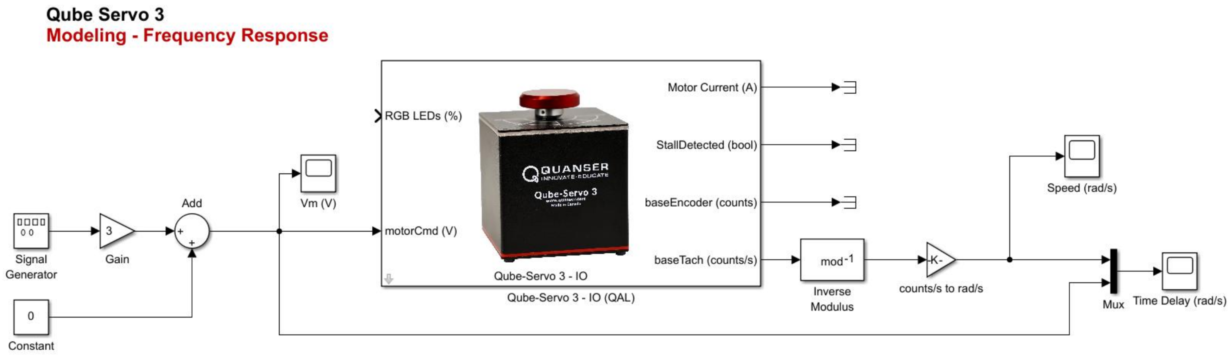


Figure 1: Model applying a voltage and measuring speed to obtain the frequency response of the Qube-Servo 3

This experiment consists of three parts that will help you understand your DC motor's behavior. First, you'll determine the system gain (K) by measuring the motor's response to a constant input voltage. Next, you'll explore how your motor responds to sinusoidal inputs of different frequencies, allowing you to create a Bode magnitude plot and calculate the time constant (τ). Finally, you'll verify this time constant through a different approach by analyzing the phase shift between input and output signals.

Determining the Motor Steady State Gain K

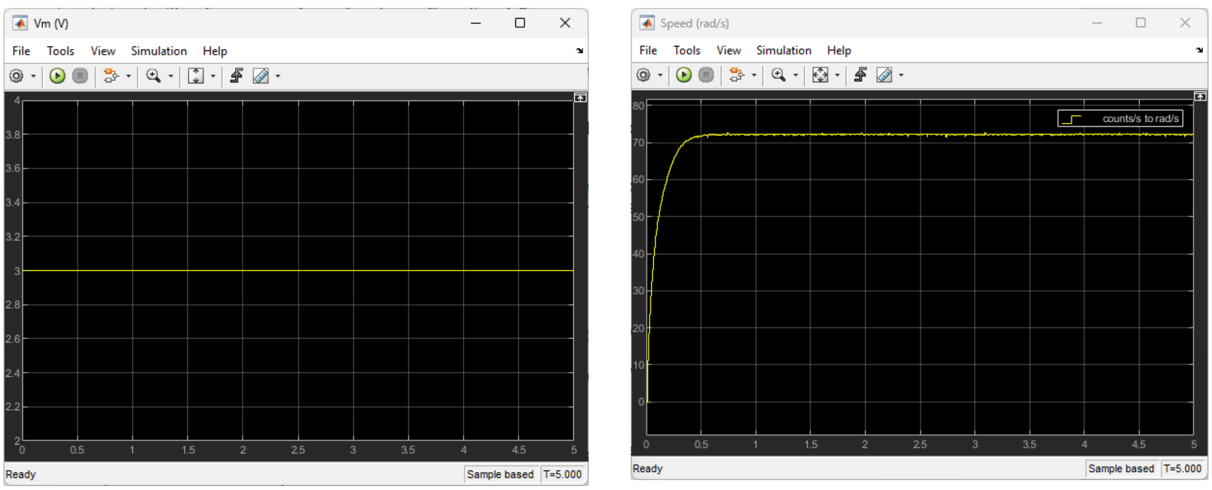
The steady state gain K of the system can be observed by applying an input signal with a frequency of ω = 0 rad.

1. Use your modified qs3_frequency_response.slx to match figure 1.

2. To apply a constant 3V voltage command, set the **`Constant`** block to a value of 3 and the **`Gain`** block to 0 (i.e. no sine wave).

3. Run the QUARC controller using the **`Run`** button on the **`Simulation`** tab.

4. The response should look similar to Figure 2. Save the voltage and speed response you obtained.



(a) Motor Voltage – Constant input

(b) Load Disc Speed

Figure 2: System response when applying a constant 3V input voltage

5. Measure the speed of the load disk and calculate the steady-state gain of the system, K, in rad/s/V (linear and decibel dB).

6. Stop your model.

7. Close Quanser Interactive Labs.

Magnitude Response Analysis

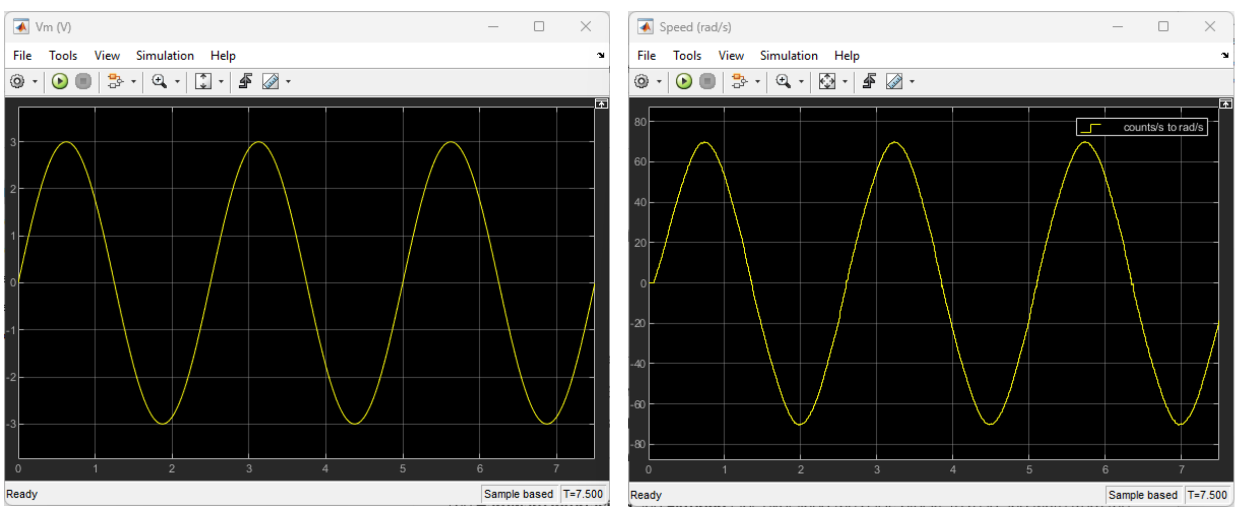
In this part of the lab, you will use sinusoidal inputs with different frequencies to determine the time constant, τ, of the system.

8. Given the equation for the system's magnitude response with respect to the input frequency: $|G(\omega)| = \frac{K}{\sqrt{1+\tau^2\omega^2}}$ .Derive an expression to determine the time constant, τ, of the system?
   Hint: Begin by evaluating the magnitude of the transfer function at the cutoff frequency, ω_c.

9. Set the **`Signal Generator`** block frequency to 0.4 Hz, and the amplitude to 1. To configure the model to apply a sine wave, set the **`Constant`** block to 0 and the **`Gain`** block to 3.

10. Run the QUARC controller using the **`Run`** button on the **`Simulation`** tab.

11. An example response is shown in Figure 3.



(a) Motor Voltage – Constant input (b) Load Disc Speed

Figure 3: System response when applying a 3V 0.4 Hz sine wave voltage

12. Measure the maximum positive speed of the response and compute the gain of the system (linear and in dB) as done in the previous section. Enter the result in the 0.4 Hz row of Table 1 below. Enter the results from the steady-state analysis in the previous section as the row for 0 Hz frequency.

13. Modify the frequency in the `Signal  Generator` block and get the values for the remaining frequencies in Table 1.

Freq (Hz)	Max Amplitude (V)	Max Load Speed (rad/s)	Gain ($\|G(\omega)\|$) ($rad/s/V$)	Gain ($\|G(\omega)\|$) (dB)
0.0				
0.4				
0.8				
1.2				
1.6				
2.0				
2.4				
2.8				

Table 1. Frequency Response Data

14. The assessment might require the result of this table as well as a Bode Magnitude plot from these results.

15. Stop your model. Keep it open for the next section.

Phase Delay Analysis

This section will help you verify the time constant τ through a different approach by analyzing the phase shift between input and output signals. Match your model to figure 1. The `Constant` block will stay as 0. The model should apply a sinusoidal voltage to the motor and measures the corresponding speed on the Qube - Servo 3. The input and output signal are plotted together in the `Time Delay` scope to measure the phase shift between the signals.

16. For the first order linear time-invariant (LTI) model of the input voltage-to-speed DC motor transfer function. Find an expression for the time constant, τ, in terms of the frequency of the input sinusoid and the resulting phase delay.

17. Express the time constant equation found in the step above directly with the time delay of the input and output signals.

18. Configure the model to apply a 3 V 0.4 Hz sine wave to the motor as done in the previous section.

19. Run the QUARC controller using the `Run` button on the `Simulation` tab. The response should look like figure 3 from the previous section.

20. Measure the time delay of the speed output when applying a 3 V at 0.4 Hz sinusoidal input. Save the response of the `Time Delay Scope` you obtained.
21. Determine the corresponding phase shift in degrees and radians. Based on these measurements, compute the time constant, τ, for the Qube - Servo 3.
22. Compare the time constant found using phase delay analysis with the result obtained previously on the above section using the Bode plot. If they are different, note one source that may have contributed to the different results.
23. Stop and close your model.
24. Close Quanser Interactive Labs.