Lab Procedure

PD Position Control Virtual

Introduction

Ensure the following:

1. You have reviewed the Application Guide – PD Position Control
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.

This experiment consists of three parts that will help you understand the gains of the system as well as creating a system response based on specific requirements. First, you'll explore what the k_p and k_d gains affect how the Qube responds. Then you will calculate the gains necessary to get a specific system response. Finally, you will test these gains with the real system and compare the performance.

Understanding System Gains

Use the qs3_pd.slx file. This model implements a proportional and rate feedback (PV) control as shown in the concept review mentioned in the application guide. Make sure to use a square wave as an input with an amplitude of $\pm 1.5\ rad$ at $0.4\ Hz$. Keep the saturation block to protect the servo. Your model should look like Figure 1. Instead of differentiating the position, this model just uses the tachometer directly.

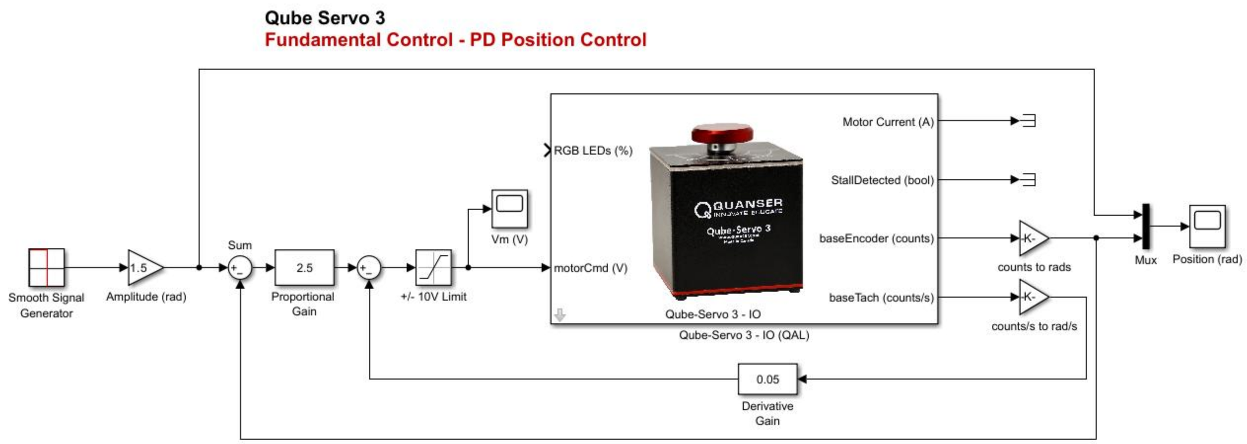


Figure 1: Proportional and rate feedback controller for the Qube-Servo 3

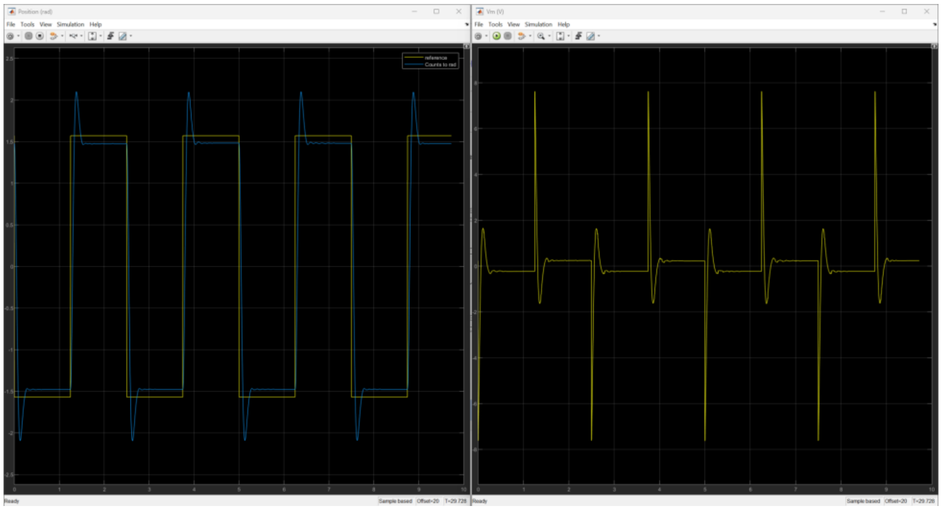
1. Using the qs3_pd.slx file add a `Smooth Signal Generator` block into your model, by double clicking on an empty part of your model and typing the block name. Configure it to output a square wave with an amplitude of $\pm 1\, rad$ at $0.4\, Hz$. Use the **`Gain`** to configure the square wave to have an amplitude of $\pm 1.5\, rad$.

2. Use the gain value found in previous labs to convert the encoder counts to radians and counts/s to rads/s. Connect all the blocks as shown in Figure 1.

3. Set the proportional gain to $k_p = 2.5$ V/rad and the derivative gain to $k_d = 0.05$ V/(rad/s).

4. Run the QUARC controller using the `Run` button on the `Simulation` tab.

5. The response should look like this:



6. Set $k_d = 0$ V/(rad/s). Keep the derivative gain at 0 and vary k_p between 1 and 4. Take note of how varying k_p affects the response of the system.

7. Set $k_p = 2.5$ V/rad. Vary the derivative gain k_d between 0 and 0.15 V/(rad/s). Take note of how varying k_d affects the response of the system.

8. Stop your model. Keep it open, you will use it later in the lab.

Calculating System Response

9. Compare the standard second order transfer function and the transfer function of the Qube-Servo 3 with a PD controller to find k_p and k_d in terms of ω_n and ζ.

$$\frac{Y(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \qquad\qquad \frac{Y(s)}{R(s)} = \frac{K \cdot k_p}{\tau s^2 + (1 + K \cdot k_d)s + K \cdot k_p}$$

10. For the response to have a peak time of 0.15s and a percent overshoot of 2.5%, calculate the natural frequence and damping ratio needed. Use the equations for peak time and percent overshoot.
    Hint: You can use MATLAB's symbolic solve to calculate the values
    https://www.mathworks.com/help/symbolic/sym.solve.html#:~:text=Solve%20Polynomial%20and%20Return%20Real%20Solutions

$$PO = 100\, e^{\left(-\frac{\pi\,\zeta}{\sqrt{1-\zeta^2}}\right)} \qquad\qquad t_p = \frac{\pi}{\omega_m \sqrt{1-\zeta^2}}$$

11. Use the Qube-Servo 3 model parameters K and τ, found in any of the Modeling Labs to calculate the k_p and k_d control gains needed to satisfy the requirements of a peak time of 0.15s and a percent overshoot of 2.5%.
    NOTE: If no modeling lab has been done, for Qube-Servo 3, $K = 24$ and $\tau = 0.1$ are good defaults if this equation needs to be used.

Measuring System Response

12. Input the k_p and k_d calculated in the previous step into the Simulink model.

13. Run the QUARC controller using the `Run` button on the `Simulation` tab and let the model run for at least 10 seconds.

14. Stop the model.

15. Take a screenshot of the position response and voltage scope.

16. Using the measurement tool, measure the peak time and percent overshoot of the response. Take note of whether they match the requirements of a peak time of 0.15s and a percent overshoot of 2.5% without saturating the motor (going beyond $\pm 10\ V$).

17. If the response did not match the specified peak time and percent overshoot, try running the model again and tuning the control gains until the response satisfies them. Take a screenshot of the new response, and record the values used for k_p and k_d. Write down your thought process for tuning the control gains.

18. Stop and close your model. Ensure you save a copy of the files for review later.

19. Close Quanser Interactive Labs.