Intro to Robot Control – Spring 2023

ME EN 5230/6230, CS 6330, ECE 6651

Introduction

The purpose of this assignment is to explore the use of basic linear control on a single DOF robot such as the Quanser SRV02, and to experimentally validate the controllers you designed and simulated in Problem Set#4. Please complete on your own time in the laboratory. You may work in teams and share data, but each student should make their own plots and turn in their own writeup. After going over the checklist on the next page, use the QUARC tutorial on the class website to configure your Simulink model. Please follow the instructions in the tutorial very closely, as there are several parameters that need to be properly configured in order for your real-time controller to operate correctly. Then complete the lab exercises as specified on the last page. In each exercise, copy a picture of your Simulink model to provide in your writeup. When plots are requested, save your data to the workspace and make a high-quality MATLAB plot with properly labeled axes (**don't just turn in a screen dump of the scope!**).

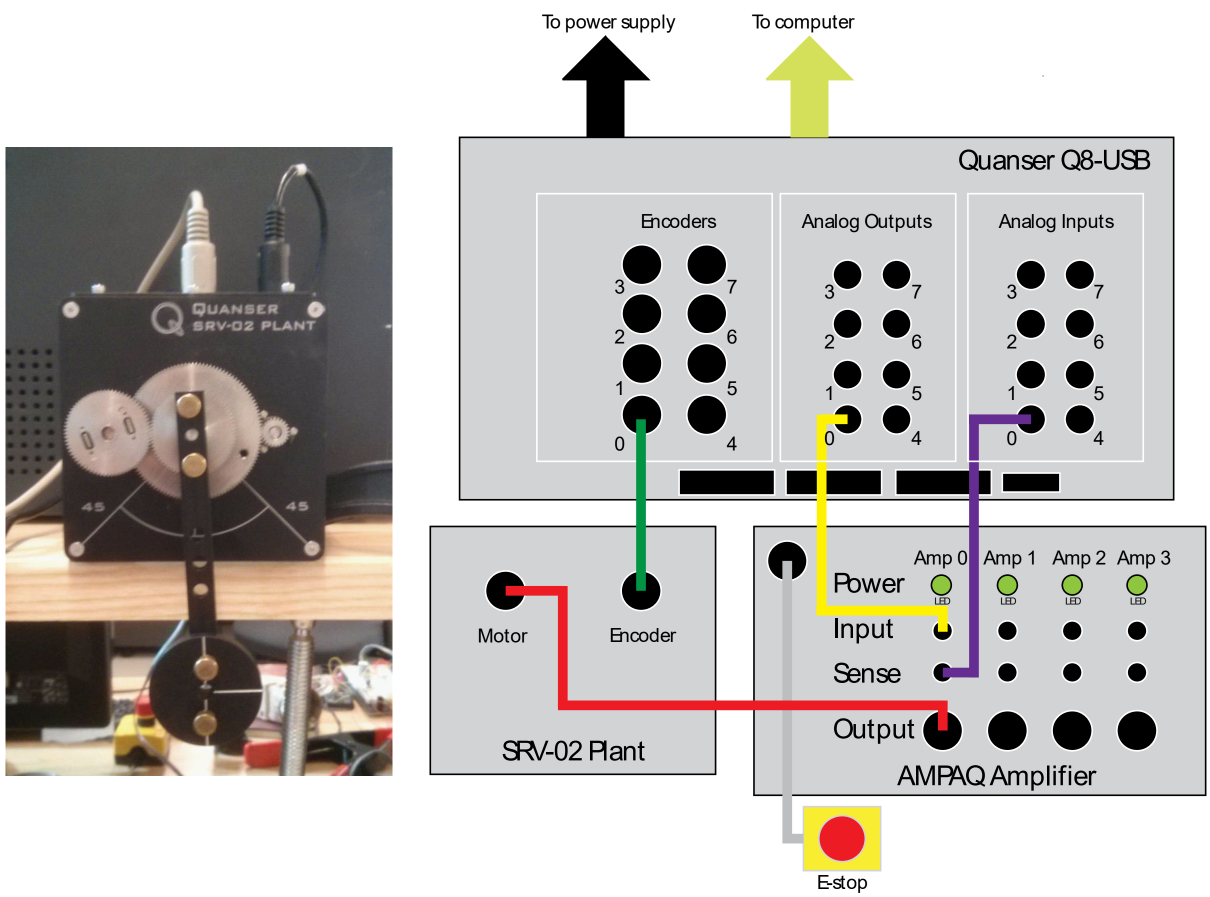

Figure 1. Experimental Setup for 1 DOF system

Checklist

The experimental hardware should already be configured for you as shown above. Go over the following checklist before you begin:

- As shown above, the SRV-02 unit should have a link attached to the output shaft, and a cylindrical weight attached to the end of the link. The unit should be standing at the edge of the desk with the link hanging down like a pendulum. To achieve consistent step responses, always begin with the link hanging straight down before each trial.
- The SRV-02 should not be wired to the AMPAQ Amplifier and Quanser Q8-USB. If your system is wired, remove all the wires and use the wiring diagram above to wire up your system. Learning how to wire up the system yourself can help you better troubleshoot port/channel issues in your Simulink model. The wires will be on or above the desk.
- Don't forget to turn on the amplifier (power switch on the back) and make sure the tethered emergency stop button is not depressed (twist button to release).
- When doing the step responses, be sure to use a small enough step input (e.g. a few degrees of link rotation is plenty) that you don't saturate the amplifier or drive the motor too hard. It is recommended to use scopes to monitor both the commanded motor current and the actual motor current. Saturating the amplifier will result in nonlinear step responses. The gain of the AMPAQ is 0.1 A/V, and they can send at most 1 Amp to the motor, so they will saturate when the analog output is 10V. Note that the amplifiers have a small bias, which is different on each channel. The QUARC tutorial demonstrates how to properly compensate for this.

Lab Management and Housekeeping:

- While working on the computers in the lab, you should make your own local folder (use your full name) and use that as your working directory in MATLAB. When you are done in the lab, make sure you copy all your files to your own personal storage device or cloud location, and delete them from the lab PC. Files left on the computer will be periodically deleted for housekeeping purposes.
- Please work with a partner and always have one hand on the E-stop when running your models. If you observe any damage to the hardware, please notify the course TA.
- When you are done in the lab, turn off the AMPAQ Amplifier and disconnect all the wires from the SRV-02, AMPAQ Amplifier and Quanser Q8-USB board. Pile them neatly nearby so that the next group of students can learn how to wire the system.

Note on Derivative Control vs. Velocity Feedback

After completing PS#4, you should have a good understanding of how PD and PV controllers differ in terms of their block diagrams and step responses. In this lab exercise, we will use velocity feedback in order to avoid differentiating the step input, which would result in a large spike in motor command that can saturate the amplifiers and result in a nonlinear step response. In future lab exercises, where we use a smooth desired trajectory rather than a step input, this will not be an issue, and it will be fine to use a PD controller.

Lab Exercises

1. **Open-Loop Control:** Following the procedure in the QUARC tutorial, set up a Simulink model to measure the open-loop step response of the SRV02. Use this to test the functionality of your analog output and counter inputs. Use the correct gain to convert the encoder counts to degrees. The encoders have 1024 counts per revolution, and the decoders have a 4x multiplication factor. Rotate the link 360 degrees with your hand and verify that you used the correct magnitude of encoder gain. Also verify that a positive step in motor voltage results in a positive step in encoder angle. Show a plot of the open-loop step response.
2. **Proportional Control:** Set up a feedback loop in your Simulink model to implement closed-loop proportional control. Start out with a low gain and feel the virtual stiffness of the link as you increase the gain. Provide plots of the step response at a couple different levels of gain. What gain would you choose to optimize the response? What is the settling time and % overshoot at this gain?
3. **PV Control:** Add velocity feedback to your proportional control. First set the proportional gain very low and turn up the velocity gain to feel the virtual damping effect. Now turn up both the P and V gains together to see how fast you can make the settling time while maintaining a reasonable amount of overshoot. If you increase them too much, the system will eventually become unstable. As you increase the gains, you may also need to decrease the magnitude of your step in order to avoid saturating the amp. Find a favorable set of gains and provide a plot of the step response. What is the smallest settling time you can achieve without risking instability? Try the set of PV gains you designed in PS#4 and compare the performance of your experimental response to your simulated response. Note: be mindful of your units when trying your gains from PS#4 (e.g. you may need to convert between A/radian and A/degree).
4. **PIV Control:** Now add integral control. Start with a low set of PV gains (such the step response exhibits significant steady-state error). Then turn on the integral control, beginning with a very small integral gain. Note how the steady-state error goes away faster as you continue to increase the integral gain. Also, use your hand to apply disturbance forces to the link, and notice how the disturbance rejection is improved as the integral gain is increased. Provide plots of the step response at a couple different levels of integral gain. Try the set of PIV gains you designed in PS#4 and compare the performance of your experimental response to your simulated response. Note: be mindful of your units when trying your gains from PS#4 (e.g. you may need to convert between A/radian and A/degree).