# ME EN 5200/6200 & ECE 5615/6615
# Lab 01: Stability

This is a group assignment with teams of three. Contact the instructor or TA if you cannot find teammates. Lab reports will be submitted as a team.

## 1. Lab Setup

You have been given U card access to the Small Robotics Lab (MEK 2333) where you will perform the labs. The stations have already been set up for you. If you have issues with the lab hardware or software, contact the TA or Quinton Christensen (quinton.christensen@utah.edu).

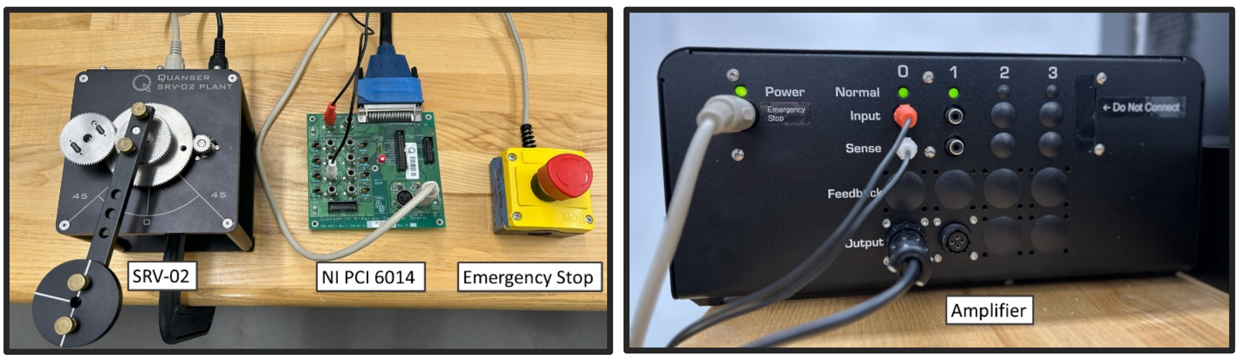


*Figure 1. Lab setup. The SRV-02 has a motor/mass system placed on the desk and connected to a computer (via a data acquisition board NI PCI 6014) and amplifier. The emergency stop connects to the amplifier to kill power.*

**NOTE**: Do not disassemble, disconnect, or tamper with these set-ups in any way! This includes the version of MATLAB.

To start the system:

1. Ensure everything is setup and connected based on the lab setup in Fig. 1:
   a. A single-linkage mass is attached to the SRV-02 as shown in Fig. 1. The system is clamped or held to the desk.
   b. The Emergency Stop is plugged into the corresponding port labeled “Emergency Stop” on the amplifier.
   c. “Output” 0 on the amplifier is connect to “Motor” on back of the SRV-02 (this is a black 4-pin cable).
   d. “Input” 0 on the amplifier is connected to “Analog Outputs” 0 on the DAQ, and “Sense” 0 on the amplifier is connected to “Analog Inputs” 0 on the DAQ (NOTE: we are not using the Sense signal for this lab).
   e. Encoder output on SRV-02 is connected to the “Encoders” 0 port on the DAQ.
2. Turn on the amplifier with the switch located next to the power cable in the back.
3. Disengage the emergency stop by twisting the red cap.
4. Turn on the desktop and login to the Student-No Password profile.

To run each lab:

1. Download a copy of the Simulink template from Canvas to the lab computer.
2. Launch Simulink within MATLAB and open your copy of the Simulink file.

3. Modify the model for the lab by double-clicking into the blocks.
4. Under the Hardware tab of Simulink, click "Monitor and Tune". The file will compile, build, and then run on your connected hardware.

**NOTE:** Make sure to ALWAYS have someone with a hand on the Emergency Stop. Because we are testing stability in this lab, the system will experience instability during one of your runs. If needed, press down on the button until it clicks. Wait for the model to finish running before twisting to release the Stop. If the Stop is released and the system keeps running after the model terminates, contact the TA.

When finished with your session:

1. Engage the Emergency Stop.
2. Turn off the amplifier.
3. Save any files needed onto your flash drive.
4. Log out of Canvas and any cloud sites (Google Chrome/Drive, OneDrive, etc.)
5. Delete any files saved to the lab computers.
6. Put the computer to sleep. DO NOT unplug any cables.

## 2. Pre-lab Assignment

Consider the following block diagram for feedback control of the Quanser system:

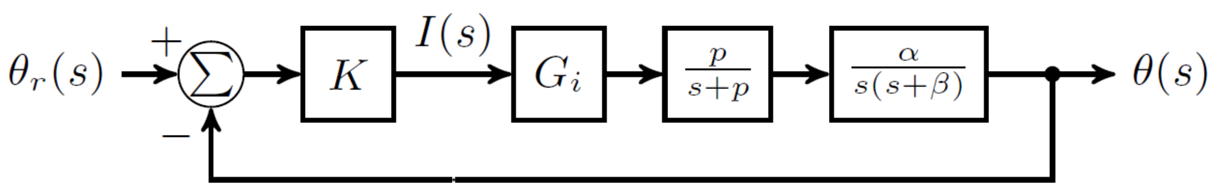


*Figure 2. Block diagram of the closed-loop feedback controller.*

In Fig. 2, the transfer function $\alpha/(s(s+\beta))$ is the motor transfer function, and $\alpha = 7.5$ and $\beta = 1.67$ are system constants that were found experimentally. The transfer function, $p/(s+p)$, is a filter function that introduces an additional pole, where $p = 20$ is the filter coefficient. $G_i = 10$ is the amplifier gain, and $K$ is the proportional gain in the controller. $I(s)$ is the commanded current input, $\theta(s)$ is the output rotational position, and $\theta_r(s)$ is the reference (desired) rotational position.

Pre-lab exercises:

1. Derive the open-loop transfer function that consists of the drive, filter, and motor. In other words, find $G(s) = \theta(s)/I(s)$, where the input is the current and output is the motor's angular position. Substitute in the values provided above.
2. Find the poles and zeros of the open-loop system from part (1). Is it stable? Marginally stable? Unstable? Please justify.
3. Find the closed-loop transfer function between $\theta_r$ and $\theta$. Substitute in the values provided above. What is the characteristic equation of the closed-loop system?
4. Use the Routh-Hurwitz table to find the range of values of $K$ for stability.
5. If $K$ was set to the maximum value for stability (i.e., the marginal stability point), at what frequency would the system oscillate?

6. What effect does the filter coefficient, *p*, have on the behavior of the closed-loop system?

## 3. Lab Assignment

The Simulink template has blocks that you will modify to test stability and oscillation. There are also Scope blocks that visualize the data and To Workspace blocks that send data to the MATLAB workspace for saving data and generating more detailed plots.

Lab Exercises:

1. Modify the filter function to match the block diagram from the Pre-Lab.
2. Modify the proportional gain of the template (*K*) to experimentally find the range of stable gains. Test and save the step response for at least three gains.
3. Find the gain for *K* that causes marginal stability on your system (or close to marginal stability) and note that gain.
4. Estimate the frequency of oscillation at marginal stability.
5. Test two different values of *p* and save the step responses. Make a note of how *p* modifies the system.

**NOTE:** Because the Pre-lab used approximations, start with a gain for *K* that is well below the gain found in the pre-lab. Then, increase *K* incrementally until you approach marginal stability. If more time is needed to let the system settle out (or show marginal stability), modify the "Stop Time" next to "Monitor and Tune" in the Hardware tab.

## 4. Lab Report

Turn in one report per team. The report will be graded on the following categories:

1. [5 pts] Coversheet – include the following information:
   a. Title of lab, i.e., Lab 01: Stability
   b. List of team members, their uNID, and signature from each team member indicating that they contributed to the lab assignment.
2. [85 pts] Content – write 2-3 pages, including the following:
   a. [40 pts] Professionally written summary of work and results from the Pre-lab, including:
      i. Open loop transfer function with its poles and stability.
      ii. Closed-loop transfer function and characteristic equation.
      iii. Routh-Herwitz table with ranges for *K* and equation for oscillatory frequency at marginal stability.
      iv. Expected effect of *p* on the system.
   b. [45 pts] A discussion and comparison of the theoretical and experimental:
      i. Range of gains (*K*) for stability.
      ii. Oscillatory frequency at marginal stability.
      iii. Results of changing the filter coefficient (*p*).
      iv. Discrepancies between theory and experiment.
3. [10 pts] Presentation - reports should be formatted professionally and should present the material in a neat, clear, and concise manner. Points will be deducted for reports that are

sloppy, unclear, or missing information. Do not submit screenshots of the Simulink Scope. Plots must be generated in MATLAB with titles, axis labels, and units.