**EE/AA 448: Sensors and Actuators**

**Laboratory Module #7**

# Modeling the Pendulum Rig

**Assigned: Feb. 19, 2007**

**Due: 12:30 PM, Tuesday Feb. 26, 2007 (In Cclass)**

**WARNING**: THE PENDULUM RIGS HAVE POWERFUL MOTORS AND CONTROL BIG PIECES OF FAST MOVING ALUMINUM. THEY RUN ON HIGH VOLTAGES AND STRONG CURRENTS. DO NOT DO ANYTHING UNLESS YOU KNOW APPROXIMATELY WHAT WILL HAPPEN WHEN YOU DO IT. WORK IN TEAMS. BE CAREFUL!!!!

## Objectives

The objective of this lab is to design a PID controller that controls the pendulum near the top of its workspace. You will then tune the controller to give you the best performance possible.

## You Will Need...

To complete this module, you will need

1. A pendulum rig
2. A power supply
3. An I/O card and workstation

## Obtain a New Model

Alter the equations given last week so that they describe the pendulum pointing upward as the rest position, instead of pointing downward. Simulate the system and make sure that it has the expected behavior. Also, linearize the system around the new zero point. Obtain a transfer function at this point and explain the poles and zeros.

NOTE: The pole-zero plot I wrote on the board last week was probably not right. I just wanted to emphasize that the system you are trying to control is unstable!

## Design a PID Controller

Design a PID controller for your system using something like sisotool. Start with a system that stabilized the pendulum, but is not too agressive.

Put the controller into your nonlinear Simulink model. Also, add a $[-3, 3]$ ampere threshold to $u$ (that is the limit of our power supply). Simulate step responses of between $\pm\pi/8$ or so.

Vary the parameters (one at a time and several at a time) in your system and make sure that your controller still works even when your paramters are way off (say by 50%). Determine which changes in the parameters cause the worst performance hit.

## Set Up The Hardware and Find a Safe Routine

Make sure the penulum rig is set up as follows:

1. The potentiometer reset point is when the pendulum is pointing straight down.
2. The limit swtich is set so that if the pendulum is pointing straigt up, the switch allows current to flow.

Determine a way to SAFELY hold the pendulum straight up while your partner(s) gets ready to turn on the code. Count "one", "two", "three" and simultaneously start your code and let go of the pendulum.

At first, make sure your code stops after a few seconds and sends 2.048 V to the I/O card to stop the motor. Later, increase the running time of your controller.

Have someone else near a swtich to turn off the pendulum if something goes wrong. Make sure all the wires are out of the way.

## Test and Refine Your Controller

GOAL: MAKE IT WORK THE FIRST TIME YOU TRY IT! PRETEND THIS IS A MARS LANDER AND THAT YOU CAN'T JUST TRY AGAIN IF IT DOESN'T WORK.

Implement your controller in m-code with a time-limit of about 2 seconds at first (to make sure it doesn't do anything totally strange). Before you run it, all lab partners should read through the code about five times to check for bugs.

One you get it to work, tune the gains in simulation and then on the hardware to get a fast settling time, zero steady state error, and no more than 2% overshoot.