ASEN 4114/5114 Project 1

The purpose of this project is to apply frequency domain modeling and design methods to control attitude of a spacecraft mockup. A combination of analytic and empirical modeling will be used to obtain a transfer function representation of the spacecraft dynamics. A controller will then be designed using frequency response methods, then implemented in real-time control on the hardware mockup. Measured responses will be compared to simulated responses. Colocated versus non-colocated control issues will be explored.

The project will be carried out in small teams. Each group will be assigned a specific module which they are to use for the whole project. Groups will be given access to the modules during weekly lab periods, and at other times as needed. Instructions for running the real-time control software needed for implementation (Part 6) will be given to each group after they have demonstrated simulation of a stable closed loop system. Groups may schedule additional time on their modules outside of class after they have demonstrated care and proficiency in running the module during lab periods.

A single report will be submitted by each team. The report should include an introduction, separate sections for each of the following parts, and a conclusion pointing out interesting aspects or difficulties. All team members should contribute approximately equally to the conduct of the project and the write-up. **The report is due Monday, April 4 at 11:59 PM.**

1. [10 pts] Convert the analytic state space model of the spacecraft mockup developed in Homework 6 (with adjusted parameters) into a transfer function model. Further adjust poles and zeros in this model to better approximate the empirical frequency response (i.e. to account for damping) provided by the Labview VI, for frequencies up through the first resonance/anti-resonance.

2. [10 pts] Given the "tuned" analytic model, repeat the empirical frequency response measurement, being careful to use a long enough wait period and enough measurement cycles to produce accurate frequency response measurements, using the analytic model as a guide, especially near the resonance. Also, pay careful attention to the "mode shapes" of all vibration modes, and annotate the frequency response accordingly. Re-tune the analytic model slightly, if needed. Show the resulting frequency responses of the analytic and empirical models on the same Bode plot.

3. [10 pts] Examine the two loop transfer functions (analytic and empirical) via Bode plots and Nyquist plots using a proportional controller $C(s)=K$. Would the control system be stable for some values of K? For all values of K?

4. [20 pts] Design a compensator $C_1(s)$ so that the unity feedback control system with $C(s)=KC_1(s)$ has at least 40 deg phase margin, 10 dB of gain margin, and a closed loop (-3 dB) bandwidth as close to 1 Hz as possible. Use the analytic plant model in this design. Compute and plot the closed loop tracking frequency response.

5. [10 pts] Repeat part 4 using the empirical plant frequency response. Adjust the control design as necessary to maintain the stability and performance objectives.

6. [20 pts] Simulate the analytic model in a unity feedback control loop in Simulink using this control design. Plot the responses to a 0.5 rad step input, and to single-sinusoid inputs at 0.5 Hz and 2.0 Hz, each with amplitude 0.5 rad. Also plot the torque input signal, along with its limiting values.

7. [15 pts] Test your control design on the hardware by first converting your continuous time controller *C(s)* to a discrete time controller C(z) using Matlab's c2d function, with a sampling frequency to be provided. Enter the coefficients of this controller into Labview and capture the response corresponding to those simulated in Part 5. Plot simulated and measured responses on the same graph and discuss comparison.

8. [10 pts – graduate credit only] Suppose the spacecraft had a model where the first resonance occurred before the anti-resonance in frequency. Sketch this Bode plot, and determine if your controller designed in Part 4 would produce a stable system. Comment on the difficulty of achieving the above closed loop stability and tracking bandwidth performance with this "non-colocated" plant.