MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Aeronautics and Astronautics
16.30: Estimation and Control of Aerospace Systems
Spring 2004

Lab 2: The Elevation(θ) and Travel(ψ) Loops
Due: 05/07/2004

Administrative

The machines are located in the lab**.** The lab is open 9am-5pm weekdays. There will be a TA available for you in the lab on Wednesdays 3-5pm. You can do this lab individually or with one partner. The competition part is optional and will take place during the last class on May 12th. If you want to participate in the competition, you need to use machine **Q3**.

Objectives

1. The objective of this lab is to design a controller which would control the elevation(θ) and travel(ψ) loops of the Quanser.
2. To win the student competition described below.

Lab Procedure

In the first lab you have designed a controller for the elevation loop of a Quanser. You found two complex poles near $j\omega$ axis and a motor pole further in the LHP. The elevation and the pitch loop are very similar and the same controller can be used for both with the gain adjusted appropriately. So:

1. The template file is in /work/16.30/base/lab2.mdl directory.
2. If needed, improve your elevation controller. In particular, make sure you have a Type 1 system.
3. Adjust the controller you have developed for the elevation axis and use it to control pitch. The pitch compensator used by you in Lab1 has the following structure:

$$G_\phi = Gain\frac{\frac{s}{(0.3} + 1)}{s}\frac{(s+1)}{(\frac{s}{10}+1)}$$

   You may use this as a template, but don't forget to adjust it accordingly for a particular machine.
4. With the pitch loop closed, consider the "plant" for the travel loop to be the transfer function from the pitch reference input to the travel output, i.e. the output of the travel controller will be the reference input to the pitch loop. Thus the closed-loop system of the pitch loop is part of the open loop "plant" for the travel loop as shown in the diagram below. Add a limiter to pitch reference input to limit that signal to some reasonable value. (Start out limiting it to $\pm 30°$ and then maybe after you have a stable loop you can increase it.) Identify the transfer function from the pitch reference input to the travel output however you wish and build a stable control loop for the travel. You will no longer have an external reference input for the pitch; you will have a reference input for the travel. Try to make your travel loop be as wide a bandwidth as you can. The elevation loop remains as it was designed in the previous lab.
5. Your job is to produce a final control design that is as good as you can or care to make it. Do what you need to do and report what you think is important. To test your final design, you may obtain and record the closed loop response to the following commands:
   (a) Start out at hover $[\theta, \psi] = [0{,}0]$.
   (b) Command $[\theta, \psi] = [10°{,}0]$.
   (c) Command $[\theta, \psi] = [0{,}0]$.
   (d) Command $[\theta, \psi] = [0{,}5°]$.
   (e) Command $[\theta, \psi] = [0{,}-15°]$.
6. Once you have designed your controller, proceed to do the competition.

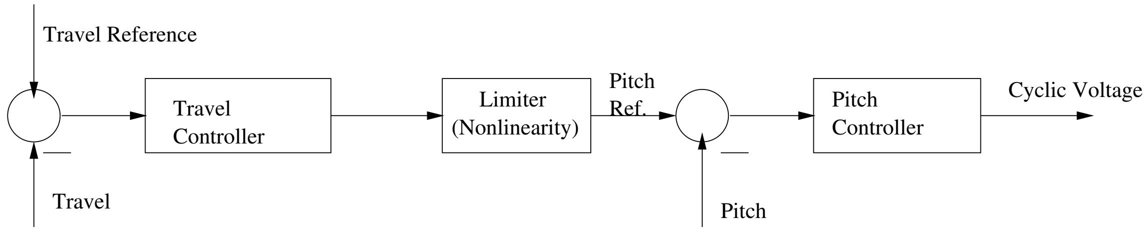

Figure 1: Sample controller structure

Competition

The competition part is optional, but there are prizes:

- **FIRST PLACE:**
  Each lab partner gets a free dinner for 2 in the Summer Shack *without* Prof. Feron.
- **SECOND PLACE:**
  Each lab partner gets a free dinner for 2 in the Summer Shack *with* Prof. Feron.
- **THIRD PLACE:**
  Each lab partner gets a Top Gun DVD or equivalent.

You are asked to make Quanser (**Q3**) go around two points in the phase plane, marked by dots in Figure 2. The location of the dots is [Elevation, Travel] = [0,-40°] and [0,40°]. The reference trajectory is for you to pick (a sample one is drawn in the figure). The competition will be judged based on two criteria:

1. The minimum time it takes your system to go around the specified points in phase plane 10 times in a row. Where "go around" is defined such that $0 < a \leq 5°$ and $0 < b \leq 10°$.
2. You will be disqualified if the machine hits the table.

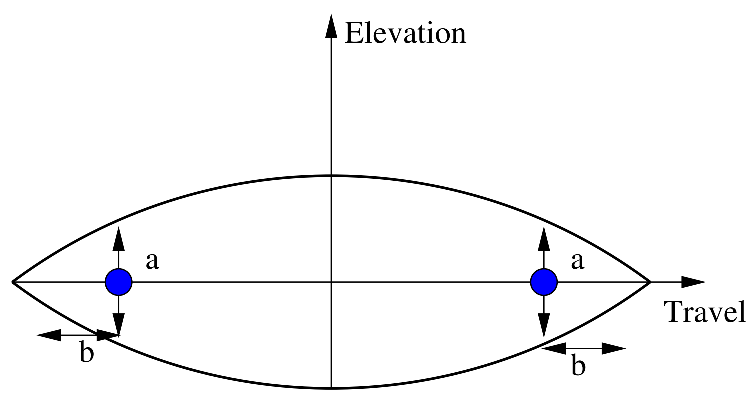

Figure 2: A Phaser Plane Description

Turn-in Requirements to be graded

You should include the following into the lab write-up:

1. Your final controller structure complete with the transfer functions for all components.
2. The closed loop response of the system to the commands described in "Lab Procedure" section. Tell us what we need to know about your design and the performance.