16.30 LAB #2: QUANSER 2 ELEVATION AND TRAVEL LOOPS
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Objectives

1. To design a controller which would control the elevation (θ) and travel (ψ) loops of the Quanser.
2. To win the student competition.

Elevation Control

The elevation control is based upon the results of a previous lab and adjusted to fit the dynamics of Quanser 2. The lead-lag control transfer function is indicated in Equation 1.

$$Elevation\ Control\ TF = 3\frac{10s+1}{s}\frac{s+0.7}{0.05s+1} \qquad (1)$$

Pitch Control

The pitch control is also based upon the results of a previous lab and adjusted to fit the dynamics of Quanser 2. The lead-lag control transfer function is indicated in Equation 2.

$$Pitch\ Control\ TF = 12.66\frac{s+0.6138}{s}\frac{s+0.4}{s+20} \qquad (2)$$

Travel Control

With the pitch loop closed, the plant for the travel loop is the pitch transfer function because the travel is actuated by pitching the Quanser while maintaining Quanser speed. The travel control is based on PID (which is also lead-lag). The PID control transfer function is indicated in Equation 3.

$$Travel\ Control\ TF = -2\left(2+\frac{0.02}{s}+2s\right) \qquad (3)$$

A limiter is added to the pitch reference input to limit the signal to some reasonable value. A saturation non-linearity in used, with limits of ± 0.9 rad, or $\pm 51.6°$.

Resulting System

The overall Quanser controller model is shown in Figure 1.

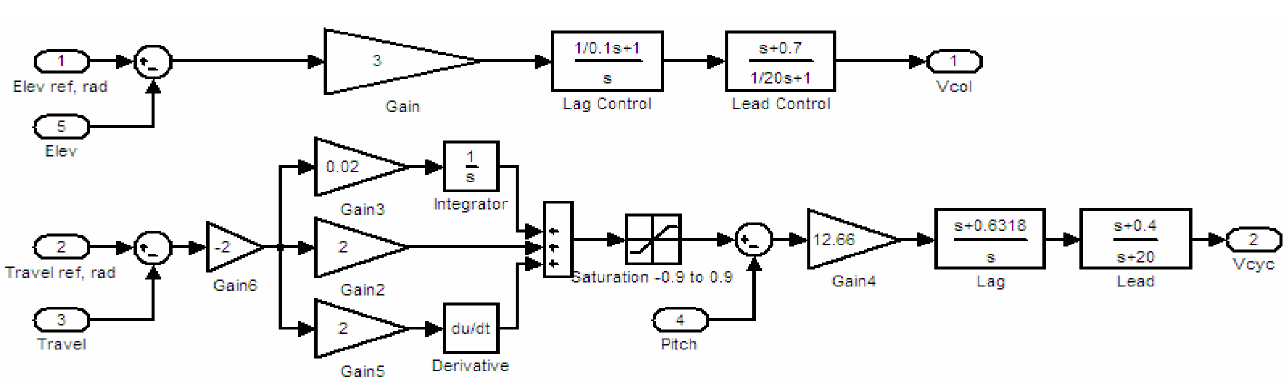


Figure 1. Quanser Controller

Test Final Design

These are the commands given to test the controller:

1. Start out at hover [θ, ψ] = [0°, 0°]
2. After 30 seconds, Command [θ, ψ] = [10°, 0°]
3. After 50 seconds, Command [θ, ψ] = [0°, 0°]
4. After 70 seconds, Command [θ, ψ] = [0°, 5°]
5. After 90 seconds, Command [θ, ψ] = [0°, -15°]

Output of Test

The result of the test is shown in Figures 2a – 2c. The elevation control response shows a 5 second settling time, with no overshoot. The travel control response has a settling time of around 6 to 8 seconds, depending on the distance of travel. There is about a 1.1° tracking error, which was considered insignificant for the purposes of this lab.

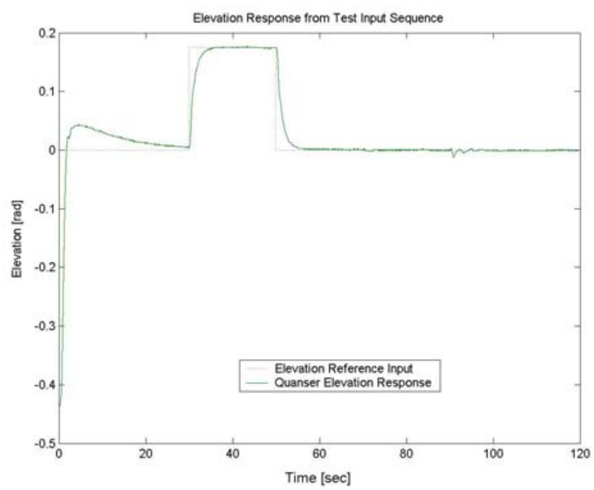


Figure 2a. Elevation Response

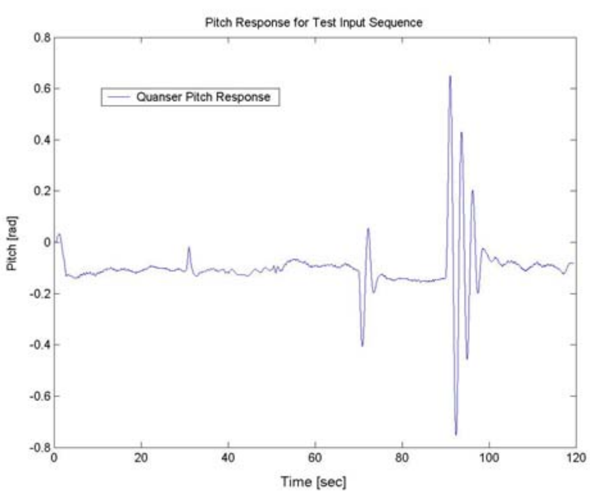


Figure 2b. Pitch Response

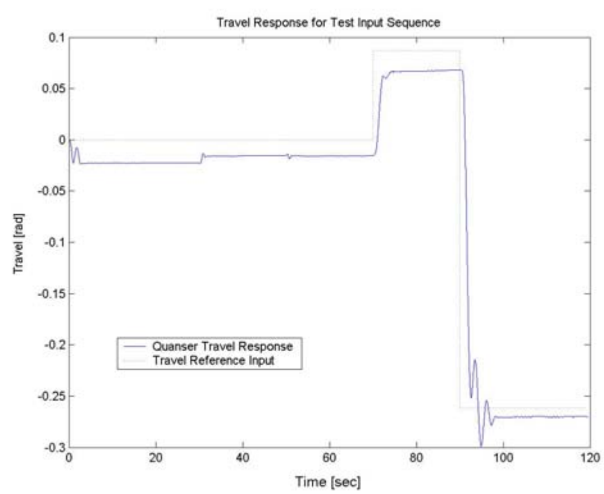


Figure 2c. Travel Response

Figure 2a – c. Test results for final design

STUDENT QUANSER CONTROL COMPETITION

Objective: Make Quanser (Q3) go around two points in the phase plane, marked by dots in Figure 3. The location of the dots is [Elevation, Travel] = [0°, -40°] and [0°, 40°].

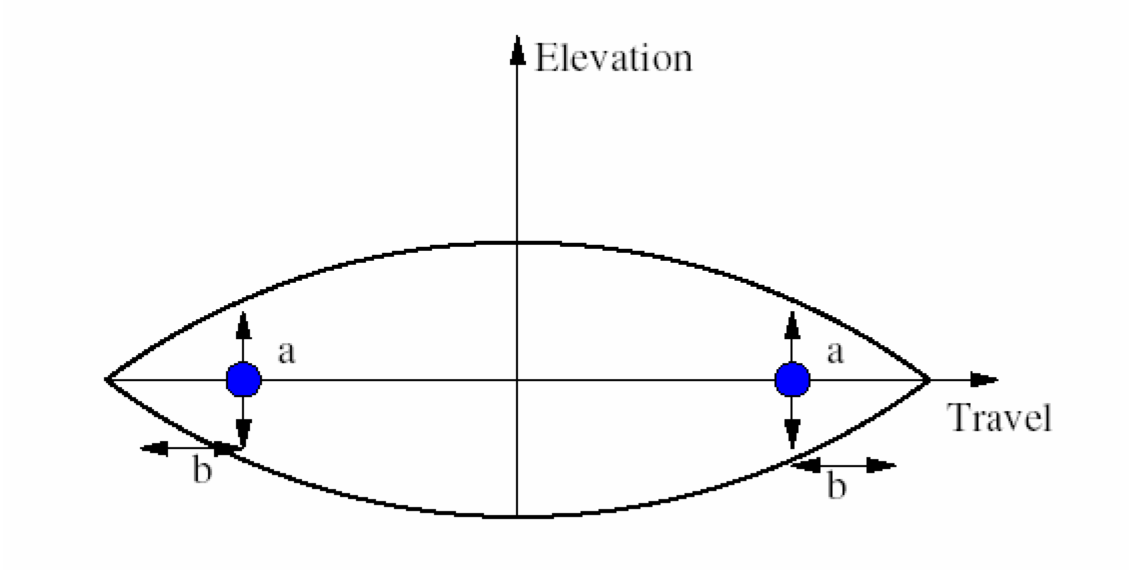


Figure 3: Phase Plane Description of Competition Objective

Reference Input Trajectory

In order to go smoothly around the two points [0°, -40°] and [0°, 40°] as indicated in Figure 1, sinusoidal inputs are used for both the elevation and travel. The phase between the two are offset by 90 degrees so that the Quanser will make an oval-shaped trajectory around the two points. The input functions are as follows:

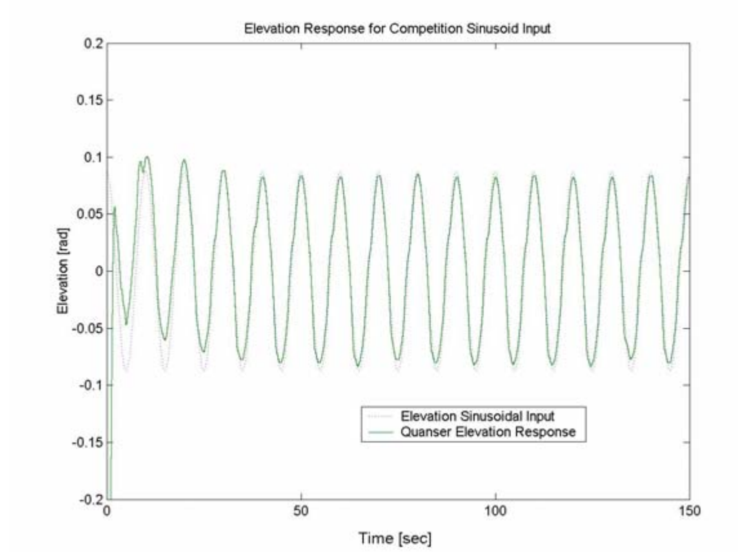
Elevation: $\left(\frac{5\pi}{180}\right)\sin\left(\frac{2\pi}{10}t+\frac{\pi}{2}\right)$

Travel: $\left(\frac{40\pi}{180}\right)\sin\left(\frac{2\pi}{10}t\right)$

Competition Control Output

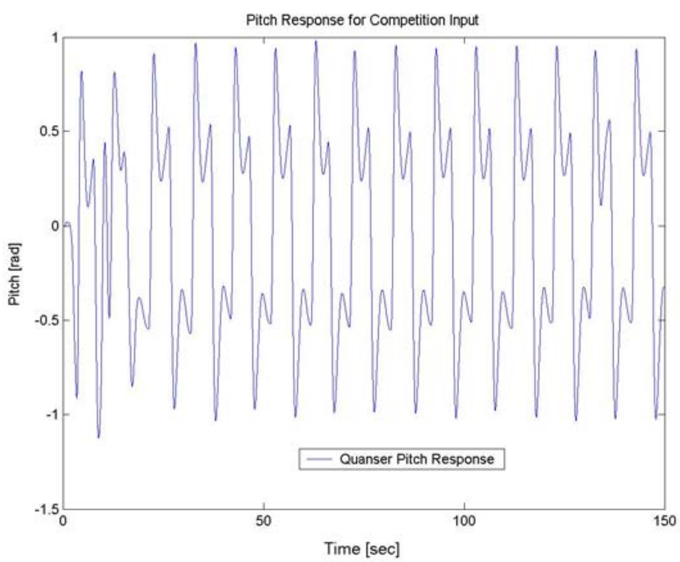
The time it takes the controlled Quanser to make 10 consecutive revolutions (0° < a < 5° and 0° < b < 10°) around the specified points in the phase plane is 100 seconds.

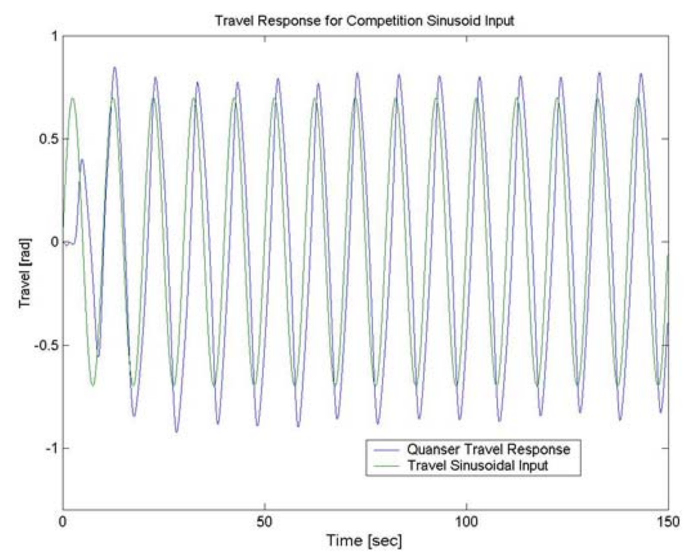
The elevation, pitch, and travel responses are shown in Figures 4a – c. The trajectories in the Phase Plane are shown in Figure 5. The travel response has a small phase lag. The Quanser still performs the function of traveling around the two specified points, but a simple way to make the response trajectory more symmetric around the two points would be to use a travel input with some phase lead.



Figures 4a – c. Responses from competition inputs

Figure 4a (left). Elevation Response
Figure 4b (left below). Pitch Response
Figure 4c (below). Travel Response





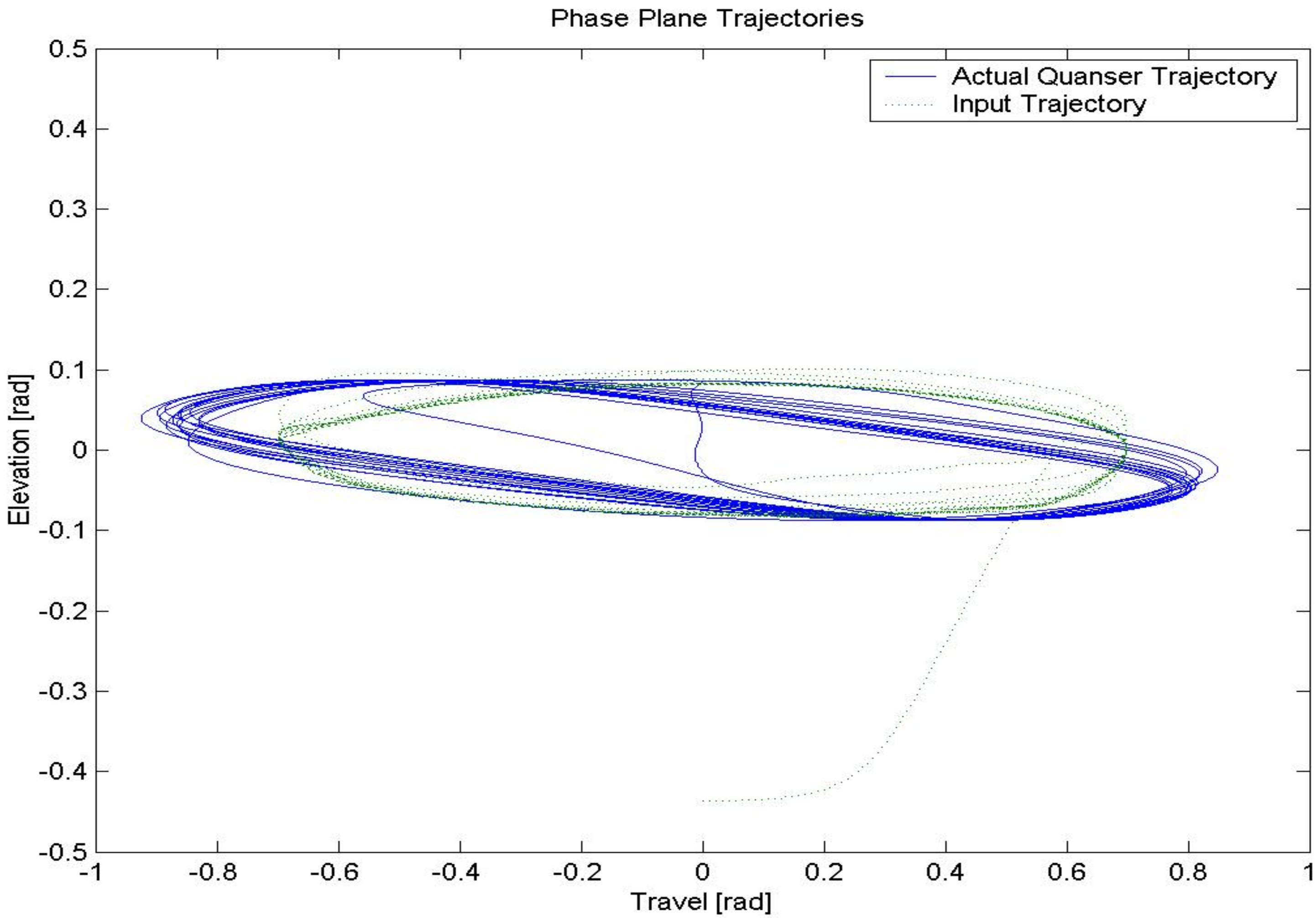


Figure 5. Elevation & Travel Phase Plane Trajectories