**MEMORANDUM**

**TO:** Dr. Bedillion

**FROM:**

**DATE:** April 27, 2018

**RE:** MLC Laboratory

A paragraph or two here should transmit the laboratory report. You should think of this as the report abstract.

This report has been proofread by all members of the group:

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Print Name Signature and Date

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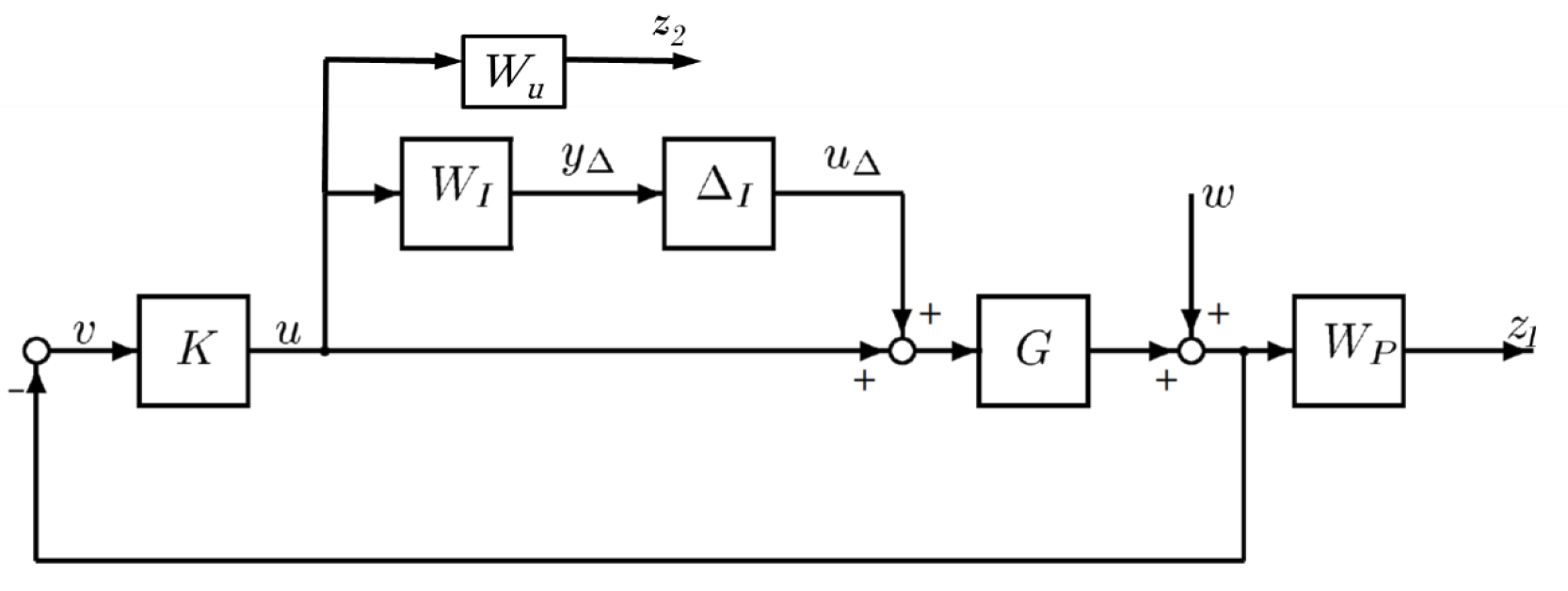
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Introduction

In this lab, we investigated the performance of various controller generation techniques on the Quanser Aero. The Quanser Aero is a DIDO system consisting of two fans mounted perpendicularly on opposing ends of a 2DOF lever arm. The system is able to move about its pitch and yaw axes, with the voltages of the two fans used to control its motion. In this lab we employed loopshaping, H2 synthesis, H∞ synthesis, μ synthesis, and H∞ loop shaping in order to make the system track a desired trajectory.

For all parts of this lab, the desired trajectory consisted of square waves with a pitch angle of π/6 radians and a frequency of .4 rad/s, and a yaw angle of π/4 radians with a frequency of .5 rad/s. The control configuration for the plant is shown below.



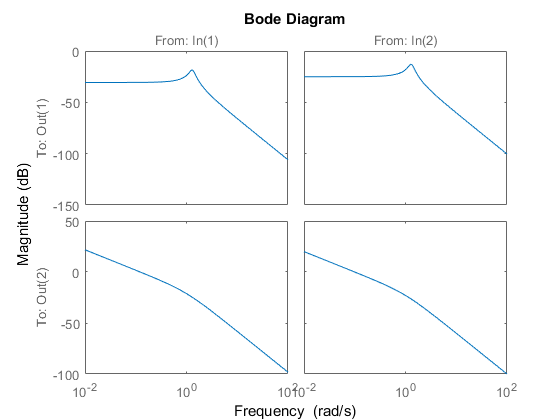
The performance weight was designed to reject DC disturbances by a factor of 100 while keeping sensitivity peaking below 3, and the control weight was set to ensure controller usage did not exceed the maximum system voltage of 25 V.

Preliminaries

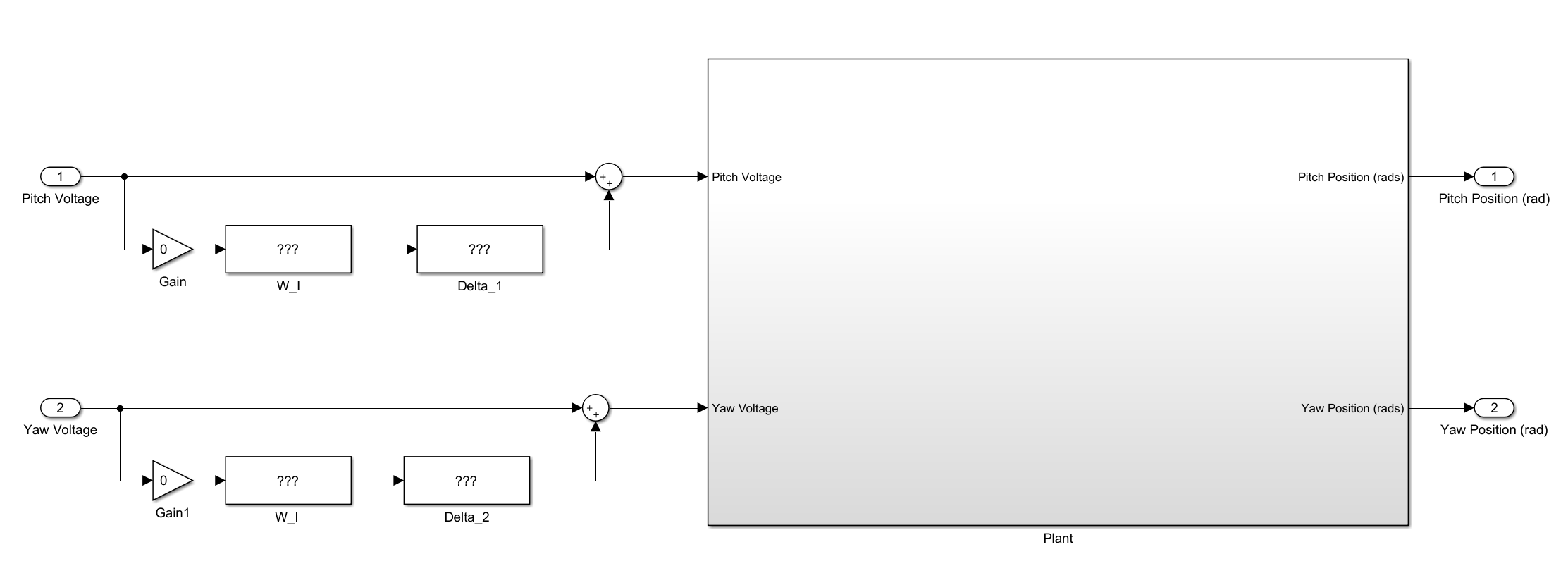
1. First, we found the poles and zeros of the nominal plant. We found that there are no zeros, and the poles are all in the closed left half plane. The poles are:
   * -0.1625 + 1.2982i
   * -0.1625 – 1.2982i
   * -1.0004
   * 0

As there are no RHP poles or zeros, we do not have any fundamental control limitations due to waterbed effects.

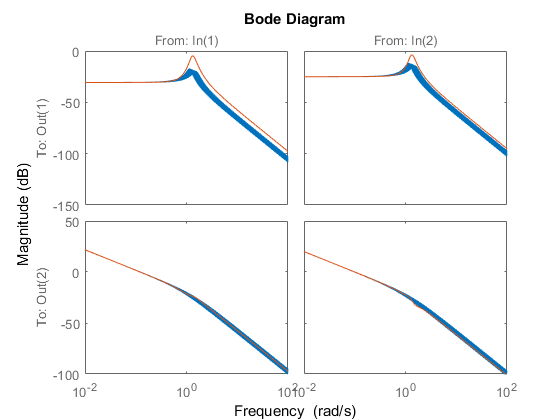
1. Below is shown the Bode plot for the nominal plant. Note that there is a peak at 1.34 rad/s, due to the complex conjugate pair of poles. Output direction one always has negative gain, so it will have poor tracking at DC.



1. We next built a Simulink model based on the nominal plant, including a saturation nonlinearity to limit the voltages to +/- 25V.



1. Given 30% uncertainty in Jp and Jy, we built an uncertain model of the plant and fit input multiplicative uncertainty weights using *ucover*. Below, you can see samples from the uncertain plant (blue) plotted with the plant fit with our generated uncertainty weight (red).



Loop Shaping

We first generated an inverse-based controller using classical loopshaping, using a desired loopshape of Ld = wc/s. The crossover frequency was initially set to 5 rad/s. As the generated controller was improper, with a zero excess of 2, we added a repeated high frequency pole at 1000 rad/s to make the controller realizable. Thus our controller is

1. Below, you can see the output of our simulation with the described controller implemented.

[plot here]

1. Next, we tested the system for robust stability by running it on 10 samples of the uncertain plant.

[plot here]

Your "Informal Laboratory Report" should start here. It should be organized in terms of numbered items in the lab procedure. For each numbered item in the lab procedure you must address the following items at a minimum:

1.) A brief description of the goals of the lab exercise, and the equipment and procedure used to achieve those goals. The equipment can be specified once per subsection, i.e. describe the pendulum system only once, not *n* times.

2.) The details of all calculations involved in generating your results. Be sure to highlight the main results.

3.) Presentation of your results in the form of plots and tables. This should include all relevant plots and Simulink models. Do not present plots that use the black background that is the Simulink scope default. Place in-line links to your Youtube videos for video results.

4.) General discussion. What sense do you make of the results? What can you conclude?

5.) Answers to all of the discussion questions in the lab procedure.

After completing these tasks for all numbered items in the lab procedure, complete the following sections to finish your report:

• Conclusions: What were the main results? What did you learn (if anything) by completing the lab? What suggestions do you have to make the lab better or more interesting?

• Work Distribution: To what specific tasks did each team member contribute? Address this for both the laboratory exercises and the report writing.

• References: Compile all of your references into a single section at the end of the document. I highly recommend the use of a reference manager, e.g. Bibtex, EndNote, etc.

• Appendix: Attach scans of any hand calculations and copy and paste any Matlab / Arduino code. This is simply for ease of grading; you will also be posting the code files in your .zip file.