PREFACE

Preparing laboratory experiments can be time-consuming. Quanser understands time constraints of teaching and research professors. That’s why the Quanser AERO experiment comes with a new generation of mix-and-match courseware that allows easy adaptation of material to a specific course. The courseware is also aligned with requirements of ABET accreditation. All this allows professors to get their labs running faster, saving months of time typically required to develop lab materials and exercises.

Quanser AERO courseware provides step-by-step pedagogy for a wide range of control challenges. You can select a pre-defined lab sequence where students start with the basic principles and progress to more advanced applications of control theories. Or you can select a specific topic and use the exercises to supplement the theory students learnt in class with hands-on experience in lab.

This courseware sample based on the material prepared for users of MATLAB®/Simulink® software.

The Quanser AERO courseware is aligned with requirements of ABET accreditation.

This document provides an abbreviated example of background and in-lab exercise courseware sections for the Quanser AERO experiment. Please note that the examples are not complete as they are intended to give you a brief overview of the structure and content of the courseware you will receive with the QUBE-Servo 2.

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1. Quanser AERO Courseware Content

The Quanser AERO courseware includes the Instructor and Student Workbooks with complete exercises and Laboratory Guides for more advanced applications, with modeling and control design examples:

System Integration Workbook

1. Background
   1.1. QUARC Software
   1.2. DC Motor
   1.3. Encoders
   1.4. Tachometers
2. IN-Lab Exercises
   2.1. Configuring a Simulink Model for the Quanser AERO
   2.2. Driving the DC Motor
   2.3. Reading the Tachometer

System Identification Workbook

1. Background
   1.1. Torques Acting on the Quanser AERO
2. In-Lab Exercises
   2.1. Measure the Thrust Constant
   2.2. Find Natural Frequency
   2.3. Measure Viscous Damping
   2.4. Model Validation

First Principles Modeling Workbook

1. Background
2. In-Lab Exercises

Gain Scheduling Workbook

1. Background
   1.1. Nonlinear Systems
   1.2. Linear Approximation
   1.3. Gain Scheduling
2. In-Lab Exercises

Measurement and Filtering Workbook

1. Background
   1.1. Inertial Measurement Unit
   1.2. Measuring Pitch Using Gravity
   1.3. Approximating Pitch Using Angular Velocity
   1.4. Low-pass Filtering
2. In-Lab Exercises
   2.1. Filtering

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3. Background Section - Sample

Measuring and Filtering Workbook

Inertial Measurement Unit

An Inertial Measurement Unit (IMU) is a combination accelerometer and gyroscope with coincident axes. Measuring the acceleration in each linear axis along with the angular velocity about those axes allows for a complete description of the attitude of the sensor.

The internal IMU in the Quanser AERO represents how a flight system would sense its attitude more realistically than the encoders since a vehicle in flight lacks an unmoving base from which such encoder measurements could be made.

The Quanser AERO IMU is located in the center of the AERO body, in line with the axes of rotation. For the purposes of measuring and controlling pitch, we are primarily interested in the acceleration along the X and Z axes, and the rotation about the Y axis as shown in Figure 1.1.

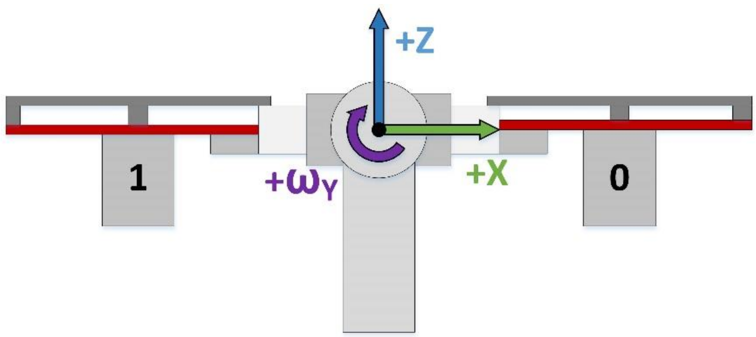

Figure 1.1: Pertinent IMU axes

Measuring Pitch Using Gravity

Since the aero body is immobile, it can be assumed that the only linear acceleration affecting the IMU will be a result of gravity. The accelerometer measures the acceleration along the three principle axes, however since the Y axis will always be perpendicular to the acceleration of gravity we are only interested in the X and Z axis accelerations. If the Aero body is pitched to an arbitrary angle θ the acceleration of gravity a_g can be separated into two perpendicular accelerations acting along the X and Z axes according to the equations

$$a_x = a_g \sin(\theta), \tag{1.1}$$

$$a_z = a_g \cos(\theta) \tag{1.2}$$

Dividing a_x by a_z and solving for theta we get

$$\theta = \tan^{-1}\left(\frac{a_x}{a_z}\right) \tag{1.3}$$

Approximating Pitch Using Angular Velocity

In many cases, such as when a vehicle is accelerating vertically, or when measuring yaw, there is no way to use acceleration to calculate the angular position of the vehicle. In this case the position is often approximated by integrating the angular velocity measured by the gyroscope. In this way the angle at time t is given by

$$\theta_t = \theta_0 + \int_0^t \omega dt \tag{1.4}$$

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4. In-Lab Exercises - Sample

Qualitative PID Control Workbook

Integral Control

1. The response should now approach the commanded value quickly and settle in a short time. However even with a large proportional gain, the final position of the Aero still differs from the command value by approximately 0.5 radians to combat this steady-state error, add an integrator with an integral gain k_i in parallel with the other two gains as shown in Figure 2.5.

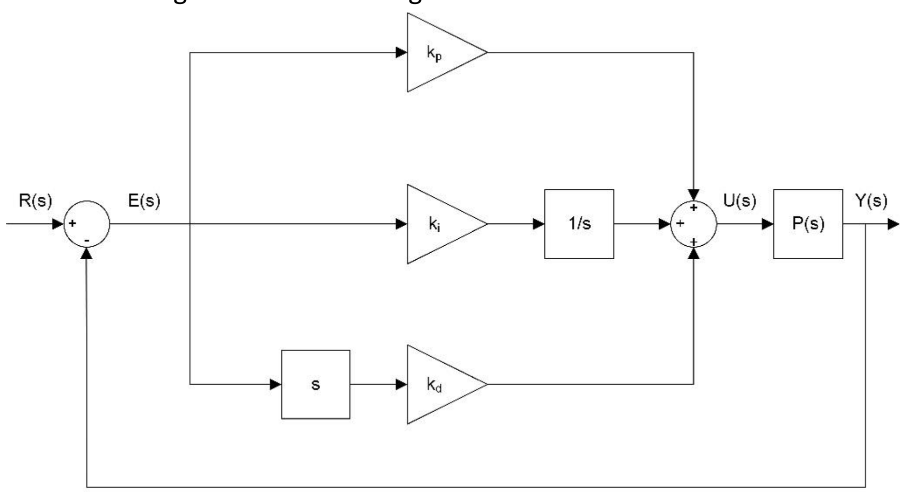

Figure 2.5: PID gains in feedback loop

2. B-5, B-2 Keeping the proportional and derivative gain at the values identified in step 5 vary the integral gain between 0 and 10. Run the QUARC® model with various integral gains. What effects does increasing the integral gain have on the system response? What happens when the integral gain is increased too much?

Answer 2.5

Outcome	Solution
B-5	To perform the qualitative analysis below, the procedure to modify the controller have been followed properly.
B-2	As ki is increased, steady-state error decreases, but overshoot increases. Increasing the integral gain too much causes the steady state error to increase again and the system to become less stable.

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3. K-1 Given the specification that the system settles within 3% of the command value. For the 0.3 radian square wave this means that the steady state value must be in the range from 0.291 to 0.309 radians. What integral gain results in a system which meets this requirement?

Answer 2.6

Outcome	Solution
K-1	The required integral gain is approximately k_i = 4

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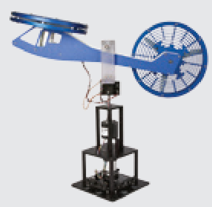
Quanser aerospace and unmanned systems for teaching and research

3 DOF Helicopter

2 DOF Helicopter



3 DOF Hover

QBall 2

Unmanned Vehicle Systems Lab

These systems allow you to study or research traditional and modern controls applications relating to spacecraft, unmanned vehicles, rescue missions and autonomous control. For more information please contact info@quanser.com

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