

ELE320 - Aero

Laboratory Assignment 1

Topics Covered

- Introduction to Quanser Aero
- Low pass signal filtering
- Accelerometer and Gyroscopes
- Approximating position
- Obtaining the equations of motion of the Aero thruster
- Creating and validating a sub-system model
- Model validation

Questions are marked with * and answers to them should be included in your hand-in. The steps without marker are necessary steps to obtain the results.

0. Getting Started

Developing Environment

The assignments will be answered using *Matlab* and *Simulink*.

Requirement: Matlab 2019a or later

Installing and running the Quanser Interactive Labs

To interact with the virtual Aero you have to install and run the Quanser Interactive Labs.

- Make sure Matlab 2019a or later is installed **before** you install Quanser Interactive Labs.
- Go to <https://portal.quanser.com/Downloads> and download the *QLabs Virtual Experiments*
- Install the downloaded file
- If you have not registered an account, go to <https://portal.quanser.com/Accounts/Register> and register with your student-e-mail
 - k.nordmann@stud.uis.no not 1234567@stud.uis.no
- Open Quanser Interactive Labs
- Sign in with your registered account
- Select the virtual Aero

The provided Simulink files are all preconfigured to communicate with the virtual Aero. When working with the virtual model, Quanser Interactive labs must be running to successfully build and run the provided software files. If you wish to apply your model to the physical plant, see the dedicated document in Canvas.

Configuring the virtual Aero

To switch between the different configurations, click the settings button in the upper right corner.

All the mandatory exercises in this course will use the following configuration:

Simulation Options

- Lock pitch
- Lock yaw
- Helicopter configuration
- High-efficiency propellers

1. Measurement and Filtering

To demonstrate and operate on realistic IMU measurements, the measurements output by the subsystem are logged values from the physical Aero. In chapter 1, the virtual Aero only serves to visualize the motion of interest.

Filtering

- 1.1 Run `aero_hardware_data.m` and open `q_aero_attitude.slx`. The *Matlab* script contains the logged data from the physical plant. The *Simulink* model contains a subsystem which commands the Quanser Aero to follow a ± 0.3 radian square wave starting at $t = 5$ s and outputs the measured values for X- and Z-axis acceleration, as well as the pitch (Y-axis) gyroscope angular velocity. The pitch encoder reading is also output for comparison.
- 1.2 Open the virtual Aero in the *Quanser Interactive labs application* and run the model in *Simulink*.
- * 1.3 Plot the signal from the X-axis accelerometer (saved in the array `out.XData` in the *Matlab* workspace) in the time period between $t = 1$ s and $t = 4$ s. Given that the Aero is stationary and level (horizontal) during this period, the X-axis acceleration should be zero in this period, so any non-zero measurements can be attribute to noise. What is the peak amplitude of the noise signal during this period?
- * 1.4 Calculate the standard deviation of the noise over the same period using the `std()` function. This is a more precise measurement of the strength of the noise signal.
- * 1.5 Run `Power_Spectrum.m`. This script performs a fast Fourier transform on the signal from the accelerometer and uses this data to calculate the power distribution of the signal. The resulting graph shows how much power is carried by signal components at different frequencies. The graph should show two peaks, one low frequency, and one higher. What is the likely source of each of these signals? What is the frequency of the noise signal which needs to be filtered? Hint: Think about what the IMU measures and what causes errors in the readings.
- * 1.6 Add a transfer function block between the X Acceleration output and the scope. Set the transfer function to a low-pass filter with a cut-off frequency of 100 rads/s. What is the transfer function for this filter?
- * 1.7 Build and run the model. Recalculate the standard deviation of the noise. How much has the noise been attenuated by the filter?
- * 1.8 Add a Mux block so that the filtered signal can be compared to the unfiltered sensor output. Provide a detailed description of the comparison.
- * 1.9 Vary the cutoff frequency, ω_f , between 10 to 200 rads/s. What effect does it have on the filtered response? Consider the benefits and the trade-off of lowering and increasing the parameter.
- * 1.10 Modify the model to calculate the Aero body pitch from the accelerometer readings using Equation 1.3 in the `AERO1_Preparation` document, and compare the calculated angle to the encoder measurement. How closely does the calculated angle match the reading from the encoder?

2. First Principle Modeling

Thruster model

- 2.1 Open `q_aero_thruster_model.slx`. This model applies a 6-14V, 0.5 Hz square wave to motor 0 and reads the propeller velocity using the tachometer as shown in Figure 2.1

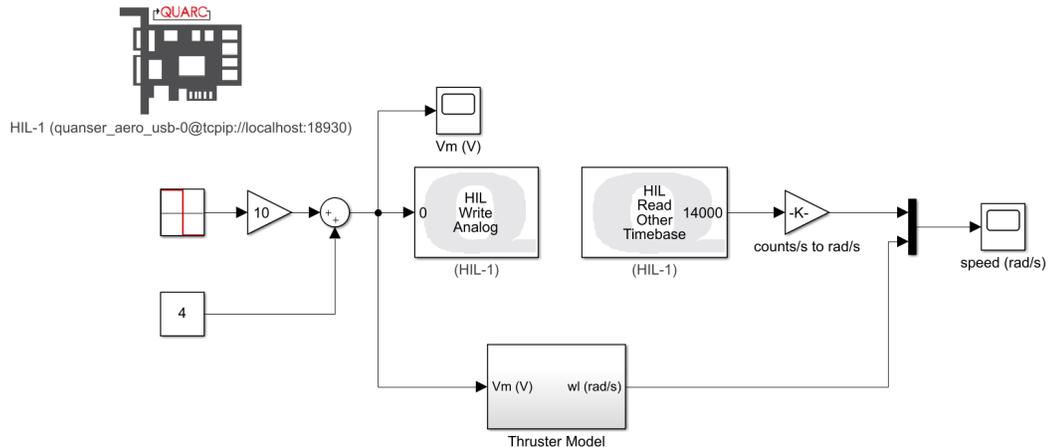


Figure 2.1: Applies a step voltage and displays measured and simulated Quanser Aero speed.

- 2.2 Open the subsystem called `Thruster Model`. The subsystem contains an incomplete block diagram of a thruster system feedback loop model.
- * 2.3 Using the equations given in the `AERO1_Preparation` document, assemble a simple block diagram in *Simulink* to model the system. It may be useful to write a short *Matlab* script that sets the various system parameters so you can use the symbol instead of entering the value numerically in the blocks. Include a screen capture of the complete system.
- * 2.4 Build and run the model. Attach an image of your scopes. Does your model represent the Quanser Aero well?
- 2.5 Stop then close the model.

3. System Identification

Measure the Thrust Constant

- 3.1 Open `q_aero_system_model.slx` and run the model.
- 3.2 Observe as the model applies a 14VDC signal to motor 0 for 30s, followed by 30s of free oscillation with no power to the motor.
- * 3.3 Capture and isolate the angle of the Aero while motor 0 is powered. From the response graphs, record the angle at which the Aero stabilizes and the average angular velocity of the motor at equilibrium. The relationship between the angular velocity of the motor and the resulting thrust is referred to as the thrust constant (K_t) and is expressed in Newton-seconds per rad. Given the physical model above, what is the value of the thrust constant which would result in the measured velocity and angle?

Find Natural Frequency

- 3.4 Returning to the captured system response, isolate the angle response of the Aero after the motor is not powered and the Aero is in free oscillation.
- * 3.5 Measure the average time required for the Aero to complete a full oscillation and calculate the natural frequency.
- * 3.6 Since the Aero body can be modeled as a complex pendulum, the mass moment of inertia can be calculated using the formula:

$$J_b = \frac{M_b D_m g}{\omega_n^2}$$

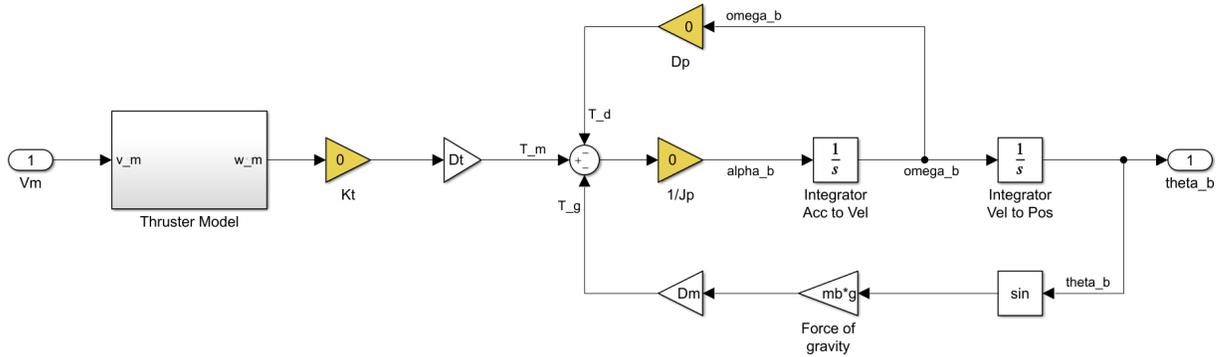
Given the natural frequency ω_n found in step 3.7 calculate the value of J_b

Measure Viscous Damping

- * 3.7 It should be observed that the free oscillation of the Aero represents a damped system. Using the angle response graph, estimate the decay time constant τ_b by measuring the time it takes for the amplitude of the oscillation to decay to $1/e$, or approximately 37% of its original amplitude.
- * 3.8 Given the time constant $\tau_b = J_b / D_b$ calculate the viscous damping coefficient D_b .
- 3.9 Close the Simulink model.

Model Validation

- 3.10 Open and run the `aero_param.m` script in *Matlab*.
- 3.11 Open `q_aero_model_validation.slx`, then open the Aero Model subsystem. Insert your thruster model and enter the values of K_t , $1/J_b$ and D_b to reflect the values found in the previous sections.



- * 3.12 Run the *Simulink* model and observe the output from the model as compared to the actual measured angle of the Aero body. Is the model accurate? If not, what aspects of the Aero may not be accurately modeled? What model values could be tuned to improve the accuracy of the model?
- 3.13 Stop the model and power down the Aero.

Original work by Quanser – modified by Didrik Efstad Fjereide

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Quanser Inc.
119 Spy Court
Markham, Ontario
L3R 5H6
Canada
info@quanser.com
Phone: 1-905-940-3575
Fax: 1-905-940-3576

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