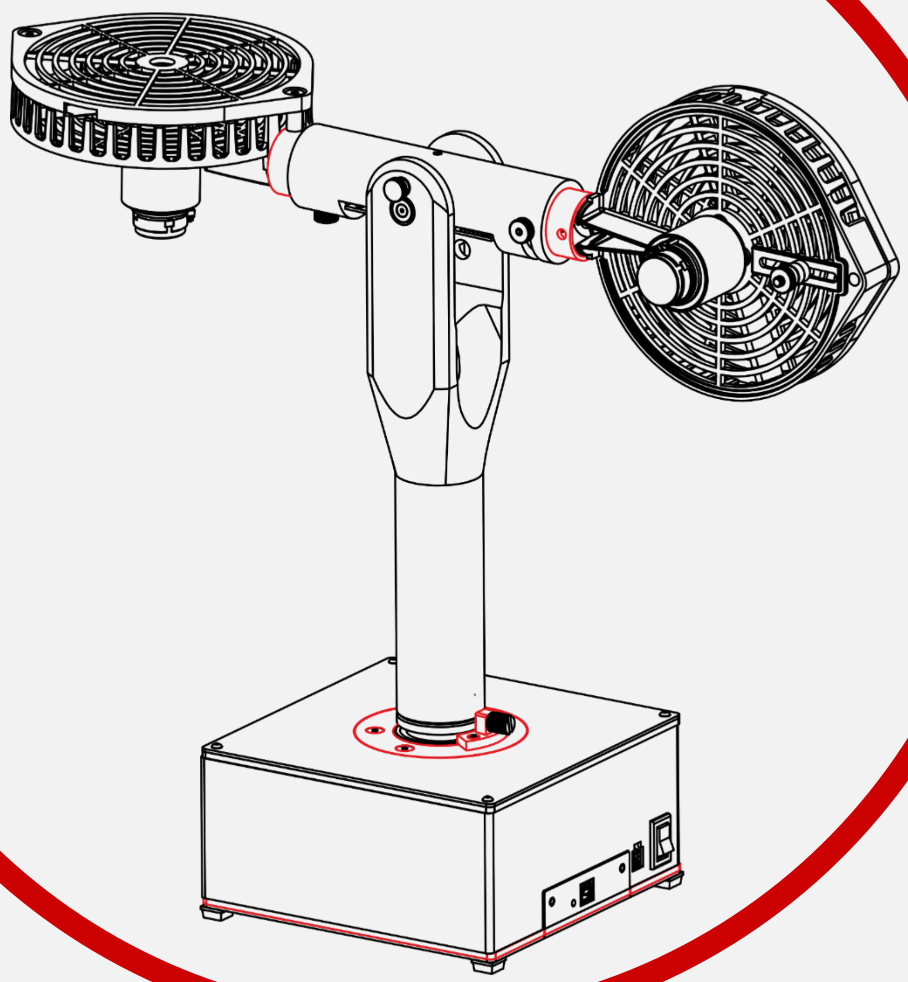

Aero 2

System Block Diagram Modeling

V1.0 – 14th February 2025

Aero 2 – Application Guide
System Block Diagram Modeling

Why Use A System Block Diagram Model?

The analysis performed in the Pitch Parameter Estimation lab models the dynamics of the Aero 2 in terms of a prototypical linear second-order system. This is a very useful skill if you have some idea what the frequency domain response of the system looks like, and how it would map to a prototypical system. However, in some cases, this is impractical, especially if the system is highly nonlinear. In the case of an unknown higher-order system, it may be more practical to approach modelling the entire system using a block diagram as was done in the Block Diagram Modelling lab for the thruster. In this lab we will expand upon the block diagram of the thruster to model the behavior of the entire Aero 2 system in the 1-DOF pitch configuration.

Topics

- Block Diagrams
- Non-linear Systems
- Model Integration
- Model Validation

This lab requires additional reading material to summarize key concepts.

1 DOF Pitch Parameter Estimation

In the Thruster Block Diagram Modelling lab, a model of the thruster/rotor was developed. The output of the thruster model is angular velocity, which does not tell us very much about the behavior of the system as a whole. The free-body diagram of the Quanser Aero when configured as a 1 DOF pitch-only system is shown in Figure 1. The system parameters defined in Table 1. Notice that there we are now dealing with two separate thrusters, applying counteracting forces to the main Aero body, and driving the motion of the system as a whole.

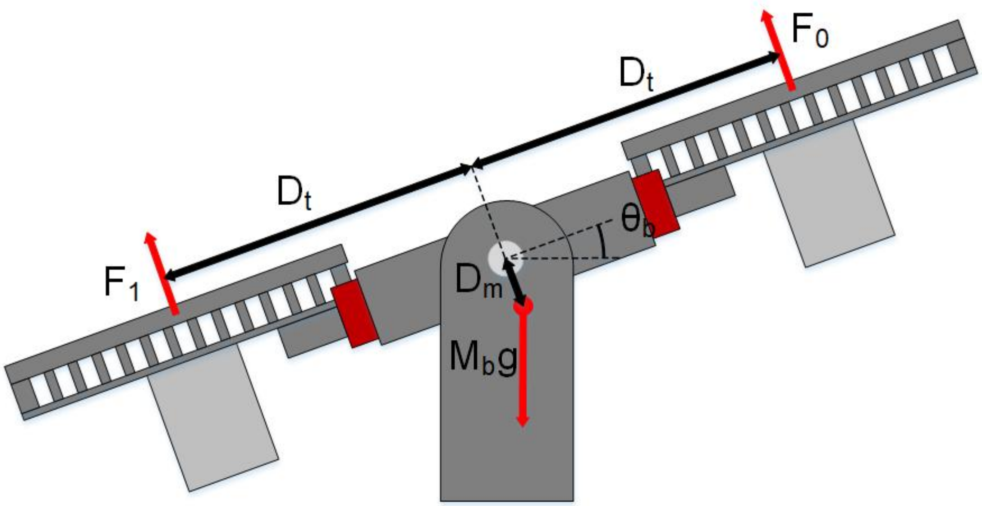

Figure 1 Free-body diagram of 1-DOF Quanser Aero

The key system parameters are summarized here, a full list of parameters can be loaded into the workspace using the included Aero 2 parameters .m file

System	Description	Value
M_b	Aero body mass	1.07 kg
D_t	Thrust displacement	0.167 m
D_m	Center of mass displacement	0.00240 m
J_p	Equivalent moment of inertia of pitch axis	0.0232 N-m/kg
K_t	Propeller thrust constant	0.0003 N-s/rad

Table 1 - Quanser Aero system parameters

Defining the Block Diagram Structure

One useful approach for constructing a block diagram is to start at a high level and break down systems into individual components until you reach fundamental parameters which are known for the system. To begin, we take the simplest model of the Aero 2 system which is shown in figure 2.

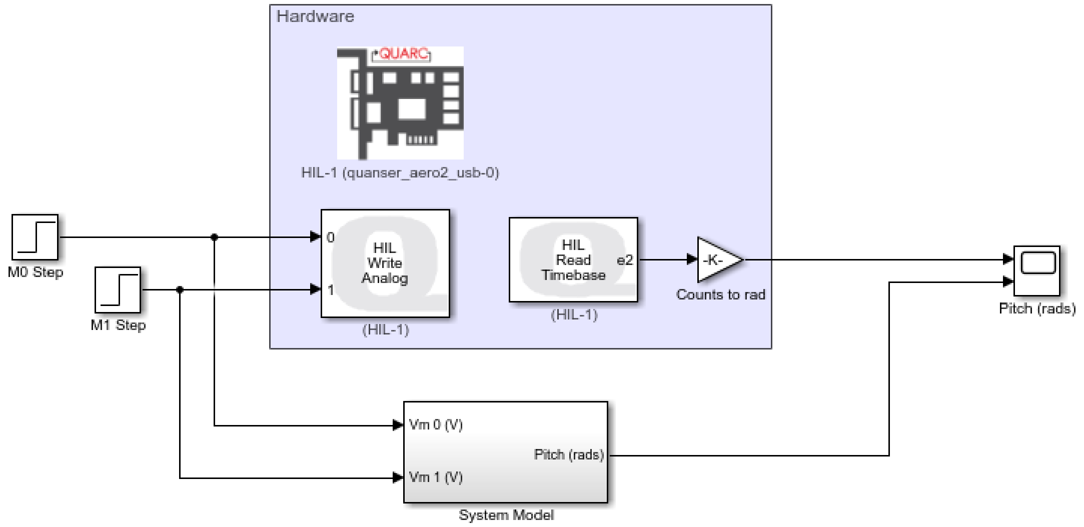

Figure 2: Top-level system model

Notice that this is not a particularly helpful diagram since the system is essentially a "black box" that is, we do not explicitly know what the relation is between the inputs and outputs. However, because we *do* know the relation between the inputs V_M and the resulting propeller velocities we can separate those blocks from the system as shown in figure 3.

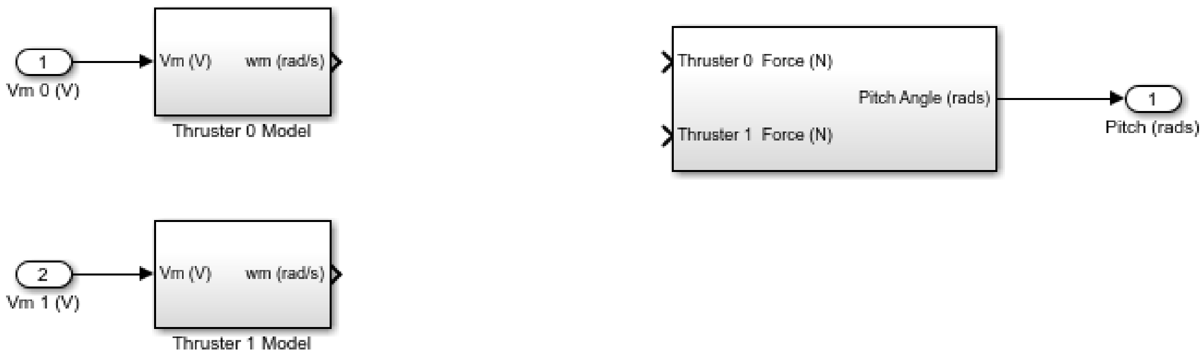

Figure 3: Expanded block model with thruster dynamics

Now we must use the free body diagram shown in Figure 1 to determine the relation between those velocities and the angular position of the pitch axis.

Accounting for Non-Linear Effects

If you have observed the Aero 2 in motion you may have observed that it behaves like a pendulum, oscillating around a marginally stable settling position. This is because the system response has a non-linear component resulting from the force of gravity.

Because the force of gravity is always directly down, gravity will apply a torque to the body which is related to the sine of the pitch angle. Where this dynamic component is impossible to ingetrate into a linear frequency-domain system model, it can be modelled with relative accuracy using a discrete time-based model.

Completing the Block Diagram

Given the free-body diagram in Figure 1 and the thruster model, we should be able to construct a block diagram which relates the propeller velocities to the angular position of the Aero. We will begin with the high-level model shown in Figure 3 and complete the model by connecting the thruster diagrams to the Pitch Dynamics block, and defining the relation therein.