1. QNET VTOL Board Courseware

Dedicating over two decades to the development of systems and solutions for control education and research, Quanser understands curricular needs and time constraints of teaching and research professors. That's why Quanser's QNET Boards for NI ELVIS come with courseware with proven practical exercises. The course materials are designed to save you time, give students a solid understanding of various control concepts and provide maximum value for your investment.

The courseware is supplied in two formats:

- Instructor Workbook – provides solutions for the in-lab exercises and contains typical experimental results from the laboratory procedure. This version is not intended for the students.
- Student Workbook – contains pre-lab assignments and in-lab procedures for students.

The **QNET VTOL courseware** provides step-by-step pedagogy for a wide range of control challenges. Starting at basic principles, students can progress to more advanced applications and cultivate a deep understanding of control theories through real-life applications of the QNET VTOL. The courseware covers topics, such as:

- Experimental Modeling
- PID Control
- Current Control
- Pitch Control

The courseware is prepared for users of National Instruments **LabVIEW™** software.

The courseware is aligned with the requirements of the Accreditation Board for Engineering and Technology (ABET), one of the most respected organizations specializing in accreditation of educational programs in applied science, computing, science and technology. The Instructor Workbook provides professors with a simple framework and set of templates to measure and document students' achievements of various performance criteria and their ability to:

- Apply knowledge of math, science and engineering
- Design and conduct experiments, and analyze and interpret data
- Communicate effectively
- Use techniques, skills and modern engineering tools necessary for engineering practice

The following material provides an abbreviated example of pre-lab assignments and in-lab procedures for the QNET VTOL. 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 plant.

2. QNET VTOL Board Courseware Contents

The Table of Contents of the QNET VTOL Courseware is shown here:

3. Background - Example

Qualitative PI Current Control - Current Control

In cases where the actuator has relatively slow dynamics, such as an electromagnet with a large inductance, it is favorable to design a current controller. Typically a proportional-integral compensator is used to regulate the current flowing in the load. This basically makes the actuator dynamics negligible and simplifies the control design of the outer-loop.

The fan of the QNET VTOL is driven by an internal controller. The resulting behavior can be approximated by the following voltage-current relationship

$$v_m = R_m i_m + L_m \frac{di_m}{dt} \tag{1.1}$$

and by the transfer function

$$I_m(s) = \frac{V_m(s)}{R_m + L_m s} \tag{1.2}$$

Figure 1.2 shows the QNET VTOL current control system implemented. The PI compensator computes the voltage necessary to reach the desired current.

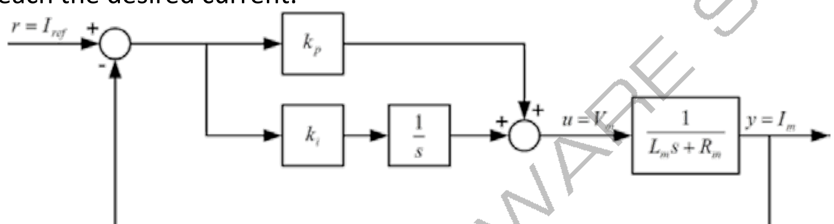

Figure 1.2: QNET VTL motor PI current control loop

Using the PI controller

$$v_m(t) = k_p(i_{ref}(t) - i_m(t)) + k_i \int i_{ref\ (t)} - i_m(t)dt \tag{1.3}$$

we obtain the following closed-loop transfer function

$$G_I(s) = \frac{k_p s + k_i}{s^2 L_m + (k_p + L_m)s + k_i} \tag{1.4}$$

Current Control Virtual Instrument

In this laboratory, current is fed to the QNET VTOL as depicted in Figure 1.3. A current-controller is used to regulate the current in the motor and the user chooses the reference current. Note that the *Current Control On?* switch is *ON* (active).

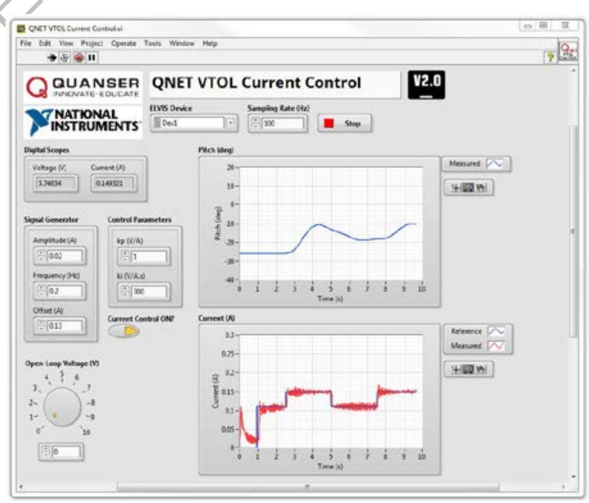

Figure 1.3: Virtual Instrument for QNET VTOL current control

4. IN-LAB EXPERIMENT EXAMPLE

PID Steady-State Error Analysis

1. **A-2** Calculate the QNET VTOL steady-state error when using the PID controller.

Answer 2.3

2.

Outcome	Solution
A-2	The steady-state error of the QNET VTOL when using a PID compensator is given in Equation 1.8, and evaluatingit gives: e_{ss}=0 deg (Ans. 2.5) Thus the integral gain eliminates the steady-state error.

2. Open the `QNET VTOL Flight Control.vi`. Make sure the correct *Device* is chosen.
3. Run the VI.
4. In the *Position Setpoint* section, set
    - Amplitude (deg) = 0
    - Frequency (HZ) = 0.05
    - Offset (deg) = 0
5. In the *Current Control Parameters* section, set
    - kp(V/A) = 10
    - ki (V/a.s) = 700
6. In the *Position Control Parameters* section, set
    - kp (A/rad) = 0.1
    - ki (A.s/rad) = 0.4
    - kd (A.s/rad) = 0.2
7. Let the QNET VTOL stabilize about the 0.0 deg setpoint. Examine, if the QNET VTOL body is horizontal and, if necessary, adjust the pitch offset by varying the *Offset* control until it is.
8. In the *Position Setpoint* section, set
    - Amplitude (deg) = 4.0
    - Frequency (HZ) = 0.05

The reference signal should be following a square wave.

9. **B-5, K-2, B-9** Capture the QNET VTOL step response when using a PID controller and measure the steady-state error. How does it compare with the computed theoretical value?

Answer 2.4

Outcome	Solution
B-5	If the experimental procedure was followed properly, the response should be similar to Figure Ans. 2.2
K-2	The response is shown in Figure Ans.2.2
B-7	Although there are slight oscillations about the reference, the steady-state error is effectively eliminated when using integral control. Thus as computed in Equation Ans.2.5, the measured steady-state error of the QNET VTOL when using PID is

$$e_{ss} = 0\ deg \quad \text{(Ans.2.6)}$$

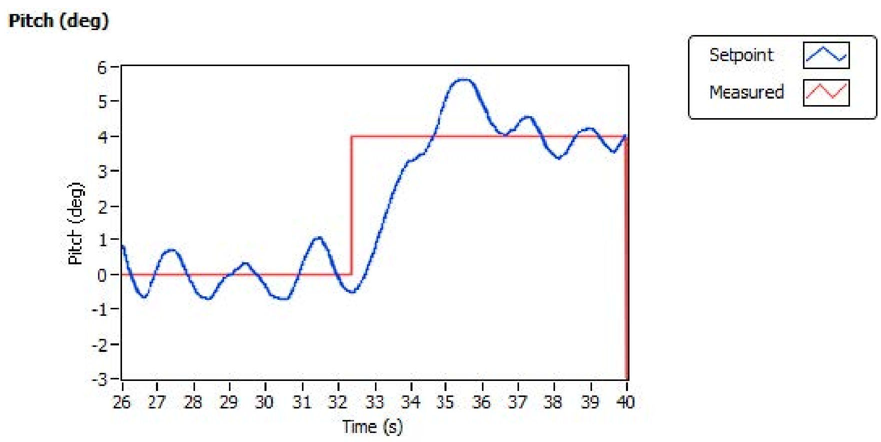

Figure Ans.2.2: QNET VTOL step response using PID control

10. Click on the *Stop* button to stop running the VI.