Lab-1: Modeling of the DC Motor

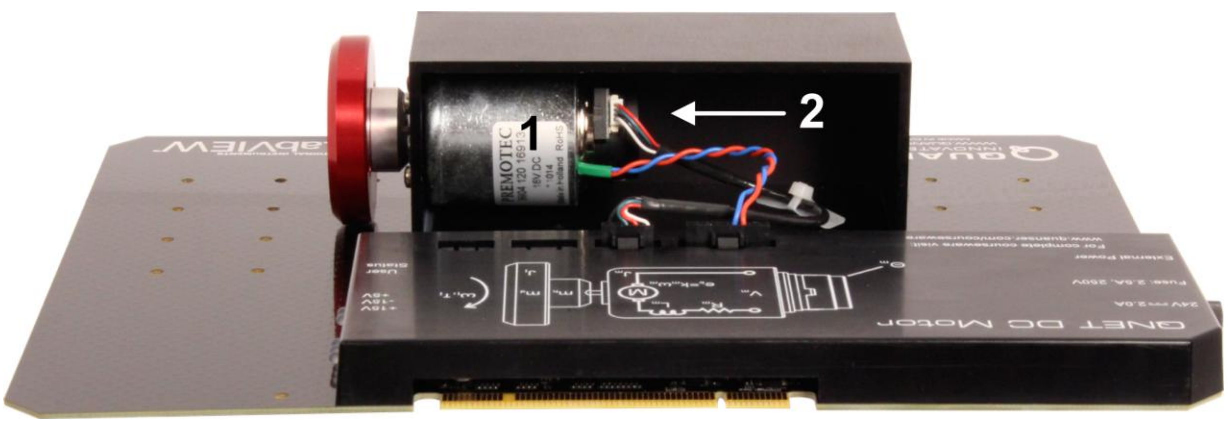
Topics Covered

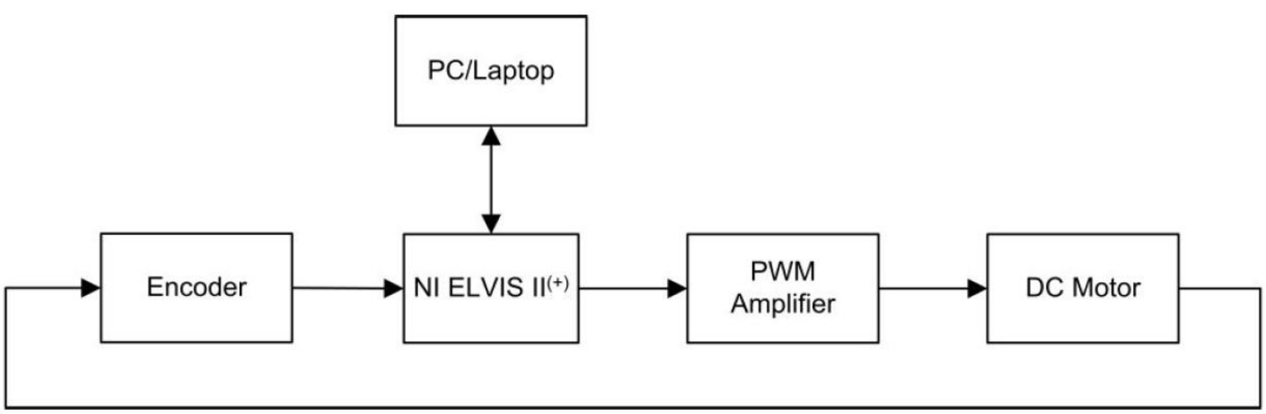
- First order transfer functions.
- Obtaining the QNET DC Motor model using the bump test method.
- Model validation.

Prerequisites

- The QNET DC Motor has been setup and tested. See the QNET DC Motor Quick Start Guide for details.
- You have access to the QNET DC Motor User Manual.
- You are familiar with the basics of LabVIEW™.

Necessary Equipment:
• Labview software
• NI Elvis II+ board
• Quanser DC Motor
• 1 optical encoder
• Power module





1 Background

1.1 Bump Test

The bump test is a simple test based on the step response of a stable system. A step input is given to the system and its response is recorded. As an example, consider a system given by the following transfer function:

$$\frac{Y(s)}{U(s)} = \frac{K}{\tau s + 1} \tag{1.1}$$

The step response shown in Figure 1.1 is generated using this transfer function with $K = 5$ rad/V.s and $\tau = 0.05$ s.

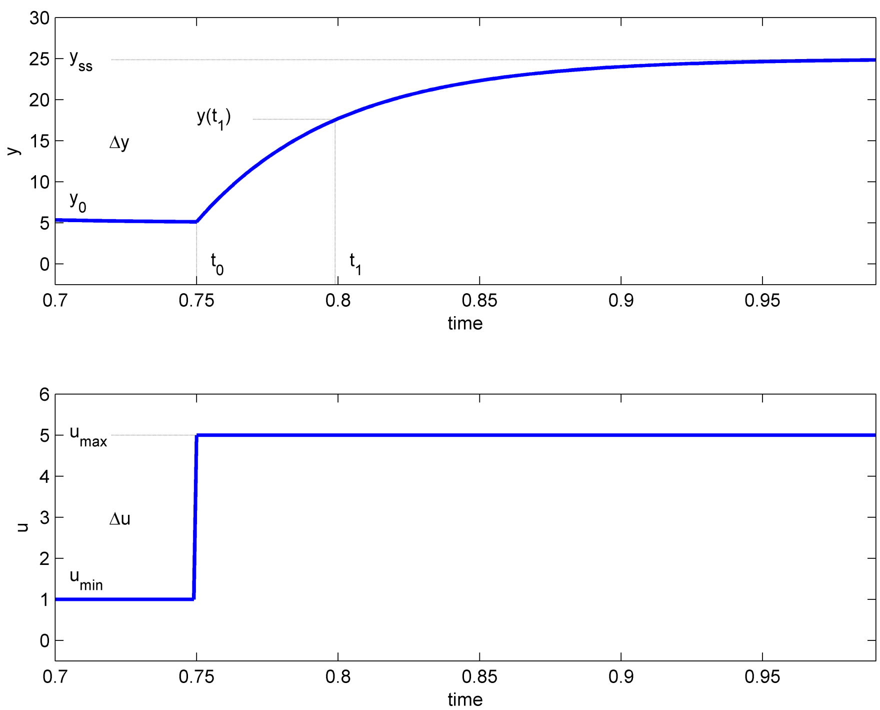


Figure 1.1: Input and output signal used in the bump test method

The step input begins at time t_0. The input signal has a minimum value of u_{min} and a maximum value of u_{max}. The resulting output signal is initially at y_0. Once the step is applied, the output tries to follow it and eventually settles at its steady-state value y_{ss}. From the output and input signals, the steady-state gain K is

$$K = \frac{\Delta y}{\Delta u}, \tag{1.2}$$

where $\Delta y = y_{ss} - y_0$ and $\Delta u = u_{max} - u_{min}$. In order to find the model time constant τ we can first calculate where the output is supposed to be at the time constant from:

$$y(t_1) = 0.632 y_{ss} + y_0. \tag{1.3}$$

Then, we can read the time t_1 that corresponds to $y(t_1)$ from the response data in Figure Figure 1.1. From the figure we can see that the time t_1 is equal to:

$$t_1 = t_0 + \tau. \tag{1.4}$$

From this, the model time constant can be found as

$$\tau = t_1 - t_0. \tag{1.5}$$

1.2 Model Validation

When the modeling is complete it can be validated by running the model and the actual process in open-loop. That is, the open-loop voltage is fed to both the model and the actual device such that both the simulated and measured response can be viewed on the same scope. The model can then be adjusted to fit the measured motor speed by fine-tuning the modeling parameters.

See Wikipedia for more information on electric motor, mathematical model, transfer function, and LTI system theory.

1.3 Modeling Virtual Instrument

Applying a voltage to the QNET DC Motor and examining its angular rate is investigated in the laboratory. The model simulation is run in parallel with the actual system to allow for model tuning and validation. The LabVIEW™ virtual instrument for modeling is shown in Figure 1.2. Figure 1.3 shows the graphs-view of the VI, which is used to take measurements.

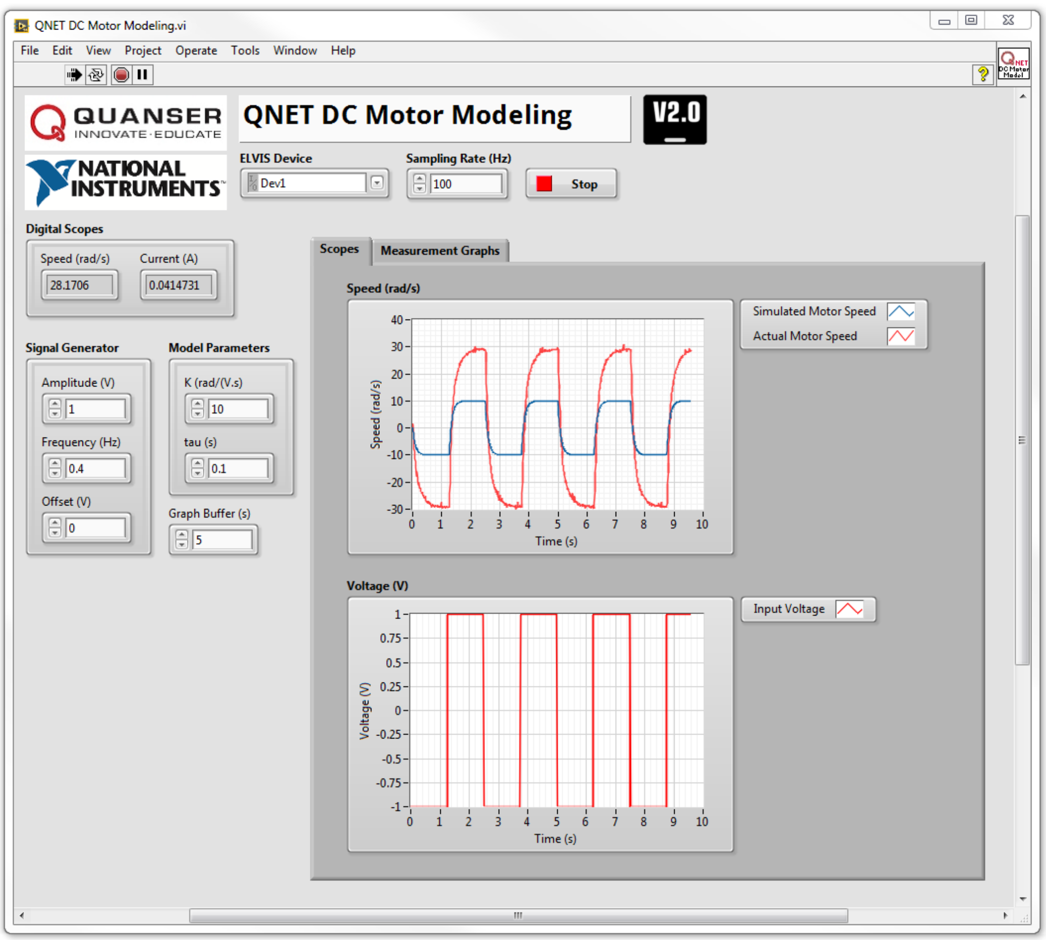


Figure 1.2: LabVIEW™ VI for modeling QNET DC Motor

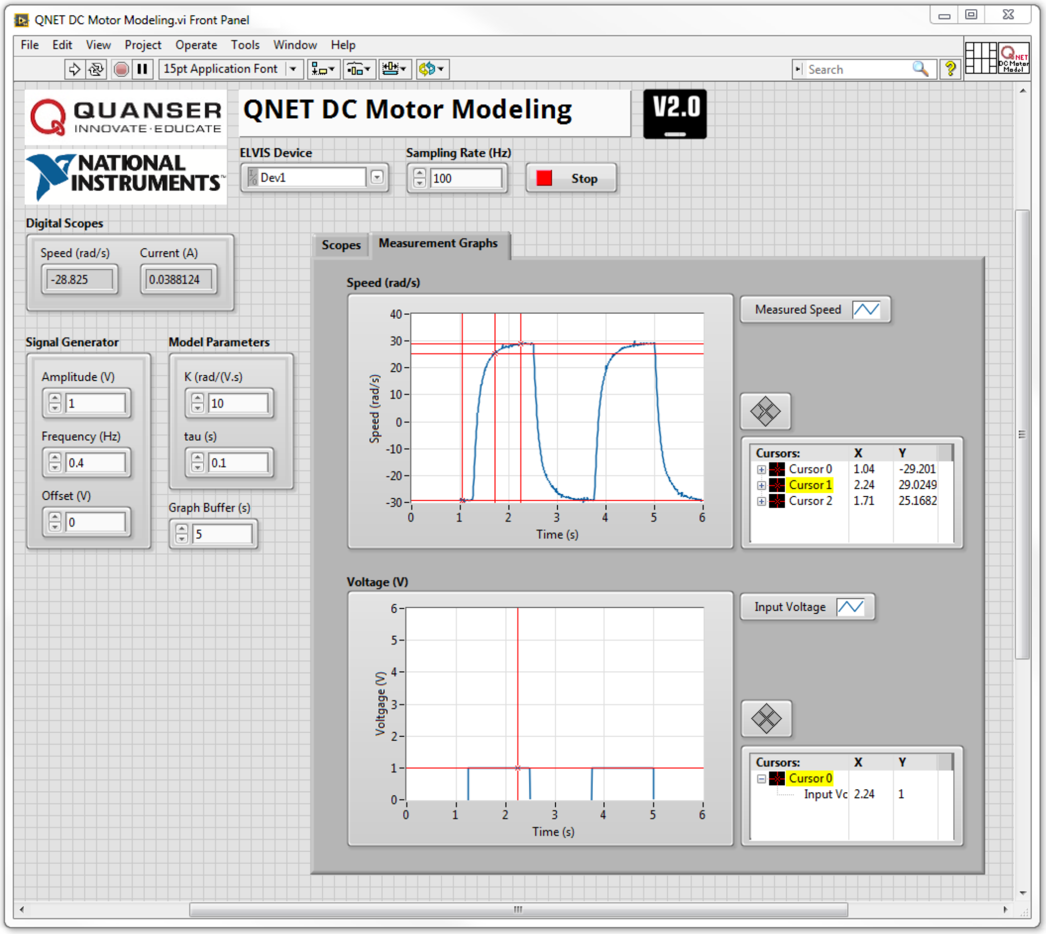


Figure 1.3: QNET DC Motor Modeling VI: sample response in Measurement Graphs

2 In-Lab Exercise

2.1 Bump Test

1. Ensure the `QNET DC Motor Modeling.vi` is open. **Make sure the correct Device is chosen.**
2. Run the VI. The DC motor should begin spinning and the scopes on the VI should appear similar to those shown in Figure 1.2.
3. In the Signal Generator section set
   - Amplitude (V) $= 2.0$
   - Frequency (Hz) $= 0.40$
   - Offset (V) $= 3.0$
4. Once you have collected a step response, click on the Stop button to stop running the VI.

R 5. Attach the responses in the Speed (rad/s) and Voltage (V) graphs.

6. Select the Measurement Graphs tab to view the measured response as depicted in Figure 1.3.

R 7. Use the responses in the Speed (rad/s) and Voltage (V) graphs to compute the steady-state gain of the DC motor. See the Background section of this laboratory for details on how to find the steady-state gain from a step response. You can use the *Cursor Palette* to measure data. See the QNET DC Motor User Manual or the LabVIEW™ help for more information.

R 8. Based on the bump test method, find the time constant. See the Background section for details on how to find the time constant of the step response.

2.2 Model Validation

1. Open the `QNET DC Motor Modeling.vi`. **Make sure the correct Device is chosen.**
2. Run the VI. You should hear the DC motor begin running and the scopes on the VI should appear similar to those shown in Figure 1.2.
3. In the Signal Generator section set:
   - Amplitude (V) $= 2.0$
   - Frequency (Hz) $= 0.40$
   - Offset (V) $= 3.0$
4. In the Model Parameters section of the VI, enter the bump test model parameters K and τ that were found in Bump Test Laboratory. The blue simulation should match the red measured motor speed more closely.

R 5. Attach the Speed (rad/s) and Voltage (V) chart responses from the Scopes tab.

R 6. How well does your model represent the actual system? If they do not match, name one possible source for this discrepancy.

R 7. Tune the steady-state gain K and time constant τ in the Model Parameters section so the simulation matches the actual system better and write down their values.

3 Lab Report

I. PROCEDURE

1. *Bumptest*
    - Briefly describe the main goal of the experiment.
    - Briefly describe the experiment procedure in Step 5 in Section 2.1.
2. *Model Validation*
    - Briefly describe the main goal of the experiment.
    - Briefly describe tuning the model parameters in step 7 in Section 2.2.

II. RESULTS

Do not interpret or analyze the data in this section. Just provide the results.

1. Bumptest plot from step 5 in Section 2.1.
2. Model validation plot from step 5 in Section 2.2.
3. Provide applicable data collected in this laboratory from Table 1.

Table 1: DC motor modeling results summary

Description	Symbol	Value	Unit
Section 2.1: Bumptest Modeling			
Motor steady-state gain	$K_{e,b}$		rad/s
Motor time constant	$\tau_{e,b}$		s
Section 2.2: Model Validation			
Motor steady-state gain	$K_{e,v}$		rad/s
Motor time constant	$\tau_{e,v}$		s

III. ANALYSIS

Provide details of your calculations (methods used) for analysis for each of the following:

1. Find the model steady-state gain in 7 in Section 2.1.
2. Find the model time constant in 8 in Section 2.1.

IV. CONCLUSIONS

Interpret your results to arrive at logical conclusions for the following:

1. How well does the model respresent the actual system in step 6 of Section 2.2.