FILTERING

Topics Covered

- Using an encoder to measure speed.
- Low-pass filters.

Prerequisites

- Hardware Interfacing laboratory experiment

1 Background

A low-pass filter can be used to block out the high-frequency components of a signal. A first-order low-pass filter transfer function has the form

$$G(s) = \frac{\omega_f}{s + \omega_f}, \tag{1.1}$$

where ω_f is the cut-off frequency of the filter in radians per seconds (rad/s). All higher frequency components of the signal will be attenuated by at least -3 dB $\approx 50\%$.

2 In-Lab Exercises

Based on the model developed in the Integration lab, the goal is to design a model that measures the servo velocity using the encoder as shown in Figure 2.1.

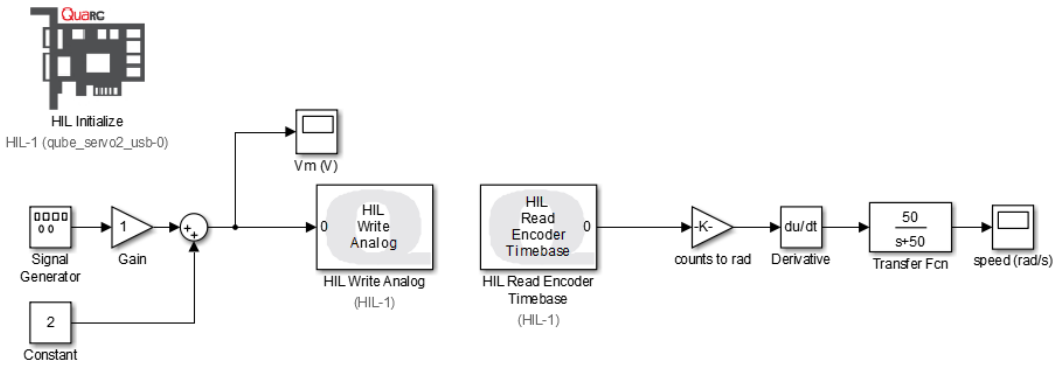
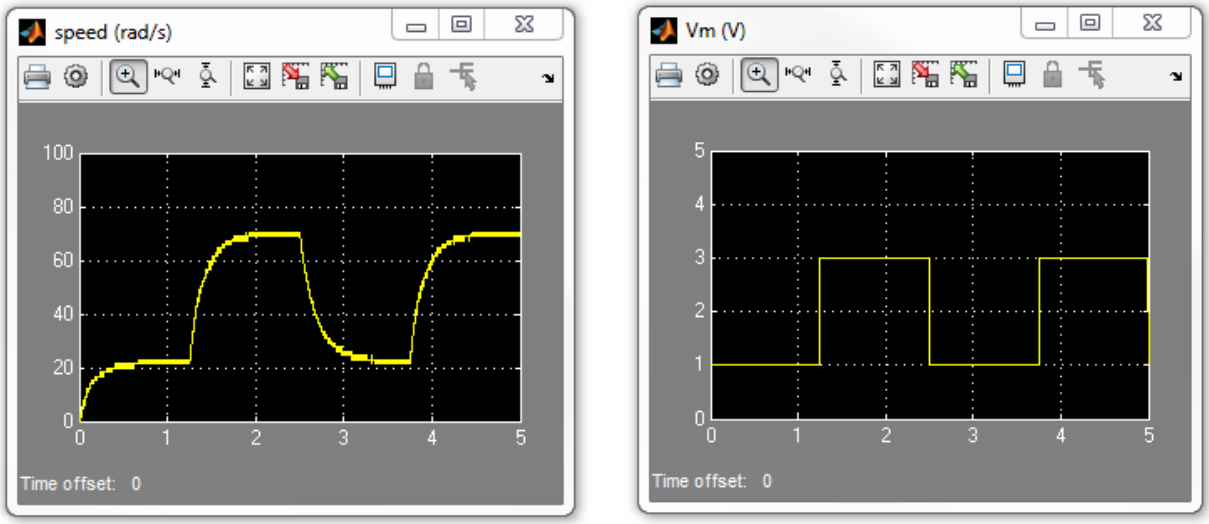


Figure 2.1: Measuring speed using the encoder

1. Take the model you developed in the QUBE-Servo 2 Integration lab. Change the encoder calibration gain to measure the gear position in radians (instead of degrees). What is the value of your gain?
2. Build the SIMULINK® diagram shown in Figure 2.1 but, for now, do not include the Transfer Fcn block (will be added later).
   - **Derivative**: Add a Derivative block to the encoder calibration gain output to measure the gear speed using the encoder (in rad/s).
   - **Scope**: Connect the output of the Derivative to a Scope.
3. Setup the source blocks to output a *step* voltage that goes from 1 V to 3 V at 0.4 Hz.
4. Build and run the QUARC controller. Examine the encoder speed response. Attach sample responses. They should look similar to Figure 2.2.



(a) Encoder Speed

(b) Motor Voltage

Figure 2.2: Measured servo speed using encoder

5. Explain why the encoder-based measurement is noisy.

   Hint: Measure the encoder position measurement using a new Scope. Zoom up on the position response and remember that this later enters derivative. Is the signal continuous?

6. One way to remove some of the high-frequency components is adding a low-pass filter (LPF) to the derivative output. From the *Simulink* | *Continuous Simulink* library, add a Transfer Fcn block after the Derivative output and connect LPF to the Scope. Set the Transfer Fcn block to $50/(s+50)$, as illustrated in Figure 2.1.

7. Build and run the QUARC controller. Show the filtered encoder-based speed response and the motor voltage. Has it improved?

8. What is the cutoff frequency of the low-pass filter $50/(s+50)$? Give you answer in both rad/s and Hz.

9. Vary the cutoff frequency, ω_f, between 10 to 200 rad/s (or 1.6 to 32 Hz). What effect does it have on the filtered response? Consider the benefit and the trade-off of lowering and increasing this parameter.

10. Stop the QUARC® controller.

11. Power *OFF* the QUBE-Servo 2.

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