Lab 1 – System Identification (Sys ID) via Frequency Response

Description In this assignment, your task is to determine an empirical transfer function for the cart system in lab. Using this, you are then to improve your approximate model of the open-loop plant. Use the "Lab 0" handout as a reference to create a simulink model to control the cart. If you are already familiar with the lab stations in HFH 3120A, please help others in getting starting. Once you have a basic working simulink model, you can reuse this in future assignments as a starting point.

Assignment Turn in the numbered problems below in the Drop Box outside 3120A. **Due Oct. 7**

1) Given the block diagram for our system (derived in lecture), solve for the expected motor-cart plant, *P(s)*, both symbolically and numerically. Here, $P(s) = \frac{X(s)}{V(s)}$, where *v(t* is the voltage input to the motor, and *x(t)* is the cart position output, in meters.

2) What is a good 2nd-order approximation for *P(s)*?

3) Use the backward Euler approximation to design a discrete-time (CT) controller, *C(z)*, that approximates the continuous-time (CT) controller $C(s) = \frac{100(s+16.88)}{(s+30)}$. Recall that for backward Euler, $s \to \frac{z-1}{zT}$. What is the resulting DT transfer function, *C(z)*?

4) Use your DT controller above, *C(z)*, to drive the cart in closed-loop control (i.e., with a standard, negative feedback loop). Based on your estimate of the plant, *P(s)*, from problems 1 and 2, select a range of frequencies at which to perform a "swept sine" analysis of the actual plant. Be sure to SAVE YOUR DATA from lab, so that both you and your partner can access it outside of lab, if necessary! Use these data to generate an empirical Bode plot for the open-loop plant, *P(s)*, and turn in this plot to answer question 4.

5) For one "interesting" set of data (e.g., near one of the system poles) include a plot of the raw data for both *v(t)* and *x(t)*, and show that your estimates of magnitude and phase at this frequency agree. To do so, estimate the actual magnitude of each signal and the time shift between them. Then, convert this time shift into a phase shift. This step is simply a "reality check" on your methods for part 4.

6) Use your data from part 4 to find an *improved* approximation for the *actual* open-loop motor-cart plant, *P(s)*.

7) Estimate the true mass of the cart, based on the original symbolic form for *P(s)* from problem 1 and your empirical plant from problem 6.

8) Estimate the additional, mechanical damping (if any) that should be included in the model. (Assume linear, viscous damping here, which effectively acts to increase along with the back EMF as a loss term.)

Parameters

K_m = 0.00767 (V/(rad/s)) or (Nm/A)	Motor torque constant (and back EMF constant)
R_m = 2.6 (Ohms)	Motor resistance
L_m = 180 x 10^{-6} (H)	Motor inductance
J_m = 3.8 x 10^{-7} (kg m^2)	Motor armature moment of inertial
K_g = 3.7 [no units]	Gear ratio of motor gearbox
r = 0.00635 (m)	Pinion radius (i.e., small output gear, that drives cart along track)
$m_c \approx$ 0.445 (kg)	Estimated mass of cart system, expected to be wrong
b_m = ?	Unknown, additional mechanical damping (see last problem)

Block Diagram

To be derived in class.