ECSE 403 lab assignment
Fall 2018 , assignment 2
Instructor: Prof. P. E. Caines
Due 5^{th} october 2018

Lab TA: Borna Sayedana

1 Objective

The main goal of this assignment is to become familiar with Simulink environment and start working with the cart stations.

2 Your responsibility

Your duty is to answer all questions which have been asked throughout this assignment and submit all your answers in addition to matlab codes and Simulink results.

3 Model Description

The equation of motion of a DC motor can be described by:

$$J_m\ddot{\theta} + (b + \frac{K_t K_e}{R_a})\dot{\theta} = \frac{K_t}{R_a} v_a$$

where θ is the shaft angle (in radians) of the motor and v_a is the applied voltage.
The system parameters are as follows:

- $J_m = 0.01 kgm^2$ be the inertia of the rotor and the shaft.
- $b = 0.001 Nmsec$ be the viscous friction coefficient
- $K_e = 0.02 V sec$ be the back emf constant

- $K_t = 0.02Nm/A$ be the motor torque constant.
- $R_a = 10\Omega$ be the armature resistance

Note that this document uses SI units for which $K_e = K_t$.

4 Questions

1. Implement the transfer function you derived in previous lab ($\frac{\theta(s)}{v_a(s)}$) in simulink. You can use blocks *Transfer Fcn* from *continuous* library, *scope* from *Sinks* library, and *Signal Generator*, and *Step*, from *Sources* library. [10 marks] (In order to include the diagrams you can use *Print To File*)

2. Using *Step*, find the rise-time and steady-state response of the system to a unit step function. [5 marks]

3. Using *Signal Generator* or *Sine Wave*, measure response of the system to sine waves of amplitude 1 and frequencies $w = [0.1, 1, 10, 100, 1000]$. [5 marks] Using these data, plot Bode diagram(gain diagram) of the system. [10 marks] Using the transfer function and *bode* command, plot the theoretical Bode diagram and then compare it with the diagram you found by experiments. [10 marks]
   Hint: Note that you have to use *w = log10(input frequencies)* as the x-axis and *20*log(gains)* as y- axis to draw your data points Bode diagram.

4. Implement the unity Feedback loop in Simulink. Repeat the steps of Q2 to derive the Bode diagram of the feedback system. [10 marks] Using the closed-loop transfer function you derived in previous session, plot the Bode diagram of the closed-loop system then plot experimental bode diagram and theoretical one in one figure. [10 marks]

5. Implement a proportional controller in simulink. By changing the amount of proportional gain K, find the corresponding K for which we get rise-time of 4 seconds. [10 marks]

6. Experimenting different proportional gains K in Simulink, find the proportional gain K for which get, 20% overshoot. [10 marks]

7. Using a *derivative* block, and an *integrator* block, implement a PID controller for the system. Suppose we name the *gain* block before the derivative block K_d, and the *gain* block before the integrator block K_i, and proportional *gain* K_p, observe the output of the system to unit step function for different combinations of $K_i, K_d, K_p \in \{0.1, 1, 10\}$(by different combinations we mean fixing two of the gains and iterating over the last one). [15 marks]

Using the above experiment describe intuitively the impact of increment in K_d, K_i(individually), on the step response of the system. [15 marks]

8. Setting $K_d = 0$, Find the step response of the system. [5 marks]
9. Setting $K_i = 0$, Find the step response of the system. [5 marks]
10. Follow instructions of the *Lab Manual*, observe the output of the system to a sine wave[It would be checked by the TA]
11. Using a ruler find the correct linear position gain.(Convert the sensor's output to the position in mm)
12. Using previous linear position gain, plot the step-response of the system.[10 marks]
    Hint: In order to bring the data out of Simulink environment you can use the *To Workspace* block.
13. Alter the Simulink model such that you can observe velocity as output of the system.($\frac{V(s)}{v_a(s)}$), and then plot the step-response. [10 marks]
14. Explain why the observed velocity on the scope is noisy.[5 marks]