Robotics and Control Laboratory
ECSE 493 W2017
Lab Assignment 1
Analysis and Simulation of a Servo System
Due January 27th by 4pm.
Please upload your assignment to the class webpage

This assignment is a review.   I will try to upload some review notes by Monday.

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

Inertia · Acceleration   Motor Torque   Back emf   Motor Torque

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

Viscous Friction   Armature Resistance   Voltage applied

where
θ is the shaft angle (in radians) of the motor and v_a is the applied voltage. Let
$J_m = 0.01\text{kgm}^2$ be the inertia of the rotor and the shaft
$b = 0.001$ Nmsec be the viscous friction coefficient
$K_e = 0.02$ Vsec be the back emf constant
$K_t = 0.02$ Nm/A be the motor torque constant
$R_a = 10\Omega$ be the armature resistance

Note that $K_e = K_t$ when one uses SI units.

(a) Find the transfer function between the applied voltage and the speed of the motor shaft. (Plug in the numbers above).

(b) Repeat part (a) but use the Matlab command *tf* and the values above to define a transfer function between the applied voltage and the speed of the motor shaft. Use the step command to estimate the steady-state speed of the motor after a voltage is applied.

(c) Use the step response plot to estimate how long it takes the motor to reach within 1% of steady state angular velocity.

(d) Look up the Final Value Theorem and calculate the steady state speed of the motor after a voltage is applied. How close was your graphical estimate of the final value?

(e) Find the transfer function between the applied voltage and the shaft angle.

(f) Apply feedback to the transfer function in (d). Draw a block diagram of the system. Add a gain of K to the forward path of your block diagram. What is the transfer function of the feedback system?

(g) What are the units of K?

(h) What is the input into the motor? (i.e., what is the applied voltage?)

(i) Find the transfer function between v_a and θ. (The system is now a position servo).

(j) What is the maximum value of K that can be used if an overshoot of Mp<20% is desired?

(k) What value of K provides a rise time of 4 seconds (ignore overshoot constraint above).

(l) Plot the step response of the position servo for K= 0.5, 1 and 2 and use the plots to find the rise time and % overshoot for each value of K.

(m) What feature of the step response is K controlling?

2. Enter the following in Matlab;

```
p=[1 1];
q=[1 5 6 0];
sys=tf(p,q);
rlocus(sys);
```

-these commands will produce a Root Locus plot.

a) What are p and q?

b) Define and explain the function of the root locus. What is being depicted in the root locus plot of the system defined above?