ECEN 4413/MAE 4053
Automatic Control Systems
Spring 2006
Computer Project

Show all your works, plots and clearly state your explanations if required. Include all the MATLAB codes with documentation.

Problem 1 Given the equation of motion for a system as below:

$$\dddot{y}(t)+45\ddot{y}(t)+100\dot{y}(t)+180y(t)=45u(t)$$

a. Compute the transfer function (*full model*) of the equation of motion, where $u(t)$ is the input and $y(t)$ is the output of the system. Assume all initial conditions are zero.

b. Plot the pole-and-zero map of the system. Is the plant open-loop stable?

c. Plot the response to the system to (1) an impulse, (2) a sin wave ($u(t)=\sin(t)$), and (3) a step signal. For the step response, obtain the settling time, overshoot percentage and steady state error.

d. Using the **sisotool**, design a controller through the root-locus procedure. The designed controller should have one pole, two zeros and be able to achieve the following specifications:

- zero steady state error; settling time less or equal to 1.3sec; overshoot less or equal to 18%.

Plot the step response of the controlled system (r to y), the final root-locus diagram, and provide the transfer function of the designed controller.

Problem 2 Design a controller for a nonlinear system. To accomplish this, you will first linearize the system model and then use the tools you have used in previous part to design a linear controller. Finally, you will analyze the applicability of your controller to the actual nonlinear system using Simulink. Now, consider the dynamic equation of a nonlinear system.

$$\dddot{y}+0.6\ddot{y}+0.22\dot{y}(1+\sin(y))+0.03\cos(y)y=0.1x$$

a. Use Simulink to create a simulation model of the nonlinear system. Generate a print out of the model (use Edit → Copy Model to Clipboard).

b. We are interested only in small variations around the origin for the output y. Using the approximation for small values of y, ($\cos(y)\cong 1 \quad \text{and} \quad \sin(y)\cong 0$) linearize the system's dynamic equation.

c. Create a Simulink model for the linearized system and generate a print out of the model. Plot the outputs y of the nonlinear and linearized systems for the following step inputs, and then discuss about the results in words. (Adjust all your simulation for a 150s duration. $u(t)$ is the unit step function)

$$x_1(t)=0.001u(t),\ x_2(t)=0.01u(t),\ x_3(t)=0.1u(t),\text{ and } x_4(t)=0.3u(t).$$

d. Using **ltiview**, obtain for the linearized system its settling time, overshoot percentage and steady state error in response to a step input.

e. Using **sisotool**, design for the linearized system a controller capable of achieving:

- Zero steady state error; Settling time less or equal to 30s; Overshoot less or equal to 15%.

(You should not require more than two zeros and two poles for this controller. Make sure your controller does not have more zeros than poles.)

f. Add your designed controller to both nonlinear and linearized systems. Don't forget to close the negative feedback loop and add a *source block* for your reference $\hat{y}$.

g. Plot the outputs y of the controlled nonlinear and linearized systems for the following reference signals: $\hat{y}_1(t) = 0.001u(t)$, $\hat{y}_2(t) = 0.01u(t)$, $\hat{y}_3(t) = 0.1u(t)$, and $\hat{y}_4(t) = 0.3u(t)$, and discuss the results.