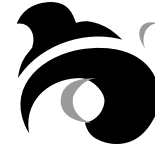




**ECEN 4413/MAE 4053**  
**Automatic Control Systems**  
**Spring 2006**  
**Computer Project**



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:

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

- 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.

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

- 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  $y$ , ( $\cos(y) \cong 1$  and  $\sin(y) \cong 0$ ) 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)

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

- 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.