University of New Mexico
Department of Electrical and Computer Engineering

EECE 445, FINAL EXAM, December 18, 2009
12:30-2:30

Closed-book. Show all work

1. Consider a SISO system described by the state-space equations,

$$\dot{x} = Fx + Gu, \quad y = Hx$$

(a) Indicate how you would compute by hand the transition matrix $\Phi(t)$ for this system.
(b) Indicate how you would compute by hand the transfer function (TF). What MATLAB function would you use to compute TF, given numerical values for the matrices F,G, and H?
(c) Indicate the equation you would use to compute the output y(t), given that the input is a unit step and that the system has a non-zero initial state.

2. The state-space equations for a certain Mag-Lev system are given by,

$$\dot{x} = Fx + Gu, \quad y = Hx$$

where (in MATLAB notation), F=[0 1:1 0],G=[0;1], and H=[1 0].

(a) Design a full-state feedback controller which places all the closed-loop eigenvalues at s=-2.
(b) If state-estimate feedback is used, and the estimation-error eigenvalues are all at s=-20, where will the closed-loop eigenvalues be located?

3. A PI controller is proposed for altitude control of a hot-air ballon with transfer function,

$$G(s) = \frac{1}{s(s+1)(s+10)}$$

(a) Use the Lienard-Chipart stability criterion to determine the set of values of gains k_P and k_I that will result in a stable closed-loop system. Sketch the

stability region in the k_P, k_I plane.
(b) What type closed-loop system will this controller yield with respect to tracking error? With respec to disturbance rejection?

4. A DC motor has a transfer function (position output, voltage input) given by,

$$G(s) = \frac{100}{s(s+2)}$$

(a) Is it possible to modify the settling time of this motor with simple proportional feedback, i.e $D(s) = K$?
(b) Compute the value of K that will result in an overshoot which does not exceed 5% (i.e. $\zeta = 0.7$).

5. Consider a plant with transfer-function,

$$G(s) = \frac{s-2}{(s-1)(s+2)}$$

(a) Sketch the Nyquist Plot for this plant.
(b) Use the Nyquist plot to determine if this plant can be stabilized with simple proportional feedback.
(c) Can this plant be stabilized with a stable compensator? Explain your answer.

6. Frequency response data of an open-loop stable plant is given in the table shown below.
(a) From the data given, sketch bode plots for this system and specify the phase margin of the closed-loop system if the compensator is given by $D(s) = 1$
(b) Assuming the DC gain of this plant is acceptable, design a lag compensator for this plant which yields a PM of 45 degrees.

7. Consider a plant with transfer function,

$$G(s) = \frac{s-1}{(s-2)(s+10)}$$

(a) Use a root-locus sketch to show that this system cannot be stabilized with simple proportional feedback.

(b) Can this plant be stabilized with a *stable* bi-proper compensator of degree equal to one? Explain your answer.

8. For each of the problems listed below, identify a MATLAB function you would use to solve the problem. Specify the input and output arguments of the MATLAB function you identify.

(a) Given state-space equations compute the output response of a system given that the initial state is not zero, but the input is zero.
(b) Compute the feedback matrix for a full-state feedback controller which places the closed-loop eigen values a given locations, if the system has more than one input. Are there any limitations on the multiplicity of the closed-loop eigenvalues using this function?
(c) Compute a table of ω, $mag(G(j\omega))$ and $arg(G(j\omega))$ given a plant with transfer function $G(s)$.
(d) Obtain a plot of $G(jw)$ which can be used to determine closed-loop stability stability range given a simple proportional compensator, $D(s) = K$ Assume the plant has 2 poles in RHP. Describe the shape your plot would have to have for closed-loop stability.
(e) Given a $G(s)$ and $D(s) = K$ find the range of K-values, that will keep the closed-loop poles in a given s-plane design region.