

UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN COMPUTER ENGINEERING



CMPE-242:
APPLIED FEEDBACK CONTROL

HOMEWORK #2
DUE 7-OCT-2010

1. *Root Locus*: Sketch the 0° and the 180° root loci vs. gain, K , for each of the following transfer functions. Show asymptotes and indicate arrival and departure angles for any complex poles or zeros. Check your results in MATLAB only after sketching them out by hand.

a. $G(s) = \frac{(s^2+4)}{s(s^2+1)}$

b. $G(s) = \frac{(s+6)}{s^3(s+8)}$

c. $G(s) = \frac{(s+2)^2}{s^2(s+10)(s^2+6s+25)}$

d. $G(s) = \frac{1}{(s-1)([s+2]^2+3)}$

2. *Root Locus*: Given the plant below, where a is a parameter that can be both positive and negative:

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

- Rewrite the transfer function to be in Evan's Form ($1-GK=0$).
 - Sketch the 0° and the 180° root loci vs. parameter, α .
 - Comment on the limits of stability for the plant.
3. *Lag Compensation*: Given a plant with three poles (at 0, -6, and -12) and no zeros in a conventional feedback configuration, design a lag compensator to meet the following specifications: settling time (t_s) < 5 seconds, maximum overshoot (M_p) < 17%, and a steady state error to a unit ramp less than 10%.

4. *Root Locus Design*: Given the plant below, design a compensator to meet the following specifications:

$$G(s) = \frac{12}{s(s+1)(s+12)}$$

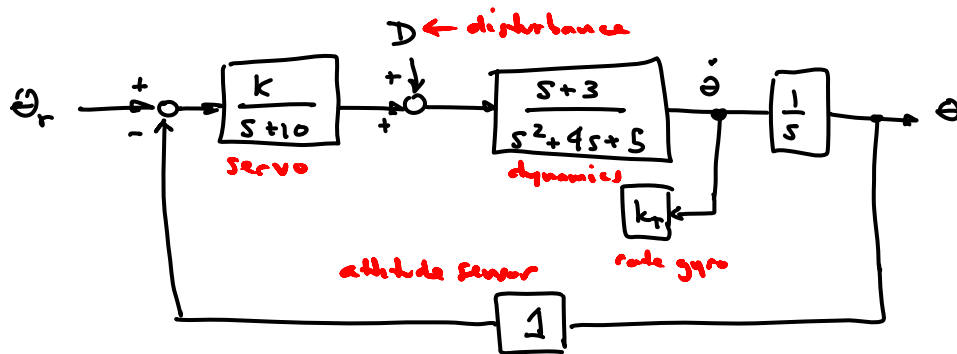
- i. Overshoot (M_p) < 16%
- ii. Rise time (t_r) < 0.04
- iii. Steady state error to a unit ramp (e_{ss}) < 0.02

Include MATLAB root locus plots, and step response plots of the final closed loop system.
Hint: you might need to add a very low frequency lag to hit the steady state error spec.

5. *Non-minimum phase plant*: Given the plant below (with a zero in the RHP), determine the feedback required to put the damping ratio (ζ) at 0.707. Use MATLAB to show the root locus with the closed loop poles indicated, and plot the step response of the closed loop system.

$$G(s) = \frac{6 - 3s}{s^2 + s + 9}$$

6. *Rate Feedback*: Given the aircraft pitch autopilot below, with a disturbance input of a step with a magnitude of 0.6, [$W(s) = 0.6/s$], answer the following questions:



- a. What value of K is required to keep the steady state error to this disturbance at less than 1 degree.
- b. Sketch the root locus with respect to the gain, K .
- c. Based on the above, at what K does the system go unstable.
- d. Assume the K required is 600, what are the closed loop poles of the system (and are they stable)?
- e. Add it where the feedback from the rate gyro should go on the block diagram.
- f. Assume K is 600, draw the root locus with respect to K_{rate} , the rate gyro gain.
- g. What can you do with the complex roots using K_{rate} ? Performance, Damping, etc.
- h. What K_{rate} maximizes the damping.
- i. Let's say you are not satisfied with the design, comment on what would happen if you added integral control, or extra lead networks (show what happens on a root locus).