

# Homework 5

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1. Consider the plant

$$G(s) = \frac{5}{s(s/1.2 + 1)(s/3.5 + 1)}$$

Design a lead compensator for the phase margin to be about 40 degrees. What is the bandwidth of the system? During your design, keep the DC gain of your compensator equal to 1.

2. The autopilot of a jet aircraft is used to control altitude. To design the autopilot loop, only the long-period airplane dynamics are important. The transfer function from altitude *rate* to elevator angle is a second-order transfer function:

$$\frac{\dot{h}(s)}{e(s)} = \frac{12(s + 0.012)}{s^2 + 0.01s + 0.0023} \text{ ft/sec/deg.}$$

The autopilot receives an electrical signal proportional to pressure altitude from the altimeter. This signal is compared with a command signal (proportional to the altitude dialed by the pilot), and the difference provides an error signal. The error signal is processed through a compensator, and the result is used to command the actuators of the elevator. A block diagram of this system is provided in Fig. 1. You have been given the task of designing the compensation. Consider first  $H(s) = K$ , a simple gain.

- (a) Sketch the magnitude and phase vs. frequency (Bode plots) of the open-loop system for  $H(s) = K = 1$ .
- (b) What value of  $K$  would provide a crossover frequency of 0.16 rad/sec?

- (c) For this value of  $K$ , would the system be stable if the loop were closed?
- (d) What is the phase margin?
- (e) Draw the Nyquist plot for the system. Locate carefully the points corresponding to (i) gain margin and (ii) phase margin.
- (f) Sketch the root-locus vs.  $K$ . Locate the roots for your value of  $K$  from (b).
- (g) What steady-state error would result if the command were a ramp of 2 ft/sec?

Consider the lead compensation

$$H(s) = K \frac{s/a + 1}{s/b + 1}$$

- (h) Choose the parameters  $K$ ,  $a$ ,  $b$  so the crossover frequency is 0.16 and the phase margin is greater than 50 degrees. Indicate your work on the same Bode plot as (a).
- (i) Show the root-locus vs.  $K$ . Locate the roots for your value of  $K$  from (h).
- (j) What steady-state error would result if the command were a *ramp* of 2 ft/sec?
- (k) If the error in (j) is too large, what type of compensation would you add? Where would you put it (over what frequency range)?