Adelaide University

Department of Mechanical Engineering

Examination for the Degree of Bachelor of Engineering

AUTOMATIC CONTROL 1: 2452

NOVEMBER, 2001

Time: 3 hours and 10 minutes

[The use of notes, textbooks and calculating devices other than computers is permitted in the examination room.]

[Graph paper is provided.]

Part 1: Fundamental Concepts. (30 points)

Provide a short answer (a few sentences and a sketch at most) to each of the following questions. **2 points per question.**

1. What type of controller is good for reducing steady state error?
2. A Lead controller will have what effect on a systems root locus?
3. For the plant transfer function, $G(s)$,

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

Sketch the systems response to a unit step input.

4. What is the reduced order model for the system specified below?

$$G(s) = \frac{500}{(s+10)(s+2)(s+5)}$$

5. Why are overdamped systems slow?
6. What does adding a derivative control do to the rise time, t_r and damping of a system ζ?
7. A system has a zero in the right-hand plane; is this system unstable?
8. Lead compensation approximates what type of control (Hint: Proportional, derivative, integral or any combination of these)

9. Lag compensation approximates what type of control (Hint: Proportional, derivative, integral or any combination of these)

10. If a system has a time delay ($e^{-t_d s}$) can you draw the root locus for the overall system? Why not/Why

11. What is the general purpose of Automatic control?

12. Sketch pole locations in the s-plane and the frequency response of a second order system for varying amounts of damping? (indicate which is the greatest and lowest)

13. If the transfer $G(s)$ is the closed loop transfer function, can K_v, K_a and K_p be used to calculate the error of a system?

14. Describe system sensitivity or system stability.

15. In relation to this course, what does a motor bike suspension and a laser guided missile system have in common?

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Part 2: Basic Skills (35 points)
Solve each of the following questions.

1. A plant has the following transfer function:

$$\frac{Y(s)}{R(s)} = 2.5\frac{e^{-5s}}{s+0.5}$$

Determine the control gains a PID controller. **(5 points)**

2. A system is described by the following transfer function:

$$G(s) = \frac{(s+12)}{s(s+3)}$$

What is the system type? Then what inputs will the system be able to track with some degree of success? To reduce the steady state error to a ramp to 0.05%, what would the ratio of the zero to pole, $\frac{z}{p}$, be for the implemented lag compensator? **(5 points)**

3. A system has the following complete block diagram.

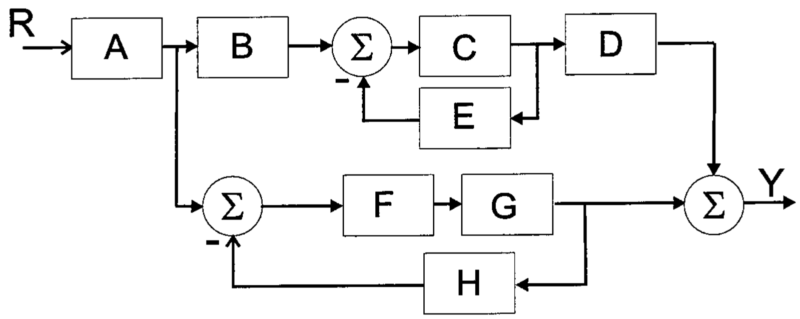

Figure 1: System block diagram

Using Masons Rule determine the Transfer Function, $\frac{Y}{R}$ **(5 points)**

4. Figure (2) shows a unity feedback loop for the pitch control of an aircraft where

$$G_{flap}(s) = \frac{4000}{s+8} \qquad G_p(s) = \frac{(s+6)(s+15)}{s(s+6s-153)}$$

Draw a Bode plot of the system's frequency response **(10 points)**.

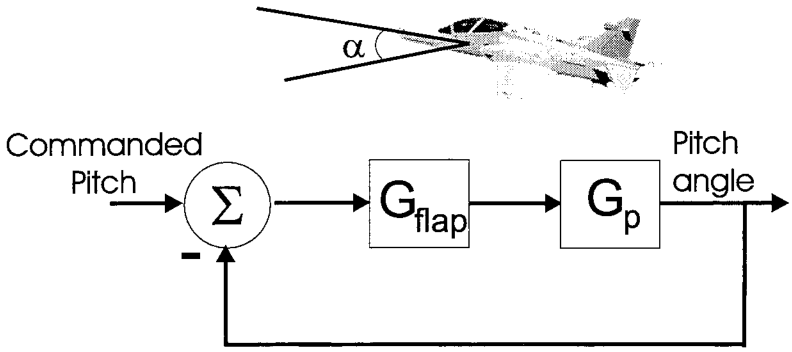

Figure 2: Pitch control of an aircraft

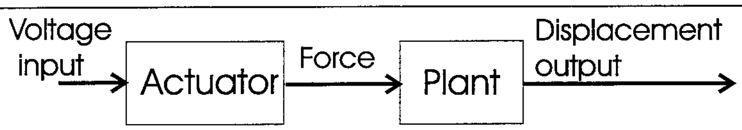

Figure 3: Force actuator system to drive a piece of mechanical equipment

5. A force actuator is used to drive a piece of mechanical equipment. Figure (3) For the actuator, the relationship between the input voltage, $v(t)$ and output force, $f(t)$ is given by the differential equation:

$$\frac{d^2f(t)}{dt^2} + 20\frac{df(t)}{dt} + 100f(t) = v(t)$$

The relationship between the force input and the displacement output has been determined experimentally and is defined by the following transfer function, $G_{plant}(s)$,

$$G_{plant}(s) = \frac{s^2+2s+10}{s^2+2s+5}$$

Plot the root locus for the overall system (actuator and plant combined) assuming initial conditions are zeroand unity feedback.
You are given that the system becomes unstable for a gain $K = 206$ and the locus crosses the imaginary axis at $\omega = 9.89$ rad/sec. When determining the cross over point we use the characteristic equation $1 + KG(s) = 0$, explain where this formula comes from.
If a damping ratio of $\zeta = 0.707$ and a rise time of 0.01 seconds were required, would the addition of a lag compensator be good enough? (don't design one) **(10 points)**.

Part 3: Compensator Design (40 points)
2 questions, 20 points each.

1. Self-guided vehicles are used in factories to transport products from station to station. One method of construction is to embed a wire in the floor to provide guidance. Another method is to use an on-board computer and laser scanning device. Bar-coded reflective devices at known locations allow the system to determine the vehicle's angular position. This system allows the vehicle to travel anywhere, including between buildings. Figure (4) shows a simplified block diagram of the vehicle's bearing control system. Design a control system such that the settling time is < 3 seconds and the overshoot is $< 15\%$.

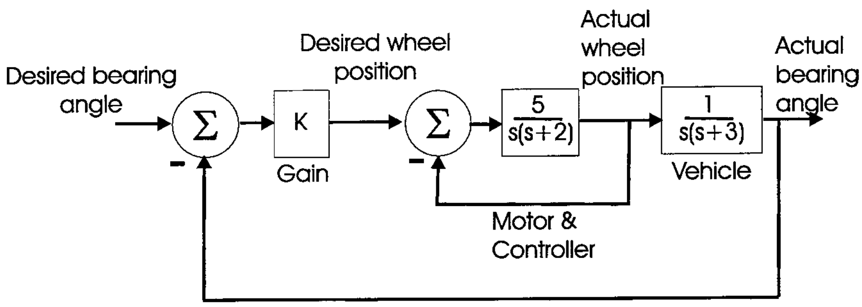

Figure 4: Simplified block diagram

2. An aircraft roll control system is shown in Figure (5). The torque on the aileron generates a roll rate. The resulting roll angle is then controlled through a feedback system as shown. Design a lead compensator for a 60° phase margin and 2% error to a ramp.

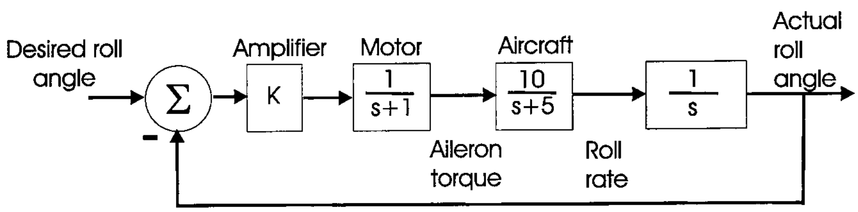

Figure 5: Aircraft Roll Control System