THE INSTITUTION OF ENGINEERS SRI LANAKA
ENGINEERING COURSE PART III

323- CONTROL SYSTEMS ENGINEERING

DURATION: THREE HOURS FROM 9:00 TO 12:00
DATE: 4 NOVEMBER 2013

Answer five (05) question only and all questions carry equal marks.

Question 01

(a) The poles of a system are given in the following five examples. In each case state giving reasons whether the system is stable, unstable, or marginally stable.

i) -2, -4 ± j5, -3
ii) -2, -4 ± j5, +3
iii) -2, -4 ± j5, ± j3
iv) -2, +4 ± j5, -3
v) -4 ± j5, 0, 0

[05 marks]

(b) A system has the characteristic equation

$$s^3 + 12s^2 + 61s + 150 = 0$$

i) Using Routh-Hurwitz criterion determine whether the system is stable, unstable, or marginally stable. [08 marks]

ii) Now move all the poles of the given system to the right of the s-plane by the real value 3. (i.e., add 3 to every pole of the original system). Using Routh-Hurwitz criterion determine whether this modified system is stable, unstable, or marginally stable. Justify your answer. [07 marks]

Question 02

The loop transfer function of a feedback control system is given by

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

(a) Sketch the root locus of the closed-loop system by first determining the:

i) location and the angles of the asymptotes; [
ii) break points;
iii) points at which the root locus intersects with the imaginary axis, and the corresponding gain value.

[10 marks]

(b) Fully justifying your answer, state whether the system is stable for K = 10.

(c) Suppose that a zero at -3 is introduced to the control loop so that

$$G(s)H(s) = \frac{K(s+3)}{s(s+1)(s+2)}$$

Sketch the root locus of the new system. [10 marks]
Note: You need not determine the break points of this new system. But you must determine the asymptotes.

Question 03

(a) Define the following terms.
   i) Gain margin
   ii) Phase margin
   iii) Gain crossover point
   iv) Phase crossover point

[08 marks]

(b) A servomechanism has an open-loop transfer function of

$$G(s) = \frac{10}{s(1+0.5s)(1+0.1s)}$$

Draw the Bode plot and determine the phase and gain margins. A network having the transfer function $(1+0.23s)/(1+0.023s)$ is now introduced in tandem. Determine the new gain and phase margins. Comment upon the improvement in system caused by the network.

[12 *marks*]

Question 04

(a) Define sensitivity of a control system. [04 marks]

(b) Determine the sensitivity of open loop transfer function of a unity feedback system

$$G(s) = \frac{25K}{s(s+5)}$$ [06 marks]

(c) Determine the gain margin and phase margin of the following open loop transfer function using Nichols chart.

$$G(s) = \frac{200(s+2)}{s(s^2+10s+100)}$$ [10 marks]

Question 05

(a) Write ***Lead Compensation*** transfer function and define each term. [05 marks]
(b) The open loop transfer function of a unity feedback system is

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

It is desired to have the velocity error constant K_v as $12\,\text{sec}^{-1}$ and phase margin as 40^0. Design a lead compensator using ***Bode Plots*** to meet the above specifications.

[15 marks]

Question 06

(a) Define the following controllers and write Laplace transform for each controller.

i. P controller
ii. I controller
iii. D controller

[06 marks]

(b) Write the Laplace transform for PID controller. [04 marks]
(c) For the unity feedback system shown in Figure Q6, the damping ratio is required to be made 0.8, by using derivative control. Calculate the value T_d and compare the rise time, peak time and maximum overshoot for the system with and without a derivate controller. [10 karks]

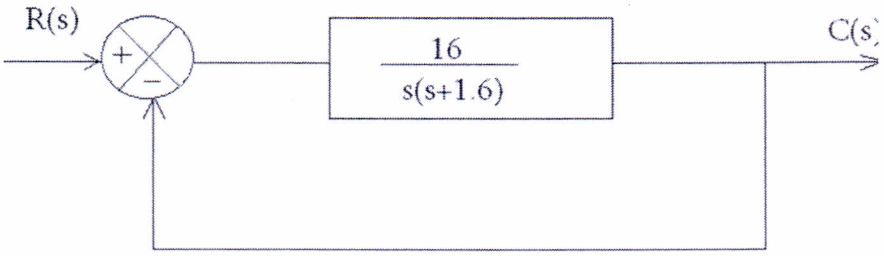

Figure Q6

Question 07

(a) Define controllability and observability. [04 marks]
(b) Obtain the state space model of the system whose transfer function is given by

$$T(s) = \frac{s^2 + 3s + 3}{s^3 + s^2 + 3s + 1}$$ [08 marks]

(c) Determine the controllability and observability of the system in given part (b).

[08 marks]

Question 08

Design a garage door controller using a) block diagram logic, and b) Ladder programing.
[20 marks]

The behavior of the garage door controller is as follows,

- there is a single button in the garage, and a single button remote control.
- when the button is pushed the door will move up or down.
- if the button is pushed once while moving, the door will stop, a second push will start motion again in the opposite direction.
- there are top/bottom limit switches to stop the motion of the door.
- there is a light beam across the bottom of the door. If the beam is cut while the door is closing the door will stop and reverse.
- there is a garage light that will be on for 5 minutes after the door opens or closes.

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