THE INSTITUTION OF ENGINEERS SRI LANKA
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

(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 an 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 \( K \), as 12 sec\(^{-1}\) and phase margin as 40\(^\circ\). 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**

(b) Write the Laplace transform for PID controller. [06 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 marks]

![Figure Q6](image)

**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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