MEHRAN UNIVERSITY OF ENGINEERING AND TECHNOLOGY, JAMSHORO

FIRST TERM FINAL YEAR (7th TERM) B.E (ELECTRONICS) REGULAR EXAMINATIONTION 2007 OF 04 BATCHES UNDER EXTERNAL SYSTEM.

Control Engineering-II

Dated: Time Allowed: 03 Hours Max: Marks-80

NOTE: *Attempt any **five** questions. All questions carry equal marks.*
1) Do not use pencil to draw the figures and graphs.
2) Laplace-z transform table is available in examination.
3) Graph papers are also available in examination.

Q. No.01 **(a)** A magnetically suspended steel ball can be described by the linear equation **[10]**

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 3 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

The state variables are x_1 = position, and x_2 = velocity, and both are measurable. Select a feedback format so that the system is critically damped and the settling time (2% criterion) is 2 seconds.

(b) State the Sylvester criteria to determine the positive definiteness, positive semi-definiteness, negative definiteness and negative semi-definiteness of a quadratic form or Hermition form of Liapunov's fictitious energy function V(x). **[06]**

Q. No.02 **(a)** A robot system is described by the vector differential equation **[12]**

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -1 & 2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$$

Both the state variables are measurable, and so the control signal is set as $u(t) = -k(x_1 + x_2)$. Design gain k so that following performance index is minimized.

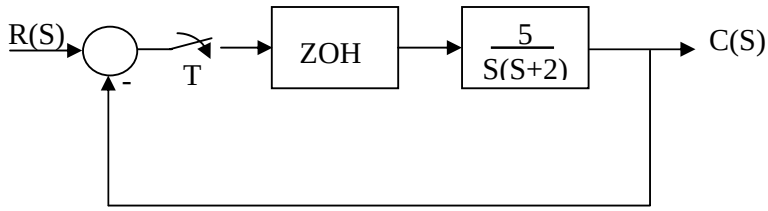
$$J = \int_0^\infty (x^T Q x + u^T R u) dt$$

Where

$$Q = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \text{ and } R = [1]$$

(b) Describe the criteria for instability, asymptotic stability and asymptotic stability in large in the sense of Liapunov. **[04]**

Q. No.03 The block diagram of a sample data control system is shown in following figure. **[16]**



(a) Derive the forward path and closed loop transfer function of the system in z-transfrom. The sampling period is 0.1 sec.
(b) Apply the Jury's direct stabilty test to check the close loop stability.
(c) Find out the steady state error due to step input.

Q. No.04 Consider the third order system **[16]**

$$\dot{x} = Ax + Bu$$

Where state feedback control $u = -kx$ is used. Assume that the system is completely state controllable. Also assume that the desired close loop poles are at $s_1 = \mu_1, s_2 = \mu_2$ *and* $s_3 = \mu_3$. Show that the state feedback gain matrix K is

$$K = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} B & AB & A^2B \end{bmatrix}^{-1} \phi(A)$$

Q.No.05 (a) Show that the root locus of the following transfer function is a circle with radius $\sqrt{3}$ and centre at (-4, 0). **[08]**

$$G(S) = \frac{K(S+4)}{(S+1)(S+3)}$$

Q.No.05 (b) Draw root locus of the following system as K varies from 0 to ∞. **[08]**

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

Using the root locus estimate percent overshoot and settling time (2% criterion) of the system at K=1.

Q.No.06 (a) Consider the system given below. Design full order state observer for the plant assume that the desired observer poles are located at s=-8 and s=-8. **[10]**

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 4 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

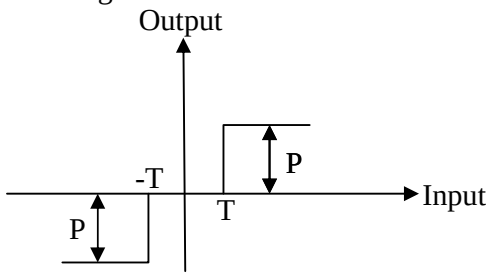
Q.No.06 **(b)** What is principle of duality? How it helps us to design state observer? **[06]**

Q.No.07 Design an op-amp compensator for the unity feedback system. The feed forward transfer function of the system is **[16]**

$$G(S) = \frac{6}{S(S+3)}$$

The damping ratio of closed loop poles is 0.6124. The undamped natural frequency is 2.4495 rad/sec. It is desired to modify the closed loop poles so that damping ratio of 0.5 and an undamped natural frequency of 4 rad/sec is obtained.

Q.No.08 **(a)** Obtain the describing function of on-off non-linearity with dead zone shown in figure below. **[10]**



Q.No.08 **(b)** Consider unity feedback system with open loop transfer function **[06]**

$$G(S) = \frac{10}{S(S+1)(S+4)}$$

PI controller is used to control the system. Apply Ziegler-Nichol's tuning rules to determine the PI Parameters.
(K_p=0.45K_{cr} and Ti=0.83P_{cr}.)