INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Department of Electrical Engineering

Mid-Semester Examination for ***Control Systems Engineering*** **(EE30009)**

Date: September 26, 2012

Time: 02:00PM – 04:00PM Full Marks 120

Answer any 4 questions. Sketch figures on white pages. Mark the values of important points in all your sketches. No graph paper is needed. Use approximation judiciously. You have 1 min for each mark.

---

1. Sketch the root locus of the open loop transfer function $KG(s)H(s)=\dfrac{K}{s(s+3)(s^2+6s+64)}$. Calculate (a) the angles of the asymptotes (b) the centroid of the asymptotes (c) the real-axis breakaway point (d) the point of intersection of the root locus and the imaginary axis and the corresponding value of K. 6+6+6+6+6

2. (a) Obtain the Transfer Function Matrix (TFM) for a MIMO system described by

$$\ddot{y}_1(t)+2\dot{y}_1(t)+3y_1(t)+4\dot{y}_2(t)+y_2(t)=u_1(t)+u_2(t)$$

$$\ddot{y}_2(t)+3\dot{y}_2(t)+2y_2(t)+2\dot{y}_1(t)+y_1(t)=2u_1(t)-u_2(t)$$ 15

(b) Sketch the asymptotic Bode magnitude plot of the loop gain transfer function

$G(s)H(s)=\dfrac{K(s+150)}{s(s+40)(s+800)(s^2+2000s+4\times10^6)}$. Where $K=13653\times10^8$ 15

3. (a) For the system shown in Fig. P3(a), find the values of K, K_1, K_2 and K_3 so that

$$\frac{C(s)}{R(s)}=\frac{100}{(s+4)(s^2+6s+25)}$$

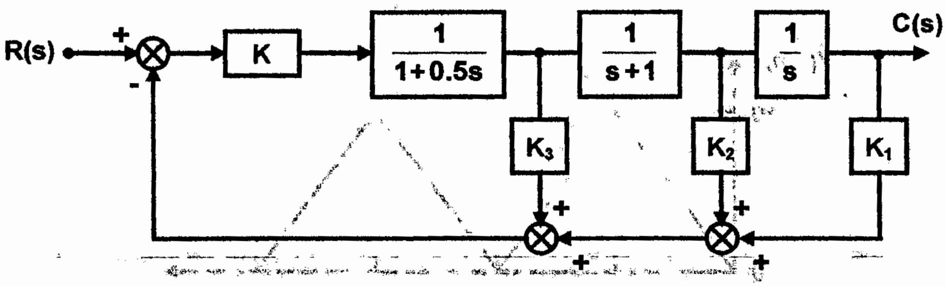

Fig. P3(a) 15

(b) Choosing the state variables x_1, x_2, x_3 for the two blocks as shown in the figure, obtain a state-variable description (A,B,C,D matrices) of the system (Fig. P3(b))

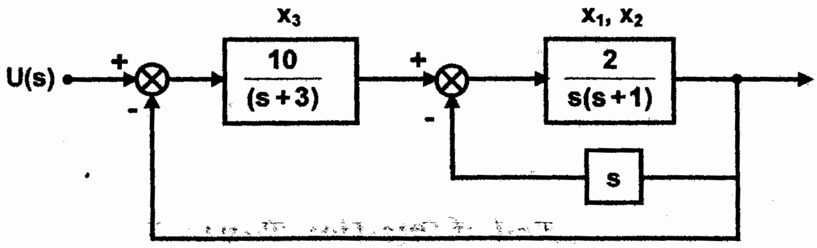

Fig. P3(b) 15

4. Consider the Maxwell's bridge circuit shown below.

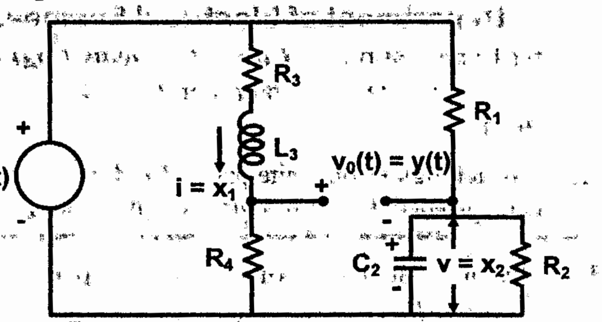

Fig. P4

(a) Find a state space model (A,B,C,D matrices) of the system with the state variable designation shown. 12

(b) Derive the transfer function relating u to y from the above state space model. 10

(c) Verify mathematically that the system is state-uncontrollable when the bridge is balanced under the condition that

$L_3 = R_1R_4C_2$ and $R_3 = \dfrac{R_1R_4}{R_2}$ 8

5. A two-axis robot is programmed to have a laser cutting tool follow a saw tooth path, as shown in Fig. P5. The forward path transfer function of the unity position feedback control system for each of the X and Y axes of the robot is $G(s) = \dfrac{100}{s(s+5)}$ with the unit of position being in centimeters. If the maximum admissible error in the position of the laser beam from the commanded position at any instant is ±0.1 mm in each axis, estimate accurately the minimum amount of time that would be needed to traverse the trajectory shown below. 30

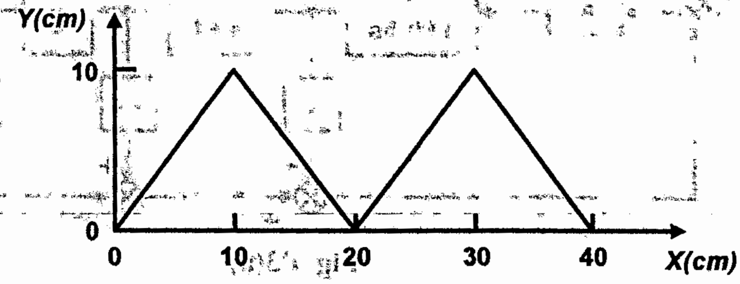

Fig. P5

End of Question Paper