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P.E.S. College of Engineering, Mandya - 571 401

(An Autonomous Institution affiliated to VTU, Belgaum)

Seventh Semester, B.E. - Electrical and Electronics Engineering

Semester End Examination; Dec. - 2014

Design of Analog Control System

Time: 3 hrs *Max. Marks: 100*

***Note**: Answer any **FIVE** full questions, selecting at least **TWO** full questions from each part.*

PART - A

1. a. Determine the following frequency domain specifications:
i) Resonant peak ii) Bandwidth iii) Cut – off rate iv) Phase margin. 8

b. Consider a lag – lead compensator $G_c(s)$ defined by $G_c(s) = K_c \dfrac{\left(S+\frac{1}{T_1}\right)\left(S+\frac{1}{T_2}\right)}{\left(S+\frac{B}{T_1}\right)\left(S+\frac{1}{BT_2}\right)}$. 8

Show that at frequency ω_1 , where $\omega_1 = \dfrac{1}{\sqrt{T_1, T_2}}$.the phase angle of $G_c(jw)$ becomes zero.

c. Differentiate between conventional approach and pole – placement approach to the design of a SISO control system. 4

2 a. Realize the following controllers using operations amplifiers and there from derive their transfer functions. i) PI controller ii) PD controller. 10

b. Consider a closed loop system shown in Fig 2 (b). G(s) and $G_c(s)$ are the transmittances of the controller and the system respectively. Mention the effect of $G_c(s)$ on (i) Steady state error for unit ramp input ii) Stability if $G_c(s)$ is (I) an integral controller and (II) a PI – controller. and III) Damping ratio 10

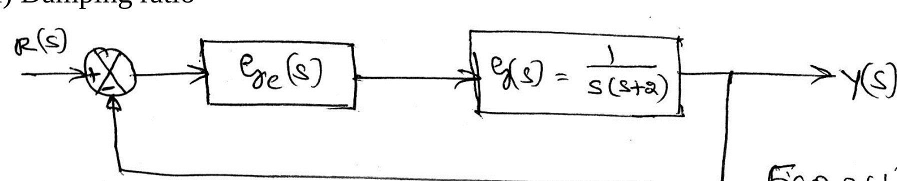

Fig Q 2(b).

3. Design a cascade PD compensator for the unity feedback system with transmittance $G(s) = \dfrac{K}{(s+2)^2 (s+3)}$ so that the following design specifications are met : 20

i) Percentage peak overshoot = 25 % ii) Settling time, t_s = 1.6 secs.
Use the time domain approach for the design of the controller.

4 a. Compare the characteristics of phase lead and phase lag elements with respect to the following,
i) Low and high corner frequencies ii) Gain at low and high frequencies (iii) Maximum phase (iv) Magnitude at $\omega = \omega_m$ (v) Signal to noise ratio. 6

b. Obtain the transfer function of a lag compensator for a UFB – unity feed back system with an open loop transfer function $G(s) = \dfrac{K}{s(s+1)(0.2s+1)}$ to meet the following specifications: 14

i) Velocity error constant K_v = 10 and ii) Phase margin = 30°

PART - B

5. a. Plot a Bode diagram of a PID controller given by $G_c(s) = \left(2.2 + \frac{2}{S} + 0.2S\right)$. 4

b. Design a PI controller of the position control system shown in Fig. 5(b) to achieve the following design goals: i) Steady state error for ramp input = 0
ii) Peak overshoot for step input = 9.48% use frequency response A approach. 16

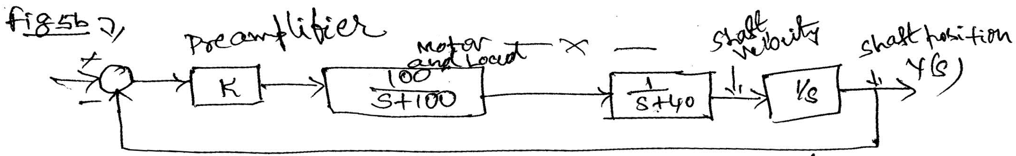

Fig. Q. 5(b).

6 a. What are regulator poles? Explain. Derive the necessary condition for arbitrary pole placement. 10

b. A system using state feedback is governed by the following equations:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -10 & -5 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 & -1 \\ 0 & 0 \\ 1 & 7 \end{bmatrix} \begin{bmatrix} u \\ r \end{bmatrix}$$

10

$$u = -\begin{bmatrix} k_1 & k_2 & k_3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \qquad y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

Determine the feedback gain contacts K so as to place the closed loop poles at s = – 4 and $(-4 \pm j2)$

Contd...3

7 a. Explain the need of an observer.
Define: i) Full – order observer ii) Minimum order observer. 4

b. Draw the general block diagram of a SISO system with full – order state observer. 3

c. Prove that the pole – placement design and the observer design are independent of each other. 8

d. Transform the system defined by the equations $\dot{X} = AX + Bu, \quad y = cX$
where $A = \begin{bmatrix} 1 & 1 \\ -4 & -3 \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 2 \end{bmatrix}$, $C = \begin{bmatrix} 1 & 1 \end{bmatrix}$, into the observable canonical form. 5

8 a. Consider the system shown in Fig. 8(a). assuming the control signal to be $u(t) = -k\,x(t)$ determine the optimal feedback gain matrix K such that following performance index is minimized:

$$J = \int_0^\infty \left(X^T Q X + u^2\right) dt \quad \text{where} \quad Q = \begin{bmatrix} 0 & 1 \\ 0 & \mu \end{bmatrix}, \; \mu \geq 0.$$

15

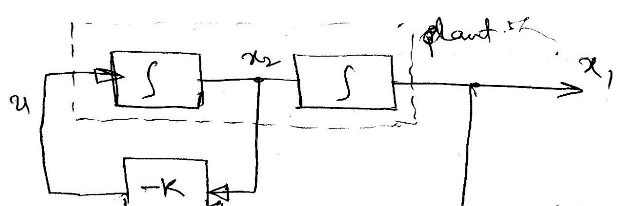

Fig. Q 8(a)

b. Show that the following quadratic form is positive definite:
$V(x) = 10x_1^3 + 4x_2^2 + x_3^2 + 2x_1x_2 - 2x_2x_3 - 4x_1x_3$ 5

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