SRN

PES University, Bangalore

(Established under Karnataka Act No. 16 of 2013)

UE15EC315

DEC. 2017: END-SEMESTER ASSESSMENT (ESA) — B.TECH. V$^{\text{th}}$ SEM.

UE15EC315 — CONTROL SYSTEMS

Time: 3 Hrs	Answer All Questions	Max. Marks: 100

Note: Use appropriate graph sheets.

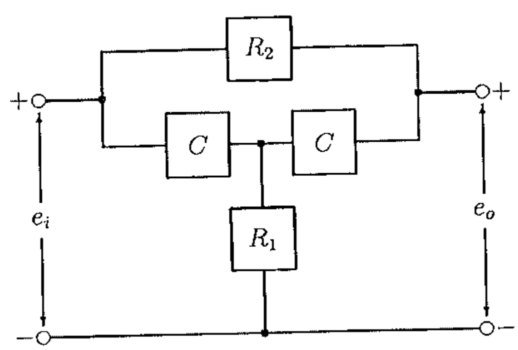
1. (a) A bridged-T network is shown below. For this network:

   i. Determine the set of equations that govern the dynamics of the network.

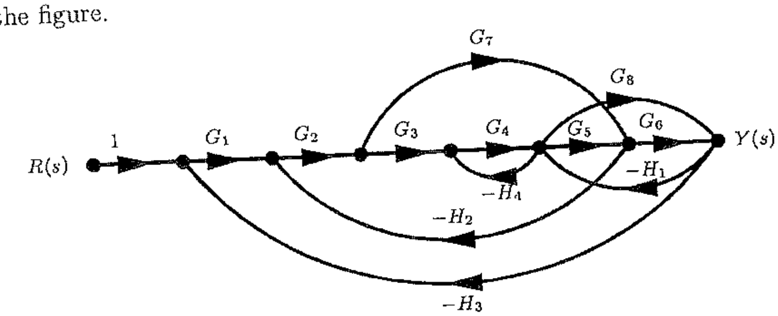
   ii. From these equations determine the transfer function $\frac{E_o(s)}{E_i(s)}$ of the network. (The final answer should be expressed as a real-rational function with the coefficients clearly evident.)

   iii. From the transfer function deduce the state-space representation in phase variable canonical form.

   Assume that the resistors R_1 and R_2 and the capacitors C are lumped, linear and time-invariant components. (9 Marks)



(b) Using Mason's gain formula deduce the transfer function $\frac{Y(s)}{R(s)}$ for the signal flow graph shown in the figure. (11 Marks)



2. (a) A plant with the transfer function

$$G(s) = \frac{2(s+8)}{s(s+4)}$$

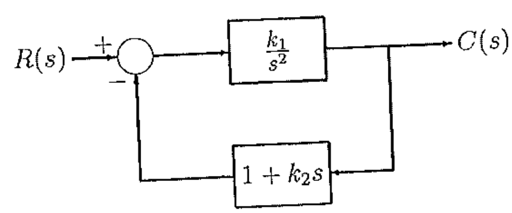
is in the forward path of a negative feedback system with unity feedback.

i. Find the response of the system to a unit step input.

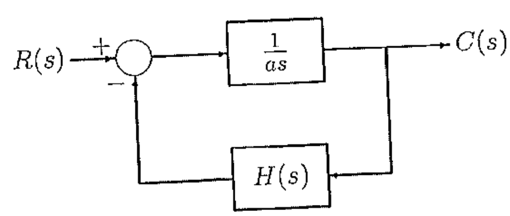
ii. Using the final value theorem, determine the steady-state value of the response for the same step input.

(6 Marks)

(b) For the system shown in the figure determine constants k_1 and k_2 so that the maximum overshoot to a step input is 4.3% and the peak time is 1 sec. (7 Marks)



(c) A control system is represented by the following block diagram where $a > 0$.



i. If $H(s)$ is a proportional controller (i.e., $H(s) \equiv k$), what is the steady-state output due to a unit step input? What are the conditions on a and k so that the closed loop system is stable?

ii. If now $H(s)$ has the transfer function of a PI controller (i.e., $H(s) = K_p + \frac{K_I}{s}$), what is the new steady-state output due to a unit step input? What are the conditions on a, K_p and K_I so that the closed loop system is stable?

(7 Marks)

3. (a) The following transfer functions are associated with a negative feedback system:

$$G(s) = \frac{k(s^2 - 2s + 5)}{(s^2 + 1.5s - 1)}, \qquad H(s) = 1$$

Sketch the root locus for this system. Determine the range of k for which the closed loop system is stable. Find the value of k for which the system has a damping factor of $\frac{1}{\sqrt{2}}$.

(13 Marks)

(b) In a system with characteristic equation

$$q(s) = s^5 - s^4 - 2s^3 + 2s^2 - 8s + 8 = 0$$

determine the number of poles that are (i) in the left half of s-plane, (ii) on the imaginary axis, and (iii) in the right half of s-plane.

(7 Marks)

4. (a) Sketch the Bode plot for the transfer function

$$G(s) = \frac{10}{s(s+1)(s+2)}.$$

Determine the gain and phase margins. Is the closed loop system stable?

(9 Marks)

(b) The open loop transfer function of a control system is

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

Using the Nyquist criterion, determine whether or not the closed loop system is stable for $k = 15$.

(11 Marks)

5. (a) A simplistic model for balancing a stick on the fingertip is as follows:

$$\begin{aligned}
\begin{pmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{pmatrix} &= \begin{pmatrix} 0 & 1 \\ \frac{g}{L} & 0 \end{pmatrix} \begin{pmatrix} x_1(t) \\ x_2(t) \end{pmatrix} + \begin{pmatrix} 0 \\ -1 \end{pmatrix} u(t) \\
y(t) &= \begin{pmatrix} 1 & 0 \end{pmatrix} \begin{pmatrix} x_1(t) \\ x_2(t) \end{pmatrix}
\end{aligned}$$

where x_1 represents the angular position, and x_2 the angular velocity, with the angle being measured with respect to the normal; u is the normalised input, g is the acceleration due to gravity, and L is the length of the stick.

i. What is the transfer function of the system?

ii. Is the open loop system stable?

iii. Can we stabilise the system by feeding back a proportion of the angular position?

iv. Can we stabilise the system by feeding back a linear combination of angular position and velocity? If so, what are the conditions on the two gains to ensure stability?

(10 Marks)

(b) A telerobot has the following state-space representation:

$$\begin{pmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \\ \dot{x}_3(t) \end{pmatrix} = \begin{pmatrix} -1 & 0 & 0 \\ 0 & -2 & 0 \\ 0 & 0 & -3 \end{pmatrix} \begin{pmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \end{pmatrix} + \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix} u(t)$$

$$y(t) = \begin{pmatrix} 1 & 0 & 2 \end{pmatrix} \begin{pmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \end{pmatrix}$$

i. Determine the transfer function.

ii. Determine whether or not the representation is controllable.

iii. Determine whether or not the representation is observable.

(10 Marks)