Scheme of Evaluation

3/4 B.Tech (Regular) Degree Examination -2019

ECE Department

Subject: Linear Control Systems (LCS)

Subject Code: 14EC/EI502

P. Surendrakumar

P SURENDRA KUMAR
Assistant Professor
Department of ECE
Bapatla Engineering College
BAPATLA

N. V... 16/11/19

Signature of HoD

Signature of the faculty

P. Surendrakumar

Associate Professor

9441265314

Scheme- Linear Control Systems

III/IV B.Tech (Regular) DEGREE EXAMINATION

November, 2019 Electronics and Communication Engineering Fifth Semester

a) **State the effect of feedback on stability, gain**
The effect of negative (or degenerative) feedback is to "reduce" the gain. ... Because negative feedback produces stable circuit responses, improves stability

b) **Define linear control systems**
which follow the principle of homogeneity and additivity

c) **Match the following in F-V analogy**
(a) Mass --- (ii) (i) reciprocal of resistance
(b) Spring constant ---1/c (ii) inductance

d) **Give the equation of a second order system with unit step input.**

$$1-\frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}}\sin\left(\omega_d t+\phi\right)$$

e) **Define the percentage of peak over shoot.**
maximum value minus the step value divided by the step value

f) **Give the formula for velocity error constant.**

$$K_v=\lim_{s\to 0} sG(s)$$

g) **A system has a transfer function (1-s)/(1+s) is called____**
_All Pass system

h) **What is gain cross over frequency?**
The frequency at which the gain plot intersects 0dB line.

i) **Define bandwidth.**
The bandwidth, or response time, of the system is a measure of how fast it responds to the changing input command

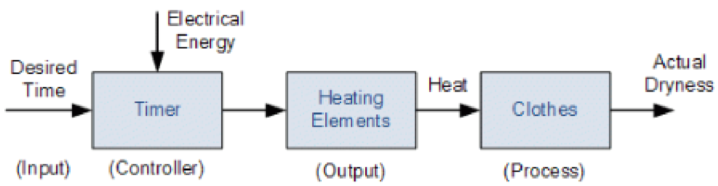
j) **What is observability?**
observability is a measure of how well internal states of a system can be inferred from knowledge of its external outputs

k) **Define state variable.**
A state variable is one of the set of variables that are used to describe the mathematical "state" of a dynamical system

l) **What is centroid?**
The point where the asymptotes meet.

UNIT I

2. a) What do you mean by open loop system? Give an example of open-loop system. Discuss the advantages of open loop system. 6M

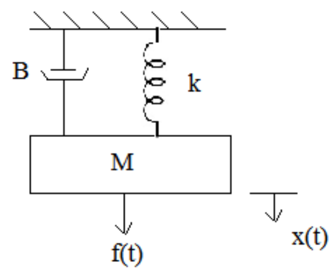


The function of any electronic system is to automatically regulate the output and keep it within the systems desired input value or "set point". If the systems input changes for whatever reason, the output of the system must respond accordingly and change itself to reflect the new input value.

Likewise, if something happens to disturb the systems output without any change to the input value, the output must respond by returning back to its previous set value. In the past, electrical control systems were basically manual or what is called an **Open-loop System** with very few automatic control or feedback features built in to regulate the process variable so as to maintain the desired output level or value.

For example, an electric clothes dryer. Depending upon the amount of clothes or how wet they are, a user or operator would set a timer (controller) to say 30 minutes and at the end of the 30 minutes the drier will automatically stop and turn-off even if the clothes where still wet or damp.

b) Find the transfer function for the given mechanical system. 6M



The differential equation at x(t) can be written as

$F(t)= Md^2x/dx^2+Bdx/dt+ K\ x(t)$

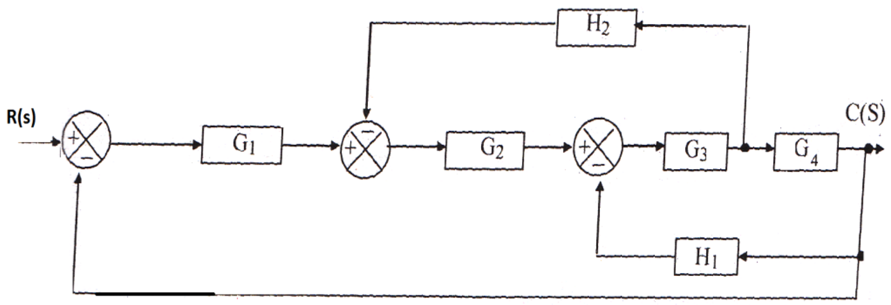
$F(s)= MS^2x(s)+Bs\ x(s)+K\ x(s)$

$F(s)=x(s)[MS^2+Bs+K]$

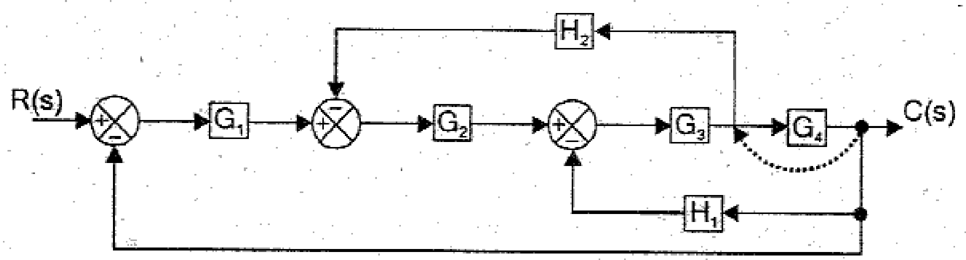
$T(s) = x(s)/f(s) = 1/\ Ms^2+Bs+K$

(OR)

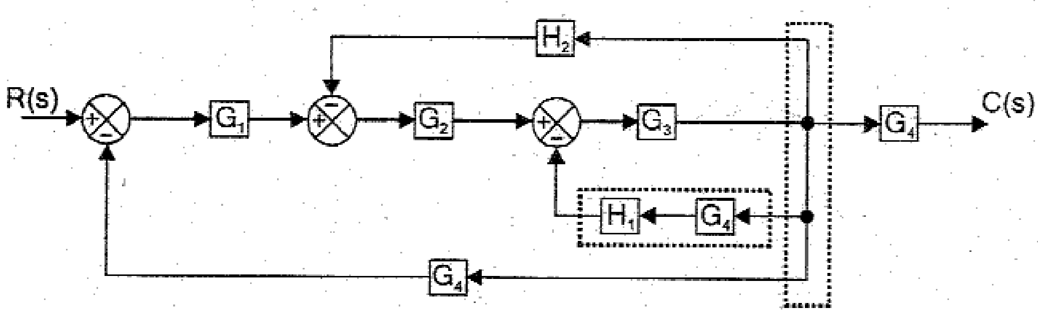
3. a) Obtain the transfer function of the given block diagram. 6M



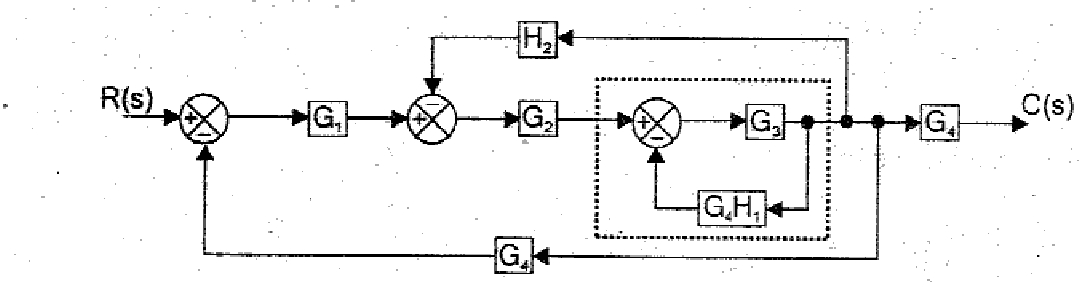
Step 1: Moving the branch point before the block



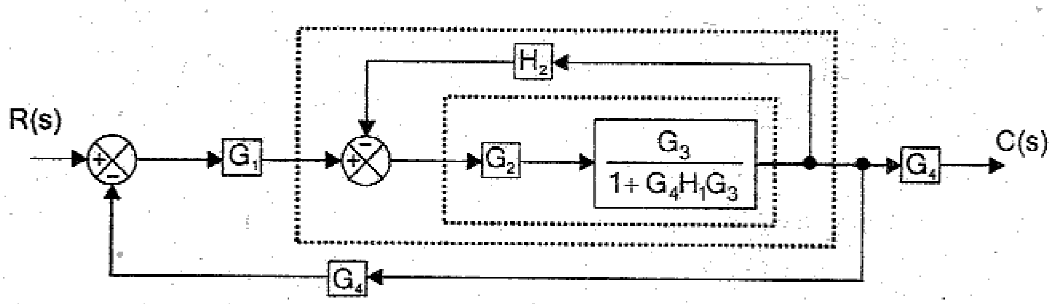
Step 2: Combining the blocks in cascade and rearranging the branch points



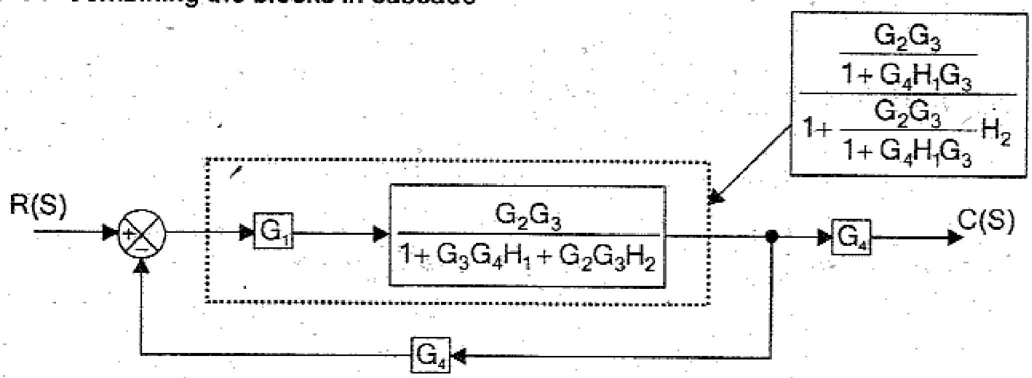
Step 3 : Eliminating the feedback path



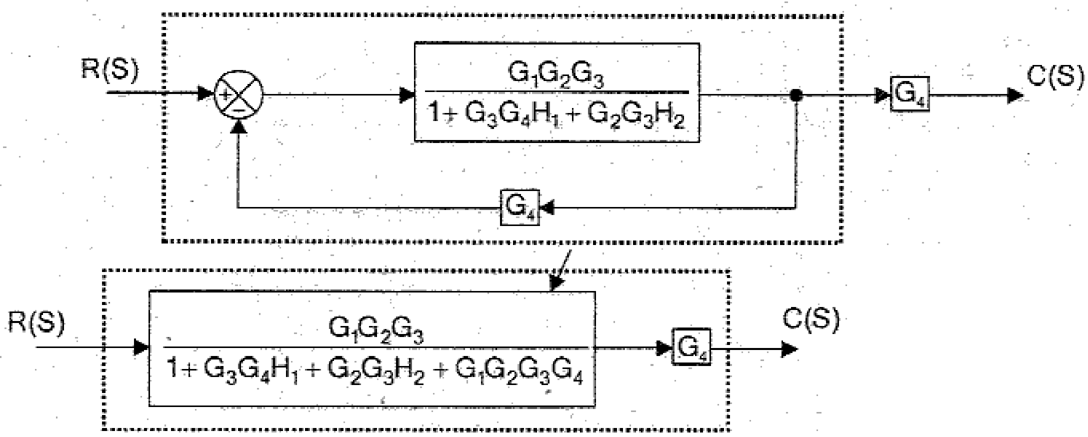
Step 4 : Combining the blocks in cascade and eliminating feedback path



Step 5 : Combining the blocks in cascade

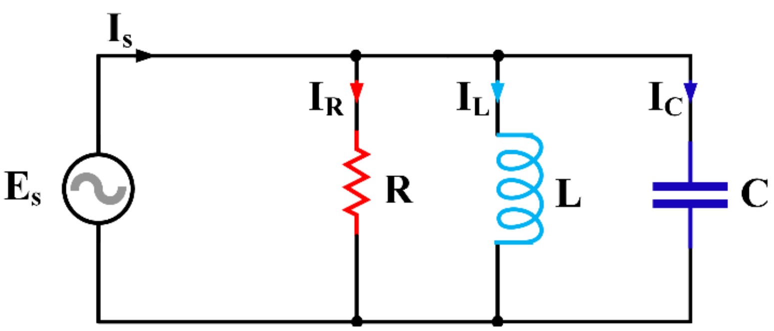


Step 6 : Eliminating the feedback path



$$\frac{C(s)}{R(s)} = \frac{G_1G_2G_3G_4}{1+G_3G_4H_1+G_2G_3H_2+G_1G_2G_3G_4}$$

b) Find the transfer function of a parallel RLC circuit by taking the output across the capacitor 6M



$$V(s) = \frac{\left(\frac{1}{C}\right)s}{s^2 + \left(\frac{1}{RC}\right)s + \left(\frac{1}{LC}\right)} I_g(s)$$

UNIT II

4. a) Find (i) w_d (ii) T_r (iii) T_s (iv) M_p for a system having transfer function $\frac{C(S)}{R(S)} = \frac{25}{s^2+6s+25}$ 8M

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

W_n=5, δ=0.6

$$\theta = \tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$$

$$\omega_d = \omega_n\sqrt{1-\zeta^2}$$

$$\%M_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}} \times 100$$

$\therefore$ For 5% error, Settling time, $t_s = 3T$:

For 2% error, Settling time, $t_s = 4T$

b) Mention the necessary and sufficient conditions for stability of a system. 4M

The Routh stability criterion is based on ordering the coefficients of the characteristic equation, into a schedule, called the Routh array as shown below.

$$a_0s^n + a_1s^{n-1} + a_2s^{n-2} + ...+ a_{n-1}s + a_n = 0, \text{ where } a_0 > 0,$$

s^n	:	a_0	a_2	a_4	a_6	a_8	......
s^{n-1}	:	a_1	a_3	a_5	a_7	a_9	......
s^{n-2}	:	b_0	b_1	b_2	b_3	b_4	......
s^{n-3}	:	c_0	c_1	c_2	c_3	c_4	......
s^1	:	g_0					
s_0	:	h_0					

The Routh stability criterion can be stated as follows.

"The necessary and sufficient condition for stability is that all of the elements in the first column of the Routh array be positive. If this condition is not met, the system is unstable and the number of sign changes in the elements of the first column of the Routh array corresponds to the number of roots of the characteristic equation in the right half of the s-plane".

(OR)

5. a) Determine the step, ramp, parabolic error constants of the following feedback control system. $G(S) = \frac{10(1+4s)(1+6s)}{s^2(s^2+2s+1)}$ 6M

Positional error constant, $K_p = \underset{s\to 0}{Lt}\ G(s)\,H(s)$

Velocity error constant, $K_v = \underset{s\to 0}{Lt}\ s\,G(s)\,H(s)$

Acceleration error constant, $K_a = \underset{s\to 0}{Lt}\ s^2G(s)\,H(s)$

Answers ∞, ∞, 10

b) For the unity feedback system with $G(S) = \frac{K}{(s+1)^3(s+4)}$, determine the range of K for the system to be stable and the frequency of oscillations. 6M

$a_0s^n + a_1s^{n-1} + a_2s^{n-2} + \ldots + a_{n-1}s + a_n = 0$, where $a_0 > 0$,

s^n	:	a_0	a_2	a_4	a_6	a_8	......
s^{n-1}	:	a_1	a_3	a_5	a_7	a_9	......
s^{n-2}	:	b_0	b_1	b_2	b_3	b_4	......
s^{n-3}	:	c_0	c_1	c_2	c_3	c_4	......
s^1	:	g_0					
s_0	:	h_0					

All the first column elements are positive to find the range of K.

Routh's table ,

Range of K (-4<K<20.41)

Frequency of oscillations 1.3628 rad/sec

UNIT III

6. a) Mention the advantages of frequency domain analysis 6M

The advantages of frequency response analysis are the following.

1. The absolute and relative stability of the closed loop system can be estimated from the knowledge of their open loop frequency response.
2. The practical testing of systems can be easily carried with available sinusoidal signal generators and precise measurement equipments .
3. The transfer function of complicated systems can be determined experimentally by frequency response tests.
4. The design and parameter adjustment of the open loop transfer function of a system for specified closed loop performance is carried out more easily in frequency domain.
5. When the system is designed by use of the frequency response analysis, the effects of noise disturbance and parameters variations are relatively easy to visualize and incorporate corrective measures.
6. The frequency response analysis and designs can be extended to certain nonlinear control systems.

b) Find the frequency domain specifications of a system having $H(S) = \frac{36}{s^2+8s+36}$ 6M

$$\frac{C(s)}{R(s)} = M(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

Resonant peak, $M_r = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$

Normalized resonant frequency, $u_r = \frac{\omega_r}{\omega_n} = \sqrt{1-2\zeta^2}$

The resonant frequency, $\omega_r = \omega_n\sqrt{1-2\zeta^2}$

Bandwidth, $\omega_b = \omega_n u_b = \omega_n \left[1 - 2\zeta^2 + \sqrt{2 - 4\zeta^2 + 4\zeta^4}\right]^{\frac{1}{2}}$

$$\gamma = 180 + \left(-90^\circ - \tan^{-1}\frac{u_{gc}}{2\zeta}\right) = 90 - \tan^{-1}\left[\frac{\left[-2\zeta^2 + \sqrt{4\zeta^4 + 1}\right]^{\frac{1}{2}}}{2\zeta}\right]$$

The gain margin of second order system is infinite.

M_r=1.006, w_r=1.99 rad/sec, BW=6.34 rad/sec

(OR)

7. a) A unity feedback control system has $G(S) = \frac{20}{s(s+2)}$ Draw the Bode plot. 4M

Closed loop transfer function is $20/S^2+2S+20$

Sub s=jw

$20/(jw)^2+2jw+20$

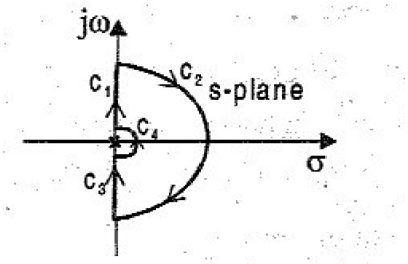
Magnitude equation

Phase angle equation

Plot Mag vs log*w*

Plot Phase angle vs log*w*

b) For the $(S)H(S) = \frac{12}{s(s+1)(s+2)}$, draw the Nyquist plot and determine the stability. Calculate gain margin also. 8M



b. *Nyquist Contour when there are poles at origin*

Section C1 equivalent is a simple polar plot.

Section c2 equivalent is a semi-circle or circle

Section C3 equivalent is a reverse polar plot

Section C4 equivalent is a circle or semi-circle.

Comment stability (unstable)

Gain margin (-6.20dB)

UNIT IV

8. a) A feedback system having open loop transfer function $G(S)H(S) = \frac{K(s+2)}{(s+3)(s^2+2s+2)}$ 8M

Sketch the root locus of the system.

Step 1 : To locate poles and zeros

Step 2 : To find the root locus on real axis.

Step 3 : To find angles of asymptotes and centroid

Step 4 : To find the breakaway and breakin points

Step 5 : To find the angle of departure

Step 6 : To find the crossing point of imaginary axis

b) Sketch the root locus of the system whose open loop transfer function is $G(S) = \frac{k}{s(s+2)}$. 4M

Step 1 : Locate the poles and zeros of G(s)H(s) on the s-plane. The root locus branch starts from open loop poles and terminates at zeros.

Step 2 : Determine the root locus on real axis.

Step 3 : Determine the asymptotes of root locus branches and meeting point of asymptotes with real axis.

Step 4 : Find the breakaway and breakin points.

Step 5 : If there is a complex pole then determine the angle of departure from the complex pole. If there is a complex zero then determine the angle of arrival at the complex zero.

Step 6 : Find the points where the root loci may cross the imaginary axis.

Step 7 : Take a series of test points in the broad neighbourhood of the origin of the s-plane and adjust the test point to satisfy angle criterion. Sketch the root locus by joining the test points by smooth curve.

Step 8 : The value of gain K at any point on the locus can be determined from magnitude condition.

(OR)

9. a) Obtain the state transition matrix for the given state matrix 6M

$$A = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}$$

[s I – A]

Adj [s I – A]

$$\therefore \quad [sI - A]^{-1} = \frac{\text{Adj}\,[sI - A]}{|sI - A|}$$

$$e^{At} = L^{-1}[sI - A]^{-1}$$

b) The state and output equations of a SISO system are 6M

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

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

Determine the controllability and observability.

The system is said to be **completely output controllable** if it is possible to construct an unconstrained input vector U(t) which will transfer any given initial output $Y(t_0)$ to any final output $Y(t_f)$ in a finite time interval $t_0 \le t \le t_f$.

In such a case, construct the test matrix Q_c as,

$$Q_c = [\ B : \ AB : \ A^2B : \ldots \ A^{n-1}B \ ]$$

output controllability, the **rank of test matrix Q_c must be p.**

$$\dot{X} = A\,X(t) + B\,U(t) \qquad \ldots(1)$$

and $$Y(t) = C\,X(t) \qquad \ldots(2)$$

where $Y(t) = p \times 1$ output vector

and $C = 1 \times n$ matrix

The system is completely observable if and only if the rank of the composite matrix Q_o is 'n'.

The composite matrix Q_o is given by,

$$Q_o = [C^T : A^T C^T : \ldots\ldots\ldots (A^T)^{n-1} C^T]$$

where C^T = Transpose of matrix C

and A^T = Transpose of matrix A

Thus if, rank of $Q_o = n$, then system is completely observable.

Scheme of Evaluation

1. 12X1=12M.

a) gain reduces, stability reduces
b) satisfies homogeneous property
c) a-ii, b-i
d) Equation of c(t)
e) M_p definition
f) formula for K_v
g) all pass system
h) W_{gc} definition
i) Bandwidth definition
j) Observability definition
k) State variable definition
l) meeting point of asymptotes

2.	a) definition of open loop system	------ 2M
	Example for open loop system	------ 2M
	Advantages of open loop system	------ 2M
	b) Differential equations	------ 4M
	Diagram for F-V analogy	------ 4M
3.	a) Transfer function of the block diagram	------ 6M
	b)) Parallel RLC circuit	------ 2M
	Equations	------ 2M
	Transfer function	------ 2M
4.	a) Formulas	------ 4M
	Answers	------ 4M
	b) Conditions for stability	------ 4M
5.	a) Formulas	------ 3M
	Answers ∞, ∞, 10	------ 3M
	b) Routh's table ,	------ 2M
	Range of K $(-4<K<20.41)$	------ 2M
	Frequency of oscillations 1.3628 rad/sec	------ 2M
6.	a) Advantages of frequency domain specifications	------ 6M
	b) M_r=1.006, w_r=1.99 rad/sec, BW=6.34 rad/sec	------ 6M
7.	a) Bode Plot	------ 4M
	b) Drawing Nyquist plot	------ 4M
	Comment stability (unstable)	------ 2M
	Gain margin (-6.20dB)	------ 2M
8.	a) Formulas of rules to construct root locus	------ 4M
	Drawing the root locus	------ 4M
	b) Drawing root locus before and after adding a zero	------ 4M
9.	a) State transition matrix	------ 6M
	b) Controllability	------ 3M
	Observability	------ 3M