SHREE SATHYAM

COLLEGE OF ENGINEERING AND TECHNOLOGY

QUESTION BANK

BRANCH: EEE **YEAR/SEM:** III/V

SUB CODE/NAME: EE- 3503 CONTROL SYSTEMS

UNIT I

MODELING OF LINEAR TIME INVARIANT SYSTEM (LTIV)

Control system: Open loop and Closed loop – Feedback control system characteristics – First principle modeling: Mechanical, Electrical and Electromechanical systems – Transfer function representations: Block diagram and Signal flow graph

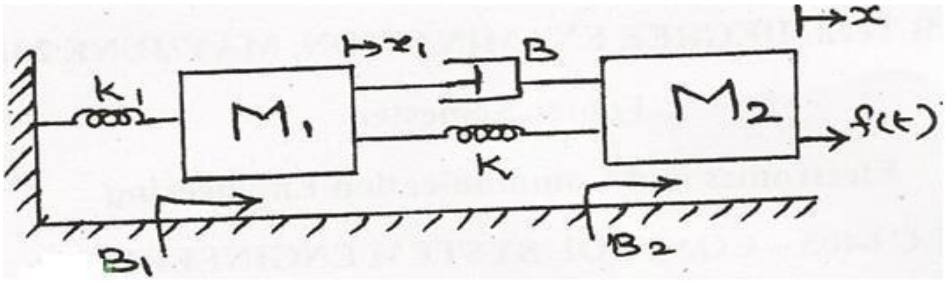
PART - A

1. What is meant by a system?
2. Write Mason's Gain formula.
3. What are the three basic elements in electrical and mechanical system?
4. How will you get closed loop frequency response from open loop response?
5. List out the advantages of closed loop and open loop control system.
6. State ''transfer function'' of a system.
7. What is an analogous system?
8. What are the basic elements of control systems?
9. Write the force balance equation for ideal dashpot and ideal spring.
10. What is Control Systems?
11. Differentiate between open loop and closed loop control systems.
12. Prove the rule for eliminating negative and positive feedback loop.
13. Name any two dynamic models used to represent control systems.
14. What are the characteristics of negative feedback?
15. What is translational system?
16. Give the types of friction.
17. What is block diagram?
18. What is signal flow graph?
19. What is the need for signal flow graph?
20. Why negative feedback is preferred over positive feedback system?

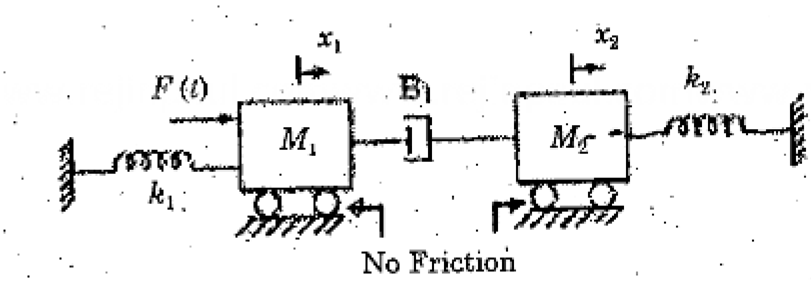
PART - B

Mechanical Translational System (15 Marks)

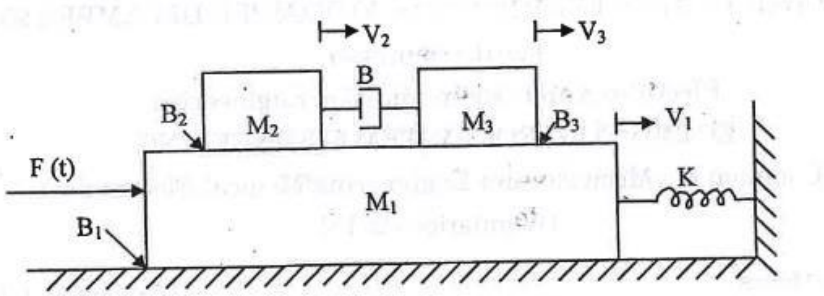
1. Write the differential equation governing the mechanical rotational systems shown in the figure and find the transfer function



2. Write the differential equation governing the mechanical rotational systems shown in the figure and find the transfer function

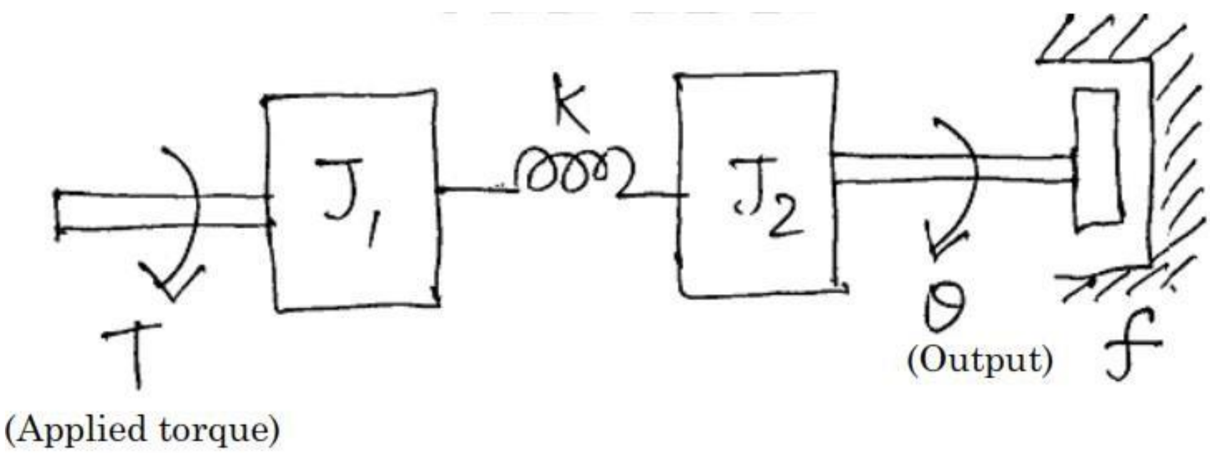


3. Write the differential equation governing the mechanical rotational systems shown in the figure and find the transfer function .



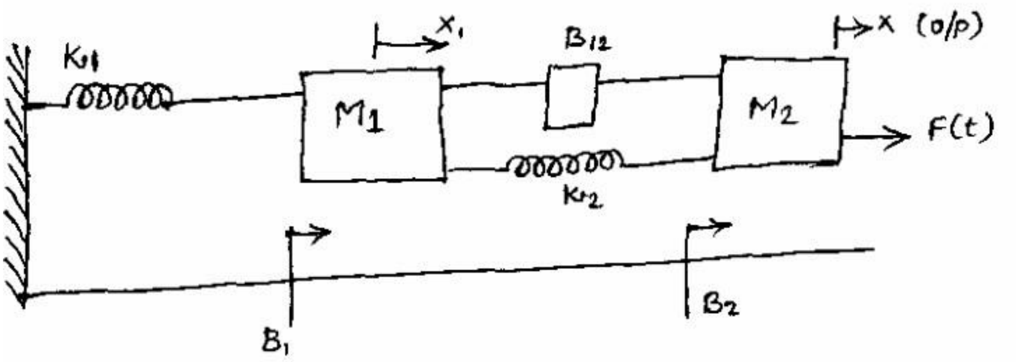
Mechanical Rotational System (16 Marks)

1. Write the differential equation governing the mechanical rotational systems shown in the figure and find the transfer function. Consider the angular displacement in J_1 as θ_1 (**MAY/JUNE 2013)**

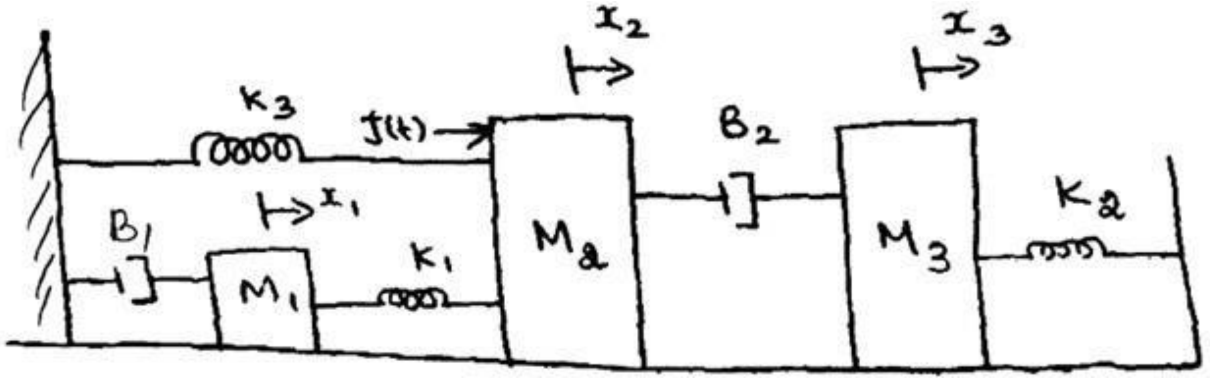


Electrical Analogous Circuits (15 Marks)

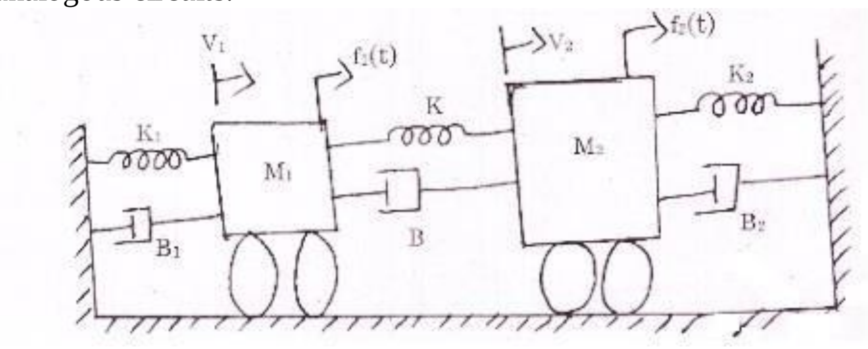
1. Obtain the transfer function of the given mechanical system. Hence the draw electrical analogous circuits.



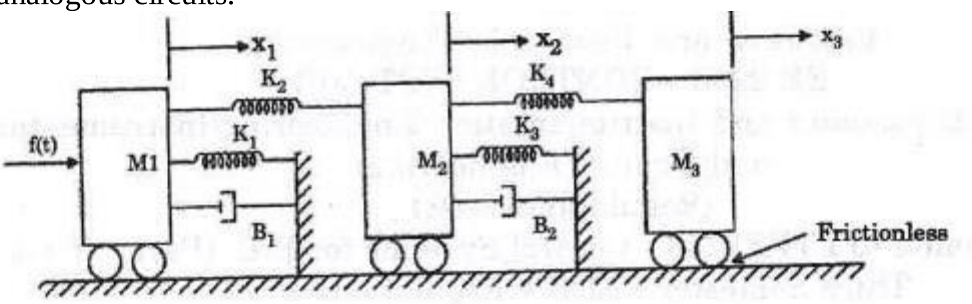
2. Write the differential equation governing the mechanical translational systems shown in the figure. Draw the Electrical analogous circuits.



3. Write the differential equation governing the mechanical translational systems shown in the figure. Draw the Electrical analogous circuits.

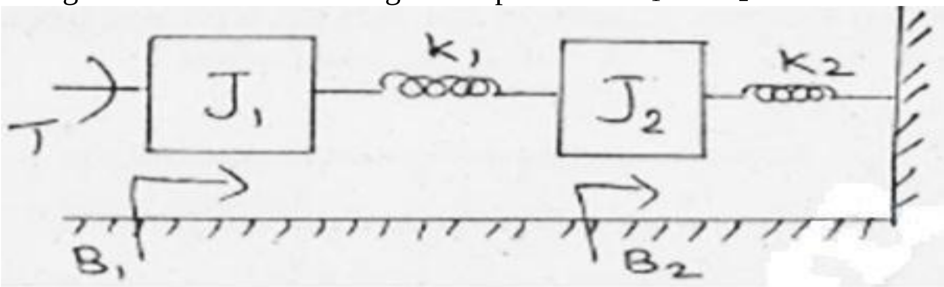


4. Write the differential equation governing the mechanical translational systems shown in the figure. Draw the Electrical analogous circuits.



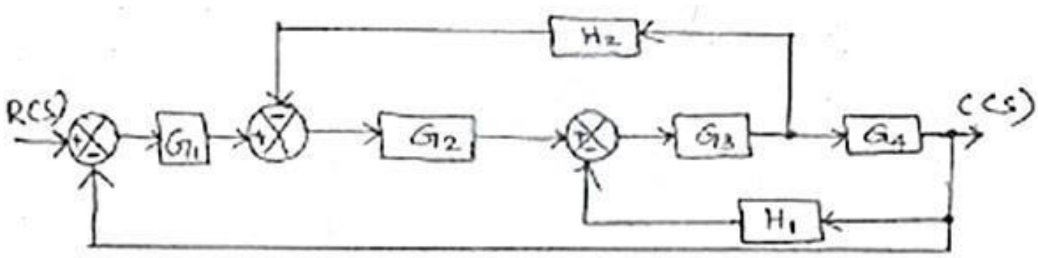
Electrical Analogous Circuits (15 Marks)

1. Write the differential equation governing the mechanical rotational systems shown in the figure. Draw the Electrical analogous circuits with two angular displacement θ_1 and θ_2

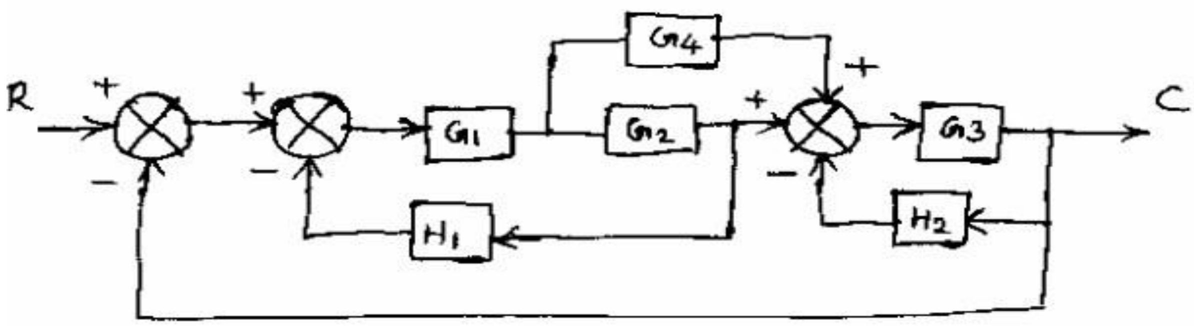


Block Diagram Reduction Technique (13 Marks)

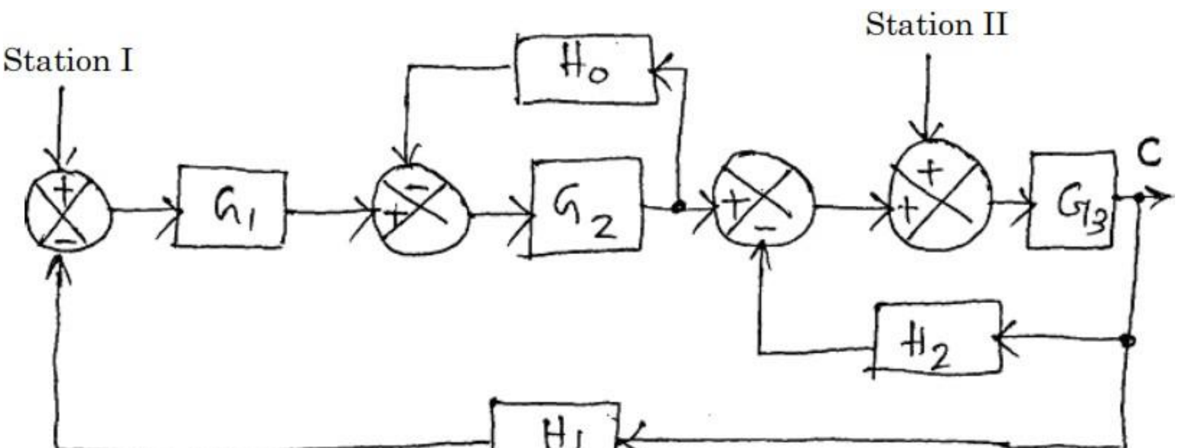
1. Reduce the given block diagram and find the overall transfer function.



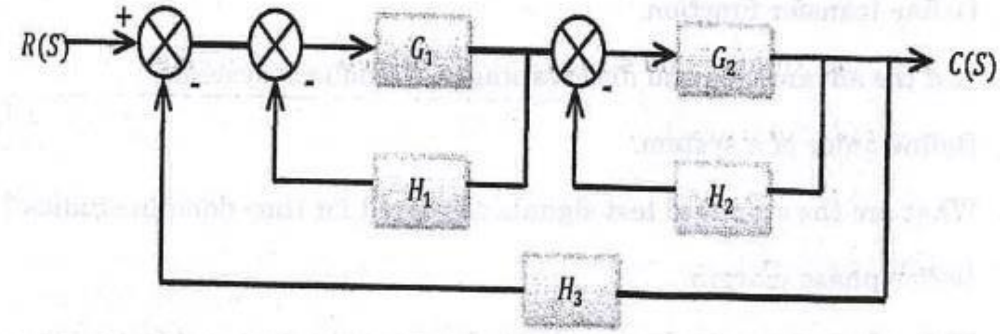
2. Reduce the given block diagram and find the overall transfer function.



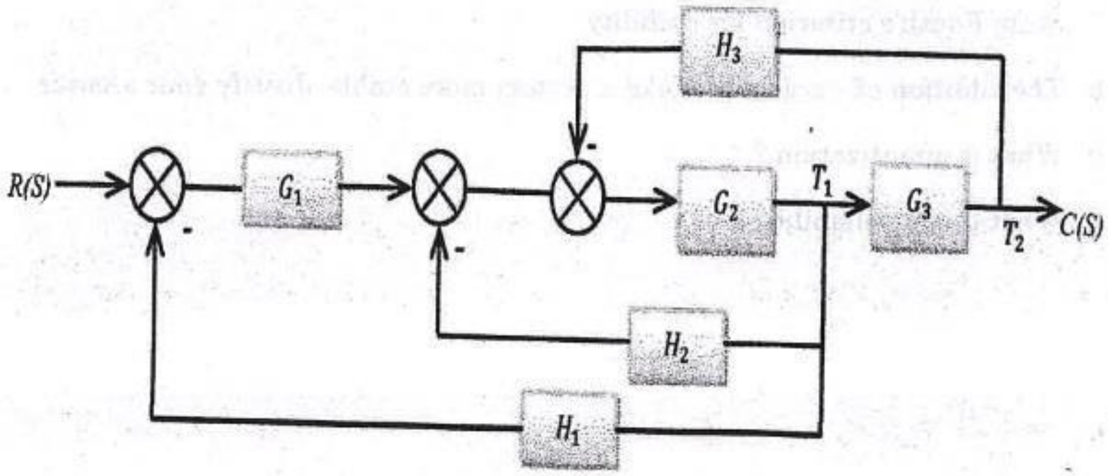
3. For the system represented by the block diagram given below, evaluate the closed loop transfer function, when input R is (i) at Station 1 and (ii) at Station 2



4. Reduce the given block diagram and find the overall transfer function.

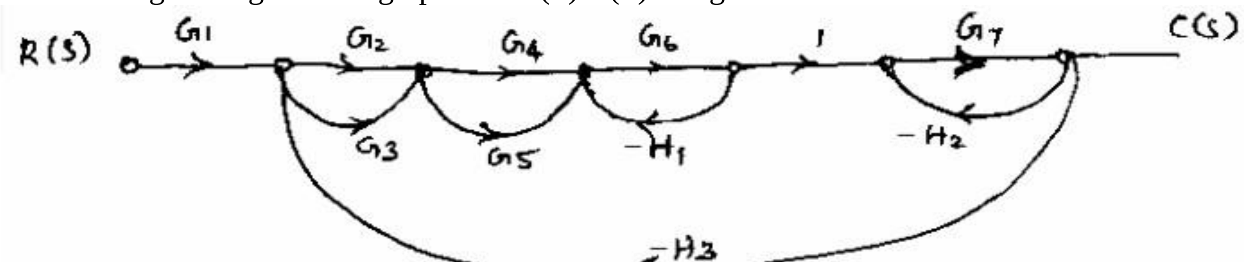


5. Reduce the given block diagram and find the overall transfer function.

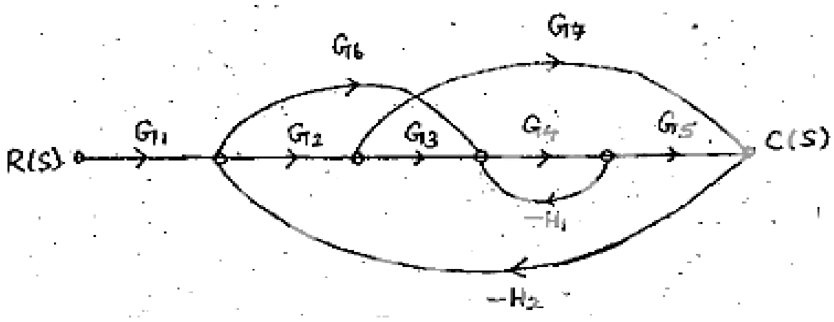


Signal Flow Graph Technique (8 Marks)

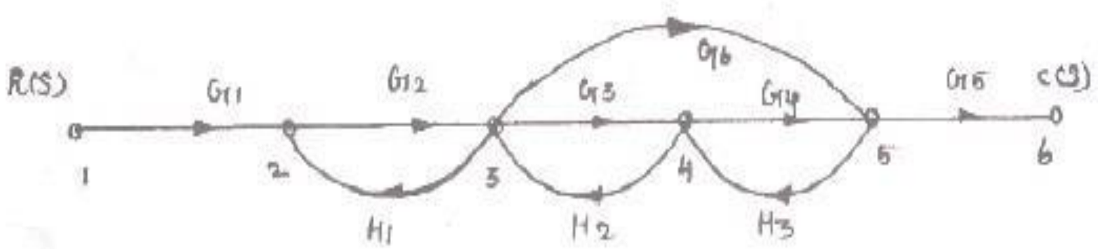
1. For the given signal flow graph find C(S)/R(S) using Mason's Gain formula.



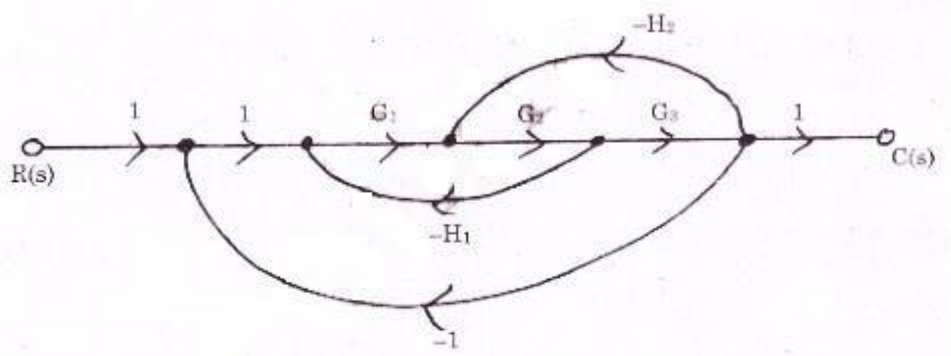
2. For the given signal flow graph find C(S)/R(S) using Mason's Gain formula.



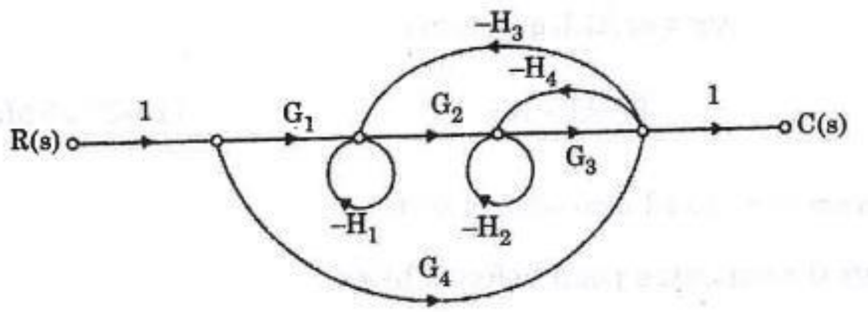
3. For the given signal flow graph find C(S)/R(S) using Mason's Gain formula.



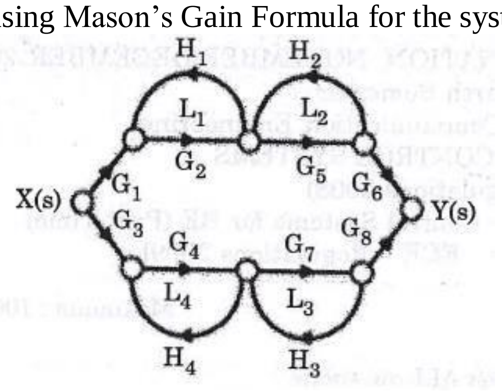
4. Obtain the transfer function using Mason's Gain Formula for the system.



5. Obtain the transfer function using Mason's Gain Formula for the system.

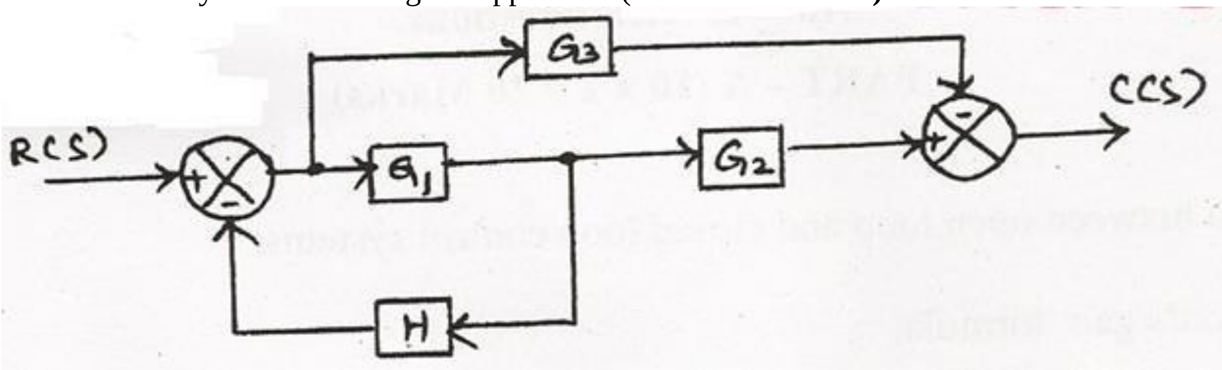


6. Obtain the transfer function using Mason's Gain Formula for the system.

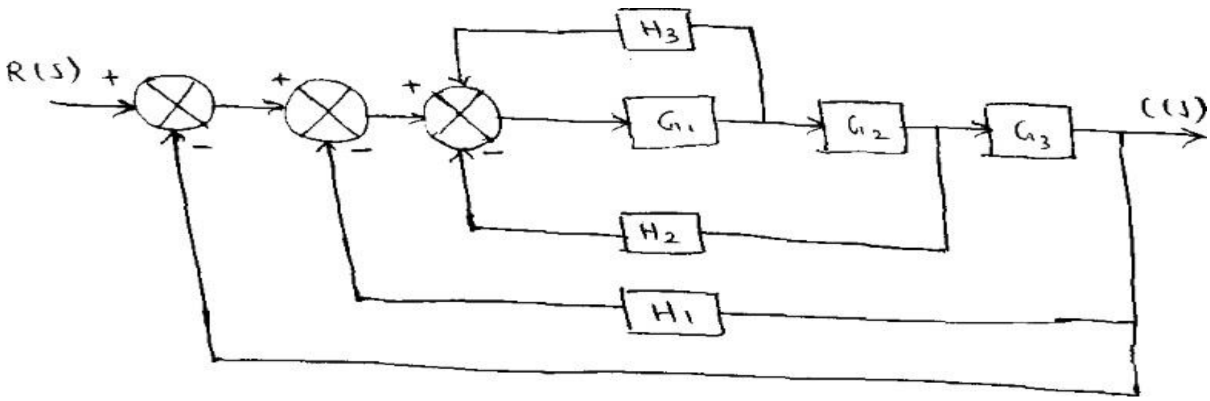


Block Diagram Reduction to Signal Flow Graph Technique

1. Convert the given block diagram to signal flow graph and find the transfer function using mason's gain formula and verify with block diagram approach. (**MAY/JUNE 2016)**



2. Convert the given block diagram to signal flow graph and find the transfer function using mason's gain formula and verify with block diagram approach.



UNIT II

TIME DOMAIN ANALYSIS

Standard test inputs – Time response – Time domain specifications – Stability analysis: Concept of stability – Routh Hurwitz stability criterion – Root locus: Construction and Interpretation. Effect of adding poles and zeros

PART - A

1. Specify the time domain Specification?
2. What is meant by steady state error?
3. List the Standard test signal used in time domain analysis.
4. State the effect of PI Compensation in system performance.
5. How do you find the type of the system?
6. Find the unit impulse response of the system H(s) = 5s/(s+2) with zero initial conditions.
7. For the system described by $\frac{C(S)}{R(S)} = \frac{16}{S^2+8S+16}$;find the nature of the time response?
8. Why is the derivative control not used in control system?
9. Give the relation between static and dynamic error coefficients.
10. What is type and order of the system?
11. What are the advantages of generalized error series?
12. What do you mean by peak over shoot?
13. Define settling time.
14. Differentiate between steady state and transient response of the system?
15. What is the effect of system performance when a proportional controller is introduced in a system?
16. What is type and order of the given system $G(S) = \frac{K}{S(ST+1)}$?
17. Define Rise time.
18. Define peak time.
19. Define stability.
20. What is nyquist contour
21. Define Relative stability.
22. What will be the nature of impulse response when the roots of characteristic equation are lying on imaginary axis?
23. What is the relationship between Stability and coefficient of characteristic polynomial?
24. What is limitedly stable system?
25. In routh array what conclusion you can make when there is a row of all zeros?
26. State any two limitations of routh stability criterion.
27. Define Routh Stability Criterion?
28. What is dominant pole?
29. How will you find the root locus on real axis?
30. State the basic properties of root locus.

PART – B

Time Response Analysis

1. Define and Derive the time domain specifications of a second order system subjected to a step input .
2. Derive the expression for unit step response for the second order
   a. Under damped, and
   b. Undamped systems.
3. Derive the time response of a first order system for unit step input **.**
4. The unity feedback control system is characteristic by an open loop transfer function $G(S) = \frac{K}{S(S+10)}$. Determine the gain K, so that the system will have damping ratio of 0.5 for this value of K. Determine the peak overshoot and peak time for a unit step input.
5. The overall transfer function of a control system is given by $\frac{C(S)}{R(S)} = \frac{16}{S^2+1.6S+16}$. It is desired that the damping ratio be 0.8. Determine the derivative rate feedback constant K_1 and compare rise time, peak time,maximum overshoot and steady state error for unit ramp input function without and with derivativefeedback control.

Static and dynamic error

1. For a unity feedback control system the open loop transfer function is given by

$G(s) = \frac{10(S+2)}{S^2(S+1)}$, find

a. The position, velocity, acceleration error constants

b. The steady state error when R(s) = $\frac{3}{S} - \frac{2}{S^2} + \frac{1}{3S^3}$

2. The open loop transfer function of a unity feedback control system is given by $G(S) = \frac{K}{S(S+1)}$. The input of the system is described by r(t)=4+6t. Find the generalized error coefficients and steady state error.

3. The unity feedback control system has the forward transfer function $G(S) = \frac{KS}{(S+1)^2}$. For the input r(t)=1+5t. Find the Minimum value of K so that the steady state error is less than 0.1.

4. The open loop transfer function of a servo system with unity feedback is $G(S) = \frac{10}{S(0.1S+1)}$. Evaluate the static error constants (Kp, Kv, Ka) for the system. Obtain the steady state error of the system when subjected to an input given by the polynomial $r(t) = a_0 + a_1 t + \frac{a_2}{2} t^2$

5. For the open loop system with $G(S) = \frac{1}{(S+1)}$ and $H(S) = 5$, Calculate the generalized error coefficients and error series **.**

ROUTH HURWITZ CRITERION

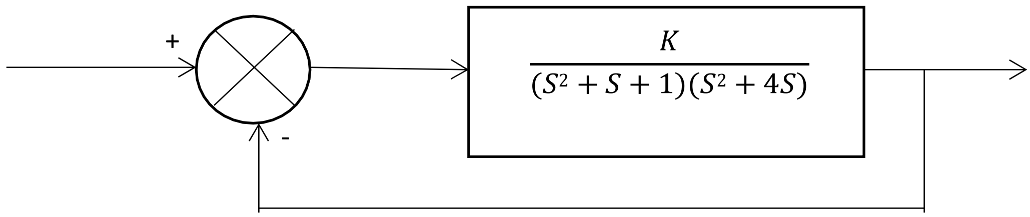
1. Using Routh array determine the range of K for stability of unity feedback system whose open loop transfer function in $\boldsymbol{G(s)} = \frac{\boldsymbol{K}}{\boldsymbol{s(s+1)(s+2)}}$

2. Construct Routh Array and determine the stability of the system whose characteristic equation is $\boldsymbol{S^6+2S^5+8S^4+12S^3+20S^2+16S+16=0}$. Also determine the number of roots lying on righthalf of s – plane, left half of s-plane and on imaginary axis.

3. Determine the stability of the given system of the given characteristic equation using Routh-Hurwitz Criterion
   i. $S^5+4S^4+8S^3+8S^2+7S+4=0$
   ii. $S^6+S^5+3S^4+3S^3+3S^2+2S+1=0$

4. The open loop transfer function of a unity feedback control system is given by $\boldsymbol{G(s)} = \frac{\boldsymbol{K}}{\boldsymbol{(s+2)(S+4)(S^2+6S+25)}}$. By applying Routh criterion, discuss the stability of the closed loop System as a function of K. Determine the values of K which will cause sustained oscillations in the closed loopsystem. What are the corresponding oscillation frequencies?

5. Consider the closed – loop system shown in the figure, determine the range of K for which thestable



ROOT LOCUS

1. With neat steps write down the procedure for construction of root locus. Each rule give a example.

2. A unity Feedback Control system has an open loop transfer function

$$G(s) = \frac{K}{S(S^2 + 4S + 13)}$$

Sketch the root locus.

3. A single loop negative feedback system has a transfer function $G_c(s)G(s) = \frac{K(S+6)^2}{S(S^2+1)(S+4)}$. Sketch the root locus as a function of K. Find the range of K for which the system is stable.

4. Draw the root locus of the system is given by $G(s) = \frac{K(S+1)}{S(S^2+5S+20)}$.

5. Plot the root locus for a unity feedback closed loop system whose open loop transfer function is $G(s) = \frac{K}{S(S+4)(S^2+2S+2)}$.

6. Sketch the root locus of a unity feedback system with an open loop transfer function $G(s) = \frac{K}{S(S+2)(S+4)}$. Find the value of K so that the damping ratio of the closed loop system is 0.5.

7. Sketch the root locus of a unity feedback system with an open loop transfer function $G(s) = \frac{K(S+0.5)}{S^2(S+4.5)}$.

8. The open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{K(S + 9)}{S(S^2 + 4S + 11)}$$

Sketch the root locus.

9. Sketch the root locus of a unity feedback system with an open loop transfer function $G(s) = \frac{K}{S(S+1)(S+2)}$.

UNIT III

FREQUENCY DOMAIN ANALYSIS

Bode plot, Polar plot and Nyquist plot: – Frequency domain specifications Introduction to closed loop Frequency Response. Effect of adding lag and lead compensators

PART - A

1. What is bode plot?
2. Define gain margin and phase margin.
3. Define Resonant Peak and Resonant Frequency.
4. Mention any four frequency response specifications.
5. What are m & n circles?
6. Define Corner Frequency.
7. What is Nichol's chart?
8. What is Gain and Phase Crossover Frequency?
9. List the advantages of Nichol's chart?
10. What are the Frequency Domain Specifications?
11. Define –Resonant Peak
12. What is bandwidth?
13. Define Cut-off rate?
14. What are the main advantages of Bode plot?
15. Define Phase cross over?
16. Define Gain cross over?
17. What is a polar plot?

PART B

BODE PLOT

1. Plot the Bode diagram for the following transfer function and obtain the gain and phase cross over frequencies.

$$G(S) = \frac{10}{S\,(1 + 0.4S)(1 + 0.1S)}$$

2. Sketch the Bode plot and hence find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin.

$$G(S) = \frac{0.75(1 + 0.2S)}{S\,(1 + 0.5S)(1 + 0.1S)}$$

3. Sketch the Bode plot and hence find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin.

$$G(S) = \frac{10(S+3)}{S(S+2)\ (S^2+4S+100)}$$

4. Plot the Bode diagram for the following transfer function and obtain the gain and phase cross over frequencies

$$G(S) = \frac{KS^2}{(1+0.2S)(1+0.02S)}$$

Determine the value of K for a gain cross over frequency of 20 rad/sec.

5. Sketch the Bode plot and hence find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin.

$$G(S) = \frac{10(1+0.1S)}{S\ (1+0.01S)\ (1+S).}$$

POLAR PLOT

1. The open loop transfer function of a unity feedback system is

$$G(S) = \frac{1}{S\ (1+S)(1+2S)}$$

Sketch the Polar plot and determine the Gain margin and Phase margin.

2. Sketch the polar plot for the following transfer function and find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin.

$$G(S) = \frac{10(S+2)\ (S+4)}{S\ (S^2+3S+10)}$$

3. Sketch the polar plot for the following transfer function .and find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin.

$$G(S) = \frac{400}{S\ (S+2)\ (S+10)}$$

NICHOL'S PLOT

1. A unity feedback system has open loop transfer function

$$G(S) = \frac{20}{S\ (S+2)(S+5)}.$$

Using Nichol's chart. Determine the closed loop frequency response and estimate all the frequency domain specifications.

2. Draw the Nichol's plot for the system whose open loop transfer function is G(S) H(S) =K / S (S+2) (S+10). Determine the range of K for which closed loop system is stable.

3. Construct Nichol's plot for a feedback control system whose open loop transfer function is given by G(S) H(S) =5/ S(1+S).Comment on the stability of open loop and closed loop transfer function.

4. Sketch the Nichol's plot for a system with the open loop transfer function G(S) H(S) =K (1+0.5S) (0.01+S) / (1+10S) (S+1). Determine the range of values of K for which the system is stable.

NYQUIST STABILITY CRITERION

1. The open loop transfer function of a unity feedback system is given by G(s)H(s)=5/s(s+1)(s+2).

Draw the nyquist plot and hence find out whether the system is stable or not

UNIT IV

STATE VARIABLE ANALYSIS

State variable formulation – Non uniqueness of state space model – State transition matrix – Eigen values – Eigen vectors - Free and forced responses for Time Invariant and Time Varying Systems – Controllability – Observability

PART - A

1. Define State and State Variable.
2. What is controllability?
3. What is observability?
4. Write the properties of state transition matrix.
5. What is modal matrix?
6. State the duality between controllability and observability.
7. What are the methods available for the stability analysis of sampled data control system?
8. What is the necessary condition to be satisfied for design using state feedback?
9. What is similarity transformation?
10. What is meant by diagonalization?
11. What is the need for controllability test?
12. What is the need for observability test?
13. What is the need for state observer?
14. What is the pole placement by state feedback?
15. How control system design is carried in state space?
16. What is state transition matrix?
17. When do you say the system is completely controllable?
18. State the limitations of state variable feedback?
19. Define Sampling Theorem?
20. Draw Sample and hold circuits

PART-B

Controllability and Observability

1. Determine whether the system described by the following state model is completely controllable and observable

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

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

2. Determine whether the system described by the following state model is completely controllable and observable **(APR/MAY 2015)**

$$\begin{bmatrix}\dot{x}\end{bmatrix} = \begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -1 & -5 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix} + \begin{bmatrix}0\\ 5\\ -24\end{bmatrix}u$$

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

3. Consider the system is defined by X = Ax+Bu and Y = Cx, Where

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix};\ B = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix};\ C = \begin{bmatrix} 10 & 5 & 1 \end{bmatrix}$$

Check the controllability and observability of the system.

State Model Transformation

4. Consider the the following system with differential equation given by

$$\dddot{y} + 6\ddot{y} + 11\dot{y} + 6y = 6u$$

Obtain the state model in diagonal canonical form.

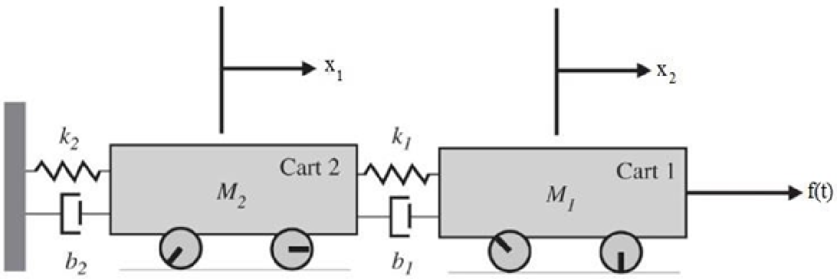
5. Construct the state model for the system characterized by the differential equation $\frac{d^3x}{dt^3} + 6\frac{d^2x}{dt^2} + 11\frac{dx}{dt} + 6x + u = 0$

6. Consider the system is defined by X = Ax+Bu and Y = Cx, Where

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix};\ B = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix};\ C = \begin{bmatrix} 10 & 5 & 1 \end{bmatrix}$$

Obtain the diagonal canonical form of the state model by a suitable transformation matrix.

7. Obtain the state model of the mechanical translational system in which f(t) is input and x2(t) is output.



State Model to Transfer Function

8. Convert the given state model to transfer function

$$[\dot{x}] = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -8 & -14 & -7 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}u$$

$$y(t) = \begin{bmatrix} 15 & 5 & 0 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

9. Obtain the transfer function of the state model Consider the system is defined by X = Ax+Bu and Y = Cx, Where

$$A = \begin{bmatrix} -7 & 1 & 0 \\ -14 & 0 & 1 \\ -8 & 0 & 0 \end{bmatrix};\ B = \begin{bmatrix} 20 \\ 125 \\ 185 \end{bmatrix};\ C = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$$

10. Convert the given state model to transfer function

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix} = \begin{bmatrix}3 & 1 & 0\\ 0 & 3 & 1\\ 0 & 0 & 3\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix} + \begin{bmatrix}0\\ 0\\ 1\end{bmatrix}u$$

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

UNIT V
DESIGN OF FEED BACK CONTROL SYSTEM

Design specifications – Lead, Lag and Lag-lead compensators using Root locus and Bode plot techniques –PID controller - Design using reaction curve and Ziegler-Nichols technique- PID control in State Feedback form

PART – A

1. What are compensators?
2. What are the two types of compensation techniques write short notes on them?
3. Define Lead compensator.
4. What is a lag compensator?
5. What is a lag lead compensator?
6. What is the need for compensator?
7. Sketch the frequency response of lead, lag-lead compensator.
8. Write the transfer function and pole zero plot of lag, lead and lag-lead compensator.
9. What is the relation between φ_m *and* α?
10. What type of compensator suitable for high frequency noisy environment?
11. What is desired performance criteria specified in compensator design?
12. Sketch the electrical circuit of a Lag, Lead, lag-lead compensator.
13. Write advantages of lag compensator.
14. List out the merits and demerits of lag and lead compensator.
15. Write difference between lag and lead compensator.
16. Give the transfer function of the PID Controller.
17. State the effect of PD Compensation in system performance.
18. Give the effects of Lead compensation.
19. Give the effects and limitations of lag compensator.
20. What is the effect of lead compensator and lag compensator on system bandwidth?
21. What is called a PID controller?
22. What is the effect of PI controller on the system performance?
23. Why derivative controller is not used alone in control systems?
24. Give the tuning method for PID controller design.
25. Describe about Reaction curve method.
26. State Ziegler-Nichols technique.
27. List the Advantage and disadvantages of Ziegler-Nichols closed-loop tuning method.
28. List the Advantage and disadvantages of Ziegler-Nichols open-loop tuning method

PART B

1. Explain the procedure for lead compensation and lag compensation?

2. Explain the design procedure for lag- lead compensation.

3. Discuss in detail about the design procedure for lag compensation using root locus.

4. The open loop transfer function of uncompensated system is **G(s) =** $\mathbf{5/\ S\ (S+2)}$**.** Design a suitable la compensator for the system so that the $\boldsymbol{Kv = 20\ sec^{-1}}$ and phase margin as 55° and the GM is 12dB.

5. The open loop transfer function of a unity feedback system is **G(s) =** $\mathbf{4/\ S\ (2S+1)}$ .It is desired to obtain a phase margin of 40 degree without the sacrificing the error constant $\boldsymbol{Kv = 12\ sec^{-1}}$ of the system. Design a suitable lag compensator to meet the above specifications.

6. Analyze on lead, lag and lead-lag compensators with neat diagram. Also explain their importance.

7. The open loop transfer function of a unity feedback system is G(s) = $\boldsymbol{Kv/\ S\ (S+1)}$ .It is desired to have the velocity error constant $\boldsymbol{Kv = 12\ sec^{-1}}$ and phase margin as 40°. Design a lead compensator to meet the above specifications.

8. Derive the transfer function of a lead compensator network.

9. Sketch the Bode plot and hence find Gain cross over frequency, Phase cross over frequency, Gain Margin and Phase Margin for the function. **G(s)=** $\mathbf{10\ (s+3)\ /\ S(S+2)(S\ 2+4S+1)}$.

10. The open loop transfer function of the uncompensated system is $\boldsymbol{G(s) = \frac{1}{S(S+1)(S+2)}}$. Compensate the system by cascading suitable lag – lead compensator for the system so that the static velocity error constant $K_V = 10sec^{-1}$, the phase margin is atleast 45° and the gain margin is atleast 10dB or more.

11. Explain P, PI, PID, PD controllers.

12. Explain in detail about the procedure to obtain the controller settings using process reaction curve method.

13. With neat block diagram explain the controller tuning using Ziegler-Nichols method.