

UNIT I

Introduction - Basic elements of control system, Open loop and closed loop systems, Differential equations and transfer function, Modelling of electric systems, Translational and rotational mechanical systems, Block diagram reduction techniques, Signal flow graph.

Chapter 1 : Introduction to Control Systems 1-1 to 1-6

1.1	Introduction	1-1
1.2	Important Definitions	1-1
1.3	Open Loop System	1-2
1.3.1	Open Loop Examples.....	1-2
1.3.2	Advantages and Disadvantages of Open Loop Systems	1-3
1.4	Closed Loop System	1-3
1.4.1	Closed Loop Examples.....	1-4
1.4.2	Advantages and Disadvantages of Closed Loop System	1-5
1.5	How does One Convert an Open Loop System to a Closed Loop System ?	1-5
1.5.1	Comparison of Open and Closed Loop Systems.....	1-6
1.6	Requirements of a Good Control System	1-6

Chapter 2 : Transfer Function and Mathematical Modelling 2-1 to 2-19

2.1	Introduction	2-1
2.2	Transfer Function	2-1
2.3	Poles and Zeros of a Transfer Function	2-4
2.4	Properties of Transfer Function (T.F.)	2-6
2.5	Proper and Improper Transfer Functions	2-7
2.6	Advantages and Disadvantages of Transfer Function	2-7
2.7	Impulse Response	2-7
2.7.1	Impulse Response of a System	2-8
2.8	Solved Examples on Transfer Functions	2-9
2.9	Mathematical Modelling of Mechanical and Electrical Systems	2-11
2.9.1	Translational Motion.....	2-11
2.9.2	Rotational Motion	2-12

2.9.3	Electrical Systems.....	2-13
2.10	Analogous Systems	2-14
2.10.1	Force - Voltage Analogy.....	2-14
2.10.2	Force - Current Analogy	2-15
2.10.3	Advantages of Analogous Systems	2-15
2.11	Representation by Nodal Method	2-15
2.12	Solved Examples on Mathematical Modelling	2-16

Chapter 3 : Block Diagram Reduction 3-1 to 3-28

3.1	Introduction	3-1
3.1.1	How to Draw a Block Diagram ?	3-1
3.2	Block Diagram Definitions	3-1
3.3	Block Diagram Reduction	3-2
3.3.1	Derivation of Closed Loop (Feedback) Transfer Function.....	3-2
3.3.2	Advantages of Block Diagram.....	3-3
3.3.3	Disadvantages of Block Diagram.....	3-3
3.4	Rules for Block Diagram Reduction	3-3
3.5	Solved Examples	3-9

Chapter 4 : Signal Flow Graph 4-1 to 4-19

4.1	Introduction	4-1
4.1.1	How to Draw a Signal Flow Graph ?	4-1
4.2	Method to Draw SFG from System Equations ...	4-1
4.3	Method to Draw SFG from Block Diagrams	4-3
4.4	Some Important Signal Flow Graph Terms	4-3
4.5	Properties of SFG	4-4
4.5.1	Comparison of Block Diagram and SFG Methods...4-4	
4.6	Mason's Gain Formula	4-4
4.6.1	Mason's Gain Equation.....	4-5
4.7	Steps for Solving S.F.G. using Mason's Gain Formula	4-5
4.7.1	Solved Examples on Mason's Gain Formula.....	4-5
4.8	Solving SFG When Equations are Given	4-18
4.8.1	Solved Examples.....	4-18
4.9	Use of Mason's Gain Formula for Electrical Network	4-19

UNIT II

Time domain analysis : Transient response and steady state response, Standard test inputs for time domain analysis, order and type of a system, Transient analysis of first and second order systems, time domain specifications of second order under damped system from its step response, Steady state error and static error constants.

Chapter 5 : Time Domain Analysis 5-1 to 5-40

5.1	Introduction.....	5-1
5.1.1	Time Domain.....	5-1
5.2	Inputs Supplied to a System	5-2
5.3	Steady State Response	5-4
5.3.1	Effect of Input R(s) on Steady State Error	5-5
5.3.2	Effect of Open Loop Transfer Function G(s) H(s) on Steady State Error e_{ss}	5-7
5.4	Subjecting a Type 0 System to a Step, Ramp and Parabolic Input	5-7
5.4.1	Step Input to a Type 0 System	5-7
5.4.2	Ramp Input to a Type 0 System	5-8
5.4.3	Parabolic Input to a Type 0 System	5-8
5.5	Subjecting a Type 1 System to a Step, Ramp and Parabola Input.....	5-9
5.5.1	Step Input to a Type 1 System	5-9
5.5.2	Ramp Input to a Type 1 System.....	5-9
5.5.3	Parabolic Input to a Type 1 System	5-10
5.6	Subjecting a Type 2 System to a Step, Ramp and Parabola Input.....	5-10
5.6.1	Step Input to a Type 2 System	5-10
5.6.2	Ramp Input to Type 2 System.....	5-10
5.6.3	Parabola Input to Type 2 System	5-11
5.6.4	Examples on Steady State Response	5-12
5.7	Transient Response	5-17
5.7.1	Analysis of First Order Systems	5-18
5.7.2	Analysis of Second Order System.....	5-19
5.7.2(A)	Damping Factor	5-20
5.7.2(B)	Natural Frequency of Oscillation (ω_n).....	5-20

5.7.2(C)	Position of Poles in a 2 nd Order System.....	5-20
5.7.3	Effect of ξ on the Position of Closed Loop Poles	5-21
5.7.4	Unit Step Response of a 2 nd Order System.....	5-21
5.7.5	Time Domain of a Second Order System with $0 < \xi < 1$	5-24
5.7.5(A)	Derivation of Unit Impulse Response of a 2 nd Order Underdamped System.....	5-24
5.7.5(B)	Derivation of Unit Step Response of a 2 nd Order Underdamped System.....	5-24
5.8	Transient Response Specifications (Design Specifications for Second Order Systems)	5-27
5.8.1	Derivation of Rise Time (T_r)	5-28
5.8.2	Derivation of Peak Time (T_p)	5-28
5.8.3	Derivation of Peak Overshoot (M_p).....	5-29
5.8.4	Derivation of Settling Time (T_s).....	5-30
5.9	Solved Examples on Transient Response.....	5-31
➤	Model Question Paper (In sem.)	M-1 to M-2

UNIT III

Characteristic equation of a system, Concept of pole and zero, Response of various pole locations in s-plane, Concept of stability absolute stability, Relative stability, Stability of system from pole locations, Routh Hurwitz stability criterion, Root locus : Definition, Magnitude and angle conditions, Construction of root locus, Concept of dominant poles, Effect of addition of pole and zero on root locus. Application of root locus for stability analysis.

Chapter 6 : Stability Analysis 6-1 to 6-18

6.1	Introduction	6-1
6.1.1	Stable System	6-1
6.1.2	Unstable System	6-1
6.1.3	Marginally Stable System	6-3
6.2	Time Response of Poles	6-2
6.3	Hurwitz Stability Criterion	6-6
6.3.1	Disadvantages of the Hurwitz Criterion.....	6-7
6.4	Routh Stability Criterion	6-8
6.5	Routh Criterion Special Cases	6-10

6.5.1	Special Case 1.....	6-10	8.2.3	Advantages of Frequency Domain Analysis	8-3
6.5.2	Special Case 2.....	6-12	8.2.4	Time Domain and Frequency Domain Analysis.....	8-3
6.6	Relative Stability.....	6-14	8.2.5	Disadvantages of Frequency Domain Methods.....	8-4
6.7	Application of Routh's Criterion.....	6-15	8.3	Transfer Function and Frequency Domain	8-4
6.8	Solved Examples	6-15	8.3.1	Transfer Function and Frequency	
Chapter 7 : Root Locus		7-1 to 7-38		Domain of a R - C Circuit	8-4
7.1	Introduction.....	7-1	8.4	Frequency Domain Specifications	8-6
7.2	Angle and Magnitude Condition.....	7-2	8.5	Co-relation between Time	
7.3	Construction of Root Locus.....	7-3		and Frequency Domain.....	8-6
7.3.1	General Method for Drawing Root Locus.....	7-3	8.5.1	Derivation of ω_r and M_r	8-6
7.4	Determining the Value of k from		8.5.2	Relationship between Frequency Domain	
	the Damping Ratio.....	7-8		Specifications and Time Domain Specifications.....	8-7
7.5	Steps for Solving Problems on Root Locus.....	7-8	8.6	Bandwidth.....	8-8
7.6	Solved Examples	7-9	8.7	Solved Examples	8-9
7.7	Some Additional Important Points	7-37	Chapter 9 : Bode Plots		9-1 to 9-48
7.7.1	More Zeros and Less Poles	7-37	9.1	Introduction	9-1
7.7.2	Value of Gain Margin	7-37	9.2	Log-Scales.....	9-2
7.7.3	Phase Margin from Root Locus	7-37	9.2.1	Why do we Use the Log Scales on the X-axis?.....	9-2
7.8	Effect of Addition of Poles and Zeros		9.2.2	What are Log-Scales?	9-2
	on Root Locus.....	7-37	9.2.3	Scale Marking.....	9-3
7.8.1	Effect of Addition of Poles - Dominant Poles.....	7-37	9.3	Standard Form for GH ($j\omega$).....	9-3
7.8.2	Effect of Addition of Zeros.....	7-37	9.4	Bode Plots of Standard Factors.....	9-4
UNIT IV			9.4.1	Bode Gain Factor K_1	9-4
<p>Frequency response and frequency domain specifications, correlation between time domain and frequency domain specifications, Polar plot, Nyquist stability criterion and construction of Nyquist plots, Bode plot, Determination of frequency domain specifications and stability analysis using Nyquist plot and Bode plot.</p>			9.4.2	Poles at Origin or Integral Factor $\left(\frac{1}{j\omega}\right)^k$	9-4
Chapter 8 : Frequency Domain Analysis			9.4.3	Zeros at Origin or Derivative Factor $(j\omega)^g$	9-6
	8-1 to 8-15		9.4.4	First Order Poles $\frac{1}{\left(1 + j\frac{\omega}{P_1}\right)}$	9-6
8.1	Introduction.....	8-1	9.4.5	First Order Zeros $\left(1 + j\frac{\omega}{Z_1}\right)$	9-8
8.2	Frequency Domain.....	8-2	9.4.6	Second Order Poles.....	9-8
8.2.1	Sinusoidal Response of a Linear System.....	8-2	9.4.7	Second Order Zeros	9-10
8.2.2	Methods Used in Frequency Domain	8-3	9.5	Frequency Domain Specifications	9-11
			9.5.1	Gain Margin (G.M.)	9-11

9.5.2	Phase Margin (ϕ_{pm}).....	9-11	10.7.2	Modified Nyquist Contour.....	10-15
9.5.3	Bandwidth.....	9-11	10.7.3	Advantages of Nyquist Plot.....	10-15
9.5.4	Cut-off Frequency (ω_c).....	9-12	10.8	Relative Stability	10-16
9.5.5	Cut-off Rate.....	9-12	10.9	Solved Examples	10-16
9.5.6	Resonance Peak Frequency (M_p).....	9-12	UNIT V		
9.5.7	Resonant Frequency (ω_p).....	9-12	State space advantages and representation, Transfer function from State space, Physical variable form, Phase variable forms : Controllable canonical form, Observable canonical form, Solution of homogeneous state equations, State transition matrix and its properties, Computation of state transition matrix by Laplace transform method only.		
9.5.8	Gain Crossover Frequency (ω_{gc}).....	9-12	Chapter 11 : State Space Representation 11-1 to 11-47		
9.5.9	Phase Margin Angle (γ).....	9-12	11.1	Introduction	11-1
9.5.10	Phase Crossover Frequency (ω_{pc}).....	9-12	11.2	Difference between State Space Analysis and Transfer Function.....	11-1
9.6	Relative Stability.....	9-12	11.3	Advantages and Disadvantages of Conventional Control Theory	11-1
9.7	Steps for Solving Bode Plots	9-13	11.4	Advantages and Disadvantages of Modern Control Theory	11-2
9.8	Summary of Bode Magnitude and Phase Plots of Various Terms	9-14	11.5	Concepts of State, State Variables and State Model.....	11-2
9.9	How to Draw Lines of 20, 40, 60 dB/dec.....	9-14	11.5.1	Definition of State and State Variables, State Vectors and State Space.....	11-2
9.10	Advantages of Bode Plots	9-16	11.6	State Variable Representation of Control System	11-3
9.11	Solved Examples	9-16	11.6.1	State Model of Linear Systems	11-4
9.12	Other Terms in Bode Plots.....	9-46	11.7	State Diagram Representation.....	11-5
9.12.1	Bode Plot for Transportation Lag.....	9-46	11.7.1	Non-uniqueness of the State Variable	11-5
Chapter 10 : Polar and Nyquist Plots 10-1 to 10-32			11.8	State Space Representation by Specific Types of State Variables.....	11-6
10.1	Introduction.....	10-1	11.8.1	Different Representation of State Model	11-6
10.2	Polar Plots	10-1			
10.2.1	Advantages of Polar Plots.....	10-1			
10.2.2	Polar Plot of a 1 st Order Pole $\frac{1}{s+p}$	10-2			
10.3	Effect of Adding More Simple Poles	10-3			
10.4	Effect of Adding Pole at Origin.....	10-5			
10.5	Stability on Polar Plots	10-8			
10.5.1	A Simple Way to Check Stability on Polar Plots.....	10-11			
10.6	Nyquist Analysis - Mapping.....	10-12			
10.7	Nyquist Stability Criterion	10-14			
10.7.1	Actual Encirclement.....	10-15			

11.8.2	Forming State Models by Physical Variables.....	11-6
11.9	To Obtain Transfer Function from State Variable Model and Vice Versa.....	11-11
11.9.1	Forming State Model by Phase Variables.....	11-13
11.9.2	State Space Representation using Phase Variable in Observable Controllable Form.....	11-13
11.9.3	Explanation of State Variable Model by Phase Variables using Differential Equation.....	11-14
11.9.4	To Obtain State Variable Form from Transfer Function	11-15
11.10	Solution of LTI State Equations	11-17
11.10.1	Solution of Homogeneous State Equation.....	11-17
11.10.2	Properties of State Transition Matrix.....	11-17
11.10.3	Solution of Non-homogeneous State Equation...	11-24
11.10.4	Another Way of Solution of LTI State Equations	11-25
11.10.4(A)	Solution in Time Domain	11-25
11.10.5	Properties of State Transition Method.....	11-26
11.10.6	Solution using Laplace Transform.....	11-26
11.10.7	Controllability and Observability.....	11-27

UNIT VI

Concept of Controller, Basic ON-OFF Controller, Concept of Dead Zone, Introduction to P, I, D, PI, PD and PID controller, OFFSET of Controller, Integral Reset, PID Characteristics. Concept of Zeigler-Nicholas method. Concept of Industrial Automation, Need of IoT based Industrial Automation.

Chapter 12 : Controllers and Digital Control Systems		12-1 to 12-29
12.1	Introduction to Controllers	12-1
12.2	Types of Controllers.....	12-1
12.2.1	ON-OFF Controllers	12-1
12.2.2	Proportional Controller (P-Controller).....	12-2
12.2.3	Proportional + Integral Controller (P-I Controller).....	12-4
12.2.4	Proportional + Derivative Controller (P-D Controller).....	12-5
12.2.5	Proportional-Integral-Derivative Controller (P-I-D Controller).....	12-6
12.3	Effect of Proportional, Integral and Derivative Control on the Time Response of the System .	12-7
12.4	PID Tuning using Ziegler-Nichols Method	12-7
12.5	Solved Examples	12-8
12.6	Digital Control Systems.....	12-10
12.6.1	Introduction	12-10
12.6.2	Advantages of Digital Control Systems.....	12-11
12.6.3	Comparison of Digital Control Systems and Analog Control Systems.....	12-11
12.6.4	Block Diagram of a Discrete Control System.....	12-11
12.6.5	Transfer Function of Sampled Data Systems	12-12
12.6.6	Block Diagram Reduction of Sampled Data Systems.....	12-22
12.7	Industrial Automation.....	12-29
12.7.1	Industrial IOT.....	12-29
➤	Model Question Paper (End sem)	M-1 to M-3

