

Contents

Preface	ix
Notes to the Instructor	xi
Chapter 1: Introduction to Systems	
1.1 Introduction	1
1.2 State of a System: The Vital Key	3
1.3 Classification of Systems	6
1.4 Multiple-Input, Multiple-Output Systems	15
1.5 System Modeling	16
Problems	20
Chapter 2: Time-Domain Analysis	
2.1 Elimination of Variables in Simultaneous Integrodifferential Equations	24
2.2 Transfer Operator	30
2.3 Solution of Linear Differential Equations	36
2.4 Zero-Input Response	38
2.5 Some Insight into Zero-Input Behavior of a System	49
2.6 Zero-State Response	52
2.7 Unit Impulse Function	60
2.8 Impulse Response of a System	63
2.9 The Convolution Integral	64
2.10 Some Convolution Relationships	67
2.11 Convolution Integral as a Superposition Integral	68
2.12 Graphical View of Convolution	70
2.13 Numerical Techniques of Convolution	73
2.14 Initial-Condition Generators	76
2.15 Multiple Inputs	77
2.16 Response of a System to Exponential Input Signal	79
2.17 Natural Response and Forced Response	80
2.18 Transient and Steady-State Response	81
2.19 Steady-State Response to Sinusoidal Inputs	82
2.20 Bode Plots	85
Problems	86
Chapter 3: Frequency-Domain Analysis	
3.1 Introduction	96
3.2 The Exponential Signal in Linear Systems	96
3.3 Response of Linear Systems to Exponential Inputs	101

3.4	Foundations of Frequency-Domain Analysis.	104
3.5	Exponential Representation of Periodic Inputs: The Fourier Series	107
3.6	Response of Linear Systems to Periodic Inputs	116
3.7	Limitations on Fourier Series Method of Analysis	118
3.8	Exponential Representation of Nonperiodic Inputs	119
3.9	Time-Domain and Frequency-Domain Representation of a Signal	123
3.10	Fourier Transforms of Some Functions	125
3.11	System Analysis Using Exponentials along $j\omega$ -Axis	132
3.12	The Unit Impulse Response	135
3.13	Some Properties of the Fourier Transform	136
3.14	Distortionless Transmission	146
3.15	Ideal Filters	148
3.16	Bandwidth and Rise-Time Relationship	152
3.17	The Sampling Theorem.	154
3.18	Some Applications of the Sampling Theorem	157
3.19	Limitations of Fourier Analysis	160
	Problems	160

Chapter 4: Frequency-Domain Analysis Using Generalized Exponentials

4.1	Generalization of Frequency: The Bilateral Laplace Transform	168
4.2	Causal Functions and Unilateral Frequency Transforms	170
4.3	Existence of the Laplace Transform.	171
4.4	Interpretation of the Laplace Transform	172
4.5	Transforms of Some Useful Functions	176
4.6	System Analysis Using Generalized Exponentials.	178
4.7	Comments on the Time-Domain and the Frequency-Domain Analysis	182
4.8	Some Properties of the Laplace Transform.	183
4.9	Frequency-Domain Analysis: Another Point of View.	190
4.10	Multiple Inputs	195
4.11	Block-Diagram Representation of Systems.	196
4.12	Signal-Flow Graph Representation of Systems	201
4.13	Analysis of Signal-Flow Graphs	203
4.14	System Simulation.	207
4.15	Natural Frequencies of a System.	219
4.16	System Stability	220
4.17	Instability and Oscillations	228
	Problems.	232

Chapter 5: Feedback and Control

5.1	Introduction	241
5.2	Analysis of a Simple Control System	244
5.3	Design Specifications	246
5.4	A Second-Order System	247
5.5	Higher-Order Systems	259
5.6	Root Locus	262

5.7	Steady-State Errors	276
5.8	Compensation	281
5.9	Direct Synthesis	289
5.10	Multiple-Variable Feedback	291
5.11	Sensitivity Considerations	297
5.12	Frequency-Response Method of Synthesis	303
	Problems	327

Chapter 6: State-Space Analysis

6.1	Description of a System.	339
6.2	State Equations of a System	340
6.3	State Equations from Block Diagram.	350
6.4	Solution of State Equations	358
6.5	Simulation	371
6.6	Linear Transformation of a State Vector.	373
6.7	Stability	381
6.8	State-Variable Feedback	385
	Problems	389

Chapter 7: Discrete-Time Systems

7.1	Introduction	397
7.2	Modeling Discrete-Time Systems	399
7.3	Transfer Operator of a Discrete-Time System	401
7.4	Time-Domain Analysis of Discrete-Time Systems	404
7.5	The z -Transform.	415
7.6	Some Properties of the z -Transform.	418
7.7	Transform Analysis of Discrete-Time Systems	420
7.8	Inverse z -Transform	422
7.9	Simulation of Discrete-Time Systems	423
7.10	Digital Processing of Analog Signals	424
7.11	Digital Filtering	428
7.12	Sampled-Data (Hybrid) Systems	431
7.13	Response during Successive Sampling Instants: Modified z -Transform	443
7.14	Design of Sampled-Data Systems	453
7.15	State-Space Analysis of Discrete-Time Systems	453
7.16	State-Space Analysis of Sampled-Data Systems	457
	Problems	460

Appendix A: Some Properties of Differential Operators

A.1	Cancellation of Common Factors in Operational Equations	463
A.2	Cancellation of Common Factors in the Numerator and the Denominator of a Rational Fraction Operator.	464
A.3	Common Factors in the Numerator and the Denominator of $H(p)$	465

Appendix B: Partial-Fraction Expansion

B.1 All Roots Simple (No Multiple Roots)	467
B.2 Complex Roots	469
B.3 Repeated (Multiple) Roots	470

Appendix C: Bode Plots

C.1 Frequency Response	472
C.2 Determination of Transfer Function from the Steady-State Response.	486

Appendix D: Vectors and Matrices

D.1 Vectors	488
D.2 Linear Vector Functions	489
D.3 Some Definitions and Properties	491
D.4 Matrix Algebra	492
D.5 Derivatives and Integral of a Matrix	499
D.6 Computation of e^{At}	500

Appendix E: Second-Order System with a Zero 502**Appendix F: Nyquist Criterion for Stability 504**

F.1 Complex Mapping	504
F.2 Graphical Criterion for Stability in Feedback Systems (the Nyquist Criterion)	508

Bibliography 513**Index 517**