

Preface	ix		
Chapter 1 Introduction to Control Systems			
1–1 Introduction 1			
1–2 Examples of Control Systems 4			
1–3 Closed-Loop Control Versus Open-Loop Control 7	,		
1–4 Design and Compensation of Control Systems 9			
1–5 Outline of the Book 10			
Chapter 2 Mathematical Modeling of Control Systems	13		
2–1 Introduction 13			
2–2 Transfer Function and Impulse-Response Function	15		
2–3 Automatic Control Systems 17			
2–4 Modeling in State Space 29			
2–5 State-Space Representation of Scalar Differential Equation Systems 35			
2–6 Transformation of Mathematical Models with MATLA	В 39		

2–7	Linearization of Nonlinear Mathematical Models 43	
	Example Problems and Solutions 46	
	Problems 60	
Chap	oter 3 Mathematical Modeling of Mechanical Systems and Electrical Systems	63
3–1	Introduction 63	
3–2	Mathematical Modeling of Mechanical Systems 63	
3–3	Mathematical Modeling of Electrical Systems 72	
	Example Problems and Solutions 86	
	Problems 97	
Chap	oter 4 Mathematical Modeling of Fluid Systems	100
	and Thermal Systems	100
4–1	Introduction 100	
4–2	Liquid-Level Systems 101	
4–3	Pneumatic Systems 106	
4–4	Hydraulic Systems 123	
4–5	Thermal Systems 136	
	Example Problems and Solutions 140	
	Problems 152	
Chap	oter 5 Transient and Steady-State Response Analyses	159
5–1	Introduction 159	
5–2	First-Order Systems 161	
5–3	Second-Order Systems 164	
5–4	Higher-Order Systems 179	
5–5	Transient-Response Analysis with MATLAB 183	
5–6	Routh's Stability Criterion 212	
5–7	Effects of Integral and Derivative Control Actions on System Performance 218	
5–8	Steady-State Errors in Unity-Feedback Control Systems 225	
	Example Problems and Solutions 231	
	Problems 263	

iv Contents

Chap	ter 6		269
6–1	Introd	luction 269	
6–2	Root-	Locus Plots 270	
6–3	Plottir	ng Root Loci with MATLAB 290	
6–4		Locus Plots of Positive Feedback Systems 303	
6-5	Root-	Locus Approach to Control-Systems Design 308	
6-6		Compensation 311	
6–7	Lag C	ompensation 321	
6-8	Lag-L	ead Compensation 330	
6–9	Paralle	el Compensation 342	
	Exam	ple Problems and Solutions 347	
	Proble	ems 394	
Chap	ter 7		398
7–1	Introd	luction 398	
7–2	Bode	Diagrams 403	
7–3	Polar l	Plots 427	
7–4	Log-N	Magnitude-versus-Phase Plots 443	
7–5	• •	st Stability Criterion 445	
7–6		ity Analysis 454	
7–7		ve Stability Analysis 462	
7–8	Closed System	d-Loop Frequency Response of Unity-Feedback ns 477	
7–9	Exper	imental Determination of Transfer Functions 486	
7–10	Contro	ol Systems Design by Frequency-Response Approach 491	
7–11	Lead (	Compensation 493	
7–12	Lag C	ompensation 502	
7–13	Lag-L	ead Compensation 511	
	Exam	ple Problems and Solutions 521	
	Proble	ems 561	
Chap	ter 8	PID Controllers and Modified PID Controllers	567
8-1	Introd	luction 567	
8–2	Ziegle	er–Nichols Rules for Tuning PID Controllers 568	

Contents

8–3	Design of PID Controllers with Frequency-Response Approach 577
8–4	Design of PID Controllers with Computational Optimization Approach 583
8–5	Modifications of PID Control Schemes 590
8-6	Two-Degrees-of-Freedom Control 592
8–7	Zero-Placement Approach to Improve Response Characteristics 595
	Example Problems and Solutions 614
	Problems 641
Chap	ter 9 Control Systems Analysis in State Space 648
9–1	Introduction 648
9–2	State-Space Representations of Transfer-Function Systems 649
9–3	Transformation of System Models with MATLAB 656
9–4	Solving the Time-Invariant State Equation 660
9–5	Some Useful Results in Vector-Matrix Analysis 668
9–6	Controllability 675
9–7	Observability 682
	Example Problems and Solutions 688
	Problems 720
Chap	ter 10 Control Systems Design in State Space 722
10-1	Introduction 722
10-2	Pole Placement 723
10-3	Solving Pole-Placement Problems with MATLAB 735
10-4	Design of Servo Systems 739
10-5	State Observers 751
10-6	Design of Regulator Systems with Observers 778
10-7	Design of Control Systems with Observers 786
10-8	Quadratic Optimal Regulator Systems 793
10-9	Robust Control Systems 806
	Example Problems and Solutions 817
	Problems 855

vi Contents

Appendix A	Laplace Transform Tables	859
Appendix B	Partial-Fraction Expansion	867
Appendix C	Vector-Matrix Algebra	874
References		882
Index		886

Contents