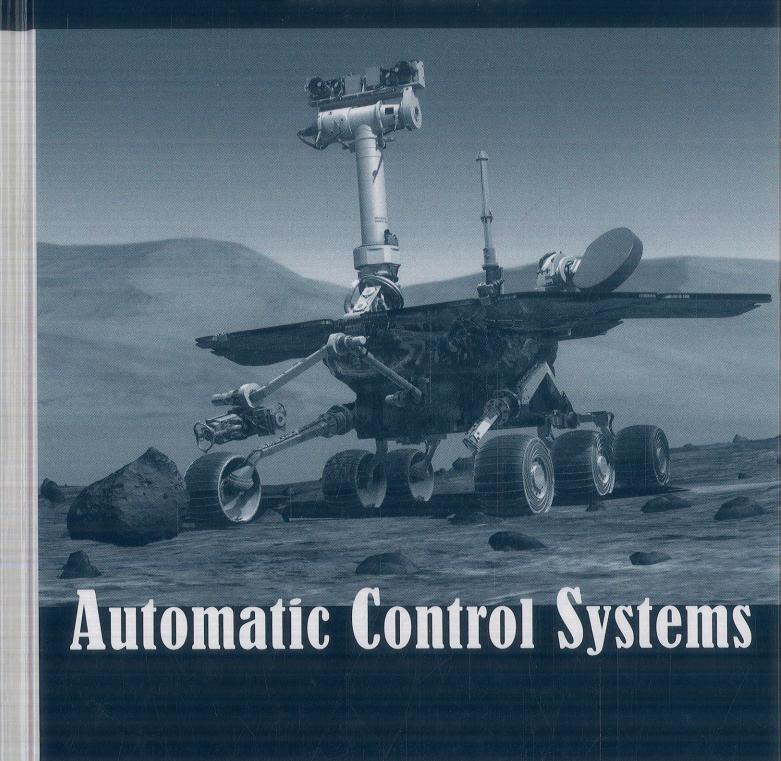
Ninth Edition



Farid Golnaraghi • Benjamin C. Kuo

Contents

Preface	e iv			2-2-8	Quadratic Poles and Zeros 39
110,				2-2-9	Pure Time Delay, $e^{-j\omega T_d}$ 42
5. 57° \$48.5	Feneral e			2-2-10	Magnitude-Phase Plot 44
	ction 1			2-2-11	Gain- and Phase-Crossover Points 46
		-		2-2-12	Minimum-Phase and Nonminimum-
1-1	Introduction				Phase Functions 47
	1-1-1	Basic Components of a Control	2-3	Introduct	tion to Differential Equations 49
		System 2		2-3-1	Linear Ordinary Differential
	1-1-2	Examples of Control-System			Equations 49
		Applications 2		2-3-2	Nonlinear Differential Equations 49
	1-1-3	Open-Loop Control Systems		2-3-3	First-Order Differential
		(Nonfeedback Systems) 5			Equations: State Equations 50
	1-1-4	Closed-Loop Control Systems		2 - 3 - 4	Definition of State Variables 50
		(Feedback Control Systems) 7		2-3-5	The Output Equation 51
1-2		eedback, and What Are Its Effects? 8	2-4	Laplace '	Transform 52
	1-2-1	Effect of Feedback on Overall Gain 8		2-4-1	Definition of the Laplace
	1-2-2	Effect of Feedback on Stability 9			Transform 52
	1-2-3	Effect of Feedback on External		2-4-2	Inverse Laplace Transformation 54
1.0	m (17	Disturbance or Noise 10		2-4-3	Important Theorems of the Laplace
1-3		eedback Control Systems 11			Transform 54
	1-3-I	Linear versus Nonlinear Control	2-5		Laplace Transform by
	1.0.0	Systems 11			raction Expansion 57
	1-3-2	Time-Invariant versus Time-Varying		2-5-1	Partial-Fraction Expansion 57
	0	Systems 12	2-6		ion of the Laplace Transform
1-4	Summary	14			olution of Linear Ordinary
b- 6343	eree 2				tial Equations 62
	matical Fou	undation 16		2-6-1	First-Order Prototype System 63
				2-6-2	Second-Order Prototype
2-1	-	Variable Concept 16		- 1	System 64
	2-1-1	Complex Numbers 16	2-7		Response and Transfer Functions
	2-1-2	Complex Variables 18			r Systems 67
	2-1-3	Functions of a Complex Variable 19		2-7-1	Impulse Response 67
	2-1-4	Analytic Function 20		2-7-2	Transfer Function (Single-Input,
	2-1-5	Singularities and Poles of a		2 = 2	Single-Output Systems) 70
	0.1.0	Function 20		2-7-3	Proper Transfer Functions 71
	2-1-6 2-1-7	Zeros of a Function 20		2-7-4	Characteristic Equation 71
2-2		Polar Representation 22		2-7-5	Transfer Function (Multivariable
2-2,		7-Domain Plots 26	2.0	o. Lili	Systems) 71
	2-2-1	Computer-Aided Construction of the	2-8		of Linear Control Systems 72
	2-2-2	Frequency-Domain Plots 26 Polar Plots 27	2-9		l-Input, Bounded-Output
					Stability—Continuous-Data
	2-2-3	Bode Plot (Corner Plot or Asymptotic Plot) 32	0.10	Systems	
	2-2-4		2-10		ship between Characteristic Equation
	2-2-4	Real Constant K 34	0.11		ad Stability 74
	∠- ∠ -0	Poles and Zeros at the Origin, $(j\omega)^{\pm\rho}$ 34	2-11		out and Asymptotic Stability of
	2-2-6	Simple Zero, $1 + j\omega T = 37$	0.10		ous-Data Systems 74
	2-2-0	Simple Pole, $1/(1+j\omega T)$ 39	2-12		s of Determining Stability 77
	۵-۵-۱	Sample role, $1/(1 \pm j\omega r)$ 38	2-13	noutn-H	Iurwitz Criterion 78

	2-13-1	Routh's Tabulation 79		4-1-5	Backlash and Dead Zone (Nonlinear
	2-13-2	Special Cases when Routh's			Characteristics) 164
		Tabulation Terminates	4-2		on to Modeling of Simple Electrical
		Prematurely 80			1.65
2-14	MATLAB 7	Fools and Case Studies 84		4-2-1	Modeling of Passive Electrical
	2-14-1	Description and Use of Transfer			Elements 165
		Function Tool 84		4-2-2	Modeling of Electrical Networks 165
	2-14-2	MATLAB Tools for Stability 85	4-3		of Active Electrical Elements:
2-15	Summary	90			d Amplifiers 172
				4-3-1	The Ideal Op-Amp 173
	apyen o			4-3-2	Sums and Differences 173
Block	Diagrams a	nd Signal-Flow Graphs 104		4-3-3	First-Order Op-Amp
3-1	Block Diag	rams 104			Configurations 174
	3-1-1	Typical Elements of Block Diagrams	4-4	Introduction	on to Modeling of Thermal Systems 177
	*	in Control Systems 106		4-4-1	Elementary Heat Transfer
	3-1-2	Relation between Mathematical			Properties 177
	0 x -	Equations and Block Diagrams 109	4-5	Introductio	on to Modeling of Fluid Systems 180
	3-1-3	Block Diagram Reduction 113		4-5-1	Elementary Fluid and Gas System
	3-1-4	Block Diagram of Multi-Input			Properties 180
	0-1-4	Systems—Special Case: Systems with	4-6	Sensors an	d Encoders in Control Systems 189
		a Disturbance 115		4-6-1	Potentiometer 189
	3-1-5	Block Diagrams and Transfer		4-6-2	Tachometers 194
	2-1-0	Functions of Multivariable		4-6-3	Incremental Encoder 195
		Systems 117	4-7		rs in Control Systems 198
0.0	Cianal Elor			4-7-1	Basic Operational Principles of DC
3-2		v Graphs (SFGs) 119 Basic Elements of an SFG 119			Motors 199
	3-2-1			4-7-2	Basic Classifications of PM DC
	3-2-2	Summary of the Basic Properties of		–	Motors 199
	0.00	SFG 120		4-7-3	Mathematical Modeling of PM DC
	3-2-3	Definitions of SFG Terms 120		1.0	Motors 201
	3-2-4	SFG Algebra 123	4-8	Systems w	ith Transportation Lags
	3-2-5	SFG of a Feedback Control	1.0	(Time Del	
	2.2.0	System 124		4-8-1	Approximation of the Time-Delay
	3-2-6	Relation between Block Diagrams		4-0-1	Function by Rational
		and SFGs 124			Functions 206
	3-2-7	Gain Formula for SFG 124	4-9	Lincorizati	ion of Nonlinear Systems 206
	3-2-8	Application of the Gain Formula	4-9	4-9-1	Linearization Using Taylor Series:
		between Output Nodes and		4-0-1	Classical Representation 207
		Noninput Nodes 127		400	Linearization Using the State Space
	3-2-9	Application of the Gain Formula to		4-9-2	
		Block Diagrams 128	(10	A a la aria a	Approach 207
	3-2-10	Simplified Gain Formula 129	4-10	Analogies	
3-3	MATLAB	Tools and Case Studies 129	4-11	Case Stud	
3-4	Summary	133	4-12	MATLAB	
			4-13	Summary	223
	appers.	I Comment	5 800 505	apter 5	
		dation and Background			alysis of Control Systems 253
Mate	rial: Modelii	ng of Dynamic Systems 147	111116-		
4-1	Introducti	on to Modeling of Mechanical	5-1	Time Res	ponse of Continuous-Data Systems:
		148		Introducti	ion 253
	4-1-1	Translational Motion 148	5-2	Typical To	est Signals for the Time Response of
	4-1-2	Rotational Motion 157		Control S	ystems 254
	4-1-3	Conversion between Translational and	5-3		Step Response and Time-Domain
		Rotational Motions 161			ions 256
	4-1-4	Gear Trains 162	5-4		ate Error 258

	5 - 4-1	Steady-State Error of Linear	\$ 608s	AFTER 6	
		Continuous-Data Control Systems 258	The C	Control Lab	337
	5-4-2	Steady-State Error Caused by	6-1	Introductio	on 337
	mı i)	Nonlinear System Elements 272	6-2		n of the Virtual Experimental
5-5	_	onse of a Prototype First-Order		System 3	
- 0	System 2	74 Response of a Prototype		6-2-1	Motor 339
5-6	Second Or	der System 275		6-2-2	Position Sensor or Speed Sensor 339
	5-6-1	Damping Ratio and Damping		6-2-3	Power Amplifier 340
	<i>0</i> -0-1.	Factor 277		6-2-4	Interface 340
	5-6-2	Natural Undamped Frequency 278	6-3	_	n of SIMLab and Virtual Lab
	5-6-3	Maximum Overshoot 280		Software	340
	5-6-4	Delay Time and Rise Time 283	6-4		and Virtual Experiments 345
	5-6-5	Settling Time 285		6-4-1	Open-Loop Speed 345
5-7	Speed and	Position Control of a DC Motor 289		6-4-2	Open-Loop Sine Input 347
	5-7-1	Speed Response and the Effects of		6-4-3	Speed Control 350
		Inductance and Disturbance-Open	6-5	6-4-4	Position Control 352 oject 1—Robotic Arm 354
		Loop Response 289	6-6		oject 1—Robbule ATII 554 oject 2—Quarter-Car Model 357
	5-7-2	Speed Control of DC Motors:	0-0	6-6-1	Introduction to the Quarter-Car
		Closed-Loop Response 291		0-0-1 i	Model 357
	5-7-3	Position Control 292		6-6-2	Closed-Loop Acceleration
5-8		nain Analysis of a Position-Control			Control 359
	,	93		6-6-3	Description of Quarter Car
	5-8-1	Unit-Step Transient Response 294			Modeling Tool 360
	5-8-2 5-8-3	The Steady-State Response 298 Time Response to a Unit-Ramp	1	6-6-4	Passive Suspension 364
	J-0-J	Input 298		6-6-5	Closed-Loop Relative Position
	5-8-4	Time Response of a Third-Order			Control 365
	001	System 300		6-6-6	Closed-Loop Acceleration
5-9	Basic Con	trol Systems and Effects of			Control 366
		les and Zeros to Transfer	6-7	Summary	367
	Functions		a 03	armer y	
	5-9-1	Addition of a Pole to the		Locus Analy	vsis 372
		Forward-Path Transfer Function:			
		Unity-Feedback Systems 305	7-1	Introducti	
	5-9-2	Addition of a Pole to the	7-2	Loci (RL)	perties of the Root
		Closed-Loop Transfer Function 307	7-3		of the Root Loci 377
	5-9-3	Addition of a Zero to the	1-0	7-3-1	$K = 0$ and $K = \pm \infty$ Points 377
	5 0.	Closed-Loop Transfer Function 308		7-3-2	Number of Branches on the Root
	5-9-4	Addition of a Zero to the			Loci 378
		Forward-Path Transfer Function:		7-3-3	Symmetry of the RL 378
5-10	Daminant	Unity-Feedback Systems 309 Poles and Zeros of Transfer		7-3-4	Angles of Asymptotes of the RL:
9-10	Functions				Behavior of the RL at $ s = \infty$ 378
	5-10-1	Summary of Effects of Poles and		7-3-5	Intersect of the Asymptotes
	0-10-1	Zeros 313			(Centroid) 379
	5-10-2	The Relative Damping Ratio 313		7-3-6	Root Loci on the Real Axis 380
	5-10-3	The Proper Way of Neglecting the		7-3-7	Angles of Departure and Angles of
		Insignificant Poles with Consideration			Arrival of the RL 380
		of the Steady-State Response 313		7-3-8	Intersection of the RL with the
5-11	Basic Con	trol Systems Útilizing Addition of Poles		# 0 0	Imaginary Axis 380
	and Zeros			7-3-9	Breakaway Points (Saddle Points)
5-12	MATLAB			7 9 10	on the RL 380
5-13	Summary	320		7-3-10	The Root Sensitivity 382

7-4	Design Aspects of the Root Loci 385 7-4-1 Effects of Adding Poles and Zeros	8-12	Relative Magnitud 8-12-1	Stability Related to the Slope of the de Curve of the Bode Plot 459 Conditionally Stable System 459
7-5	to $G(s)H(s)$ 385 Root Contours (RC): Multiple-Parameter Variation 393	8-13		Analysis with the Magnitude-Phase
7-6	MATLAB Tools and Case Studies 400	8-14	Constant	-M Loci in the Magnitude-Phase Plane:
7-7	Summary 400	0.15		nols Chart 463
k 6084.	aptet e	8-15		Chart Applied to Nonunity-Feedback
	ency-Domain Analysis 409	8-16	Systems	ty Studies in the Frequency Domain 470
	•	8-17		B Tools and Case Studies 472
8-1	Introduction 409 8-1-1 Frequency Response of	8-18	Summar	
	Closed-Loop Systems 410	a. 8778.8	aptera o	
		12.		ol Systems 487
8-2	M_r , ω_r , and Bandwidth of the Prototype	_		
	Second-Order System 413	9-1		tion 487
	8-2-1 Resonant Peak and Resonant		9-1-1	Design Specifications 487
	Frequency 413		9-1-2	Controller Configurations 489
0.0	8-2-2 Bandwidth 416	0.0	9-1-3	Fundamental Principles of Design 491
8-3	Effects of Adding a Zero to the Forward-Path	9-2	9-2-1	with the PD Controller 492 Time-Domain Interpretation of PD
0.4	Transfer Function 418		9-2-1	Control 494
8-4	Effects of Adding à Pôle to the Forward-Path Transfer Function 424		9-2-2	Frequency-Domain Interpretation of
8-5	Nyquist Stability Criterion: Fundamentals 426		0- 2-2	PD Control 496
o- <i>u</i>	8-5-1 Stability Problem 427		9-2-3	Summary of Effects of PD Control 497
	8-5-2 Definition of Encircled and	9-3		with the PI Controller 511
	Enclosed 428	0.0	9-3-1	Time-Domain Interpretation and
	8-5-3 Number of Encirclements and		0 0 1	Design of PI Control 513
	Enclosures 429		9-3-2	Frequency-Domain Interpretation and
	8-5-4 Principles of the Argument 429			Design of PI Control 514
	8-5-5 Nyquist Path 433	9-4	Design v	with the PID Controller 528
	8-5-6 Nyquist Criterion and the $L(s)$ or	9-5	Design v	with Phase-Lead Controller 532
	the $G(s)H(s)$ Plot 434		9-5-1	Time-Domain Interpretation and
8-6	Nyquist Criterion for Systems with			Design of Phase-Lead Control 534
	Minimum-Phase Transfer Functions 435		9-5-2	Frequency-Domain Interpretation and
	8-6-1 Application of the Nyquist Criterion			Design of Phase-Lead Control 535
	to Minimum-Phase Tranfer		9-5-3	Effects of Phase-Lead
	Functions That Are Not Strictly			Compensation 554
	Proper 436		9-5-4	Limitations of Single-Stage Phase-Lead
8-7	Relation between the Root Loci and the		~	Control 555
	Nyquist Plot 437		9-5-5	Multistage Phase-Lead Controller 555
8-8	Illustrative Examples: Nyquist Criterion	0.0	9-5-6	Sensitivity Considerations 559
	for Minimum-Phase Transfer	9-6	_	with Phase-Lag Controller 561
0.0	Functions 440		9-6-1	Time-Domain Interpretation and
8-9	Effects of Adding Poles and Zeros		9-6-2	Design of Phase-Lag Control 561 Frequency-Domain Interpretation
	to $L(s)$ on the Shape of the Nyquist		9-0-2	and Design of Phase-Lag Control 563
0 10	Plot 444 Polativa Stability Cain Margin and Phase		9-6-3	Effects and Limitations of Phase-Lag
8-10	Relative Stability: Gain Margin and Phase		0-0-0	Control 574
	Margin 449 8-10-1 Gain Margin (GM) 451	9-7	Design	with Lead–Lag Controller 574
	8-10-2 Phase Margin (PM) 453	9-8		ro-Cancellation Design: Notch Filter 576
8-11	Stability Analysis with the Bode Plot 455		9-8-1	Second-Order Active Filter 579
V 11	8-11-1 Bode Plots of Systems with Pure		9-8-2	Frequency-Domain Interpretation and
	Time Delays 458			Design 580

		· ·			
9-9	Forward a	and Feedforward Controllers 588		10-8-1	Characteristic Equation from a
9-10	Design of	Robust Control Systems 590			Differential Equation 695
9-11	Minor-Loc	op Feedback Control 601		10-8-2	Characteristic Equation from a Transfer
	9-11-1	Rate-Feedback or			Function 696
		Tachometer-Feedback Control 601		10-8-3	Characteristic Equation from State
	9-11-2	Minor-Loop Feedback Control with			Equations 696
		Active Filter 603		10-8-4	Eigenvalues 697
9-12	A Hydrau	lic Control System 605		10-8-5	Eigenvectors 697
	9-12-1	Modeling Linear Actuator 605		10-8-6	Generalized Eigenvectors 698
	9-12-2	Four-Way Electro-Hydraulic	10-9	Similarity '	Transformation 699
		Valve 606		10-9-1	Invariance Properties of the Similarity
	9-12-3	Modeling the Hydraulic System 612			Transformations 700
	9-12-4	Applications 613		10-9-2	Controllability Canonical Form (CCF)
9-13	Controller	Design 617			701
	9-13-1	P Control 617		10-9-3	Observability Canonical Form (OCF) 703
	9-13-2	PD Control 621		10-9-4	Diagonal Canonical Form (DCF) 704
	9-13-3	PI Control 626		10-9-5	Jordan Canonical Form (JCF) 706
	9-13-4	PID Control 628	10-10	Decompos	sitions of Transfer Functions 707
9-14	MATLAB	Tools and Case Studies 631		10-10-1	Direct Decomposition 707
9-15	Plotting T	utorial 647		10-10-2	Cascade Decomposition 712
9-16	Summary	649	1	10-10-3	Parallel Decomposition 713
			10-11	Controllab	oility of Control Systems 714
	apyen 16			10-11-1	General Concept of Controllability
State	Variable Ai	nalysis 673			716
10-1	Introducti	ion 673		10-11-2	Definition of State Controllability 716
10-2	Block Dia	grams, Transfer Functions, and State		10-11-3	Alternate Tests on Controllability 717
	Diagrams		10-12	Observabil	lity of Linear Systems 719
	10-2-1	Transfer Functions (Multivariable		10-12-1	Definition of Observability 719
		Systems) 673		10 - 12 - 2	Alternate Tests on Observability 720
	10-2-2	Block Diagrams and Transfer Functions	10-13		ip among Controllability,
		of Multivariable Systems 674			lity, and Transfer Functions 721
	10-2-3	State Diagram 676	10-14		Theorems on Controllability and
	10-2-4	From Differential Equations to State		Observabi	
		Diagrams 678	10-15		y: Magnetic-Ball Suspension
	10-2-5	From State Diagrams to Transfer		System 7	
		Function 679	10-16		Back Control 728
	10-2-6	From State Diagrams to State and	10-17		ement Design Through State
		Output Equations 680		Feedback	
10-3		atrix Representation of State	10-18		dback with Integral Control 735
	Equations		10-19	40 40 4	Tools and Case Studies 741
10-4		nsition Matrix 684		10-19-1	Description and Use of the State-Space
	10-4-1	Significance of the State-Transition		10.10.0	Analysis Tool 741
		Matrix 685		10-19-2	Description and Use of tfsym for
	10-4-2	Properties of the State-Transition	10.20		State-Space Applications 748
		Matrix 685	10-20	Summary	751
10-5		nsition Equation 687			
	10-5-1	State-Transition Equation Determined	p- 8868	9894 773	\$
		from the State Diagram 689	Appen	dices can be	e found on this book's companion Web site:
10-6	Y Y		www.wiley.com/college/golnaraghi.		
10 =	High-Order Differential Equations 691		» Appendix A		
10-7	*		Elementary Matrix Theory and Algebra A-1		
10.0	Transfer Functions 693				
10-8		ristic Equations, Eigenvalues,	A-1		y Matrix Theory A-1
	and Eiger	nvectors 695		A-1-1	Definition of a Matrix A-2

A.2-1 Equality of Matrices A.5 A.2-2 Addition and Subtraction of Matrices A.5 A.2-3 Associative Law of Matrix (Addition and Subtraction) A.6 A.2-4 Commutative Law of Matrix (Addition and Subtraction) A.6 A.2-5 Matrix Multiplication A.7 A.2-7 Multiplication b.7 A.2-8 Inverse of Matrix Multiplication A.7 A.2-9 Rank of a Matrix A.9 A.3-1 Computer Aided Solutions of Matrices A.9 A.3-2 Maltiplication b.7 A.2-9 Rank of a Matrix A.9 A.3-1 Difference Equations B-1 B.1 Difference Equations B-1 B.1 Difference Equations B-1 B.1 Difference Equations B-1 B.2 APPRENDING C Laplace Transform Table C-1 APPRENDING C Fransform	A-2	Matrix Alge	ebra A-5	s. 65.9%	- 200.00 868 676 876 F - 675	3
A-2-3 Associative Law of Matrix (Addition and Subtraction) A-6 A-2-4 Commutative Law of Matrix (Addition and Subtraction) A-6 A-2-5 Matrix Multiplication A-7 A-2-7 Multiplication by a Scalar A-8 A-2-8 Rank of a Matrix (Matrix Division) A-5 A-2-9 Rank of a Matrix (Matrix Division) A-5 A-2-9 Rank of a Matrix (Matrix Division) A-7 B-2-9 Rank of a Matrix (Matrix Division) A-7 B-2-9 Rank of a Matrix A-9 B-2-1 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Difference Equations B-1 B-3 Symmetry of the Root Loci E-1 B-1 F-1 K ≪ Damak E ≪ Difference Equations B-1 B-2 Symmetry of the Root Loci E-2 B-3 Symmetry of the Root Loci E-2 B-3 Symmetry of the Root Loci E-2 B-4 Angles of Asymptotes of the Root Loci E-2 B-5 Intersect of the Asymptotes of the Root Loci E-1 B-9 I (Saddle Point) on the Root Loci E-1 B-9 I (Saddle Point) on the Root Loci E-16 B-4 Piper B-2 Difference Equations B-1 B-3 Symmetry of the Root Loci E-16 B-4 Angles of Asymptotes of the Root Loci E-16 B-5 Intersection of the Root Loci E-16 B-6 Stability of Discrete-Data Systems H-14 State Equations B-1-1 B-9 I (Saddle Point) on the Root Loci E-16 B-4 Systems B-5 B-5 Root Loci Discrete-Data Systems B-14 Systems B-6 B-4 Angles of Discrete-Data Systems B-14 Systems B-7 B-2 Systems With Minimum Phase Loop Transfer Functions F-4 B-4	Λ-Δ	1.7				
A-2-3 Associative Law of Matrix (Addition and Subtraction) A-6 A-2-4 Commutative Law of Matrix (Addition and Subtraction) A-6 A-2-5 Matrix Multiplication A-7 A-2-7 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-1 Multiplication by a Scalar k A-8 A-2-1 Multiplication by a Scalar k A-8 A-2-2 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-2 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 A-2-2 Rank of a Matrix Multiplication A-7 A-2-1 Multiplication by a Scalar k A-8 Biscrete-Data Control Systems H-1 B-1 Laptocution H-1 B-2 Transform H-1 B-2 Transform H-1 B-2 Deficience Equations B-1 B-1 Laptocution H-1 B-2 Deficience Equations B-1 B-1 Laptocution H-1 B-2 Transform Multiplication by a Scalar k A-9 Biscrete-Data Control Systems H-1 B-2 Nome Important Theorems of the Scalar k A-9 Biscrete-Data Control Systems H-1 B-2 Scalar k A-2-2 Some Important Th						
A 2 3						
Subtraction) A-6 A-2-4 Commutative Law of Matrix (Addition and Subtraction) A-6 A-2-5 Rules of Matrix Multiplication A-7 A-2-6 Rules of Matrix Multiplication A-7 A-2-7 Aubtriplication by a Scalar & A-8 A-2-8 Inverse of Matrix Multiplication A-7 A-2-8 Inverse of Matrix Multiplication A-7 A-2-8 Inverse of Matrix Multiplication A-7 A-2-9 Rank of a Matrix Austra Division) A-8 A-2-9 Rank of a Matrix Austra Division A-8 A-2-9 Rank of a Matrix Austra Division A-9 A-3 Computer-Aided Solutions of Matrices A-9 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Number of Branches on the Root Loci E-1 E-1 K = 0 and K = ±∞ Points E-1 E-2 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes (Centroid) E-5 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci E-16 E-1 E-9-1 (Saddle Points) on the Root Loci E-16 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-16 E-10 Calculation of Noquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions of Noquist Criterion F-1 F-1-2 System with Minimum-Phase Loop Transfer Functions of Noquist Criterion F-1 F-1-2 System with Minimum-Phase Loop Transfer Functions of Noquist Criterion F-1 F-1-2 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Interoper Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 H-2-5 Stability of Discrete-Data Systems H-26 H-3-5 Stability Tests of Discrete-Data Systems H-26 H-4-5 State Diagrams of Discrete-Data Systems H-26 H-5-2 Stability of Discrete-Data Systems H-26 H-5-2 Stability Tests of Discrete-Data Systems H-26 H-5-2 Stability of Discrete-Data Systems H-27 Stability of Discrete-Data Systems H-28 H-5-2 Stability of Discrete-Data Systems H-27 Stability of Di		A-2-3		G-2		
A-2-4 Commutative Law of Matrix (Addition and Subtraction) A-6 A-2-5 Matrix Multiplication A-6 A-2-6 Mules of Matrix Multiplication A-7 A-2-7 Multiplication by a Scalar k A-8 A-2-9 Rank of a Matrix (Matrix Division) A-5 A-2-9 Rank of a Matrix (Matrix Division) A-5 A-2-9 Rank of a Matrix (Matrix Division) A-5 Difference Equations B-1 B-1 Difference Equations B-1 B-2-FERENSIA C Laplace Transform Table C-1 B-3-FERENSIA C Laplace Transform Table D-1 APPERENSIA C Laplace Transform Table C-1 H-2-1 Cand K = ±∞ Points E-1 E-1 K = 0 and K = ±∞ Points E-1 E-1 K = 0 and K = ±∞ Points E-1 E-1 Number of Branches on the Root Loci E-2 E-2 Systems of Asymptotes of the Root Loci and Behavior of the Root Loci at lyl = ∞ E-4 E-5 Intersect of the Asymptotes (Centrod) E-5 E-6 Root Loci at lyl = ∞ E-4 E-7 Transform Table D-1 APPERENSIA E Laplace Transform Table D-1 APPERENSIA C Laplace Transform Table D-1 APPERENSIA C Laplace Transform Table D-1 APPERENSIA C Laplace Transform Table C-1 H-2-2 Transform H-1 H-2-1 Introduction H-1 H-2-1 Definition of the z-Transform H-1 H-2-2 Relationship between the Laplace Transform H-2 R-1-2 Relationship between the Laplace Transform H-2 R-1-2 Relationship between the Laplace Transform H-3 H-2-3 Some inportant Theorens of the Pl-2-3 Systems H-3 H-2-4 H-2-5 Computer Solution of the Transform H-2 H-2-5 Computer Solution of the Partial- Fra						
A 2-5 Matrix Multiplication A-6 A 2-6 Rules of Matrix Multiplication A-7 A 2-7 Multiplication by a Scalar & A-8 A 2-8 Inverse of a Matrix (Matrix Division) A-8 A 2-9 Rank of a Matrix (Matrix Division) A-8 A 2-9 Rank of a Matrix (Matrix Division) A-8 A 2-9 Rank of a Matrix (Matrix Division) A-8 A 2-10 Rank of a Matrix (Matrix Division) A-8 A 2-10 Rank of a Matrix (Matrix Division) A-8 B 2-10 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Difference Equations B-1 B-3 Difference Equations B-1 B-4 Difference Equations B-1 B-4 Appleable E B-4 Appleable E B-4 Appleable E B-5 Intersection of the Root Loci E-1 B-1 Number of Branches on the Root Loci E-2 B-3 Symmetry of the Root Loci E-2 B-4 Angles of Appmytotes (Centrod) E-5 B-6 Root Loci of the Root Loci and Behavior of the Root Loci and Behavior of the Root Loci and Behavior of the Root Loci E-9 B-6 Root Loci E-9 B-7 Rank of a Matrix Multiplication A-7 B-2-8 Intersection of the Root Loci and Behavior of the Root Loci and Behavior of the Root Loci and Behavior of the Root Loci E-11 B-9-1 (Saddle Points) on the Root Loci E-11 B-9-2 The Angle of Arrival and Departure of Root Loci E-16 B-8 PPENDENCE F B-1 Intersection of the Root Loci E-16 B-2 Transform H-3 B-2 Transform H-5 B-2 Transform H-5 B-2 Transform H-5 B-2 Transform H-5 B-2 Transform H-1 B-2 Transform H-1 B-2 Transform H-1 B-2 Transform H-1 B-2 Transform H-2 B-2 Transform H-2 B-2 Transform H-3 B-2 Transform H-5 B-2 Transform H-5 B-2 Transform H-5 B-2 Transform H-5 B-2 Transform H-1 B-2 Transform H-2 B-2 Transform H-1 B-2 Transform H-2 B-2 Transform H-2 B-2 Transform H-1 B-2 Transform H-1 B-2 Transform H-1 B-2 Transform H-1 B-2 Transform H-2 B-2 Transform H-1 B-2 Transf		A-2-4				
A-2-5 Rules of Matrix Multiplication A-7 A-2-7 Multiplication by a Scalar & A-8 A-2-9 Rank of a Matrix (Antix Division) A-8 A-3-9 Rank of a Matrix (Antix Division) A-8 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-2 PREPAIRE C Laplace Transform Table C-1 B-3 PREPAIRE C Laplace Transform Table C-1 B-4 PPERAIRE C Laplace Transform Table C-1 B-4 PPERAIRE C Laplace Transform Table C-1 B-4 PPERAIRE C Laplace Transform Table C-1 B-5 Properties and Construction of the Root Loci E-1 E-1 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at the Breakow of the Root Loci is B-1 E-9 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci at the Breakow Foints E-11 E-9-1 (Saddle Points) on the Root Loci E-16 B-4 PPERAIRE F General Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-1-2 Systems with Minimum-Phase Loop Transfer Functions F-4 F-1-1 System with Minimum-Phase Loop Minimum and Nonminimum Transfer Functions F-4 F-1 Illustrative Examples—General Nyquist Criterion F-4 F-1 Illustrative Examples—General Nyquist Criterion F-4 F-1 Illustrative Examples—General Nyquist Criterion F-4 F-2 Illustrative Examples—General Nyquist Criterion F-4 F-1 Illustrative Examples—General Nyquist Criterion F-4 F-1 Illustrative Examples—General Nyquist Criterion F-4 F-1 Illustrative Examples—General Nyquist Criterion F-4 F-2 Illustrative Examples—General Nyquist Criterion F-4 F-1 Illustrative Examples—General Nyquist Criterion F-4 F-2 Illustrative Examples—General Nyquist Criterion F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-1 Illustrative Examples—General Nyquist Criterion F-1 F-1 Illustrative Examples—General Nyquist Criterion F-1 F-1 Illustrative Examples—Gene						
A 2-6 Rules of Matrix Multiplication A 7 A-2-8 Iranese of a Matrix (Matrix Division) A-2-9 Rank of a Matrix (A-9 A-3 Computer-Aided Solutions of Matrices A-9 Bifference Equations B-1 B-1 Difference Equations B-1 B-2 Difference Equations B-1 B-3 Difference Equations B-1 B-4 Difference Equations B-1 B-4 Difference Equations B-1 B-5 Difference Equations B-1 B-6 Difference Equations B-1 B-7 Difference Equations B-1 B-8 Difference Equations B-1 B-9 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Difference Equations B-1 B-3 Difference Equations B-1 B-4 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Difference Equations B-1 B-3 Difference Equations B-1 B-4 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Difference Equation B-1 B-1 Difference Equations B-1 B-1 Difference Equation B-1 B-		A-2-5	Matrix Multiplication A-6	G 0		
A-2-7 Multiplication by a Scalar & A-5 A-2-8 Inverse of a Matrix (Matrix Division) A-2-9 Rank of a Matrix (Astrix Division) A-3 Computer-Aided Solutions of Matrices A-9 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Relationship between the Laplace Transform and the z-Transform H-2 Some Important Theorems of the z-Transform H-3 Relationship between the Laplace Transform and the z-Transform H-2 Some Important Theorems of the z-Transform Table D-1 B-2 FIGURE TO TRANSITION TO TRANSFORM B-2 Transform Table D-1 B-3 FIGURE TO TRANSFORM B-2 Transform Table D-1 B-4 FIGURE TO TRANSFORM B-2 Transform Table D-1 B-5 FIGURE TO TRANSFORM B-1 B-2 Transform Table D-1 B-3 FIGURE TO TRANSFORM B-2 Transform Table D-1 B-4 FIGURE TO TRANSFORM B-2 Transform Table D-1 B-4 FIGURE TO TRANSFORM B-2 Transform Table D-1 B-4 FIGURE TO TRANSFORM B-2 Transform Table D-1 B-5 FIGURE TO TRANSFORM B-2 Transform Table D-1 B-6 FIGURE TO TRANSFORM B-1 B-2 Transform Table D-1 B-2 FIGURE TO TRANSFORM B-2 Transform B-1 B-2 Transform Table B-2 Tran		A-2-6		G-3	Final Com	ments G-4
A-3 Computer-Aided Solutions of Matrices A-9 A-3 Computer-Aided Solutions of Matrices A-9 February Febr		A-2-7	Multiplication by a Scalar k A-8	b 4.0	THE NEW 2007	
A-2-9 Rank of a Matrix A-9 A-3 Computer-Aided Solutions of Matrices A-9 H-1 H-2 The x-Transform H-1 H-2 The x-Transform H-1 H-2 The x-Transform H-1 H-2 The x-Transform H-1 H-2 Transform and the x-Transform H-2 H-2 Transform Table C-1 H-2 APPRENDIXE C Laplace Transform Table C-1 H-2 APPRENDIXE D H-2 Transform Table C-1 H-2 APPRENDIXE D H-2 Transform H-3 APPRENDIXE D H-2 Transform H-3 APPRENDIXE D H-2 Transform H-3 APPRENDIXE D H-2 Transform H-5 APPRENDIXE D H-2 Transform H-3 APPRENDIXE D H-2 Transform H-5 APPRENDIXE D H-2 Transform H-7 APPRENDIXE D H-2 T		A-2-8	Inverse of a Matrix (Matrix Division) A-8	Discre	ete-Data Co	ntrol Systems H-1
H-2 The x-Transform H-1		A-2-9	Rank of a Matrix A-9			
Definition of the z-Transform H-1	A-3	Computer-	Aided Solutions of Matrices A-9			
B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-1 Difference Equations B-1 B-2 Difference Equations B-1 B-3 Difference Equations B-1 B-4 Difference Equations B-1 B-2 Caplace Transform Table C-1 B-2 Caplace Transform Table C-1 B-2 Caplace Transform Table C-1 B-3 Seme Important Theorems of the Caplace Transform H-5 B-2 Transform Table D-1 B-3 Difference Equations B-1 B-4 DFENDANCE B-2 Number of Branches on the Root Loci E-1 B-2 Number of Branches on the Root Loci E-2 B-3 Symmetry of the Root Loci at s = ∞ E-4 B-4 Angles of Asymptotes (Centroid) E-5 B-5 Intersect of the Asymptotes (Centroid) E-5 B-6 Root Loci on the Real Axis E-8 B-7 Angles of Departure and Angles of Arrival of the Imaginary Axis E-11 B-9-1 (Saddle Points) on the Root Loci E-11 B-9-1 (Saddle Points) on the Root Loci E-16 B-4 DFENDANCE B-6 Root Loci at the Breakaway Point E-12 B-10 Calculation of K on the Root Loci E-16 B-10 Calculation of K on the Root Loci E-16 B-10 Calculation of K on the Root Loci E-16 B-11 Systems with Minimum-Phase Loop Transfer Function of Nyquist Criterion F-1 B-1-1 System with Minimum-Phase Loop Transfer Functions F-4 B-1-1 Systems with Improper Loop Transfer Functions F-4 B-1-2 Systems with Improper Loop Transfer Functions F-4 B-1-3 Systems with Improper Loop Transfer Functions F-4 B-1-4 State Diagrams of Discrete-Data Systems H-26 B-10 Caplation of Nyquist Criterion F-1 B-1-1 System with Minimum-Phase Loop Transfer Functions F-4 B-1-2 Systems with Improper Loop Transfer Functions F-4 B-1-3 Systems with Improper Loop Transfer Functions F-4 B-1-4 State Diagrams of Discrete-Data Systems H-26 B-10 Caplation B-1 B-10 Ca	. 9.99	meanannon name	2	П-2		_
Properties and Construction of the Root Loci E-1 H-3 H-3 Systems with Cascade Elements H-12 H-3 Systems with Cascade Elements H-12 H-3 Systems H-14 Systems H-16 H-3 Systems H-26 H-4 State Diagrams for Sampled-Data Systems H-26 H-5 State Diagrams for Sampled-Data Systems H-27 H-5 State Diagrams for Sampled-Data Systems H-27						
H-2-3 Some Important Theorems of the z-Transform H-5	Dillett				11-2-2	
Laplace Transform Table C-1	B-1	Difference	Equations B-1		H-2-3	
H-2-4 Inverse z-Transform H-5 Computer Solution of the Partial- Fraction Expansion of K(z)/z H-7 z-Transform Table D-1 → APPERISE ▼ Properties and Construction of the Root Loci E-1 E-1 K = 0 and K = ±∞ Points E-1 E-2 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci at = ∞ E-4 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci is 1 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-16 F-9-1 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Function F-4 F-2 Illustrative Examples—General Nyquist Criterion F-4 F-2 Illustr	. 22.23	. X = 27 · 80 X S = 0 · 60 × · 6	œ.		11-2 0	
## APPENDIX © z-Transform Table D-1 **Properties and Construction of the Root Loci E-1 E-1 K = 0 and K = ±∞ Points E-1 E-2 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at s = ∞ E-4 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Root Loci with the Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9-1 (Saddle Points) on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-1-2 Illustrative Examples—General Nyquist Criterion F-1 F-1-3 Intersect Obsceret—Data Systems H-26 H-2-5 Computer Solution of Ye 2 Transfer Function of Yeoliscrete Equations of Discrete-Data Systems H-18 H-3-1 Transfer Functions of Discrete-Data Systems H-8 H-3-2 Transfer Functions of Discrete-Data Systems H-18 H-3-1 Transfer Functions of Discrete-Data Systems H-19 H-3-2 Transfer Function of Yeoliscrete State Equations of Linear Difference Equations of Discrete-Data Systems H-18 H-3-1 Transfer Functions of Discrete-Data Systems H-19 H-4-3 Transfer Function of Yeoliscre					H-2-4	
Fraction Expansion of Y(z)/z H-7 Fraction Expansion of Y(z)/z H-7 Application of the 2-Transform to the Solution of Linear Difference Equations H-7 Froperties and Construction of the Root Loci E-1 E-1	Lapia	se mansion	III Labia C-I			
z-Transform Table D-1 > APPERISON E Properties and Construction of the Root Loci E-1 E-1 K = 0 and K = ±∞ Points E-1 E-2 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at s = ∞ E-4 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 F-1 Systems with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Transfer Functions of Discrete-Data Systems H-26 H-3-3 Transfer Functions of Closed-Loop Discrete-Data Systems H-26 H-3-3 Transfer Functions of Linear Discrete-Data Systems H-16 H-3-3 Transfer Functions of Linear Discrete-Data Systems H-16 H-3-2 Transfer Function of Linear Discrete State Equations H-16 H-4-4 Transfer-Function Matrix and the Characteristic Equation H-20 H-4-5 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 H-5-1 BIBO Stability H-26 H-5-1 Stability Tests of Discrete-Data Systems H-27	6 A.F	PENDIK	€ 3			
Froperties and Construction of the Root Loci E-1 E-1 K = 0 and K = ±∞ Points E-1 E-2 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at s = ∞ E-4 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci et B-9 E-7 Angles of Departure and Angles of Arrival of the Root Loci in E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum And Nomminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-3 Stability Tests of Discrete-Data Systems H-27 F-3 Stability Fo	<i>z</i> -Trar	nsform Tabl	e D-1		H-2-6	
From ties and Construction of the Root Loci E-1 E-1 K = 0 and K = ±∞ Points E-1 E-2 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at s = ∞ E-4 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci in E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 F-1-1 System with Minimum-Phase Loop Transfer Functions of Discrete-Data Systems H-12 H-3-2 Systems with Cascade Elements H-12 H-3-2 Transfer Functions of Closed-Loop Discrete-Data Systems H-14 H-3-3 Transfer Functions of Closed-Loop Discrete-Data Systems H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of the Discrete State Equations: Discrete State Equations: H-19 H-4-3 z-Transforr Solution of Hopicines H-18 H-4-1 Discrete State Equations H-18 H-4-2 Solutions of Discrete-Data Systems H-12 H-4-3 z-Transfer Function of Discrete State Equations: H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of the Discrete State Equations: Discrete State Equations: H-19 Transfer Functions of Discrete-Data Systems H-26 H-4-5 State Diagrams of Discrete-Data Systems H-26 H-4-5 State Diagrams for Sampled-Data Systems H-26 H-4-6 State Diagrams for Sampled-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-3 Stability Tests of Discrete-Data Systems H-27 Transfer Functions of Discrete-Data Systems H-27 Transfer Functions of Discrete-Data Systems H-12 H-3-2 Transfer Functions of Closed-Loop Discrete-Data Systems H-16 H-4-1 Discrete State Equations H-16 H-4-1 Discrete State Equations H-16 H-4-1 Transfer Function of the Root Loci and H-4-1 Discrete State Equations H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of the Root Loci and H-16 H-4-3 Zequations H-16 H-4-5 State						
E-1 K = 0 and K = ±∞ Points E-1 E-2 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at s = ∞ E-4 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions of Discrete-Data Systems H-18 E-10 Calculation of Nyquist Criterion F-1 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum And Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-1 Formulation of Nyquist Criterion F-1 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-2 Illustrative Examples—Function F-1 F-3 Illustrative Examples—Function F-1 F-4 Illustrative Examples—Function F-2 F-						Equations H-7
E-2 Number of Branches on the Root Loci E-2 E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at s = \infty E-4 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci with the Imaginary Axis E-11 E-9 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 F-1 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 Ind H-3-2 Transfer Function of the Zero-Order-Hold H-13 H-3-3 Transfer Function of Closed-Loop Discrete-Data Systems H-14 State Equations of Linear Discrete-Data Systems H-14 State Equations of the Discrete State Equations H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of the Discrete State Equations H-18 Transfer Function of the Zero-Order-Hold H-13 H-3-3 Transfer Functions of Closed-Loop Discrete-Data Systems H-14 State Equations of Linear Discrete-State Equations H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of the Discrete State Equations H-18 H-4-3 Z-Transform Solution of Discrete State Equations H-18 H-4-3 Transfer Function Matrix and the Characteristic Equation H-20 H-4-3 State Diagrams of Discrete-Data Systems H-26 H-4-5 State Diagrams for Sampled-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-1 BIBO Stability H-26 H-5-1 BIBO Stability H-26 H-5-1 Repair Functions F-4 H-5-1 Repair Functions of Linear Discrete-Data Systems H-14 H-4-2 Solutions of the Discrete State Equations H-16 H-4-1 Discrete State Equations H-16 H-4-1 Transfer Function of Matrix and the Characteristic Equation H-18 H-4-3 State Diagrams of Discrete-Data Systems H-28 H-4-5 State Diagrams for Sampled-Data Systems H-26 H-	Prope	rties and C	onstruction of the Root Loci E-1	H-3	Transfer F	unctions of Discrete-Data
E-3 Symmetry of the Root Loci E-2 E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at s = ∞ E-4 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axīs E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 E-4 Angles of Asymptotes of the Root Loci at s = ∞ E-4 H-3-2 Transfer Functions of Closed-Loop Discrete-Data Systems H-14 H-3-3 Transfer Functions of Closed-Loop Discrete-Data Systems H-14 State Equations of Linear Discrete-Data Systems H-16 H-4-1 Discrete State Equations of the Discrete State Equations: Discrete State-Transition Equations H-18 H-4-2 Solutions of the Discrete State Equations H-16 H-4-1 Discrete State Equations of the Discrete State Equations: Discrete State Equations H-16 H-4-1 Discrete State Equations of the Discrete State Equations: Discrete State Equations H-16 H-4-1 Discrete State Equations of the Discrete State Equations: Discrete State Equations H-16 H-4-1 Discrete State Equations of the Discrete State Equations of the Discrete State Equations: Discrete State Equations H-16 H-4-1 Discrete State Equations of the Discrete State Equations: Discrete State Equations of the Discrete State Equations: Discrete State Equations H-16 H-4-1 Discrete State Equations of the Discrete State Equations: Discrete State Equations of the Discrete State Equations of	E-1	K=0 and	$K = \pm \infty$ Points E-1		Systems 1	H-8
E-4 Angles of Asymptotes of the Root Loci and Behavior of the Root Loci at s = ∞ E-4 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 F-1 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-1 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-1 F-3 Illustrative Examples—General Nyquist Criterion F-4 F-4 In H-4-1 F-4 In F-3 State Equations of Linear Discrete-Data Systems H-16 H-4-1 Discrete State Equations Obscrete State Equations of Linear Discrete State Equations of Linear Discrete-Data Systems H-16 H-4-1 Discrete State Function of Linear Discrete State Equations of Linear Discrete State Equations of Linear Discrete State Equations	E-2	Number o	f Branches on the Root Loci E-2		H-3-1	
Behavior of the Root Loci at s = \infty E-4 E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 E-5 Intersect of the Asymptotes (Centroid) E-5 H-3-3 Transfer Functions of Closed-Loop Discrete-Data Systems H-14 State Equations of Linear Discrete-Data Systems H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of the Discrete State E-quations: Discrete State E-quations: Discrete State E-quations H-18 F-4-3 Transfer Functions of Closed-Loop Discrete-Data Systems H-16 H-4-1 Discrete State Equations: Discrete State E-quations: Discrete State E-quations: Discrete State E-quations: Discrete State F-4-4-3 z-Transform Solution of Discrete State E-quations: Discrete State	E -3	Symmetry	of the Root Loci E-2			
E-5 Intersect of the Asymptotes (Centroid) E-5 E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 E-6 Root Loci on the Real Axis E-8 H-3-3 Transfer Functions of Closed-Loop Discrete-Data Systems H-14 State Equations of Linear Discrete-Data Systems H-16 H-4-1 Discrete State Equations of the Discrete State Equations of the Discrete State Equations: Discrete State Equations: Discrete State Equations H-18 E-7 Transform Solution of Discrete State Equations H-18 E-7 Transform Solution of Discrete State Equations H-18 E-7 Transform Solution of Discrete State Equations H-18 E-4-2 Solutions of the Poiscrete State Equations H-16 H-4-1 Discrete State Equations of Linear Discrete-Data Systems H-24 State Equations of Linear Discrete-Data Systems H-14 H-4-2 Solutions of the Discrete State Equations of Linear Discrete State Equations of Linear Discrete-Data Systems H-14 H-4-1 Discrete State Equations of Linear Discrete State Equations of Linear Discrete-Data Systems H-26 H-4-1 Discrete State Equations of Linear Discrete State Equations of Linear Discrete State Equations of Linear Discrete-Data Systems H-16 H-4-1 Discrete State Equations of Linear Discrete State Equations of the Discrete State Equations of Linear Discrete State Equations H-16 H-4-3 Z-17-10 State Discrete State Equations of Linear Discrete State Equations H-16 H-4-3 Z-17-10 State Discrete State	E-4	Angles of A	Asymptotes of the Root Loci and		H-3-2	
E-6 Root Loci on the Real Axis E-8 E-7 Angles of Departure and Angles of Arrival of the Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-1 Root Loci of the Root Loci with the State Equations of Linear Discrete-Data Systems H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of the Discrete State Equations: Discrete State Equations H-18 H-4-3 z-Transform Solution of Discrete State Equations H-18 H-4-3 z-Transform Solution of Discrete State Equations H-18 H-4-3 State Equations of Linear Discrete State Equations H-16 H-4-1 Discrete State Equations:		Behavior o	of the Root Loci at $ s = \infty$ E-4			
E-7 Angles of Departure and Angles of Arrival of the Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 F-10 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum Angles Interval Equations H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of Lincar Discrete State Equations H-16 H-4-3 Z-Transform Solution of Lincar Discrete State Equations H-16 H-4-3 Z-Transform Solution of Lincar Discrete State Equations H-16 H-4-3 Z-Transform Solution of Lincar Discre					H-3-3	
Root Loci E-9 E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 F-1 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum Angle Park Interval Examples Angle Park Interval Equations H-16 H-4-1 Discrete State Equations H-16 H-4-2 Solutions of the Discrete State F-4-3 Z-Transform Solution of Discrete State F-4-4-3 Z-Transform Solution of Discrete State F-4-4-4 Transfer-Function Matrix and the Characteristic Equations H-19 H-4-3 State Diagrams of Discrete-Data Systems H-26 F-4-5 Stability of Discrete-Data Systems H-26 H-4-5 State Diagrams for Sampled-Data Systems H-26 F-1 BIBO Stability H-26 H-4-5 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 F-1 Formulation of Nyquist Criterion F-1 F-2 Illustrative Examples—General Nyquist Criterion F-1				TT 4	01.1. 77	
E-8 Intersection of the Root Loci with the Imaginary Axis E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 F-10 Calculation of K on the Root Loci E-16 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum And Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum And Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Systems H-27 F-3 Illustrative Examples—General Nyquist Criterion F-4 F-4-4 Transfer State Equations H-16 H-4-2 Solutions of the Discrete State Equations: Discrete State F-4 Illustration Equations: Discrete State F-4 Illu	E-7			11-4		
Imaginary Axís E-11 E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 F-10 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer F-1-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 Minimum and Nonminimum Transfer Functions F-4 M-4-2 Solutions of the Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: H-18 H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State H-4-3 z-Transform Solution of Discrete State Equations: Discrete State Equat	~ .					
E-9 Breakaway Points E-11 E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 F-10 Calculation of K on the Root Loci E-16 General Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 Equations: Discrete State—Transition Equations H-18 F-4-3 z-Transform Solution of Discrete State Equations: H-18 F-4-3 z-Transform Solution of Discrete State Equations: Discrete State—Transition Equations H-18 F-4-3 z-Transform Solution of Discrete State Equations: H-18 F-4-3 z-Transform Solution of Discrete State Equations: H-18 F-4-3 z-Transform Solution of Discrete State Equations: H-19 H-4-3 z-Transform Solution of Discrete State Equations: H-18 F-4-3 z-Transform Solution of Discrete State Equations: H-19 H-4-3 z-Transform Solution of Discrete State Equations: H-18 F-4-3 z-Transform Solution of Discrete State Equations: H-19 H-4-4 Transfer-Function Matrix and the Characteristic Equation H-20 H-4-5 State Diagrams of Discrete-Data Systems H-22 H-4-5 State Diagrams of Discrete-Data Systems H-23 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 II-5-3 Stability Tests of Discrete-Data Systems H-27	E-8					
E-9-1 (Saddle Points) on the Root Loci E-11 E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 H-4-3 z-Transform Solution of Discrete State Equations H-19 H-4-4 Transfer-Function Matrix and the Characteristic Equation H-20 H-4-5 State Diagrams of Discrete-Data Systems H-22 H-4-6 State Diagrams for Sampled-Data Systems H-23 Systems H-23 H-5-1 BIBO Stability H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 H-5-2 Zero-Input Stability H-26 H-5-3 Stability Tests of Discrete-Data Systems H-27 II-5-3 Stability Tests of Discrete-Data Systems H-27 II-5-3 Stability Tests of Discrete-Data Systems H-26 II-5-3 Stability Tests of Discrete-Data Systems H-27 II-5-3 Stability Tests of Discrete-Data Systems H-26	77.0				11 -4- 2	
E-9-2 The Angle of Arrival and Departure of Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 H-4-4 Transfer-Function Matrix and the Characteristic Equation H-20 H-4-5 State Diagrams of Discrete-Data Systems H-22 H-4-6 State Diagrams for Sampled-Data Systems H-23 H-4-6 State Diagrams for Sampled-Data Systems H-23 H-5-1 Systems with Improper Loop Transfer Functions F-4 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 H-5-3 Stability Tests of Discrete-Data Systems H-27 H-5-1 Systems H-27 H-5-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 H-5-1 F-5-2 Transform Solution of Discrete State Equations H-19 H-4-3 Z-Transform Solution of Discrete State Equations H-19 H-4-3 Transfer-Function Matrix and the Characteristic Equation H-20 H-4-5 State Diagrams for Sampled-Data Systems H-23 H-5-1 BIBO Stability H-26 H-5-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4	E-9					
Root Loci at the Breakaway Point E-12 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 E-10 Calculation of K on the Root Loci E-16 H-4-4 Transfer-Function Matrix and the Characteristic Equation H-20 H-4-5 State Diagrams of Discrete-Data Systems H-22 H-4-6 State Diagrams for Sampled-Data Systems H-23 H-4-6 State Diagrams for Sampled-Data Systems H-23 H-5-1 Systems with Improper Loop Transfer F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 H-5-1 Stability of Discrete-Data Systems H-26 H-5-2 Zero-Input Stability H-26 II-5-3 Stability Tests of Discrete-Data Systems H-27					H-4-3	
E-10 Calculation of K on the Root Loci E-16 H-4-4 Transfer-Function Matrix and the Characteristic Equation H-20 H-4-5 State Diagrams of Discrete-Data Systems H-22 F-1 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 H-4-5 State Diagrams of Discrete-Data Systems H-23 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 II-5-3 Stability Tests of Discrete-Data Systems H-27 H-5-1 BIBO Stability H-26 H-5-2 Transfer Function Matrix and the Characteristic Equation H-20 H-4-5 State Diagrams for Sampled-Data Systems H-23 H-5-1 BIBO Stability H-26 H-5-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4		13-9-2			11 1 5	
the Characteristic Equation H-20 H-4-5 State Diagrams of Discrete-Data Systems H-22 F-1 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 the Characteristic Equation H-20 H-4-5 State Diagrams of Discrete-Data Systems H-22 H-4-6 State Diagrams for Sampled-Data Systems H-23 H-5-1 BIBO Stability H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 III-5-3 Stability Tests of Discrete-Data Systems H-27	F-10	Calculation			H-4-4	
General Nyquist Criterion F-1 F-1 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 H-4-5 State Diagrams of Discrete-Data Systems H-22 H-4-6 State Diagrams of Discrete-Data Systems H-23 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 II-5-3 Stability Tests of Discrete-Data Systems H-27 III-5-3 Stability Tests of Discrete-Data	E-10	Carculation	it of K off the Root Exci 12 10			
General Nyquist Criterion F-1 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-1-2 Systems H-23 Systems H-23 Systems H-23 Systems H-23 Systems H-23 Systems H-23 Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 III-5-3 Stability Tests of Discrete-Data Systems H-27 III-5-3 Stability Tests of Discrete-Data	\$ A.F	PRINCIPAL I	ŗ		H-4-5	
F-1 Formulation of Nyquist Criterion F-1 F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-1-2 Systems With Improper Loop Transfer F-2 Illustrative Examples—General Nyquist Criterion Minimum And Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-3 State Diagrams for Sampled-Data Systems H-23 F-2 Exposure Diagrams for Sampled-Data Systems H-23 F-2 Exposure Diagrams for Sampled-Data Systems H-23 F-3 Stability of Discrete-Data Systems H-26 F-3 Stability H-26 F-4 F-5-1 BIBO Stability H-26 F-5-2 Systems H-5-2 Zero-Input Stability Tests of Discrete-Data Systems H-5-2 Zero-Input Stability Tests of Discrete-Data Systems H-23 F-5-1 BIBO Stability H-26 F-6-1 BIBO Stability H-26 F-7-1 Systems H-27 F-7-2	Gene	ral Nyquist	Criterion F-1			Systems H-22
F-1-1 System with Minimum-Phase Loop Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum And Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum And Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-4 Illustrative Examples—General Nyquist Criterion Minimum And Nonminimum Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion F-3 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 Illustrative Examples—General Nyquist Criterion F-4 Stability of Discrete-Data Systems H-26 H-5-2 Zero-Input Stability H-26 H-5-2 Systems H-27 Illustrative Examples—General Nyquist Criterion F-4 Stability Of Discrete-Data Systems H-26 H-5-2 Zero-Input Stability H-26 H-5-2 Systems H-27 Illustrative Examples—General Nyquist Criterion F-4 Stability of Discrete-Data Systems H-26 H-5-2 Zero-Input Stability H-26 H-5-2 Systems H-27 Illustrative Examples—General Nyquist Criterion F-4 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 H-5-2 Systems H-27 Illustrative Examples—General Nyquist Criterion F-4 Systems H-27 Illustrative Examples—General Nyquist Criterion F-4 Systems H-27 Illustrative Examples—General Nyquist Criterion F-4 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Systems H-27 Illustrative Examples—General Nyquist Criterion F-4 Systems H-27	F-1	Formulatio	on of Nyauist Criterion F-1		H-4-6	
Transfer Functions F-4 F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 Minimum Representations F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum Representations F-4 F-3 Stability of Discrete-Data Systems H-26 H-5-1 BIBO Stability H-26 H-5-2 Zero-Input Stability H-26 III-5-3 Stability Tests of Discrete-Data Systems H-27	1 1		* 1			Systems H-23
F-1-2 Systems with Improper Loop Transfer Functions F-4 F-2 Illustrative Examples—General Nyquist Criterion Minimum and Nonminimum Transfer Functions F-4 Minimum Representations F-4 Minimum F-1-2 Systems H-26 Minimum F-1-2 Systems H-27 Minimum F-1-2 Systems W-1-26 Minimum F-1-2 Systems				H-5	Stability of	
Functions F-4 H-5-2 Zero-Input Stability H-26 F-2 Illustrative Examples—General Nyquist Criterion H-5-3 Stability Tests of Discrete-Data Minimum and Nonminimum Transfer Functions F-4 Systems H-27		F-1-2				
Minimum and Nonminimum Transfer Functions F-4 Systems H-27 W.G. Tive Device Reporting of Dispute Date						
Minimum and Nonminimum Transfer Functions F-4 Systems H-27	F-2	Illustrative	Examples—General Nyquist Criterion		H-5-3	·
F-3 Stability Analysis of Multiloop Systems F-13 H-6 Time-Domain Properties of Discrete-Data				** -		
	F-3	Stability A	nalysis of Multiloop Systems F-13	H-6	Time-Dom	nam Properties of Discrete-Data

	Systems	H-31		H-10-2	Digital Implementation of Analog
	H-6-1	Time Response of Discrete-Data			Controllers II-52
		Control Systems H-31		H-10-3	Digital Implementation of the PID
	H-6-2	Mapping between s-Plane and z-Plane			Controller II-54
		Trajectories H-34		H-10-4	Digital Implementation of Lead and
	H-6-3	Relation between Characteristic-			Lag Controllers H-57
		Equation Roots and Transient	II-11	Digital Co	ontrollers H-58
		Response II-38		H-11-1	Physical Realizability of Digital
H-7	Steady-Sta	te Error Analysis of Discrete-Data			Controllers H-58
	Control Sy	rstems H-41	H-12		Discrete-Data Control Systems in
H-8		of Discrete-Data Systems H-45		the Frequ	ency Domain and the z-Plane H-61
H-9	Frequency	-Domain Analysis of Discrete-Data		H-12-1	Phase-Lead and Phase-Lag Controllers
	Control Sy	stems H-49			in the w -Domain H-61
	H-9-1	Bode Plot with the	H-13		Discrete-Data Control Systems
		$w ext{-Transformation} ext{H-50}$			lbeat Response H-68
H-10	Design of	Discrete-Data Control Systems H-51	H-14		ement Design with State
	H-10-1	Introduction H-51		Feedback	H-70