

Contents

1	Introduction	1
1.1	Introduction	1
1.2	Notations	3
1.3	The Standard H_∞ Optimization Problem	4
1.4	Some Common Robust Control Problems	10
1.4.1	The Mixed-sensitivity Problem	11
1.4.2	Maximization of Complex Stability Radius	14
1.4.3	Robust Stabilization with Additive Perturbations	15
1.4.4	Robust Stabilization with Multiplicative Perturbations	16
1.5	Preview of Each Chapter	17
2	Linear System Tools	19
2.1	Introduction	19
2.2	Jordan and Real Jordan Canonical Forms	20
2.3	Structural Decompositions of Matrix Pairs	22
2.4	Special Coordinate Basis	28
2.5	Proofs of Properties of Special Coordinate Basis	45
3	Structural Mappings of Bilinear Transformations	57
3.1	Introduction	57
3.2	Mapping of Continuous-time to Discrete-time	58
3.3	Mapping of Discrete-time to Continuous-time	65
3.4	Proof of Theorem 3.2.1	69
4	Existence Conditions of H_∞ Suboptimal Controllers	83
4.1	Introduction	83
4.2	Continuous-time Systems	84
4.3	Discrete-time Systems	88

5	Solutions to Discrete-time Riccati Equations	95
5.1	Introduction	95
5.2	Solution to a General DARE	96
5.3	Solution to an H_∞ -DARE	97
5.4	Proofs of Main Results	104
6	Infima in Continuous-time H_∞ Optimization	111
6.1	Introduction	111
6.2	Full Information Feedback Case	112
6.3	Output Feedback Case	123
6.4	Plants with Imaginary Axis Zeros	133
7	Solutions to Continuous-time H_∞ Problem	143
7.1	Introduction	143
7.2	Full State Feedback	144
7.3	Full Order Output Feedback	152
7.4	Reduced Order Output Feedback	158
7.5	Proofs of Main Results	164
8	Continuous-time H_∞ Almost Disturbance Decoupling	177
8.1	Introduction	177
8.2	Solvability Conditions	180
8.3	Solutions to Full State Feedback Case	184
8.4	Solutions to Output Feedback Case	191
	8.4.1 Full Order Output Feedback	192
	8.4.2 Reduced Order Output Feedback	194
8.5	Proofs of Main Results	199
9	Robust and Perfect Tracking of Continuous-time Systems	215
9.1	Introduction	215
9.2	Solvability Conditions and Solutions	217
	9.2.1 Solutions to State Feedback Case	222
	9.2.2 Solutions to Measurement Feedback Case	225
	A. Full Order Measurement Feedback	226
	B. Reduced Order Measurement Feedback	228
9.3	Robust and Perfect Tracking for Other References	230
9.4	Proofs of Main Results	237

10 Infima in Discrete-time H_∞ Optimization	249
10.1 Introduction	249
10.2 Full Information Feedback Case	249
10.3 Output Feedback Case	261
10.4 Plants with Unit Circle Zeros	266
11 Solutions to Discrete-time H_∞ Problem	269
11.1 Introduction	269
11.2 Full Information and State Feedbacks	270
11.3 Full Order Output Feedback	275
11.4 Reduced Order Output Feedback	280
12 Discrete-time H_∞ Almost Disturbance Decoupling	287
12.1 Introduction	287
12.2 Solvability Conditions	289
12.3 Solutions to State and Full Information Feedback Cases	293
12.4 Solutions to Measurement Feedback Case	301
12.4.1 Full Order Output Feedback	301
12.4.2 Reduced Order Output Feedback	305
12.5 Proofs of Main Results	309
13 Robust and Perfect Tracking of Discrete-time Systems	339
13.1 Introduction	339
13.2 Solvability Conditions and Solutions	340
13.2.1 Solutions to State Feedback Case	344
13.2.2 Solutions to Measurement Feedback Case	345
13.3 An Almost Perfect Tracking Problem	349
14 Design of a Hard Disk Drive Servo System	363
14.1 Introduction	363
14.2 Modeling of the VCM Actuator	365
14.3 Servo System Design and Simulation Results	369
14.4 Implementation Results	373
15 Design of a Piezoelectric Actuator System	381
15.1 Introduction	381
15.2 Linearization of the Nonlinear Hysteretic Dynamics	385
15.3 Formulation of the Problem as an H_∞ -ADDPMS	388
15.4 Final Controller and Simulation Results	395

16 Design of a Gyro-stabilized Mirror Targeting System	407
16.1 Introduction	407
16.2 The Free Gyro-stabilized Mirror System	408
16.3 Controller Design Using the RPT Approach	413
16.4 Simulation and Implementation Results	417
 Bibliography	 429
 Index	 443