
Contents

Preface	ix
Algorithms Summary	xi
PART 1. PREPARATION	1
1. The Windup Phenomenon and Anti-windup Illustrated	3
1.1 Introduction	3
1.2 Illustrative examples	4
1.3 Summary	21
1.4 Notes and references	22
2. Anti-windup: Definitions, Objectives, and Architectures	23
2.1 Preliminaries	23
2.2 Qualitative objectives	26
2.3 Anti-windup augmentation	32
2.4 Quantitative performance objectives	40
2.5 Notes and references	47
3. Analysis and Synthesis of Feedback Systems: Quadratic Functions and LMIs	48
3.1 Introduction	48
3.2 Unconstrained feedback systems	50
3.3 Linear matrix inequalities	51
3.4 Constrained feedback systems: global analysis	59
3.5 Constrained feedback systems: regional analysis	63
3.6 Analysis examples	67
3.7 Regional synthesis for external stability	70
3.8 Notes and references	73
PART 2. DIRECT LINEAR ANTI-WINDUP AUGMENTATION	75
4. Static Linear Anti-windup Augmentation	77
4.1 Overview	77
4.2 Key state-space representations	78
4.3 Algorithms providing global guarantees	81
4.4 Algorithms providing regional guarantees	98
4.5 Notes and references	107

5. Dynamic Linear Anti-windup Augmentation	109
5.1 Overview	109
5.2 Key state-space representations	110
5.3 Factoring rank-deficient matrices	113
5.4 Algorithms providing global guarantees	114
5.5 Algorithms providing regional guarantees	141
5.6 Notes and references	152
PART 3. MODEL RECOVERY ANTI-WINDUP AUGMENTATION	155
6. The MRAW Framework	157
6.1 Introduction	157
6.2 A block diagram/transfer function description	158
6.3 A state-space description (linearity not needed)	161
6.4 Robust, fragile, or both?	164
6.5 Notes and references	167
7. Linear MRAW Synthesis	174
7.1 Introduction	174
7.2 Global stability-based algorithms	176
7.3 Regional stability and performance algorithms	195
7.4 Notes and references	199
8. Nonlinear MRAW Synthesis	200
8.1 Introduction	200
8.2 Switching and scheduling linear controllers	201
8.3 Model predictive control for anti-windup design	208
8.4 Global designs for non-exponentially unstable plants	217
8.5 Designs for exponentially unstable plants that maximize the basin of attraction	222
8.6 Notes and references	225
9. The MRAW Structure Applied to Other Problems	226
9.1 Rate- and magnitude-saturated plants	226
9.2 Anti-windup for dead-time plants	232
9.3 Bumpless transfer in multicontroller schemes	235
9.4 Reliable control via hardware redundancy	240
9.5 Notes and references	243
10. Anti-windup for Euler-Lagrange Plants	245
10.1 Fully actuated Euler-Lagrange plants	245
10.2 Anti-windup construction and selection of the stabilizer v	246
10.3 Simulation examples	250
10.4 Notes and references	268
11. Annotated Bibliography	269
11.1 Overview	269
11.2 Problem discovery	269
11.3 The first constructive techniques	270

CONTENTS	vii
11.4 Call for systematization	271
11.5 Modern anti-windup schemes	272
11.6 Additional references	281
Index	285