

TABLE OF CONTENTS

1. INTRODUCTION	1
1.1 Background and Problem Description	1
1.2 Organization	3
2. PRELIMINARIES	6
2.1 Introduction	6
2.2 State-Space Systems	7
2.2.1 State-Space Forms	7
2.2.2 Controllability and Observability	7
2.2.3 Inner and Co-Inner Systems	9
2.3 Frequency Domain Spaces	11
2.4 Linear Fractional Transformations	12
2.5 Coprime Factorizations	15
2.5.1 Definitions	15
2.5.2 State-Space Properties of Normalized Coprime Factors	17
2.6 Stability Results	19
2.6.1 Well-Posedness and Internal Stability	19
2.6.2 Closed-Loop Stability Results	22
3. ROBUST STABILIZATION OF UNCERTAIN SYSTEMS	24
3.1 Introduction	24
3.2 Modelling of Uncertainty	26
3.2.1 Background	26
3.2.2 Frequency Domain Error Modelling	27
3.3 Robust Stability Analysis	32
3.3.1 Introduction	32
3.3.2 Frequency Domain Uncertainty Analysis	32
3.4 Robust Controller Design Using H_∞ Optimization	39
3.4.1 The Robust Stabilization Problem	39
3.4.2 Nominal Performance Problems	40
3.4.3 H_∞ Problem Specification	43
3.4.4 Solution to the H_∞ Optimization Problem	46
3.5 Summary	50
4. ROBUST STABILIZATION OF NORMALIZED COPRIME FACTOR PLANT DESCRIPTIONS	51
4.1 Introduction and Problem Statement	51
4.2 Characterizing all Solutions	53
4.2.1 Solution Via a Nehari Extension Approach	53
4.2.2 Parametrizing All Controllers	60
4.3 A State Space Representation of Sub-Optimal Controllers	62
4.3.1 Characterizing All Controllers	62
4.3.2 The Central Controller	66
4.4 Solution Using the Procedure of Glover and Doyle, (1988)	69
4.5 Related Issues	72
4.5.1 H_∞ Problems with Exact Solutions	72

4.5.2	Robust Stability of Passive Systems	78
4.6	Review of Results	81
5.	REDUCED ORDER CONTROLLER DESIGN	82
5.1	Introduction	82
5.2	Review	83
5.2.1	Model Reduction Techniques	83
5.2.2	Coprime Factor Model Reduction	85
5.3	Reduced Order Controller Design	88
5.3.1	Problem Statement	88
5.3.2	Reduced Order Controllers by Plant Model Reduction	89
5.3.3	Reduced Order Controllers by Controller Model Reduction	93
5.4	Summary	97
6.	A LOOP SHAPING DESIGN PROCEDURE	98
6.1	Introduction	98
6.2	Loop Shaping Methods	100
6.3	The Design Procedure	106
6.4	Using ϵ as a Design Indicator	110
6.4.1	Guarantees on the Achieved Loop Shape	110
6.4.2	Assessing Stabilizing Controllers using ϵ	119
6.5	Shaping Functions and Closed-Loop Behaviour	124
6.5.1	Behaviour of Standard Closed-Loop Objectives	124
6.5.2	Bounds on the Normalized Coprime Factors	127
6.6	Discussions	128
6.6.1	The Role of the Shaping Function in Design	128
6.6.2	Model Reduction	130
6.7	Summary	131
7.	DESIGN EXAMPLES	132
7.1	Introduction	132
7.2	Example 1: Attitude Control of a Flexible Spacecraft	133
7.2.1	Problem Description	133
7.2.2	Design Objectives	134
7.2.3	The Loop Shaping Design Procedure	135
7.2.4	Results	137
7.2.5	Analysis of Results	138
7.3	Example 2: Attitude Control of a Flexible Space Platform	143
7.3.1	The Dynamic Model	143
7.3.2	Design Objectives	144
7.3.3	The Loop Shaping Design Procedure	145
7.3.4	Results	146
7.3.5	Analysis of Results	147
7.3.6	Spillover Mode Analysis	148
7.3.7	Design on a Model with Reduced Number of Inputs	148
7.3.8	Summary	149
7.4	Example 3: Vertical Plane Dynamics Control of an Aircraft	161
7.4.1	Problem Description	161
7.4.2	Design Objectives	162

7.4.3	The Loop Shaping Design Procedure.....	162
7.4.4	Results	164
7.4.5	Analysis of Results	165
7.4.6	Comparison with Maciejowski's Results	166
7.5	Concluding Remarks.....	181
Appendix A	The Algebraic Riccati Equation	182
Appendix B	Sub-Optimal Nehari Extensions	185
Appendix C	Proof of Miscellaneous Results	187
Appendix D	State-Space Systems for Chapter 7.....	192
REFERENCES.....		200