

# Contents

*Preface* *page ix*

**PART I INTRODUCTION AND BACKGROUND**

<b>1 Introduction</b>	3
1.1 Motivation, Background, and Overview	3
1.2 Overview of Automotive Control Systems	7
<b>2 Automotive Control-System Design Process</b>	21
2.1 Introduction	21
2.2 Identifying the Control Requirements	22
<b>3 Review of Engine Modeling</b>	33
3.1 Engine Operations	33
3.2 Engine Control Loops	37
3.3 Control-Oriented Engine Modeling	42
<b>4 Review of Vehicle Dynamics</b>	54
4.1 Coordinates and Notation for Vehicle Dynamics	54
4.2 Longitudinal Vehicle Motion	58
4.3 Lateral Vehicle Motion	64
4.4 Vertical Vehicle Motion	77
<b>5 Human Factors and Driver Modeling</b>	93
5.1 Human Factors in Vehicle Automation	93
5.2 Driver Modeling	101

**PART II POWERTRAIN CONTROL SYSTEMS**

<b>6 Air-Fuel Ratio Control</b>	119
6.1 Lambda Control	119
6.2 PI Control of a First-Order System with Delay	120
<b>7 Control of Spark Timing</b>	124
7.1 Knock Control	124

<b>8 Idle-Speed Control</b>	126
<b>9 Transmission Control</b>	131
9.1 Electronic Transmission Control	131
9.2 Clutch Control for AWD	133
<b>10 Control of Hybrid Vehicles</b>	148
10.1 Series, Parallel, and Split Hybrid Configurations	148
10.2 Hybrid Vehicle-Control Hierarchy	152
10.3 Control Concepts for Series Hybrids	157
10.4 Control Concepts for Parallel Hybrids	166
10.5 Control Concept for Split Hybrids	177
10.6 Feedback-Based Supervisory Controller for PHEVs	178
<b>11 Modeling and Control of Fuel Cells for Vehicles</b>	187
11.1 Introduction	187
11.2 Modeling of Fuel-Cell Systems	189
11.3 Control of Fuel-Cell Systems	196
11.4 Control of Fuel-Cell Vehicles	201
11.5 Parametric Design Considerations	205
<b>PART III VEHICLE CONTROL SYSTEMS</b>	
<b>12 Cruise and Headway Control</b>	213
12.1 Cruise-Controller Design	213
12.2 Autonomous Cruise Control: Speed and Headway Control	224
<b>13 Antilock Brake and Traction-Control Systems</b>	232
13.1 Modeling	234
13.2 Antilock Braking Systems	236
13.3 Traction Control	247
<b>14 Vehicle Stability Control</b>	257
14.1 Introduction	258
14.2 Linear Vehicle Model	261
14.3 Nonlinear Vehicle Model	263
14.4 VSC Design Principles	266
<b>15 Four-Wheel Steering</b>	272
15.1 Basic Properties	272
15.2 Goals of 4WS Algorithms	274
<b>16 Active Suspensions</b>	287
16.1 Optimal Active Suspension for Single-DOF Model	288
16.2 Optimal Active Suspension for Two-DOF Model	290
16.3 Optimal Active Suspension with State Estimation	294

PART IV INTELLIGENT TRANSPORTATION SYSTEMS

17 **Overview of Intelligent Transportation Systems** . . . . . 309

    17.1 Advanced Traffic Management Systems . . . . . 310

    17.2 Advanced Traveler Information Systems . . . . . 312

    17.3 Commercial Vehicle Operations . . . . . 314

    17.4 Advanced Vehicle-Control Systems . . . . . 314

18 **Preventing Collisions** . . . . . 322

    18.1 Active Safety Technologies . . . . . 322

    18.2 Collision Detection and Avoidance . . . . . 322

19 **Longitudinal Motion Control and Platoons** . . . . . 332

    19.1 Site-Specific Information . . . . . 332

    19.2 Platooning . . . . . 337

    19.3 String Stability . . . . . 343

20 **Automated Steering and Lateral Control** . . . . . 348

    20.1 Lane Sensing . . . . . 348

    20.2 Automated Lane-Following Control . . . . . 352

    20.3 Automated Lane-Change Control . . . . . 356

APPENDICES

Appendix A: **Review of Control-Theory Fundamentals** . . . . . 363

    A.1 Review of Feedback Control . . . . . 363

    A.2 Mathematical Background and Design Techniques . . . . . 370

Appendix B: **Two-Mass Three-Degree-of-Freedom Vehicle**  
                  **Lateral/Yaw/Roll Model** . . . . . 385

*Index* . . . . . 391