

CONTENTS

Lists ix

- Figures ix
- Tables xiv
- Class Discussion Items xv
- Examples xvii
- Design Examples xviii

Preface xix

Chapter 1

Introduction to Mechatronics and Measurement Systems 1

- 1.1 Mechatronics 1
- 1.2 Measurement Systems 4

Chapter 2

Electric Circuits and Components 6

- 2.1 Introduction 7
- 2.2 Basic Electrical Elements 9
 - 2.2.1 Resistor 10
 - 2.2.2 Capacitor 13
 - 2.2.3 Inductor 14
- 2.3 Kirchhoff's Laws 16
 - 2.3.1 Series Resistance Circuit 18
 - 2.3.2 Parallel Resistance Circuit 20
- 2.4 Voltage and Current Sources and Meters 23
- 2.5 Thevenin and Norton Equivalent Circuits 29
- 2.6 Alternating Current Circuit Analysis 30
- 2.7 Power in Electrical Circuits 36
- 2.8 Transformer 38
- 2.9 Impedance Matching 39

- 2.10 Grounding and Electrical Interference 41
 - 2.10.1 Electrical Safety 44

Chapter 3

Semiconductor Electronics 53

- 3.1 Introduction 54
- 3.2 Semiconductor Physics as the Basis for Understanding Electronic Devices 54
- 3.3 Junction Diode 56
 - 3.3.1 Zener Diode 60
 - 3.3.2 Voltage Regulators 65
 - 3.3.3 Optoelectronic Diodes 66
 - 3.3.4 Analysis of Diode Circuits 67
- 3.4 Bipolar Junction Transistor 70
 - 3.4.1 Bipolar Transistor Physics 70
 - 3.4.2 Common Emitter Transistor Circuit 72
 - 3.4.3 Bipolar Transistor Switch 74
 - 3.4.4 Bipolar Transistor Packages 77
 - 3.4.5 Darlington Transistor 77
 - 3.4.6 Phototransistor and Opto-Isolator 78
- 3.5 Field Effect Transistors 80
 - 3.5.1 Behavior of Field-Effect Transistors 81
 - 3.5.2 Symbols Representing Field Effect Transistors 83
 - 3.5.3 Applications of MOSFETs 84

Chapter 4

System Response 96

- 4.1 System Response 97
- 4.2 Amplitude Linearity 98
- 4.3 Fourier Series Representation of Signals 99
- 4.4 Bandwidth and Frequency Response 102

- 4.5 Phase Linearity 108
- 4.6 Distortion of Signals 109
- 4.7 Dynamic Characteristics of Systems 110
- 4.8 Zero-Order System 111
- 4.9 First-Order System 112
 - 4.9.1 *Experimental Testing of a First-Order System* 114
- 4.10 Second-Order System 115
 - 4.10.1 *Step Response of a Second-Order System* 119
 - 4.10.2 *Frequency Response of a System* 121
- 4.11 System Modeling and Analogies 130

Chapter 5

Analog Signal Processing Using Operational Amplifiers 141

- 5.1 Introduction 142
- 5.2 Amplifiers 142
- 5.3 Operational Amplifiers 144
- 5.4 Ideal Model for the Operational Amplifier 144
- 5.5 Inverting Amplifier 147
- 5.6 Noninverting Amplifier 150
- 5.7 Summer 152
- 5.8 Difference Amplifier 152
- 5.9 Instrumentation Amplifier 155
- 5.10 Integrator 157
- 5.11 Differentiator 158
- 5.12 Sample and Hold Circuit 159
- 5.13 Comparator 160
- 5.14 The Real Op Amp 161
 - 5.14.1 *Important Parameters from Op Amp Data Sheets* 163

Chapter 6

Digital Circuits 178

- 6.1 Introduction 179
- 6.2 Digital Representations 180
- 6.3 Combinational Logic and Logic Classes 183
- 6.4 Timing Diagrams 186

- 6.5 Boolean Algebra 187
- 6.6 Design of Logic Networks 189
 - 6.6.1 *Define the Problem in Words* 189
 - 6.6.2 *Write Quasi-Logic Statements* 190
 - 6.6.3 *Write the Boolean Expression* 190
 - 6.6.4 *AND Realization* 191
 - 6.6.5 *Draw the Circuit Diagram* 191
- 6.7 Finding a Boolean Expression Given a Truth Table 192
- 6.8 Sequential Logic 194
- 6.9 Flip-Flops 195
 - 6.9.1 *Triggering of Flip-Flops* 196
 - 6.9.2 *Asynchronous Inputs* 198
 - 6.9.3 *D Flip-Flop* 199
 - 6.9.4 *JK Flip-Flop* 200
- 6.10 Applications of Flip-Flops 203
 - 6.10.1 *Switch Debouncing* 203
 - 6.10.2 *Data Register* 204
 - 6.10.3 *Binary Counter and Frequency Divider* 205
 - 6.10.4 *Serial and Parallel Interfaces* 205
- 6.11 TTL and CMOS Integrated Circuits 207
 - 6.11.1 *Using Manufacturer IC Data Sheets* 209
 - 6.11.2 *Digital IC Output Configurations* 213
 - 6.11.3 *Interfacing TTL and CMOS Devices* 215
- 6.12 Special Purpose Digital Integrated Circuits 217
 - 6.12.1 *Decade Counter* 217
 - 6.12.2 *Schmitt Trigger* 220
 - 6.12.3 *555 Timer* 220
- 6.13 Integrated Circuit System Design 224
 - 6.13.1 *IEEE Standard Digital Symbols* 227

Chapter 7

Microcontroller Programming and Interfacing 238

- 7.1 Microprocessors and Microcomputers 239
- 7.2 Microcontrollers 242
- 7.3 The PIC16F84 Microcontroller 244
- 7.4 Programming a PIC 248

- 7.5** PicBasic Pro 254
 - 7.5.1 *PicBasic Pro Programming Fundamentals* 254
 - 7.5.2 *PicBasic Pro Programming Examples* 262
- 7.6** Using Interrupts 274
- 7.7** Interfacing Common PIC Peripherals 277
 - 7.7.1 *Numeric Keypad* 278
 - 7.7.2 *LCD Display* 280
- 7.8** Interfacing to the PIC 282
 - 7.8.1 *Digital Input to the PIC* 284
 - 7.8.2 *Digital Output from the PIC* 287
- 7.9** Method to Design a Microcontroller-Based System 287

Chapter 8

Data Acquisition 297

- 8.1** Introduction 298
- 8.2** Quantizing Theory 302
- 8.3** Analog-to-Digital Conversion 303
 - 8.3.1 *Introduction* 303
 - 8.3.2 *Analog-to-Digital Converters* 307
- 8.4** Digital-to-Analog (D/A) Conversion 310

Chapter 9

Sensors 315

- 9.1** Introduction 316
- 9.2** Position and Speed Measurement 316
 - 9.2.1 *Proximity Sensors and Switches* 317
 - 9.2.2 *Potentiometer* 318
 - 9.2.3 *Linear Variable Differential Transformer* 319
 - 9.2.4 *Digital Optical Encoder* 322
- 9.3** Stress and Strain Measurement 330
 - 9.3.1 *Electrical Resistance Strain Gage* 330
 - 9.3.2 *Measuring Resistance Changes with a Wheatstone Bridge* 335
 - 9.3.3 *Measuring Different States of Stress with Strain Gages* 339
 - 9.3.4 *Force Measurement with Load Cells* 345

- 9.4** Temperature Measurement 347
 - 9.4.1 *Liquid-in-Glass Thermometer* 348
 - 9.4.2 *Bimetallic Strip* 348
 - 9.4.3 *Electrical Resistance Thermometer* 349
 - 9.4.4 *Thermocouple* 349
- 9.5** Vibration and Acceleration Measurement 357
 - 9.5.1 *Piezoelectric Accelerometer* 362
- 9.6** Pressure and Flow Measurement 366
- 9.7** Semiconductor Sensors and Microelectromechanical Devices 366

Chapter 10

Actuators 372

- 10.1** Introduction 373
- 10.2** Electromagnetic Principles 373
- 10.3** Solenoids and Relays 374
- 10.4** Electric Motors 376
- 10.5** DC Motors 383
 - 10.5.1 *DC Motor Electrical Equations* 386
 - 10.5.2 *Permanent Magnet DC Motor Dynamic Equations* 386
 - 10.5.3 *Electronic Control of a Permanent Magnet DC Motor* 389
- 10.6** Stepper Motors 393
 - 10.6.1 *Stepper Motor Drive Circuits* 397
- 10.7** Selecting a Motor 400
- 10.8** Hydraulics 404
 - 10.8.1 *Hydraulic Valves* 406
 - 10.8.2 *Hydraulic Actuators* 410
- 10.9** Pneumatics 411

Chapter 11

Mechatronic Systems—Control Architectures and Case Studies 416

- 11.1** Introduction 417
- 11.2** Control Architectures 417
 - 11.2.1 *Analog Circuits* 417
 - 11.2.2 *Digital Circuits* 418

11.2.3 Programmable Logic Controller	418
11.2.4 Microcontroller	418
11.2.5 Single-Board Computer	418
11.2.6 Personal Computer	419
11.3 Case Study 1—Mechatronic Design of a Coin Counter	419
11.4 Case Study 2—Mechatronic Design of a Robotic Walking Machine	429
11.5 List of Various Mechatronic Systems	435
<u>Appendix A</u>	
Measurement Fundamentals	437
A.1 Systems of Units	437
A.1.1 Three Classes of SI Units	439
A.1.2 Conversion Factors	441
A.2 Significant Figures	442
A.3 Statistics	444
A.4 Error Analysis	447
A.4.1 Rules for Estimating Errors	448
<u>Appendix B</u>	
Physical Principles	451
<u>Appendix C</u>	
Mechanics of Materials	456
C.1 Stress and Strain Relations	456
Index	461