




# MODERN INDUSTRIAL ELECTRONICS

THIRD EDITION

TIMOTHY J. MALONEY

# MODERN INDUSTRIAL ELECTRONICS



**3<sup>RD</sup>**  
**EDITION**



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Monroe, Michigan



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■ **To my dear wife, Pat**

## ■ PHOTO CAPTIONS AND CREDITS

- Page xxii Automated machine tooling accomplishes precision cutting of large gear teeth (*Courtesy of Society of Manufacturing Engineers*)
- Page 34 On the production floor, parts usage is electronically counted and periodically compared to predicted draw-down. A restocking order is then automatically issued to produce just-in-time inventory replenishment. (*Courtesy of General Electric Company*)
- Page 72 I/O rack of a large PLC system (*Courtesy of General Electric Company*)
- Page 138 Magnetic levitation vehicle cruising at 400 km/hr (*Courtesy of Railway Technical Research Institute of Japan*)
- Page 162 This Advanced Computed Tomography Inspection System (ACTIS) uses X-rays to make a detailed internal examination of manufactured parts. It can thereby discover internal flaws and stress fractures. (*Courtesy of NASA*)
- Page 192 Chemical distillation towers often have their heating and condensing processes controlled by high-power thyristors. (© *Brownie Harris*)
- Page 224 Welding robot (*Courtesy of Society of Manufacturing Engineers*)
- Page 266 The MagLev vehicle on its approach track, where it is riding on its mechanical suspension, but propelled by sidewall electromagnets as usual (*Courtesy of Railway Technical Research Institute of Japan*)
- Page 282 When a compact disk is played, the laser pickup head starts close to the center, then moves radially outward to the outside edge. If the disk's spinning speed were kept constant, the outside tracks would move faster across the pickup head than the inside tracks; this cannot be tolerated. CD players use an electronic feedback system to adjust the disk's rotational spinning speed so that the timing bits that are recorded beside the music code bits are detected at a constant rate. Thus, the recorded music is picked up and played at a constant speed. (© *Steve Dunwell for General Electric Company*)
- Page 336 Testing apparatus for Hall-Effect proximity detectors used on a magnetic levitation track. (*Courtesy of Railway Technical Research Institute of Japan*)
- Page 408 High-frequency test instrumentation (*Courtesy of Tektronix, Inc.*)
- Page 456 State-of-the-art dc motors have overall shaft efficiencies in excess of 95% (© *Joe McNally, General Electric Company*)
- Page 520 Small robotic assembly systems often use stepper motors or position-triggered brushless dc motors for making their motions. (*Courtesy of Seiko Instruments USA, Inc.*)
- Page 554 Variable-frequency ac motor drive system (*Courtesy of Tektronix, Inc.*)
- Page 606 Unlike a simple stamping press machine, this large forming press machine uses a proportional controller to regulate its applied force. (© *Brownie Harris*)
- Page 658 Machining and polishing of these wheels is done under precisely controlled conditions of rotational speed. (*Courtesy of Railway Technical Research Institute of Japan*)
- Page 718 Telemetry receiving station for space satellites (*Courtesy of Tektronix, Inc.*)
- Page 760 Microcomputer software bugs are discovered by using a Logic Analyzer, which provides a CRT display of instruction codes, or a display of waveform graphs like an oscilloscope. (*Courtesy of Tektronix, Inc.*)
- Page 798 Cylindrical-configuration robot (*Courtesy of Seiko Instruments USA, Inc.*)
- Page 832 Fire is one of the safety hazards of industrial circuits. (*Courtesy of NASA*)



# PREFACE

**M**odern *Industrial Electronics*, Third Edition, provides a total-system view of the world of manufacturing and automated production for students of electrical and electronics technology. It maintains the original commitment, intact since the first edition, of showing how the devices of modern electronics are applied in realistic industrial applications.

In this edition, five new chapters—12, 13, 14, 17, and 20—cover the following topics:

1. More extensive treatment of dc motor operating principles and characteristics, with a view to how those motor characteristics lend themselves to particular industrial tasks. Specific dc machines that are presented with greater thoroughness are:
  - Conventional wound-rotor/wound-field dc motors.
  - Starting, stopping, and dynamic braking, presented in ladder-logic format.
  - Permanent-magnet dc motors.
  - Coreless motors.
  - Brushless, electronically commutated dc motors.
  - Stepper motors.
  - Pulse-width modulated speed-control using a 555 timer.
2. Coverage of various ac motors' operating principles and characteristics, and their compatibility to particular industrial tasks. Specifically:
  - True 2-phase squirrel-cage motors.
  - Split-phase motors, capacitor-assisted.
  - Shaded-pole and reluctance-start motors.
  - Three-phase squirrel-cage motors.
  - Ac motor-starting and plugging to a stop, presented in ladder-logic format.
  - The advantages of 3-phase systems in generation, transmission, and electrical-to-mechanical energy conversion (motoring).
  - Power-measurement and power factor-correction in three-phase systems.
3. Programmable Logic Controllers have been treated in the context of a more powerful model—the Allen-Bradley PLC-5/12. Enhanced PLC instruction coverage includes:
  - Greater emphasis on the Master Control Reset (MCR) instruction and zone-control.
  - Use of analog information in the user-program by reading an Analog Input Module mounted in the I/O rack.
  - Arithmetic computations, comparisons of numeric values, and data transfers within the user-program.
  - Flexibility and portability of control programs via hard disk and floppy disk.

4. PID (Proportional-Integral-Derivative) closed-loop feedback control implemented digitally by a PLC. This coverage pays careful attention to:
  - Update timing of the PID control algorithm.
  - Initial configuration and scaling of the Analog Input Module that measures the process variable.
  - Proper selection of data file addresses and control file addresses for the Reading (Input) operation, the PID calculation operation, and the Writing (Output) operation.
  - Programmed scheduled variation of process conditions for gathering research data on a process's performance.
5. Telemetry of data using pulse-modulation techniques, including pulse-width, pulse-position, and pulse-frequency modulation. Special coverage has been accorded to:
  - The 555 IC as a pulse-width modulator.
  - The 555 IC as a pulse-frequency modulator.
  - The phase-locked-loop (PLL), implemented by a type 565 IC, used as a pulse-frequency demodulator.
  - Multiplexing several measurements over one telemetry channel.
  - Digitally encoded telemetry.
  - Sampling rate limitations.

## ■ A WORD TO STUDENTS

The capabilities of industrial manufacturing systems have expanded at a startling rate since the first edition of *Modern Industrial Electronics* was published in 1979. Part of the new capability has to do with more precise control over machines and processes, and part has to do with our greater ability to measure and make records of production variables. This expansion has two direct effects on you. First, it makes your work more demanding; second, it gives you the opportunity for even greater satisfaction and personal reward, because anyone who can learn and master today's high-technology industrial controls is sought after by employers. As a technician or engineering technologist working in modern industry, you are a member of a select group, indispensable for your company's productivity and profitability. In fact, your work contribution has obvious impact on our entire society's productivity and economic security. What a compliment to you that you are entrusted with that responsibility.

In this third edition, as in the previous two editions that your predecessors used to launch their careers, I have made every effort to help you reach the skill level needed for carrying out your job responsibilities. Toward that goal, this edition features a Job Assignment at the end of every chapter. These Job Assignments require you to apply the knowledge that you have gained from that chapter, usually for the purpose of solving a problem. By carrying out the Job Assignments individually or as a team member, you will find yourself exercising your technical understanding, thinking imaginatively, and solving realistic problems—in other words, making the transition from classroom student to on-the-job functioning technician or technologist in the industrial arena.

My best wishes for your working career.

## ■ FEATURES OF THE TEXT

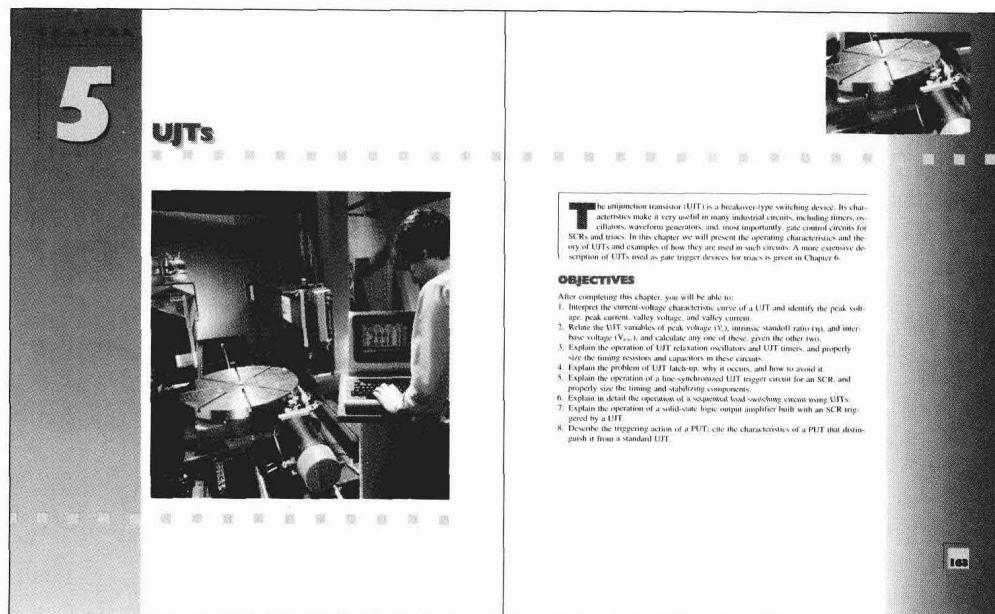
### Chapter-Opening Photograph

Each chapter begins with a photograph and explanatory caption that depicts some modern industrial practice. Figure A shows the opening pages of Chapter 5. Use these pre-

# FIGURE A

Opening photograph for Chapter 5: X-ray inspection system for detecting hidden flaws in manufactured parts.

Courtesy of NASA



sentations to get a feel for some of the interesting opportunities and work responsibilities in the field of industrial electronics. Descriptive captions and credits for the photographs are listed on page iv.

## Objectives

The first edition, published in 1979, was the original college technology textbook to explicitly state the learning objectives at the beginning of each chapter. That precedent is continued, naturally, in this third edition. As you are reading and studying, try to perform the task that each objective calls for. If you can perform these tasks, then you are receiving what the book and the course have to offer. If you find that you cannot satisfy the objectives, ask further questions in class or consult in private with your instructor.

## Job Assignments

The final section of each chapter gives a Job Assignment that is representative of the duties that you will be performing when working as a technician or engineering aide. Figure B shows Job Assignment 13, from pages 552–553, which requires you to analyze a stepper motor test circuit. These assignments invariably require you to use the knowledge that you have learned from that chapter in an imaginative way. Your instructor may ask for your written or drawn solution to be done individually. Or you may be placed in a two- or three-person team to work on the problem. Various solutions are possible in most cases; therefore you may find yourself presenting your solution to the entire class so that everyone can share the differing thoughts and approaches that were brought to bear on the problem.

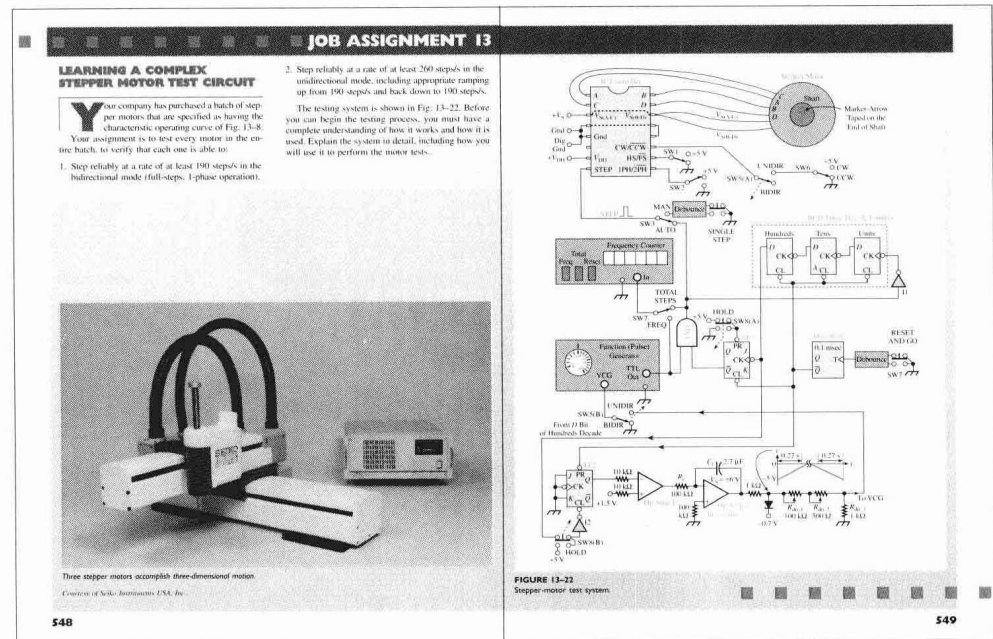
## Examples

When trying to understand new ideas, especially the use of new mathematical formulas, all people are helped by examples. In this text, examples are provided for all situations where numerical calculations are required.



### FIGURE B

**Job Assignment feature in Chapter 13: On-the-job exercises, accompanied by illustrations and photos, challenge you to perform real-life duties.**



## Summary

At the end of each chapter, there appears a list of the main ideas that were developed within that chapter. The chapter's mathematical formulas, if any, are also collected for your ready reference in solving the homework.

## Questions and Problems

Numerous questions and problems, organized by chapter section, are provided for sharpening your understanding and exercising your problem-solving skills. Your instructor will assign some of them for homework. You may wish to tackle additional problems for our own satisfaction. The more you practice, the more you learn.

## Glossary

Definitions of hundreds of terms used in industrial electronics are listed in the glossary at the end of the book. Most of these terms were introduced in this text, but some come from earlier course work in electricity and electronics. Use the glossary to refresh your memory or to verify your understanding of a word's meaning.

## ACKNOWLEDGMENTS

My thanks to all the people who contributed to this revision. In particular, the planning and development work of Carol Robison, and her suggestions for material inclusion and presentation, made a considerable contribution to the final outcome. The prodding and encouragement of Charles Stewart were quite a psychological help. Carol Robison and Diane Elmer made all the personal contacts and requests for photo acquisitions, a job requiring great perseverance and patience. James Davis of Muskingum Area Technical Col-

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—T. J. M.

# BRIEF CONTENTS

<b>1</b>	The Transistor Switch as a Decision-Maker	xxii
<b>2</b>	Transistor Switches in Memory and Counting Applications	34
<b>3</b>	Programmable Logic Controllers	72
<b>4</b>	SCRs	138
<b>5</b>	UJTs	162
<b>6</b>	Triacs and Other Thyristors	192
<b>7</b>	An Industrial Automatic Welding System with Digital Control	224
<b>8</b>	Special Uses of Op Amps	266
<b>9</b>	Feedback Systems and Servomechanisms	282
<b>10</b>	Input Transducers—Measuring Devices	336
<b>11</b>	Final Correcting Devices and Amplifiers	408
<b>12</b>	Wound-Rotor Dc Motors	456
<b>13</b>	Nontraditional Dc Motors	520
<b>14</b>	Ac Motors	554
<b>15</b>	Nine Examples of Closed-Loop Industrial Systems	606
<b>16</b>	Motor Speed Control Systems	658
<b>17</b>	Telemetry	718
<b>18</b>	Closed-Loop Control with an On-Line Microcomputer	760
<b>19</b>	Industrial Robots	798
<b>20</b>	Safety	832
	Appendix A: Universal Time-Constant Curves	847
	Glossary	G-I
	Index	I-I

# CONTENTS

## I THE TRANSISTOR SWITCH AS A DECISION-MAKER

xxii

### Objectives 1

- 1-1 Systems Containing Logic Circuits 2
- 1-2 Logic Circuits Using Magnetic Relays 2
- 1-3 Relay Logic Circuit for a Conveyor/Classifying System 4
- 1-4 Logic Performed by Transistors 8
- 1-5 Logic Gates—The Building Blocks of Solid-State Logic 10
- 1-6 Solid-State Logic Circuit for the Conveyor/Classifying System 11
- 1-7 Input Devices for Solid-State Logic 13
- 1-8 Output Devices for Solid-State Logic 18
- 1-9 Solid-State Logic Compared to Relay Logic 19
- 1-10 A Solid-State Logic Circuit for a Machine Tool Routing Cycle 22
- 1-11 Logic Circuit for a First Failure Annunciator 24
- 1-12 Logic Circuit for a Machine Tool Drilling Cycle 26

### ■ JOB ASSIGNMENT:

*Expanding the Machine Tool Drilling System 29*

Summary 29

Questions and Problems 30

## 2 TRANSISTOR SWITCHES IN MEMORY AND COUNTING APPLICATIONS

34

### Objectives 35

- 2-1 Welder Control Circuit Using RS Flip-Flops 36
- 2-2 Oscillating Machining Table Using Clocked RS Flip-Flops 37
- 2-3 JK Flip-Flops 40
- 2-4 Shift Registers 40
- 2-5 Counters 45
- 2-6 Decoding 46
- 2-7 Palletizing System Using Decade Counters and Decoders 47

- 2-8 One-Shots 50
- 2-9 Clocks 53
- 2-10 Automatic Tank Filler Using a Clock and One-Shots 54
- 2-11 Down-Counters and Encoders 56
- 2-12 Timers 58
- 2-13 Bin-Filling System Using a Down-Counter, an Encoder, and Timers 65

#### ■ **JOB ASSIGNMENT:**

*Expanding the Oscillating Planing Circuit 69*

Summary 69

Formula 69

Questions and Problems 69

### **3 PROGRAMMABLE LOGIC CONTROLLERS 72**

#### *Objectives 73*

- 3-1 The Parts of a Programmable Logic Controller 74
- 3-2 Programming a PLC to Control the Conveyor/Classifying System 93
- 3-3 Programming Timing and Counting Functions 99
- 3-4 A Machining Apparatus Utilizing Timing and Counting Functions 105
- 3-5 Other PLC Relay-Type Functions 111
- 3-6 Handling Analog Input Data 114
- 3-7 Improving the Milling Machine System by Making it Temperature-Sensitive 126

#### ■ **JOB ASSIGNMENT:**

*Refining the Temperature-Response of the Milling Process 131*

Summary 132

Formula 133

Questions and Problems 133

### **4 SCRS 138**

#### *Objectives 139*

- 4-1 Theory and Operation of SCRs 140
- 4-2 SCR Waveforms 140
- 4-3 SCR Gate Characteristics 142
- 4-4 Typical Gate Control Circuits 142
- 4-5 Other Gate Control Circuits 145
- 4-6 Alternative Methods of Connecting SCRs to Loads 148
- 4-7 SCRs in Dc Circuits 148

#### ■ **JOB ASSIGNMENT:**

*MagLev Vehicles 152*

Summary 157

Formula 158



Questions and Problems	158
Suggested Laboratory Projects	159

## **5 UJTS 162**

### **Objectives 163**

5-1 Theory and Operation of UJTs	164
5-2 UJT Relaxation Oscillators	167
5-3 UJT Timing Circuits	171
5-4 UJTs in SCR Trigger Circuits	173
5-5 PUTs	181

### **■ JOB ASSIGNMENT:**

<i>Triggering the SCRs in a MagLev Control Module</i>	185
Summary	187
Formulas	187
Questions and Problems	187
Suggested Laboratory Projects	189

## **6 TRIACS AND OTHER THYRISTORS 192**

### **Objectives 193**

6-1 Theory and Operation of Triacs	194
6-2 Triac Waveforms	195
6-3 Electrical Characteristics of Triacs	196
6-4 Triggering Methods for Triacs	197
6-5 Silicon Bilateral Switches	199
6-6 Unilateral Breakover Devices	204
6-7 Breakover Device (SUS) Used to Trigger a Triac	205
6-8 Critical Rate of Rise of Off-State Voltage ( $dv/dt$ )	207
6-9 UJTs as Trigger Devices for Triacs	208

### **■ JOB ASSIGNMENT:**

<i>Removal of Ash Particulates from a Coal-Fired Electric Utility Stack</i>	215
Summary	218
Formulas	218
Questions and Problems	218
Suggested Laboratory Projects	220

## **7 AN INDUSTRIAL AUTOMATIC WELDING SYSTEM WITH DIGITAL CONTROL 224**

### **Objectives 225**

7-1 Physical Description of the Wheel-Welding System	226
7-2 Sequence of Operations in Making a Weld	227

- 7-3 Block Diagram of the Sequence Control Circuit 230
- 7-4 Detailed Description of the Sequence Initiation Circuit and the Interval Triggering and Gating Circuit 234
- 7-5 Detailed Description of the Interval Stepping Circuit and Decoder 239
- 7-6 Interval Time Counter and Interval Time Counter Preset Circuit 242
- 7-7 Heat-Cool Stepping and Gating Circuit 247
- 7-8 Heat-Cool Counter and Heat-Cool Counter Preset Circuit 249
- 7-9 The Weld Power Circuit 251

■ **JOB ASSIGNMENT:**

*Re-creating the Schematic Diagram of the Weld Power Circuit with Alternating-Polarity Heat Subintervals 261*

Summary 261

Questions and Problems 262

## **8 SPECIAL USES OF OP AMPS**

**266**

*Objectives 267*

- 8-1 Op Amp Characteristics and Basic Circuits 268
- 8-2 Op Amp Differential Amplifier 268
- 8-3 Op Amp Voltage-To-Current Converter 269
- 8-4 Op Amp Integrators and Differentiators 270

■ **JOB ASSIGNMENT:**

*Troubleshooting the MagLev Sidewall Position Signal Processing Circuit 272*

Summary 279

Formulas 279

Questions and Problems 279

Suggested Laboratory Project 280

## **9 FEEDBACK SYSTEMS AND SERVOMECHANISMS**

**282**

*Objectives 283*

- 9-1 Open-Loop Versus Closed-Loop Systems 284
- 9-2 Closed-Loop System Diagrams and Nomenclature 287
- 9-3 Examples of Closed-Loop Control Systems 289
- 9-4 Modes of Control in Industrial Closed-Loop Systems 293
- 9-5 On-Off Control 294
- 9-6 Proportional Control 296
- 9-7 Proportional Plus Integral Control 307
- 9-8 Proportional Plus Integral Plus Derivative Control 310
- 9-9 Process Response 314
- 9-10 Relationship Between Process Characteristics and Proper Mode of Control 320
- 9-11 PID Process Control with a Programmable Logic Controller 323

■ **JOB ASSIGNMENT:**

*Using a PLC for Automated Variation of Process Conditions and Data-Gathering* 328

Summary 330

Questions and Problems 330

**10 INPUT TRANSDUCERS—MEASURING DEVICES 336**

*Objectives* 337

10-1 Potentiometers 338

10-2 Linear Variable Differential Transformers (LVDTs) 342

10-3 Pressure Transducers 344

10-4 Thermocouples 345

10-5 Thermistors and Resistive Temperature Detectors (RTDs) 349

10-6 Other Temperature Transducers 352

10-7 Photocells and Photoelectric Devices 354

10-8 Optical Fibers 370

10-9 Ultrasonics 372

10-10 Strain Gages 373

10-11 Accelerometers 376

10-12 Tachometers 377

10-13 Hall-Effect Transducers 380

10-14 Resolvers 384

10-15 Humidity Transducers 394

■ **JOB ASSIGNMENT:**

*Troubleshooting with a Multi-Channel Digital Storage Scope* 398

Summary 401

Formulas 402

Questions and Problems 402

**11 FINAL CORRECTING DEVICES AND AMPLIFIERS 408**

*Objectives* 410

11-1 Solenoid Valves 410

11-2 Two-Position Electric Motor-Driven Valves 411

11-3 Proportional-Position Electric Motor-Driven Valves 413

11-4 Electropneumatic Valves 414

11-5 Electrohydraulic Valves 417

11-6 Valve Flow Characteristics 418

11-7 Relays and Contactors 421

11-8 Thyristors 424

11-9 Split-Phase Ac Motors 425

11-10 Ac Servo Motors 430

11-11 Solid-State Ac Servo Amplifiers 437

11-12 Dc Servo Motors 446

11-13 Amplifiers for Dc Servo Motors 448

■ **JOB ASSIGNMENT:**

*Troubleshooting an Electropneumatic Valve Operator 451*

Summary 452

Questions and Problems 452

## **12 WOUND-ROTOR DC MOTORS**

**456**

**Objectives 457**

12-1 Motor Types 458

12-2 Wound-Rotor Dynamo Principles 459

12-3 Wound-Rotor Dc Motor Performance 476

12-4 Characteristic Graphs of Shunt-Configured Dc Motors 491

12-5 Characteristics of Series-Configured Dc Motors 493

12-6 Compound Configuration 501

12-7 Interpoles 502

12-8 Starting, Stopping, and Reversing 503

■ **JOB ASSIGNMENT:**

*Removal of Sulfur from a Coal-Fired Electric Utility Stack 510*

Summary 515

Formulas 515

Questions and Problems 516

## **13 NONTRADITIONAL DC MOTORS**

**520**

**Objectives 521**

13-1 Conventional Permanent-Magnet Motors 522

13-2 Coreless Permanent-Magnet Motors 523

13-3 Stepper Motors 526

13-4 Brushless Dc Motors 542

13-5 Comparing Electronically Commutated to Brush-Equipped Dc Motors 544

■ **JOB ASSIGNMENT:**

*Learning a Complex Stepper Motor Test Circuit 548*

Summary 550

Formulas 550

Questions and Problems 550