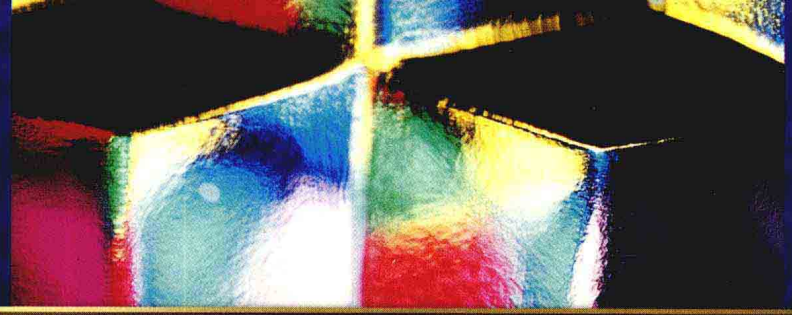

MODERN INDUSTRIAL ELECTRONICS

THIRD EDITION

TIMOTHY J. MALONEY

MODERN INDUSTRIAL ELECTRONICS

3RD EDITION

TIMOTHY J. MALONEY

Monroe County Community College
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

Modern 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-

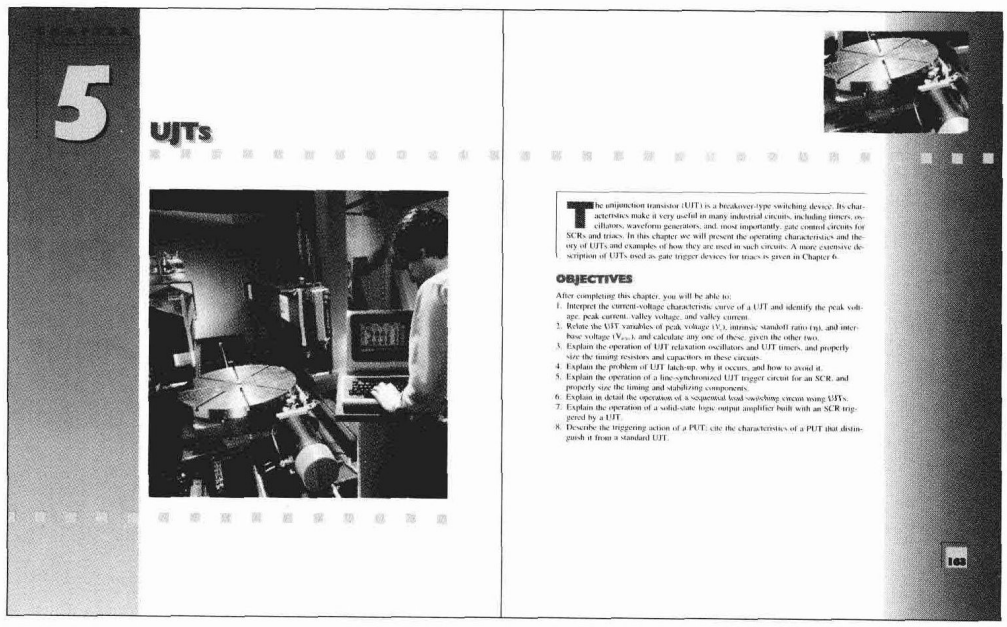


FIGURE A
Opening photograph for Chapter 5: X-ray inspection system for detecting hidden flaws in manufactured parts.

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.

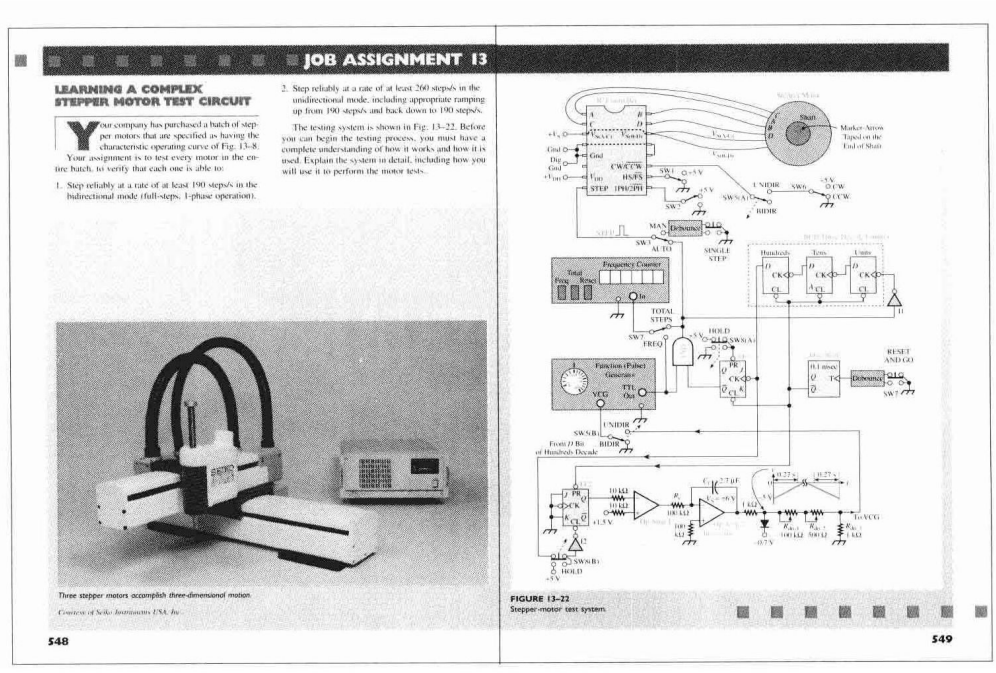
Job Assignments

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.


JOB ASSIGNMENT 13

LEARNING A COMPLEX STEPPER MOTOR TEST CIRCUIT

Your company has purchased a batch of stepper motors that are specified as having the characteristic operating curve of Fig. 13-8. Your assignment is to test every motor in the entire batch, to verify that each one is able to:

1. Step reliably at a rate of at least 190 steps/s in the bidirectional mode (full-steps, 1-phase operation).
2. Step reliably at a rate of at least 260 steps/s in the unidirectional mode, including appropriate ramping up from 190 steps/s and back down to 190 steps/s.

The testing system is shown in Fig. 13-22. Before you can begin the testing process, you must have a complete understanding of how it works and how it is used. Explain the system in detail, including how you will use it to perform the motor tests.

Three stepper motors accomplish three-dimensional motion.
Courtesy of Seiko Instruments USA, Inc.

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FIGURE 13-22
Stepper-motor test system.

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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

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—T. J. M.

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