Preface

INTRODUCTION

The 1970s witnessed the birth of two types of computers that changed the world and the way business is conducted. The Apple II, introduced in 1976, was the world's first widely used microcomputer. Today's multibillion-dollar personal computer industry is an outgrowth of this small computer company started by two young entrepreneurs in a garage.

The second computer, created in 1972 by Richard Morley and now called a *programmable logic controller* (PLC), does not have the instant name recognition of the personal computer, but it has had an equally significant impact in manufacturing. The PLC is often called the personal computer for the factory floor.

PLCs are the de facto standard used to control automation systems in every industry across the globe. Control applications range from a single machine to an entire production facility with processes that have both analog and discrete control requirements. This textbook addresses the application, operation, programming, and troubleshooting of PLCs used in automation and control applications.

IMPORTANT FEATURES

The text has the following salient features:

- The text is divided into two parts. Part 1, Chapters 1 through 9, introduces the reader to fundamental PLC concepts and the basic operation and programming format for the commonly used instructions in most PLC applications. If you learn the instructions in Part 1 you will be able to program and interpret 90 percent of the ladder rungs used in automation control. Part 2, Chapters 10 through 17, addresses the advanced instructions, covers four of the languages (Ladder Diagram, Function Block, Sequential Function Chart, and Structured Text) in the IEC 61131 PLC standard, and provides a practical introduction to industrial networks. Goals and learning objectives are provided at the beginning of every chapter.
- The presentation format includes a description of programming and PLC instructions for all three Allen-Bradley PLCs, PLC 5, SLC 500, and ControlLogix, with the SLC 500 system used most often in the example problems.

- Standard ladder logic building blocks are developed for PLC instructions in Chapters 4 through 11, 13, 15, and 16. The standards start with a description of the automation control requirement and then present the ladder rung options used for a solution. Example problems show how these standard rungs are grouped for a total automation solution.
- The operation and programming for two generations of PLC software—rack/slot-based addressing and variable- or tag-based addressing systems—is discussed.
- Text content is sequenced to support a laboratory with a class lecture.
- All end-of-chapter questions and problems, including references to Allen-Bradley manuals and chapter illustrations, are conveniently located in Appendix D.
- Troubleshooting is integrated into every chapter.
- The text is written in a direct, clear, and easy-to-read style that is designed for students with no prior PLC experience.
- Real-world control problems are used in illustrated programming examples.
- A pneumatic robot material handler and a process tank control problem are used in Chapters 3, 4, 7, 11, 13, 15, and 16 to illustrate PLC control of a sequential machine and process system. The control solution for each problem changes as new PLC instructions are introduced in the chapters.
- The text includes a generous number of example problems at varying levels of difficulty and a large number of descriptive figures.
- A CD-ROM with reference material from Allen-Bradley is provided with the text.
- The text content and organization permits teachers to adjust the chapter sequence to fit a current syllabus.
- A glossary of terms is provided in an appendix.
- A description of the five IEC 61131 programming languages with detailed coverage of the four supported in Allen-Bradley PLCs is given.

FOR THE STUDENTS

An increasing number of graduates of engineering and engineering technology programs are working in manufacturing automation because production systems have become increasingly complex and highly automated. As a result, students need to understand the theory and operation of PLCs used in the control of production systems. Our primary goal for this book is to create a clear and comprehensive text for students to use to learn programmable logic controllers. Every effort is made to present the material in a logical order, to express the concepts in a writing style that a first-time user of PLCs can understand, and to keep the needs of the student foremost in every part of the text development. Texts often include technical terms when describing new concepts that have not been previously defined or that are not common knowledge for the students. A special effort is made in this text not to use any term or technical language that is not introduced or defined earlier in the text.

In addition, the text is written as both a learning tool and as a future reference resource. If you work in automation, you will have to use PLCs or PLC-like controllers. The information presented in the text describes PLCs clearly for the student learner, and the broad coverage of topics serves as an ideal resource when the student graduate is working with industrial controls.

STUDENT CD-ROM INCLUDED WITH TEXT

The text comes with a student CD-ROM with valuable resources for learning to operate and program programmable logic controllers. Reference material from Allen-Bradley is included on the CD-ROM. The material provides quick access to technical data related to Allen-Bradley PLCs. The chapter questions and problems make use of the PLC data presented on the CD-ROM.

LEVEL, AUDIENCE, AND USE

The primary audiences for the text are students in two- and four-year technology curriculums and engineering students studying PLCs. Part 1 of the text assumes only that the reader has a good understanding of DC and AC circuits and a basic under-

standing of digital circuits; therefore, the text could be used for an introduction PLC course as early as the third semester/quarter. The second half of the text, Part 2, introduces process control. The differential equation format for the control algorithms is given, but the PLC implementation is reduced to an algebra formulation. In addition, the text-based programming language, Structured Text, is covered in Chapter 15, which uses the structures normally found in a structured programming language. Classes for students without any previous programming courses or experience may require more time for this chapter to introduce programming structures and their operation.

PLCs are taught in one-, two-, and three-course sequences, with courses in the semester and quarter systems. Although the majority of institutions teach one PLC course, the move toward a two-course sequence is growing. Because the courses at each institution are slightly different, the text is presented in a flexible format that can be adapted to each institution's syllabus. The following table lists suggestions for chapters that could be used for the multiple-course sequences in both the semester and quarter systems. The content suggestions are for 3-credit courses with 2 hours of lecture and 2 hours of laboratory per week. If other lecture hour times are used, then adjustments to the content are possible.

The text integrates all three of the Allen-Bradley PLC processors (PLC 5, SLC 500, and ControlLogix) throughout the text. The SLC 500, however, is used for the majority of the examples and is the processor described when an instruction operates in the same way in all three processors. When operation differs for the three processors or where different instructions are present, each process is covered in a separate section. Because the operation of the PLC 5 is similar to the SLC 500 in many cases, these two are frequently covered in the same section. However, the chapter organization permits an instructor to

Single Course – semester system	Chapters 1 through 9 (Part 1) plus introduction to shift registers (Chapter 10), sequencers (Chapter 11), and PLC networks (Chapter 17). The focus is on the SLC 500 with PLC 5 and ControlLogix content added as time permits. Chapter 3 is covered completely since it introduces all three PLC systems' addressing modes.
Single Course – quarter system	Chapters 1 through 9 (Part 1) with the focus on the SLC 500. Chapter 3 is covered completely since it introduces all three PLC systems' addressing modes.
First Course – semester system *Or*	Chapters 1 through 9 (Part 1) with the focus on either the SLC 500 or the PLC 5 plus the ControlLogix instruction format. Chapter 3 is covered completely since it introduces all three PLC systems' addressing modes. Chapters 1 through 12 with the focus on the SLC 500 and PLC 5 PLCs.
Second Course – semester system *Or*	Review Chapter 3 for the addressing format of the ControlLogix PLC system. Then cover Chapters 10 and 11 with the focus on either the SLC 500 or the PLC 5 plus the ControlLogix instruction format. Finally, cover Chapters 12 through 17. Chapters 3 through 11 and 13 through 17 with the focus on the ControlLogix PLC.
First Course – quarter system	Chapters 1 through 9 (Part 1) with the focus in on the SLC 500.
Second Course – quarter system	ControlLogix content in Chapter 3 is covered and then Chapters 10 through 17 for all PLC systems.

separate the SLC 500 and PLC 5 processors from the ControlLogix if the course requires just one type of PLC content.

The text is organized in two parts. Part 1 introduces PLCs and covers in detail the programming instructions used to write a large number of the PLC programs used in industry. Part 2 is written to support additional topics in an introductory course, a second course in PLCs, or an advanced PLC offering as illustrated in the previous table.

VENDOR RESOURCES OR A PLC TEXTBOOK?

A review of PLC texts indicates that many add little new information from what is available online directly from the vendors that manufacture the devices. Vendor reference and resource material is a valuable aid to the PLC application engineer or technician when device-specific information is needed. This text is designed to complement vendor resources by providing concepts and content not provided by the vendors. For example, thirteen of the chapters have standard application solutions for instructions with comments on how an instruction can be used most effectively. In addition, information on troubleshooting and programming not provided by the vendors is included.

The writing style of this text differs from the industry material as well. Industry resources are written for an industry audience and assume a certain minimum knowledge base on the subject. This text makes no such assumption and describes the technology so that students can learn PLCs with no previous experience in PLCs or discrete and analog system control. The text does make good use of vendor resources so that students learn how to use the material, which will be their source of PLC information in the future.

CHAPTER CONTENT

Part 1, titled *Programmable Logic Controller—Fundamental Concepts*, includes nine chapters written to support a first course in programmable logic controllers. Chapter 1 and all subsequent chapters start with chapter goals and objectives. In addition, this chapter defines a PLC and covers a brief history of PLCs, a description of the system and components, an introduction to vendor systems, a description of PLC types and types of input and output modules, and a comparison between relay ladder logic and PLC ladder logic. Every chapter ends with general chapter questions, Web and data sheet questions, and problems divided into general, PLC 5, SLC 500, ControlLogix, and challenge groups.

Chapter 2 focuses on discrete input devices and output actuators and describes the operation of the most frequently used input devices and output actuators in automation control systems. Devices covered include manual and mechanically operated switches, transducers and sensors including proximity and photoelectric devices, interfacing switches and sensors, input wiring, field device current sourcing and current sinking concepts, electromagnetic output and solenoid-controlled devices, control relays, contactors, motor starters, pilot lights, alarms, interfacing output devices, and output wiring.

Chapter 3 covers an introduction to PLC programming with the following topics: decimal, octal, and binary number systems, ladder logic fundamentals, addressing rack/slot and tag-based systems, examine if closed and examine if open inputs selection and applications, retentive and non-retentive coil outputs, virtual or internal relays, scan time, multiple inputs, standard input logic, sealing contacts, multiple outputs, latched outputs, and using internal memory bits. In addition, empirical program design is introduced along with programming devices and software. Troubleshooting techniques for PLC-controlled systems and program design are also covered.

Chapter 4 covers programming timers, and the standard ladder logic used for timers. Topics include mechanical and electronic timing relays, and PLC timer instructions, such as on-delay timers, off-delay timers, retentive timers, and the reset instruction. In addition, cascaded timers, empirical design of timer ladders, and troubleshooting of timer ladders and input/output modules are addressed. The use of timers in pneumatic robot control is also described.

Chapter 5 describes the counter function present in PLCs, and the standard ladder logic used for counters. Topics include counter

instructions, such as up counters, down counters, up/down counters, and cascade counters; using counter output bits; programming counter instructions; and counter applications. In addition, the reset instruction and one-shot function are covered along with programming and application issues.

Chapter 6 focuses on arithmetic and move instructions available in the PLC instruction set, and the standard ladder logic used for these instructions. Topics include instructions and format for addition, subtraction, multiplication, division, square root, and move instructions; programming these instructions; and application of math and move instructions.

Chapter 7 describes the binary-coded decimal (BCD) and the hexadecimal numbering systems and covers the conversion and comparison instructions. In addition, the standard ladder logic used for these instructions is covered. The instructions for converting to and from BCD numbers are presented. The comparison instructions covered include equal to, not equal to, less than, greater than, less than or equal to, and greater than or equal to. In addition, programming and application of the comparison instructions are addressed.

Chapter 8 focuses on instructions that change the flow of the program execution and covers some special-purpose instructions. In addition, the standard ladder logic used for these instructions is covered. The program flow instructions described include master control and zone control instructions, jump instructions, subroutines, and immediate input and output instructions. In addition, the clear instruction is covered along with programming and application issues.

Chapter 9 is the last chapter in Part 1 of the text. The addressing modes discussed include direct, indirect, indexed, and indexed indirect. Typical applications for the addressing modes are included to indicate how each mode is used.

Part 2 of the text, titled *Advanced PLC Instructions and Applications*, includes Chapters 10 through 17. The content of Part 2 could be used selectively to enhance a first course in PLCs or it could be used for a second, more advanced PLC offering.

Chapter 10 covers instructions related to data handling and shift register applications. In addition, the standard ladder logic used for these instructions is covered. Topics include the copy and fill instructions, the FIFO, LIFO, and FAL functions, bit patterns in a register, changing a register bit status, shift register functions, programming FIFO, LIFO, and shift register instructions.

Chapter 11 addresses the programming and operation of PLC sequencers, and the standard ladder logic used for sequencers. Topics include electromechanical sequencing, the basic PLC sequencer function, PLC sequencer with timing, cascading sequencers, and programming applications for the sequencer function.

Chapter 12 covers analog PLC applications. The concepts covered include analog sensors and actuators, types of PLC analog modules and systems, PLC analog input and output data, programming analog instructions, and analog applications.

Chapter 13 introduces the first of the new IEC 61131 programming languages, Function Block Diagram (FBD). The Allen-Bradley FBD instruction format is used in the description, which includes programming examples and application information. In addition, the standard ladder logic used for these instructions is covered.

Chapter 14 describes how the analog principles from Chapter 12 and FBD instructions from Chapter 13 are applied to the control of on-off and continuous processes. The topics include on-off control, two-position control, floating control, PID principles, fuzzy logic, and programming the PID function.

Chapter 15 introduces the second of the new IEC 61131 programming languages, Structured Text (ST). The Allen-Bradley ST instruction format is used in the description, which includes programming examples and application information. In addition, the standard ladder logic used for these instructions is covered.

Chapter 16 introduces the third of the new IEC 61131 programming languages, Sequential Function Chart (SFC). The Allen-Bradley instruction format is used in the description, which includes programming examples and application information.

Chapter 17 addresses industrial networks and distributive control. The network topics include PLC network architecture, Ethernet/IP, DeviceNet,

ControlNet, remote I/O, Data Highway Plus, DH 485, Modbus, and Profibus. In addition, wireless networks and the human-machine interface (HMI) are covered.

SUPPLEMENTS

- Online Instructor's Resource Manual with PowerPoints
- Online TestGen
- Laboratory Exercises

To access supplementary materials online, instructors need to request an instructor access code. Go to **www.pearsonhighered.com/irc**, where you can register for an instructor access code. Within 48 hours after registering, you will receive a confirming e-mail, including an instructor access code. Once you have received your code, go to the site and log on for full instructions on downloading the materials you wish to use.

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James A. Rehg
(jamesrehg@plcteacher.com)
Glenn J. Sartori
(glennsartori@plcteacher.com)