

Programmable Logic Controllers:

An Emphasis on Design and Application

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Dedicated to Fran, Esther, and David

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PREFACE

The field of automatic control has been undergoing a transformation over the past twenty years. Twenty years ago, the engineering undergraduate had a course in feedback control theory and those interested in control engineering secured a position in the aerospace or chemical industries. Due to various factors, the number of control engineering positions in the aerospace industry has been declining, but the number of control engineering positions in manufacturing has been dramatically increasing to the point that the majority of control engineering positions is now in manufacturing and involves PLCs.

This book presents the subject of programming industrial controllers, called programmable logic controllers (PLCs) with an emphasis on the design of the programs. Many texts teach one how to program the PLC in its languages, but little, if any, attention is paid to how does one attack the problem: “Given a set of operational specifications, how does one develop the PLC program?” This book develops the design process: the tasks involved, breaking the program into manageable pieces, standard code for the various parts, and handling the sequential parts of the problem. The emphasis is toward those who will be programming PLCs.

Because of its popularity (now and in the future), ladder logic is the language that is used for the majority of the text. The industry trend is toward using the IEC 61131-3 (formerly IEC 1131-3) standard, and so it is the primary language. However, IEC 61131-3 is only a voluntary standard and individual manufacturers have some freedom in the implementation. Therefore, the Allen-Bradley ControlLogix, Modicon, and Siemens S7 implementations of the 61131-3 standard are covered. Because of their large installed base, Allen-Bradley PLC-5/SLC-500 and GE Fanuc PLC languages are also covered.

Due to the limitations of ladder logic, the IEC 61131-3 standard defines four other languages: function block diagram, structured text, instruction list, and sequential function chart. These four languages will become more popular in the future. Therefore, this text also covers these languages.

Since a typical manufacturing plant may contain discrete, continuous, and batch processes, all of these applications are treated in this text, although the emphasis is on discrete and continuous processes. The emphasis is on a methodology that can be applied to any automation project, regardless of the size.

Throughout, the book contains example problems demonstrating good design practice. In addition, these problems are solved with each PLC covered in the book. The text culminates in two full-length case studies where the application of the design techniques to a large problem is illustrated.

This book takes a practical approach to the design of PLC control systems. Some mathematical theory is used to backup the presentation on PID controllers. However, the theory is not detailed and can be omitted.

Except for Chapters 1 and 13, every chapter begins with a scenario that reflects the experience of the author and his colleagues in the challenging world of factory automation.

These scenarios present a small problem and the solution and are intended to illustrate troubleshooting techniques.

Objectives

The main objectives of this text are to teach:

- PLC programming languages (with emphasis on IEC 61131-3)
- Approach to sequential problems
- Good program design practice
- Simple PID control tuning
- Introduction to sensors and actuators
- Factory communications
- Human-machine interface (HMI) concepts

Content Overview

The book starts by introducing programmable logic controllers (PLCs) and their distinguishing characteristics. Chapters 2 – 5 cover basic ladder logic programming: contact, timer, and counter instructions. As part of the basics, the memory structure of the five particular PLCs and installation topics are treated. Chapter 6 covers ladder logic program design for sequential applications, probably the most significant contribution of the text. Chapters 7 and 8 treat computation, comparison, and advanced ladder logic instructions. Alternate sequential implementations in ladder logic are covered in Chapter 9 and PID controller tuning is covered in Chapter 10. Chapters 11 – 14 cover the other four IEC programming languages: function block diagram, statement list, instruction list, and sequential function chart. PLC troubleshooting is covered in Chapter 15. Sensors and actuators appear in Chapter 16. Chapter 17 introduces factory communication networks. Operator interface, often called human-machine interface (HMI), issues are treated in Chapter 18. Control system security is addressed in Chapter 19 and PLC selection is introduced in Chapter 20. Chapter 21 presents the perspective of an entire automation project, bringing together the various pieces of PLC control design. Chapter 22 outlines two full-length project case studies. One case study is for a process that is primarily discrete and the other case study is for a process that is primarily continuous in nature. Details about number systems and drawing symbols are included as appendices, rather than interrupt the flow of the text material.

The Audience

This book primarily serves the academic market, at the junior or senior undergraduate electrical, mechanical, or industrial engineering or engineering technology level. This text is also suitable for the two-year technical school market. There is nothing in the material that requires a college degree, though the material will be more challenging than the typical PLC textbook for this level of student.

In addition, this text serves the professional market. Economic and regulatory pressures in the manufacturing, chemical, petrochemical, pharmaceutical, and food industries have forced control engineers to design new systems or retrofit existing control systems. Hence, there are many control engineers (primarily chemical and electrical) who need to rapidly

educate themselves in an area of technology in which they are probably only somewhat familiar. This book is valuable to this audience.

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Portions of this material were taught in industrial short courses and university courses and the students are acknowledged for their help in pointing out errors in the text and where the presentation was unclear.

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