PROGRAMMABLE LOGIC CONTROLLERS

PRINCIPLES AND APPLICATIONS

SECOND EDITION

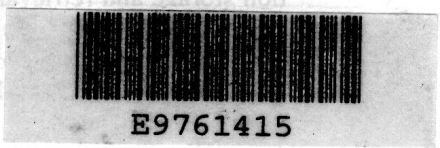
John Webb

Programmable Logic Controllers

Principles and Applications

Second Edition

John W. Webb
Northcentral Technical College
Wausau, Wisconsin



Merrill, an imprint of
Macmillan Publishing Company
New York

Maxwell Macmillan Canada
Toronto

Maxwell Macmillan International
New York* □ *Oxford* □ *Singapore* □ *Sydney

Cover photo courtesy of Allen-Bradley

Editor: Dave Garza
Production Editor: Rex Davidson
Art Coordinator: Vincent A. Smith
Cover Designer: Robert Vega
Production Buyer: Pamela D. Bennett

This book was set in Times Roman by Bi-Comp, Inc. and was printed and bound by Book Press, Inc., a Quebecor America Book Group Company.

The cover was printed by Lehigh Press, Inc.

Printed in the United States of America

First edition, entitled *Programmable Controllers: Principles and Applications,* copyright © 1988 by Merrill Publishing Company.

Macmillan Publishing Company, 866 Third Avenue, New York, NY 10022

Macmillan Publishing Company is part of the
Maxwell Communication Group of Companies.

Maxwell Macmillan Canada, Inc.
1200 Eglington Avenue East, Suite 200
Don Mills, Ontario M3C 3N1

Library of Congress Cataloging-in-Publication Data
Webb, John W.
Programmable logic controllers : principles and applications / John W. Webb. -- 2nd ed.
p. cm.
Rev. ed. of: Programmable controllers. 1988.
Includes bibliographical references and index.
ISBN 0-02-424970-X
1. Programmable controllers. I. Webb, John W. Programmable controllers. II. Title.
TJ223.P76W43 1992
629.8'95--dc20 91-14613
CIP

Printing: 2 3 4 5 6 7 8 9 Year: 3 4 5

Preface

The market for programmable logic controllers is projected to grow to hundreds of millions of dollars a year in the United States. The need for training in PLC application is increasing at all levels, in technical schools, colleges, and industry. The purpose of this text is to provide PLC training in all of these educational areas.

The second edition has been revised to include a number of new features:

- "PC" has been changed to "PLC" throughout the book where we mean Programmable Logic Controller. "PC" can stand for Personal Computer, which can create some confusion in terms.
- The book has been divided into seven sections.
- Updated equipment illustrations are included.
- Alternate programming formats have been added to make the book more generic.
- To get into actual PLC programming earlier in the book, chapter order has been revised.
- Newly developed functions have been added in appropriate chapters.
- Simpler examples have been added at the beginning of many chapters to ease the student into the subjects.
- Added exercises are included in some chapters.
- Explanations have been added as to where a function can be used to advantage (for an example, see the chapter on Matrices).

- Two new chapters have been added:
  Chapter 20: Networking PLCs and Chapter 21: PID Control.
- The Bibliography, Glossary, and Index have been appropriately revised.

Each chapter includes learning objectives, an introduction, explanations and examples, and questions. There is a glossary and bibliography at the end. A solutions manual, which includes answers to all chapter questions, is available. Unlike manufacturers' manuals and most PLC texts, this book includes many programming examples and exercise problems for each type of PLC function. It is also generic, to apply to many different PLC models.

Another feature of this book is that it is possible to use a portion of each chapter, depending on the depth of training required. For example, chapter 14 covers the PLC Move functions; for a course in basic functions, only Section A on the Move function need be covered. Chapter questions are arranged so that only the applicable sections (the first series of questions) need be used when a function does not have to be covered in depth. For more extensive training on a function, the other portions of a chapter may be covered as required.

For a longer course, all chapters in the text could be covered. For a shorter course, only selected chapters could be used. Depending on students' backgrounds, chapters could be included or omitted. In some cases the sequential order may not follow the order in the book.

The text is divided into seven sections. The chart shows which sections would probably be of interest in the listed training situations. Certain sections are of high interest (H) for a given audience, others of medium interest (M), and some of low interest (L). Of course, each training situation calls for a varying amount of time and emphasis on each section and chapter. Also, individual chapters can be covered completely or lightly, depending on the students' background.

	Section of this Book						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Limited Length PLC School	H	H	H	M	L	L	L
In-house Manufacturer's School	H	H	H	H	M	L	L
Electrical Trades	H	H	H	M	L	L	H
Vocational Electrical/Mechanical Programs	H	H	H	H	L	L	L
Associate Degree, Electronics Related	H	H	H	H	M	L	L
Associate Degree, Electromechanical/Robotics	H	H	H	H	H	H	M
Technology, Four-year School	H	H	H	H	H	H	H
Engineering School	H	H	H	H	H	H	H

Acknowledgments

I would like to thank the reviewers for their helpful comments:

Roger Bertrand, Central Maine Technical Institute; Ken Edwards, International Brotherhood of Electrical Workers; Phil Henning, Williamsport Community College; Thomas Kissell, Terra Technical College; E.W. McCullough, Rowan Technical College; William G. Pfautz, De Kalb Area Technical School; Terry S. Taebel; and Stephen Tubbs, Pennsylvania State University—McKeesport. I also want to thank the following companies and people for their support and cooperation in preparing *Programmable Logic Controllers:* Giddings and Lewis Electronics; Westinghouse Electric, Numa Logic; Texas Instruments, Inc.; General Electric; Eaton Corp, Cutler Hammer Products; TII Robotics Systems, Division of TII Robotic Systems, Inc.; Northcentral Technical College, Wausau, Wisconsin; L and S Electric, Schofield, Wisconsin; Amatrol; Best Power Technology; ABB Robotics; Bussmann Division/Cooper Industries; Square D Company; Paula Webb Clark; and Thelma Webb.

NOTICE TO THE READER

The publisher and the author(s) do not warrant or guarantee any of the products and/or equipment described herein nor has the publisher or the author(s) made any independent analysis in connection with any of the products, equipment, or information used herein. The reader is directed to the manufacturer for any warranty or guarantee for any claim, loss, damages, costs, or expense, arising out of or incurred by the reader in connection with the use or operation of the products and/or equipment.

The reader is expressly advised to adopt all safety precautions that might be indicated by the activities and experiments described herein. The reader assumes all risks in connection with such instructions.

To my wife, Thelma

MERRILL'S INTERNATIONAL SERIES IN ENGINEERING TECHNOLOGY

ADAMSON

Applied Pascal for Technology, 0-675-20771-1
The Complete Dictionary of Electronics, 0-02-300820-2
Microcomputer Repair, 0-02-300825-3
Structured BASIC Applied to Technology, 0-675-20772-X
Structured C for Technology, 0-675-20993-5
Structured C for Technology (w/ disks), 0-675-21289-8

ANTONAKOS

The 68000 Microprocessor: Hardware and Software Principles and Applications, 0-675-21043-7

ASSER/STIGLIANO/ BAHRENBURG

Microcomputer Servicing: Practical Systems and Troubleshooting, 0-675-20907-2
Microcomputer Theory and Servicing, 0-675-20659-6
Lab Manual to accompany Microcomputer Theory and Servicing, 0-675-21109-3

ASTON

Principles of Biomedical Instrumentation and Measurement, 0-675-20943-9

BATESON

Introduction to Control System Technology, Third Edition, 0-675-21010-0

BEACH/JUSTICE

DC/AC Circuit Essentials, 0-675-20193-4

BERLIN

Experiments in Electronic Devices to accompany Floyd's Electronic Devices and Electronic Devices: Electron Flow Version, Third Edition, 0-02-308422-7
The Illustrated Electronics Dictionary, 0-675-20451-8

BERLIN/GETZ

Experiments in Instrumentation and Measurement, 0-675-20450-X
Fundamentals of Operational Amplifiers and Linear Integrated Circuits, 0-675-21002-X
Principles of Electronic Instrumentation and Measurement, 0-675-20449-6

BERUBE

Electronic Devices and Circuits Using MICRO-CAP II, 0-02-309160-6

BOGART	*Electronic Devices and Circuits, Second Edition,* 0-675-21150-6
BOGART/BROWN	*Experiments in Electronic Devices and Circuits, Second Edition,* 0-675-21151-4
BOYLESTAD	*DC/AC: The Basics,* 0-675-20918-8
	Introductory Circuit Analysis, Sixth Edition, 0-675-21181-6
BOYLESTAD/KOUSOUROU	*Experiments in Circuit Analysis, Sixth Edition,* 0-675-21182-4
	Experiments in DC/AC Basics, 0-675-21131-X
BREY	*Microprocessors and Peripherals: Hardware, Software, Interfacing, and Applications, Second Edition,* 0-675-20884-X
	The Intel Microprocessors—8086/8088, 80186, 80286, 80386, and 80486—Architecture, Programming, and Interfacing, Second Edition, 0-675-21309-6
BROBERG	*Lab Manual to accompany Electronic Communication Techniques, Second Edition,* 0-675-21257-X
BUCHLA	*Digital Experiments: Emphasizing Systems and Design, Second Edition,* 0-675-21180-8
	Experiments in Electric Circuits Fundamentals, Second Edition, 0-675-21409-2
	Experiments in Electronics Fundamentals: Circuits, Devices and Applications, Second Edition, 0-675-21407-6
BUCHLA/McLACHLAN	*Applied Electronic Instrumentation and Measurement,* 0-675-21162-X
CICCARELLI	*Circuit Modeling: Exercises and Software, Second Edition,* 0-675-21152-2
COOPER	*Introduction to VersaCAD,* 0-675-21164-6
COX	*Digital Experiments: Emphasizing Troubleshooting, Second Edition,* 0-675-21196-4
CROFT	*Getting a Job: Resume Writing, Job Application Letters, and Interview Strategies,* 0-675-20917-X
DAVIS	*Technical Mathematics,* 0-675-20338-4
	Technical Mathematics with Calculus, 0-675-20965-X
	Study Guide to Accompany Technical Mathematics, 0-675-20966-8
	Study Guide to Accompany Technical Mathematics with Calculus, 0-675-20964-1
DELKER	*Experiments in 8085 Microprocessor Programming and Interfacing,* 0-675-20663-4
FLOYD	*Digital Fundamentals, Fourth Edition,* 0-675-21217-0
	Electric Circuits Fundamentals, Second Edition, 0-675-21408-4

	Electronic Devices, Third Edition, 0-675-22170-6
	Electronic Devices: Electron Flow Version, 0-02-338540-5
	Electronics Fundamentals: Circuits, Devices, and Applications, Second Edition, 0-675-21310-X
	Fundamentals of Linear Circuits, 0-02-338481-6
	Principles of Electric Circuits, Electron Flow Version, Second Edition, 0-675-21292-8
	Principles of Electric Circuits, Third Edition, 0-675-21062-3
FULLER	*Robotics: Introduction, Programming, and Projects,* 0-675-21078-X
GAONKAR	*Microprocessor Architecture, Programming, and Applications with the 8085/8080A, Second Edition,* 0-675-20675-8
	The Z80 Microprocessor: Architecture, Interfacing, Programming, and Design, 0-675-20540-9
GILLIES	*Instrumentation and Measurements for Electronic Technicians,* 0-675-20432-1
GOETSCH	*Industrial Supervision: In the Age of High Technology,* 0-675-22137-4
GOETSCH/RICKMAN	*Computer-Aided Drafting with AutoCAD,* 0-675-20915-3
GOODY	*Programming and Interfacing the 8086/8088 Microprocessor,* 0-675-21312-6
HUBERT	*Electric Machines: Theory, Operation, Applications, Adjustment, and Control,* 0-675-21136-0
HUMPHRIES	*Motors and Controls,* 0-675-20235-3
HUTCHINS	*Introduction to Quality: Management, Assurance and Control,* 0-675-20896-3
KEOWN	*PSpice and Circuit Analysis,* 0-675-22135-8
KEYSER	*Materials Science in Engineering, Fourth Edition,* 0-675-20401-1
KIRKPATRICK	*The AutoCAD Book: Drawing, Modeling and Applications, Second Edition,* 0-675-22288-5
	Industrial Blueprint Reading and Sketching, 0-675-20617-0
KRAUT	*Fluid Mechanics for Technicians,* 0-675-21330-4
KULATHINAL	*Transform Analysis and Electronic Networks with Applications,* 0-675-20765-7
LAMIT/LLOYD	*Drafting for Electronics,* 0-675-20200-0
LAMIT/WAHLER/HIGGINS	*Workbook in Drafting for Electronics,* 0-675-20417-8
LAMIT/PAIGE	*Computer-Aided Design and Drafting,* 0-675-20475-5
LAVIANA	*Basic Computer Numerical Programming, Second Edition,* 0-675-21298-7
MacKENZIE	*The 8051 Microcontroller,* 0-02-373650-X

MARUGGI

Technical Graphics: Electronics Worktext, Second Edition, 0-675-21378-9

The Technology of Drafting, 0-675-20762-2

Workbook for the Technology of Drafting, 0-675-21234-0

McCALLA

Digital Logic and Computer Design, 0-675-21170-0

McINTYRE

Study Guide to accompany Electronic Devices, Third Edition, and *Electronic Devices, Electron Flow Version,* 0-02-379296-5

Study Guide to accompany Electronics Fundamentals, Second Edition, 0-675-21406-8

MILLER

The 68000 Microprocessor Family: Architecture, Programming, and Applications, Second Edition, 0-02-381560-4

MONACO

Essential Mathematics for Electronics Technicians, 0-675-21172-7

Introduction to Microwave Technology, 0-675-21030-5

Laboratory Activities in Microwave Technology, 0-675-21031-3

Preparing for the FCC General Radiotelephone Operator's License Examination, 0-675-21313-4

Student Resource Manual to accompany Essential Mathematics for Electronics Technicians, 0-675-21173-5

MONSSEN

PSpice with Circuit Analysis, 0-675-21376-2

MOTT

Applied Fluid Mechanics, Third Edition, 0-675-21026-7

Machine Elements in Mechanical Design, Second Edition, 0-675-22289-3

NASHELSKY/BOYLESTAD

BASIC Applied to Circuit Analysis, 0-675-20161-6

PANARES

A Handbook of English for Technical Students, 0-675-20650-2

PFEIFFER

Proposal Writing: The Art of Friendly Persuasion, 0-675-20988-9

Technical Writing: A Practical Approach, 0-675-21221-9

POND

Introduction to Engineering Technology, 0-675-21003-8

QUINN

The 6800 Microprocessor, 0-675-20515-8

REIS

Digital Electronics Through Project Analysis, 0-675-21141-7

Electronic Project Design and Fabrication, Second Edition, 0-02-399230-1

Laboratory Manual for Digital Electronics Through Project Analysis, 0-675-21254-5

ROLLE

Thermodynamics and Heat Power, Third Edition, 0-675-21016-X

ROSENBLATT/FRIEDMAN

Direct and Alternating Current Machinery, Second Edition, 0-675-20160-8

ROZE	*Technical Communication: The Practical Craft*, 0-675-20641-3
SCHOENBECK	*Electronic Communications: Modulation and Transmission, Second Edition*, 0-675-21311-8
	Laboratory Manual to Accompany Electronic Communications, 0-675-21397-5
SCHWARTZ	*Survey of Electronics, Third Edition*, 0-675-20162-4
SELL	*Basic Technical Drawing*, 0-675-21001-1
SMITH	*Statistical Process Control and Quality Improvement*, 0-675-21160-3
SORAK	*Linear Integrated Circuits: Laboratory Experiments*, 0-675-20661-8
SPIEGEL/LIMBRUNNER	*Applied Statics and Strength of Materials*, 0-675-21123-9
STANLEY, B.H.	*Experiments in Electric Circuits, Third Edition*, 0-675-21088-7
STANLEY, W.D.	*Operational Amplifiers with Linear Integrated Circuits, Second Edition*, 0-675-20660-X
SUBBARAO	*16/32-Bit Microprocessors: 68000/68010/68020 Software, Hardware, and Design Applications*, 0-675-21119-0
TOCCI	*Electronic Devices: Conventional Flow Version, Third Edition*, 0-675-20063-6
	Fundamentals of Pulse and Digital Circuits, Third Edition, 0-675-20033-4
	Introduction to Electric Circuit Analysis, Second Edition, 0-675-20002-4
TOCCI/OLIVER	*Fundamentals of Electronic Devices, Fourth Edition*, 0-675-21259-6
WEBB	*Programmable Logic Controllers: Principles and Applications, Second Edition*, 0-02-424970-X
WEBB/GRESHOCK	*Industrial Control Electronics*, 0-675-20897-1
WEISMAN	*Basic Technical Writing, Sixth Edition*, 0-675-21256-1
WOLANSKY/AKERS	*Modern Hydraulics: Ths Basics at Work*, 0-675-20987-0
WOLF	*Statics and Strength of Materials: A Parallel Approach*, 0-675-20622-7

Contents