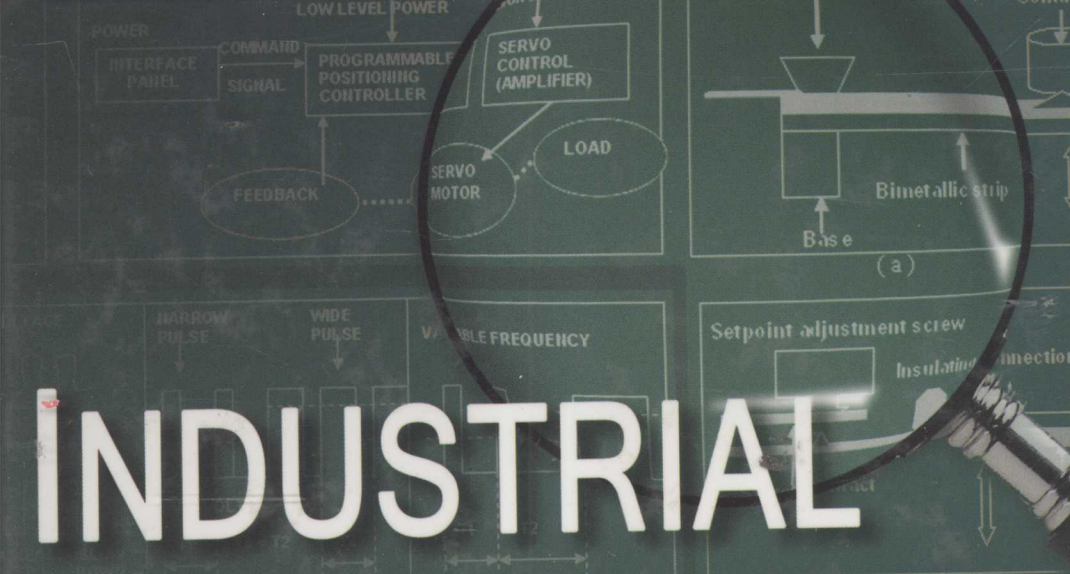

INDUSTRIAL CONTROL TECHNOLOGY

A Handbook for Engineers and Researchers

PENG ZHANG

William Andrew

INDUSTRIAL CONTROL TECHNOLOGY

A Handbook for Engineers and Researchers

Peng Zhang
Beijing Normal University, People's Republic of China

William Andrew
Norwich, NY, USA

ISBN: 978-0-8155-1571-5

Library of Congress Cataloging-in-Publication Data

Zhang, Peng.
Industrial control technology : a handbook for engineers and researchers / Peng Zhang.
p. cm.
Includes bibliographical references and index.
1. Process control--Handbooks, manuals, etc. 2. Automatic control--Handbooks, manuals, etc. I. Title.
TS156.8.Z43 2008
670.42--dc22

2008002701

Printed in the United States of America

This book is printed on acid-free paper.

10 9 8 7 6 5 4 3 2 1

Published by:
William Andrew Inc.
13 Eaton Avenue
Norwich, NY 13815
1-800-932-7045
www.williamandrew.com

ENVIRONMENTALLY FRIENDLY
This book has been printed digitally because this process does not use any plates, ink, chemicals, or press solutions that are harmful to the environment. The paper used in this book has a 30% recycled content.

NOTICE
To the best of our knowledge the information in this publication is accurate; however the Publisher does not assume any responsibility or liability for the accuracy or completeness of, or consequences arising from, such information. This book is intended for informational purposes only. Mention of trade names or commercial products does not constitute endorsement or recommendation for their use by the Publisher. Final determination of the suitability of any information or product for any use, and the manner of that use, is the sole responsibility of the user. Anyone intending to rely upon any recommendation of materials or procedures mentioned in this publication should be independently satisfied as to such suitability, and must meet all applicable safety and health standards.

INDUSTRIAL CONTROL TECHNOLOGY

Preface

Objectives

Industrial control consists of industrial process control and industrial production automation. This book applies to both industrial process control and industrial production automation, and it covers the technology in three branches: theory, design, and technology.

In recent years, there has been a technical revolution in the semiconductor industry and in the electronics industry, which has significantly advanced the existing technologies in industrial control. The recent technical developments in the semiconductor and electronics industries are mainly represented as these seven aspects:

(1) The microprocessor chipsets have been very capable in interrupt handling, data passage, and interface communication.
(2) The operating speeds of both microprocessors and programmable integrated circuits have become much faster.
(3) The enhancements in the register arrays and the instruction set of microprocessor units have made multitasking or multithreads possible.
(4) The sizes of various semiconductor chips are being increased and their production costs are going lower and lower.
(5) The controllers of intelligent functionalities are more and more designed to perform various control strategies and protocols. For example, Programmable Logic Control (PLC) controllers implement Ladder Logic, and fuzzy logic controllers operate in terms of fuzzy control theory; the Controller Area Network (CAN) is a very powerful automatic system used even in aerospace. These industrial intelligent controllers are being increasingly used in industrial control so that the establishment of industrial control systems is becoming more and more feasible.
(6) The various development tools for both hardware and software are becoming more and more feasible and powerful, which is largely shortening the time for developing software and hardware and is significantly enhancing their quality.
(7) The programmable application-specific integrated circuits (ASIC) have now approached an intelligence similar to that of microprocessors, so that they are performing a more important functional role in various control systems.

These technical developments in both the semiconductor industry and the electronics industry have advanced industrial control into both real-time control and distributed control. Real-time control requires controllers to capture all the significant target activities and to deliver their responses as swiftly as possible so that system performance is never degraded. Distributed control indicates that controls are performed by a number of microprocessor controllers and executed in a group of independent agents or units that are physically and electronically connected and communicate with each other. This tendency in industrial control has led to the future continuation of both real-time control and distributed control. Consequently, industrial control has been gradually extended from device and machine control to plant and enterprise and industry.

To demonstrate that these technical developments satisfy the new industrial control requirements, this book provides comprehensive technical details, including the necessary rationales, methodologies, types, parameters, and specifications, for the devices of industrial control. As a technical handbook for engineers, a technical reference, and an academic textbook for students, this book particularly emphasizes the following seven areas:

(1) the sensors, actuators, and valves currently existing in all kinds of industrial control systems;
(2) the electronic hardware resident on the microprocessor chipset system;
(3) the system interfaces including devices, Fieldbuses, and techniques used for all kinds of industrial control;
(4) the digital controllers performing the written programs and the given protocols;
(5) the embedded software on a microprocessor chipset for real-time control applications;
(6) the data-transmission hardware and protocols between independent agents or units of their own microprocessors;
(7) the routines, containing special hardware and software, which are very useful to any kind of industrial control system.

All these seven areas are crucial for accomplishing both real-time control and distributed control in industry. This book, therefore, provides the key technologies applied to modern industrial control so that it will be widely available to all the engineers and researchers as well as students who are working in industrial control and its relative disciplines.

Readership

This book has been written primarily as an engineering handbook for those engineers working in the research and development of all kinds of control systems. However, the faculties and postgraduates in universities or colleges will also find this book a useful technical reference for their projects related to control and computer engineering. For university students, this book can be taken as a textbook in classes such as automation, control, computer network, and other related technical subjects.

As an engineering handbook, this book will help professionals to design, deploy, and make both manufacture control equipment and production process control systems. Modern industrial control technologies involve three essential phases: machinery, hardware, and software. However, no matter what phase a control engineer is working with, he or she will find that this book is very helpful.

As a reference, this book will aid the faculties and postgraduates in universities and colleges to understand all the technical details involved in their research projects on controls. The wide coverage of this book allows it to bridge the gap between theory and technique in control. In addition, it is suitable for practicing postgraduates who wish or need to gain an engineering knowledge of the control topics.

This book is also intended to be a course textbook for students studying the subjects of automatic control, computer hardware and electronics, computer network, as well as data communication. Typically, the students will be in electronic engineering, computer control, control systems, or industrial automation courses.

Synopsis

This book has been organized into chapters, sections, and titled graphs, etc.

The first of its seven chapters, "Sensors and Actuators for Industrial Control," lists the typical sensors, meters, actuators, and valves that are crucial devices located between the front and the rear of industrial control systems. This chapter provides the mechanism concepts, working principles, device types, technical data, and the guides to enable engineers to design and develop industrial control systems.

The second chapter, "Computer Hardware for Industrial Control," provides a detailed list of the types of electronic devices resident on the

system given by a microprocessor chipset. These are the microprocessor, programmable peripheral devices, and ASIC. The architecture of the electronic components on a computer motherboard is also plotted so that engineers are able to see how the microprocessor chipset is populated. This chapter provides engineers with an explanation of how microprocessors operate, and also all the necessary technical data for microprocessors to perform.

The third chapter, "System Interfaces for Industrial Control," discusses four types of interfaces: actuator–sensor interface, control system interfaces, human–machine (or human–controller) interfaces, and highway addressable remote transducer (HART) field interfaces. These four interfaces basically cover all the interface devices and technologies existing in various industrial control systems. The actuator–sensor interface is located at the front or rear of the actuator–sensor level to bridge the gap between this level and the controllers. The control system interfaces include the Fieldbus and microprocessor chipset interfaces that are used for connecting and communicating with controllers. The human–machine interfaces contain both the tools and technologies to provide humans with easy and comfortable methods of handling the devices. The HART field communications include the HART protocol and HART interface devices used for field communications in industrial process control.

The fourth chapter is entitled "Digital Controllers for Industrial Control." A controller, similar to a computer, is a system with its own hardware and software capable of performing independent control. This chapter lists the controllers necessary for both industrial production control and industrial process control: they are PLC controllers, CNC controllers, SCADA system, PID controller, batch controllers, servo controllers, and the fuzzy controllers.

The title of the fifth chapter is "Application Software for Industrial Control." The real-time control works with the microprocessor chipset installed on a motherboard or a daughter board. Any microprocessor chipset, except for the inherent microcode and BIO to the CPU, must have a software package consisting of three program systems: boot code, operating system, and application system. This chapter provides engineers with the basic rationale, semantics, principles, work sequence, and program structures for each of these three systems. With reference to this chapter, an experienced software engineer should be capable of programming the design of the whole software package of a microprocessor controller board.

The sixth chapter is "Data Communications in Distributed Control System." Several independent units, each of which will probably have their own microprocessor to monitor a number of mechanical systems, are

physically and electronically connected together. These communicate with each other electronically in an interactive manner so as to form a distributed control system. In distributed control, to set up this type of industrial control system the engineers must understand the connection methodologies and communication rationales between the independent units. This chapter contains all the technical information, data, methodologies, and some theories necessary for the implementation of a distributed control system.

The seventh chapter is for the complex topics. These are the topics dealing with subjects that are over and above the basics when compared with the first six chapters. Chapter 7 explains system routines that make the control systems more user friendly and safe to operate. With the Power-up and Power-down routines, the system is able to safely establish and terminate when power is switched ON and OFF, respectively. The installation and configuration routines permit the system devices to communicate with each other through both the software and the hardware. The diagnostic routines then allow engineers to determine the root reasons when a system suffers from a malfunction.

Bibliography

Writing this book has involved reference to a large number of sources including academic books, journal articles, and in particular industry technical manuals and company introductory or demonstrational materials displayed on web sites of various dates and locations. The number and the scale of the sources are such that it would be practically impossible to acknowledge each source individually in the body of the book. The sources are, therefore, alphabetically ordered and placed at the end of each chapter. This method has two benefits. It enables the author to acknowledge the contribution of other individuals and institutions whose scholarship or products have been referred to in this book. It also provides the reader the convenience of tracing more relevant sources.

Acknowledgments

My most sincere thanks go to my family: to my wife, Minghua and my son Huza for their unwavering understanding and support. I would also like to thank my younger brother Zhang wei for the ideas he contributed to this book.

I am extremely grateful to Professor D. T. Pham, director of the Manufacturing Engineering Center, Cardiff University, United Kingdom, who granted me some very valuable suggestions in his review of some portions of this manuscript, and to Dr. Chunquian Ji in Cardiff University and to Dr. Wenbo Mao in Hewlett Packard Research Laboratory, United Kingdom, for their valuable comments and suggestions on the manuscripts. Without the support of these people, there would not have been this book.

Peng Zhang
Beijing

May 2008

Contents