Programmable logic controller

[Science](), [Computer Science]()

Programmable Controllers Theory and Implementation Second Edition L. A. Bryan E. A. Bryan PROGRAMMABLE CONTROLLERS T HEORY AND I MPLEMENTATION Second Edition L. A. Bryan E. A. Bryan An Industrial Text Company Publication Atlanta • Georgia • USA First edition 1988. Second edition 1997 Printed and bound in the United States of America 03 02 01 00 99 98 97 10 9 8 7 6 5 4 3 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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SECTION 3 PLC PROGRAMMING

Industrial Text & Video Company 1-800-752-8398 www. industrialtext. com vii This page intentionally left blank. Preface PREFACE Since the first edition of this book in 1988, the capabilities of programmable logic controllers have grown by leaps and bounds. Likewise, the applications of PLCs have grown with them. In fact, in today's increasingly computercontrolledenvironment, it is almost impossible to find a technical industry that does not use programmable controllers in one form or another.

To respond to these phenomenal changes, we introduce the second edition of Programmable Controllers: Theory and Implementation. This second edition, like the first, provides a comprehensive theoretical, yet practical, look at all aspects of PLCs and their associated devices and systems. However, this version goes one step further with new chapters on advanced PLC topics, such as I/O bus networks, fuzzy logic, the IEC 1131-3 programming standard, process control, and PID algorithms.

This new edition also presents revised, up-to-date information about existing topics, with expanded graphics and new, hands-on examples. Furthermore, the new layout of the book—with features like two-tone graphics, key terms lists, well-defined headings and sections, callout icons, and a revised, expanded glossary— makes the information presented even easier to understand. This new edition has been a labor-intensivelearning experiencefor all those involved. As with any task so large, we could never have done it alone.

Therefore, we would like to thank the following companies for their help in bringing this book to press: Allen-Bradley Company—Industrial Computer Group, ASI-USA, B & R Industrial Automation, Bailey Controls Company, DeviceNet Vendors Association, ExperTune Software, Fieldbus Foundation, Hoffman Engineering Company, Honeywell—MicroSwitch Division, LANcity—Cable Modem Division of Bay Networks, Mitsubishi Electronics, Omron Electronics, Phoenix Contact, PLC Direct, PMC/BETA LP, Profibus Trade

Organization, Schaevitz Engineering Company, Siemens Automation, Square D Company, Thermometrics, and WAGO.

We hope that you will find this book to be a valuable learning and reference tool. We have tried to present a variety of programmable control operations; however, with the unlimited variations in control systems, we certainly have not been able to provide an exhaustive list of PLC applications. Only you, armed with the knowledge gained through this book, can explore the true limits of programmable logic controllers. Stephanie Philippo Editor Industrial Text & Video Company 1-800-752-8398 www. industrialtext. com ix About the Authors A BOUT THE AUTHORS L UIS B RYAN

Luis Bryan holds a Bachelor ofSciencein Electrical Engineering degree and a Master of Science in Electrical Engineering degree, both from the University of Tennessee. His major areas of expertise are digital systems, electronics, and computer engineering. During his graduate studies, Luis was involved in several projects with national and international governmental agencies. Luis has extensive experience in the field of programmable controllers. He was involved in international marketing activities, as well as PLC applications development, for a major programmable controller manufacturer.

He also worked for a consulting firm, providing market studies and companyspecific consultations about PLCs. Furthermore, Luis has given lectures and seminars in Canada, Mexico, and South America about the uses of programmable controllers. He continues to teach seminars to industry and government entities, including the National Aeronautics and Space Administration (NASA). Luis is an active member of several professional organizations, including the Institute of Electrical and Electronics Engineers (IEEE) and the IEEE's instrument and computer societies.

He is a senior member of the Instrument Society of America, as well as a member of Phi Kappa Phi honor society and Eta Kappa Nu electrical engineering honor society. Luis has coauthored several other books about programmable controllers. E RIC B RYAN Eric Bryan graduated from the University of Tennessee with a Bachelor of Science in Electrical Engineering degree, concentrating in digital design and computer architecture. He received a Master of Science in Engineering degree from the Georgia Institute ofTechnology, where he participated in a special computer-integrated manufacturing (CIM) program.

Eric's specialties are industrial automation methods, flexible manufacturing systems (FMS), and artificial intelligence. He is an advocate of artificial intelligence implementation and its application in industrial automation. Eric worked for a leading automatic laser inspection systems company, as well as a programmable controller consulting firm. His industrial experience includes designing and implementing large inspection systems, along with developing PLC-based systems. Eric has coauthored other publications about PLCs and is a member of several professional and technical societies.

Industrial Text & Video Company 1-800-752-8398 www. industrialtext. com x How to Use this Book HOW TO USE THIS B OOK Welcome to Programmable Controllers: Theory and Implementation. Before you begin reading, please review the following strategies for using this book. By following these study strategies, you will more thoroughly understand the information presented in the text and, thus, be better able to apply this knowledge in real-life situations. B EFORE Y OU B EGIN R EADING • • • Look through the book to familiarize yourself with its structure. Read the table of contents to review the subjects you will be studying.

Familiarize yourself with the icons used throughout the text: Chapter Highlights Key Terms • Look at the appendices to see what reference materials have been provided. A S Y OU S TUDY E ACH C HAPTER • Before you start a chapter, read the Chapter Highlights paragraph at the beginning of the chapter’s text. This paragraph will give you an overview of what you’ll learn, as well as explain how the information presented in the chapter fits into what you’ve already learned and what you will learn. Read the chapter, paying special attention to the bolded items.

These are key terms that indicate important topics that you should understand after finishing the chapter. When you encounter an exercise, try to solve the problem yourself before looking at the solution. This way, you'll determine which topics you understand and which topics you should study further. • • W HEN Y OU F INISH E ACH C HAPTER • At the end of each chapter, look over the list of key terms to ensure that you understand all of the important subjects presented in the chapter. If you’re not sure about a term, review it in the text. Review the exercises to ensure that you understand the logic and equations involved in each problem.

Also, review the workbook and study guide, making sure that you can work all of the problems correctly. When you’re sure that you thoroughly understand the information that has been presented, you’re ready to move on to the next chapter. Industrial Text & Video Company 1-800-752-8398 www. industrialtext. com xi • • SECTION O NE INTRODUCTORY CONCEPTS •

Introduction to Programmable Controllers • Number Systems and Codes • Logic Concepts Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com This page intentionally left blank. Industrial Text and Video Company 1-800-752-8398 www. ndustrialtext. com C HAPTER O NE INTRODUCTION TO PROGRAMMABLE CONTROLLERS I find the great thing in this world is not so much where we stand as in what direction we are moving. —Oliver Wendell Holmes Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com SECTION 1 Introductory Concepts Introduction to Programmable Controllers CHAPTER 1 C HAPTER H IGHLIGHTS Every aspect of industry—from power generation to automobile painting tofoodpackaging—uses programmable controllers to expand and enhance production. In this book, you will learn about all aspects of these powerful and versatile tools.

This chapter will introduce you to the basics of programmable controllers—from their operation to their vast range of applications. In it, we will give you an inside look at the designphilosophybehind their creation, along with a brief history of their evolution. We will also compare programmable controllers to other types of controls to highlight the benefits and drawbacks of each, as well as pinpoint situations where PLCs work best. When you finish this chapter, you will understand the fundamentals of programmable controllers and be ready to explore the number systems associated with them. 1-1 D EFINITION

Programmable logic controllers, also called programmable controllers or PLCs, are solid-state members of the computerfamily, using integrated circuits instead of electromechanical devices to implement control functions.

They are capable of storing instructions, such as sequencing, timing, counting, arithmetic, data manipulation, and communication, to control industrial machines and processes. Figure 1-1 illustrates a conceptual diagram of a PLC application. Process or Machine Measure Control Field Inputs Programmable Controller Field Outputs Figure 1-1. PLC conceptual application diagram. Programmable controllers have many definitions.

However, PLCs can be thought of in simple terms as industrial computers with specially designed architecture in both their central units (the PLC itself) and their interfacing circuitry to field devices (input/output connections to the real world). Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 4 SECTION Introductory 1 Concepts Introduction to Programmable Controllers CHAPTER 1 As you will see throughout this book, programmable logic controllers are mature industrial controllers with their design roots based on the principles of simplicity and practical application. -2 A H ISTORICAL B ACKGROUND The Hydramatic Division of the General Motors Corporation specified the design criteria for the first programmable controller in 1968. Their primary goal was to eliminate the high costs associated with inflexible, relaycontrolled systems. The specifications required a solid-state system with computer flexibility able to (1) survive in an industrial environment, (2) be easily programmed and maintained by plant engineers and technicians, and (3) be reusable. Such a control system would reduce machine downtime and provide expandability for the future.

Some of the initial specifications included the following: • • • • • • • The new control system had to be price competitive with the use of relay systems. The system had to be capable of sustaining an industrial environment. The input and output interfaces had to be easily replaceable. The controller had to be designed in modular form, so that subassemblies could be removed easily for replacement or repair. The control system needed the capability to pass data collection to a central system. The system had to be reusable. The method used to program the controller had to be simple, so that it could be easily understood by plant personnel.

T HE F IRST P ROGRAMMABLE C ONTROLLER The product implementation to satisfy Hydramatic's specifications was underway in 1968; and by 1969, the programmable controller had its first product offsprings. These early controllers met the original specifications and opened the door to the development of a new control technology. The first PLCs offered relay functionality, thus replacing the original hardwired relay logic, which used electrically operated devices to mechanically switch electrical circuits. They met the requirements of modularity, expandability, programmability, and ease of use in an industrial environment.

These controllers were easily installed, used less space, and were reusable. The controller programming, although a little tedious, had a recognizable plant standard: the ladder diagram format. Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 5 SECTION 1 Introductory Concepts Introduction to Programmable Controllers CHAPTER 1 In a short period, programmable controller use started to spread to other industries. By 1971, PLCs were being used to provide relay replacement as the first steps toward control automation in other industries, such as food and beverage, metals, manufacturing, and pulp and paper.

T HE C ONCEPTUAL D ESIGN OF THE PLC The first programmable controllers were more or less just relay replacers. Their primary function was to perform the sequential operations that were previously implemented with relays. These operations included ON/OFF control of machines and processes that required repetitive operations, such as transfer lines and grinding and boring machines. However, these programmable controllers were a vast improvement over relays. They were easily installed, used considerably less space and energy, haddiagnosticindicators that aided troubleshooting, and unlike relays, were reusable if a project was scrapped.

Programmable controllers can be considered newcomers when they are compared to their elder predecessors in traditional control equipment technology, such as old hardwired relay systems, analog instrumentation, and other types of early solid-state logic. Although PLC functions, such as speed of operation, types of interfaces, and data-processing capabilities, have improved throughout the years, their specifications still hold to the designers' original intentions—they are simple to use and maintain. T ODAY ' S P ROGRAMMABLE C ONTROLLERS Many technological advances in the programmable controller industry continue oday. These advances not only affect programmable controller design, but also the philosophical approach to control system architecture. Changes include both hardware (physical components) and software (control program) upgrades. The following list describes some recent PLC hardware enhancements: • • Faster scan times are being achieved using new, advanced microprocessor and electronic technology. Small, low-cost PLCs (see Figure 1-2), which can replace four to ten relays, now have more power than their predecessor, the simple relay replacer.

High-density input/output (I/O) systems (see Figure 1-3) provide space-efficient interfaces at low cost. Intelligent, microprocessor-based I/O interfaces have expanded distributed processing. Typical interfaces include PID (proportional6 • • Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com SECTION Introductory 1 Concepts Introduction to Programmable Controllers CHAPTER 1 integral-derivative), network, CANbus, fieldbus, ASCII communication, positioning, host computer, and language modules (e. g. , BASIC, Pascal). Mechanical design improvements have included rugged input/output enclosures and input/output systems that have made the terminal an integral unit. Special interfaces have allowed certain devices to be connected directly to the controller. Typical interfaces include thermocouples, strain gauges, and fast-response inputs. Peripheral equipment has improved operator interface techniques, and system documentation is now a standard part of the system. • • Courtesy of Mitsubishi Electronics, Mount Prospect, IL Figure 1-2. Small PLC with built-in I/O and detachable, handheld programming unit. Figure 1-3.

PLC system with high-density I/O (64-point modules). All of these hardware enhancements have led to the development of programmable controller families like the one shown in Figure 1-4. These families consist of a product line that ranges from very small “ microcontrollers,” with as few as 10 I/O points, to very large and Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 7 Courtesy of Mitsubishi Electronics, Mount Prospect, IL SECTION 1 Introductory Concepts Introduction to Programmable

Controllers CHAPTER 1 sophisticated PLCs, with as many as 8, 000 I/O points and 128, 000 words of memory.

These family members, using common I/O systems and programming peripherals, can interface to a local communication network. The family concept is an important cost-saving development for users. Figure 1-4. Allen-Bradley's programmable controller family concept with several PLCs. Like hardware advances, software advances, such as the ones listed below, have led to more powerful PLCs: • • • PLCs have incorporated object-oriented programming tools and multiple languages based on the IEC 1131-3 standard. Small PLCs have been provided with powerful instructions, which extend the area of application for these small controllers.

High-level languages, such as BASIC and C, have been implemented in some controllers' modules to provide greater programming flexibility when communicating with peripheral devices and manipulating data. Advanced functional block instructions have been implemented for ladder diagram instruction sets to provide enhanced software capability using simple programming commands. Diagnostics and fault detection have been expanded from simple system diagnostics, which diagnose controller malfunctions, to include machine diagnostics, which diagnose failures or malfunctions of the controlled machine or process.

Floating-point math has made it possible to perform complex calculations in control applications that require gauging, balancing, and statistical computation. 8 • • • Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com Courtesy of Allen-Bradley, Highland, Heights, OH SECTION Introductory 1 Concepts Introduction to Programmable Controllers

CHAPTER 1 • Data handling and manipulation instructions have been improved and simplified to accommodate complex control and data acquisition applications that involve storage, tracking, and retrieval of large amounts of data.

Programmable controllers are now mature control systems offering many more capabilities than were ever anticipated. They are capable of communicating with other control systems, providing production reports, scheduling production, and diagnosing their own failures and those of the machine or process. These enhancements have made programmable controllers important contributors in meeting today's demands for higher quality and productivity. Despite the fact that programmable controllers have become much more sophisticated, they still retain the simplicity and ease of operation that was intended in their original design.

P ROGRAMMABLE C ONTROLLERS AND THE F UTURE The future of programmable controllers relies not only on the continuation of new product developments, but also on the integration of PLCs with other control and factory management equipment. PLCs are being incorporated, through networks, into computer-integrated manufacturing (CIM) systems, combining their power and resources with numerical controls, robots, CAD/ CAM systems, personal computers, management information systems, and hierarchical computer-based systems. There is no doubt that programmable controllers will play a substantial role in the factory of the future.

New advances in PLC technology include features such as better operator interfaces, graphic user interfaces (GUIs), and more human-oriented man/ machine interfaces (such as voice modules). They also include the development of interfaces that allow communication with equipment, hardware, and software that supports artificial intelligence, such as fuzzy logic I/O systems. Software advances provide better connections between different types of equipment, using communication standards through widely used networks. New PLC instructions are developed out of the need to add intelligence to a controller.

Knowledge-based and process learning–type instructions may be introduced to enhance the capabilities of a system. The user's concept of the flexible manufacturing system (FMS) will determine the control philosophy of the future. The future will almost certainly continue to cast programmable controllers as an important player in the factory. Control strategies will be distributed with " intelligence" instead of being centralized. Super PLCs will be used in applications requiring complex calculations, network communication, and supervision of smaller PLCs and machine controllers. Industrial Text and Video Company 1-800-752-8398 www. ndustrialtext. com 9 SECTION 1 Introductory Concepts Introduction to Programmable Controllers CHAPTER 1 1-3 P RINCIPLES OF O PERATION A programmable controller, as illustrated in Figure 1-5, consists of two basic sections: • • the central processing unit the input/output interface system I N P U T S Central Processing Unit O U T P U T S Figure 1-5. Programmable controller block diagram. The central processing unit (CPU) governs all PLC activities. The following three components, shown in Figure 1-6, form the CPU: • • • the processor the memory system the system power supply Processor Memory

Power Supply Figure 1-6. Block diagram of major CPU components. Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 10

SECTION Introductory 1 Concepts Introduction to Programmable Controllers CHAPTER 1 The operation of a programmable controller is relatively simple. The input/ output (I/O) system is physically connected to the field devices that are encountered in the machine or that are used in the control of a process. These field devices may be discrete or analog input/output devices, such as limit switches, pressure transducers, push buttons, motor starters, solenoids, etc.

The I/O interfaces provide the connection between the CPU and the information providers (inputs) and controllable devices (outputs). During its operation, the CPU completes three processes: (1) it reads, or accepts, the input data from the field devices via the input interfaces, (2) it executes, or performs, the control program stored in the memory system, and (3) it writes, or updates, the output devices via the output interfaces. This process of sequentially reading the inputs, executing the program in memory, and updating the outputs is known as scanning. Figure 1-7 illustrates a graphic representation of a scan. SCAN READ (1)

EXECUTE (2) WRITE (3) Figure 1-7. Illustration of a scan. The input/output system forms the interface by which field devices are connected to the controller (see Figure 1-8). The main purpose of the interface is to condition the various signals received from or sent to external field devices. Incoming signals from sensors (e. g. , push buttons, limit switches, analog sensors, selector switches, and thumbwheel switches) are wired to terminals on the input interfaces. Devices that will be controlled, like motor starters, solenoid valves, pilot lights, and position valves, are connected to the terminals of the output interfaces.

The system power supply provides all the voltages required for the proper operation of the various central processing unit sections. Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 11 SECTION 1 Introductory Concepts Introduction to Programmable Controllers CHAPTER 1 0 0 1 2 3 4 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 1 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 2 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 3 0 1 2 3 4 5 6 7 0 1 2 INPUT MODULE Processor 5 and 6 Power Supply 7 0 1 2 3 4 5 6 7 OUTPUT MODULE 3 4 5 6 7 I/O Interfaces Figure 1-8. Input/output interface.

Although not generally considered a part of the controller, the programming device, usually a personal computer or a manufacturer’s miniprogrammer unit, is required to enter the control program into memory (see Figure 1-9). The programming device must be connected to the controller when entering or monitoring the control program. (a) (b) Figure 1-9. (a) Personal computer used as a programming device and (b) a miniprogrammer unit. Chapters 4 and 5 will present a more detailed discussion of the central processing unit and how it interacts with memory and input/output interfaces.

Chapters 6, 7, and 8 discuss the input/output system. Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 12 Courtesy of Mitsubishi Electronics, Mount Prospect, IL Courtesy of Omron Electronics, Schaumburg, IL SECTION Introductory 1 Concepts Introduction to Programmable Controllers CHAPTER 1 1-4 PLC S V ERSUS O THER T YPES OF C ONTROLS PLC S V ERSUS R ELAY C ONTROL For years, the question many engineers, plant managers, and original equipment manufacturers (OEMs) asked was, “ Should I be using a programmable controller? At one time, much of a systems engineer’s time was spent trying to determine the costeffectiveness of a PLC over relay control. Even today, many control system designers still think that they are faced with this decision. One thing, however, is certain—today's demand for high quality and productivity can hardly be fulfilled economically without electronic control equipment. With rapid technology developments and increasing competition, the cost of programmable controls has been driven down to the point where a PLC-versus-relay cost study is no longer necessary or valid.

Programmable controller applications can now be evaluated on their own merits. When deciding whether to use a PLC-based system or a hardwired relay system, the designer must ask several questions. Some of these questions are: • • • • • • • • • • Is there a need for flexibility in control logic changes? Is there a need for high reliability? Are space requirements important? Are increased capability and output required? Are there data collection requirements? Will there be frequent control logic changes? Will there be a need for rapid modification? Must similar control logic be used on different machines?

Is there a need for future growth? What are the overall costs? The merits of PLC systems make them especially suitable for applications in which the requirements listed above are particularly important for the economic viability of the machine or process operation. A case which speaks for itself, the system shown in Figure 1-10, shows why programmable controllers are easily favored over relays. The implementation of this system using electromechanical standard and timing relays would have made this control panel a maze of large bundles of wires and interconnections.

Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 13 SECTION 1 Introductory Concepts Introduction to Programmable Controllers CHAPTER 1 Figure 1-10. The uncluttered control panel of an installed PLC system. If system requirements call for flexibility or future growth, a programmable controller brings returns that outweigh any initial cost advantage of a relay control system. Even in a case where no flexibility or future expansion is required, a large system can benefit tremendously from the troubleshooting and maintenance aids provided by a PLC.

The extremely short cycle (scan) time of a PLC allows the productivity of machines that were previously under electromechanical control to increase considerably. Also, although relay control may cost less initially, this advantage is lost if production downtime due to failures is high. PLC S V ERSUS C OMPUTER C ONTROLS The architecture of a PLC's CPU is basically the same as that of a general purpose computer; however, some important characteristics set them apart. First, unlike computers, PLCs are specifically designed to survive the harsh conditions of the industrial environment.

A well-designed PLC can be placed in an area with substantial amounts of electrical noise, electromagnetic interference, mechanical vibration, and noncondensing humidity. Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 14 Courtesy of Omron Electronics, Schaumburg, IL SECTION Introductory 1 Concepts Introduction to Programmable Controllers CHAPTER 1 A second distinction of PLCs is that their hardware and software are designed for easy use by plant electricians and technicians. The hardware interfaces for connecting field devices are actually part of the PLC itself and are easily connected.

The modular and self-diagnosing interface circuits are able to pinpoint malfunctions and, moreover, are easily removed and replaced. Also, the software programming uses conventional relay ladder symbols, or other easily learned languages, which are familiar to plant personnel. Whereas computers are complex computing machines capable of executing several programs or tasks simultaneously and in any order, the standard PLC executes a single program in an orderly, sequential fashion from first to last instruction. Bear in mind, however, that PLCs as a system continue to become more intelligent.

Complex PLC systems now provide multiprocessor and multitasking capabilities, where one PLC may control several programs in a single CPU enclosure with several processors (see Figure 1-11). Figure 1-11. PLC system with multiprocessing and multitasking capabilities. PLC S V ERSUS P ERSONAL C OMPUTERS With the proliferation of the personal computer (PC), many engineers have found that the personal computer is not a direct competitor of the PLC in control applications. Rather, it is an ally in the implementation of the control solution.

The personal computer and the PLC possess similar CPU architecture; however, they distinctively differ in the way they connect field devices. While new, rugged, industrial personal computers can sometimes sustain midrange industrial environments, their interconnection to field devices still presents difficulties. These computers must communicate with I/O interfaces not necessarily designed for them, and their programming languages may not meet the standards of ladder diagram programming. This presents a problem to people familiar with the ladder diagram standard when troubleshooting and making changes to the system.

Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 15 Courtesy of Giddings & Lewis, Fond du Lac, WI SECTION 1 Introductory Concepts Introduction to Programmable Controllers CHAPTER 1 The personal computer is, however, being used as the programming device of choice for PLCs in the market, where PLC manufacturers and third-party PLC support developers come up with programming and documentation systems for their PLC product lines. Personal computers are also being employed to gather process data from PLCs and to display information about the process or machine (i. . , they are being used as graphic user interfaces, or GUIs). Because of their number-crunching capabilities, personal computers are also well suited to complement programmable controllers and to bridge the communication gap, through a network, between a PLC system and other mainframe computers (see Figure 1-12). Main Computer System Personal Computer PLC Figure 1-12. A personal computer used as a bridge between a PLC system and a main computer system. Some control software manufacturers, however, utilize PCs as CPU hardware to implement a PLC-like environment.

The language they use is based on the International Electrotechnical Commission (IEC) 1131-3 standard, which is a graphic representation language (sequential function charts) that includes ladder diagrams, functional blocks, instruction lists, and structured text. These software manufacturers generally do not provide I/O hardware interfaces; but with the use of internal PC communication cards, these systems can communicate with other PLC manufacturers' I/O hardware modules. Chapter 10 explains the IEC 1131-3 standard. Industrial Text and Video Company 1-800-752-8398 www. industrialtext. om 16 SECTION Introductory 1 Concepts Introduction to Programmable Controllers CHAPTER 1 T YPICAL A REAS OF PLC A PPLICATIONS Since its inception, the PLC has been successfully applied in virtually every segment of industry, including steel mills, paper plants, food-processing plants, chemical plants, and power plants. PLCs perform a great variety of control tasks, from repetitive ON/OFF control of simple machines to sophisticated manufacturing and process control. Table 1-1 lists a few of the major industries that use programmable controllers, as well as some of their typical applications.

CHEMICAL/PETROCHEMICAL Batch process Finished product handling Materials handling Mixing Off-shore drilling Pipeline control Water/waste treatment MANUFACTURING/MACHINING Assembly machines Boring Cranes Energy demand Grinding Injection/blow molding Material conveyors Metal casting Milling Painting Plating Test stands Tracer lathe Welding GLASS/FILM Cullet weighing Finishing Forming Lehr control Packaging Processing METALS FOOD/BEVERAGE Accumulating conveyors Blending Brewing Container handling Distilling Filling Load forming Metal forming loading/unloading Palletizing Product handling

Sorting conveyors Warehouse storage/retrieval Weighing Blast furnace control Continuous casting Rolling mills Soaking pit MINING Bulk material conveyors Loading/unloading Ore processing Water/waste management POWER Burner control Coal handling Cut-to-length processing Flue control Load shedding Sorting Winding/processing Woodworking

LUMBER/PULP/PAPER Batch digesters Chip handling Coating Wrapping/stamping Table 1-1. Typical programmable controller applications. Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 17 SECTION 1 Introductory Concepts Introduction to Programmable Controllers

CHAPTER 1 Because the applications of programmable controllers are extensive, it is impossible to list them all in this book. However, Table 1-2 provides a small sample of how PLCs are being used in industry. AUTOMOTIVE Internal Combustion Engine Monitoring. A PLC acquires data recorded from sensors located at the internal combustion engine. Measurements taken include water temperature, oil temperature, RPMs, torque, exhaust temperature, oil pressure, manifold pressure, and timing. Carburetor Production Testing. PLCs provide on-line analysis of automotive carburetors in a production assembly line.

The systems significantly reduce the test time, while providing greater yield and better quality carburetors. Pressure, vacuum, and fuel and air flow are some of the variables tested. Monitoring Automotive Production Machines. The system monitors total parts, rejected parts, parts produced, machine cycle time, and machine efficiency. Statistical data is available to the operator anytime or after each shift. Power Steering Valve Assembly and Testing. The PLC system controls a machine to ensure proper balance of the valves and to maximize left and right turning ratios.

CHEMICAL AND PETROCHEMICAL Ammonia and Ethylene Processing. Programmable controllers monitor and control large compressors used during ammonia and ethylene manufacturing. The PLC monitors bearing temperatures, operation of clearance pockets, compressor speed, power consumption, vibration, discharge temperatures, pressure, and suction flow. Dyes. PLCs monitor and control the dye processing used in the textile industry. They match and blend colors to predetermined values. Chemical Batching. The PLC controls the batching ratio of two or more materials in a continuous process.

The system determines the rate of discharge of each material and keeps inventory records. Several batch recipes can be logged and retreived automatically or on command from the operator. Fan Control. PLCs control fans based on levels of toxic gases in a chemical production environment. This system effectively removes gases when a preset level of contamination is reached. The PLC controls the fan start/stop, cycling, and speeds, so that safety levels are maintained while energy consumption is minimized. Gas Transmission and Distribution.

Programmable controllers monitor and regulate pressures and flows of gas transmission and distribution systems. Data is gathered and measured in the field and transmitted to the PLC system. Pipeline Pump Station Control. PLCs control mainline and booster pumps for crude oil distribution. They measure flow, suction, discharge, and tank low/high limits. Possible communication with SCADA (Supervisory Control and Data Acquistion) systems can provide total supervision of the pipeline. Oil Fields. PLCs provide on-site gathering and processing of data pertinent to characteristics such as depth and density of drilling rigs.

The PLC controls and monitors the total rig operation and alerts the operator of any possible malfunctions. Table 1-2. Examples of PLC applications.

Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 18 SECTION Introductory 1 Concepts Introduction to Programmable Controllers CHAPTER 1 GLASS PROCESSING Annealing Lehr Control. PLCs control the lehr used to remove the internalstressfrom glass products. The system controls the operation by following the annealing temperature curve during the reheating, annealing, straining, and rapid cooling processes through different heating and cooling zones.

Improvements are made in the ratio of good glass to scrap, reduction in labor cost, and energy utilization. Glass Batching. PLCs control the batch weighing system according to stored glass formulas. The system also controls the electromagnetic feeders for infeed to and outfeed from the weigh hoppers, manual shut-off gates, and other equipment. Cullet Weighing. PLCs direct the cullet system by controlling the vibratory cullet feeder, weight-belt scale, and shuttle conveyor. All sequences of operation and inventory of quantities weighed are kept by the PLC for future use.

Batch Transport. PLCs control the batch transport system, including reversible belt conveyors, transfer conveyors to the cullet house, holding hoppers, shuttle conveyors, and magnetic separators. The controller takes action after the discharge from the mixer and transfers the mixed batch to the furnace shuttle, where it is discharged to the full length of the furnace feed hopper. MANUFACTURING/MACHINING Production Machines. The PLC controls and monitors automatic production machines at high efficiency rates. It also monitors piece-count production and machine status.

Corrective action can be taken immediately if the PLC detects afailure. Transfer Line Machines. PLCs monitor and control all transfer line machining station operations and the interlocking between each station. The system receives inputs from the operator to check the operating conditions on the line-mounted controls and reports any malfunctions. This arrangement provides greater machine efficiency, higher quality products, and lower scrap levels. Wire Machine. The controller monitors the time and ON/OFF cycles of a wiredrawing machine. The system provides ramping control and synchronization of electric motor drives.

All cycles are recorded and reported on demand to obtain the machine's efficiency as calculated by the PLC. Tool Changing. The PLC controls a sychronous metal cutting machine with several tool groups. The system keeps track of when each tool should be replaced, based on the number of parts it manufactures. It also displays the count and replacements of all the tool groups. Paint Spraying. PLCs control the painting sequences in auto manufacturing. The operator or a host computer enters style and color information and tracks the part through the conveyor until it reaches the spray booth.

The controller decodes the part information and then controls the spray guns to paint the part. The spray gun movement is optimized to conserve paint and increase part throughput. MATERIALS HANDLING Automatic Plating Line. The PLC controls a set pattern for the automated hoist, which can traverse left, right, up, and down through the various plating solutions. The system knows where the hoist is at all times. Table 1-2 continued. Industrial Text and Video Company 1-800-752-8398 www. industrialtext. com 19 SECTION 1 Introductory Concepts Introduction to Programmable Controllers CHAPTER 1

Storage and Retrieval Systems. A PLC is used to load parts and carry them in totes in the storage and retrieval system. The controller tracks information like a lane numbers, the parts assigned to specific lanes, and the quantity of parts in a particular lane. This PLC arrangement allows rapid changes in the status of parts loaded or unloaded from the system. The controller also provides inventory printouts and informs the operator of any malfunctions. Conveyor Systems. The system controls all of the sequential operations, alarms, and safety logic necessary to load and circulate parts on a main line conveyor.

It also sorts products to their correct lanes and can schedule lane sorting to optimize palletizer duty. Records detailing the ratio of good parts to rejects can be obtained at the end of each shift. Automated Warehousing. The PLC controls and optimizes the movement of stacking cranes and provides high turnaround of materials requests in an automated, high-cube, vertical warehouse. The PLC also controls aisle conveyors and case palletizers to significantly reduce manpower requirements. Inventory control figures are maintained and can be provided on request. METALS Steel Making.

The PLC controls and operates furnaces to produce metal in accordance with preset specifications. The controller also calculates oxygen requirements, alloy additions, and power requirements. Loading and Unloading of Alloys. Through accurate weighing and loading sequences, the system controls and monitors the quantity of coal, iron ore, and limestone to be melted. It can also control the unloading sequence of the steel to a torpedo car. Continuous Casting. PLCs direct the molten steel transport ladle to the continuouscasting machine, where the steel is poured into a water-cooled mold for solidification. Cold Rolling.

PLCs control the conversion of semifinished products into finished goods through cold-rol