Computers in Process Control

Table of Contents

Lesson One History and Overview........3

Lesson Two Small Computers in Process Control........19

Lesson Three DCS Architecture........35

Lesson Four DCS Configuration and Operation........51

Lesson Five Systems and Applications Integration........67

PREVIEW COPY

© Copyright 1993, 1997, 2001 by TPC Training Systems, a division of Telemedia, Inc.

All rights reserved, including those of translation.

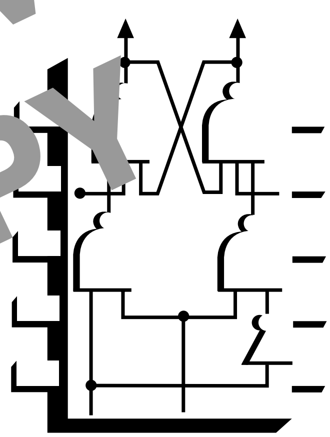
Printed and videotaped courseware are subject to the copyright laws of the United States. You are not authorized to make any copies of this material. If you do, then you are subject to the penalties provided under the copyright law, which include statutory damages up to $50,000 for each infringement of copyrighted material, and also recovery of reasonable attorneys' fees. Further, you could be subject to criminal prosecution pursuant to 18 U.S.C. § 2319.

COMPUTERS IN PROCESS CONTROL

Lesson One

History and Overview

PREVIEW COPY



TPC Training Systems

28401

Lesson

1 History and Overview

TOPICS

Introduction
Development of Computers in Process Control
Business Computer Experiments
Supervisory Control and Data Acquisition (SCADA)
Microprocessor-Based Instruments
Distributed Control
Personal Computers
Programmable Logic Controllers
Artificial Intelligence, Expert Systems, and Fuzzy Logic
Integrated Control Systems

PREVIEW COPY

OBJECTIVES

After studying this Lesson, you should be able to:

- Discuss the history of the application of computers to continuous and batch process control.
- Describe the function of an RTU in a SCADA system.
- Describe the development of distributed control systems from microprocessor-based instruments, including programmable logic controllers.
- Compare the hardware, operating systems, software, and applications of a PC with a household VCR.
- Compare the concepts of artificial intelligence, expert systems, and fuzzy and crisp logic.

KEY TECHNICAL TERMS

Supervisory control 1.09 the use of a computer to adjust the setpoints of conventional controllers

DDC (direct digital control) 1.10 the use of a computer to adjust the position of a final control element

SCADA (supervisory control and data acquisition) 1.12 computer control applied over very long distances

RTU (remote terminal unit) 1.13 the intelligent working element in a SCADA system

DCS (distributed control system) 1.22 a collection of small computers connected by a network to form a system specifically designed for process control

AI (artificial intelligence) 1.48 a programming method that makes a computer appear to think or reason like a human

Fuzzy logic 1.51 a programming method that allows the computer to evaluate by degrees, not just by discrete binary conditions

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Computers, in one form or another, are in practically everything you work or play with, drive, look at, or listen to, so it is easy to forget how new they really are. Computers as we know them today have been available only since the late 1970s, and became important to process control only in the 1980s.

Computer technology has progressed at an incredible pace. A large business computer of the mid-1960s filled a room, had 8000 to 16,000 memory locations, and performed in milliseconds. Today, a memory-bank wristwatch may have hundreds of thousands of memory locations, a desktop personal computer can have hundreds of millions of memory locations, and the performance of both is measured in microseconds.

This explosive development has strained computer terminology. If "micro" means very small, is a pocket calculator a "microcomputer" when current pocket calculators have more memory and speed than some of the computers that controlled the space program's first moon landing? Few computer terms have any standard, universal, or constant meanings, and it is important to understand these terms as used. This Lesson will attempt to clarify terms used throughout this Unit.

Introduction

1.01 Prior to the emergence of computer-based programmable logic controllers (PLCs) and distributed control systems (DCSs) in the late 1970s, "instruments" and "controls" were distinctly different and manufacturing processes were clearly separated. Instruments had meters and gauges, while controls had switches and lights and provided feedback control functions. Continuous processes dealt with materials that flowed (liquid chemicals, for example), while discrete processes dealt with materials that were carried, mainly machined parts. Data acquisition for record keeping and quality control were considered part of the business operations, not part of the process control system.

PREVIEW COPY

1.02 The first computer-based devices were designed to preserve these distinctions and mimic the older equipment they replaced, and considerable effort went into hiding the computer from the user, at least in offices. Very quickly, however, the distinctions began to disappear from both the processes and the control equipment as plant computer installations grew larger and integrated control systems developed to serve them.

1.03 This Unit will focus on computers used to control continuous processes (for example, petroleum refining and chemicals production) and batch processes (for example, food processing and pharmaceuticals production). These are often called *wet* processes and use materials that flow through pipes, ducts, and valves. Older continuous processes were managed by instruments and maintained by a plant's instrument department. While many of the older plants still exist, modern processes are managed by microprocessor-based instruments and distributed control systems. They are still maintained by the instrument department, which now includes personnel with computer expertise.

1.04 This Unit will deal less with the discrete processes used to make machined parts or to manufacture appliances, bicycles, and cars, for example. These *dry* processes use materials that are carried mainly by conveyors or robots. Older discrete processes were managed by electrical controls and maintained by a plant's electrical department. Such processes are now managed by programmable logic controllers, discussed briefly in this Lesson to clarify terminology.

1.05 This Unit is not about computers by themselves. It will deal with designs, operating systems, programming, data transmission, networking, installation, and repair only to the extent needed to understand the application of computers in process control. However, data transmission is the subject of another Unit in this Course.

Development of Computers in Process Control

1.06 Prior to World War II, processing plants were relatively small and easily managed with the pneumatic

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Fig. 1-1. Data acquisition

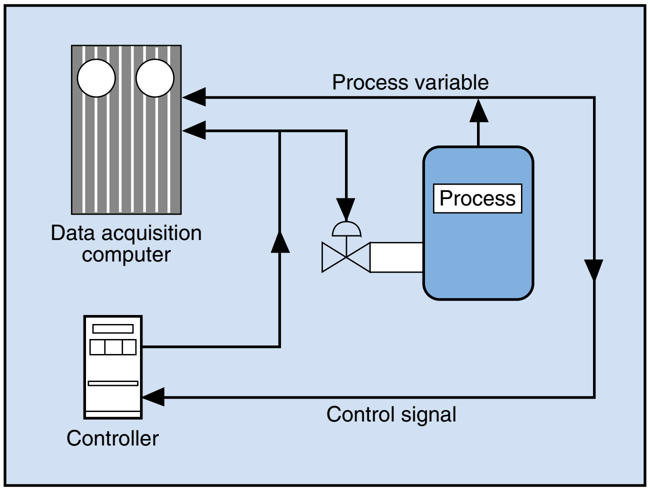
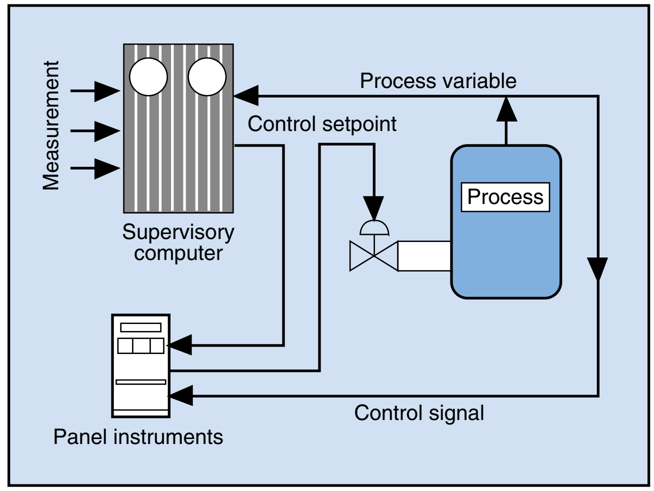


Fig. 1-2. Supervisory control



instruments that had been developed in the 1930s. The war effort created much larger facilities and the need for the faster, more capable electronic instruments that were developed after the war. Plants continued to grow in size and complexity, requiring larger control rooms that sometimes developed into entirely separate control buildings with large staffs.

1.07 The paperwork requirements of business—payrolls, taxes, inventory control, and so on—also grew, and some plants used large (for the time) computers to manage them. These business computers often had free time available, and engineering theories began to develop for their use in process control. There were compelling reasons to pursue these theories, and most of them remain valid today. Objectives were to have:

- more capability
- faster operation
- high reliability
- smaller control rooms
- lower installation costs
- reduced operator requirements
- greater flexibility for change and expansion
- ability to do more complex control strategies.

Business Computer Experiments

1.08 The earliest applications of business computers for process control were for *data acquisition*, shown in Fig. 1-1, bringing process measurements of temperatures, pressures, flow rates, and so on into the computer. This alone was an engineering challenge because computers are digital devices in an analog world. Computers understand only discrete logical conditions (for example, ON/OFF, TRUE/FALSE, and YES/NO), while process values are analog (0 to 200 degrees, 50 to 500 pounds per square inch, or 0 to 15 gallons per minute).

1.09 Once process measurement data were available in the computer, control strategies could be developed. In the experimental phases, the strategy was to determine a control setpoint with the computer and transmit that setpoint to the pneumatic or electronic analog controller in the plant's control room. This could be done fairly easily by equipping the controller with a stepping motor geared to its setpoint knob. The analog controller determined the control output and the entire existing control loop remained unchanged. This approach, shown in Fig. 1-2, became known as *supervisory control*.

1.10 As knowledge and confidence grew, computers were programmed to use process measurement data to calculate the required control output and transmit that value directly to a final control element (usually a valve), as shown in Fig. 1-3. This approach became known as *direct digital control* (*DDC*).

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

The DDC controller output went to the valve. The analog control loop was completely bypassed, although it always remained in place and operative for backup purposes. In most cases, these experiments required dedicated business-style computers, but they had no business applications.

1.11 Only the largest and richest industries were able to perform these experiments. The equipment was limited, the programming effort was immense, and the void between process knowledge and computer expertise was large and often complicated by a desire of the business computer departments to keep control of this new application.

Application 1-1

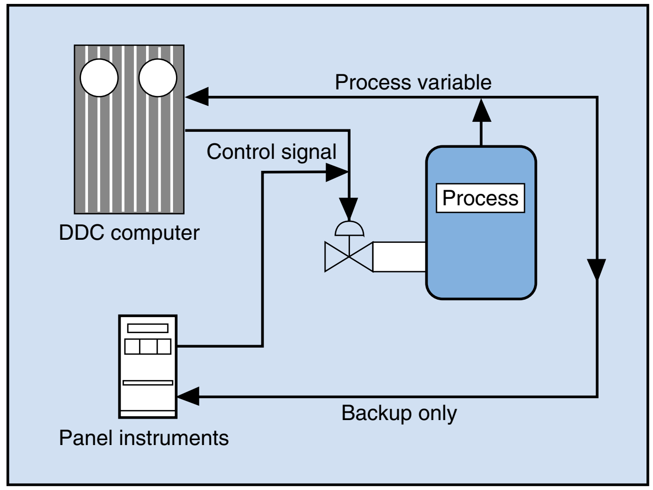
A brand new experimental processing plant was built in the mid-1960s to be run entirely under direct digital control by computer. The computer was programmed by experts to order raw material deliveries, control the continuous process, and package the product. This process previously was characterized by high personnel requirements and significant waste product, and computer control was intended to reduce both.

During trials, the process started up successfully, ran briefly, and shut down automatically. This happened repeatedly, but nothing could be found wrong with the plant equipment or the computer. The cause of the shutdowns was found when someone realized that the computer program had been written to reduce waste product to a minimum, and there was zero waste product when the process was shut down. The computer program was modified to allow a small amount of waste product, and this plant ran successfully for many years. After transferring the technology, so did the old plant.

Supervisory Control and Data Acquisition (SCADA)

1.12 One survivor of the pioneering experiments is *SCADA* (*supervisory control and data acquisition*),

Fig. 1-3. Direct digital control (DDC)



PREVIEW COPY

which continues to be used in certain industries—for example, electric power distribution, gas and oil pipelines, and off-shore drilling. These industries are characterized by facilities connected over hundreds or thousands of miles. Figure 1-4 on the following page shows a SCADA system.

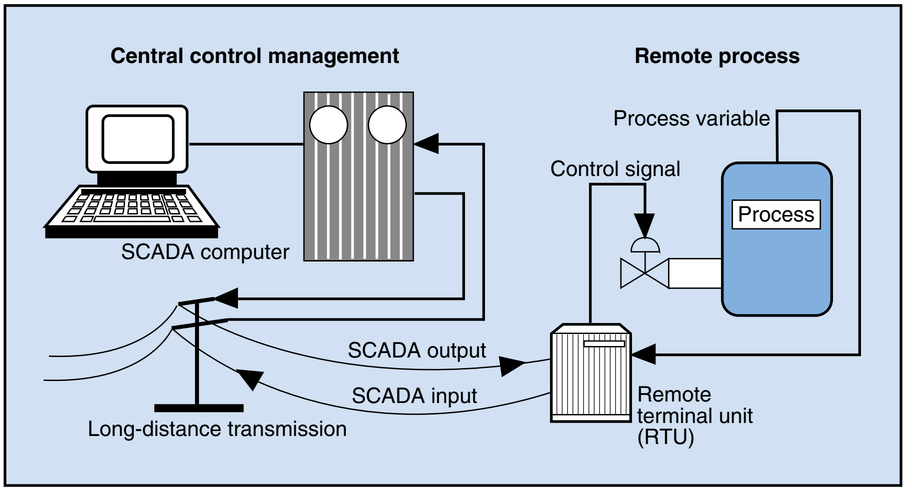
1.13 SCADA systems use large mainframe computers at a central location and *remote terminal units* (*RTUs*) at the distant facilities, which are generally unattended. The RTUs gather and store local data and transmit them to the central computer on request, although emergency conditions can be transmitted without a computer request. The central computer analyzes the data it receives and sends instructions back to the appropriate RTUs.

1.14 Remote terminal units are intelligent devices. Once an RTU has its instructions (for example, a setpoint value to be maintained) from the central computer, it is able to obtain input data, make calculations on the data, and produce control outputs, all without further assistance from the central computer. If the data transmission system fails, the RTU maintains the process at the current setpoints. The RTU holds information about events in its own memory and can transmit this information to the computer on request. If an emergency condition (an alarm) occurs, the RTU can interrupt the supervisory function of the SCADA computer and ask for assistance.

1.15 The computer in a SCADA system acts like a human supervisor with a crew of workers at several

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Fig. 1-4. Supervisory control and data acquisition (SCADA)



widely separated job sites, and the RTUs are like highly competent workers. The supervisor can call each worker with instructions and then leave it up to the worker to do the job. The supervisor can call each worker on a regular schedule or at his or her convenience to find out how the site work is progressing. Any worker can call the supervisor at any time if something goes wrong and help is needed. Finally, the supervisor makes up a summary report for the whole project and presents it to the manager.

1.16 Both the hardware and the software of SCADA systems are usually custom-built to the owner's specifications. SCADA system owners always

Application 1-2

East coast people often don't believe it, but Lincoln, Nebraska, and Tulsa, Oklahoma, are seaports. The U.S. Corps of Engineers created a navigable waterway from Lincoln to the Gulf of Mexico. A series of dams and artificial lakes is used to keep the water level constant in the waterway.

Electric power companies use the water system for a hydroelectric method of power generation called pumped storage. When excess electric power is available, usually at night, they pump water up from a Corps of Engineers lake to another artificial lake of their own on higher ground and store it there. When extra electric power is needed, they let the water flow back down through turbine generators.

Pumped storage facilities are in remote locations and are unattended. However, the control system is quite sophisticated and can account for variable water levels, flow rates, and power requirements. Originally, an operator was dispatched in a pickup truck (preferably four-wheel drive) to stop or start the pumping or generating operation. Driving away from a running facility was an act of faith.

Some of the first SCADA systems were applied to pumped storage and proved to be very successful. Intelligent remote terminal units at the dam itself were able to meet the control requirements. These RTUs could be started and stopped by an operator in a control room miles away. They reported lake levels, flow rates, and power generation at the operator's request. If something went wrong, an RTU could call for help.

The long-range transmission was by telephone wires where possible, but many really remote facilities required microwave (radio) transmission. In any case, many truck transmissions were saved.

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Fig. 1-5. Microprocessor

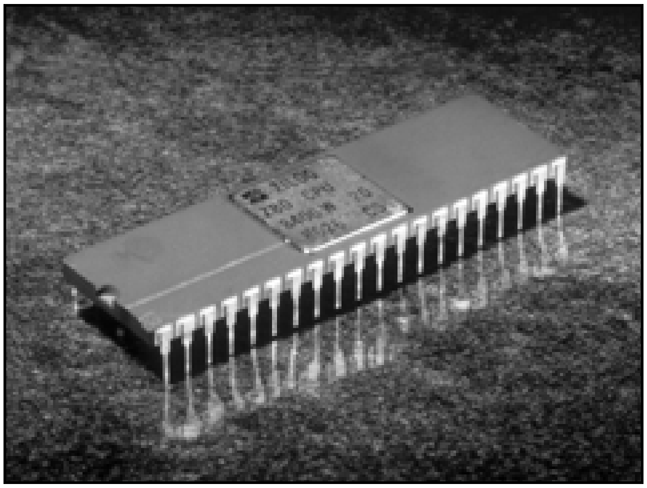


Fig. 1-6. Early microprocessor-based controller

employ high-level computer experts who are capable of operating, maintaining, and modifying their systems.

1.17 Very recently some distributed SCADA systems have been introduced, made possible by the increased power of off-the-shelf computers and the acceptability of open systems. *Open systems* are designed to use standard hardware and as much standard software as possible to minimize the difficulty, expense, and development time required for custom-built systems. "Open" implies a feedback protocol that lets equipment of different manufacturers communicate with each other. This arrangement is an extension of distributed control, discussed later in this Lesson.

PREVIEW COPY

Microprocessor-Based Instruments

1.18 The meaning of the term *microprocessor* has changed, but the earliest microprocessors, like the one shown in Fig. 1-5, were the basic components of small computers that could be built up to perform specific functions. A pocket calculator is an example. Today, the entire calculator, or a similar device, may be called a microprocessor.

1.19 The first microprocessor-based instruments were designed as replacements for electronic analog process controllers. The experiments with supervisory control and direct digital control created a demand for instruments that could communicate directly in the digital world of the computer.

1.20 Also, there were significant manufacturing advantages to an instrument that could be built in volume to standard specifications and customized simply by loading a software program. Previously, each controller was built to order, a lengthy and expensive process, and it was seldom practical to make changes after the instrument was manufactured.

1.21 As shown in Fig. 1-6, early models were nearly exact replacements for current single-loop controllers. They had all the functions of a "fully loaded" analog controller, and desired options could be selected as needed. As users became accustomed to these instruments, and as microprocessor speed and capability increased, microprocessor-based controllers were designed to control four, eight, and up to 64 different loops from a single controller.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

1-1. PLCs and DCSs emerged in the late ________.	1-1. 1970s Ref: 1.01
1-2. Traditionally, "instruments" were used in ________ processes and "controls" were used in ________ processes.	1-2. CONTINUOUS or WET; DISCRETE or DRY Ref: 1.03, 1.04
1-3. The earliest applications of computers for process control were for ________.	1-3. DATA ACQUISITION Ref: 1.08
1-4. One survivor of the earliest applications of computers to process control is ________.	1-4. SCADA Ref: 1.12
1-5. A(n) ________ is the intelligent remote device used in a supervisory control and data acquisition system.	1-5. RTU (REMOTE TERMINAL UNIT) Ref: 1.13
1-6. In ________ systems, equipment of different manufacturers can communicate with each other.	1-6. OPEN Ref: 1.17
1-7. The earliest ________ were the basic components of small computers.	1-7. MICROPROCESSORS Ref: 1.18
1-8. Early DCS controllers could handle up to ________ loops.	1-8. 64 Ref: 1.21

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Distributed Control

1.22 Distributed control came about because with DDC if the computer failed, the whole plant was shut down. You can consider *distributed control* to be a concept and a *distributed control system* (*DCS*) to be hardware. Oddly, perhaps, the hardware came first.

1.23 A typical first-generation distributed control system was, basically, a series of microprocessor-based multiloop controllers distributed along a communications network, often called a *data highway*, as shown in Fig. 1-7. Sampling techniques made it possible for each of these distributed controllers to replace eight single-loop controllers. Now a system could control up to 64 different loops, creating a mass of data. Therefore, an operator's station, resembling a personal computer, was included on the network to display the control operations being performed.

1.24 Early distributed control systems were designed by and built up from components by their manufacturers. Like today, even the operator's stations were built up from cathode-ray tubes, circuit boards, special cabinets, and custom-built keyboards.

1.25 Control functions (*algorithms*) were virtually identical to the traditional proportional-integral-derivative (*PID*) capabilities of analog controllers, but also added many new functions. The operator station displays were designed by the manufacturer to resemble photographs of the old familiar control panels. The keyboards were labeled to resemble the old analog instrument knobs and buttons, and often had no traditional alphanumeric typing keys at all.

Application 1-3

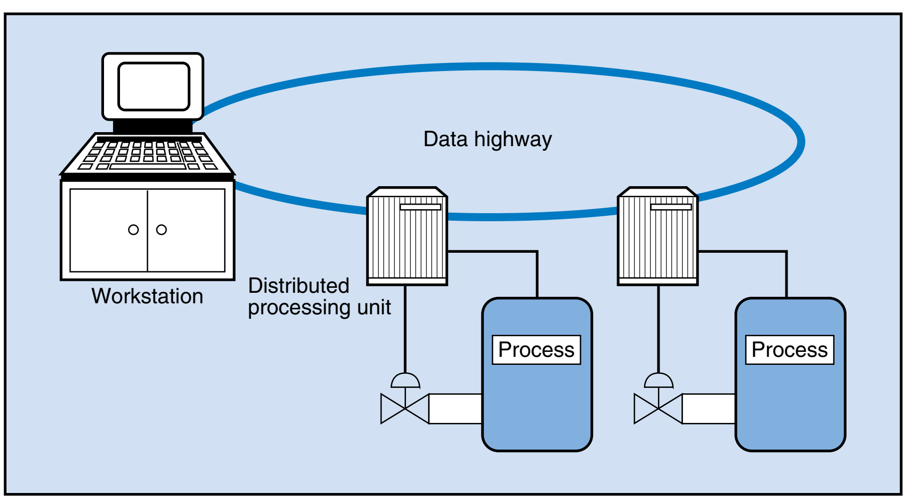
Back in the early 1980s, a chemical company called Progressive Processing purchased one of the first small distributed control systems put on the market. After several months, the vendor sales manager noticed that Progressive was buying more analog instruments than usual. Concerned that Progressive was unhappy with the DCS, he decided to investigate. He called Progressive's instrument engineer.

He asked if the DCS was working out OK. "Yes, it's great." "What processes have you installed it on?" "Well, we haven't installed it—not exactly." "I beg your pardon?" asked the sales manager. The instrument engineer explained that Progressive had lots of ideas about improving their many small processes, but it had always been too expensive and time-consuming to buy and install instrumentation for the experiments to prove these ideas.

When they acquired their DCS, they were able to connect and configure it to try out their ideas in various ways. When the experiments were successful, they recorded the instrument specifications

PREVIEW COPY

Fig. 1-7. Distributed control



This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

from the DCS configuration and ordered the corresponding analog instruments needed to improve that process. They then disconnected the DCS, erased its configuration, and started again on another process.

This early DCS helped its user improve its operations and profitability. Progressive doesn't use many analog instruments today, but they have expanded their DCS several times.

1.26 DCSs provided the same benefits that had led to the earliest experiments with business computers for process control. Panel-building costs had reached $1000/ft and wiring approached $100/wire within the panel, so the installation of a typewriter-sized operator's station in a network cable was financially attractive. And, after installation, a single operator could view, adjust, or respond to any operation without leaving his or her chair.

1.27 Later-generation DCSs appeared rapidly and grew in size and complexity. The original 64-loop limit has grown to 2000 or more, and some plants have over 25,000 indicator and data acquisition points. Color displays and pictorial representations of plant operations are universal and have themselves become an engineering specialty. DCSs have acquired some of the capabilities of programmable logic controllers, discussed later in this Lesson. Data acquisition, reporting and statistical capabilities, logging, and printing are included. In addition, all DCSs can communicate with business-management computers. This means that management has access to real-time operations data. Decisions can be made by the minute instead of by the week.

1.28 The concept of distributed control continued to develop as systems grew. At the same time, suitable off-the-shelf equipment of sufficient power at low cost became available. Practically all the hardware and software needed for a distributed control system can be purchased. Therefore, suppliers can concentrate on applying their process knowledge to the design of operating software for commercial hardware.

Personal Computers

1.29 Present-day personal computers are far more powerful than some of the business computers used by the largest industries in their early experiments with DDC. Today's reduced costs, improved hardware, and greatly simplified software permit even the smallest industries to implement successfully some of the concepts of DDC with personal computers.

1.30 Software is readily available to enable personal computers to control laboratories, specialty operations (for example, fermenters), and more conventional processes. Commercial input/output equipment and suitable sensors and final control elements make do-it-yourself systems practical and economical.

1.31 Personal computers now are available in special packages from their manufacturers or repackagers as *hardened* units that can survive harsh industrial environments. Some even can operate submerged in water.

1.32 If you are unfamiliar with personal computers (PCs) or know them only as video games or word processors, you may wonder how they can be used as process control instruments. Figure 1-8 draws a reasonable analogy between a PC and a video cassette recorder (a VCR, which is itself a small computer) to help explain this somewhat unusual application. The paragraphs that follow explain this analogy.

1.33 **Hardware.** When you unpack a new VCR or a new PC, you hold its hardware in your hands:

VCR	PC
VCR unit	Central processing unit (CPU)
Remote control	CRT display and keyboard
Cables	Cables

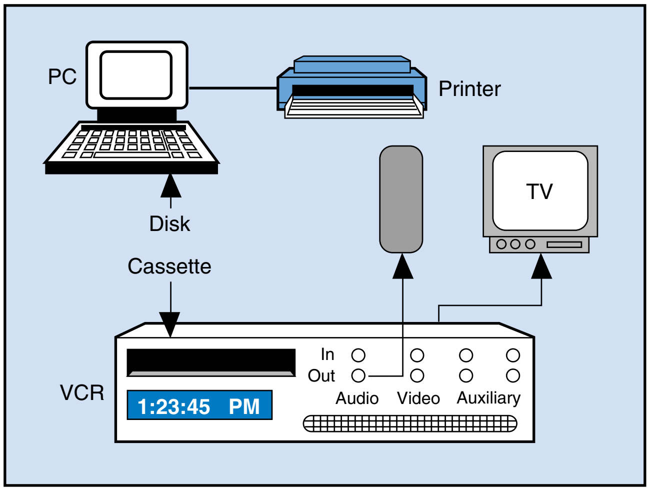
When you connect the parts and turn the power on, some "signs of life" appear (for example, a clock), but the VCR cannot play a video tape yet and the PC cannot yet compute.

1.34 **Firmware.** The initial displays are created on microprocessor-based equipment by a set of nonvolatile instructions called *firmware* stored within it in read-only memory (ROM). The term *nonvolatile* means permanent—that is, firmware is not lost when the power is turned off. An operating system stored in ROM is an example of firmware.

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Fig. 1-8. Analogy between VCR and PC



1.35 Firmware enables the machine to complete the first part of its start-up procedure, enabling it to accept further instructions. This start-up procedure is called *booting*, a term that comes from the old expression "lifting oneself up by one's own bootstraps." Software provides the additional instructions.

1.36 **Operating systems.** VCRs have distinct operating systems. Some use Beta, others use VHS, and still others use less familiar formats—for example, 8-millimeter and 1/2-in. formats. Similarly, some PCs use DOS (disk operating system), others use UNIX (an operating system originated by AT&T), and still others use other formats.

1.37 An operating system enables a microprocessor to function by telling it where to get data, how to interpret and process the data, where to store results internally, and how to send information to a person (or an industrial process) in the world outside. The operating system also determines what application software the equipment can accept and operate.

1.38 **Software.** Software is the set(s) of instructions loaded into the machine after it is started from its built-in firmware. There are several categories, including the following:

- system software
- application software
- utility software.

All kinds of software are commonly called *programs*, but the term is not really proper for system software.

1.39 *System software* is the term for an operating system. System software is "read only" and cannot be changed by the user without special procedures. System software is permanently installed in VCRs and some PCs, but most PCs require that system software be loaded from a floppy or hard disk at start-up. In any case, the operating system is not sufficient to make the equipment operational, and so additional software (applications or utilities) is needed.

1.40 *Application software* enables the computer to perform specific tasks. It is a misconception to think that the machine is or does something specific by itself. You know that a VCR can act as a movie projector, but it also can be a movie camera (recorder), a TV tuner, or a tape editor. A personal computer can be a word processor, but it also can be an industrial process control system.

1.41 When a video cassette is loaded into a VCR, the TV screen displays whatever was recorded on the cassette. This might be a movie, but it also could be a display that turns the TV into a dry aquarium full of colorful exotic fish. In a similar manner, when application software is loaded into a PC from a disk (floppy or hard), the PC runs whatever was recorded on the disk. This might be a word processing program, but could be a spreadsheet or a process control program. Other kinds of application software include databases and computer-aided design (CAD) programs.

1.42 *Utility software* generally adds to or improves the capability of standard software. A VCR utility might display test patterns and color bars to aid with adjustments. PC utilities include clocks and calendars, various cursor shapes, recovery utilities, and many others.

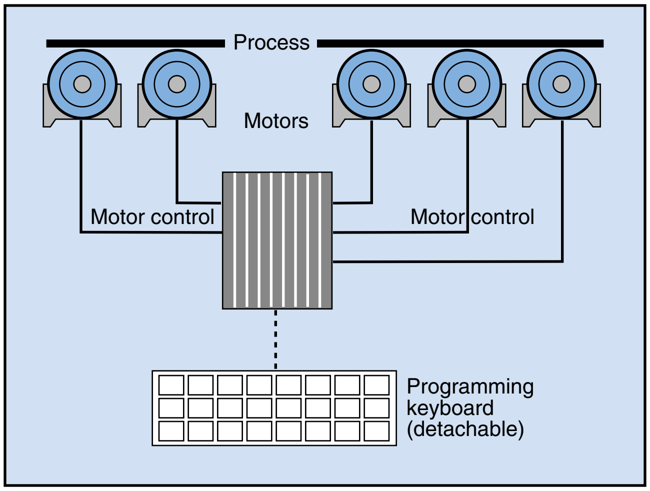
1.43 You might hear references to vaporware. *Vaporware* is a special category of software that does not exist (yet). A VCR movie might be advertised ("Coming Soon!") before it is actually available. A computer program might be announced when it is planned, but it may never materialize.

1.44 Although not always strictly analogous, other comparisons can be made that may help you understand how a personal computer can function as an industrial process control system on the following page:

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Fig. 1-9. Programmable logic controller (PLC)



- A VCR connected to a cable broadcasting system or satellite dish is like a personal computer connected to a local area network or wide area network (*LAN* or *WAN*).

- VCRs have input/output (I/O) systems (video in/out, audio in/out, speaker, etc.), as do PCs (printer, mouse, signals to equipment).

- VCRs operate with peripherals—cameras for input, special monitors for output, duplicators to make multiple cassettes for sale. PCs operate with peripherals—a personal computer used for process control uses a data acquisition system for input, a signal conditioning system for input and/or output, and control valves to help manufacture chemicals for sale.

Programmable Logic Controllers

1.45 Programmable logic controllers, shown controlling motors in Fig. 1-9, were originally designed to replace the switches and push buttons of motor control centers. They are used mostly in discrete manufacturing. However, their success helped make microprocessors and computers practical in industrial applications, enabling the development of distributed control systems.

1.46 These devices have developed enough over time to require several name changes. *Logic* to a computer means ON or OFF (1 or 0), and the original programmable logic controllers (PLC) were limited to ON/OFF operations. PLCs then acquired some limited analog capabilities (for example, PID control) and became known as P(L)Cs—programmable (mostly logic) controllers. Current devices have complete digital and analog capabilities and are known as PCs (programmable controllers), easily (and wrongly) confused with personal computers, also called PCs.

1.47 The distinction between programmable control and distributed control is blurred. It may be one of size (the largest DCSs are larger than the largest PCs), but the clearest distinction remains the application.

Artificial Intelligence, Expert Systems, and Fuzzy Logic

1.48 *Artificial intelligence* (*AI*) refers to computer programs that appear to think or reason like humans. The concept can lead to philosophical controversy, but process control applications of AI consider only the results. If a computer closes the same valve that a human would close under the same circumstances, it is using artificial intelligence. Because it is impossible to emulate the human brain, all apparent process control AI is really an application of expert systems.

1.49 *Expert systems* are a subset of AI. They are constructed (programmed) by interviewing a human expert and then storing his or her conclusions in a computer, as in the following examples:

"Doctor, what is your diagnosis of these patients?"

1. His eyes are closed. He is not moving. He is breathing.	2. His eyes are closed. He is not moving. He is not breathing.
"HE IS SLEEPING."	"HE IS DEAD."

"Engineer, what do you think is wrong with these processes?"

1. The tank is empty.

   "THE PUMP IS STOPPED."

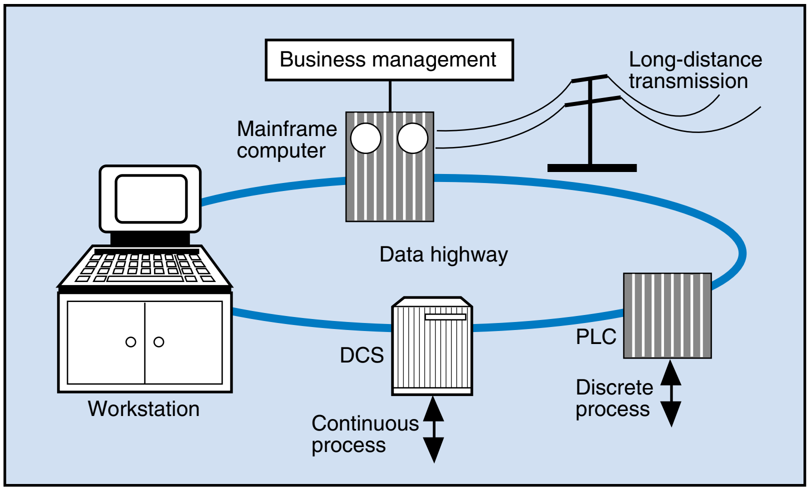
2. The tank is empty.
   The pump is running.

   "THE VALVE IS CLOSED."

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Fig. 1-10. Integrated control



3. The tank is empty.
The pump is running.
The valve is open.

"THE INLET PIPE IS PLUGGED."

1.50 Expert systems can guide a computer automatically or can guide a human operator to make the best response to an unfamiliar situation. They can be successful whenever combinations of symptoms lead to a specific conclusion, as is usually true in process control.

1.51 *Fuzzy logic* is a programming method that allows the computer to evaluate by degrees, not just by two-state (discrete, binary) conditions. Conventional two-state logic is called *crisp logic*. Crisp logic might say, "The pressure is 100 psig."/"The pressure is 10 psig." Fuzzy logic might say, "The pressure is quite high."/"The pressure is quite low." Computers still cannot understand "quite," "some," or "very," but they can use the familiar "on a scale of 1 to 10" method to evaluate a condition by degrees.

1.52 Fuzzy logic is used to model processes or controllers where the interaction between variables or the variables themselves are largely unknown and the processes are too complex or too nonlinear to model simply. Successful fuzzy controllers have been developed using knowledge from operators and control engineers. This success is being expanded, and the true potential of fuzzy modeling is still evolving.

Integrated Control Systems

1.53 Before computers entered the scene and began to be widely used in process control, several independent functions were applied to the process, including:

- research and development
- operation
- data acquisition
- record keeping
- inventory management
- quality control
- financial management.

The development of computer capabilities has made it possible to combine all of these functions, and more, into a single system, as shown in Fig. 1-10. Integrated control systems appear to be the current trend.

1.54 Superficially, an integrated control system appears to be no different from a DCS. Within it, however, are the loop control functions for continuous and batch processes, programmable controller functions for discrete operations, data acquisition and storage, powerful computational and analytical abilities, and the multipurpose capabilities of a large computer. Integrated systems are the subject of the final Lesson in this Unit.

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

1-9. Algorithms of early DCSs were almost identical to the ________ capabilities of analog controllers.	1-9. PID Ref: 1.25
1-10. Personal computers are enabled to perform process control by means of ________.	1-10. SOFTWARE Ref: 1.30
1-11. The nonvolatile instructions that permit booting a computer are an example of ________.	1-11. FIRMWARE Ref: 1.35
1-12. DOS and UNIX are kinds of ________.	1-12. OPERATING SYSTEMS Ref: 1.36
1-13. What kind of software enables a computer to perform specific tasks?	1-13. APPLICATION Ref: 1.40
1-14. Logic to a PLC means ________ or ________ (1 or 0).	1-14. ON; OFF Ref: 1.46
1-15. The term PC can mean ________ or ________, depending on the context.	1-15. PERSONAL COMPUTER, PROGRAMMABLE CONTROLLER Ref: 1.46
1-16. ON/OFF are terms in ________ logic, and quite high/quite low are terms in ________ logic.	1-16. CRISP; FUZZY Ref: 1.51

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. The first computers used for process control were

- ☐ a. business computers
- ☐ b. dedicated computers
- ☐ c. microcomputers
- ☐ d. personal computers

1-2. Which of the following computer control systems requires the analog controller to determine the control output?

- ☐ a. DCS
- ☐ b. DDC
- ☐ c. SCADA
- ☐ d. supervisory control

1-3. SCADA systems typically span

- ☐ a. an entire plant
- ☐ b. many miles
- ☐ c. part of a plant
- ☐ d. up to 5000 ft

1-4. If the data transmission system fails in a SCADA system, the RTUs

- ☐ a. also fail
- ☐ b. maintain the process at the current setpoints
- ☐ c. reduce the process to a safe level
- ☐ d. shut down the process

1-5. Early microprocessor-based loop controllers

- ☐ a. made pneumatic controllers almost obsolete
- ☐ b. required very large control panels
- ☐ c. resembled conventional controllers
- ☐ d. used detachable programming terminals

1-6. The control capacity of today's DCS is about ________ loops.

- ☐ a. 8
- ☐ b. 64
- ☐ c. 1024
- ☐ d. 2000

1-7. A hardened personal computer

- ☐ a. cannot be reprogrammed
- ☐ b. has no software
- ☐ c. is specially packaged
- ☐ d. uses a fail-safe operating system

1-8. A computer starts up from its

- ☐ a. firmware
- ☐ b. operating system
- ☐ c. random-access memory
- ☐ d. utility software

1-9. Today's programmable controllers

- ☐ a. are exclusively digital devices
- ☐ b. cannot be integrated into distributed systems
- ☐ c. have extensive analog and digital capabilities
- ☐ d. require personal computers to operate

1-10. Current control systems that combine several previously independent systems are called ________ systems.

- ☐ a. crisp logic
- ☐ b. integrated control
- ☐ c. supervisory control and data acquisition
- ☐ d. supervisory control

PREVIEW COPY

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.

SUMMARY

Discrete manufacturing uses programmable logic controllers. Continuous processes use a wide variety of small computers in smart devices, panelboard instruments, and distributed control systems.

Industries with widely separated facilities use supervisory control and data acquisition systems (SCADA), a survivor of the earliest experiments with business applications for computers. SCADA consists of centralized computers that communicate over long distances with small computers that act as intelligent remote terminal units (RTUs) with independent local process control capabilities.

Early models of microprocessor-based instruments were nearly exact replacements for current single-loop controllers. Distributed control systems (DCSs) developed from a series of multiloop controllers connected by a data highway. Later-generation DCSs manage hundreds more than the original limit of 64 loops.

Personal computers (PCs) may be compared to VCRs. Both have hardware, firmware, operating systems, software, and applications. Proammable logic controllers, originally called PLCs but now also known as PCs, are used mostly in discrete manufacturing and should not be confused with personal computers, despite the confusion in terminology.

Expert systems are based on artificial intelligence (AI), a programming method that makes a computer appear to think or reason like a human. Computer programming uses conventional crisp logic and also fuzzy logic to evaluate a condition by degrees. Today's integrated control combines all the various functions of a plant into a single system.

PREVIEW COPY

Answers to Self-Check Quiz

1-1. a. Business computers. Ref: 1.07

1-2. d. Supervisory control. Ref: 1.09

1-3. b. Many miles. Ref: 1.12

1-4. b. Maintain the process at the current setpoints. Ref: 1.14

1-5. c. Resembled conventional controllers. Ref: 1.21

1-6. d. 2000. Ref: 1.27

1-7. c. Is specially packaged. Ref: 1.31

1-8. a. Firmware. Ref: 1.35

1-9. c. Have extensive analog and digital capabilities. Ref: 1.46

1-10. b. Integrated control. Ref: 1.53

Contributions from the following sources are appreciated:

Figure 1-5 Reproduced by permission © 1980, Zilog, Inc. This material shall not be reproduced without the written consent of Zilog, Inc.

Figure 1-6 Barber-Colman Company Industrial Process Controls

This material is protected by U. S. Copyright law. Copying by any optical, electronic, or other means is illegal without permission.