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Computer Control in the Process Industries

Brian Roffel and Patrick Chin

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COMPUTER CONTROL IN THE PROCESS INDUSTRIES

by Brian Roffel
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PREFACE

Techniques such as dead time compensation, adaptive control, and Kalman filtering have been around for some time, but as yet find little application in industry. This is due to several reasons, including:

- Articles in the literature usually assume that the reader is familiar with a specific topic and are therefore often difficult for the practicing control engineer to comprehend.
- Many practicing control engineers in the process industry have a chemical engineering background and did not receive a control engineering education.
- There is a wide gap between theory and practical implementation, since implementation is primarily concerned with robustness, and theory is not. The user therefore has to build an "expert shell" in order to achieve the desired robustness. Little is published on this issue, however.

This book tries to promote the use of advanced control techniques by taking the reader from basic theory to practical implementation. It is therefore of interest to practicing control engineers in various types of industries, especially the process industry. Graduate and undergraduate students in control engineering will also find the book extremely useful, since many practical details are given which are usually omitted in books on control engineering.

Of special interest are the simulation examples, illustrating the application of various control techniques. The examples are available on a 5–1/4" floppy disk and can be used by anyone who has access to LOTUS 1-2-3.

Chapter 1 is the introduction; Chapters 2 through 6 deal with distributed control system networks, computer system software, computer system selection, reliability and security, and batch and continuous control. Chapter 7 gives an introduction to advanced control. Chapters 8 through 11 deal with dead time compensation techniques and model identification. Chapters 12 through 14 discuss constraint control and design, and the adjustment and application of simple process models and optimization. Chapter 15 gives a thorough introduction to adaptive control, and the last two chapters deal with state and parameter estimation.

This book is a valuable tool for everyone who realizes the importance of advanced control in achieving improved plant performance. It will take the reader from theory to practical implementation.

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CHAPTER 1

Introduction

Computers play an integral part in daily life. With the introduction of the chip they now are within the reach of almost everyone. Computers are being increasingly used in education, which has resulted in much greater familiarity with concepts that were known only to computer specialists 15 years ago. Nevertheless, much misconception exists regarding what a computer can do. Many people think that computers can perform miracles, but efficient software is needed for each specific task that has to be performed. There is also the tendency to use a computer in the manner that a pocket calculator has been used, that is: without knowing how it works you can still use it for many purposes.

One of the problems in many companies today is that managers are not always aware that computers for plant monitoring and control cannot be compared to the IBM-PCs on their desks. The purposes of this book are to illustrate that the introduction of computers in a plant requires much more than the purchase of hardware and software and to introduce some basic concepts that everyone who is involved in plant automation should know.

PRODUCTIVITY VS FLEXIBILITY

Computers are essential if one wants to achieve increased product quality and production flexibility in order to remain competitive. The two key words in today's competitive environment are quality and flexibility. This is also true for the chemical and petrochemical industry. Ten years ago operations were oriented toward production. High volumes were processed at relatively low cost. Even though product quality was not always good, it was less important than volume. Besides, customers did not have the equipment to analyze the product they bought and depended entirely on data provided by the product manufacturer for quality analysis.

However, more sensitive analytical equipment became available at lower prices, enabling many customers to test the materials they purchase. Sometimes, by using statistical quality control techniques, they can even determine if they buy material which has been blended with other material to meet quality requirements.

The next decade will be characterized by decreased demand for products but higher specifications for product quality. The chemical and petrochemical process industry in particular will have to adjust to this situation by producing a larger variety of products at lower volumes with increased quality. To achieve these results effectively and economically, in-plant computers will be necessary for monitoring and improved control.

PROBLEMS IN PLANT AUTOMATION

The introduction of a process computer into a plant for monitoring and control can produce a number of problems. First, financial limitations have to be overcome. Although personal computers are continually decreasing in price, process computers are not. This is probably because they are different from any other type of computer: they are tied to a real process and therefore require extensive checking of hardware and software to make sure that the right outputs are transmitted to the field. Although the hardware may become less expensive, system software becomes more complicated in order to give increased system functionality, and this largely offsets the reduced hardware cost. For example, ten years ago process computers usually communicated with a limited number of black and white consoles. Today's systems support multiple-color operator stations.

The second problem is lack of knowledge. To control a process effectively an in-depth understanding of the process is required. Although some technology is reasonably well developed, e.g., olefins technology, there are many chemical processes which are not well understood. Operators run the plant by experience, but the computer does not have this prior knowledge base. It is important that what has to be controlled is well defined.

In order to develop a system that controls and monitors the plant, experienced personnel who are capable of translating functional specifications for process operation into computer software are required.

The computer system is usually so complicated that personnel are required to maintain and improve the computer software, whereas other specialists develop and maintain the software that runs the plant (application software). Although system software comes with the computer, application software needs to be developed because it is specific for each plant. This often requires a large number of person-years, which is often underestimated.

Another problem is that processes can change. Therefore, the resources have to be available to modify the software in order to deal with the new situation. In these cases, especially, one often finds that software that was developed some time ago is poorly documented or not documented at all. This can lead to a waste of many person-years, and a small change may require as much time as the original design.

ORGANIZATIONAL CHANGE

The introduction of a computer system into a plant must be accompanied by a change in organization. System and application engineers will become a resident part of the plant operating personnel. The system and application engineer supervisor will have a responsible task with a wide range of activities. He must be a technical manager with enough knowledge to stimulate and support the engineers. He will have to keep abreast of new technologies in order to make sure that they can be used whenever the need arises.

On the other hand, he has to relate to process engineers, supervisors, and managers in order to create a team environment in which his engineers can best function. This is often not well understood. In many companies process engineers list their desires for plant automation and expect the application engineers to do the job. Many process supervisors and managers do not understand what is involved in using process computers and underestimate the effort required to design and implement a control, monitoring, and optimization package. Proper decisions can be made only in a team environment.

COST ESTIMATE

Recognizing that plant automation may produce some problems, it is logical to list them all and attack them one by one. After the decisions have been made on organizational change, technical support, and operations support, the computer system requirements for control, monitoring, and information processing should be defined. Once the needs are defined, one can ask for bids from computer vendors. Chapter 6 provides assistance in computer selection.

It is important to realize that the purchase of a computer will generate a number of other costs. An example of the distribution of costs for automation of a chemical plant is given in Giles and Bulloch [1] and shown in Table 1.1. Although these numbers will vary from plant to plant, they clearly indicate that computer hardware and software are only a small portion of the total cost of plant automation. A process computer makes plant automation more feasible than before, but often additional instruments, especially analytical instruments, must be purchased and installed to fully utilize the increased capability.

Table 1.1. Distribution of Costs for a Process Computer System

	Cost (%)
Computer hardware	13%
Process interface	24%
Analytical instruments	11%
Software	18%
Instrumentation engineering	8%
Application engineering	20%

MODERN COMPUTER SYSTEMS

Modern computer systems are characterized by distributed data processing. Figure 1.1 shows the structure of a local plant automation system. It may be connected to a plantwide information and management system that collects data from the various plants and stores it for further processing. The local system can also be connected to local analytical instruments, which usually have their own microcomputer.

The computer system collects data from the plant and processes it for monitoring and control purposes. Signals are converted via D/A and A/D converters, digital to analog, and analog to digital converters.

Usually two data channels are used for communication in order to increase the total system reliability. As will be discussed in a later chapter, data channels are the most critical part of modern computer systems.

There are a number of tasks for the computer system, as shown in Figure 1.2 [2]. Although these tasks will be dealt with in detail in a later chapter, they will be briefly reviewed here.

Planning is the highest level of activity. At this level the distribution of raw materials and products is controlled. The process plants have to be operated in such a way that inventories are maintained. When there are many plants involved, a complex problem is created, which is often solved off-line on a mainframe computer. There is an increasing tendency, however, to perform these activities on an on-line plant management system, which is connected to all process computers.

The next level of activity is control of the mode of operation. This indicates that during a certain period, certain products must be made out of certain raw materials. Each mode of operation can be improved by applying optimization of throughput, and so on. This activity can be done in the process control computer; the optimization of large and complex plants is often performed by a separate computer. The result of the optimization is the calculation of setpoints (desired values) for the lower level of control, e.g., impurities in distillation tower overhead and bottom compositions.

Next is the level where quality control takes place. A large part of this book

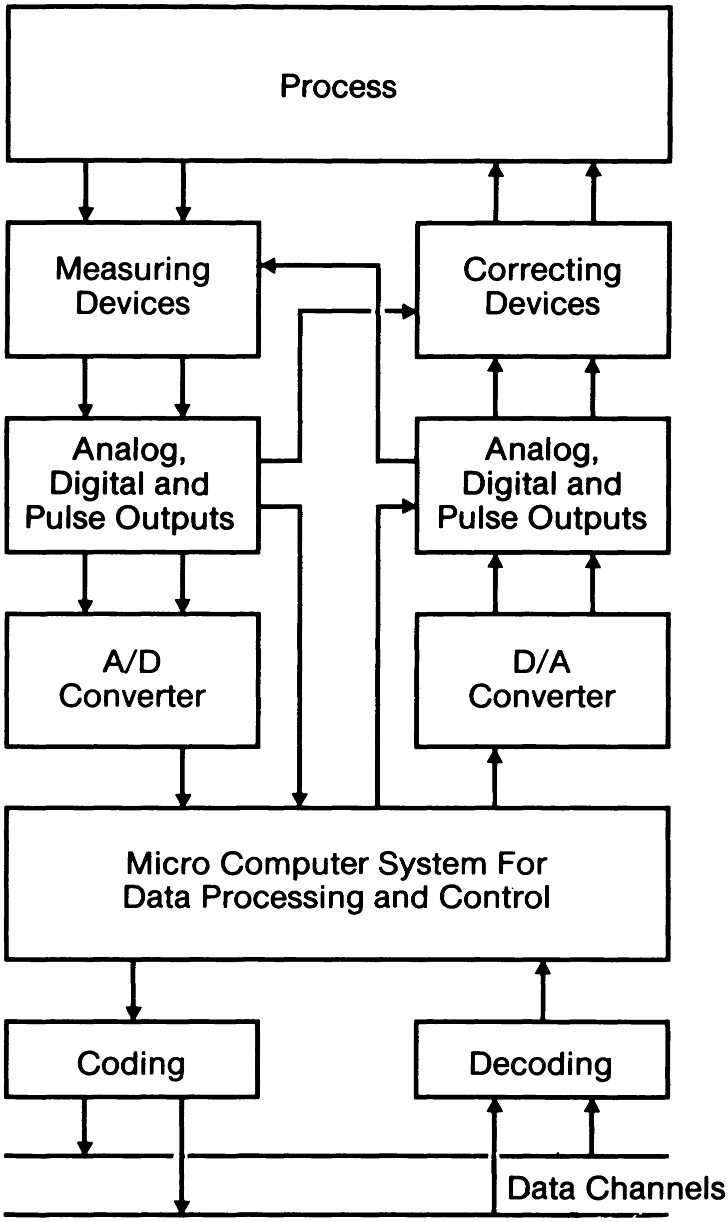

Figure 1.1. Local plant automation system.

will be dedicated to it. Quality control in the chemical and petrochemical industry creates some special control problems which have never received sufficient attention in the literature. Although process analyzers for quality

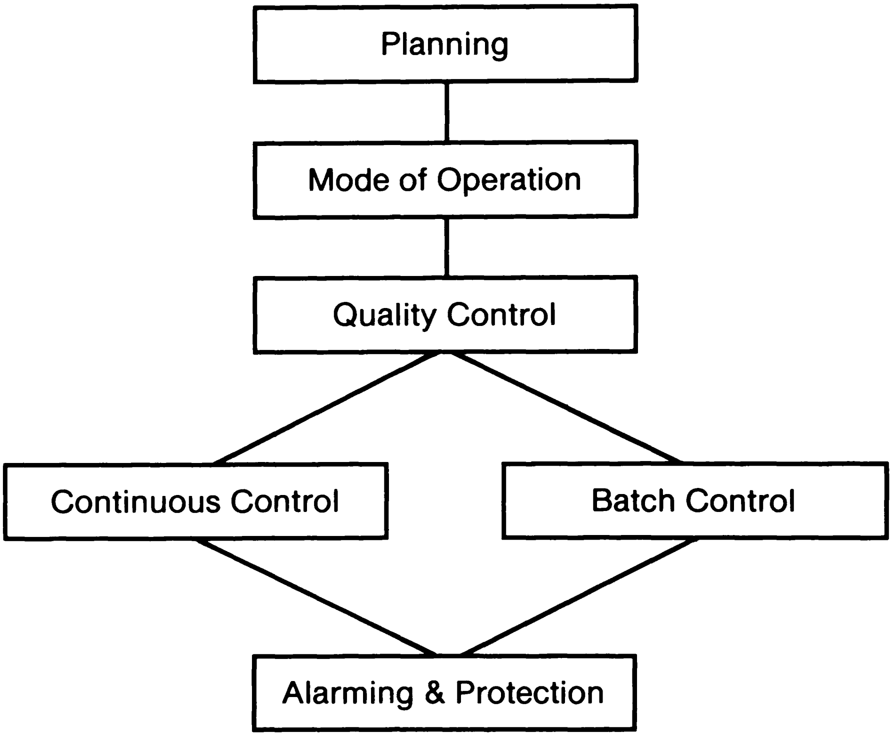

Figure 1.2. Hierarchy of activities in process control.

control are still fairly expensive, they have to be used in order to produce high quality products. In this book some techniques will be discussed to accomplish quality control in a different way, although an analyzer can never be replaced by any of these techniques.

The next level of activity is continuous and batch control. In continuous control, process values are maintained close to their targets despite process upsets, equipment fouling, cleaning, and so forth. One should never try to use the computer as a replacement for conventional controllers. Conventional controllers today are modern microcomputers, which can do an excellent job. The computer should be used to do more advanced control (e.g., adaptive control or control using Kalman filters).

In batch process control, pumps have to be started and stopped, and valves have to be opened and closed in a certain sequence. Computers interfacing to programmable controllers or batch controllers can provide tremendous savings in batch process operation. Unfortunately batch control design is still much of an art: no methodology or optimal design procedure yet exists.

The lowest level of activity involves alarming and protection, although this is often done in multiple microprocessors. The process computer can play a significant role, however, by informing the operator of possible causes of problems and by presenting selective information.

COMPUTER HARDWARE AND SOFTWARE

The heart of a computer is a central processing unit with main memory (Figure 1.3). The main memory is usually a combination of random access and read-only memory. The central processing unit can be considered as an instruction set, ready to manipulate data. Data is stored in main memory together with the program for use of the instruction set. This general set-up of the computer is one of the reasons for the low price of the computer hardware. Any specialist implementing computers in industry should have a reasonable understanding of computer hardware and software layout. Chapters 2 and 3 are dedicated to this topic.

Another important part of the computer system is the peripherals through which the user can communicate with the system. Color CRTs are used for presentation of data, graphic information, and trends. For system software development, black and white consoles are preferable, however.

Although alarm printers were popular many years ago, most process alarming today is done through the color CRTs in order to avoid the noise of the alarm printers. Alarms are stored in an alarm file of which specific parts can be printed on request.

For software development, a high-speed printer is essential.

Disks are increasingly being replaced by solid state electronic memory, mainly because of the higher reliability, although disks remain important for massive data storage.

For communication, the computer uses a data channel or highway. For short distances, one can use a parallel data channel. In this case, data is transported along many parallel channels. Usually, however, when distances are long, the serial data channel is used. This is a coaxial or glass fiber cable along which

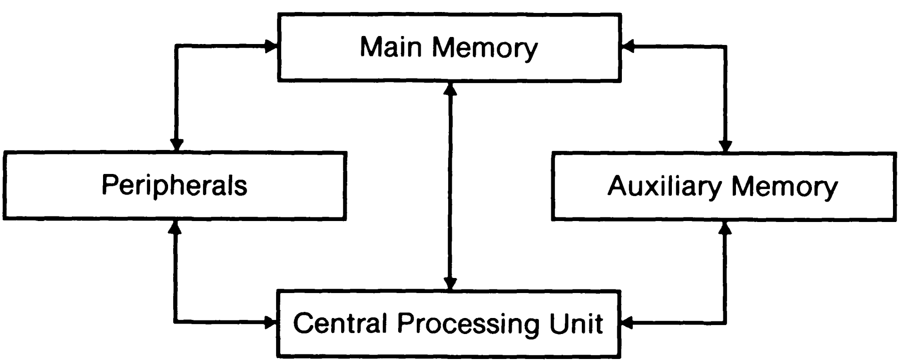

Figure 1.3. Simplified structure of a computer system.

information is passed in sequence. The rate of information processing is obviously lower than with a parallel data channel.

Computer system software is often classified into two categories: system software and application software. The system software provides general functions, such as compilation of programs, linking of programs, communication with peripherals, mathematical manipulations, data collection and storage, text editing, and servicing of console functions. A detailed description is given in Chapter 3.

Application software is the software that is used for monitoring and control. To use this software, the user often has to learn a language specific to the computer system. With this software complicated control strategies can be designed. Often the computer system also offers a higher level language, e.g., Pascal or Fortran. This is especially important when one wants to write one's own software, e.g., to optimize a section of the plant, to produce custom-designed reports or perform functions which are not standard on the system. The ability to use a higher level language may play an important part in system selection.

APPLICATION SOFTWARE DESIGN

As mentioned before, application software is the software that is used for monitoring and control. The design of this software is not an activity that should be done by a computer application engineer alone. Careful planning and teamwork are required.

First, standards for display building, program design, and documentation should be written and adhered to. In order to build process displays and to design control, monitoring, or optimization programs, the input from plant operators and plant engineers is desired. It is bad practice to present a complete system to the operators; if they input into various designs or even do part of certain designs (e.g., build displays), they will take ownership of the new computer system rather than having it forced upon them.

Application design should involve a continuous dialogue between the application engineer(s) and the process engineer(s). Only a team effort can make an automation project a success.

SUMMARY OF FOLLOWING CHAPTERS

The contents of this book are strongly oriented toward the engineer in the field who is using or is going to use and apply process computers. Chapters 2 through 5 are basic—things that every chemical and control engineer should know about process computers before using them. Chapter 2 deals with computer hardware, Chapter 3 with computer software, and Chapter 4 with computer selection. This chapter is particularly important for first-time users. Chapter 5 discusses reliability and security. Chapter 6 deals with batch and continuous control.

The following chapters focus more on the practical use of computers in implementing control strategies. Chapter 7 gives an introduction to advanced control, describing some simple process models and control elements. Difference equations and z-transform are introduced as a requirement for the next chapters.

The following chapters deal with techniques applied in quality control. Many chemical and petrochemical processes involve large dead times and time lags. Techniques are presented to deal with these situations. Many practical guidelines are given. Chapter 12 deals with constraint control as a means of plant optimization. Chapter 13 discusses the design, adjustment, and application of simple process models, whereas Chapter 14 focuses on optimization. The following three chapters discuss more advanced control techniques, such as adaptive control and Kalman filters.

CHAPTER 2

Distributed Computer Control System Networks

COMPUTER HARDWARE

The purpose of this chapter is to make the reader familiar with the concepts of modern computer networks. It is possible to discuss the advantages and disadvantages of different network structures without having a knowledge of computer hardware; however, it will be to the reader's benefit to have a basic understanding of the functional operation of a computer.

The four basic elements of a computer are the input/output circuit, the central processing unit, the (fast) main memory, and the (slower) auxiliary memory. This structure, called a Von Neumann structure, is usually applied in general purpose computers (Figure 2.1).

Process computers sometimes employ the Harvard structure (Figure 2.2). In this set-up there is another read-only memory (ROM), in which standard programs are stored, which can perform dedicated functions.

The central processing unit can be divided into an arithmetic and logic unit (ALU) and a control unit. The ALU performs the actual data manipulations that are required and will use temporary storage locations (registers) to store

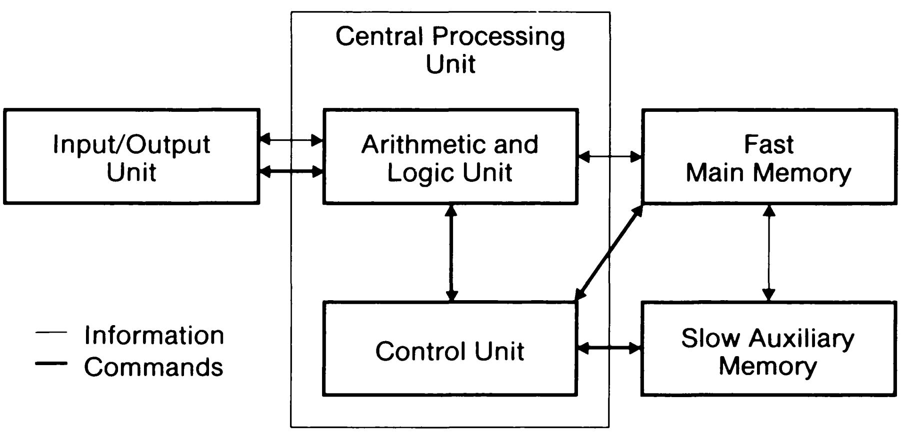

Figure 2.1. Von Neumann computer structure.