Computer Control of Industrial Processes

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To my wife, Helen, for her patience and understanding,
and my diverting young son and would-be assistant, Jonathan

Preface

The field of computer control is growing rapidly and achieving widespread industrial recognition and acceptance. Forecasts indicate that by 1970 there will be over 3,500 computer control systems in operation. Engineers in the process industries and application engineers in the computer and instrumentation industries will be drawn into computer control projects in increasing numbers and therefore require information about the concepts, equipment, and applications of this new technology. Technical and nontechnical managers in these same industries likewise are faced with the challenge of mastering this new tool and applying it wisely for their purposes. Those engineers still in the universities and aiming for careers in industry will be better prepared for future work by an early exposure to computer control.

This book is intended to bring to these diverse audiences an understanding of computer control from an application-oriented and production-oriented point of view. The dominant emphasis is on digital-computer control, and the reader is expected to have merely an acquaintance with the general capabilities of digital computers.

Hopefully, the organization indicated in the Table of Contents will help achieve the avowedly ambitious goal of satisfying this multiplicity of potential readers. Chapter 1 introduces the basic terminology of computer control. Chapter 2 describes the functions of control computers and illustrates them with a broad variety of examples from the process and utilities industries. It organizes these functions within a useful tutorial framework and emphasizes the relation between computer control and other data-processing activities in industry. Chapter 3 dwells on the requirements and construction of mathematical process models, while Chapter 4 portrays the practical application of statistical methods to model development. Chapters 5 and 6 complete Part I of the book, entitled "Principles of Computer Control," by discussing the theory and details of steady-state and dynamic optimizing control. Matrix relations and elementary matrix manipulations are employed in Chapters 4 and 6 as a shorthand means of expression.

Part II of this book, entitled "Computer Control in Practice," begins with Chapter 7, which describes the practical work involved in planning

and executing a computer control project in industry and presents a "PERT"-like diagram showing the logical interrelation and sequence of tasks in this type of interdisciplinary and interdepartmental system project. Chapter 8 discusses the tangible and intangible incentives for computer control and the cost factors which enter the picture. Chapters 9, 10, and 11 discuss the equipment implications of computer control, including direct digital control, both in terms of the computer system and the measurement and control devices required with it. The discussion does not rely on any particular model of control computer system for illustration. Chapter 12 presents the unique characteristics of programming for computer process control. Chapter 13 surveys a large number and variety of published and unpublished applications of computer control systems. In it, an attempt was made to present fundamental principles and approaches, rather than to enumerate specific instrumentation points, individual calculation procedures, and local operating details; the extensive supporting list of reference citations, providing literature coverage through early 1965, may be consulted for further details.

The busy executive can restrict his reading to Chapters 1, 2, 7, and 8. The technically oriented manager should add Chapters 3 and 9, at least, to this list and browse through Chapter 13 as well. The practicing engineer is likely to find each chapter rewarding, while the student may be particularly attracted to Part I of the book plus Chapters 9, 11, and 13. Those familiar with computers, but not yet with processes, should find Chapters 1, 2, 9, and 12 [13] most enlightening.

Despite the publisher's admonition against arraying a lengthy list of names, I would be ungrateful not to acknowledge the advice of many friends and colleagues, including D. M. Bates, D. B. Brandon, M. J. Carnaby, C. W. Carroll, J. F. Conneran, C. M. Elmer, R. J. Ferguson, D. R. Flinn, F. A. Fuentes, W. Helmreich, R. L. Johnson, S. A. Komjathy, D. R. Kuehn, D. R. Mangold, C. Martin, A. A. Melnychuk, R. Roeloffs, W. J. Slatosky, H. Wachtel, C. B. Van Winter, and R. K. Wolfe.

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Emanuel S. Savas

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PART I

Principles of Computer Control

1

Introduction

One of the most significant and profound developments of the technological revolution is the electronic digital computer. Computers have been applied with far-reaching consequences in the many and diverse fields of human endeavor. In agriculture, for example, computers are used to aid in crop planning and to formulate blends of livestock feed; medical applications range from patient diagnosis to heart studies and drug evaluation; they are employed by research scientists to help retrieve technical information, and their use in the field of finance includes processing of checks, analysis and preparation of bond bids, and audio response to inquiries about fast-changing stock prices; the design of supersonic aircraft and the planning and tracking of space flights have been materially aided by digital computers, and the early launching of the first nuclear submarine was attributed in large measure to the computer; bridge building along the Amazon and sales forecasting in the garment district are both made easier by computers.

The vast potential of computers, which has to date merely been glimpsed, lies in their character as information-handling and information-processing machines. Under man's guidance, they can take diverse information in large quantities and transform it rapidly into usable form. This unique information-processing ability rests on the computational and decision-making prowess of the computer and on its information input, output, and storage capability.[1]

Industrial concerns have adopted computers and used them to serve their information-processing needs in a wide variety of activities. For example, the application of computers for miscellaneous accounting, clerical, and engineering tasks is already quite conventional and has resulted in better control over some areas of the total industrial operation. However, the need to improve process profitability has produced a demand for improved control over process operations, and this in turn has led to the introduction and increasing utilization of computers in the production process itself.

1-1 ROLE OF THE COMPUTER IN PROCESS INFORMATION FLOW

The fundamental reason why processes lend themselves to computer techniques is that every process involves three kinds of flow: flow of material, flow of energy, and *flow of information*. Information is the essential ingredient of control: higher management needs information both to formulate operating policies and to gauge their execution; supervisory management needs information for detailed planning and performance evaluation; the operator at a particular process unit needs information so that he may execute properly the production plans assigned to him; and simple control devices require information in the form of signals fed back from process sensors in order to achieve their limited objectives. Because of this key role of information in control—whether single-variable control, process control, plant control, or corporate control—the computer is a logical tool to be applied: the outstanding characteristic of a digital-computer control system is the ability to acquire, assimilate, analyze, and disseminate large amounts of information with great speed, accuracy, and flexibility. Therefore, just as there have long been excellent devices designed to facilitate material handling and energy transmission, the control computer takes its place as a modern device designed to facilitate information processing in industrial operations.

1-2 CONFIGURATION OF COMPUTER - PROCESS SYSTEMS

Let us examine the role of computers in industrial control and define the various modes of interconnection between the computer and the process.

1-2a Off Line

One possible configuration is shown in Fig. 1-1. The computer is off line to the process; that is, it receives process information through a human intermediary and the results of its computations are applied similarly through a human operator. The input data are handled completely manually; for example, data are read from instruments, written on a log sheet, punched into cards or tape, and later carried to the computer. Alternatively, data may be collected automatically (by a data logger or tape recorder, for example) in a form that can be used directly by a computer (cards, paper tape, or magnetic tape), as represented in Fig. 1-2. In either case, off-line operation involves the accumulation of data which, after some delay, are brought to the computer, entered, and processed, all in batch fashion. This may be appropriate wherever timing