MINICOMPUTERS
theory & operation

Donald Eadie

Minicomputers: theory and operation

微型计算机原理和操作

Donald Eadie

Reston Publishing Company, Inc.
A Prentice-Hall Company
Reston, Virginia

To my grandchildren:
Cara, Christopher, Diana, and Patrick Willis

Library of Congress Cataloging in Publication Data

Eadie, Donald.
Minicomputers, theory and operation.

Includes bibliographical references and index.
1. Minicomputers. I. Title.
QA76.5.E16 001.6'4'04 79-10973
ISBN 0-8359-4387-9

Reston Publishing Company, Inc.
A Prentice-Hall Company
Reston, Virginia

10 9 8 7 6 5 4 3 2 1

Printed in the United States of America

Preface

This book is intended to introduce all fundamentals of data processing. The first three chapters lay the foundation. The remainder of the book burrows into the more specialized areas unique to the field. In the past it has been customary for practitioners to specialize primarily in one area—hardware design, analysis, system design, programming, or data processing. This approach has led to isolation of people in different specialties. Even today communications can be strained. There is much effort with learning a specialty; thus, it is understandable that a person thinks in terms of the area he understands best, and feels strange outside that area. No one person knows all there is to know about data processing and the associated specialties—especially in light of the explosion of knowledge that has occurred over the past twenty years.

The object of this writing is to unite the specialties—at least on an introductory level—in the hope that the specialties will blend more into a total picture. In this way it is hoped the reader can decide which specialty, if any, he might feel inclined to study further. Today it is most important that a user be able to translate his particular application into terms to which those who are responsible for system design (hardware and software) can relate. When the user defines what he wants, he becomes a vital participant in the system design process. He will be able to see if his desires can be built into a successful finality, understanding which of the specified requirements are achievable in a realistic manner. The development of an entirely new system is not without technical and financial risk, but these are controllable to a large degree.

This book places considerable emphasis on the minicomputer because of its wide application since 1968. This class of machine is widely versatile, relatively easy to apply, and replaces many of the more costly machines of earlier vintage. However, technology advances in an unabated sequence. In 1972 the microcomputer was announced. This is a small computer consisting generally of a few LSI packages usually mounted on a single small plug-in board. This approach dramatically lowers the eventual cost of minimum computers and extends their

operating range downward into almost every nook and cranny of control applications.

The book starts out by emphasizing the elements of data processing. After introductory Chapter 1, Chapter 2 continues with codes employed in data processing, number systems generally, with further emphasis on binary, octal, and hexidecimal systems, which are used universally in computer systems. Chapter 3 outlines forms of binary data and commands, and introduces the general computer block diagrams. Chapter 4 explains digital logic, combinational digital elements, and some of the circuits used for system interfacing. Chapter 5 continues with an introduction how a simple minicomputer functions, and closes with a discussion of various interfacing methods employed today in minicomputers and microcomputers. Chapter 6 introduces peripheral devices of various types and concludes with examples of control system interfacing methods (multiplexors, converters, and direct digital interfacing). Chapters 7 and 8 discuss typical instruction formats, programming, and software with an introduction to the interpreter BASIC, which was used originally for time-share systems, but now has effectively been adopted as a compiler like FORTRAN. Chapter 9 briefly outlines FORTRAN and COBOL as examples. Chapter 10 describes the Honeywell H316 minicomputer—an example of an early version, while Chapter 11 explores the Interdata 7/16, a fourth-generation minicomputer with the capability of the large-scale processors of a decade earlier. Chapter 12 introduces a few of the microcomputers at the moment among the most used. This chapter was included because the two fields—microprocessors and minicomputers—are rapidly merging. Chapter 13 lists a few sample applications of minicomputers and microcomputers. Microcomputers are generally used where 16-bit minicomputers are not needed, and too costly to apply in an underused application.

Thus, Chapters 1 through 9 treat the fundamentals of data processing. Chapters 10 through 13, on the other hand, discuss typical minicomputer and microcomputer hardware and their application. In reality there are two sections to the book which together are probably too extensive to complete in a one-semester course. The teacher will have to decide which topics to treat and which to ignore if the course is to be of standard length. There is a lot of detail—enough to spend two semesters of work.

Practice problems are included at the end of each chapter. Answers for the even-numbered problems are included in Appendix A at the back of the book. These answers should allow the student to check his own work.

My grateful thanks to those people who encouraged me to complete this work, including my wife Ruth, my brother Stuart, and my

many associates at Aero-Florida Division of Honeywell Inc. Special thanks are due Mrs. Lori McMahon, who typed the majority of the manuscript, and to Mr. Matthew I. Fox, president of Reston Inc., who allowed me to complete a work he expected from me much in advance of this date. Thanks are extended to the staff at Hillsborough Community College, especially Professor Arnold Kroeger. Also I thank Mr. Barton Hoeg, Manager of Editorial Services of Interdata Inc. for supplying photos for Chapter 11.

Donald Eadie
Belleair Bluffs, Florida

Contents

1

History and Processors in Society

1-1 INTRODUCTION

This chapter introduces the reader to the subject of data processing. It is rather general in its discussion, and for specific details on the persons and devices mentioned, the reader is referred to more detailed treatments appearing in other publications. A few of the events of historical significance are mentioned to illustrate the growth in ideas leading to the modern computer.

The computer is really an evolution rather than an invention of any one person. Not only have the mechanisms themselves evolved, but so have the applications of how a processor fits into a system. Although *batching* and *control* applications were conceived rather early in the computer explosion following World War II, it was a few years before experiments in *time sharing* began in earnest. This chapter discusses in an introductory way many of these topics.

1-2 THE BEGINNINGS

1-2.1 Abacus

The advantages of instruments to assist with computations were recognized in antiquity. The Abacus, consisting of several rows of beads on a frame, permitted merchants in early Egypt and Babylon to compute transactions beyond the range of their individual fingers and toes. The Abacus is still employed today in many parts of the world.

1-2.2 Napier's Bones

In the early 1600s, John Napier of Scotland invented a device that assisted greatly in the use of logarithms to perform arithmetic operations such as multiplication and long division. This device became known as

"Napier's bones." Today, the descendant device, employed so often by engineers and others, is the *slide rule*.

1-2.3 Early Calculating Machines

Calculating machines, first employed historically by Blaise Pascal in 1642 and by Von Leibniz a few years later, defined techniques that have been improved through the centuries and led directly to calculation approaches employed by processors designed in the past 20 years.

1-2.4 Babbage's Work

It is to Charles Babbage, a nineteenth-century English mathematician, that the title *"Father of the Modern Computer"* generally applies. His earnest, but largely unsuccessful, effort to develop two major computing machines for British government departments in the early to mid-1800s outlined generally the basic organization of a modern processor. The *memory*, the *arithmetic processor*, and the *input/output* are identifiable in his descriptive writings. Also, he proposed the idea of storing in the form of commands the operation sequence to be performed on the data. However, the technology of his era was not up to the task of mechanizing successful hardware. Nevertheless, a hundred or so years later, his work was studied before the design of the Harvard Machines (MARK I, etc.) was embarked upon.

1-2.5 Continued Development of Calculating Machines

Such improvements as *keyboards*, *punch paper tapes*, and *punched cards* continued to be added from time to time to the early designs. In fact, the machines that Babbage planned were eventually built in Sweden and the United States. In the late 1800s, Hollerith invented the *punched card*, and this invention was the initial impetus behind the establishment of the office machine industry that mushroomed so rapidly in the first half of the twentieth century.

1-3 THE PUNCHED-CARD ERA

The punched card invented by Herman Hollerith about 1890, inaugurated the era of machine data processing. Machines soon were designed to punch, read, verify, and sort punched cards. Thus, it was possible to record data on a standard form that could be manipulated by machines, and such routine processes as "searching" for an item among

stacks of items, sorting the items in a preordered sequence, and obtaining tabulations could now be performed by electromechanical machinery rather than by the manual process of eyeballing records, i.e., studying columns of figures. This era extended uninterrupted into the early 1940s. In the later years, even more talented card-handling machines manipulated the data, for example, permitting arithmetic calculations (addition, multiplication, division, etc., on the data) and providing the capability to print out business reports. It was the existence throughout the nation and the world of vast quantities of card-handling equipment and the decision to use it for inputting data to a computer or reading out data from a computer that gave IBM Corporation such a natural jump on its competitors in the 1950s. Many potential processor customers were already familiar with the IBM equipment, had been serviced well by the vast force of IBM field servicemen, and naturally, because of past experience, favored systems supplied by IBM. The card readers and card punches have survived into the electronic data processing (EDP) era of the 1970s in substantially their original role. Such familiar operations as sorting, tallying, and calculating are less likely to be done by the mechanical equipment nowadays on the card decks themselves, but the processor performs the data manipulation on the data once they have been committed to the processor's memory. Then, if the final results are required to be stored on cards, these can be provided as a readout form by a card punch peripheral. One might alternately consider readout in the form of a magnetic tape record, or perhaps a printed page, for example. Most modern computer installations provide a variety of options on how to represent the final output results.

Figure 1-1 illustrates the Hollerith card keypunch machine. Blank

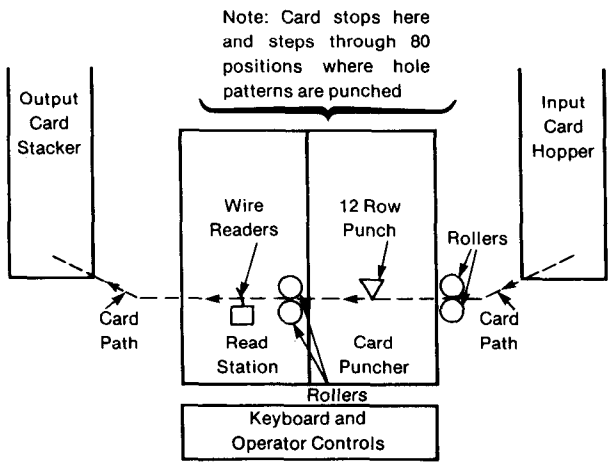

FIGURE 1-1. Keypunch machine functional diagram.

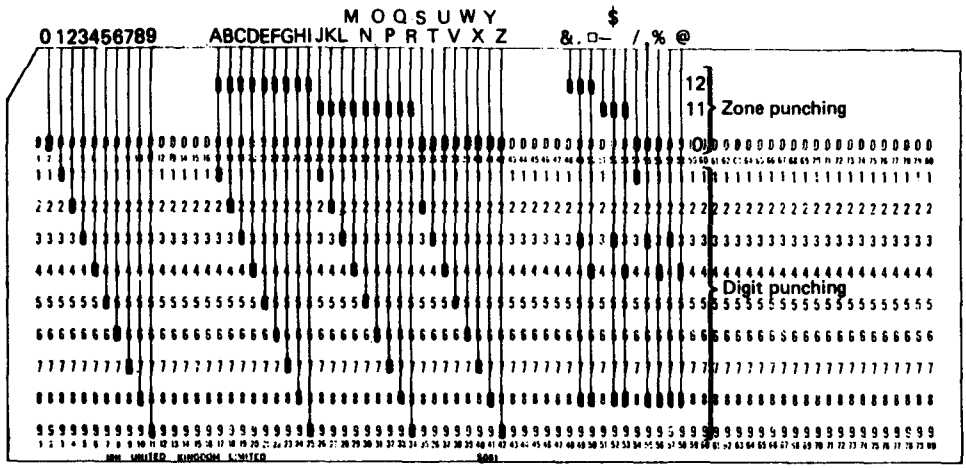

FIGURE 1-2. Hollerith card.

cards are placed in the hopper above and at the right top of the machine. An individual card is fed into the card station (called the *punch station*) on the right center by the operator's pressing a button. The actual punching is performed by pressing keys on a typewriter-like keyboard. Card columns—1, followed by 2, followed by 3, etc. as far as column 80—are punched in sequence with a Hollerith code. The station at the center (called the *read station*) reads cards after they have been punched and is used primarily to duplicate cards. By pressing other buttons the operator collects punched cards in the hopper at the top left of the keypunch.

Figure 1-2 illustrates a Hollerith card punched with appropriate codes. Note the alphanumeric listing on the card top to assist card checking. Other card-handling machines provide complete mechanical data processing for business. Table 1-1 lists some of these with their general

TABLE 1-1. Other card-handling equipment—general functions

Name	*Function*
1. Verifier	Verifies the correctness of a punched card.
2. Sorter	Sorts on selected data fields, and sorts cards into selected stacks.
3. Collator	A multiprocess device that merges card files, compiles, or matches separate card files. It selects records based on contained data. It checks a file sequence.
4. Calculator	Performs simple arithmetic operations (adds, subtracts, multiplies, divides) on groups of cards.
5. Accounting machine	Prepares printed reports.
6. Reproducing punch	Prepares punched-card data records.

functions. Although mechanical methods had lost their impact by 1978, the keypunch is still a most important tool for programmers. Its coding form still reflects Hollerith code formats, and many programs are inputted to computers in this manner. In some instances cards are completely bypassed by using paper tapes, key-to-tape, and key-to-disk equipment. Since this book is not concerned with mechanical data processing, the important equipment of this general type is listed only in Table 1-1. Most of this form of data processing gear is being replaced by computers of various sizes and types. The efficiency, speed, and capacity of electronic computers to handle a sizeable computing load are much greater.

1-4 COMPUTER DEVELOPMENT BEFORE AND DURING WORLD WAR II

1-4.1 Analog Scientific Calculations

Shortly before World War II, Dr. Vannevar Bush and others recognized the need for calculating machines to compute rapidly the responses of complex physical systems. In many branches of engineering, physics, etc., the behavioral response of these systems can be characterized as differential equations. In many cases, the solution form is well-known, but there are numerous coefficient values to be determined before the precise solution is obtained. In other cases, the system is represented by families of equations, each one interacting on another. In either instance, *mechanical differential analyzers* proved themselves handy tools to characterize solutions. Several *mechanical differential analyzers* (MDAs) were constructed between 1928 and 1942. After World War II, the *electronic differential analyzer* (EDA) performed similar computations. Both of these computing machine forms are classified as *analog machines,* because numerical quantities were represented in magnitude as a physical quantity, such as a voltage or the relative angular positions of shafts. For example, one volt might equal 10 miles per hour, whereas 5.7 volts would represent 57 miles per hour. The basic computing element of the *mechanical differential analyzer* (MDA) was the *ball* and *disk integrator* (an invention of Lord Kelvin over 70 years before). Special amplifiers with capacitor feedback performed the corresponding integrator action in the *electronic differential analyzers* (EDA). In addition, the EDAs were much easier to set up for a new problem than the MDAs. The setup of a problem for solution on an *MDA* involved positioning long mechanical shafts and changing gear boxes. In the EDAs, the setup changes involved moving wires around on plug boards (much in the way that a telephone operator makes manual connections), and/or adjusting potentiometer settings. Further advances in the differential analyzer concept was made