

Understanding
and
Programming

COMPUTERS

UNDERSTANDING AND PROGRAMMING COMPUTERS

Samiha Mourad

Illustrated



An Exposition-University Book

Exposition Press

Hicksville, New York

FIRST EDITION

© 1978 by Samiha Mourad

All rights reserved, including the right of reproduction in whole or in part, in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system. No part of this book may be reproduced without permission in writing from the publisher. Inquiries should be addressed to Exposition Press, Inc., 900 South Oyster Bay Road, Hicksville, N.Y. 11801

ISBN 0-682-49033-4

Printed in the United States of America

UNDERSTANDING AND PROGRAMMING COMPUTERS

PREFACE

This book was written mainly for liberal arts students. Its main objective is to give an integrated overview of the digital computer and its uses, potentials and limitations. The intention is to educate the students to the basic principles underlying the design of and operation of this machine and not just to train them how to program it.

There are many books that approach the topic from mainly a programming viewpoint since this is what they assume students need to know in order to use the computer in other disciplines, e.g. psychology or business. Although such need is genuine and important, the author believes that it is essential to inform the students about the functioning of the computer if it is hoped to help the students become well rounded, educated people and not just technicians. Training people to program the computer with no attempt to explain its functioning is similar to training them to drive an automobile without explaining how the engine operates. A person who is familiar with the engine, knowing why to shift gears and not just how to shift them, is, no doubt, a better driver than one who just knows the mechanics of driving. He is also more capable of making good decisions in case of malfunctioning emergencies. In addition, he is in a better position to comprehend automobiles in general and the development of automotive technology without having to be an expert. Finally, he will be using the automobile in a non-passive manner, and passivity in the use of technology is one of the main problems in our present society. It is with this philosophy in mind that this book has been written.

The general nature of the computer and its evolution are the topics of the first chapter. The hardware of the machine is covered in chapter two through five. The concepts of mathematics and physics used in these chapters are presented as puzzles and games (binary system and switching circuits) or without complicated algebraical expressions (electromagnetic theory).

Chapter six through nine deal with the programming of the computer. The first of these chapters presents the methodology of computer-oriented problem solving in terms general enough to be applicable to any area of endeavor.

Chapter seven deals with data structure. It is meant as an overview of the topic rather than an in-depth study. After outlining the hierarchy of programming languages, Chapter Eight discusses assembly language, and gives a comparative study of three high-level languages -- BASIC; FORTRAN; and COBOL. In addition, the chapter contains sections on microprogramming, and the psychology of programming. (The reader who needs to learn more about the concepts of assembly language can read Appendix B.) The author chose to illustrate the concepts covered in this chapter by using an actual assembly language, that of the IBM 370 system, instead of a fictitious one, as is usually done in similar textbooks. The rationale for this choice is twofold: first, if the reader eventually decides to learn assembly language, he will have been introduced to it from the beginning; second, it is always better to draw one's

illustrations and examples from actual practice -- particularly when this does not hamper the learning process. Those readers who opt to learn enough FORTRAN to write simple programs are referred to Appendix C. Chapter nine complements chapter six; it demonstrates how the computer is managed internally to follow the instructions submitted by the users. Chapter ten consider computer applications from a new angle. It is customary to focus on the different areas (such as education or business) in which computers are used; in contrast, chapter ten, by focusing on the main roles of the computer -- record keeper, controller, and analyser -- illustrates how the computer has the potential to serve in any of large number of areas. Hence, by way of examples, chapter ten demonstrates the relevance of the computer as a record keeper in business, scientific research and education.

The appendices complement or clarify the chapters. Thus those who are not familiar with electrical and electronic circuits are advised to read Appendix A. The appendices also include a selected list of periodicals in the computer field, as well as the names of the major professional computer societies. Finally there is a glossary of computer terms, which will be found at the end of the text.

Strong scientific or mathematical background is not a pre-requisite for reading this text. Knowledge of the basic arithmetic operations and an interest in learning about computers are the only requirements. However, those who have had a strong training in

mathematics will not find the text too elementary. This is because its emphasis throughout is on the operational principles of the computer.

The need for the book and its approach have been tested for the last six years of the author's teaching at an undergraduate liberal arts college of Fordham University. The book has been used for a first year course in computational mathematics curriculum as well as for an elective course for non-mathematics majors.

The author wishes to express her deepest appreciation to the students who showed no reluctance in using the first drafts. Their constructive criticism helped improve the presentation and organization of the text. Without Bernard Gilligan's moral support this textbook would never have been written. Finally, and most importantly, the author owes a great deal to Jerry Green, Jr. who patiently typed many drafts, photocopied and collated the students' copies.

Samiha Mourad

New York City
September 1977

TABLE OF CONTENTS

PREFACE	ix
1. THE GENERAL NATURE OF COMPUTERS	1
1.1 Classification of Computers	1
1.2 The Role of the Computer	4
1.3 Basic Components of the Computer	5
1.4 Communicating with the Computer	7
1.5 A Brief History of the Computer: Through the 19th century	9
1.6 A Brief History of the Computer: The 20th century	13
Key Terms and Review Questions	18
2. THE ARITHMETIC OF THE COMPUTER	20
2.1 Number Systems	20
2.2 What is the Binary Number System?	20
2.3 Conversion from Binary to Decimal	21
2.4 Conversion into Binary	23
2.5 Binary Arithmetic	25
2.6 Binary Arithmetic using Complements	27
2.7 Data Representation	29
2.8 Hexadecimal System	31
Key Terms and Review Questions	34
3. LOGIC AND LOGICAL CIRCUITS	35
3.1 Boolean Algebra	35
3.2 Mechanization of the Logical Operations	38
3.3 Binary Addition as Logical Operations	43
3.4 Adders	45
3.5 Registers	52
3.6 Capacity of Registers	53
3.7 Operations on Integers	55
3.8 Floating-point Operations	57
Key Terms and Review Questions	59
4. MEMORY OF THE COMPUTER	61
4.1 Classification	62
4.2 The Memory	63
4.3 Elementary Magnetic Theory	64

4.4	Magnetic Materials	66
4.5	Magnetic Cores	68
4.6	Writing and Reading from Cores	70
4.7	Memory Configuration	72
4.8	Addressing the Memory	76
4.9	Size of the Memory	77
4.10	Other Magnetic Types of Memory	77
4.11	Semiconductor Memory	80
	Key Terms and Review Questions	84
5.	INPUT AND OUTPUT MEDIA AND DEVICES	85
5.1	Channels	85
5.2	Punched Cards	90
5.3	Paper Tape	94
5.4	Printers	96
5.5	Magnetic Media	100
5.6	Magnetic Tape	102
5.7	Magnetic Disk	105
5.8	Magnetic Drum	106
5.9	Typewriter	106
5.10	Other Devices	108
5.11	Data Transmission	109
	Key Terms and Review Questions	111
6.	PROGRAMMING THE COMPUTER SYSTEM	113
6.1	Systems Analysis	113
6.2	Flowcharting	115
6.3	Structured Programming	123
6.4	Decision Tables	127
6.5	Coding and Compiling	127
6.6	Debugging	131
6.7	Programmer Aids	132
6.8	Documentation	134
	Key Terms and Review Questions	135
7.	DATA STRUCTURE AND ORGANIZATION	137
7.1	Records	138
7.2	Files	142
7.3	Creating and Updating Files	142
7.4	List Structure	147
7.5	List Processing	150
7.6	Trees	152
7.7	Concepts of Data Base	156
	Key Terms and Review Questions	158

8. COMPUTER PROGRAMMING LANGUAGES	161
8.1 Machine-oriented languages	162
8.2 Examples of an Assembly Language Program	165
8.3 The Assembler	169
8.4 Problem-Oriented Languages	169
8.5 Brief History of Problem-Oriented Languages	170
8.6 Comparative Study of Problem-Oriented Languages	171
8.7 Job Control Languages	179
8.8 Compilers	182
8.9 Microprogramming	184
8.10 The Psychology of Programming	184
Key Terms and Review Questions	186
9. THE MANAGEMENT OF THE COMPUTER SYSTEM	187
9.1 Components of the Control Unit	187
9.2 Steps Followed in Processing a Job	190
9.3 The CPU Cycle	192
9.4 Multiprogramming	196
9.5 Allocation of the Memory	198
9.6 Virtual Memory	200
9.7 Batch Versus Time-Sharing Operations	204
Key Terms and Review Questions	206
10. USE OF THE COMPUTER	207
10.1 The Scope of Applications	208
10.2 Record-Keeping	209
10.3 Analysis and Design	212
10.4 Guidance and Control	218
10.5 Computers and Intelligence	220
10.6 Computers and Society	224
Key Terms and Review Questions	225
APPENDICES	227
A. Electrical and Electronic circuits	228
B. Assembly Language	231
C. FORTRAN	252
D. Computer Manufacturers	278
E. Computer Professional Organizations	283
F. List of Selected Periodicals	285

BIBLIOGRAPHY	293
GLOSSARY OF TECHNICAL TERMS	297
INDEX	311

CHAPTER ONE

THE GENERAL NATURE OF COMPUTERS

Today, the word computer is on almost everyone's lips. At school ID numbers and course cards remind one that information regarding registration and tuition has been processed by computer. Telephone and electric bills are punched on IBM cards that remind one not to mutilate them because they will be processed by computer. In the record stores, one can find music produced by the computer.

In each example, the computer appears to be a brain that performs calculations, makes decisions and produces organized reports. Actually, the computer usually referred to is just one member of a family of computers, the most well known of all. The correct name for it is the "general-purpose electronic digital computer."

The qualifiers "general-purpose," "electronic," and "digital" point to the fact that computers fall into different categories based on various factors which will be considered in the next section.

1.1 Classification of Computers

Depending on the mode of representation of information, computers are divided into three main types: analog, digital, and hybrid. In an analog computer, the information is represented in a continuous form by a suitable physical quantity: length in centimeters, current in amperes or voltage in units. The speedometer, for example, is an analog computer that gives an indication of the speed of a car. Other examples are thermometers, gas meters and slide rules.

A digital computer represents information in a discrete form,

beads, knots, or electrical pulses. The abacus and the cash register are examples of digital computers.

Analog computers are less accurate than digital ones since their use entails reading measurements. Even with very fine measuring scales, the accuracy is impaired by the reading itself. They also are suitable only for handling numbers while digital computers accept non-numeric information as well.

The third type of computer represents information concurrently in both a continuous and a discrete form. This is the hybrid type. Hybrid computers form the intersection of the sets of digital and analog computers.

Depending on the components used to construct them, computers can be classified as either mechanical or electronic. Electro-mechanical machines are also widely used. Figure 1.1 shows the different categories in this classification.

The early versions of calculators are examples of purely manual rotation of a system of gears. In later versions, electric motors have been used to operate these gears. Most of the calculators in use nowadays are of the electronic type.

The difference between electrical and electronic concepts is explained in Appendix 1. In general, electronic devices are faster, less noisy and more reliable than electro-mechanical ones. Electronic devices themselves have developed from the vacuum-tube type to the transistorized ones. From Figure 1.2, where real scale diagrams of a vacuum tube and a transistor are shown, it is obvious that devices using transistors can be built smaller in size.

From the standpoint of use, a computer of any of the types

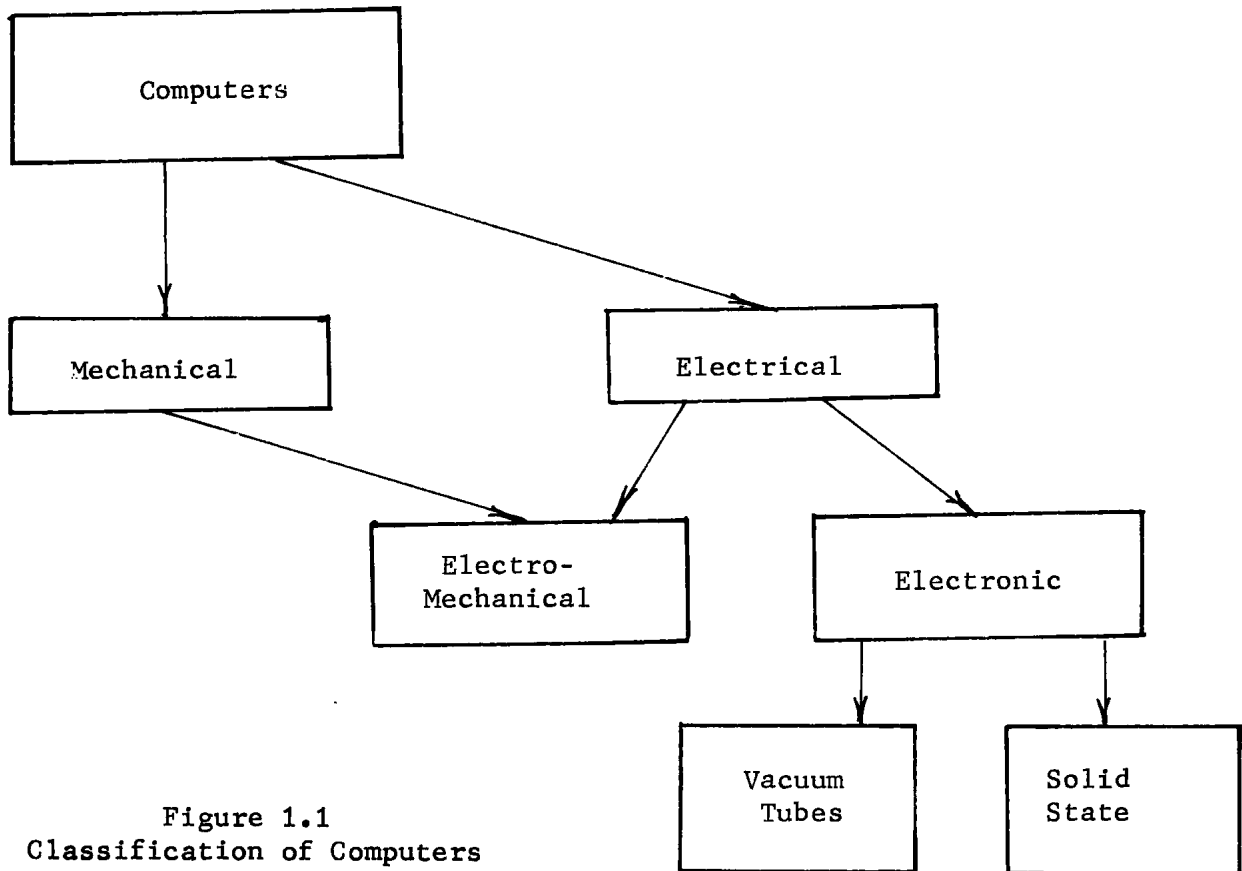


Figure 1.1
Classification of Computers

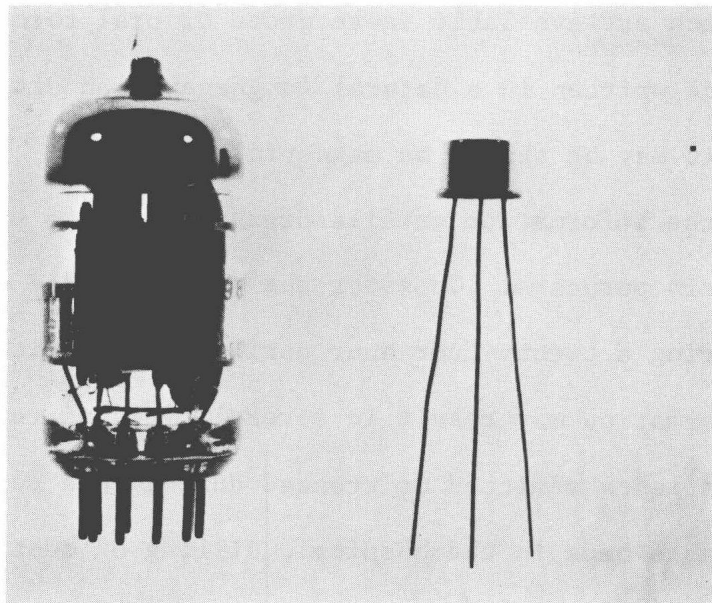


Figure 1.2
Size comparisons of vacuum tubes,
transistors, and solid state technology
(Courtesy IBM Corp.)

mentioned above may be designed for a special purpose or a general purpose. General purpose digital computers may be labeled commercial or scientific according to their use. A digital computer which serves a university community can be utilized for purely scientific research or for processing registration and staff payroll or for both. This subdivision of the general-purpose digital computer is rather artificial since it does not pertain to a special feature of the machine, but rather to the kind of problem solved by the machine.

In this text, the only type of computer dealt with will be the "general-purpose electronic digital computer." Hereafter, therefore, the term "computer" should be understood to refer only to this type.

1.2 The Role of the Computer

The computer has been labeled a universal machine because of the role it plays in processing information. Information is known, intelligible facts which are available in recorded or oral form. Recorded information may be written in a natural language or an artificially coded one; also it may be stored on magnetic tapes.

Processing the information entails organizing it to produce reports for certain purposes. Consider the specific case of information gathered during a twenty-four hour period in a hospital. Processing this information may result in several types of reports: listing of the patients admitted or treated during this period, updates of available beds in the hospital, billing of customers, schedule for nurses and doctors. Such bookkeeping efforts have been carried out manually; however, with the advent of the computer, the task has been enormously accelerated. Computer-oriented information

processing system consists of three main subsystems: people, procedures and the computer.

People collect the data and prepare procedures to organize them. The procedures are usually called programs. A program is a sequence of instructions arranged in a fashion to organize the information to achieve a desired goal.

The computer, which consists of physical equipment called the hardware, processes the information according to the procedures introduced to it by people. Because of the availability of specialized programs, the operating system, the different parts of the hardware are capable of communicating with each other and cooperate to process the information according to the procedures (programs) supplied by the users. Operating system and programs representing the procedures are known as the software of the computer.

In the next two sections, the functional components of the computer will be listed with a brief description of their roles. Then the problem of how people communicate with the computer will be addressed.

1.3 Basic Components of the Computer

Although the general-purpose digital computers may differ in some particulars, they all consist of five basic components which are shown in Figure 1.3. The components are:

1. An input device which receives the data and the procedure, a set of instructions to be followed in solving a problem.
2. An output unit which transmits the results, the outcome of the data processing, outside the computer.
3. An arithmetic and logical unit (ALU) which performs the main