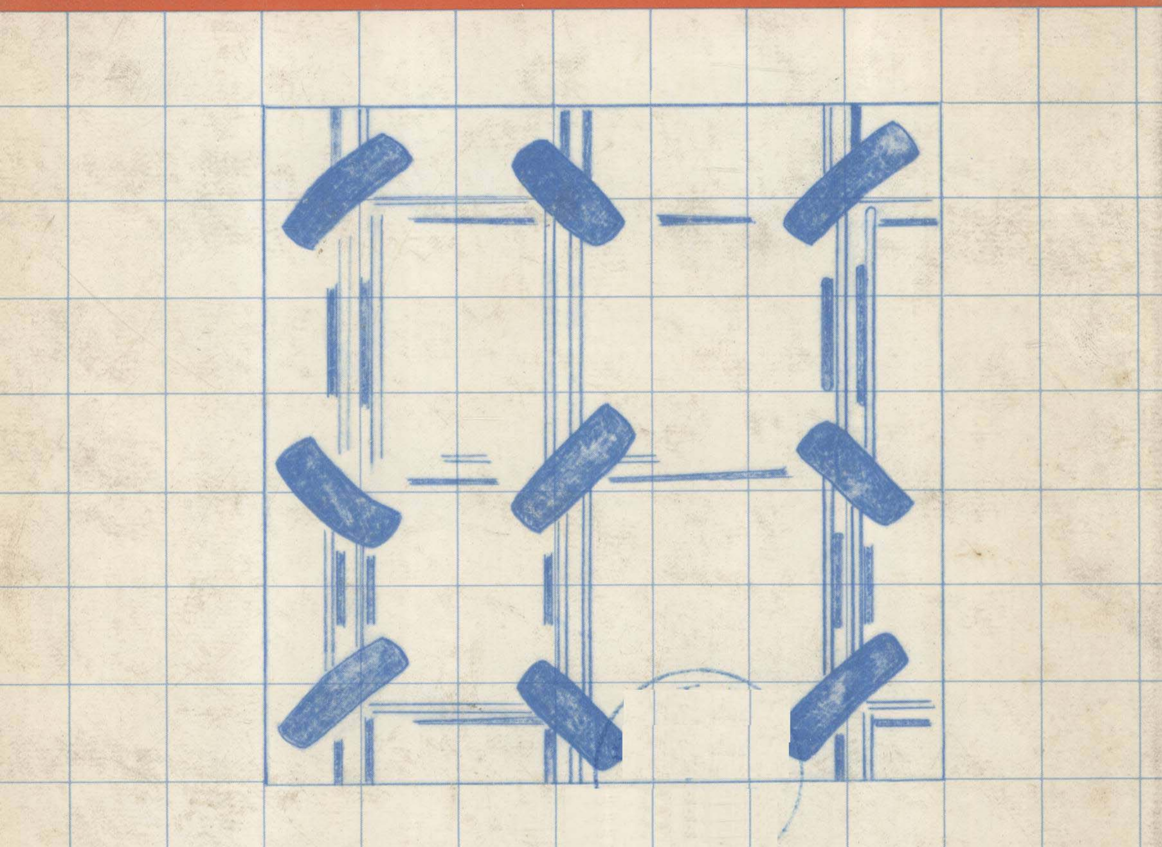
Introduction to Digital Computer Technology 2nd Ed.



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INTRODUCTION TO DIGITAL COMPUTER TECHNOLOGY, SECOND EDITION

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INTRODUCTION TO DIGITAL COMPUTER TECHNOLOGY

To Katrin, Kira, and Larren

PREFACE

The digital area continues to undergo rapid change, making necessary the revision of books covering digital circuitry and digital computers. Integrated circuits (ICs) continue to improve, with smaller, faster, and more complex units becoming available. The second edition of *Introduction to Digital Computer Technology* includes up-to-date material on small-scale integrated (SSI), medium-scale integrated (MSI), and large-scale integrated (LSI) circuitry. Since the trend continues to be toward an increased use of MSI and LSI units, including microprocessors (μ processors), the new material provided here includes more coverage in these areas.

Surprisingly, the basic material of the first edition remains appropriate today. Although the primary purpose in first revising the original text, published in 1966, was to incorporate improvements in the organization and development of the subject matter, based on the experience of many teachers around the country, this second edition of *Introduction to Digital Computer Theory* is being published mainly for the inclusion of current material. No new chapters are introduced, and the order in which the material is presented remains the same. The upgrading of IC material, based on our courses at Queensborough Community College, and on the suggestions of other teachers, is particularly relevant for a textbook on digital computer theory.

I have retained the original organization, with sections on fundamentals, computer circuits, and computer units. In the fundamentals section, the chapters covering basic number systems, machine language programming, and basic computer codes are not substantially changed. Those covering Boolean algebra have been revised, however, to provide emphasis on more current logic design, such as use of exclusive-OR gates, wired-OR and wired-AND connections, design with MSI units, and the removal of initial concept development on relay logic.

The computer circuits section is greatly changed, since this section has the largest amount of new material and a new emphasis. Discrete circuits are covered very briefly. Chapter 7 now provides the most material on SSI logic units. Similarly, Chapter 8 is essentially new, with revised material reflecting the present use of SSI and MSI logic units. Although Chapter 9 still covers counters and transfer registers, it too is essentially a new chapter, providing applications using SSI and MSI units. Chapters 7 to 9, then, are those that are most heavily modified, reflecting the greatest change that has taken place in IC units.

Section Three has been updated and now includes material on microprocessors and on MSI multiplexer circuitry in Chapter 10, and on IC memory (RAM, ROM, and PROM) in Chapter 11. MSI arithmetic units are discussed in Chapter 12, and more material on teletype, optical I/O, and MODEMs is provided in Chapter 13.

The book continues to include numerous examples that highlight the important aspects of each chapter. Exercises are provided at appropriate places within the chapter, and problems (which are keyed by section) appear at the end of each chapter. This breakdown of exercises and problems allows the instructor to select suitable material for assignment to students when covering specific topics in a chapter, and then to give them problems relating to the material of the entire chapter. Answers to selected problems are given at the end of the book, and a solutions manual for both exercises and problems is available to instructors.

There is sufficient material in the three sections to meet the needs of curricula in which specific sections of study are more important than others, or in which certain material has already been covered in a previous course. For example, if digital computer circuits have been studied in another course, the sections on computer fundamentals and computer units still contain sufficient material for a one-term course. If only a single course is provided as an introduction to the digital computer, then Chapters 1 to 5 of the fundamentals section, parts of Chapters 7 to 9 on computer circuits, and parts of Chapters 10 to 13 on computer units can be integrated into a single course. When a number of courses are provided, as in a computer technology curriculum, separate courses covering fundamentals, computer circuits, and computer units can be offered by using the full text material.

In essence, the amount of material provided in the book, and its sequence of presentation, is appropriate either for a single course in a two-year college curriculum or for more detailed courses in a computer technology curriculum. The book can also be used as a supplementary text in a four-year computer course (especially the fundamentals and IC material); or the fundamentals and circuits sections may be used in a technical high school course.

I express my appreciation to the many companies who supplied illustrative material used in the book. International Business Machines Corporation supplied many of the illustrations and the photographs for several chapters (mainly in Chapter 13). A number of fine photographs were also supplied by the Digital Equipment Corporation, Control Data Corporation, Hazeltine Corporation, DIGIAC Corporation, Honeywell Corporation, and Burroughs Corporation.

I especially thank Professor Joseph B. Aidala, Chairman of the Electrical Technology Department of Queensborough Community College, for his continual encouragement and support. I also thank Doris Topel for her excellent typing of the original manuscript, as well as Sylvia Neiman and Helene Rosenberg. I also express thanks to Al Lesure of Wiley, for his interest and help in making this second edition a technically superior book.

Louis Nashelsky

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Section One—Fundamentals

SECTION ONE
FUNDAMENTALS

0001 INTRODUCTION

1–1 GENERAL

Digital computers continue to be an important item of study in the technology area as well as in mathematics, science, and business. The profound effect of computers on society is already quite evident. It is therefore essential to have an understanding of how the computer is used and how it operates. Although calculating machine history can be traced back to the nineteenth century (if not earlier) the modern computer was first considered in the 1930s and actually developed only around 1950. In essence, the modern electronic digital computer has been around for about 30 years. It seems incredible that in so short a time it could have advanced so far and become so essential a tool in scientific and business operation. There is no doubt that a combination of growth in the technological field and the need for high-speed data processors and calculators have spurred development in this short period of time.

Digital computers fall into two general categories: general-purpose and special-purpose computers. A general-purpose machine is designed to be programmed to solve a large variety of problems. Within a few minutes it can study some medical problem, do financial bookkeeping, study an engineering design, or play checkers with the operator. A special-purpose machine is designed around a specific problem and is optimized to do only that type of problem. As such it is usually smaller, less expensive, and more efficient in performing that specific task. Two applications of special-purpose computers are production control of a refinery and guidance control of a missile or plane. Both types of digital computer are basically the same in structure. The distinctions are in specific units used to bring data into the computer and feed information out, and in the flexible steps of operation of the general-purpose as compared to the special-purpose machine. Microprocessors are presently quite useful in designing special purpose computers—their small size and low cost making them excellent for solving special problems.

1–2 BACKGROUND HISTORY

We could start our brief view of computer history with the calculating "bones" of Napier in 1642 or the mechanical "analytical engine" of Babbage in the first half of the 1800s. The modern electronic computer, however, started with the ENIAC (Electronic Numerical Integrator And Calculator) completed in 1946 by Eckert and Mauchly at the University of Pennsylvania.

The ENIAC, which was used for ballistic calculations, had limited storage capacity, and required laborious setup or programming by numerous switches and plugboards. It was however, a considerable improvement on the electro-mechanical calculator, the Mark I built for IBM by Aiken of Howard University in 1944. Whereas the Mark I used relays, the ENIAC memory and operations were performed by vacuum-tube electronic circuits.

The first electronic computer used in a commercial field was the UNIVAC I built for Sperry Rand, for use by the Bureau of Census, by Eckert and Mauchly. This early UNIVAC Computer (UNIVersal Automatic Computer) opened the door to the basic computer structure that is still used today. Although the ENIAC, for example, had to be programmed by a fixed, plugged-in set of instructions, the UNIVAC employed an internal stored program concept in which any desired program could be easily entered into memory *and changed by the computer itself.* The excitement of this new concept can be seen in the following report written by John von Neumann in 1946 based on work being carried out at the Moore School of Engineering at the University of Pennsylvania:

> "*Since the orders that exercise the entire control are in the memory, a higher degree of flexibility is achieved than in any previous mode of control. Indeed, the machine, under control of its orders, can extract numbers (or orders, from memory, process them (as numbers!), and return them to the memory (to the same or other locations); i.e., it can change the contents of the memory—indeed this is its normal modus operandi. Hence it can, in particular, change the orders (since they are in memory!)—the very orders that control its actions. Thus all sorts of sophisticated order-systems become possible, which keep successively modifying themselves and hence also the computational processes that are likewise under its control.*"

The ENIAC, the first fully electronic machine, was followed quickly by a variety of machines such as the EDVAC, SEAC, and Whirlwind I which were one of a kind machines. The UNIVAC I and IBM 650 were the first machines built for production. These were *first generation* computers using tubes and operating in machine language. After about 1950 the advent of the transistor considerably affected the size and reliability of computers built as *second-generation* machines. In the 1960s the computer structure became quite important and operating systems were developed as integral to the operation of these *third-generation* computers. *Fourth-generation* computers entered the market in the 1970s with integrated circuits (ICs) organized in the mass structure design (large scale integration or LSI) and operating systems of great complexity.

Such concepts as multiprccessing, multiplexed operation, and overlay operation have allowed more work to be performed by the computer. They also allow *time-shared* operation in which a number of users, at remote points, use the computer via telephone line connections, all at the "same" time. Actually, the third- and fourth-generation computers are so fast internally that the slow entry from keyboard, for example, allows sufficient time to switch around among the users so that all *seem* to be operating the machine at the same time.

1–3 DIGITAL COMPUTER SYSTEM

The basic parts of any digital computer are the input unit, arithmetic unit, control unit, memory unit, and output unit. Figure 1–1 shows a simplified block diagram indicating the many computer flow paths. Let us consider a general-purpose machine first; the input units may be paper tape, punched card, magnetic tape, typewriter (specially adapted), or magnetic disk, to list the most common. The input unit provides data and instructions to the computer. To change the type of problem being solved only requires feeding a new set of instructions and data to the computer. Each type of input device is suited to a particular use. Punched cards may contain individual instructions

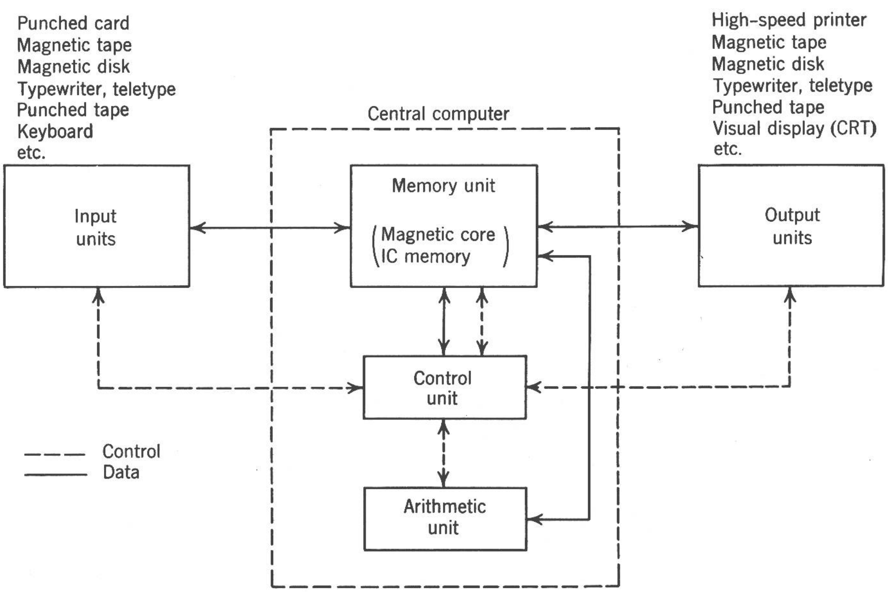

FIGURE 1–1. Basic computer units, block diagram.