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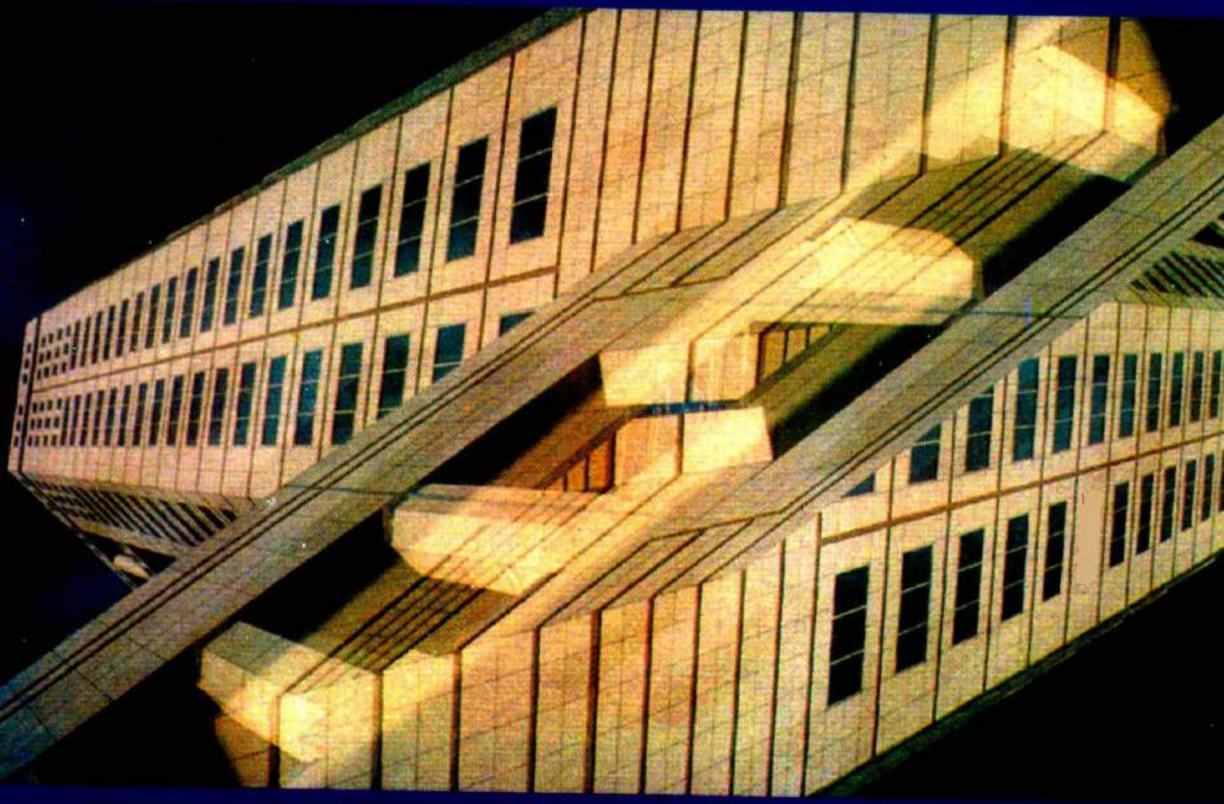
COMPUTER SYSTEM ARCHITECTURE

THIRD EDITION



M. Morris Mano

THIRD EDITION

COMPUTER SYSTEM ARCHITECTURE

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COMPUTER SYSTEM ARCHITECTURE, 3rd Ed.
by M. Morris Mano

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Preface

This book deals with computer architecture as well as computer organization and design. Computer architecture is concerned with the structure and behavior of the various functional modules of the computer and how they interact to provide the processing needs of the user. Computer organization is concerned with the way the hardware components are connected together to form a computer system. Computer design is concerned with the development of the hardware for the computer taking into consideration a given set of specifications.

The book provides the basic knowledge necessary to understand the hardware operation of digital computers and covers the three subjects associated with computer hardware. Chapters 1 through 4 present the various digital components used in the organization and design of digital computers. Chapters 5 through 7 show the detailed steps that a designer must go through in order to design an elementary basic computer. Chapters 8 through 10 deal with the organization and architecture of the central processing unit. Chapters 11 and 12 present the organization and architecture of input-output and memory. Chapter 13 introduces the concept of multiprocessing. The plan of the book is to present the simpler material first and introduce the more advanced subjects later. Thus, the first seven chapters cover material needed for the basic understanding of computer organization, design, and programming of a simple digital computer. The last six chapters present the organization and architecture of the separate functional units of the digital computer with an emphasis on more advanced topics.

The material in the third edition is organized in the same manner as in the second edition and many of the features remain the same. The third edition, however, offers several improvements over the second edition. All chapters except two (6 and 10) have been completely revised to bring the material up to date and to clarify the presentation. Two new chapters were added: chapter 9 on pipeline and vector processing, and chapter 13 on multiprocessors. Two sections deal with the reduced instruction set computer (RISC). Chapter 5 has been revised completely to simplify and clarify the design of the basic computer. New problems have been formulated for eleven of the thirteen chapters.

The physical organization of a particular computer including its registers, the data flow, the microoperations, and control functions can be described symbolically by means of a hardware description language. In this book we develop a simple register transfer language and use it to specify various computer operations in a concise and precise manner. The relation of the register transfer language to the hardware organization and design of digital computers is fully explained.

The book does not assume prior knowledge of computer hardware and the material can be understood without the need of prerequisites. However, some experience in assembly language programming with a microcomputer will make the material easier to understand. Chapters 1 through 3 can be skipped if the reader is familiar with digital logic design.

The following is a brief description of the subjects that are covered in each chapter with an emphasis on the revisions that were made in the third edition.

Chapter 1 introduces the fundamental knowledge needed for the design of digital systems constructed with individual gates and flip-flops. It covers Boolean algebra, combinational circuits, and sequential circuits. This provides the necessary background for understanding the digital circuits to be presented.

Chapter 2 explains in detail the logical operation of the most common standard digital components. It includes decoders, multiplexers, registers, counters, and memories. These digital components are used as building blocks for the design of larger units in the chapters that follow.

Chapter 3 shows how the various data types found in digital computers are represented in binary form in computer registers. Emphasis is on the representation of numbers employed in arithmetic operations, and on the binary coding of symbols used in data processing.

Chapter 4 introduces a register transfer language and shows how it is used to express microoperations in symbolic form. Symbols are defined for arithmetic, logic, and shift microoperations. A composite arithmetic logic shift unit is developed to show the hardware design of the most common microoperations.

Chapter 5 presents the organization and design of a basic digital computer. Although the computer is simple compared to commercial computers, it nevertheless encompasses enough functional capabilities to demonstrate the power of a stored program general purpose device. Register transfer language is used to describe the internal operation of the computer and to specify the requirements for its design. The basic computer uses the same set of instructions as in the second edition but its hardware organization and design has been completely revised. By going through the detailed steps of the design presented in this chapter, the student will be able to understand the inner workings of digital computers.

Chapter 6 utilizes the twenty five instructions of the basic computer to illustrate techniques used in assembly language programming. Programming examples are presented for a number of data processing tasks. The relationship between binary programs and symbolic code is explained by examples. The basic operations of an assembler are presented to show the translation from symbolic code to an equivalent binary program.

Chapter 7 introduces the concept of microprogramming. A specific microprogrammed control unit is developed to show by example how to write microcode for a typical set of instructions. The design of the control unit is carried-out in detail including the hardware for the microprogram sequencer.

Chapter 8 deals with the central processing unit (CPU). An execution unit with common buses and an arithmetic logic unit is developed to show the general register organization of a typical CPU. The operation of a memory stack is explained and some of its applications are demonstrated. Various instruction formats are illustrated together with a variety of addressing modes. The most common instructions found in computers are enumerated with an explanation of their function. The last section introduces the reduced instruction set computer (RISC) concept and discusses its characteristics and advantages.

Chapter 9 on pipeline and vector processing is a new chapter in the third edition. (The material on arithmetic operations from the second edition has been moved to Chapter 10.) The concept of pipelining is explained and the way it can speed-up processing is illustrated with several examples. Both arithmetic and instruction pipeline is considered. It is shown how RISC processors can achieve single-cycle instruction execution by using an efficient instruction pipeline together with the delayed load and delayed branch techniques. Vector processing is introduced and examples are shown of floating-point operations using pipeline procedures.

Chapter 10 presents arithmetic algorithms for addition, subtraction, multiplication, and division and shows the procedures for implementing them with digital hardware. Procedures are developed for signed-magnitude and signed-2's complement fixed-point numbers, for floating-point binary numbers, and for binary coded decimal (BCD) numbers. The algorithms are presented by means of flowcharts that use the register transfer language to specify the sequence of microoperations and control decisions required for their implementation.

Chapter 11 discusses the techniques that computers use to communicate with input and output devices. Interface units are presented to show the way that the processor interacts with external peripherals. The procedure for asynchronous transfer of either parallel or serial data is explained. Four modes of transfer are discussed: programmed I/O, interrupt initiated transfer, direct memory access, and the use of input-output processors. Specific examples illustrate procedures for serial data transmission.

Chapter 12 introduces the concept of memory hierarchy, composed of cache memory, main memory, and auxiliary memory such as magnetic disks. The organization and operation of associative memories is explained in detail. The concept of memory management is introduced through the presentation of the hardware requirements for a cache memory and a virtual memory system.

Chapter 13 presents the basic characteristics of mutiprocessors. Various interconnection structures are presented. The need for interprocessor arbitration, communication, and synchronization is discussed. The cache coherence problem is explained together with some possible solutions.

Every chapter includes a set of problems and a list of references. Some of the problems serve as exercises for the material covered in the chapter. Others are of a more advanced nature and are intended to provide practice in solving problems associated with computer hardware architecture and design. A solutions manual is available for the instructor from the publisher.

The book is suitable for a course in computer hardware systems in an electrical engineering, computer engineering, or computer science department. Parts of the book can be used in a variety of ways: as a first course in computer hardware by covering Chapters 1 through 7; as a course in computer organization and design with previous knowledge of digital logic design by reviewing Chapter 4 and then covering chapters 5 through 13; as a course in computer organization and architecture that covers the five functional units of digital computers including control (Chapter 7), processing unit (Chapters 8 and 9), arithmetic operations (Chapter 10), input-output (Chapter 11), and memory (Chapter 12). The book is also suitable for self-study by engineers and scientists who need to acquire the basic knowledge of computer hardware architecture.

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