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Computer Architecture

Educational Book

Specialty: Computer Science

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Foreword

This course is primarily intended for undergraduate students pursuing a Bachelor's degree in computer science (LMD Second Year Bachelor's) and those in vocational training institutes and schools. It consists mainly of five chapters, the last of which is dedicated to practical exercises.

This course handout is the result of several years of experience in computer architecture. It covers the curriculum defined by the national teaching committee. It consists of three sections: lectures, exercises, and practical work. The latter is covered in five chapters: Von Neumann Architecture, External Architecture of the MIPS R3000 Microprocessor, Synchronous State Automata Theory, Internal Architecture of the MIPS R3000 Microprocessor, and the final chapter is dedicated to practical exercises using DOS *debugging and Turbo Assembler*.

The first and second chapters are very important and precisely follow the curriculum and pedagogical approach. Therefore, we have added a series of exercises with answer keys at the end of each chapter.

1 Von Neumann's Architecture

1.1. History of computer machines

Several classifications have been given regarding the evolution of computer machines:

The evolution of computer machines reflects a continuous advancement in technology, moving from large and inefficient systems to highly powerful and intelligent devices. In the first generation, computers relied on vacuum tubes, making them bulky, expensive, and unreliable. With the introduction of transistors in the second generation, computers became smaller, faster, and more energy-efficient. The development of integrated circuits in the third generation further improved performance and enabled the emergence of operating systems and multiprogramming. The fourth generation marked a major breakthrough with the invention of microprocessors, leading to the widespread use of personal computers and modern software applications. Today, the fifth generation focuses on artificial intelligence, parallel processing, and advanced computing technologies, aiming to create machines capable of learning, reasoning, and interacting naturally with humans. This progression highlights the shift from hardware-oriented systems to intelligent, software-driven solutions that shape modern society.

Generation	Period	Main Technology	Processing Speed	Main Memory	Secondary Storage	Examples
1st Generation	1940 – 1956	Vacuum Tubes	Very slow (milliseconds)	Magnetic drums	Punched cards, paper tape	ENIAC, UNIVAC I
2nd Generation	1956 – 1963	Transistors	Faster (microseconds)	Magnetic core memory	Magnetic tapes, disks	IBM 1401, IBM 7090
3rd Generation	1964 – 1971	Integrated Circuits (IC)	Faster (nanoseconds)	Semiconductor memory	Hard disks	IBM System/360
4th Generation	1971 – Present	Microprocessors	Very fast (picoseconds)	RAM (semiconductor)	SSD, HDD	Intel-based PCs, Apple Macintosh
5th Generation	Present – Future	AI, Parallel Processing	Extremely fast	Advanced semiconductor & cloud memory	Cloud storage	AI systems, Quantum computers

1.2. Elements of a computer system

A computer is defined as an information-processing machine. A computer system is defined as a set of hardware and software necessary for information processing.

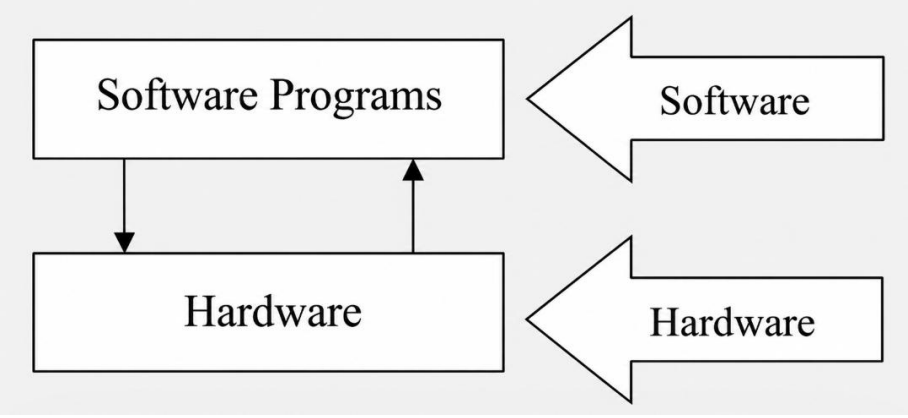

Figure 1-1. Element of computer.

1.2.1. Hardware

The section that represents the hardware components with which the computer is built:

- The processor or CPU
- The MC
- Exchange units or input/output units
- The peripherals

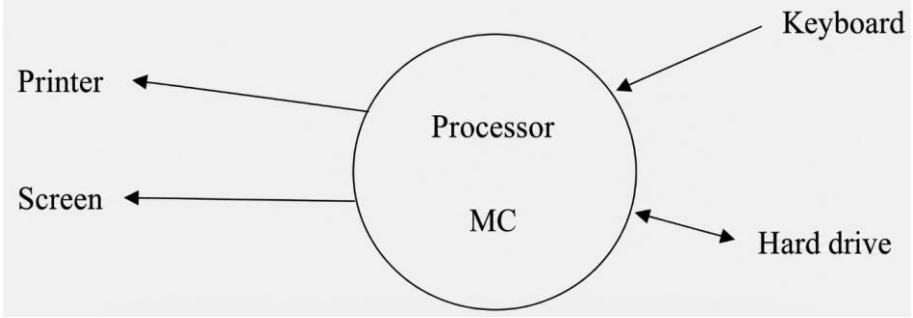

Figure 1-2. Hardware of computer

1.2.2. Software

Software represents the logical component of a computer system. It encompasses all programs and instructions that enable the hardware to operate and allow users to perform specific tasks according to their needs. Unlike hardware, which is physical and tangible, software is intangible and exists in the form of coded instructions.

A program is defined as a structured sequence of instructions written in a programming language that the computer can interpret and execute. For a program to function correctly, it must operate on data, which it processes to produce meaningful results.

Software can be broadly classified into two main categories:

- System software (basic programs)
- Application software

1.2.2.1. System Software (Basic Programs)

System software consists of programs designed to manage and control the hardware resources of a computer. It provides a platform for running application programs and ensures the proper functioning of the entire system. The most important component of system software is the operating system (OS).

The operating system acts as an intermediary between the user and the hardware. It is responsible for tasks such as process management, memory management, file systems, device control, and security. Over time, operating systems have evolved significantly, differing in their architecture, user interfaces, performance, and security features.

Some well-known operating systems include:

- MS-DOS (early command-line operating system)
- Microsoft Windows (widely used graphical operating system)
- Unix (multiuser, multitasking system, widely used in servers)
- macOS (Apple's operating system for Macintosh computers)

1.2.2.2. Application programs

Application software refers to programs designed to help users perform specific tasks or solve particular problems. These programs run on top of the operating system and are tailored to various domains and user requirements.

Depending on their purpose, application software can be classified into several categories:

- Office and desktop software (word processors, spreadsheets, presentation tools)
- Programming software (compilers, interpreters, development environments)
- Management and business software (databases, accounting systems, ERP)
- Simulation and scientific software (modeling, engineering, research applications)
- Communication software (email clients, messaging, collaboration tools)

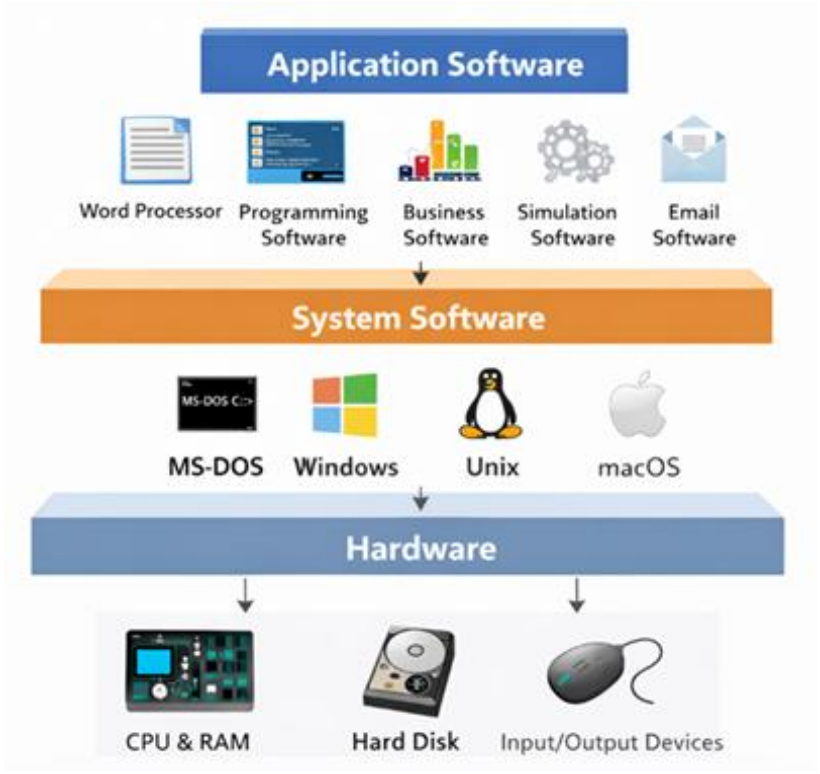

Figure 1-3. Computer System