Chapter 1

INTRODUCTION

Overview

- Computer Organization and Architecture
- Digital Computer
- Operating System
- Von Neumann Concept

1.1 Preamble

A computer is an electronic device that stores, retrieves and processes data. It can be programmed with instructions and is composed of hardware and software. A computer can exist in a variety of sizes and configurations.

To be more precise it can be said that a computer is a computing machine, which performs computational jobs based on a program.

Types of computers

Computers are mainly of two types:

A) Analog Computer

It deals with continuous values and continuous time domain and does not support discrete values. So values should be like, say, 5.4, 6.9 etc. (i.e. continuous values). Analog computers though not in use nowadays, were mainly used to simulate systems based on differential equations.

B) Digital Computer

This computer performs computational tasks using the binary number system, having digits, 0 and 1. Information in this computer is represented by variables that take a limited number of discrete values.

A binary digit is called a ***bit***. Information is represented in digital computers in groups of bits. These types of computers will have two states: 0 and 1.

1.2 Computer Organization and Architecture

The distinction between a computer's architecture and its organization is very apparent.

Computer Organization

Computer Organization is concerned with the way the hardware components operate and the way they are connected together to form the computer system. It refers to the operational units & their interconnections that realize the architectural specifications. Organization is basically the designer view of the computer hardware i.e. as a designer, one must know, how the different hardware elements are designed and implemented, how they are to be interconnected, how they operate. It basically deals with the in-depth detailed view of the computer hardware and also verifies whether the computer parts do operate as intended.

Computer Architecture

Computer Architecture is the study of the structure and behavior of the various functional modules of digital computers as seen by a programmer and also how they interact to provide the processing needs of the user. Architecture includes the instruction formats,

instruction sets, and addressing modes. It refers to those attributes of the system that have a direct impact on the logical execution of the program i.e. what are the basic hardware needed, what functions they do, what are the elements that are needed for the direct execution of the programs, etc. It is basically the higher-level or top-level functional view of the computer hardware. Architecture does not provide any information regarding the detailed implementation of the hardware elements.

Differences between Computer Organization and Architecture

Let us discuss the differences between the two considering an example.

Suppose an Accumulator is to be designed. So, ***organization*** is concerned with the details its implementation, how it will be designed, what are the parts and their details, how the different elements of the accumulator will be interconnected, how they will operate etc.

On the other hand, ***architecture*** will just handle the different functioning and behavioral aspects of the accumulator as seen by the programmer i.e. what functions the accumulator will do and how it will behave (because as a programmer, one is only concerned about the functions of the accumulator and not with its implementation details).

1.3 Parts of a Digital Computer

A digital computer consists of the following main parts:

Central Processing Unit (CPU)

Memory Unit

I/O (input-output) Unit

Block Diagram of a Digital Computer

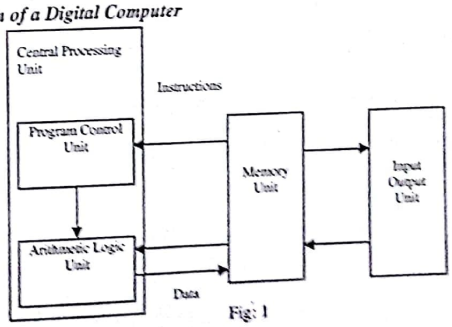


Fig: 1

Structure and Functions of the Different Units of a Digital Computer

Consider the figure 1.

(a) Memory Unit

Its purpose is to store both instructions & data. It is also called the Random-Access Memory (RAM) because the CPU can access any memory location at random.

(b) CPU

It acts as the brain of the computer and performs the bulk of data processing operations in a computer. The two main units of a CPU are the Arithmetic Logic Unit and the Program Control Unit. The important parts of CPU are:

(i) Arithmetic Logic Unit (ALU)

It performs instructions related to arithmetic operations like ADD, SUB, MUL etc. and logical operations like AND, OR etc.

(ii) Program Control Unit (PCU)

It interprets & sequences instructions i.e., interprets & sequences which instruction in a program is to be executed first.

(iii) Register Sets

These are collections of registers that store data.

(c) Input-Output (I/O) Unit

This unit provides an efficient mode of communication between the central system (computer) & the outside environment. Through the I/O unit, programs & data must be entered into computer memory for processing & results obtained from computations must be recorded or displayed to the user.

1.4 Operating System

In order to use computer hardware in an efficient manner, each computer must have an operating system in it. An Operating System is a program (can also be considered as a system software) that acts as an intermediary between a user of a computer & the computer hardware.

Block Diagram

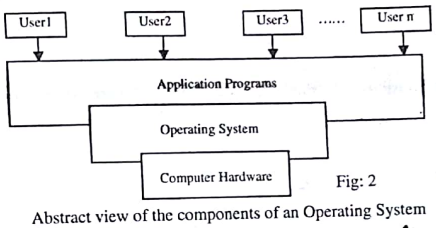


Fig: 2

Abstract view of the components of an Operating System

Explanation

As explained earlier an Operating System is a program (or system software) that acts as an intermediary between a user of a computer & the computer hardware. Its purpose is to provide an environment in which a user can execute programs conveniently. So, an O.S. helps to use the computer hardware in an efficient manner.

O.S. and computer architecture & organization have a great deal of influence on each other. To facilitate the use of the hardware, O.S. was developed. So design and use of O.S. has made the hardware design more simplified.

Types of Operating Systems

The following are some of the different types of O.S. in use:

(a) Microsoft Disk Operating System (MS-DOS)
(b) Microsoft Windows Operating Systems (WIN 95, WIN 98, WIN 2K, WIN XP etc.)
(c) Linux Operating System
(d) Unix Operating System
(e) MAC-OS
(f) Sun Solaris Operating System

Functions of an Operating System:

O.S. has the following functions.

(a) O.S. coordinates the efficient use of the hardware

Operating System controls & coordinates the use of the hardware among the various application programs (like compilers, database systems, games etc.) for the various users (like people, machines, and other computers).

(b) O.S. provides an environment within which other programs can do useful work

Operating System provides the means for the proper use of the resources (like hardware, software & data) of a computer system in the meaningful & smooth operation of the computer.

(c) O.S. acts as a resource allocator

O.S. manages the various resources (hardware and software) of a computer system & allocates them to specific programs & users as necessary for their tasks.

(d) O.S. acts a control program

As a control program O.S. focuses on the need to control the operations of the various input-output devices & user programs i.e. it controls the execution of user programs to prevent errors & improper use of the computer.

1.5 Von Neumann Concept

John Von Neumann was a mathematician who was a consultant on the ENIAC project (Electronic Numerical Integrator and Computer), the world's first general-purpose electronic digital computer.

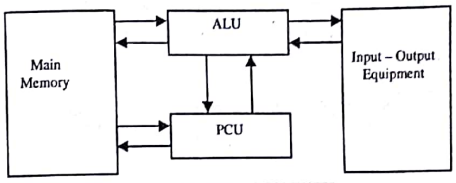
Explanation of the Von Neumann Concept

Neumann proposed the idea, known as the stored- program concept, which deals with making the programming process easier by representing programs in a form such that they can be suitably stored in memory alongside the data. So, a computer could get its instructions by reading them from memory & also a program could be set or altered depending on the memory values.

Thus Von Neumann introduced the key concept of stored programs (i.e. programs & their data were located in the same memory) in the first generation computers. Neumann published the idea in 1945 while proposing a new computer, the EDVAC (Electronic Discrete Variable Computer) and in 1946, Neumann along with others began the design of the new stored-program computer, known as the IAS computer at the Princeton Institute for Advanced Studies & got it complete by 1952.

Structure of the Computer Deigned by Neumann

The computer designed based on the idea of stored-program concept proposed by Von Neumann is known as the ***IAS computer.*** It was designed at the Princeton Institute for Advanced studies in 1952.



STRUCTURE OF THE IAS COMPUTER Fig: 3

Main Features of the IAS Computer

The main features of an IAS computer are:

(a) A main memory, which stores both data & instructions.
(b) An arithmetic-logical unit (ALU) capable of operating on binary data.
(c) A control unit, which interprets the instructions in memory & causes them to be executed.
(d) Input & output (I/O) unit operated by the control unit.
(e) The memory is read-write in nature.
(f) The contents of this memory are addressable by location.
(g) Execution generally occurs in a sequential fashion from one instruction to the next.

Von Neumann 'architecture'

All of today's computers, generally, having the same general structure & function are thus referred to as ***Von Neumann machines*** and this design is referred to as the ***Von Neumann architecture.***

Bottlenecks of the Von Neumann concept

Some of the shortcomings of the Von Neumann design are:

a) Bandwidth between CPU and memory is very small in comparison with the amount of memory.
b) The address modification scheme in the IAS computer was inefficient and so, to restart a program, the original unmodified program must be reloaded into main memory.
c) No facilities were provided for structuring programs e.g. instructions to link program modules such as subroutines (procedures) that implement frequently used program steps.
d) Floating-point arithmetic was not implemented due to the cost of hardware needed.
e) As in each word two instructions were stored, hence the program control unit and the instruction set got highly complicated.

Related Questions & Answers

Question 1

What is meant by the word 'digital'?

Answer:
Information in the computer is represented by variables that take a limited number of discrete values.

Example
Decimal digits 0, 1, 2, ..., 9 provide 10 discrete values. Binary digits 0 & 1 provide 2 discrete values.

These discrete values are processed internally by components that can maintain a limited number of discrete states i.e. each discrete value can represent a discrete state.

Example
Computers with binary discrete values like 0 & 1, will take 2 states e.g. false & true / off & on/ low & high etc.

Question 2

What would happen if a computer does not have any O.S. installed in it?

Answer:
In absence of the O.S. a computer can perform none of the previous mentioned functions correctly and smoothly.

Question 3

Give names of some early computers using the stored-program concept.

Answer:

a. IBM Selective Sequence Electronic Calculator (SSEC) built by IBM in 1948.
b. The Manchester Small-Scale Experimental Machine (SSEM) built at the University of Manchester in 1948.
c. Electronic Numerical Integrator and Computer (ENIAC) built at the University of Pennsylvania in 1948.

Question 4

Give examples of present day computers using Von Neumann Architecture.

Answer:
Currently, Von Neumann architecture appears in many types of computers existing worldwide. Some of which are:

a. Supercomputers
b. Personal Computers
c. Laptops
d. Workstations.

Question 5

Describe the function of Major Components of a digital computer with neat sketch. **[WBUT 2003, 2005, 2007]**

OR,

Draw a block diagram to illustrate the basic organization of computer system and explain the function of various units. **[WBUT 2006]**

Answer: Refer to section 1.3.

Question 6

Give example of a non-Von Neumann Architecture.

Answer:
Neural Network is a popular non-Von Neumann architecture as such architectures do not have the concept of 'processes'. Also presence of operating system is not that well known in such architectures.

Question 7

What is a Harvard Architecture? How is it different from Von Neumann architecture?

Answer:
Harvard architecture is a computer architecture where the storage and signal pathways for instructions and data are physically separated. So, CPU can read both instructions and data simultaneously from the memory.

Unlike Von Neumann architecture, in a Harvard Architecture, separate memories are used to store instructions and data. Also Harvard Architecture-based computers are faster than Von Neumann computers. But the circuitry used in the Harvard Architecture computers are more complicated than their Von Neumann counterparts.

Question 8

After a computer is turned on, explain the stages within the boot-up sequence.

Answer:
Broadly speaking, there are four different stages within the boot-up sequence after a computer is turned on. These are:

a) POST (Power-on, Self-test) stage:
In this stage, it is checked whether all the fundamental units in the computer systems are functioning properly i.e., whether CPU can be accessed, the cache is powered up and the BIOS is working fine or not. The BIOS then takes over the control once everything is working fine.

b) BIOS (Basic Input/Output System) stage:
In this stage, the other basic systems including the hard disk drive starts up. The bootstrap loader program, which is located at the first sector of the hard disk drive, is searched by the BIOS.

c) Bootstrap Loader stage:
This is a small program located at the hard disk drive, and has the only function of loading the operating system. The bootstrap loader program does this by loading the different drivers controlling the different required sub-systems and then it prepares or activates the rest of the memory to handle the smooth running of the operating system. Finally, the bootstrap loader leaves the system control fully on the operating system once all the sub-systems are ready to function properly.

d) Operating System stage:
This is the final stage of the boot-up sequence. The operating system in this stage takes control of the entire system from the bootstrap loader program and controls the running of the entire system accordingly.

Question 9

What are first, second, third and fourth generation processors?

Answer:
These are the processors made up of PMOS, NMOS, HMOS and HCMOS (High-density n- type Complimentary Metal Oxide Silicon field effect transistor) technologies and four, eight, thirty two and sixty four bits respectively.

Question 10

Explain the role of an operating system in a computer system. **[WBUT 2003, 2008]**
OR,
Write down the functions of an 'Operating system'? **[WBUT 2005, 2006, 2009]**

Answer: Refer to section 1.4.

Question 11

Why is the clock an important part of a digital system?

Answer:
This is because the digital computers work as per the 'clocked logic', which means that most of the circuit components are designed to operate and communicate with each other in a well-defined, coordinated, synchronous way i.e. all the operations are coordinated to the rhythm or beat of a clock. This leads to a less error-prone and simpler design circuit, unlike the asynchronous one.

Question 12

What is Von Neumann architecture? **[WBUT 2004, 2007, 2008, 2009]**
What is Von Neumann bottleneck? **[WBUT 2004, 2006, 2007, 2008, 2009]**

Answer: Refer to section 1.5.

Question 13

What are real-time operating systems?

Answer:
Real-time operating systems, also known as Mission Critical Systems, are those operating systems, which has well-defined fixed time constraints. In order for the system to be fully functional successfully, the different processes that make up the system should function

properly within the defined constraints. Example: Operating system for computers controlling flight operations or medical imaging systems.

Question 14

Explain the different types of real-time operating systems.

Answer:
Real-time operating systems can be either of hard or soft real time operating systems.

Hard Real-time Operating Systems: In such real-time operating systems, it is guaranteed that the critical tasks should be completed on time. So, if an operation or a task is completed after the deadline is reached it is considered as useless in such systems and it might also lead to the failure of the entire system. Example: Access of data stored in short term memory systems.

Soft Real-time Operating Systems: In such cases, though the deadline of completion for a critical task is not to strong as the previous one but critical real-time tasks do get priority over others until the critical tasks gets completed. Example: Operating systems used in multimedia or virtual reality applications.

Question 15

Write short notes on Von Neumann architecture. [WBUT 2005]

Answer: Refer to section 1.5.

Question 16

Explain the different design philosophies of real-time operating systems.

Answer:
There are two different design philosophies behind the designing of real-time operating systems. These are:
Event-Driven Designing: These are priority scheduling designing approaches in which the next event to be designed or processed, gets switched if a higher priority event needs service at that particular time.

Time-Sharing Designing: In such approaches, an event or task to be processed, is switched if there is a clocked interrupt or the entire system is designed in a round-robin fashion.

Question 17

Write short notes on Data flow architecture. [WBUT 2009]

Answer:
Dataflow architectures do not have any program counter and conceptually, depending on whether input arguments to instructions are available (i.e. only if an operand is available, instructions are executed), the executability of instructions is determined. This is in contrast to the commonly used Von Neumann architectures or the control flow architectures. Dataflow architectures find their usage in specialized hardware used in digital signal processing, data warehousing, network routing, parallel computing and graphics processing purposes.

Question 18

How in Von Neumann Scheme, is it decided whether a word fetched from memory is date or instruction?

Answer:
In Von Neumann concept, the same memory could store both data and instructions. There was hardly any typical rule to distinguish between them. Binary numbers used to interpret both data and instructions. However, if computations could be done upon the binary numbers fetched then those can be considered as data and if those fetched can be used for generating control signals, then they are considered ad instructions i.e. instructions were considered as data that can be interpreted as codes for generating various kinds of control signals.

Multiple Choice Type Questions

1. The basic principle of the von Neumann computer is *[WBUT 2007]*

a) Storing program and data in separate memory
b) Using pipelining concept
c) Storing both program and data in the same memory
d) Using a large number of registers

Answer: (c)

2. From a Source Code, a compiler can detect *[WBUT 2010]*

a) Run-time error *b) Logical errors*
c) Syntax error *d) None of these*

Answer: (c)

3. How many minimum, NAND gates are required to make a flip-flop?

a) 4 *b) 3* *c) 2* *d) 5* *[WBUT 2010]*

Answer: (c)

Exercise

1. What do you mean by an operating system?
2. What are the characteristic features of an O.S.?
3. What are the different types of O.S.? Give examples.
4. What are the functions of an O.S.?
5. With the help of a block diagram, explain the structure and functions of the different units of a digital computer.
6. Explain Von Neumann concept.
7. What were the bottlenecks of the Von Neumann concept?
8. What is Von Neumann architecture?