INSTITUTE OF DISTANCE EDUCATION

JIWAJI UNIVERSITY

Gwalior, MP

PGDCA102

COMPUTER ORGANIZATION & ARCHITECTURE

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SCHOOL OF STUDIES IN DISTANCE EDUCATION
JIWAJI UNIVERSITY
Gwalior, MP
INDIA

Syllabus

Computer Organization & Architecture

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CHAPTER 1

BASIC CONCEPTS

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- *Introduction to Computers*
- *Brief History of Computers*
- *Computer Generations*
- *Types of Computers*
- *Basic Operations of a Computer*

1.1 INTRODUCTION

Let us begin with the word 'compute'. It means 'to calculate'. We all are familiar with calculations in our day-to-day life. We apply mathematical operations like addition, subtraction, multiplication, etc. and many other formulae for calculations. Simpler calculations take less time. But complex calculations take much longer time. Another factor is accuracy in calculations. So man explored with the idea to develop a machine which can perform this type of arithmetic calculation faster and with full accuracy. This gave birth to a device or machine called '**computer'**.

The computer we see today is quite different from the one made in the beginning. The number of applications of a computer has increased, the speed and accuracy of calculation has increased. You must appreciate the impact of computers in our day-to-day life. Reservation of tickets in Air Lines and Railways, payment of telephone and electricity bills, deposits and withdrawals of money from banks, business data processing, medical diagnosis, weather forecasting, etc. are some of the areas where computer has become extremely useful.

However, there is one limitation of the computer. Human beings do calculations on their own. But computer is a dumb machine and it has to be given proper instructions to carry out its calculation. This is why we should know how a computer works.

1.2 WHAT IS A COMPUTER?

Computer is an electronic device. As mentioned in the introduction it can do arithmetic calculations faster. But as you will see later it does much more than that. It can be compared to a magic box, which serves different purpose to different people. For a common man computer is simply a calculator, which works automatic and quite fast. For a person who knows much about it, computer is a machine capable of solving problems and manipulating data. It accepts data, processes the data by doing some mathematical and logical operations and gives us the desired output.

Therefore, we may define *computer as a device that transforms data*. Data can be anything like marks obtained by you in various subjects. It can also be name, age, sex, weight, height, etc. of all the students in your class or income, savings, investments, etc., of a country. Computer can be defined in terms of its functions: It can (i) accept data (ii) store data, (iii) process data as desired, and iv) retrieve the stored data as and when required and v) print the result in desired format. You will know more about these functions as you go through the later lessons.

Figure 1.1 shows personal computer.

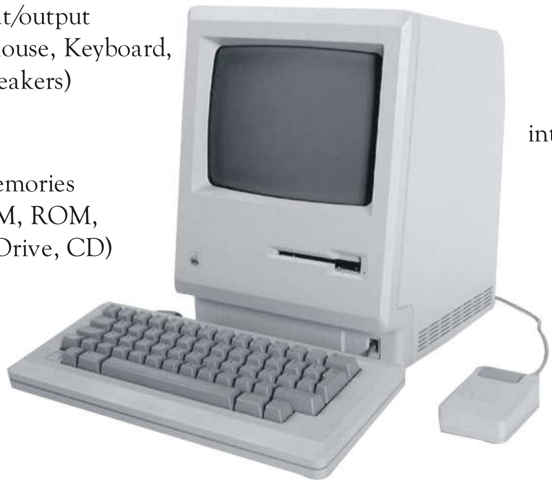


Figure 1.1 *Personal Computer*

1.3 CHARACTERISTICS OF COMPUTER

Let us identify the major characteristics of computer. A computer can be judged by various factors, some of them are:

Speed

As we know computer can work very fast. It takes only few seconds for calculations that we take hours to complete. Suppose you are asked to calculate the average monthly income of one thousand persons in your neighborhood. For this you have to add income from all sources for all persons on a day-to-day basis and find out the average for each one of them. *How long will it take for you to do this?* One day, two days or one week? *Do you know your small computer can finish this work in few seconds?* The weather forecasting that you see every day on TV is the results of compilation and analysis of huge amount of data on temperature, humidity, pressure, etc. of various places on computers. It takes few minutes for the computer to process this huge amount of data and give the result.

We will be surprised to know that computer can perform millions (1,000,000) of instructions and even more per second. Therefore, we determine the speed of computer in terms of microsecond (10^{-6} part of a second) or nano-second (10^{-9} part of a second). From this you can imagine how fast your computer performs work.

Accuracy

Suppose some one calculates faster but commits a lot of errors in computing. Such result is useless. There is another aspect. Suppose you want to divide 15 by 7. You may work out up to 2 decimal places and say the dividend is 2.14. I may calculate up to 4 decimal places and say that the result is 2.1428. Some one else may go up to 9 decimal places and say the result is 2.142857143. Hence, in addition to speed, the computer should have accuracy or correctness in computing.

The degree of accuracy of computer is very high and every calculation is performed with the same accuracy. The accuracy level is determined on the basis of design of computer. The errors in computer are due to human and inaccurate data.

Diligence

A computer is free from tiredness, lack of concentration, fatigue, etc. It can work for hours without creating any error. If millions of calculations are to be performed, a computer will perform every calculation with the same accuracy. Due to this capability it overpowers human being in routine type of work.

Versatility

It means the capacity to perform completely different type of work. You may use your computer to prepare payroll slips. Next moment you may use it for inventory management or to prepare electric bills.

Power of Remembering

Computer has the power of storing any amount of information or data. Any information can be stored and recalled as long as you require it, for any numbers of years. It depends entirely upon you how much data you want to store in a computer and when to lose or retrieve these data.

No IQ

Computer is a dumb machine and it cannot do any work without instruction from the user. It performs the instructions at tremendous speed and with accuracy. It is you to decide what you want to do and in what sequence. So a computer cannot take its own decision as you can.

Storage

The Computer has an in-built memory where it can store a large amount of data. You can also store data in secondary storage devices such as floppies, which can be kept outside your computer and can be carried to other computers.

1.4 HISTORY OF COMPUTER

History of computer could be traced back to the effort of man to count large numbers. This process of counting of large numbers generated various systems of numeration like Babylonian system of numeration, Greek system of numeration, Roman system of numeration and Indian system of numeration. Out of these the Indian system of numeration has been accepted universally. It is the basis of modern decimal system of numeration (0, 1, 2, 3, 4, 5, 6, 7, 8, 9). Later you will know how the computer solves all calculations based on decimal system. But you will be surprised to know that the computer does not understand the decimal system and uses binary system of numeration for processing.

We will briefly discuss some of the path-breaking inventions in the field of computing devices.

1.5 CALCULATING MACHINES

It took over generations for early man to build mechanical devices for counting large numbers. The first calculating device called ABACUS was developed by the Egyptian and Chinese people.

The word ABACUS means calculating board. It consists of sticks in horizontal positions on which were inserted sets of pebbles. A modern form of ABACUS is given in Figure 1.2. It has a number of horizontal bars each having ten beads. Horizontal bars represent units, tens, hundreds, etc.

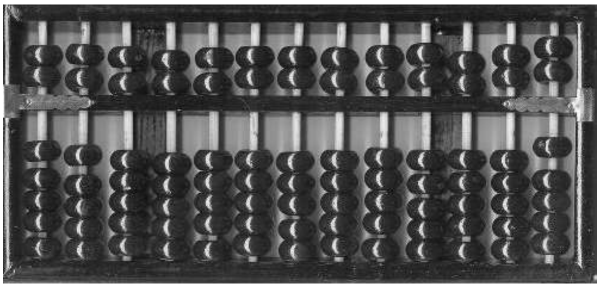


Figure 1.2 *Abacus Computer*

Napier's bones

English mathematician John Napier built a mechanical device for the purpose of multiplication in 1617 A D. The device was known as Napier's bones.

Slide Rule

English mathematician Edmund Gunter developed the slide rule. This machine could perform operations like addition, subtraction, multiplication, and division. It was widely used in Europe in 16th century.

1.5.1 Pascal's Adding and Subtractory Machine

You might have heard the name of Blaise Pascal. He developed a machine at the age of 19 that could add and subtract. The machine consists of wheels, gears and cylinders (shown in figure 1.3).

1.5.2 Leibniz's Multiplication and Dividing Machine

The German philosopher and mathematician Gottfried Leibniz built around 1673 a mechanical device that could both multiply and divide.

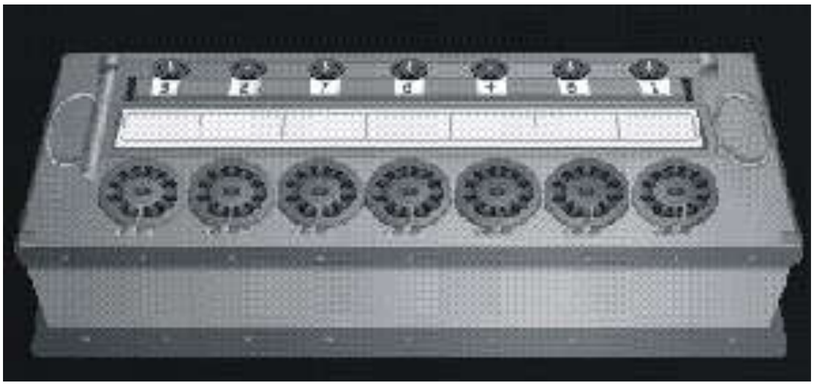


Figure 1.3 *Leibniz's Machine*

1.5.3 Babbage's Analytical Engine

It was in the year 1823 that a famous English man Charles Babbage built a mechanical machine to do complex mathematical calculations. It was called *difference engine*. Later he developed a general-purpose calculating machine called *analytical engine*. He is known as the *father of computer*.

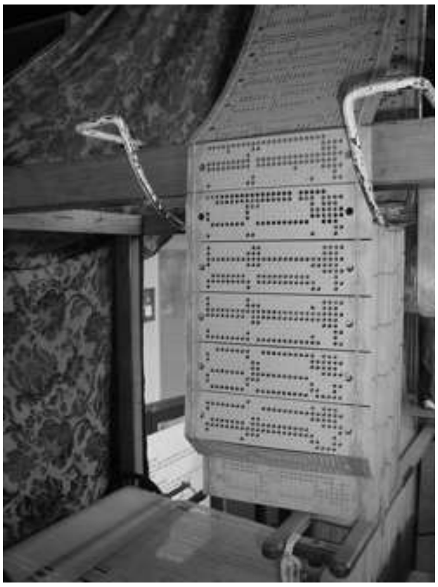


Figure 1.4 *Babbage's machine*

1.5.4 Mechanical and Electrical Calculator

In the beginning of 19^{th} century the mechanical calculator was developed to perform all sorts of mathematical calculations. Up to the 1960s it was widely used. Later the rotating part of mechanical calculator was replaced by electric motor. So it was called the electrical calculator.

1.5.5 Modern Electronic Calculator

The electronic calculator used in 1960s was run with electron tubes, which was quite bulky. Later it was replaced with *transistors* and as a result the size of calculators became too small.

The modern electronic calculator can compute all kinds of mathematical computations and mathematical functions. It can also be used to store some data permanently. Some calculators have in-built programs to perform some complicated calculations.

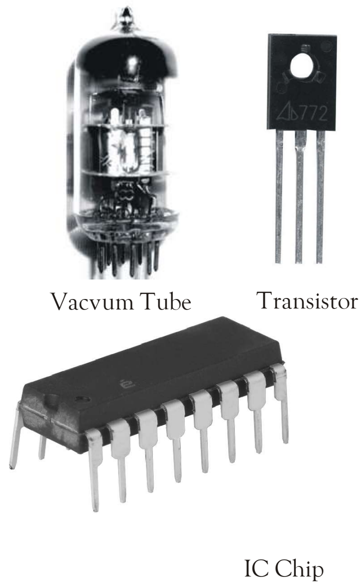


Figure 1.5 *Vacuum tube, transistor, IC*

1.6 COMPUTER GENERATIONS

You know that the evolution of computer started from 16th century and resulted in the form that we see today. The present day computer, however, has also undergone rapid change during the last fifty years. This period, during which the evolution of computer took place, can be divided into five distinct phases known as *Generations of Computers*. Each phase is distinguished from others on the basis of the type of *switching circuits* used.

1.6.1 First Generation Computers

First generation computers used *Thermion valves*. These computers were large in size and writing programs on them was difficult. Some of the computers of this generation were:

ENIAC: It was the first electronic computer built in 1946 at University of Pennsylvania, USA by John Eckert and John Mauchy. It was named Electronic Numerical Integrator and Calculator (ENIAC). The ENIAC was 30-50 feet long, weighed 30 tons, contained 18,000 vacuum tubes, 70,000 registers, 10,000 capacitors and required 150,000 watts of electricity. Today your favorite computer is many times as powerful as ENIAC, still size is very small.

EDVAC: It stands for Electronic Discrete Variable Automatic Computer and was developed in 1950. The concept of storing data and instructions inside the computer was introduced here. This allowed much faster operation since the computer had rapid access to both data and instructions. The other advantages of storing instruction was that computer could do logical decision internally.

Other Important Computers of First Generation

EDSAC: It stands for Electronic Delay Storage Automatic Computer and was developed by M.V. Wilkes at Cambridge University in 1949.

UNIVAC-1: Ecker and Mauchly produced it in 1951 by Universal Accounting Computer setup.

Limitations of First Generation Computer

Followings are the major drawbacks of First generation computers:

1. The operating speed was quite slow.
2. Power consumption was very high.
3. It required large space for installation.
4. The programming capability was quite low.

1.6.2 Second Generation Computers

Around 1955 a device called *Transistor* replaced the bulky electric tubes in the first generation computer. Transistors are smaller than electric tubes and have higher operating speed. They have no filament and require no heating. Manufacturing cost was also very low. Thus, the size of the computer got reduced considerably.

It is in the second generation that the concept of Central Processing Unit (CPU), memory, programming language and input and output units were developed. The programming languages such as COBOL, FORTRAN were developed during this period. Some of the computers of the Second Generation were:

1. **IBM 1620:** Its size was smaller as compared to First Generation computers and mostly used for scientific purpose.
2. **IBM 1401:** Its size was small to medium and used for business applications.
3. **CDC 3600:** Its size was large and is used for scientific purposes.

1.6.3 Third Generation Computers

The third generation computers were introduced in 1964. They used *Integrated Circuits* (ICs). These ICs are popularly known as *Chips*. A single IC has many transistors, registers and capacitors built on a single thin slice of silicon. So it is quite obvious that the size of the computer got further reduced. Some of the computers developed during this period were IBM-360, ICL-1900, IBM-370, and VAX-750. Higher level language such as BASIC (Beginners All purpose Symbolic Instruction Code) was developed during this period.

Computers of this generations were small in size, low cost, large memory and processing speed is very high.

1.6.4 Fourth Generation Computers

The present day computers that you see today are the fourth generation computers that started around 1975. It uses *large scale Integrated Circuits* (LSIC) built on a single silicon chip called microprocessors. Due to the development of microprocessor it is possible to place computer's *central processing unit* (CPU) on single chip. These computers are called microcomputers. Later *very large scale Integrated Circuits* (VLSIC) replaced LSICs.

Thus, the computer which was occupying a very large room in earlier days can now be placed on a table. The personal computer (PC) that you see in your school is a Fourth Generation Computer.

1.6.5 Fifth Generation Computer

The computers of 1990s are said to be Fifth Generation computers. The speed is extremely high in fifth generation computer. Apart from this it can perform *parallel processing*. The concept of *Artificial intelligence* has been introduced to allow the computer to take its own decision. It is still in a developmental stage.

1.7 TYPES OF COMPUTERS

Now let us discuss the varieties of computers that we see today. Although they belong to the fifth generation they can be divided into different categories depending upon the size, efficiency, memory and number of users. Broadly they can be divided it to the following categories:

1. **Microcomputer:** Microcomputer is at the lowest end of the computer range in terms of speed and storage capacity. Its CPU is a microprocessor. The first microcomputers were built of 8-bit microprocessor chips. The most common application of personal computers (PC) is in this category. The PC supports a number of input and output devices. An improvement of 8-bit chip is 16-bit and 32-bit chips. Examples of microcomputer are IBM PC, PC-AT .
2. **Mini Computer**: This is designed to support more than one user at a time. It possesses large storage capacity and operates at a higher speed. The mini computer is used in multi-user system in which various users can work at the same time. This type of computer is generally used for processing large volume of data in an organisation. They are also used as servers in Local Area Networks (LAN).

3. **Mainframes:** These types of computers are generally 32-bit microprocessors. They operate at very high speed, have very large storage capacity and can handle the work load of many users. They are generally used in centralised databases. They are also used as controlling nodes in Wide Area Networks (WAN). Example of mainframes are DEC, ICL and IBM 3000 series.
4. **Supercomputer:** They are the fastest and most expensive machines. They have high processing speed compared to other computers. They have also multiprocessing technique. One of the ways in which supercomputers are built is by interconnecting hundreds of microprocessors. Supercomputers are mainly being used for whether forecasting, biomedical research, remote sensing, aircraft design and other areas of science and technology. Examples of supercomputers are CRAY YMP, CRAY2, NEC SX-3, CRAY XMP and PARAM from India.

A computer as shown in Figure 1.6 performs basically five major operations or functions irrespective of their size and make. These are:

1. it accepts data or instructions by way of input,
2. it stores data,
3. it can process data as required by the user,
4. it gives results in the form of output, and
5. it controls all operations inside a computer. We discuss below each of these operations.

1. **Input:** This is the process of entering data and programs into the computer system. You should know that computer is an electronic machine like any other machine which takes as inputs raw data and performs some processing giving out processed data. Therefore, the input unit takes data from us to the computer in an organized manner for processing.

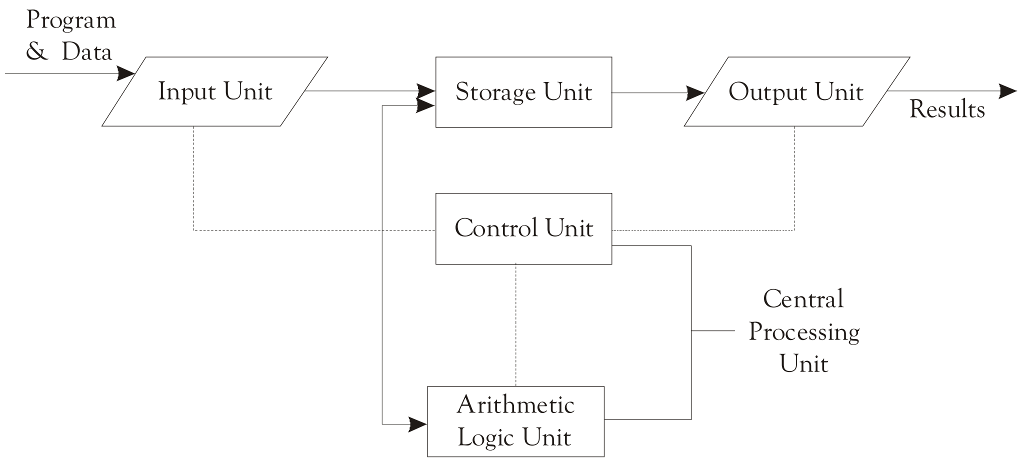


Figure 1.6 *Basic computer Operations*

2. **Storage:** The process of saving data and instructions permanently is known as storage. Data has to

be fed into the system before the actual processing starts. It is because the processing speed of Central Processing Unit (CPU) is so fast that the data has to be provided to CPU with the same speed. Therefore, the data is first stored in the storage unit for faster access and processing. This storage unit or the primary storage of the computer system is designed to do the above functionality. It provides space for storing data and instructions.

The storage unit performs the following major functions:

- All data and instructions are stored here before and after processing.
- Intermediate results of processing are also stored here.

3. **Processing:** The task of performing operations like arithmetic and logical operations is called processing. The Central Processing Unit (CPU) takes data and instructions from the storage unit and makes all sorts of calculations based on the instructions given and the type of data provided. It is then sent back to the storage unit.
4. **Output:** This is the process of producing results from the data for getting useful information. Similarly the output produced by the computer after processing must also be kept somewhere inside the computer before being given to you in human readable form. Again the output is also stored inside the computer for further processing.
5. **Control:** The manner how instructions are executed and the above operations are performed. Controlling of all operations like input, processing and output are performed by control unit. It takes care of step-by-step processing of all operations in side the computer.

1.8 FUNCTIONAL UNITS

In order to carry out the operations mentioned in the previous section the computer allocates the task between its various functional units. The computer system is divided into three separate units for its operation: 1. arithmetic logical unit, 2. control unit, and 3. central processing unit.

1.8.1 Arithmetic Logical Unit (ALU)

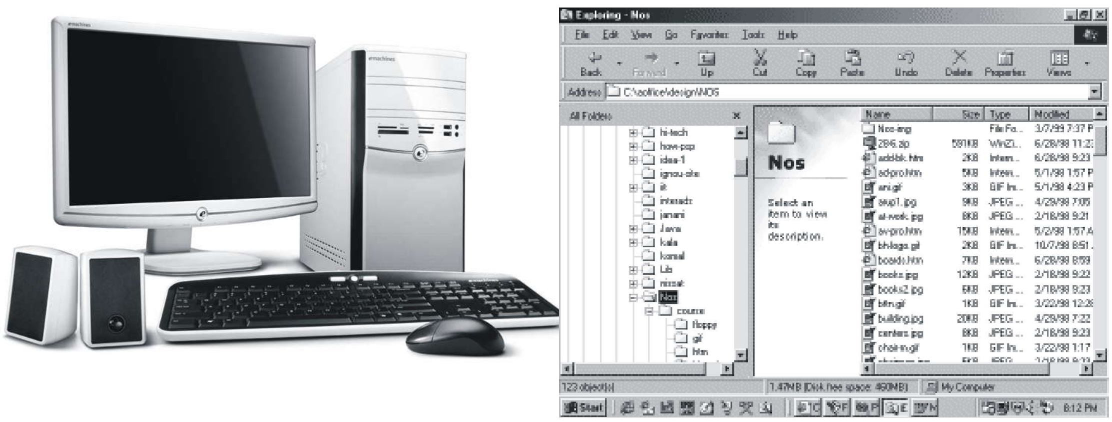
After you enter data through the input device it is stored in the primary storage unit. The actual processing of the data and instruction are performed by Arithmetic Logical Unit. The major operations performed by the ALU are addition, subtraction, multiplication, division, logic and comparison. Data is transferred to ALU from storage unit when required. After processing the output is returned back to storage unit for further processing or getting stored.

1.8.2 Control Unit (CU)

The next component of computer is the Control Unit, which acts like the supervisor seeing that things are done in proper fashion. The control unit determines the sequence in which computer programs and instructions are executed. Things like processing of programs stored in the main memory, interpretation of the instructions and issuing of signals for other units of the computer to execute them. It also acts as a switch board operator when several users access the computer simultaneously. Thereby it coordinates the activities of computer's peripheral equipment as they perform the input and output. Therefore, it is the manager of all operations mentioned in the previous section.

1.8.3 Central Processing Unit (CPU)

The ALU and the CU of a computer system are jointly known as the central processing unit. You may call CPU as the brain of any computer system. It is just like brain that takes all major decisions, makes all sorts of calculations and directs different parts of the computer functions by activating and controlling the operations.



Hardware Software

Figure 1.7 *Computer Architecture*

Personal Computer Configuration

Now let us identify the physical components that make the computer work. These are:

1. Central Processing Unit (CPU)
2. Computer Memory (RAM and ROM)
3. Data bus
4. Ports
5. Motherboard
6. Hard disk
7. Output Devices
8. Input Devices

All these components are inter-connected for the personal computer to work.

Computer organization is how operational attributes are linked together and contribute to realize the architectural specifications. Computer architecture is the architectural attributes like physical address memory, CPU and how they should be made and made to coordinate with each other keeping the future demands and goals in mind. Computer architecture comes before computer organisation. It's like building the design and architecture of house takes maximum time and then organisation is building house by bricks or by latest technology keeping the basic layout and architecture of house in mind.

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(Established in 1964)

जीवाजी विश्वविद्यालय, ग्वालियर (स्थापना वर्ष 1964)

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