

2

COMPUTER ORGANISATION

2.1 INTRODUCTION

In the previous lesson we discussed about the evolution of computer. In this lesson we will provide you with an overview of the basic design of a computer. You will know how different parts of a computer are organized and how various operations are performed between different parts to complete a specific task. As you know from the previous lesson the internal architecture of computer may differ from system to system, but the basic organization remains the same for all computer systems.

2.2 OBJECTIVES

After going through this lesson you would be able to:

- explain basic organization of computer system
- define arithmetic logical unit, control unit and central processing unit
- differentiate between bit, byte and a word
- differentiate between primary memory and secondary memory
- explain primary storage and secondary storage units

2.3 BASIC COMPUTER OPERATIONS

A computer as shown in Fig. 2.1 performs basically five major opera-

tions or functions irrespective of their size and make. These are 1) it accepts data or instruction 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 in to the computer system. You should know that computer is an electronic machine like any other machine, which takes as input 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.

Fig. 2.1: 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. The result is then sent back to the storage unit.
 4. **Output:** This is the process of producing results from the data for getting useful information. The results could either be displayed on the screen or may be printed for future reference. The output unit therefore allows the results to be either stored inside the computer for further processing or may give you the results in human readable form.
 5. **Control:** The process of input, output, processing and storage is performed under the supervision of a unit called 'Control Unit'. It decides when to start receiving data, when to stop it, where to store data, etc. It takes care of step-by-step processing of all operations inside the computer.

2.4 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. These are 1) arithmetic logical unit, 2) control unit, and 3) central processing unit.

(a) Arithmetic Logical Unit (ALU)

After you enter data through the input device it is stored in the primary storage unit. Arithmetic Logical Unit performs the actual processing of data and instruction. 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.

(b) Control Unit (CU)

The next component of computer is the Control Unit, which acts like the supervisor seeing whether things are done in proper fash-

ion. 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.

Hardware

Software

Fig. 2.2: Computer Architecture

(c) 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 a human brain that takes all major decisions, makes all sorts of calculations and directs different parts of the computer by activating and controlling the operations.

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.

INTEXT QUESTIONS

1. What are the five basic operations performed by the computer?
2. What is the full form of ALU, CU and CPU.
3. Choose the correct answer.
 - (a) The unit which performs arithmetic and logical operations is called
 - (i) ALU (ii) editing (iii) storage (iv) output
 - (b) The ALU and CU jointly are known as
 - (i) RAM (ii) ROM (iii) CPU (iv) none of the above
 - (c) The process of producing results from the data for getting useful information is called.
 - (i) output (ii) input (iii) processing (iv) storage

2.5 MEMORY SYSTEM IN A COMPUTER

There are two kinds of computer memory: primary and secondary. Primary memory is an integral part of the computer system and is accessible directly by the processing unit. RAM is an example of primary memory. As soon as the computer is switched off the contents of the primary memory is lost. The primary memory is much faster in speed than the secondary memory. Secondary memory such as floppy disks, magnetic disk, etc., is located external to the computer. Primary memory is more expensive than secondary memory. Because of this, the size of primary memory is less than that of secondary memory. We will discuss about secondary memory in later lesson.

Computer memory is used to store two things: I) instructions to

execute a program and ii) data. When the computer is doing any job, the data that have to be processed are stored in the primary memory. This data may come from an input device like keyboard or from a secondary storage device like a floppy disk.

As program or the set of instructions is kept in primary memory, the computer is able to follow instantly the set of instructions. For example, when you book ticket from railway reservation counter, the computer has to follow the same steps: take the request, check the availability of seats, calculate fare, wait for money to be paid, store the reservation and get the ticket printed out. The program containing these sequential steps is kept in memory of the computer and is followed for each request.

But inside the computer, the steps followed are quite complex than what we actually see on the monitor or screen. In computer's memory both programs and data are stored in the binary form. You have already been introduced with decimal number system, that is the numbers 1 to 9 and 0. The binary system has only two values 0 and 1. These are called bits. As human beings, we all understand decimal system but the computer can only understand binary system. It is because a large number of integrated circuits inside the computer can be considered as switches, which can be made ON or OFF. If a switch is ON it is considered 1 and if it is OFF it is 0. A number of switches in different states will give you a message like this: 110101...10. So the computer takes input in the form of 0 and 1 and gives output in the form 0 and 1 only. Is it not absurd if the computer gives outputs as 0's & 1's only? But you do not have to worry about. Every number in binary system can be converted to decimal system and vice versa; for example, 1010 meaning decimal 10. Therefore it is the computer that takes information or data in decimal form from you, convert it into binary form, process it producing output in binary form and again convert the output to decimal form to make it understandable.

The primary memory in the computer is in the form of IC's (Integrated Circuits). These circuits are called Random Access Memory (RAM). Each of RAM's locations stores one byte of information. (One byte is equal to 8 bits). A bit is an acronym for binary digit, which stands for one binary piece of information. This primary or internal storage section is made up of several small storage locations (ICs) called cells. Each of these cells can store a fixed number of bits called word length.

Each cell has a unique number assigned to it called the address of

the cell and it is used to identify the cells. The address starts at 0 and goes up to (N-1). You should know that the memory is like a large cabinet containing as many drawers as there are addresses on memory. Each drawer contains a word and the address is written on outside of the drawer.

(a) Capacity of Primary Memory

You know that each cell of memory contains one character or one byte of data. So the memory capacity is defined in terms of byte or words. The relation is: 1 kilobyte (KB) = 1024 bytes. Thus 64 kilobyte (KB) memory is capable of storing $64 \times 1024 = 32,768$ bytes. The memory size ranges from few kilobytes in small systems to several thousand kilobytes in large mainframe and super computers. In your personal computer you will find memory capacity in the range of 32 MB, 64 MB and even 128 MB (MB = Million bytes and 1 MB = 1024 KB).

The following terms related to memory of a computer are discussed below:

1. **Random Access Memory (RAM):** The primary storage is referred to as random access memory (RAM) because it is possible to randomly select and use any location of the memory directly for storing and retrieving data. It takes same time to reach any address of the memory whether it is in the beginning or in the last. It is also called read/write memory. The storage of data and instructions inside the primary storage is temporary. It disappears from RAM as soon as the power to the computer is switched off. The memory, which lose its contents on failure of power supply, are known as volatile memories. So now we can say that RAM is volatile memory.
2. **Read Only Memory (ROM):** There is another memory in computer, which is called Read Only Memory (ROM). Again it is the ICs inside the PC that form the ROM. The storage of program in the ROM is permanent. The ROM stores some standard processing programs supplied by the manufacturer to operate the personal computer. The ROM can only be read by the CPU but it cannot be changed. The basic input/output program, which is required to start and initialize equipment attached to the PC, is stored in the ROM. The memories, which do not lose their contents on failure of power supply, are known as non-volatile memories. ROM is a non-volatile memory.

3. **PROM:** There is another type of primary memory in computer, which is called Programmable Read Only Memory (PROM). You know that it is not possible to modify or erase programs stored in ROM, but it is possible for you to store your program in PROM chip. Once the programs are written it cannot be changed and remain intact even if power is switched off. Therefore, programs or instructions written in PROM or ROM cannot be erased or changed.
4. **EPROM:** This stands for Erasable Programmable Read Only Memory, which overcomes the limitations of PROM & ROM. EPROM chip can be programmed time and again by erasing the information stored earlier in it. Exposing the chip for some time to ultraviolet light erases information stored in EPROM. The chip can be reprogrammed using a special programming facility. When the EPROM is in use, information can only be read.
5. **Cache Memory:** The speed of CPU is extremely high compared to the access time of main memory. Therefore the performance of CPU decreases due to the slow speed of main memory. To minimize the mismatch in operating speed, a small memory chip is attached between CPU and Main memory whose access time is very close to the processing speed of CPU. It is called CACHE memory. CACHE memories are accessed much faster than conventional RAM. It is used to store programs or data currently being executed or temporary data frequently used by the CPU. So cache memory makes main memory to work faster and larger than it really is. It is also very expensive to have bigger size of cache memory and therefore it is available in limited capacity generally KiloBytes.
6. **Registers:** The CPU processes data and instructions with high speed. There is also movement of data between various units of computer. It is necessary to transfer the processed data with high speed. So the computer uses a number of special memory units called registers. These are not part of the main memory but they store data or information temporarily and pass it on as directed by the control unit.

INTEXT QUESTIONS

4. Distinguish between bit and byte.
 5. Define volatile and non-volatile memory.
-

6. Write True or False:

- (a) There are two kinds of computer memory—primary and secondary.
- (b) The computer takes inputs in the form of 0 and 1.
- (c) The storage of program and data in the RAM is permanent.
- (d) PROM is a secondary memory.
- (e) The memories, which do not lose their content on failure of power supply, are known as non-volatile memories.

2.6 SECONDARY STORAGE

You are now clear that the operating speed of primary memory or main memory should be as fast as possible to match with the CPU speed. These high-speed storage devices are very expensive and hence the cost per unit of storage is also very high. Again the storage capacity of the main memory is also very limited. Often it is necessary to store hundreds of millions of bytes of data for the CPU to process. Therefore additional memory is required in all the computer systems. This memory is called auxiliary storage, backup storage or secondary storage.

In this type of memory the cost per bit of storage is low. However, the operating speed is slower than that of the primary storage. Huge volume of data are stored here on permanent basis and transferred to the primary storage as and when required. Most widely used secondary storage devices are magnetic tapes, floppy disk, magnetic disk and optical disks.

1. **Magnetic Tape:** Magnetic tapes are used for large computers like mainframe computers where large volume of data is stored for a longer time. In PC also you can use tapes in the form of cassettes. The storage of data in tapes is inexpensive. Tapes consist of magnetic materials that store data permanently. It can be 12.5 mm to 25 mm wide plastic film-type and 500 meter to 1200 meter long, which is coated with magnetic material. The tape unit is connected to the central processor and information is fed into or read from the tape through the processor. It is similar to a cassette tape recorder.
-

Fig 2.3: Magnetic Tape

Advantages of Magnetic Tape:

- **Compact:** A 10-inch diameter reel of tape is 2400 feet long and is able to hold 800, 1600 or 6250 characters in each inch of its length. The maximum capacity of such tape is 180 million characters. Thus data are stored much more compactly on tape.
 - **Economical:** The cost of storing data is very less as compared to other storage devices.
 - **Fast:** Copying of data is easier and fast.
 - **Long term Storage and Re-usability:** Magnetic tapes can be used for long term storage and a tape can be used repeatedly with out loss of data.
2. **Magnetic Disk:** You might have seen the gramophone record, which is like a circular disk and coated with magnetic material. Magnetic disks used in computer are made on the same principle. It rotates with very high speed inside the computer drive. Data is stored on both the surfaces of the disk. Magnetic disks are most popular as direct access storage device. Each disk consists of a number of invisible concentric circles called tracks. Information is recorded on tracks of a disk surface in the form of tiny magnetic spots. The presence of a magnetic spot represents one bit and its absence represents zero bit. The information stored in a disk can be read many times without affecting the
-

stored data. So the reading operation is non-destructive. But if you want to write a new data, then the existing data is erased from the disk and new data is recorded.

Fig. 2.4: Magnetic Disk

3. **Floppy Disk:** It is similar to magnetic disk discussed above. It is 3.5 inch in diameter. These come in single or double density and recorded on one or both surface of the diskette. The capacity of a high-density 3.5 inch floppy it is 1.44 mega bytes. It is cheaper than any other storage devices and is portable. The floppy is a low cost device particularly suitable for personal computer system.

Fig. 2.5: Floppy Diskette

4. **Optical Disk:**

With every new application and software there is greater demand for memory capacity. It is the necessity to store large volume of data that has led to the development of optical disk storage medium. Optical disks read and write the data using light and not the magnetization as in above storage devices. Optical disks can be divided into the following categories:

1. **Compact Disk/Read Only Memory (CD-ROM):** CD-ROM disks are made of reflective metals. CD-ROM is written during the process of manufacturing by high power laser beam. Here the storage density is very high, storage cost is very low and access time is relatively fast. Each disk is approximately 4 ½ inches in diameter and can have over 600 MB of data. As the CD-ROM can be read only we cannot write or make changes into the data contained in it.
2. **Write Once, Read Many (WORM):** The inconvenience that we cannot write anything onto a CD-ROM is avoided in WORM. A WORM allows the user to write data permanently on to the disk. Once the data is written it can never be erased without physically damaging the disk. Here data can be recorded from keyboard, video scanner, OCR equipment and other devices. The advantage of WORM is that it can store vast amount of data amounting to gigabytes (10⁹ bytes). Any document in a WORM can be accessed very fast, say less than 30 seconds.
3. **Erasable Optical Disk:** These are optical disks where data can be written, erased and re-written. This makes use of a laser beam to write and re-write the data. These disks may be used as alternatives to traditional disks. Erasable optical disks are based on a technology known as magneto-optical (MO). To write a data bit on to the erasable optical disk the MO drive's laser beam heats a tiny, precisely defined point on the disk's surface and magnetises it.

2.7 DATA REPRESENTATION IN COMPUTER MEMORY

As we know the central processing unit (CPU) in a computer system uses electronic elements such as switches, etc. which are represented in one of the two states viz, on or off, high or low, etc. These two states are indicated as 1 and 0. If a switch is on, it is said to be in state 1 and if it is off, it is state 0. In other words, a computer oper-

ates with only two digits 0 and 1, called *binary digits* (or bits). In memory, a bit position is a miniature transistor within an integrated circuit. The data is represented as a string consisting of 0s and 1s. Hence the ordinary decimal system of data representation is not suited to CPU. It works with simple but rather longish binary system.

2.7.1 Binary System:

Binary system works with only two bits: 0 and 1 unlike the decimal system that works with 10 digits, 0 through 9. Let us take the number 1267 of ordinary decimal system. Its binary equivalent is computed below by successive division by 2. And, then (on the right hand side) 1267 is got back by conversion by weightage of 2^* .

| Number , 2 | Quotient | Remainder | Weightage, 2^* | Remainder x 2^* |
|-----------------|----------|-----------|------------------|-------------------|
| Col. 1 | 2 | 3 | 4 | 5 = 3 x 4 |
| $1267 \div 2 =$ | 633 + | 1 | $2^0 = 1$ | 1 |
| $633 \div 2 =$ | 316 + | 1 | $2^1 = 2$ | 2 |
| $316 \div 2 =$ | 158 + | 0 | $2^2 = 4$ | 0 |
| $158 \div 2 =$ | 79 + | 0 | $2^3 = 8$ | 0 |
| $79 \div 2 =$ | 39 + | 1 | $2^4 = 16$ | 16 |
| $39 \div 2 =$ | 19 + | 1 | $2^5 = 32$ | 32 |
| $19 \div 2 =$ | 9 + | 1 | $2^6 = 64$ | 64 |
| $9 \div 2 =$ | 4 + | 1 | $2^7 = 128$ | 128 |
| $4 \div 2 =$ | 2 + | 0 | $2^8 = 256$ | 0 |
| $2 \div 2 =$ | 1 + | 0 | $2^9 = 512$ | 0 |
| $1 \div 2 =$ | 0 + | 1* | $2^{10} = 1024$ | 1024 |
| *(Senior digit) | | | | 1267 |

$$1267 = 10011110011$$

Table 2.1

The equivalent is obtained by writing the contents of Col. 3 starting with the senior digit i.e., from bottom to top.

Binary Arithmetic : 2^* , in the above example gives the various positional values: 1, 2, 4, 8, 16, 32, 64.... Just as there is a decimal point there is binary point too. The positional values on both sides of the binary point are given in the table hereunder:

| | | | | | | | | | |
|--|-------|-------|-------|-------|-------|----------|----------|----------|----------|
| Position | 4 | 3 | 2 | 1 | 0 | -1 | -2 | -3 | -4 |
| Position Value | 2^4 | 2^3 | 2^2 | 2^1 | 2^0 | 2^{-1} | 2^{-2} | 2^{-3} | 2^{-4} |
| Quantity represented by Position Value | 16 | 8 | 4 | 2 | 1 | 1/2 | 1/4 | 1/8 | 1/16 |

The table can, of course, be extended infinitely on both sides. The decimal equivalent of a number written in binary is found by adding the products of the absolute and positional values as illustrated in the above example where 1267 was got back from 10011110011. This procedure also applies to binary numbers containing binary point. You may want to verify as an exercise that the binary number 1001.011 is $9^{3/8}$ in the decimal system by using the above table of positional values.

We saw that a whole decimal number can be converted to binary by successive division by 2. The remainder juxtaposed starting from bottom to top yields the binary equivalent. Below is the conversion of a decimal fraction, 0.3125 given to show the procedure, which consists of successive doubling of the fraction (i.e., multiplying by 2), retaining the integers and stopping when we get 0.

| | | | |
|---|---|-------|-------|
| | | .3125 | |
| | | x 2 | |
| | 0 | .6250 | |
| | | x 2 | |
| Integers resulting from doubling | 1 | .2500 | |
| | | x 2 | |
| | 0 | .5000 | |
| | | x 2 | |
| | 1 | .0000 | Stop. |

Thus, $0.3125 = 0.0101$, the bits having been arranged from top to bottom.

And $9.3125 = 1001.0101$.

Binary Addition is performed similar to decimal addition, i.e., we proceed from right to left with a carry over, if any. The following rules are for the carry-over.

$1 + 1 = 0$ and carry 1 to add to next column.

$1 + 0 = 1$

$0 + 1 = 1$

$0 + 0 = 0$

Example :

Binary addition

| | | | | | | | | | | | |
|------------|---|---|---|---|---|---|---|---|---|---|---|
| Carry over | 1 | 1 | 1 | 1 | 1 | 1 | 1 | x | x | 1 | x |
| | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| + 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |

We shall stop here and would not take up binary subtraction, multiplication and division since computer performs these operations too in addition mode. For example, to multiply 9 by 5 it would add 1001 (equivalent of 9) 5 times. Therefore, computer is sometimes simply defined as a fast adder.

2.7.2 Octal Number System

It is seen that the length of binary numbers can become quite long and cumbersome to use. Octal system (base 8) is thus often used to convert binary numbers to a form requiring lesser number of digits. The octal system uses the eight symbols 0, 1, 2, 7. As its radix 8 is a power of 2, it is fairly simple to convert binary to octal and *vice-versa*.

To convert a binary number into an octal number, we will group together successive three bits of the binary number starting with its least significant bit (i.e., the right-most). These three bit groups are then replaced by their octal equivalents. This mechanism works because all the digits in octal system, namely 0, 1, 2,.....7, may be represented by three bit groups. The table below illustrates this.

| <i>Octal</i> | <i>Binary</i> | <i>Octal</i> | <i>Binary</i> | <i>Octal</i> | <i>Binary</i> |
|--------------|---------------|--------------|---------------|--------------|---------------|
| 0 | 000 | 3 | 011 | 6 | 110 |
| 1 | 001 | 4 | 100 | 7 | 111 |
| 2 | 010 | 5 | 101 | | |

Example : Binary numbers 001 100 111 001

Octal equivalent 1 4 7 1

Decimal equivalent $1 \times 8^3 + 4 \times 8^2 + 7 \times 8^1 + 1 \times 8^0$
 $= 512 + 256 + 56 + 1$
 $= 825$

2.7.3 Binary Coded Decimal (BCD) System

The pure binary system discussed above is more appropriate for scientific applications where the bulk of work consists of arithmetic computations. Business applications entail reading and writing of voluminous amount of plain English, *viz.*, names and address of customers and suppliers, employees, descriptions of stock items, etc. and comparatively less arithmetic. Therefore, most business computers employ a version of the pure binary system, the BCD system that is a hybrid of the pure binary system and the decimal system.

In this system, the decimal weighting is maintained, but the digit is represented by a combination of the binary digits 0 and 1. Since ten digits 0...9 have to be represented, a minimum of four bits must be used to encode each digit. Hence, each digit is represented by its binary equivalent using four bits, e.g., the digit 5 is equivalent to binary 0101 and the digit 9 is equivalent to binary 1001. By this method, the number 59 is represented as 0101 1001. The pure binary equivalents of the decimal digits 0 through 9 are given in Table 2.2 below.

| <i>Digit</i> | <i>Pure Binary Equivalents (or BCD's)</i> |
|--------------|---|
| 0 | 0000 |
| 1 | 0001 |
| 2 | 0010 |
| 3 | 0011 |
| 4 | 0100 |
| 5 | 0101 |
| 6 | 0110 |
| 7 | 0111 |
| 8 | 1000 |
| 9 | 1001 |

Table 2.2

The BCD equivalents of longer numbers are simply derived by appropriate juxtaposition of the equivalents in the above table. For example, the BCD equivalent of 951 is got by juxtaposing the individual equivalents of 9, 5 and 1 from this table as below:

BCD equivalent of 951 : 1001 0101 0001.

This codification scheme has been extended to cover the alphabets

and special symbols by adding two more bits (known as the zone bits) on the left of the 4 bit sets in the above table. By permuting the two zones bits, the representations for alphabets and special symbols as shown in Table. 2.3 can be obtained, those for the alphabets as hereunder:

| Character | BCD representation | Character | BCD representation |
|-----------|--------------------|-----------|--------------------|
| 0 | 00 0000 | J | 10 0001 |
| 1 | 00 0001 | K | 10 0010 |
| 2 | 00 0010 | L | 10 0011 |
| 3 | 00 0011 | M | 10 0100 |
| 4 | 00 0100 | N | 10 0101 |
| 5 | 00 0101 | O | 10 0110 |
| 6 | 00 0110 | P | 10 0111 |
| 7 | 00 0111 | Q | 10 1000 |
| 8 | 00 1000 | R | 10 1001 |
| 9 | 00 1001 | | |
| A | 11 0001 | | |
| B | 11 0010 | S | 01 0010 |
| C | 11 0011 | T | 01 0011 |
| D | 11 0100 | U | 01 0100 |
| E | 11 0101 | V | 01 0101 |
| F | 11 0110 | W | 01 0110 |
| G | 11 0111 | X | 01 0111 |
| H | 11 1000 | Y | 01 1000 |
| I | 11 1001 | Z | 01 1001 |

Table. 2.3

With the 6 bits, it is possible to have $2^6 = 64$ codes and this suffices to represent all the digits (10), alphabets (26, only upper case) and special symbols (around 15).

2.7.4 Hexadecimal System

Although the BCD system increases the flexibility and ease of programming numeric data, it does require more computer space to record each number. The hexadecimal (hex) system, using base 16, incorporates the convenience of the BCD system with the full stor-

age capabilities. It is base 16 that uses the symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F. Each hex place value is expressed in binary by a group of four bits, as shown in Table 2.4.

| Decimal | Hexadecimal | Binary |
|---------|-------------|--------|
| 0 | 0 | 0000 |
| 1 | 1 | 0001 |
| 2 | 2 | 0010 |
| 3 | 3 | 0011 |
| 4 | 4 | 0100 |
| 5 | 5 | 0110 |
| 6 | 6 | 0111 |
| 7 | 7 | 1000 |
| 8 | 8 | 1001 |
| 9 | 9 | 1010 |
| 10 | A | 1011 |
| 11 | B | 1100 |
| 12 | C | 1101 |
| 13 | D | 1110 |
| 14 | E | 1111 |
| 15 | F | 1111 |

Table 2.4

For example, consider a string (0010 1111 0001 1110 1100). This can be converted into hexadecimal system as follows.

$$\begin{array}{ccccc}
 0010 & 1111 & 0001 & 1110 & 1100 \\
 2 & F & 1 & E & C = (2F1EC)_{16}
 \end{array}$$

We take few examples for demonstrating the conversion procedure from one number system to another system.

Example 1: Convert the following numbers into decimal system:

- (i) 101011010 (Binary)
- (ii) 765 (Octal)
- (iii) 125F (Hexadecimal)

Solution:

(i) 10101010 (binary)

$$= 1 \times 2^7 + 0 \times 2^6 + 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$$

$$= 1 \times 128 + 1 \times 32 + 1 \times 8 + 1 \times 2$$

$$= 128 + 32 + 8 + 2 = 170$$

Hence 10101010 (binary) = 170 (decimal)

(ii) 765 (octal)

$$= 7 \times 8^2 + 6 \times 8^1 + 5 \times 8^0$$

$$= 7 \times 64 + 6 \times 8 + 5 \times 1$$

$$= 448 + 48 + 5 = 501$$

Hence 765 (octal) = 501 (decimal)

(iii) 125F (Hexadecimal)

$$= 1 \times 16^3 + 2 \times 16^2 + 5 \times 16^1 + 15 \times 16^0$$

$$= 1 \times 4096 + 2 \times 256 + 5 \times 16 + 15 \times 1$$

$$= 4096 + 512 + 80 + 15$$

$$= 4703$$

Hence 125F (Hexadecimal) = 4703 (decimal).

The number (2F1EC)₁₆ can be converted into decimal system as follows:

| Positional | 16^4 | 16^3 | 16^2 | 16^1 | 16^0 |
|------------|-------------------------|-----------------------|------------------|----------------|------------|
| Value | 2 | F | 1 | E | C |
| | | | | └─ 12 x 1 = 12 | |
| | | | └─ 14 x 16 = 224 | | |
| | | └─ 1 x 256 = 256 | | | |
| | | └─ 15 x 4096 = 61,440 | | | |
| | └─ 2 x 65536 = 1,31,072 | | | | |
| | | | | | = 1,93,004 |

Thus $(0010\ 1111\ 0001\ 1110\ 1100)_2 = (2F1EC)_{16} = (193004)_{10}$

Example 2: Write the BCD equivalent of the following binary numbers:

- (i) 110101
 (ii) 10111
 (iii) 1010110

Solution:

- (i) $110101 = 1 \times 2^5 + 1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$
 $= 32 + 16 + 4 + 1 = 53$
 $= 0101\ 0011$ (in BCD)
- (ii) $10111 = 1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$
 $= 16 + 4 + 2 + 1 = 23$
 $= 0010\ 0011$ (in BCD)
- (iii) $1010110 = 1 \times 2^6 + 0 \times 2^5 + 1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$
 $= 64 + 16 + 4 + 2 = 86$
 $= 1000\ 0110$ (in BCD)

Example 3: Convert the following from one number system to another number system:

- (i) (123) decimal = () binary
 (ii) (1011010) binary = () decimal
 (iii) (4567) octal = () decimal
 (iv) (BABA) hexadecimal = () decimal
 (v) (1357) octal = () binary

Solution :

- (i) (123) decimal = () binary

| 2 | 123 | Remainder |
|---|-----|-----------|
| 2 | 61 | 1 |
| 2 | 30 | 1 |
| 2 | 15 | 0 |
| 2 | 7 | 1 |
| 2 | 3 | 1 |
| 2 | 1 | 1 |
| | 0 | 1 |

Hence, (123) decimal = (1111011) binary

$$\begin{aligned}
 \text{(ii) } (1011010) \text{ binary} &= (\quad) \text{ decimal} \\
 (1011010)_2 &= 1 \times 2^6 + 0 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 \\
 &\quad + 1 \times 2^1 + 0 \times 2^0 \\
 &= 64 + 16 + 8 + 2 \\
 &= 90
 \end{aligned}$$

$$(1011010) \text{ binary} = (90) \text{ decimal}$$

$$\begin{aligned}
 \text{(iii) } (4567) \text{ octal} &= (\quad) \text{ decimal} \\
 (4567)_8 &= 4 \times 8^3 + 5 \times 8^2 + 6 \times 8^1 + 7 \times 8^0 \\
 &= 4 \times 512 + 5 \times 64 + 6 \times 8 + 7 \\
 &= 2048 + 320 + 48 + 7 \\
 &= 2423
 \end{aligned}$$

$$\text{Hence, } (4567) \text{ octal} = (2423) \text{ decimal}$$

$$\begin{aligned}
 \text{(iv) } (\text{BABA}) \text{ hexadecimal} &= (\quad) \text{ decimal} \\
 (\text{BABA})_{16} &= 11 \times 16^3 + 10 \times 16^2 + 11 \times 16^1 + \\
 &\quad 10 \times 16^0 \\
 &= 11 \times 4096 + 10 \times 256 + 11 \times \\
 &\quad 16 + 10 \\
 &= 45056 + 2560 + 176 + 10 \\
 &= 47802
 \end{aligned}$$

$$\text{Hence, } (\text{BABA}) \text{ hexadecimal} = (47802) \text{ decimal}$$

$$\text{(v) } (1357) \text{ octal} = (\quad) \text{ hexadecimal}$$

To convert the given number from octal to hexadecimal, let us first represent each digit by a group of three binary bits. Thereafter, we combine these bits in groups of four, starting from right to left and adding significant zeros if required.

$$\begin{aligned}
 (1357) \text{ octal} &= 001 \quad 011 \quad 101 \quad 111 \\
 &= 0010 \quad 1110 \quad 1111 \\
 &= (2 \quad \text{E} \quad \text{F}) \\
 (1357) \text{ octal} &= (2\text{EF}) \text{ hexadecimal}
 \end{aligned}$$

2.7.5 Byte

A single bit which can only be 'off' or 'on' cannot be used to represent the decimal digit 0-9, nor can single bit represent the letters of the alphabets or special characters. For a computer memory to be useful, it must be able to store numbers, letters of the alphabets and special characters. To accomplish such a task, computer designers utilize a series of bits. Codes are assigned to the various combinations, which can be obtained from the series of bits being 'on' or 'off'. The various combinations represent letters of the alphabet, numbers, and special characters as shown in Table 2.5.

Many computers use a combination of *eight bits* as a unit for storing data. These eight bits are called a byte. Thus, byte is a location in the main computer memory consisting of eight adjacent bits.

| <i>Character</i> | <i>BCD</i> | <i>EBCDIC</i> | <i>ASCII-8</i> |
|------------------|------------|---------------|----------------|
| 0 | 00 0000 | 1111 0000 | 0011 0000 |
| 1 | 00 0001 | 1111 0001 | 0011 0001 |
| 2 | 00 0010 | 1111 0010 | 0011 0010 |
| 3 | 00 0011 | 1111 0011 | 0011 0011 |
| 4 | 00 0100 | 1111 0100 | 0011 0100 |
| 5 | 00 0101 | 1111 0101 | 0011 0101 |
| 6 | 00 0110 | 1111 0110 | 0011 0110 |
| 7 | 00 0111 | 1111 0111 | 0011 0111 |
| 8 | 00 1000 | 1111 1000 | 0011 1000 |
| 9 | 00 1001 | 1111 1001 | 0011 1001 |
| A | 11 0001 | 1100 0001 | 0100 0001 |
| B | 11 0010 | 1100 0010 | 0100 0010 |
| C | 11 0011 | 1100 0100 | 0100 0100 |
| D | 11 0100 | 1100 0101 | 0100 0101 |
| E | 11 0101 | 1100 0101 | 0100 0101 |
| F | 11 0110 | 11 00 0110 | 01 00 0110 |
| G | 11 0111 | 11 00 0111 | 01 00 0111 |
| H | 11 1000 | 1100 1000 | 0100 1000 |
| I | 11 1001 | 1100 1001 | 0100 1001 |

| | | | |
|---|---------|-----------|-----------|
| J | 10 0001 | 1101 0001 | 0100 1010 |
| K | 10 0010 | 1101 0010 | 0100 1011 |
| L | 10 0011 | 1101 0011 | 0100 1100 |
| M | 10 0100 | 1101 0100 | 0100 1101 |
| N | 10 0101 | 1101 0101 | 0100 1110 |
| O | 10 0110 | 1101 0111 | 0101 1111 |
| P | 10 0111 | 1101 0111 | 0101 0000 |
| Q | 10 1000 | 1101 1000 | 0101 0001 |
| R | 10 1001 | 1101 1001 | 0101 0010 |
| S | 01 0010 | 1110 0010 | 0101 0011 |
| T | 01 0011 | 1110 0011 | 0101 0100 |
| U | 01 0100 | 1110 0100 | 0101 0101 |
| V | 01 0101 | 1110 0101 | 0101 0110 |
| W | 01 0110 | 1110 0110 | 0101 0111 |
| X | 01 0111 | 1110 0111 | 0101 1000 |
| Y | 01 1000 | 1110 1000 | 0101 1001 |
| Z | 01 1001 | 1110 1001 | 0101 1010 |

Table 2.5: Common methods of representing data

2.7.6 ASCII Code : One of the most widely used coding systems to represent data in main computer memory is the American Standard Code for Information Interchange, called the ASCII Code. In ASCII system, each digit in a numeric value is stored in a single byte. For example, the numeric value 4263 would require four bytes of memory when stored using the ASCII code. The ASCII code uses the right most seven bits of the 8-bits = one byte to represent number, letters of the alphabet, and special characters. This provides for the representation of a maximum of 128 individual characters. With the ASCII code, the left most bit is not used to represent characters.

Each letter of the alphabet is represented by a unique combination of bits being 'on' or off. Table 2.5 above illustrates the representation of the letters of the alphabet A-Z.

2.7.7 EBCDIC System

While the ASCII code is widely used on personal computer and many

minicomputers, it is not the only coding format used on computers. One of the most commonly used coding schemes for mainframes is the **Extended Binary Coded Decimal Interchange Code** (EBCDIC). With EBCDIC, each byte (eight bits) is divided into two portions - zone portion and the digit portion. The bits in both the zone portion and the digit portion are assigned numeric values based upon the binary number system, forming the basis for a logical representation of data in storage. Numeric values are represented in EBCDIC with all zone bits “on” and the proper combination of bits in the digit portion of the byte “on” to represent the particular value. For example value 4 is represented in the following manner.

| | |
|--------------|---------------|
| 1111 | 0100 |
| Zone portion | digit portion |

Alphabetic data is represented using EBCDIC with a combination of bits “on” and “off” in both the zone and digit portions of the byte as shown in Table 2.5.

2.7.8 Parity bit is an additional or redundant bit that is used to provide a check on the integrity of a representation. Consider, for example, Z which is represented by 01 1001 in the 6 bit BCD code (see Table 2.5). The parity bit is derived from this representation itself. Since the number of 1’s in this representation is 3 and 3 is an odd number, 1 is placed usually to the left of this representation so that the number of 1’s in the 7-bits are even. Likewise, another representation with even number of 1’s (viz. 100001 for J) would have 0 bit to its left. Thus by the addition of the parity bit, the representation for Z and J in 7-bit would appear as follows.

| | |
|---|---------|
| Z | 1011001 |
| J | 0100001 |

The parity bit is put to use each time the computer processes a representation. The number of 1’s in the 6-bits set of a representation is compounded and is ascertained if they correspond to the parity bit placed on the left. If they correspond, the representation is accepted and processed, otherwise, an error signal is given by the computer meaning that there is something wrong with the computer circuitry. For example, suppose because of improper working of the computer circuit, Z is being mis-represented as 1011000. In the 6-bits of the mis-representation, there are two 1’s meaning that parity bit should be 0 whereas actually it is 1.

The above type of parity bit is known as the even parity bit since the number of 1's in the 7-bits set for a representation is always even. Similarly, the odd parity check can be employed but the two checks are mutually exclusive, i.e., only one of them is performed.

INTEXT QUESTIONS

7. Convert the following numbers into decimal system:
- (a) $(1100001)_2$
- (b) $(2315)_8$
- (c) $(121A)_{16}$
8. Convert the following from one number system to another number system.
- (a) $(572)_{10} = ()_8$
- (b) $(A = 29)_{16} = ()_{10}$
- (c) $(101101.01)_2 = ()_{10}$
- (d) $(3572)_8 = ()_{16}$
- (e) $(256)_8 = ()_2$
-

2.8 INPUT-OUTPUT (I/O) DEVICES

A computer is useful only when it is able to communicate with the external environment. When you work with the computer you feed your data and instructions through some device to the computer. These devices are called Input devices. Similarly computer after processing gives output through other devices called output devices.

For a particular application one form of device is more desirable compared to others. We will discuss various types of Input-Output devices that are used for different types of applications. They are also known as peripheral devices because they surround the CPU and make a communication between computer and the outer world.

2.8.1 Input Devices

Input devices are necessary to convert our information or data into a form, which can be understood by the computer. A good input device should provide timely, accurate and useful data to the main memory of the computer for processing. Following are the most useful input devices.

1. **Keyboard:** This is the standard input device attached to all computers. The layout of keyboard is just like the traditional typewriter of the type QWERTY. It also contains some extra command keys and function keys. It contains a total of 101 to 104 keys. A typical keyboard used in a computer is shown in Fig. 2.6. You have to press correct combination of keys to input data. The computer can recognize the electrical signals corresponding to the correct key combination and processing is done accordingly.

Fig. 2.6: Keyboard

2. **Mouse:** Mouse is an input device shown in Fig. 2.7 that is used with your personal computer. It rolls on a small ball and has two or three buttons on the top. When you roll the mouse across a flat surface, the cursor on the screen moves in the direction of mouse movement. The cursor moves very fast with mouse giving you more freedom to work in any direction. It is easier and faster to move through a mouse.

Fig. 2.7: Mouse

3. **Trackball:** Trackball is another pointing device. Essentially, a trackball is a mouse lying on its back. To move the pointer, you rotate the ball with your thumb, your fingers, or the palm of your hand. There are usually one to three buttons next to the ball, which you use just like mouse buttons.

The advantage of trackball over **mouse** is that the trackball is stationary so it does not require much space to use it. In addition, you can place a trackball on any type of surface, including your lap. For both these reasons, trackballs are popular pointing devices for portable computers.

Fig. 2.8

4. **Joystick:** A Joystick consists of a lever that moves in all directions and controls the movement of a pointer or some other display symbols. It is similar to a mouse, except that with a mouse the cursor stops moving as soon as you stop moving the mouse. With a joystick, the pointer continues moving in the direction the joystick is pointing. To stop the pointer, you must return the joystick to its upright position. Most joysticks include two buttons called triggers.

Joysticks are used mostly for computer games, but they are also used occasionally for CAD/CAM systems and other applications.

Fig. 2.9 Joystick

5. **Digitizing Tablet:** This is an input device that enables you to enter drawings and sketches into a computer. A digitizing tablet consists of an electronic tablet and a cursor or pen.

A cursor (also called a puck) is similar to a mouse, except that it has a window with cross hairs for pinpoint placement, and it can have as many as 16 buttons.

Fig. 2.10 Digitizer and Stylus

Fig. 2.11 Puck

A pen (also called a stylus), looks like a simple ballpoint pen but uses an electronic head instead of ink. The tablet contains electronic

signals that enable it to (i) detect movements of the cursor or pen, and (ii) translate the movements into digital signals that it sends to the computer.

For digitizing tablet, each point on the tablet represents a point on the display screen in a fixed manner. Thus it differs from mouse, in which all movement is relative to the current cursor position. The static nature of digitizing tablets makes them particularly effective for tracing drawings. Most modern digitizing tablets also support a 'mouse emulation mode', in which the pen or cursor acts like a mouse.

Digitizing tablets are also called digitizers, graphics tablets, touch tablets, or simply tablets.

6. **Light Pen:** Light pen is an input device that utilizes a light sensitive detector to select objects on a display screen. A light pen is similar to a mouse, except that with a light pen you can move the pointer and select objects on the display screen by directly pointing to the objects with the pen.

Fig. 2.12

7. **Scanner:** The keyboard can input only text through keys provided in it. If we want to input a picture, the keyboard cannot help us. Scanner is an optical device that can input any graphical chart or picture and display it back. The common optical scanning devices are Magnetic Ink Character Recognition (MICR), Optical Mark Reader (OMR) and Optical Character Reader (OCR).

- **Magnetic Ink Character Recognition (MICR):** This is widely used by banks to process large volumes of cheques and drafts.

The cheque numbers and other related information is printed with specialized magnetic ink. As the cheques enter the reading unit, the cheques pass through the magnetic field which causes the 'read head' to recognize the cheque number and branch data.

- **Optical Mark Reader (OMR):** This technique is used when students have appeared in objective type tests and they had to mark their answer by darkening a square or circular space by pencil. These answers are directly read and made available to a computer for grading.
- **Optical Character Recognition (OCR):** This technique allows the direct reading of any printed or typed character. Suppose you have a set of hand written or typed text on a piece of paper, the same can be read by the computer. This pattern is compared with a site of patterns stored inside the computer. Whichever pattern is matched is called a character read. Patterns that cannot be identified are rejected.

2.8.2 Output Devices

1. **Visual Display Unit :** The most popular output device is the Visual Display Unit (VDU). It is also called the monitor. A Keyboard is used to input data and Monitor is used to display the input data and to receive messages from the computer. A monitor has its own box which is separated from the main computer system and is connected to the computer by cable. In some systems it is compact with the system unit. It can be color or monochrome.
2. **Terminals :** It is a very popular interactive unit. It can be divided into two types: hard copy terminals and soft copy terminals. A hard copy terminal provides a printout on paper whereas soft copy terminals provide visual copy on monitor. A terminal when connected to a CPU sends instructions directly to the computer. Terminals are also classified as dumb terminals or intelligent terminals depending upon the work situation.
3. **Printers :** Printer is a device that prints text or illustrations on paper and in many cases on transparencies and other media. There are different kinds of printers. In terms of the technology utilized, printers fall into the following categories.

Daisy-wheel Printer

Daisy-wheel printers are a type of printer that produces letter-quality print. A daisy wheel printer works on the same principle as a ball-head typewriter. The daisy wheel is a disk made of plastic or metal on which characters stand out in relief along the outer edge. To print a character, the printer rotates the disk until the desired letter is facing the paper. Then a hammer strikes the disk, forcing the character to hit an ink ribbon, leaving an impression of the character on the paper. You can change the daisy wheel to print different fonts.

Daisy-wheel printers cannot print graphics, and in general they are noisy and slow, printing from 10 to about 75 characters per second. As the price of laser and ink-jet printers has declined, and the quality of dot-matrix printers has improved, daisy-wheel printers have become almost obsolete.

Dot-matrix Printer

Dot-matrix printers create characters by striking pins against an ink ribbon. Each pin makes a dot, and combinations of dots form characters and illustrations.

Dot-matrix printers are inexpensive and relatively faster than daisy wheel printers, but they do not produce high-quality output.

Dot-matrix printers vary in two important characteristics:

Speed – Given in characters per second (cps), the speed can vary from about 50 to over 500 cps. Most dot-matrix printers offer different speeds depending on the quality of print desired.

Print quality – Determined by the number of pins (the mechanism that prints the dots), it can vary from 9 to 24. The best dot-matrix printer (24 pins) can produce near letter-quality type, although you can still see a difference if you look closely.

Fig. 2.13

In addition to these characteristics, you should also consider the noise factor. Compared to laser and ink-jet printers, dot-matrix printer is more noisy. Although the prices of laser and ink-jet printers are dropping rapidly, dot-matrix printers are still cheaper to operate. In addition, since they are impact printers, the dot-matrix printers can print to multi-page forms (that is, carbon copies), something laser and ink-jet printers cannot do.

Ink-jet Printer

Ink-jet printers work by spraying ionized ink at a sheet of paper. Magnetized plates in the ink's path direct the ink onto the paper in the desired shapes. Ink-jet printers are capable of producing high quality print approaching to that produced by laser printers. A typical ink-jet printer provides a resolution of 300 dots per inch, although some newer models offer higher resolutions.

Fig. 2.14

In general, the price of ink-jet printers is lower than that of laser printers. However, they are also considerably slower. Another drawback of ink-jet printers is that they require a special type of ink that is apt to smudge on inexpensive copier paper.

Because ink-jet printers require smaller mechanical parts than laser printers, they are especially popular as portable printers. In addition, colour ink-jet printers provide an inexpensive way to print full-colour documents.

Laser Printer

Laser printer utilizes a laser beam to produce an image on a drum.

The light of the laser alters the electrical charge on the drum wherever it hits. The drum is then rolled through a reservoir of toner, which is picked up by the charged portions of the drum. Finally, the toner is transferred to the paper through a combination of heat and pressure. This is also the way photocopy machines work.

Fig. 2.15

Because an entire page is transmitted to a drum before the toner is applied, laser printers are sometimes called page printers. There are two other types of page printers that fall under the category of laser printers even though they do not use laser beam at all. One uses an array of LEDs to expose the drum, and the other uses LCDs. Once the drum is charged, however, they both operate like a real laser printer.

One of the chief characteristics of laser printer is its resolution – how many dots per inch (dpi) it lays down. The available resolutions range from 300 dpi at the low end to 1,200 dpi at the high end. By comparison, offset printing usually prints at 1,200 or 2,400 dpi. Some laser printers achieve higher resolutions with special techniques generally known as resolution enhancement technology (RET).

In addition to the standard monochrome laser printer, which uses a single toner, there also exist colour laser printers that use four toners to print in full colour. Colour laser printers tend to be about five to ten times as expensive as monochrome.

Laser printers produce very high-quality print and are capable of printing an almost unlimited variety of fonts. Most laser printers come with a basic set of fonts, called internal or resident fonts, but you can add additional fonts in one of two ways:

Font cartridges – Laser printers have slots in which you can insert font cartridges, ROM boards on which fonts have been recorded. The advantage of font cartridges is that they use none of the printer's memory.

Soft fonts – All laser printers come with a certain amount of RAM memory, and you can usually increase the amount of memory by adding memory boards in the printer's expansion slots. You can then copy fonts from a disk to the printer's RAM. This is called downloading fonts. A font that has been downloaded is often referred to as a soft font, to distinguish it from the hard fonts available on font cartridges. The more RAM a printer has, more fonts can be downloaded at one time.

In addition to text, laser printers are very adept at printing graphics. However, you need significant amounts of memory in the printer to print high-resolution graphics. To print a full-page graphics at 300 dpi, for example, you need at least 1 MB (megabyte) of printer RAM. For a 600-dpi graphics, you need at least 4 MB RAM.

Because laser printers are non-impact printers, they are much quieter than dot matrix or daisy wheel printers. They are also relatively fast, although not as fast as some dot-matrix printers. The speed of laser printers ranges from about 4 to 25 pages of text per minute (ppm). A typical rate of 6 ppm is equivalent to about 40 characters per second (cps).

LCD and LED Printers

Similar to a laser printer but uses liquid crystals or light-emitting diodes rather than a laser to produce an image on the drum.

Line Printer

Line printers are high-speed printers capable of printing an entire line at one time. A fast line printer can print as many as 3,000 lines per minute. The disadvantage of line printers is that they can print only one font, they cannot print graphics, the print quality is low and they are very noisy.

Thermal Printer

Thermal printers produce images by pushing electrically heated pins against special heat-sensitive paper. Thermal printers are inexpensive and are used in most calculators and many fax machines. They produce low-quality print and the paper tends to curl and fade after a few weeks or months.

Printers are also classified according to the following characteristics:

Quality of type - The output produced by printers is said to be either letter quality (as good as a typewriter), near letter quality, or draft quality. Only daisy-wheel, ink-jet, and laser printers produce letter-quality type. Some dot-matrix printers claim letter-quality print, but if you look closely, you can see the difference.

Speed – Measured in characters per second (cps) or pages per minute (ppm), the speed of printers varies widely. Daisy-wheel printers tend to be the slowest, printing about 30 cps. Line printers are fastest (up to 3,000 lines per minute). Dot-matrix printers can print up to 500 cps, and laser printers range from about 4 to 25 text pages per minute.

Impact or non-impact – Impact printers include all printers that work by striking an ink ribbon. Daisy wheel, dot matrix, and line printers are impact printers. Non-impact printers include laser printers and ink-jet printers. The important difference between impact and non-impact printers is that impact printers are much noisier but are useful for making multiple copies like carbon copies.

Graphics – Some printers (daisy-wheel and line printers) can print only text. Other printers can print both text and graphics.

Fonts – Some printers, notably dot-matrix printers, are limited to one or a few fonts. In contrast, laser and ink-jet printers are capable of printing an almost unlimited variety of fonts. Daisy-wheel printers can also print different fonts, but you need to change the daisy wheel, making it difficult to mix fonts in the same document.

4. **Plotter**

Plotter is a device that draws pictures on paper based on commands from a computer. Plotters differ from printers in that they draw lines using a pen. As a result, they can produce continuous lines, whereas printers can only simulate lines by printing a closely spaced series of dots. Multicolour plotters use different-coloured pens to draw different colours.

In general, plotters are considerably more expensive than printers. They are used in engineering applications where precision is mandatory.

Fig. 2.16

5. **Sound Cards and Speakers**

The sound or audio output can also be produced from a computer system. An expansion board that enables a computer to manipulate and output sounds is called Sound Card. Sound cards are necessary for nearly all systems having CD-ROMs and have become commonplace on modern personal computers making them a multimedia system. Sound cards enable the computer to output sound through speakers connected in the board, to record sound input from a microphone connected to the computer and manipulate sound stored on a disk.

Nearly all sound cards support MIDI (Musical Instrument Data Interchange), a standard for representing music electronically. In addition, most sound cards are sound blaster-compatible, which means that they can process commands written for a Sound Blaster Card, the de facto standards for PC sound.

Sound cards use two basic methods to translate digital data into analog sounds.

- FM (Frequency Modulation) Synthesis mimics different musical instruments according to built-in formulas.
 - Wavetable Synthesis relies on recordings of actual instruments to produce sound. Wavetable synthesis produces more accurate sound, but is also more expensive.
-

6. 3D-Audio

3D audio is a technique for giving more depth to traditional stereo sound. Typically 3D sound or 3D audio is produced by placing a device in a room with stereo speakers. The device dynamically analyzes the sound coming from the speakers and sends feedback to the sound system so that it can readjust the sound to give the impression that the speakers are further apart.

3D audio devices are particularly popular for improving computer audio where the speakers tend to be small and close together. There are a number of 3D audio devices that attach to a computer's sound card.

INTEXT QUESTIONS

9. Distinguish between impact and non-impact printers.
10. Define soft copy and hard copy.
11. Write True or False:
 - (a) In addition to text, laser printers are very adapt at printing graphics.
 - (b) The magnetic tapes and magnetic disk are primary memories.
 - (c) A CD-ROM is read only memory.
 - (d) Mouse is an output device.
 - (e) Daisy wheel printer cannot print graphics.

2.9 WHAT YOU HAVE LEARNT

In this lesson we discussed five basic operations that a computer performs. These are input, storage, processing, output and control. A computer accepts data as input, stores it, processes it as the user requires and provides the output in a desired format. The storage unit of a computer is divided into two parts: primary storage and secondary storage. We have discussed the devices used for these two types of storage and their usefulness.

2.10 TERMINAL QUESTIONS

1. Define the five basic operations performed by any computer system.
-

2. Draw a block diagram to illustrate the basic organization of computer system and explain the function of various units.
3. What is an input device? How does it differ from output device?
4. Differentiate between
 - (a) RAM and ROM.
 - (b) PROM and EPROM.
 - (c) Primary memory and Secondary memory
6. Explain cache memory. How is it different from primary memory?
7. Write short notes on
 - (a) Control Unit
 - (b) Random Access Memory
 - (c) Laser printer
 - (d) Ink-jet printer
 - (e) Thermal printer

2.11 KEY TO INTEXT QUESTIONS

1. The five basic operations that a computer performs are input, storage, processing, output and control.
 2. ALU : Arithmetic Logic Unit
CU : Control Unit
CPU : Central Processing Unit
 3. (a) i (b) iii (c) i
 4. A bit is an acronym for binary digit, which stands for one binary piece of information. This can be either 0 or 1. A byte is equal to 8 bits.
 5. The memories, which are erased if there is a power failure, are known as volatile memories. RAM is an example of volatile memory. The memories, which do not lose their content on failure of power supply, are known as non-volatile memories. ROM is non-volatile memory.
 6. (a) True (b) True (c) False
(d) False (e) True
-

-
7. (a) 97 (b) 1229 (c) 4234
8. (a) $(1074)_8$ (b) $(41001)_{10}$ (c) $(45.25)_{10}$
(d) $(77A)_{16}$ (e) $(10101110)_2$
9. Impact printers use the familiar typewriter approach of hammering a typeface against the paper and inked ribbon. Non-impact printer do not hit or impact a ribbon to print. They use electro-static chemicals and ink-jet technologies.
10. A hard copy terminal provides a printout on paper whereas soft copy terminal provides visual copy on monitor.
11. (a) True (b) False (c) True (d) False (e) True
-