For example, if a memory has 1024 locations, then the address ranges between 0 and 1023. Thus, at address 0 we find a word, at address 1 a second word, at address 2 a third word, and so on upto the final word at the largest address.

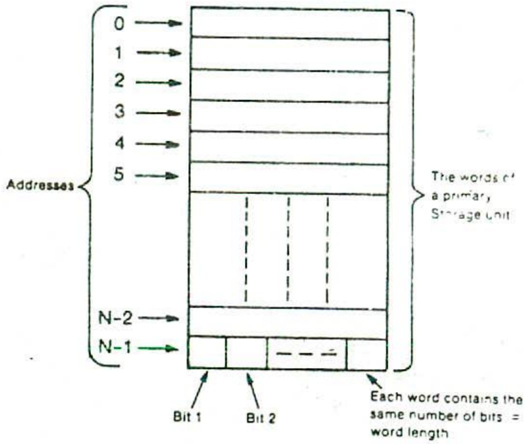


Figure 7.1. Organization of a Primary Storage Unit having N words.

There is an important difference between the address number and the contents of the address. A memory is like a large cabinet containing as many drawers as there are addresses in memory. Each drawer contains a word and the address of each word is written on the outside of the drawer. If we write or store a word say 10101010 at address 125, it is like placing the word 10101010 in the drawer labelled 125. Later, reading from address 125 is like looking in that drawer to see its contents which is now 10101010. We do not remove the word at an address when we read, but change the contents at an address only when we store or write a new word. Thus, entering data into a storage location is *destructive* of previous contents, but retrieving data from a location is *non-destructive.*

STORAGE CAPACITY

The storage capacity of large computer systems is normally more than small systems. This capacity is defined in terms of bytes or words. A symbol commonly used to denote the storage capacity of a computer is the letter K (Kilo) which is equal to 2^{10}, or 1024. Thus a 32 Kilobyte memory is capable of storing 32 x 1024 = 32,768 bytes or characters. Memory sizes range from a few K bytes or words in small machines to several thousand K bytes or words in large machines. However, if the memory capacity is stated in terms of words, it is necessary to know the word size in bits or bytes in order to determine the actual storage capacity of the computer. Thus, while specifying the memory capacity in terms of words, it is customary to specify the total number of bits per word along with the total number of words. So a memory with 4096 locations each with a different address and with each location storing 16 bits is called a "16-bit 4096-word memory,by or,in the vernacular of the computer trade, a "4 K 16-bit memory". Similarly, a memory having 2^{15} words with each word of 16 bits is called a "32 K 16-bit memory". If the word size of a memory is 8 bits (equal to a byte) then it becomes immaterial whether the memory capacity is expressed in terms of bytes or words. Thus a memory having 2^{16} words with each word of 8 bits is simply referred to as 64 K memory (word size of 8-bits is implicit here).

WHY MORE BITS

You might have heard about 8-bit computers, 16-bit computers, 32-bit computers, etc. This refers to the word size of a particular computer in terms of total number of bits. Word size is an important architectural factor. Small machines have word sizes of 8 or 16 bits; large machine word sizes are 32 bits or more. The obvious question that arises to ones mind is that what is the advantage of having more number of bits per word instead of having more words of smaller size ?

For an answer to the above question, imagine a highway with eight lanes, and a heavy flow of traffic. If it is expanded to sixteen lanes, the flow of traffic speeds up considerably. '8-bits' refers to the number of 'lanes' on a microchip. Greater bits means a more rapid flow of electronic signals. In other words, a faster computer. Thus, what an 8-bit computer takes one minute to do, a 32-bit computer can do in one second.

in word-sized bunches. Therefore, even if the electronic circuits used are comparable in speed, small machines are slower than big machines. This difference is analogous to providing the user of a small machine with a small data shovel and the user of a large machine with a large data shovel. Even though they both may be shoveling at comparable speeds, the user with the smaller shovel will be slower because more shovelfuls are needed to move the same amount of data.

FIXED AND VARIABLE WORD LENGTH STORAGE

The primary storage section of some computers is designed to store a fixed number of characters (equal to its word-length in bytes) in each numbered address location. Such computers are said to be *word addressable*, and they employ a *fixed word-length storage* approach. In these computers, storage space is always allocated in multiples of word-length. So if a word addressable computer has a fixed word-length of 4 characters then this computer will require one word (4 bytes) to store the word "CAT" and two words (8 bytes) to store the word "BOMBAY".

In many computers, the primary storage section is also designed in such a way that each numbered address can only store a single character (A, B, 1, 2, +, -, etc). Computers designed in this manner are said to be *character addressable* and they employ a *variable word-length storage* approach. Thus in these machines, only 3 bytes will be required to store the word "CAT" and only 6 bytes will be required to store the word "BOMBAY". Figure 7.2 summarizes the difference between the fixed-length and variable-length storage approach.

Both the fixed and the variable word-length storage systems have their own merits and demerits. The fixed word-length storage approach is normally used in large scientific computers for gaining speed of calculation. On the other hand, the variable word-length approach is used in small business computers for optimizing the use of storage space. For example, let us consider a fixed word-length machine with a word size of eight characters. If most of the data words to be stored are of less than five characters then more than half of the storage space will remain unused. This will not happen in case of a machine with variable word-length primary storage because a character can be placed in every storage cell of this machine. However, word addressable computers possess faster calculating capability because they can add two data words in a single operation. If the fixed-length word is eight charcters, two eight digit numbers can be added in single operation. On the other hand, with a character addressable machine only one digit in each number is added during a single operation and eight steps would thus be needed to add two eight digit numbers.

Most of the today's business and scientific processing is handled by flexible computers which can employ either a fixed word-length or a variable word-length storage organization. The set of instructions available with these computers allow them to be operated as either variable or fixed word-length computers.

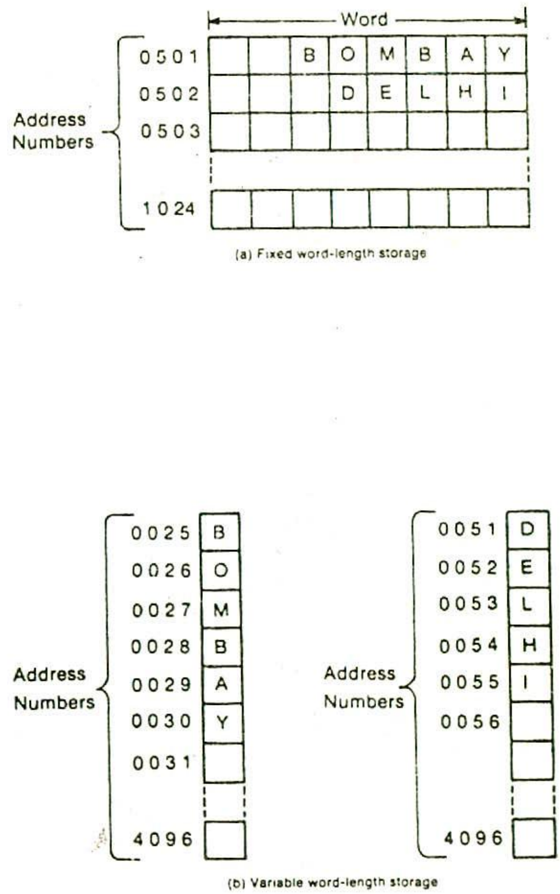


Figure 7.2. Fixed word-length storage compared with variable word-length storage.

RAM, ROM, PROM and EPROM

Primary storage is usually referred to as random access memory (RAM) because it is possible to randomly select and use any location of this memory to directly store and retrieve data and instructions. Each separate location inside the memory is as easy to access as any other location, and takes the same amount of time. It is also referred to as read/write memory because information can be 'read' from a RAM chip and can also be 'written' into it.

A read only memory (ROM) is one in which information is permanently stored. The information from the memory can only be read and it is not possible to write fresh information into it. This is the reason why it is called ROM. When the power supply is switched off, the information stored inside a ROM is not lost as it is in the case of a RAM chip. Such memories are also known as field stores, permanent stores or dead stores.

The most basic computer functions are carried out by wired electronic circuits. However, there are several higher-level operations that are very frequently used but will require very complicated electronic circuits for their implementations. Hence instead of building electronic circuits for these operations, special programs are written to perform these operations. These programs are called *microprograms* because they deal with low-level machine functions and are essentially substitutes for additional hardware. Microprograms are written to aid the control unit in directing all the operations of the computer system. ROMs are mainly used by computer manufacturer's for storing these microprograms so that they cannot be modified by the users.

A variation of ROM chip is programmable read only memory (PROM). ROM chips are supplied by the computer system manufacturer and it is not possible for a customer (user) to modify the programs stored inside the ROM chip. However, it is possible for a user to "customize" a system by converting his own programs to microprograms and storing them in a PROM chip. Once the users programs are stored in a PROM chip, they can usually be executed in a fraction of the time previously required. PROMs are programmed to record information using a special facility known as a prom-programmer. However, once the chip has been programmed, the recorded information cannot be changed, i.e. the PROM becomes a ROM and it is only possible to read the stored information. PROM is also non-volatile storage, i.e. the stored information remains intact even if power is switched off.

Once information is stored in a ROM chip or a PROM chip it cannot be changed or altered. However, there is another type of memory chip called erasable programmable read only memory (EPROM) that overcomes this problem. As the name implies, it is possible to erase information stored in an EPROM chip and the chip can be reprogrammed to store new information using a special prom-programmer facility. Information stored in an EPROM chip is erased by exposing the chip for some time to ultraviolet light. When an EPROM is in use, information can only be 'read' and the information remains on the chip until it is erased. EPROMs are mainly used by R & D personnel (experimenters) because they frequently change the microprograms to test the efficiency of the computer system with new programs.

Regardless of the type of ROM chip used, they all serve to increase the efficiency of a CPU by controlling the performance of a few specialized tasks. A generalized CPU can be made to meet the unique needs of different users merely by changing microprograms.

CACHE MEMORY

A special very high speed memory is sometimes used to increase the speed of processing by making current programs and data available to the CPU at a rapid rate. As you may be aware, CPU speeds are quite high compared to the access time of main memory. In many situations the performance of the processors are limited due to the slow speed of the main memory. A technique used to compensate for the mismatch in operating speeds is to employ an extremely fast, small memory between CPU and main memory whose access time is close to the processing speed of the CPU. This type of memory is called a *high-speed buffer* or *cache memory*. It is used to store segments of programs currently being executed and/or temporary data frequently needed in the present calculations. By making active programs and data available at a rapid rate, it is possible to increase the performance rate of the CPU.

As the name implies, cache memory is a memory in hiding and is not addressable by the user of the computer system. Its purpose is to look ahead and to provide the CPU with currently needed information. Cache memory makes main memory appear to be faster and larger than it really is. It is very expensive as compared to the main memory and hence its size is normally very small. The most important effect of cache memory is in improving the memory transfer rates and thus raising the processor speed.

REGISTERS

As the instructions are interpreted and executed by the CPU, there is a movement of information between the various units of the computer system. In order to handle this process satisfactorily and to speed up the rate of information transfer, the computer uses a number of special memory units called *registers*. These registers are not considered as a part of the main memory and are used to retain information on a temporary basis.

The number of registers varies among computers as does the data-flow pattern. Most computers use several types of registers, each designed to perform a specific function. Each of these registers possess the ability to receive information, to hold it temporarily, and to pass it on as directed by the control unit. The length of a register equals the number of bits it can store. Thus a register that can store 8 bits is normally referred to as 8-bit register. Although the number of registers varies from computer to computer, there are some registers that are common to all computers. The function of these registers is described below.

1. *Memory Address Register (MAR)* : It holds the address of the active memory location. It is loaded from the program control register when an instruction is read from memory.

2. *Memory Buffer Register (MBR)* : It holds the contents of the memory word read from, or written in, memory. An instruction word placed in this register is transferred to the instruction register. A data word placed in this register is accessible for operation with the accumulator register or for transfer to the I/O register. A word to be stored in a memory location must first be transferred to the MBR, from where it is written in memory.

3. *Program Control Register (PC)* : It holds the address of the next instruction to be executed. This register goes through a step-by-step counting sequence and causes the computer to read successive instructions previously stored in memory. It is assumed that instruction words are stored in consecutive memory locations and read and executed in sequence unless a branch instruction is encountered. A *branch instruction* is an operation that calls for a transfer to a non-consecutive instruction. The address part of a branch instruction is transferred to the PC register to become the address of the next instruction. To read an instruction, the contents of the PC register are transferred to the MAR and a memory read cycle is initiated. The instruction placed in the MBR is then transferred to the instruction register.

4. *Accumulator Register (A)* : This register holds the initial data to be operated upon, the intermediate results, and also the final results of processing operations. It is used during the execution of most instructions. The results of arithmetic operations are returned to the accumulator register for transfer to main storage through the memory buffer register. In many computers there are more than one accumulator registers.

5. *Instruction Register* (I) : It holds the current instruction that is being executed. As soon as the instruction is stored in this register, the operation part and the address part of the instruction (see Chapter 12) are separated. The address part of the instruction is sent to the MAR while its operation part is sent to the control section where it is decoded and interpreted and ultimately command signals are generated to carry out the task specified by the instruction.

6. *Input/Output Register (I/O)* : This register is used to communicate with the input/output devices. All input information such as instructions and data is transferred to this register by an input device. Similarly, all output information to be transferred to an output device is found in this register.

Table 7.1 summarises the functions of each of these registers.

Table 7.1. **Functions of Various Registers**

SE No.	NAME OF REGISTER	FUNCTION
1.	Memory Address (MAR)	Holds the address of the active memory location
2.	Memory Buffer (MBR)	Holds information on its way to and from memory
3.	Program Control (PC)	Holds the address of the next instruction to be executed
4.	Accumulator (A)	Accumulates results and data to be operated upon
5	Instruction (I)	Holds an instruction while it is being executed
6.	Input/Output (I/O)	communicates with the I/o devices

QUESTIONS

1. Differentiate between a bit, a byte, and a word.

2. What is a memory address ? Describe with an example.

3. Explain the difference between an address and the contents of an address.

4. Write a note on the storage capacity' of a computer.

5. How many bytes can be stored in the primary storage unit of a 512 K-byte computer ?

6. What is the memory capacity in terms of bytes of a 128 K 16-bit computer ?

7. What is the importance of the difference in word sizes between small and large computers ?

8. Distinguish between word-addressable and character-addressable computers. Discuss their relative advantages and disadvantages.

9. How many bytes will be required to store the word 'MEMORY' in (a) a character-addressable computer (b) a word-addressable computer having word-length of 64 bits ?

10. What is a microprogram ?

11. How is read only memory used ?

12. Differentiate between RAM, ROM, PROM and EPROM.

13. What is a cache memory ? How is it different from a primary memory ?

14. What are registers ? Name some of the commonly used registers and briefly describe the function of each.

15. Give the full form of the following abbreviations :

    (a) K
    (b) RAM
    (c) ROM
    (d) PROM
    (e) EPROM
    (f) MAR
    (g) MBR

CHAPTER 8

8. SECONDARY STORAGE DEVICES

It is desirable that the operating speed of the primary storage of a computer be as fast as possible because most of the transfers of data to and from the processing unit is via the main memory. For this reason, storage devices with very fast access times, such as semiconductors, are generally chosen for the design of main memory. These high-speed storage devices are expensive and hence the cost per bit of storage is also high for a primary storage. Thus the storage capacity of the main memory of a computer system is limited. Often, it is necessary to store many millions, sometimes billions, of bytes of data. Unfortunately, the storage capacity of the primary storage of today's computers is not sufficient to store the large volume of data handled by most data processing centres. As a result, additional memory, called the *auxiliary memory* or *secondary storage*, is used with most computer systems. This section of the computer's memory is characterised by low cost per bit stored, but it generally has an operating speed far slower than that of the primary storage. This section of the memory is also referred to as *backup storage* because it is used to store large volume of data on a permanent basis which can be partially transferred to the primary storage as and when required for processing. Data are stored in secondary storage in the same binary codes as in main storage and are made available to main storage as needed. A wide range of secondary storage devices is available. Typical hardware devices are magnetic tape and magnetic disk. In this chapter you will learn about many different types of secondary-storage devices.

SEQUENTIAL AND DIRECT-ACCESS DEVICES

Several different devices can be used as a secondary storage, but the one selected for a particular application mainly depends upon how the stored information needs to be accessed. Basically there are two methods of accessing information - sequential or serial access and direct or random access. *A sequential-access device* is one in which the arrival at the location desired may be preceded by sequencing through other locations, so that access time varies according to location. In other words, information on a serial device can only be retrieved in the same sequence in which it is stored. Sequential processing is quite suitable for such applications like preparation of monthly payslips, or monthly electricity bills, etc., where each address needs to be accessed in turn. In these applications, data for each and every employee or customer needs to be processed at scheduled intervals (in this case monthly). However, while working with a sequential-access device, if an address is required out of order, it can only be reached by searching through all those addresses which are stored before it. For instance, data stored at last few locations cannot be accessed until all preceding locations in the sequence have been traversed. Magnetic tape and punched paper media are typical sequential-access storage devices.

In many applications, we need to access information in a more direct manner than serial devices allow. For example, in a computerised bank, at any instant it is required to determine the exact balance in the savings account of a particular customer. Similarly, in a computerised airline ticket booking system, immediate access may be required to reservation system records to find out if seats are currently available on a particular flight. In such applications, if we use sequential-access device, the time taken to access the desired information may be enormous which will cause frustration to the customer. Backing storage devices exist which permit access to individual information in a more direct or immediate manner. These direct devices are also called random-access devices because the information is literally available at random, i.e., it is available in any order. Thus a *random-access storage device* is one in which any location in the device may be selected at random, access to the information stored is direct, and approximately equal access time is required for each location. Magnetic disk and magnetic drum are typical direct-access storage devices. We will now discuss in detail some of the sequential and direct-access secondary storage devi:es.

PUNCHED PAPER TAPE

It is a sequential-access secondary storage device. Data is coded on paper tape in the form of punched hole combinations. The tape is normally 1 inch wide, comes in rolls, and may be used in any length upto several hundred feet. There is a line of sprocket holes in the middle of the tape for the purpose of feeding the tape through the tape punching and reading device. Information is recorded as holes punched in rows across the width of the tape, with one row representing one character (Figure 8.1). The maximum number of holes per row is referred to as the number of *channels* on the tape. The particular coding system used to record information on the tape depends on the number of channels. An eight channel tape is the one most commonly used.

The number of characters that can be stored in a given physical space is low for paper tape storage. Moreover, the paper tape media is easily torn and mutilated. Hence, the use of paper tapes as a secondary storage device is very rare today and is vanishing day by day. However, the storage capacity of punched paper tape is virtually unlimited, and the cost per bit stored is very low.

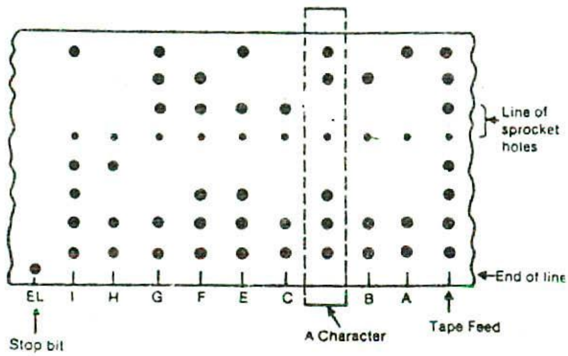


Figure 8.1. An eight channel punched paper tape.

MAGNETIC TAPE

Magnetic tape is one of the most popular storage medium for large data that are sequentially accessed and processed. The tape is a plastic ribbon usually 1/2 inch wide that is coated on one side with an iron-oxide material which can be magnetized. The tape ribbon itself is stored in *reels* of 50 to 2400 feet or a small *cartridge* or *cassette*. It is similar to the tape used on a tape recorder except that it is of higher quality and more durable. Like recorder tape, computer tape can be erased and reused indefinitely. Old data on a tape are automatically erased as new data are recorded in the same area.

Information is recorded on the tape in the form of tiny invisible magnetized and non-magnetized spots (representing 1's and 0's) on the iron-oxide side of the tape. The tape is divided into vertical columns called *frames* and horizontal rows called channels or *tracks*. A character is recorded per frame using one of the computer codes described in Chapter 4. As shown in Figure 8.2, older tapes had 7 tracks and they used the 6-bit BCD code format for data recording. As in BCD code, the letter A is represented on this tape by the code 110001. The first six tracks are used for recording the 6 bits of the BCD code. The seventh track is used for recording the parity bit.

A *parity bit* or *check bit* is used to detect errors that may occur due to the loss of a bit from a string of 6 or 8 bits during data input or output operations. If the basic code for a character requires an odd number of 1 bits (such as 1, 2, or A in BCD) an additional 1 bit is added to the check bit location so that there will always be an even number of 1 bits. This is an example of *even-parity*. Similarly, in *odd-parity*, the check bit is used to always produce an odd number of 1 bits. That is, the check bit will be 1 if the total number of 1 bits for representing a particular character is even and it will be 0 otherwise. The tape shown in Figure 8.2 uses the parity bit for an even parity.

Most of the modern magnetic tapes have 9 tracks and they use the 8-bit EBCDIC code format for data recording. As shown in Figure 8.3, in this case the fourth track is used for parity bit which produces an odd parity in this example. Mark that the letter A is represented here by the code 11000001 as in the 8-bit EBCDIC format.

Magneitc tape drive is a machine that can either read data from a tape into the CPU or it can write the information being produced by the computer onto a tape. You can see in Figure 8.5 that the tape on a real moves through a tape drive in much the same way that a film moves through a movie projector. During processing, the tape moves from a supply reel to a take-up reel via two vacuum channels and through a read/write head assembly. The read/write head assembly is a single unit having one read/write head for each tape track. They either read information, or write information on the tape. The two vacuum channels are designed to take up slack tape, acting as buffers to prevent the tapes from snapping or stretching when starting from a stationary position or slowing down from full speed. Several methods are used to prevent tape damage from sudden bursts of speed and different tape drives may use different mechanisms for this purpose.

Data transfer rate or data rate is one measure of the quality of a secondary storage device. The data transfer rate for magnetic tape is the product of tape density and tape speed. *Tape density* is the number of frames that can be compressed into 1 inch of tape. Because a frame contains a character, or a byte, tape densities are expressed in characters per inch (CPI) or by.es per inch (BPI). Typical tape densities are 556 BPI, 800 BPI, 1600 BPI, 3250 BPI or even 6250 BPI, with the higher densities applicable to the more modern systems. *Tape speed* is measured in inches per second, and high-performance tapes have speed in excess of 200 inches per second. Thus, for a magnetic tape, the data transfer rate can be in excess of 1 million bytes per second.

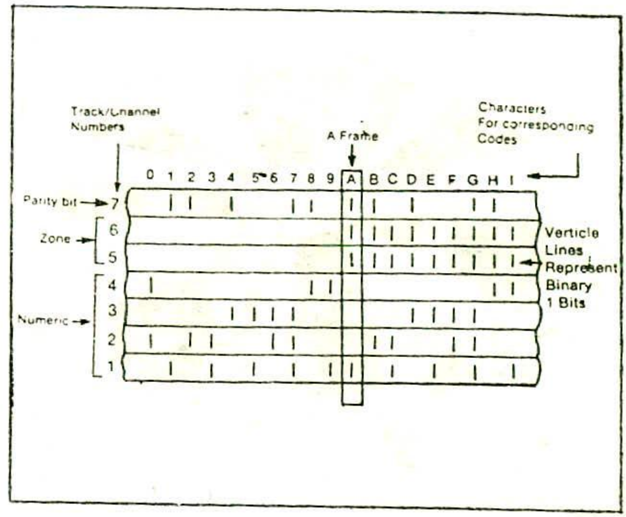


Figure 8.2. Data recording on a 7 track magnetic tape using 6-bit BCD code format. Here the 7th tack is used for an even parity so all frames contain an even number of 1 bits.

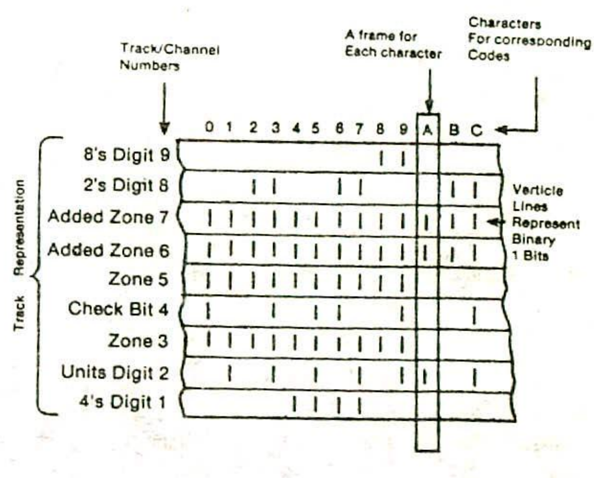


Figure 8.3. Data recording on a 9 track magnetic tape using 8-bit EBCDIC code format. This figure illustrates a so-called odd parity tape on which all the frames contain an odd number of 1 bits.

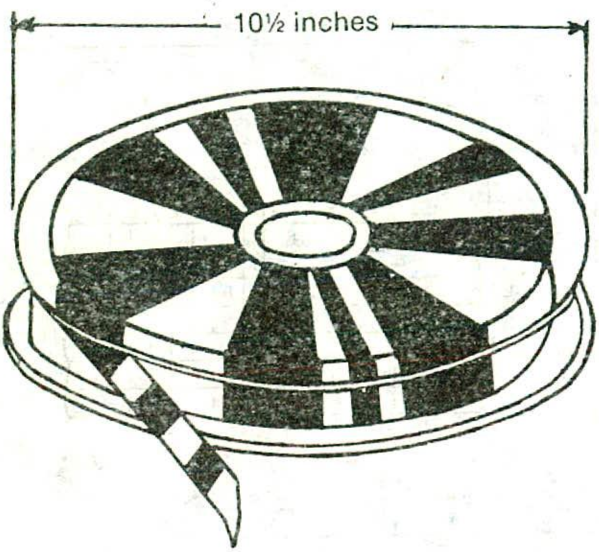


Figure 8.4. Magnetic tape in reel form.

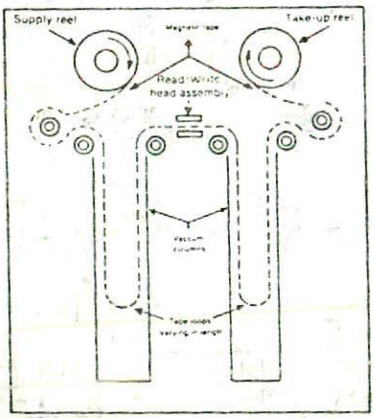


Figure 8.5. A magnetic tape drive.

Advantages of Magnetic Tape

1. *Unlimited storage* : The storage capacity of a magnetic tape is virtually unlimited because we can use as many tapes as required for recording our data.

2. *High data density* : A typical 10.5 inch reel of magnetic tape is 2,400 feet long and is able to hold 800, 1600, or 6250 characters per inch of this length. Thus, if 6250 characters are held per inch and if the tape is 28,800 inches long (2400 feet times 12 inches), then the maximum capacity of the tape is 180 million characters.

3. *Low Cost* : A 10.5 inch real of tape costs around Rs400/-(about US $32) This is much less as compared to other data storage devices. An additional cost benefit is that tapes can be erased and reused many times. Punched paper tapes do not have this advantage.

4. *Rapid transfer rate* : As already discussed, data transfer rate for a magnetic tape can be in excess of 1 million bytes per second.

5. *Ease of handling* : Since the reel is compact and weighs less than 3 pounds, it obviously takes up much less storage space and is much easier to handle. Large computer centres make use of extensive tape libraries, which contains thousands and thousands of reels of stored information and may occupy an entire room in an organization.

6. *Portability* : A reel of tape is also a convenient way of carrying information from one place to another. It is often used for transferring data and programs from one computer to another which are not linked together.

Limitations of Magnetic Tape

1. *No direct access* : Magnetic tape is a sequential access device and hence data recorded on tape cannot be addressed directly. They can only be retrieved serially. So if a data item is at the end of a tape, all the earlier parts have to be read before accessing the required information. If random access is frequently required then magnetic tape is not a suitable storage media for such type of data. Too much operator time would be required to load and unload tapes, and too much machine time would be wasted in fetching the exact data that is needed.

2. *Indirect interpretation* : Data stored on a magnetic tape are in the form of tiny invisible magnetized and non-magnetized spots. Hence the contents of a tape cannot be interpreted and verified directly. Instead a printing run must be made if the accuracy of tape data is questioned. This calls for the need of machine interpretation of the stored data.

3. *Environmental problems* : Specks of dust and uncontrolled humidity or temperature levels can cause tape-reading errors. Moreover, tapes and reel containers must be stored in a dust free environment and should be properly labeled so that some useful data stored on a particular tape is not erased by mistake.

TAPE CASSETTES AND CARTRIDGES

Magnetic tape reels are suitable for use only with large and medium size computers. The same magnetic tape is used in smaller systems in the form of cassettes and cartridges. The changeable tape cassette used in the familiar home recorder is now becoming an attractive means for recording digital data because they are small, changeable, and inexpensive. Unfortunately, the quality of tape and the tape moving mechanism in the conventional home tape cassette are not good enough for computer usage. As a result, a number of high-quality digital cassettes have been developed that are very similar in appearance to the home cassettes. Figure 8.6 shows a tape cassette.

There are also large tape cartridges which contain long strips of magnetic tape and which resemble large cassettes. These cartridges provide a more *convenient* way to package tape, and greatly simplify the mounting of tape which is normally a problem with conventional reels of tape that have to be manually mounted on the mechanism. Moreover, tape cartridges also provide protection against dirt and contamination, since the tape is sealed in the cartridge. A tape cartridge is shown in Figure 8.7. Tape cassettes and cartridges have relatively low data-transfer-rate which is typically less than 10,000 bytes per second.

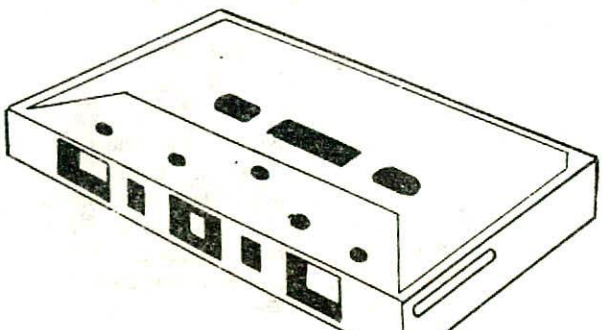


Figure 8.6. Magnetic tape cassette.

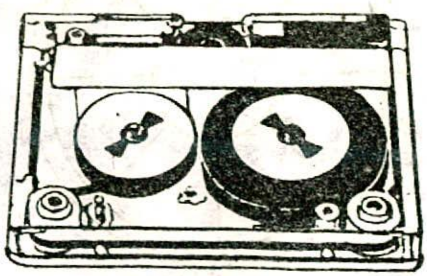


Figure 8.7. Magnetic tape cartridge.

MAGNETIC DISK

A magnetic disk is a thin, circular metal plate/platter coated on both sides with a magnetic material. It is very similar in appearance to a LP gramophone record. A *disk pack* consists of a number of these disks, three or more, mounted about half-an-inch apart from each other on a central shaft which rotates at speeds of 2,400 or more revolutions per minute (rpm). Thus all the disks of a disk pack move simultaneously in the same direction and at equal speed. Magnetic disks are the most popular medium for direct-access secondary storage.

Storage of Information. In a disk pack, information is stored on both the surfaces of each disk plate except the upper surface of the top plate and the lower surface of the bottom plate which are not used. As shown in Figure 8.8, each disk consists of a number of invisible concentric circles called *tracks*. A set of corresponding tracks in all the surfaces is called a *cylinder* (Figure 8.9). Thus a disk pack having 10 disk plates will have 18 recording surfaces and hence it will have 18 tracks per cylinder. Each track is further subdivided into sectors (Figure 8.10).

Information is recorded on the tracks of a disk surface in the form of invisible tiny magnetic spots. The presence of a magnetized spot represents a 1 bit and its absence represents a 0 bit. A standard binary code, usually 8-bit EBCDIC, is used for recording data. In some systems, the outer tracks, contain more bits than the inner tracks, because the circumference of an outer track is greater than that of an inner track. However in most systems, each track contains the same number of characters, which means that the outer tracks of the disk are less densely packed with characters than those towards the centre.

The information stored on a disk can be read many times without affecting the stored data. So the reading operation is non-destructive. But the writing of new data erases data previously stored at that location of the disk. The data stored on a magnetic disk remains indefinitely until they are erased and reused at a future time.

Storage Capacity. The more disk surfaces a particular disk pack has, the greater will be its storage capacity. But the storage capacity of disk system also depends on the tracks per inch of surface and the bits per inch of track. Although the diameter of a standard sized disk is 14 inches, some disks are quite large running upto 4 feet in diameter. Larger disks have more tracks and hence they have greater storage capacity.

The total number of bytes that can be stored in a disk pack is :

Number of cylinders x Tracks per cylinder x Sectors per track x Bytes per sector.

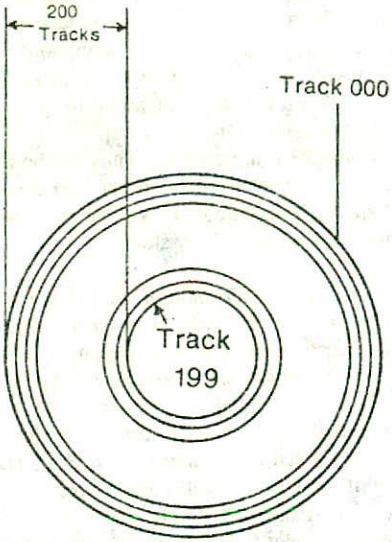


Figure 8.8. Tracks on a disk. The number of tracks varies (often 200 or more). The outer track is numbered 000 and inner track number is one less than total number of tracks. The inner track on a disk with 200 tracks is numbered 199.

For a typical example, let us assume that a disk pack has 10 disk plates each having 200 tracks. Suppose there are 40 sectors per track and each sector can store 256 bytes. Since the disk pack has 10 disk plates, so it will have 18 recording surfaces or in other words 18 tracks per cylinder. 200 tracks per plate means that there are 200 cylinders. So the capacity of this disk pack is : 200 x 18 x 40 x 256 = 36864000 bytes or 36.864 million bytes.

Disk packs are potentially very high capacity storage devices typically in the range 20 to 1000 megabytes (M bytes). One megabyte is equal to 10^6 bytes. Essentially one character can be stored per byte. So a 50 M byte disk pack has the capacity to store 50 million characters of information.

Accessing of Data. Data are recorded on the tracks of a spinning disk surface and read from the surface by one or more *read/write heads*. There are two basic types of disk systems - moving-head and fixed-head. The *moving-head-system* consists of one read/write head for each disk surface mounted on an access arm which can be moved in and out (Figure 8.11). So in this system, each read/write head moves horizontally across the surface of the disk so that it is able to access each track individually. Each usable surface of the disk pack has its own head and all the heads move together. Information stored on the tracks which

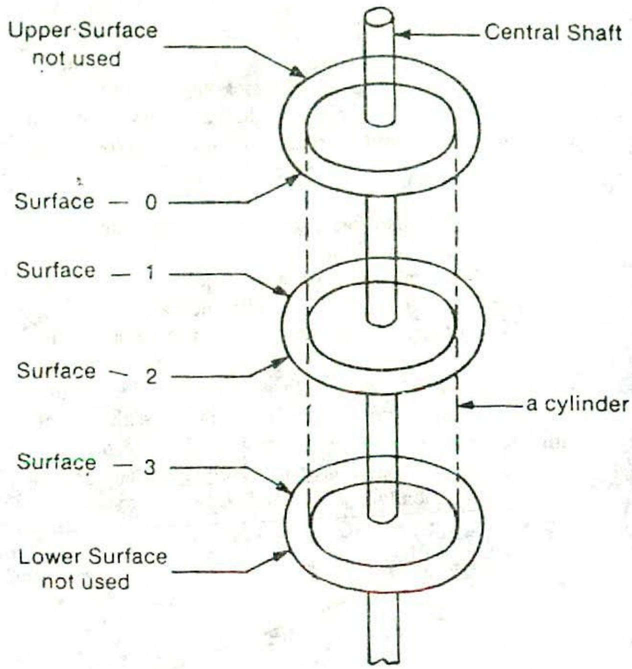


Figure 8.9. A disk having 3 disk platters. The upper surface of the top plate and the lower surface of the bottom plate are not used. So altogether there are 4 usable surfaces numbered 0, 1, 2 and 3. A set of corresponding tracks on all the 4 surfaces is called a cylinder as shown here.

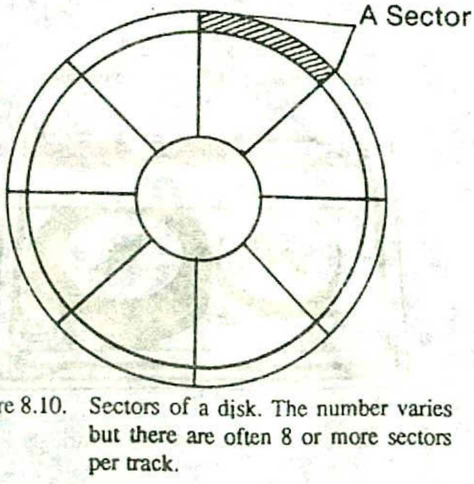


Figure 8.10. Sectors of a disk. The number varies but there are often 8 or more sectors per track.

constitute a cylindrical shape through the disk pack are therefore accessed simultaneously. Note the cylindrical storage arrangement of information in a disk pack.

In the *fixed-head system*, the access arm is non-movable. A large number of read/write heads are distributed over the disk surfaces, one head for each track (Figure 8.12). As a result, no head movement is required and therefore information is accessed more quickly. However, because of the space required for the additional read/write heads, fixed-head disks have less capacity and cost more per byte of data stored than moving-head disks.

The disk pack on some disk storage devices is permanently fixed in position, while on others, the pack can be removed and replaced by another one in a matter of seconds. So the storage capacity of a removable disk pack system is virtually unlimited because the storage space can be increased without the heavy expense of buying

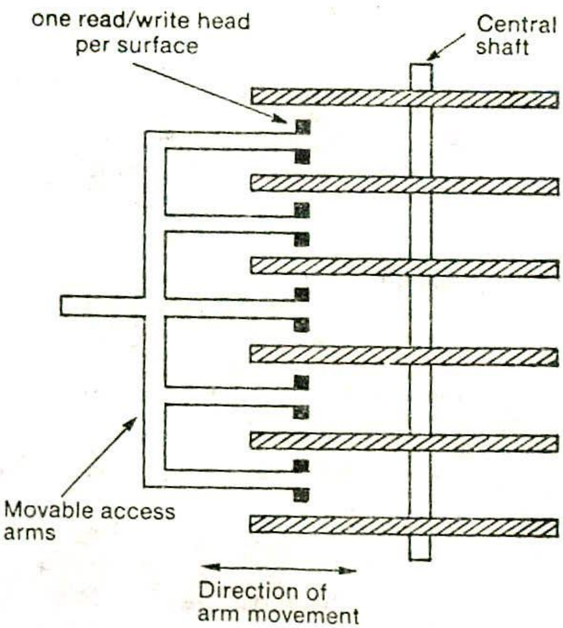


Figure 8.11. Vertical cross section of a moving-head disk system. There is one read/write head per surface. The heads move horizontally across the surface of the disk.

another complete device. In this context, it is important to note that exchangeable disk packs are only associated with moving-head systems. The disk packs of a fixed-head system are non-removable.

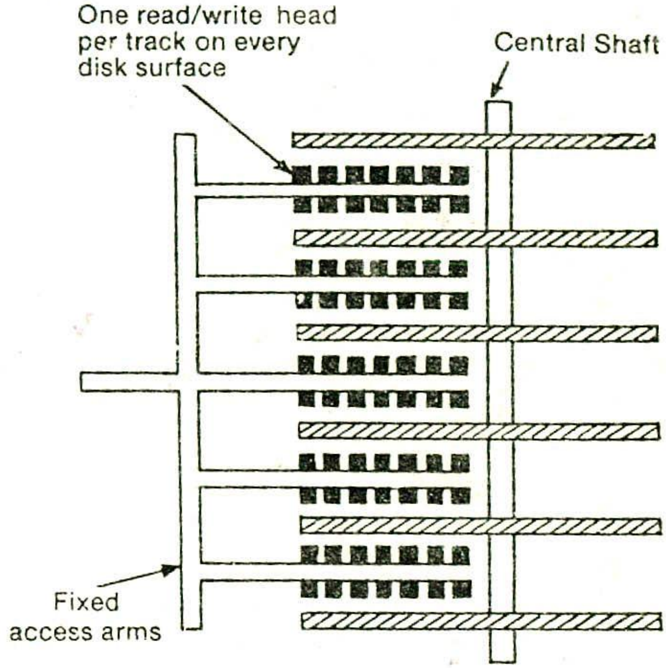


Figure 8.12. Vertical cross section of a fixed-head disk system. There is one read/write head per track on every disk surface. No head movement is required and so the access arms are non-movable.

Another point to be noted is that in case of both the fixed-head and the moving-head systems, the read/write heads are of flying type, i.e., they do not have direct contact with the surface of the disks. When a disk rotates at a high speed, a thin layer of air rotates with the disk. The head is so shaped that it rides on this layer of rotating air, thus maintaining a separation of about 1/400th of an inch from the disk surface. This prevents wear on the surface of the disk.

Access Time. In order to access information from a disk, the disk address of the desired data has to be specified. The disk address is specified in terms of the track number, the surface number, and the sector number. Information is always written from the beginning of a sector and can be read only from the track beginning.

As soon as a read/write command is received by the disk unit, the read/write heads are first positioned on to the specified track number by moving the arm assembly in the proper direction. This involves a mechanical motion of the arms and is slow. The time required to position the head over the proper track is called the *seek time*. The seek time varies depending on the position of the arm assembly when a read/write command is received. If the arm assembly is positioned on the outer most track and the track to be reached is the inner most one then the seek time will be maximum, and it will be zero if the arm assembly already happened to be on the desired track. The average seek time is thus specified for most systems which is generally somewhere between several milliseconds to fractions of a second. Note that seek time is associated only with movable-head systems. For a fixed-head system, the seek time is always zero because there is a head for each track and no movement of head is required for accessing a particular track.

Once the heads are positioned on the desired track, the head on the specified surface is activated. Since the disk is continuously rotating, this head should wait for the desired data (specified sector) to come under it. This rotational waiting time, i.e., the time required to spin the needed data under the head is called the *latency time*. The latency time is also a variable and depends on the distance of the desired data from the initial position of the head on the specified track. It also depends on the rotational speed of the disk. An average latency time is thus normally specified which is of the order of 10 to 15 milliseconds.

The total access time for a disk is equal to the seek time plus the latency time. The average access time for most disk systems is usually between 10 and 100 milliseconds. Technically speaking, disk systems have direct but not random access to the stored data. *Random access* refers to a storage device in which the access time is independent of the physical location of the data. For example, primary storage is a random access storage. Since the disk access time is dependent on the physical location of data, it is more correct to say that disks provide *direct access*. This distinction is not always observed and hence disk systems are sometimes referred to as random access storage devices.

The data transfer rate of a disk system depends on the density of the stored data and the rotational speed of the disk. Maximum rate usually ranges between 400,000 and 2 million characters per second.

Comparison Between Magnetic Tape And Magnetic Disk Storage

The following are the relative advantages and disadvantages of a magnetic tape and a magnetic disk storage systems :

1. Magnetic disk has the flexibility of being used as a sequential as well as a direct access storage device. On the other hand, magnetic tapes can be used only for sequential processing of data.

2. Magnetic disks are less vulnerable to damage from dust or careless handling than magneitc tapes.

3. Any information desired from a disk storage can be accessed in a few milliseconds because it is a direct access storage device. This is not possible in case of a tape storage which is a sequential access storage device.

4. Data transfer rate for a magnetic disk system is normally higher than a tape system.

5. A disk pack equal in storage capacity to a reel of magnetic tape may be about 25 times more expensive. On a cost-per-bit basis, the cost of disks is low. But the cost of magnetic tape is even less.

6. Sequential processing using disks may be slower and less efficient than when tapes are used.

7. It is easier to maintain the security of information stored on a tape as compared to information stored on a disk.

8. Disk packs are not so easily portable like magnetic tapes.

FLOPPY DISK

The metallic disks that we described above are called hard-disks. These disks, in the form of disk-packs, are suitable only for large and medium sized computers and often are too expensive for small computer systems. An increasingly popular direct access secondary storage medium for micro and mini computer systems is the flexible, or floppy, disk. Floppy disks are also referred to as diskettes or floppies. They were introduced by IBM in 1972 and are now being produced in various sizes by many manufacturers.

A floppy disk is made of flexible plastic which is coated with magnetic oxide. The flexible disk is enclosed within a square plastic or cardboard jacket, often referred to as a cartridge. The jacket gives handling protection to the disk surface. Moreover, it has a special liner that provides a wiping action to remove dust particles that are harmful for the disk surface and the read/write head. The disks are mounted on the disk drive along with the jacket cover and information is written and read through an aperture in the jacket (Figure 8.13). The cartridge can be very easily loaded into, and unloaded from, a drive unit. Unlike the hard-disk drives, the read/write heads of a floppy-disk unit make direct contact with the disk surface during the process of reading or writing, and floppy disks therefore get worn with constant use.

Floppy disks are typically 3, 5.25, or 8 inches in diameter. They come in either single - or double - density versions and record on one or both surfaces of a diskette. Thus there are basically four types of diskettes:

(a) single-sided-single-density,
(b) single-sided-double-density,
(c) double-sided-single-density, and
(d) double-sided-double-density.

The capacity of diskettes varies depending on their size (diameter) and type (mode of data recording). Thus, the capacity of a single-sided-single-density 5.25 inch diskette may only be a little over 100 kilobytes (1 kilobyte = 10^3 bytes), while the capacity of a double-sided-double-density 8 inch diskette may be almost 2 megabytes.

Floppy disks are very cheap as compared to other storage devices. They greatly enhance the on-line storage capacity of small systems at affordable price. They are also convenient off-line storage medium for the small system users. *On-line* means connected to a computer system and under the control of the central processing unit. *Off-line* means not connected to a computer system. Diskettes are currently the most popular, inexpensive storage medium used in microcomputers.

WINCHESTER DISK

There is a third type of relatively new disk storage unit known as winchester disk. In this unit disks are permanently housed in sealed, contamination-free containers. The disks are coated with a special lubricant which reduces the friction when the read/write heads land on the disk surface. The container is usually not removed from the disk drive. High-capacity systems using these sealed housings are said to employ winchester technology. The technology enables greater precision of alignment, an increase in the number of tracks on the disk surface and a higher storage density per track.

Winchester disks are fast and highly reliable, yet low priced compared with conventional hard-disk devices. They are normally 5.25, 8, or 14 inches in diameter and storage capacities of 10, 20, and 40 megabytes are typical. Some winchester units employ dual disk drives in which case the storage capacity is doubled.

Winchester disks are used in all but the smallest computer systems. They are extensively used to support minicomputers and their smaller versions are now competing with floppies to make their place in microcomputer systems.

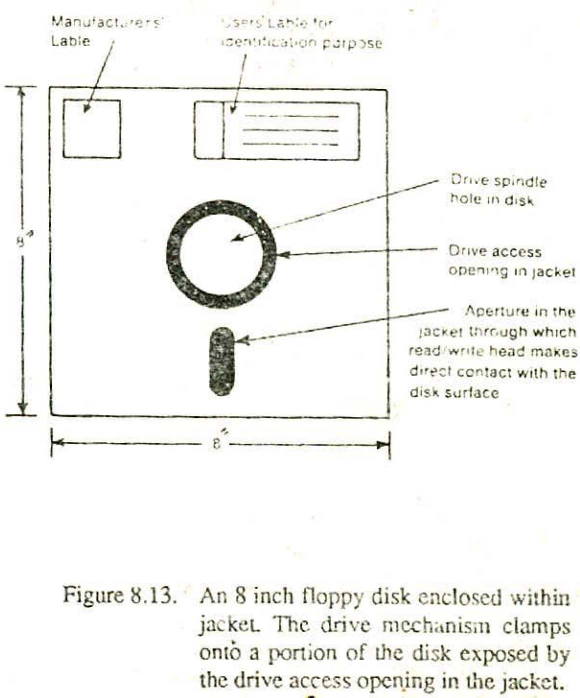


Figure 8.13. An 8 inch floppy disk enclosed within jacket. The drive mechanism clamps onto a portion of the disk exposed by the drive access opening in the jacket.

MAGNETIC DRUM

Like the magnetic disk, magnetic drum is a direct access storage device that can be used for both sequential and random processing. It consists basically of a cylinder whose outer surface is coated with a thin layer of magnetizable material. A motor rotates the cylinder on its axis at a constant and rapid rate. As shown in Figure 8.14, the surface of the drum is divided into tracks upon which data is stored as magnetized spots in the same manner as on the surface of a disk. Data is recorded on the rotating drum and read from the drum by a set of stationary read/write heads, which are positioned a fraction of an inch from the drum surface. The writing of new data on the drum erases data previously stored at that location. However, the data recorded on the drum surface will remain indefinitely until they are erased.

The drum rotates at a speed of few hundred to several thousand rotations per minute to produce a relatively fast access time. To decrease access time, heads are sometimes located in sets around the periphery of the drum, so that a drum with 15 tracks may have 30 read/write heads divided in two sets of 15 heads, each set located 180° from the other. For very fast access time, there may be even more than two sets of heads.

The sizes and storage capacities of magnetic drums vary greatly. Small drums have capacity of less than 5,000 bytes. They generally have 20 to 30 tracks. Much larger drums having 500 to 1,000 tracks can store upto 100 megabytes.

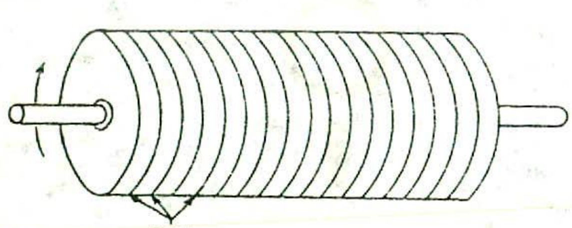


Figure 8.14. A magnetic drum storage

The larger drums normally rotate much slower than small drums and the access time obviously decreases as the drum speed increases. However, larger drums use several sets of read/write heads per track to maintain a relatively fast access time.

Magnetic drums have fast data transfer rates but are more limited in capacity than magnetic disks. They were an early means of primary storage. They were then used for online secondary storage when fast response was more important than large capacity. For example, they were used to store mathematical tables, data, or program segments that were frequently needed during processing operations. Since drums are permanently mounted and cannot be replaced like disks, and since their storage capacity is relatively low, they are seldom used today.

MASS STORAGE

Mass storage systems are storage systems that provide access to hundreds of billions of bytes of stored data. They combine the advantages of both tape and disk technologies. The storage medium is essentially a length of flexible plastic material upon which short strips of magnetic tape are mounted. These strips are then placed in cartridges, and the cartridges are loaded into a storage device that is online to the CPU. The same read/write technique as used with magnetic tape is used here to read and write data.

An example of such a device is the IBM 3850 Mass Storage System that can store 472 billion characters of data. The storage mechanism is shown in Figure 8.15. Honeycomb storage compartments are used in this system to hold cartridges that contain data on tape.

The access times of mass storage systems are measured in seconds instead of milliseconds because a transport mechanism must move to retrieve the cartridge upon which the desired data is stored. It requires several seconds to locate the cartridge specified and then several more seconds are needed to transfer the data to a magnetic disk and then to the CPU. Thus an access time of 10 seconds is common for these storage systems. But a mass storage device has huge storage capacity and a very small cost per bit stored. Around 500000 books of this size (size of this book) can be stored in the IBM 3850.

Relatively slow access times limit the use of mass storage system in many applications. However, mass storage systems are cost-effective alternative to on-line magnetic tape or disk storage in applications that require huge storage capacity and in which rapid access to data is not essential. When used for off-line storage, mass storage systems are often referred to as archival storage because of the very large volumes of historical or backup data that they can store.

OPTICAL DISK

An optical-disk storage system consists of a rotating disk which is coated with a thin metal or other material that is highly reflective. Data recording is done by focussing a laser beam on the surface of the spinning disk. The laser beam is turned on and off at a varying rate because of which tiny holes (or pits) are burnt into the metal coating of the disk along its tracks. In order to read the stored data, a less-powerful laser beam is focussed on the disk surface. This beam is strongly reflected by the coated surface and weakly reflected by the pits, producing patterns of on-off reflections that can be converted into electronic signals.

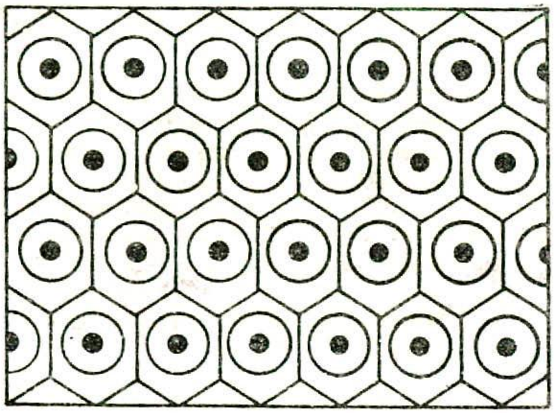


Figure 8.15. IBM 3850 Mass Storage System. The unit is a bee-hive of electronic activity. It can store upto 472 billion characters. This is accomplished by cartridges in each honeycomb cell that contain data on tape.

The storage density of optical disks is enormous, the storage cost is extremely low, and the access time is relatively fast. One small inexpensive disk will be able to replace 25 to 30 reels of magnetic tape and any data on the disk can be accessed within a few milliseconds. Hence it is particularly suitable for the archival storage of vast amounts of data. Typical applications are image processing, geological survey data, medical publishing indexes, historical information files, and very large business data bases.

A serious shortcoming of currently available optical-disk systems is that they are permanent storage devices. Data, once recorded, cannot be erased and hence the disk cannot be reused. Extensive research is being carried out to develop erasable optical disks and experts hope that it will be available within a decade.

MAGNETIC BUBBLE MEMORY

The secondary storage devices that we have considered till now are electromechanical. Magnetic bubble memory (MBM), on the other hand, is an electronic secondary storage made with solid-state electronic chips and have no moving parts. Magnetic bubble can be thought of as a tiny positively charged island in a sea of negatively charged film. They are formed by applying magnetic fields to thin sheets of certain magnetic materials, such as garnet crystal. The magnetic fields strengthen some regions in the material and weaken others. The strengthened regions break into isolated cylinders that resemble small positively charged islands surrounded by a sea of negative charges (Figure 8.16). Data is represented in bubble storage by the presence or absence of bubbles just as it is represented in punched paper tapes by the presence or absence of holes. The presence or absence of bubble corresponds to a 1 or 0 in the binary code. Bubble chips are non-volatile and retain their stored data even when the power is switched off.

Magnetic bubble memories are used as main memory in several microprocessor applications. They are also used as a low-cost alternative to magnetic disks. Portable terminals use bubble devices to store data until they can be transmitted to a larger system. Bubble chips are also used in telephone systems that redirect improperly dialed numbers, machine tools, robots, and military computers.

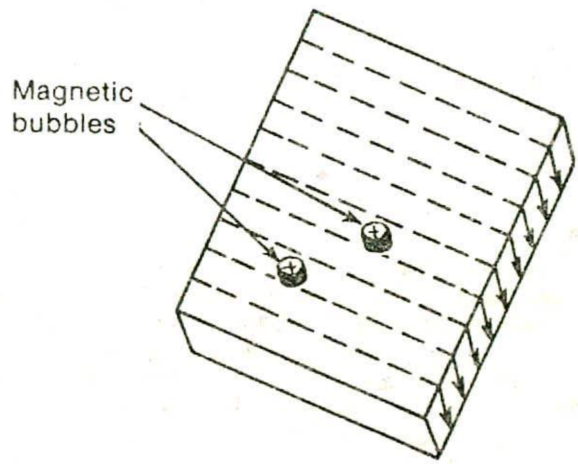


Figure 8.16. Formation of magnetic bubbles in a magnetic bubble memory.

CHARGE-COUPLED DEVICE

Like magnetic bubble memory, a charge-coupled device (CCD) is also completely electronic, fabricated on semiconductor chips. It is a semiconductor that uses electrons within a metal-oxide semiconductor (MOS) crystal to store data. CCD is faster than MBM, is very compact, and may be inexpensive to produce in future. Unfortunately, however, CCD storage is volatile.

A NOTE ON STORAGE HIERARCHY

As we have already learnt about the various types of storage devices used with computer systems, we will now briefly discuss the storage hierarchy that is applicable to most computer systems. A cost effective technique for the design of large computer systems is the use of a hierarchy of memory technologies. A typical storage hierarchy ladder is shown in Figure 8.17. It includes cahce memory, main memory, secondary storage, and archival storage. As we move up the ladder, we encounter memory elements that have faster access time, higher cost per bit stored,

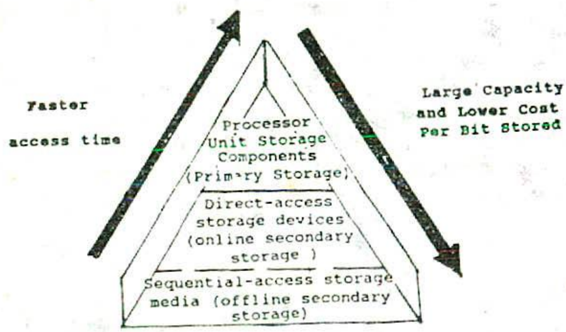


Figure 8.17. A typical stor:.ge hierarchy ladder.

and less capacity. A larger storage capacity, lower cost per bit stored, and slower access time are the results of moving down the ladder. Thus, CPU storage components generally have the fastest access times, the smallest storage capacity, and the highest cost per bit stored. On the other end, the archival storage elements have the slowest access times, the largest storage capacity, and the minimum cost per bit stored.

The cache memory which is plugged in between the CPU and the main memory is a very high speed semiconductor memory used to enhance the speed of main memory. The primary storage falls next in the memory hierarchy list. Secondary storage media such as magnetic disk memories make up the level of hierarchy just below main memory. Slower secondary storage devices, often referred to as archival storage, are at the bottom of the memory hierarchy. They are cost-effective for the storage of very large quantities of data when fast access time is not necessary.

QUESTIONS

1. What is secondary storage ? How does it differ from a primary storage ?
2. Distinguish between a sequential access, a direct access, and a random access device. Give one example of each.
3. "The storage approach selected for a particular application is determined by the way the data are organized and processed." Discuss this statement.
4. Explain how information is recorded on a magnetic tape.
5. What is a parity bit ? How is it used for detecting errors ?
6. What is the data transfer rate for a magnetic tape system for which the tape density is 800 BPI and the tape speed is 200 inches per second ?
7. Discuss the relative advantages and disadvantages of magnetic tape and magnetic disk storage.
8. Discuss the advantages and disadvantages of tape cassettes and tape cartridges compared to conventional tape systems.
9. What is a disk pack ? Explain how information is stored in a disk pack.
10. What factors determine the storage capacity of disks ?
11. A disk pack consists of 6 disk plates. Each plate has 400 tracks and there are 50 sectors per track. If 256 bytes can be stored per sector then calculate the total number of bytes that can be stored in this pack.
12. List out the relative advantages and disadvantages of movable-head and fixed-head disk systems.
13. Explain seek time and latency for disk storage. What is the access time for a magnetic disk unit that has seek time of 20 milliseconds and a latency of 7 milliseconds ?

14. Fixed-head disk systems reduce total access time by avoiding either seek time or latency. Which is avoided and why ?

15. What is "flying-head"? How does it help in increasing the life of a disk storage ?

16. A magnetic drum has circumference of 50 inches and a packing density of 1000 bits/inch. If the drum has 40 tracks, how many bits can be stored on the surface of the drum ?

17. What are the characteristics of a mass storage system ? Why are they referred to as archival storage ?

18. How are data recorded on and read from an optical disk ? What is the major drawback of an optical disk storage ?

19. What is a magnetic bubble ? How are magnetic bubbles formed ? Name some of the applications of magnetic bubble memories.

20. What is a memory hierarchy ? Name the general classes of storage media that might make up a memory hierarchy.

21. For what type of application would you select magnetic tape? Magnetic disk ? Archival storage ?

22. Tell which secondary storage device would you choose for the following kinds of computer and why:

    (a) Microcomputers
    (b) Minicomputers
    (c) Large computers.

23. Write short notes on the following :

    (a) Punched paper tape
    (b) Tape Cassettes and cartridges
    (c) Floppy disk
    (d) Winchester disk

24. Give the full form of the following abbreviations :
    (a) CPI (d) CCD
    (b) BPI (c) MOS
    (c) MBM

CHAPTER 9

9. INPUT - OUTPUT DEVICES

We have already seen in Chapter 2 that data and instructions must enter the computer system before any computation can be performed and the results of computation must be supplied to the outside world. Thus, a computer system can be proved to be useful only when it is able to communicate with its external environment. The input-output (abbreviated I/O) devices provide the means of communication between the computer and the outer world. They are also known as *peripheral devices* because they surround the CPU. Input devices are used to enter data into primary storage and output devices accept result from the primary storage to supply them to the users or to store them on a secondary storage device for future processing. There are some devices which are used for both the input and the output functions. The goal of this chapter is to familiarize the readers with the various types of I/O devices available for computer systems.

A vide variety of I/O devices are now available. For a particular application, one type of device may be more desirable than another. However, regardless of the nature of the I/O devices, special processors called *I/O interfaces* are required to convert the input data to the internal codes used by the computer and to convert internal codes to human readable form while supplying the output. These I/O interfaces are also called channels or *I/O processors* (IOP). It is important to note that even the fastest of the I/O devices is very slow when compared to the speed of primary storage and CPU. The main reason for this is that the speed of I/O devices in most cases depends upon mechanical movement and the potential for improvement of such devices is limited. It has been difficult to produce I/O devices that can match the processor and storage speeds, and there is a constant demand for faster and faster I/O devices. We will now discuss at length the various types of I/O devices that are used for different types of applications.

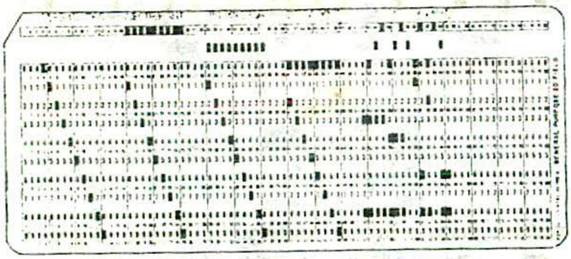
PUNCHED HOLE DEVICES

Punched hole devices are one of the oldest and cheapest I/O devices. Cards and paper tapes are the two most familiar punched hole devices. Data is recorded on these devices in the form of punched holes using some standard code. With the advent of better and faster I/O devices, the use of punched hole devices is diminishing day by day. However, many data processing centres still use them as a major input device.

PUNCHED CARDS

Few years back, punched cards were the most widely used input medium for most computer systems. Even today they are extensively used in several computer centres. There are two types of punched cards. One has 80 columns and the other has 96 columns.

The 80-Column Card. It is 19.3 cms in length, 9.5 cms in width, and 0.018 cm in thickness. As shown in Figure 9.1, the card is divided from left to right into 80 vertical columns numbered 1 to 80. It is again divided into 12 rows numbered 12, 11, 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 from top to bottom. Each column of this card can represent one character. So a maximum of 80 characters can be represented by a single card. The digits 0 to 9 are represented by punching just one hole in the corresponding row position. The alphabets A to Z are represented by a combination of two holes in two of the row positions. The top three rows - 12, 11 and 0 are zone punching positions and the rows 0 to 9 are numeric punching positions. A logical combination of zone and numeric punches is required to represent alphabets. For example, letter A through I are coded by using a 12-zone punch and numeric punches 1 through 9; letters J through R are coded by using a 11-zone punch and numeric punches 1 through 9 and letters S to Z are coded by using a 0-zone punch and numeric punches 2 through 9 respectively. Special characters are coded by punching one, two, or three holes. The coding system used to represent data in 80-column cards is known as *Hollerith Code* after the name of Dr. Herman Hollerith who first used punched cards to handle the U.S. cencus data in 1889.



If only a numeric punch is in any Column, it represents whatever number is punched out	12 punch and	11 punch and	0 punch and
	1 - - - A	1 - - - J	2 - - - S
	2 - - - B	2 - - - K	3 - - - T
	3 - - - C	3 - - - L	4 - - - U
	4 - - - D	4 - - - M	5 - - - V
	5 - - - E	5 - - - N	6 - - - W
	6 - - - F	6 - - - O	7 - - - X
	7 - - - G	7 - - - P	8 - - - Y
	8 - - - H	8 - - - Q	9 - - - Z
	9 - - - I	9 - - - R	

Figure 9.1. An 80-column card.

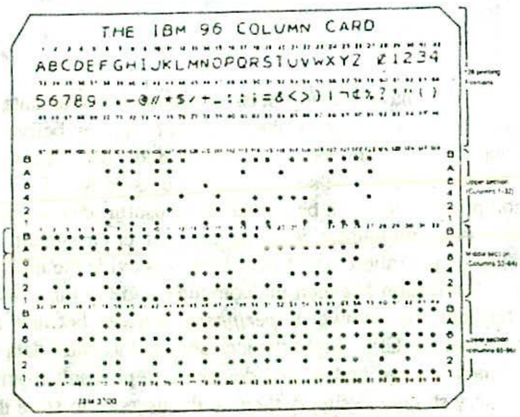


Figure 9.2. A 96-column card.

The 96-Column Card. As shown in Figure 9.2, it is only one-third the size of an 80-column card. The 96 columns are separated into three 32-column sections or tiers. The upper portion of the card which is not used for punching holes is used as a print area. These cards have round holes instead of rectangular holes of 80-column cards. Moreover, the standard 6-bit BCD code is used instead of Hollerith code for recording data on a 96-column card. Each of the 96 columns has six punch positions. The upper two are zone positions and the remaining four are numeric positions. The presence of a hole in a punch position indicates a 1 bit. It can be verified from the figure that the letter A is represented by the BCD code 110001.

Card Punch machine. It is used to transcribe data into cards. It resembles an elaborate typewriter which punches a set of holes in a card instead of printing characters on a paper. When the operator depresses a key, the correct combination of holes is punched in the column that is under the punch position at that particular moment. The machine contains a hopper in which blank cards are placed and a stacker in which the punched cards are stacked. The blank cards are automatically brought to the punch position from the hopper by pressing a special key meant for this purpose.

After punching, the cards are normally verified to ensure the correctness of data entered into the cards. A machine called a *verifier* is used for this purpose. The deck (group) of cards punched by an operator is placed in the hopper of the verifier and a second operator keys the same data. The verifier does not punch new cards, but compares what the second operator punches with the data already punched by the first operator. If a mismatch occurs in any card, the operator is notified to take corrective action. There are some machines which perform both the punching and the verifying tasks. In these machines, the first keying enters the data into an inbuilt storage section. A rekeying of the same data is then compared with the stored data. If the data match, a card is punched. In case of a mismatch, the operator makes necessary corrections and then the card is punched.

Card Reader. A card reader reads the information punched into a card, converting the presence or absence of a hole into an electrical signal representing a binary 0 or 1. Thus the holes in a card are converted into coded electrical pulses that the CPU can accept. The mechanism of a card reader is illustrated in Figure 9.3. As the card moves from the hopper to the stacker, it passes through a sensing station. At this sensing station, either wire brushes or photoelectric cells detect the presence or absence of holes. After the data is read at the first sensing station, the card passes through a second sensing station where it is read again. The data read at the two stations are then compared to verify the accuracy of the input operation. If the two reads match, the data is accepted by the card reader. If there is a mismatch, the card reader stops and an error message is given to the operator.

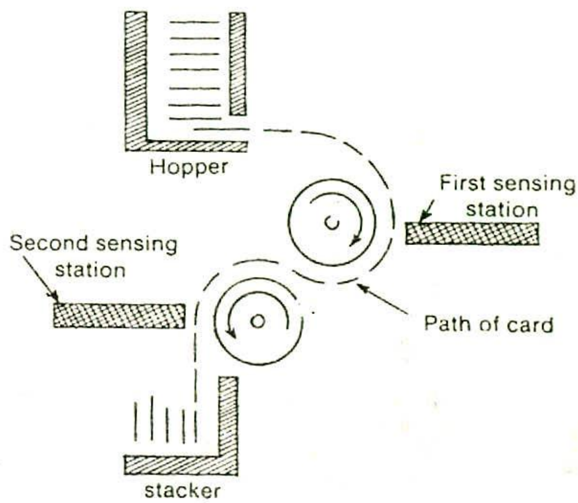


Figure 9.3. Mechanism of a card reader.

Card readers speeds vary from 300 to 2000 cards per minute. Thus for an 80-column card reader which operates at a speed of 2000 cards per minute, the data transfer rate will be 80 x 2000 or 160,000 characters per minute. This data transfer rate is not even 1 percent of the data transfer rates of the magnetic devices such as magnetic disk and tape.

Advantages of Card Input

1. An erroneous instruction or data in a card-deck can be changed by simply throwing the incorrect card and replacing it with a correct card. This is not so easy in case of a magnetic tape, magnetic disk, or a punched-paper tape.

2. Unlike magnetic tape and magnetic disk, cards are humanly readable. Hence machine interpretation of data is not always necessary in case of cards.

3. In case of a card deck, insertion or removal of instructions or data is performed simply by inserting or removing individual cards. This is not so easy in case of a magnetic tape, magnetic disk, or a punched paper tape.

4. Cards are an old and reliable medium. They

remain a viable means of entering moderate amount of data into computer systems.

Limitations of Card Input

1. Cards cannot be erased and used to enter new data.

2. A card deck needs careful handling because cards can be misplaced or separated from their proper deck. If a deck of cards falls down or somehow the cards get shuffled then the cards have to be laboriously rearranged in proper order before feeding the deck to the card reader.

3. The term *data density* refers to the number of characters that can be stored in a given physical space. Even when all columns are punched, the data density of a card is quite low. In most applications, however, not all columns will be punched and data density is thus further reduced.

4. Because of low data density, card files are often very bulky. Hence, cards are not suitable for the storage of voluminous data.

5. Folded, stapled, or mutilated cards are not acceptable by a card reader. So cards must be stored properly.

PUNCHED PAPER TAPE

Perforated paper tape is also a very old media used as an I/O device for computers. Punched paper tape was already discussed in detail in Chapter 8 and hence its details will not be repeated here.

Tape Punch Machine. It resembles a typewriter. The keyboards of many tape punch machines are identical with the keyboards of conventional typewriters. When a key on the tape-punch keyboard is depressed, the binary-coded symbol for the character selected is punched into the tape, and the tape then advances to the next line. In addition to punching holes for a character on the tape, most tape punch machines also print the punched character on a separate piece of paper just like a typewriter. This printed copy of the data punched on a tape is called the *hard copy* which is used for manual detection of errors, if any, that might have occured during punching.

Paper Tape Reader. It reads the information punched into a paper tape and converts the coded information into electrical signals that the CPU can accept. It operates in a similar manner to the card reader. As the tape passes from the sensing station, the holes are sensed either by sensing pins or photoelectric cells. Readers using photoelectric cells are much faster as compared to those using sensing pins. Typical speeds of paper tape readers are in the range of 250 characters per second to 1000 characters per second.

Advantages and Limitations of Paper Tape

1. Paper tape has greater data density than punched cards.

2. Unlike punched cards, there is no wastage of columns with punched tapes.

3. Paper tape is cheaper than cards, and paper tape equipments are less expensive than card machines.

4. Tape accuracy is harder to verify than card accuracy, and errors that are detected are not so easy to correct.

5. It is also difficult to delete or add information in the middle. Splicing is often required.

6. Like cards, paper tapes are easily torn and mutilated.

7. Like cards, it is not possible to erase data from a paper tape and to enter new data on the same tape.

MAGNETIC MEDIA DEVICES

Magnetic disks, diskettes, and tapes can record data as output from primary storage and can also serve as input devices returning the data to primary storage. In fact, all the secondary storage devices discussed in Chapter 8 - magnetic tape, tape cassettes and cartridges, magnetic disk, floppy disk, winchester disk, magnetic drum, magnetic bubble, optical disk, etc. are both input and output devices.

Because the magnetic media devices have already been described in detail in Chapter 8, we will not discuss them here.

PRINTERS

Printers are the most commonly used output devices that can be found in almost all computer centers. They are the primary output devices used to prepare permanent documents in human-readable form (hard copy). There are several types of printe.s that are designed for different types of applications. Depending on their speed and approach of printing, printers are classified as *character printers, line printers*, and *page printers*. In addition, there is another classification according to which printers are of two types - impact and nonimpact. *Impact printers* use the familiar typewriter approach of hammering a typeface against paper and inked ribbon. *Nonimpact printers* do not hit or impact a ribbon to print. They use thermal, electrostatic, chemical, and inkjet technologies.

CHARACTER PRINTERS

Character printers print only one character at a time. A typewriter is an example of a character printer. Three of the most commonly used character printers are described below.

Letter-Quality Printers. These printers use a printwheel font know as a daisy wheel (Figure 9.4). Each petal of the daisy wheel has a character embossed on it. A motor spins the wheel at a rapid rate. When the desired character spins to the correct position, a print hammer strikes it to produce the output. Thus, daisy wheel printers are impact printers. Their output resembles a typed output and they are noted for their print quality. The speed of these letter-quality printers normally ranges from 10 to 50 characters per second.

Dot-Matrix Printers. These printers print each character as a pattern of dots. The print head comprises a matrix of tiny needles, typically seven rows with nine needles in each (9 x 7 matrix), which hammers out characters in the form of patterns of tiny dots. The shape of each character, i.e. the dot pattern, is obtained from information held electronically in the printer. Figure 9.5 shows a dot-matrix printer and Figure 9.6 shows the dot pattern used to produce the characters.

The print quality of a dot-matrix printer is inferior to that of a daisywheel printer. But dot-matrix printers are generally faster than letter-quality printers - in the range of 40 to 250 characters per second. They are also less expensive than a daisywheel printer and hence if the quality of output is not an important factor then the dot-matrix printer is used with most microcomputer systems. There is an additional advantage of dot-matrix printers over letter quality printers in the sense that dot-matrix printers do not have a fixed character font. So they can print any shape of character that a programmer can describe. This allows for many special characters, different sizes of print, and the ability to print graphics such as charts and graphs.

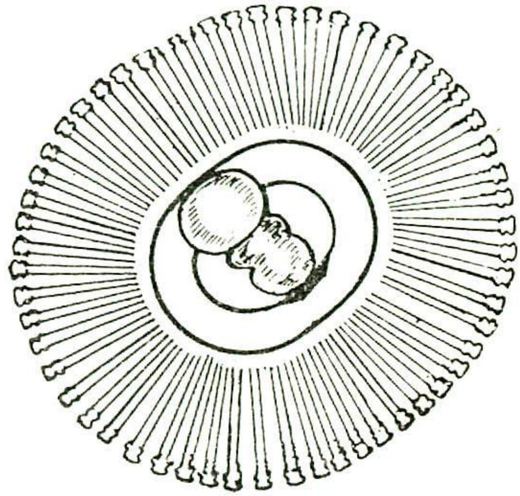


Figure 9.4. A daisy wheel.

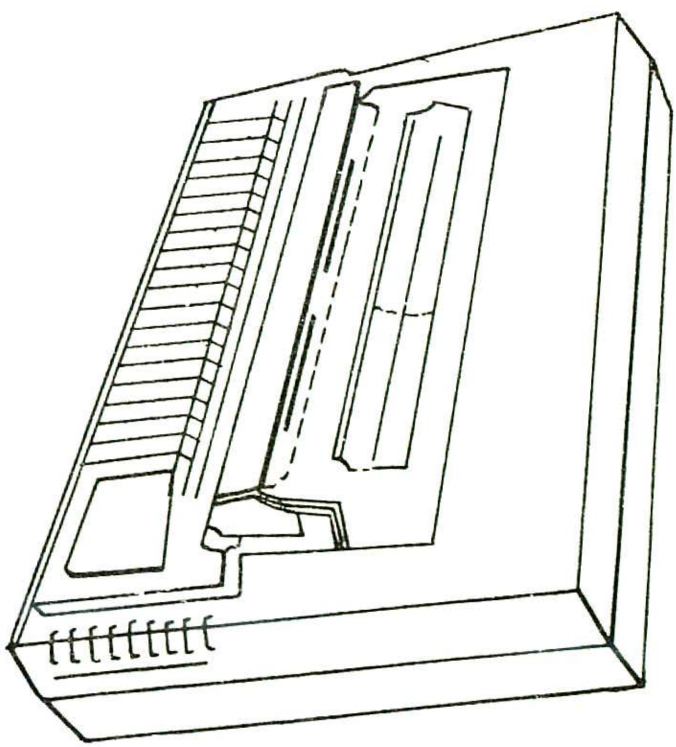


Figure 9.5. A dot-matrix printer.

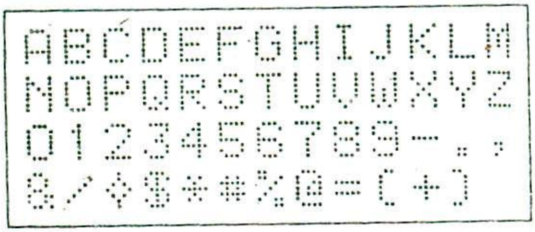


Figure 9.6. Character pattern for a dot-matrix printer.

Ink-Jet Printers. These are nonimpact character printers based on a relatively new technology. They print characters by spraying small drops of ink onto paper. Special type of ink having a high iron content is used. Droplets of ink are electrically charged after leaving a nozzle. The droplets are then guided to the proper position on the paper by electrically charged deflection plates. Ink-jet printers produce high quality output because the characters are formed by dozens of tiny ink dots. Moreover, they are quiet (nonimpact) and can form any kind of character. The document printed may contain multiple character styles and a variety of type sizes. Some models also allow for different colours of ink for multiple colour printing. Of course, inkjet and other nonimpact printers cannot produce multiple copies of a document in a single printing which is possible with impact printers. An inkjet printer is shown in Figure 9.7.

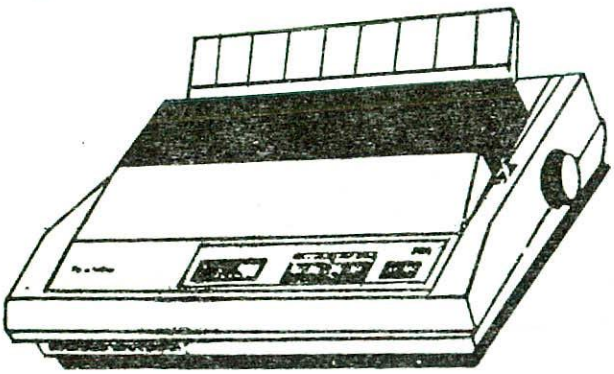


Figure 9.7. An inkjet printer.

LINE PRINTERS

Line printers are impact printers used with most medium and large computer systems for producing high volume paper output. They are fast printers having speeds in the range of 300 to 2500 lines per minute. Their printing speeds are such that to an observer they appear to be printing a line at a time and hence the name 'line printer'. There are normally 132 or 136 print positions per line. Some line printers even have a line length of 120 characters and a few have a line length of 144 characters. Character sets vary in content and size for different line printers. The 64-set has more special characters than the 48-set and the 96-set prints in lower-case (small) letters as well as in upper-case (capitals). The output efficiency of a line printer can be increased by using multiple-part papers (pages with carbon paper inserts) when more than one copy of the output is required. Drum printer and chain printer are the two most commonly used line printers.

Drum Printers. As shown in Figure 9.8, a drum printer consists of a solid, cylindrical drum that has raised characters in bands on its surface. There are as many bands as there are printing positions. Each band contains all the possible characters. The drum rotates at a rapid speed. For each possible print position, that is, opposite to each band of the drum, there is a print hammer located behind the paper. These hammers strike the paper, along with the inked ribbon, against the proper character on the drum as it passes. One revolution of the drum is required to print each line. This means that all characters on the line are not printed at exactly the same time, but the time required to print the entire line is fast enough to call them line printers. Typical speeds of drum printers are in the range of 300 to 2000 lines per minute.

Chain printers. They use a rapidly moving chain called a *print chain*. Each link of the chain is a characters font. A typical print chain is shown in Figure 9.9. Instead of a chain, some models of printers use a metal band having raised print characters on it. For each possible print position, there is a print hammer located behind the paper. As the print chain or the band rotates, the properly timed print hammers strike the paper, along with the inked ribbon, against the proper character on the chain/band as it passes. In order to enhance the speed of the chain printers, the character set is repeated several times on the chain. Hence it is not necessary to wait for the chain to make a complete revolution to position the desired character in the correct print position. A standard character set is of 48 characters. So chain printers that use the 64-set or the 96-set repeat the characters fewer times than the standard set. This increases the time to position the desired character and therefore reduces the effective print speed of the printer. Speeds of chain printers range from 400 to 2500 characters per minute.

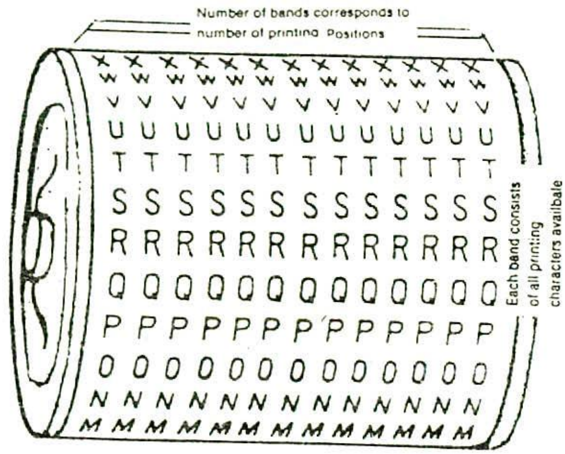


Figure 9.8. The solid cylindrical drum of a drum printer.

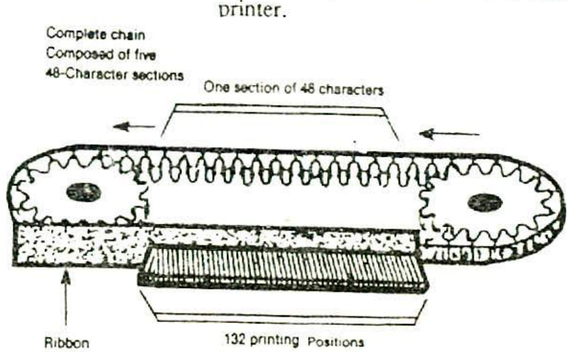


Figure 9.9. The print chain of a chain printer.

PAGE PRINTERS

These are very high speed nonimpact printers which can produce documents at speeds of over 20,000 lines per minute. (That is fast enough to print this entire book within five minutes !). Electronics, xerography, lasers, and other technologies have made these high-volume systems possible. These techniques, called *electrophotographic techniques*, have developed from the paper copier technology. Page printers can produce pages of output at a rate equal to a paper copier. Each page produced on these printers is an original one since there are no carbon copies. Because of their extremely high cost, these printers are economical only when hundreds of thousands of pages are to be printed each month.

KEYBOARD DEVICES

Keyboard devices are online devices that are used for entering data directly into a computer. Data is entered into the computer by pressing a set of keys available with these devices. Keyboard devices are becoming more and more popular day-by-day. They are extensively being used today both as input and output devices. They are available in a wide variety. Few of the most commonly used ones have been described below. These and other online processing devices have the following characteristics :

1. No intermediate data recording media is required with these devices. They are able to enter data directly into the computer.

2. They can be situated far away from the main computer room. This allows these devices to be located at or near the data source.

3. These devices allow the computer to be used in interactive mode. That is, they allow the user to enter data through the keyboard while the program is running and to get immediate answers from the computer.

4. They are economical for handling a lower and/or more irregular volume of input data.

VIDEO DISPLAY TERMINALS

Video display terminals (VDTs) are the most popular I/O devices used today in direct-access processing applications. A typewriter like keyboard, as shown in Figure 9.10, is used to enter data into the computer, and a cathode ray tube (CRT) that looks like a television screen is used to display the input data as well as the messages and processed output from the computer. The terminal consists of a small memory known as a buffer. The size of this buffer is normally equal to the total number of characters (usually 1920 - 24 rows x 80 columns) that can be displayed at a time on the terminal screen. Each character entered through the keyboard is stored in the buffer and is also displayed simultaneously on the CRT. The data is not sent on to the computer until the operator presses an enter/transmit key on the keyboard. This gives an opportunity to the operator to proofread the data being entered by reading the data displayed on the screen. A small square or underscore character, called a *cursor*, indicates the operator where the next character to be keyed will be displayed on the screen. Any keystroke error can be easily corrected by moving the cursor to the erroneous character and rekeying the data. Thus, error correction process is very easy as long as the data has not been transmitted on to the computer. A typical VDT is shown in Figure 9.11. VDTs facilitate instantaneous display of operation and they are totally silent in their operation. The primary disadvantage is that no "hard copy" or record of what is typed by the terminal operator or output displayed by the computer remains when the terminal is switched off. However, it is normally possible to add a printing device which can be switched on to provide a hard copy of the display when it is needed. Thus more expensive VDTs include cameras to photograph the scope face, small printer, and tape cassettes to record data.

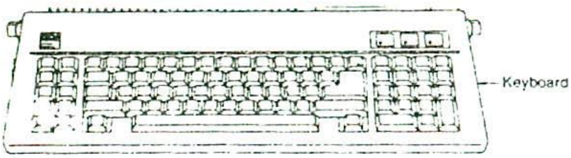


Figure 9.10. A keyboard of a video display terminal.

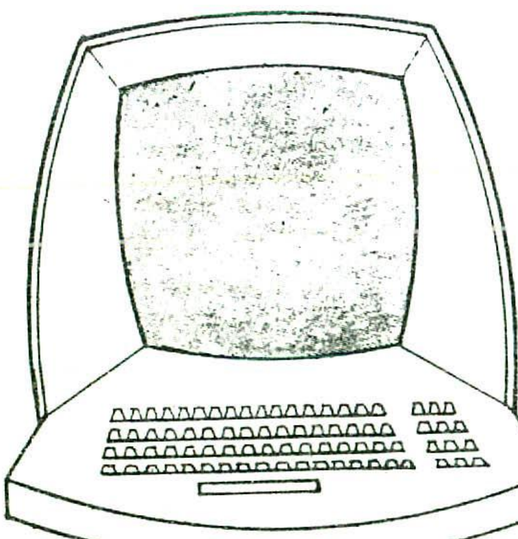


Figure 9.11. A typical video display terminal.

Initially used in applications where information is required quickly, for example in airline reservation systems, bank counters, etc. where speed is the essence in handling customer enquiries, VDTs are now widely used for general data entry and retrieval of stored information. They come in a wide variety ranging from simple alphanumeric devices to complex graphic and light pen devices.

Alphanumeric VDTs. These are low cost VDTs that are used to enter and retrieve only letters, numbers, and special characters. They may be used by shop employees to update production records, by word processing operators to create letters, by bank tellers to update savings account records, etc. The availability of airline seats, railway berths, or hotel rooms, the current stock of various items available in a shop, the details of employees working in an organisation, etc., can be kept current in online files in a computer and then a query entered through the keyboard is instantly answered by the computer by displaying the information on the terminal screen. Alphanumeric display terminals are also used by programmers to directly prepare and/or maintain computer programs. New programs can be directly entered and old programs already stored inside the computer can be retrieved and displayed on the terminal screen and can be modified before storing it back into the computer.

Graphic VDTs. Video display terminals with a graphic display capability are normally much more expensive than the alphanumeric VDTs. They are capable of displaying graphics and diagrams as well as alphanumeric characters and are used particularly as an aid to design. Graphic devices provide not only a means of displaying high-resolution drawings but also the capability of manipulating and modifying the drawings and designs displayed on the terminal screen. Different views of a design such as a building can be displayed and it is also possible to alter the scale of presentation so that either the entire design or a small section of the design can be properly examined. Using coloured graphic devices, it is also possible to display different portions of the design in different colours and to highlight particular portions of the display.

Graphic devices are currently being used as an aid in the design of cars, ships, aircrafts, buildings, highways, electronic circuits, etc. They are also being used to present business, financial, and operating data in graphical form so that managers can spot trends and relationships and can then make faster and better decisions. Pages of computer printouts detailing the performance of product lines and sales divisions can be replaced by a few colourful charts, graphs, and maps which are very helpful for higher management in making future policy decisions. A copying device can be used in conjunction with a graphic VDT to provide hard copy of any display. A typical graphic display is shown in Figure 9.12.

Light Pen VDTs. A light pen is an input device attached to some video display terminals. It is penlike photo-sensitive instrument which can sense a position on the CRT when the end of the pen is held against the screen. It consists of photocell placed in a small tube. When the user moves the pen over the screen, the pen is able to detect the light coming from a limited field of view. The light from the CRT causes the photocell to respond when the pen is pointed directly at a lighted area. These electrical responses are transmitted to the computer,

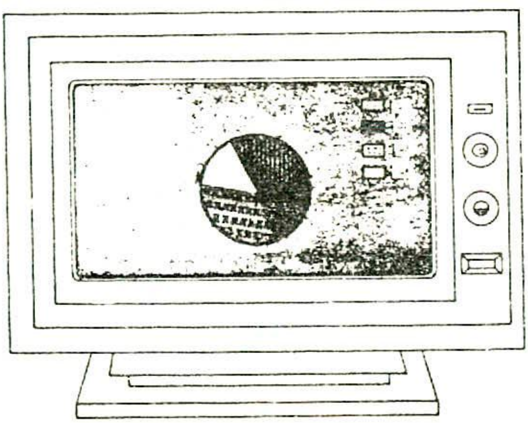


Figure 9.12. A typical graphic display.

which is able to determine that part of the displayed item which is trigerring the photocell response.

By sensing the position on the screen being touched by the light pen, the user inputs data to the program that is currently active in the computer. For example, the screen display might have a set of command choices such as COPY, DELETE, EDIT, HELP, INSERT, PRINT, SORT. If the user touches by the light pen that portion of the terminal screen where PRINT is displayed, then he is inputting PRINT command as his choice to the computer. Similarly, there are various other applications of light pen devices.

Light pens are also used in conjunction with graphic terminals to help in computer-aided design (CAD). The user "draws" directly on the screen with the light pen. By using the light pen and a keypad attached to the terminal, the user can select different colours and line thickness, can reduce or enlarge drawings, and can add or erase lines. This approach is commonly used by engineers to modify designs which are displayed on a CRT during the design and development process.

TELEPRINTER TERMINALS

A teleprinter terminal is very similar to a video display terminal except that it uses a printer in conjunction with a keyboard instead of a CRT. Thus it provides 'hard copy' (printed record) of the input, system information and program results. However, these printers are character printers that print one character at a time and therefore teleprinter terminals are slower than video display terminals. A teleprinter terminal is shown in Figure 9.13.

Several small portable teleprinters are being used today by salespeople, managers, newspaper reporters, engineers, and others on the move. The portable teleprinter, in effect, lets these people take a computer with them wherever they go and enables the collection of data at the place where it is generated. This avoids the delay and cost of data preparation at the computer site. For example, a route salesman calling on retailers can carry a terminal through a customer's store and can directly key in the product number and quantity needed into the terminal when items are found to be short of supply. Similarly a manager can carry a terminal along with him on a business trip and keep up with office work whenever he finds some free time.

POINT-OF-SALE TERMINALS

A point-of-sale (POS) terminal is basically an electronic equivalent of a cash register. It can perform all the functions of a cash register with an added advantage of capturing more data than a cash register. Some POS terminals are offline devices that record data on cassette tapes. These tapes are then collected and are carried to computer site where the actual processing is done. Thus, these POS devices do not avail the facility of a computer directly. However, most of todays POS terminals function online and are directly connected to a computer. These POS devices process transactions immediately while the customer is making purchase. For example, under computer control, the terminal may display the transaction data and then print on itemized sales receipt that shows the total amount of the purchase including taxes. If a credit card is used to complete the transaction, the number on the credit card can be entered into the computer to update the customer's credit account. Transaction data can also be used to update inventory records and provide sales analysis information to managers. Till now POS devices are not in common use in India.

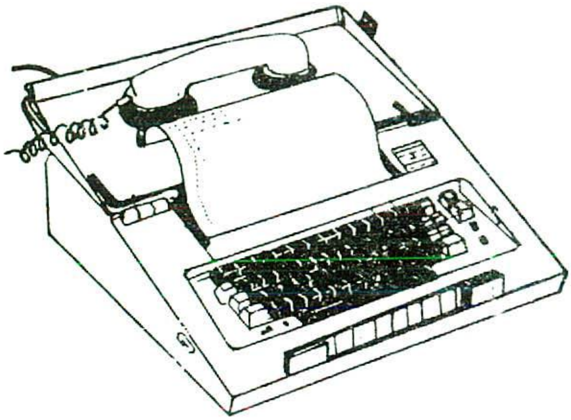


Figure 9.13. A teleprinter terminal.

INTELLIGENT TERMINALS

Terminals are extensively being used today as online, remote data entry devices. Depending on their local processing capability, these terminals are classified as dumb, smart, and intelligent.

A simple, low-cost teleprinter or alphanumeric display device is generally classified as a *dumb terminal*. These units have a keyboard for input, a means of communicating with the CPU of the central-site computer, and a printer or screen to receive output. Dumb terminals need not appear dumb to the user. Because of the rapidity with which the central-site computer can communicate back to the data entry station, many applications are not affected if no actual processing is done locally. However, dumb terminals transmit all data directly to the central-site computer. This type of data is called "dirty" data because errors are transmitted along with good data. The errors are then identified by the CPU of the central-site computer and processing could be delayed until "clean" data are obtained from remote users. This type of delay, accompanied by the need to process the data over again, can be expensive.

Smart terminals have additional features. They usually have a microprocessor (a CPU) and some internal storage in addition to I/O capabilities. They have local data editing capability and the ability to consolidate input data prior to sending them to the CPU of the main computer-site. This means that preliminary processing of input data can take place locally and that the data can be cleaned up before it is transmitted to the central-site computer. However, smart terminals cannot be programmed by users.

An intelligent terminal is a small computer by itself. It consists of a built-in microcomputer that can be programmed by users. These programmable terminals have extensive local data processing power. Large working files can be maintained locally and small data processing jobs can be handled by the terminal itself without the need to interact with the CPU of the main computer system. Online secondary floppy disk storage devices are often used during the processing of these small jobs. Programmed error-detection tests can also be stored in the terminal for the validation of input data which can ensure the transmission of clean data to the main computer system for further processing.

With the fast reduction in the cost of microcomputer components, most future terminals will be intelligent or at least smart to help make data entry and retrieval easier for the users.

SCANNERS

Scanners are basically input devices that are capable of recognising marks or characters. Thus they are used for direct data entry into the computer system. The following are the characteristics of scanners:

1. They eliminate some of the duplication of human effort required to get data into the computer. Human beings do not have to key the data.
2. The reduction in human intervention improves data accuracy and can increase the timeliness of the information processed.
3. Since scanners are direct data entry devices so they demand high quality of input documents. Documents that are poorly typed or have strikeovers or erasures are normally rejected.
4. With these devices, form design and ink specification may become more critical than is the case when people key the data from the forms.
5. Most of these devices are not economically feasible unless the daily volume of transactions is relatively high.

Though not very popular in India, scanners are extensively used in advanced countries like U.S.A. The two major type of scanners are optical scanners and magnetic-ink character recognition devices.

OPTICAL SCANNERS

As the name implies, the technique used in these devices for the recognition of marks/characters involves a light source and light sensors. These devices are capable of interpreting handmade marks and characters, machine-printed characters, and special bar code. Thus the common optical scanner devices are optional mark readers (OMR), optical character readers (OCR) and bar-code readers.

Optical Mark Readers. These scanners are capable of recognising a prespecified type of mark made by pencil or pen. For example, many students might have appeared in objective type tests where they had to mark their answers to questions on a special test-scoring sheet by darkening a square or circular space by a pencil to indicate their correct choice out of the various alternatives (Figure 9.14). These answer sheets are directly fed to a computer for grading with the use of an optical mark reader. The use of OMR is not limited to the grading of objective type tests. In fact, any input data that is of a choice or selection nature can be recorded for OMR input.

Questions:

1. The capital of India is:
   (a) Bombay
   (b) Delhi
   (c) Calcutta
   (d) Madras
2. The binary equivalent of decimal 4 is :
   (a) 101
   (b) 111
   (c) 001
   (d) 100

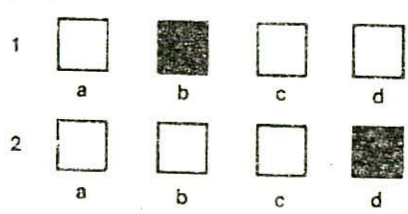


Figure 9.14. Sample questions of an objective test and its answer sheet that can be read by an optical mark reader to grade the test.

The actual technique used by an OMR device for recognition of marks involves focussing a light on the page being scanned and detecting the reflected light pattern from the marks. Pencil marks made with a soft lead pencil (high graphite content) will reflect the light.

Optical Character Readers. These scanner devices are capable of detecting alphabetic and numeric characters printed on paper. These characters may be either typewritten or handwritten. In case of handwritten characters, special care has to be taken to ensure that the characters are of standard size, lines making up the characters are connected, and no stylish loops etc. are used. On the other hand, if the characters are typewritten, they must be typed using a special type font called an OCR font. A wide range of fonts, using ordinary inks, can now be accepted by OCR devices. The standard fonts used are OCR-A (American standard) and OCR-B (European standard). OCR-A fonts are shown in Figure 9.15. Most brands of typewriters are available with an OCR character set. Some OCR devices can also accept computer print-out and complete pages of typed text.

OCR devices examine each character as if it were made up of a collection of minute spots (pixels). Once the whole character has been scanned, it is compared with the characters (standard fonts) the machine has been programmed to recognize. Whichever pattern it matches, or nearly matches, is considered to be the character read. If the scanned character does not match satisfactorily with any of the fonts, it is rejected.

OCR devices are expensive and are used only for large-volume processing applications. For example, the computer-printed bills sent to customers by many public utilities, credit card companies, and other businesses in U.S.A. are prepared with characters that can be read by OCR devices. When customers make their monthly payments, they are instructed to return the bill or a remittance stub with their checks. These documents are then entered directly into optical readers to update accounts-receivable records. Little or no human keying is needed. Other large-volume applications of OCR devices include the reading of zip codes by the U.S. postal service, the reading of passenger tickets and freight bills by airlines, and the processing of social security forms and motor vehicle registrations by governments.

Bar-Code Readers. Data coded in the form of light and dark lines or bars are known as bar codes. *Bar-Codes* are used particularly by the retail trade for labelling goods and by supermarkets for labelling shelves and in stock control. They are also used for numbering books in public libraries so that when a book is borrowed or returned, it can be recorded using a computer.

Bar-Code reader is a device used for reading (decoding) bar-coded data. Bar-code reading is performed

Figure 9.15. OCR-A fonts.

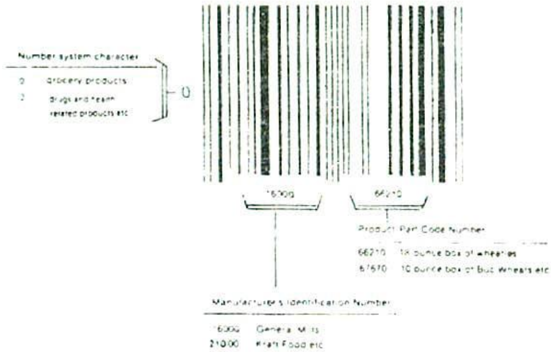


Figure 9.16. UPC bar code.

by a laser-beam scanner which is linked to a computer. The laser-beam is stroked across the pattern of bits that is recorded as the input data.

The most widely known bar code is the *Universal Product Code* (UPC) which now appears on almost all retail packages in U.S.A. These bars are decoded as 10 digits. The first five of these digits identify the manufacturer or supplier of the product and the second five digits identify a specific product of the manufacturer (Figure 9.16).

The UPC is designed to simplify customer checkout and retail store inventory management. For example, when bar-coded items are received at a merchant's automated checkout stand, they are decoded by a bar-code reader and the data is transmitted to a computer that looks up the price possibly updates inventory and sales records, and forwards price and description information back to the check stand for output on the sales receipt.

MAGNETIC-INK CHARACTER RECOGNITION

Magnetic-ink character recognition (MICR) devices were developed to assist the banking industry in processing the tremendous volume of checks being written every day. A special type of cheque is used in banks that employ MICR devices. The bank's identification code and the customer's account number is pre-printed (precoded) on all these cheques with a special ink that contains magnetizeable particles of iron oxide (Figure 9.17). When a filled-in cheque is presented at the bank, a bank employee encodes the amount in the lower right corner. This cheque is then processed using a MICR device.

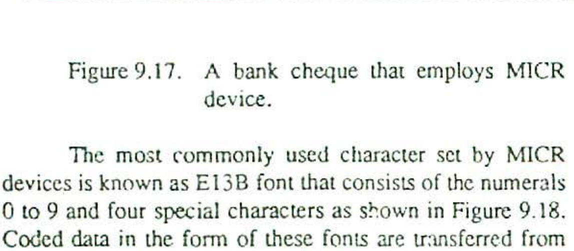


Figure 9.17. A bank cheque that employs MICR device.

The most commonly used character set by MICR devices is known as E13B font that consists of the numerals 0 to 9 and four special characters as shown in Figure 9.18. Coded data in the form of these fonts are transferred from cheques to the computer by a MICR reader-sorter. As the cheques enter the reading unit, they pass through a magnetic field which causes the particles in the ink to become magnetized. Read heads then interpret these characters by examining their shapes using a 7 x 10 matrix and determines, from the response of the segments of the matrix to the magnetic ink, which of the characters has passed under the reader's head. The sorter is basically used to sort the cheques into different pockets according to their identification code numbers.

The following are some of the advantages and limitations of MICR system :

1. Even roughly handled, folded, smeared, and over stamped cheques can still be read with a high degree of accuracy

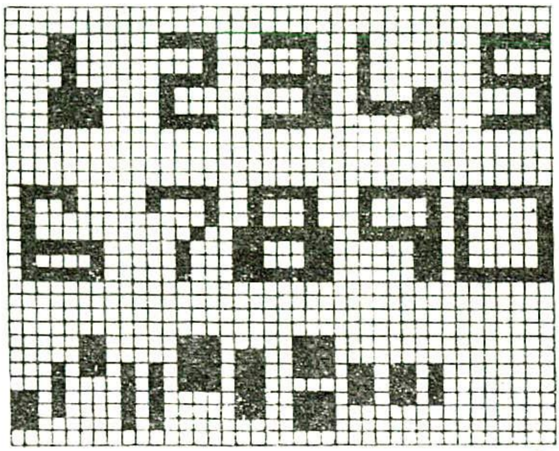


Figure 9.18. The E13B font (character set) used by MICR devices.

2. MICR devices speed up data input for the banking industry because cheques can be directly fed into the input device.

3. The characters coded on the cheques using magnetic ink can also be easily read by people.

4. The main limitation of MICR is that only the 10 digits and 4 special characters needed for bank processing are used. No alphabetic characters are available.

5. Special type of magnetic ink is required for encoding the characters to be read by the machine.

OTHER DEVICES

In addition to the already discussed I/O devices, there are some I/O devices which are not so common in use. These are specialized devices used for some special type of application by few data processing centres. Such type of devices will be discussed in this section.

COMPUTER OUTPUT MICROFILM

Computer output microfilm (COM) technology is used to record computer output information as microscopic filmed images. Thus COM is basically an output device that records information on a sheet or roll of microfilm. A sheet of film measuring 4 x 6 inches is called a microfiche. (Fiche is a French word meaning card and is pronounced as "fish"). A typical microfiche is capable of holding 270 frames (pages of information) and some ultrafiche systems can even store 1,000 frames in the same space. Rolls of 16 or 35 millimeter film packaged in cartridges are also used for COM recording. COM recording process produces characters that are 48 or more times smaller than those produced by conventional printers. Thus a single microfiche can hold approximately 300 times as much information as a standard computer printed page.

The COM recording technology consists of a microfilm recorder that receives information that are normally stored on magnetic tapes. Recorders may also receive the information directly from the CPU. The recorder in turn projects the characters of output information on to a CRT screen. A high-speed camera, in-built into the system, now takes a picture of the displayed information. In some systems, the recorder processes the film from the camera and in other systems, a separate automated film developer is used. Film duplicators can make as many copies of the developed film as needed.

A special device known as *microfilm reader* (Figure 9.19) is used to view the information recorded on the sheets or rolls of film. In some COM systems, users must locate and then manually search through the film cartridge or card to find the desired information. However, in computer assisted retrieval systems, the correct document from the thousands of pages that may be recorded on the film can be automatically picked up in a matter of seconds simply by specifying the preassigned index that corresponds to that particular document. The microfilm reader operates on a 'back projection' principle displaying a frame at a time on a translucent screen, typically about A4 size. Some COM systems also use a reader-printer combination to produce a hard copy of what is presented on the screen. A COM system is ideal for use in applications where there is a large amount of information to be retained which is required only for manuals, industrial catalogues and archives. Companies often need to retain records of such things as bills and invoices for a number of years before destroying them. COM provides an easy and compact way of retaining the information, of retrieving it in a matter of seconds using a compact desk top reader, and is ideal when multiple copies of reports or information are required. Banking and insurance companies, government agencies, public utilities, and many other types of organizations are regular users of COM

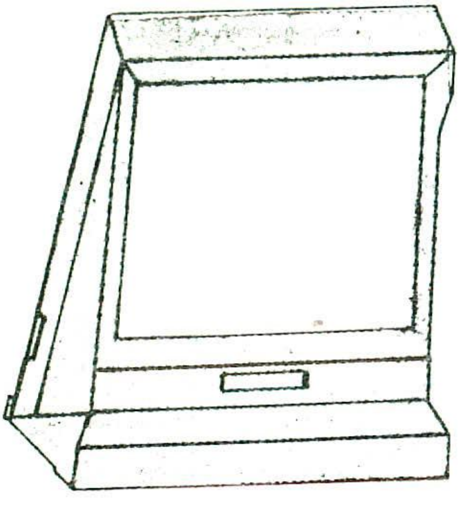


Figure 9.19. Microfiche reader.

The advantages and limitations of COM are as follows:

1. The speed of recording of a COM system is 20 to 25 times faster than the average line printer. Thus, a single COM recorder can do the work of a dozen line printers.

2. The microfilm equivalent of thousands of pages of computer output can be stored in a small drawer. Thus the mailing and storage costs of filmed documents are much less than paper documents.

3. Microfilm output is even less costly as compared to printed output. The cost of the paper needed to print a 1000 page, three-part report is about 30 times greater than the cost of the film needed to do the same job.

4. In case of filmed output, it is possible to record drawings or pictures as well as alphanumeric character texts.

5. COM systems are relatively expensive to install and their high initial investment is justified only in case of high volume workload.

6 Because of retrieval delays and the lack of facility to write notes on the margins of the reports, many people feel uncomfortable when using a COM system

DIGITIZERS

A digitizer is an input device that converts graphic and pictorial data to digital (binary) form which can be directly fed and stored inside a computer. There are two types of digitizers: rectangular-coordinate or flatbed digitizer and image-scan digitizer.

In case of a flatbed digitizer, the drawing to be digitized is spread and fixed over a rectangular flatbed table. A mechanism is now moved over the surface of the drawing that scans the drawing and produces signals related to the X and Y coordinates of the table.

Image-scan digitizers scan and reproduce entire drawing and photographs automatically. They are costlier and more powerful than the flatbed digitizers and are capable of digitizing not only the shape and size of the drawings but also the varying intensities on a gray-to-black scale at different points of the drawings. Thus, flatbed digitizers are mainly used to digitize simple drawings, graphs, charts, etc. and image-scan digitizers are used to digitize more complex pictures and photographs.

PLOTTERS

A plotter is an output device used to produce hard copies of graphs and designs. Plotters are basically of two types - drum and flatbed. In case of a drum plotter, the paper on which the design has to be made is placed over a drum that rotates back and forth to produce vertical motion. The mechanism also consists of one or more pen holders mounted horizontally across the drum. The pen(s) clamped in the holder(s) can move to produce horizontal motion. Under the control of the computer, the drum and the pen(s) move simultaneously to produce the designs and graphs. Since each pen is program selectable, pens having ink of different colours can be mounted in different holders to produce multi-coloured designs.

As the name implies, a flatbed plotter plots on papers that are spread and fixed over a rectangular flatbed table. In this type, normally the paper does not move and the pen-holding mechanism is designed to provide all the motion. Here also provision is there to mount more than one pen in the pen(s) holding mechanism. Normally pens with ink of different colours are used for multi-coloured plotting. The plot size is restricted by the area of the bed. Some may be as small as A4 size whilst some very large beds used in the design of cars, ships, aircrafts, buildings, highways, etc. can be up to 20 ft. by 50 ft. Some plotters are also designed to etch plastic or metal plates.

Plotters are normally very slow in motion because of excessive mechanical movement required during plotting. Hence there is a great mismatch between the speed of the CPU and the speed of a plotter. Because of this reason, in most cases, output is first transferred by the CPU on to a tape and then the plotter is activated to plot the design from the information on the tape. However, in case of a computer system dedicated to design work, the CPU may send output directly to a plotter.

VOICE RECOGNITION AND RESPONSE DEVICES

These I/O devices have made it possible for the computer systems to communicate verbally with the users. A voice recognition system, which is an input device, consists of a microphone or telephone that converts human speech into electrical signals. A signal pattern obtained in this manner is transmitted to the computer where it is matched against pre-stored patterns to identify the input. When a close match is found, a word is recognised by the system. The set of pre-stored patterns is known as the vocabulary of the system. To build up this vocabulary, the system has to be trained to recognize the words and phrases that are to be present in the vocabulary. Hence the system is initially operated in a `training mode' when the user speaks the words and phrases (to be stored in the vocabulary) several times to train the system to recognize his/her particular voice pattern. In this mode, the patterns are created and stored for future matching. Because the accent of different speakers varies, most voice recognition systems, are *speaker-dependent*. However, a system may be trained to recognize the voice of more than one operator in which case a different vocabulary is maintained for each operator.

Although in its infancy, voice recognition systems have found wide application in areas where a person wants to input data to a computerised system in situations where his hands are busy, or his eyes must be fixed on a measuring instrument or some other object. They are also used by security systems for identifying authorised users of the system, by individuals with physical disabilities, and where telephone input is desirable. In fact, voice recognition systems can be used whenever the input is limited and precise.

The potential advantages of voice recognition system are numerous. Their use lowers data entry costs by replacing manual key stroking with verbal instructions. Higher accuracy is also gained when data is entered using voice instead of a keyboard. Obviously, the operator enjoys tremendous freedom of movement with a voice recognition system as compared to a keyboard device. With voice recognition, the operator is free to stand up and move around, entering data with a conveniently located microphone. Finally, training of operators is an easy task in case of a voice recognition system.

Just as a voice recognition system allows the user to talk to computer, similarly, a voice response system enables a computer to talk to the user. Audio response is an output media that produces verbal responses from the computer system. In a voice response system, all the sounds needed to process the possible enquiries are pre-recorded on a storage medium. Each sound is given a code. When enquiries are received, the computer follows a set of rules to create a reply message in a coded form. This coded message is then transmitted to an audio-response device, which assembles the sounds in the proper sequence and transmits the audio message back to the station requesting the information.

Voice response should only be considered for those applications where there is a low-speed human-machine interaction. The primary business uses of voice response devices are to instruct a person in how to enter data and to output very low volume answers to requests. The banking industry is the largest user of voice response techniques. The most common banking application includes responding to bank account status inquiries over tellers' telephones. Voice response systems are also being used in elevators, by insurance companies in televisions, and by telephone companies. There are also many toys that teach and entertain young children using voice response units. "Touch and Tell" toys that teach basic vocabulary and English have been developed for pre-school children.

OFFLINE DATA ENTRY DEVICES

Data entry is the process of getting data into a form the computer system can understand and use. It will be surprising to note that the cost of data entry alone is around 30 to 50 percent of the total data processing cost of a typical data processing centre.

In general we can consider data entry devices in two broad categories: offline and online. Briefly, online data entry involves devices such as terminals which are connected directly to the computer. On the other hand, offline data entry involves devices through which data is recorded on some media (such as punched cards or tapes) and then entered into the computer later. Since data entry is done by data entry operators and the speed with which a human being can enter data is very very less as compared to the data processing speed of a computer, so in almost 90% of the applications, data entry is done offline. This saves the precious computer time. As the major forms of permanent storage are cards, tapes, and disks, there are offline data entry devices for each type.

KEY-TO-CARD

It is one of the oldest offline data entry devices. It allows an operator to convert data recorded on paper or other source documents to punched cards. Keypunch machines exist for both the 80-column card and the 96-column card. The latest keypunch machines contain electronic circuits and buffers (temporary storage area) that allow them to temporarily store (remember) data, allowing the keypunch operator to edit and correct errors before the data is punched on cards.

KEY-TO-TAPE

A key-to-tape device, also known as *magnetic tape encoder* is designed to record keyed data directly onto magnetic tape. An operator, keys the source data electronically using a typewriter-like keyboard. The data is stored temporarily by the device and typically displayed on a CRT for visual checking of the correctness of entered data before being transferred to magnetic tape. Magnetic tape encoders are available for recording data magnetically on reels, on cassettes and on tape cartridges. The magnetic tape reels produced by key-to-tape systems are in a computer-compatible format for subsequent direct data input into a computer. However, data on cartridges and cassettes often are transferred to higher-speed media, such as full sized reel of magnetic tape or magnetic disk, for efficient data transfer to the computer.

KEY-TO-FLOPPY

These data entry machines have been introduced as low-cost data recording systems. They are used to store data directly on flexible disks, called diskettes or floppies that are inexpensive and reusable. A key-to-floppy data entry system consists of a typewriter-like keyboard with additional control keys and a display screen which displays each character keyed in. A data entry operator records data from the source document on the floppy by depressing appropriate keys on the keyboard. The keyed data is held in a buffer (temporary storage area) in a coded form and is also displayed on the display screen. While entering, the operator can verify the correctness of the entered data by seeing the characters displayed on the display screen. If an error is made in entering a data item, the operator can backspace and re-enter it. When the data is found to be correct and the operator wants to store it on the floppy, he presses a control key which causes the data to be stored on the floppy from the buffer.

The same machine can also be used to verify the correctness of the data which has already been stored on a floppy. For this, the machine is operated in a "verify" mode and another operator keys in the same data from the source document with the floppy, having the stored data, inserted in the slot. In this mode, the data keyed in and stored in a buffer is compared with the data in the floppy by reading the data from the floppy. If the two data do not agree, an audible and visual signal alerts the operator. The operator re-enters the data which replaces the incorrect data.

KEY-TO-DISK

Key-to-disk devices are used as data recording stations in systems where data from different points has to be recorded for processing at one point. Typically, from 8 to 64 keyboard stations are linked to a small special-purpose computer to record source data on a disk. Each station has a keyboard and a CRT display. Information entered via the keyboard is displayed on the CRT to allow a visual check. The small special-purpose computer is required to control the input from the various stations, enabling the data to be held temporarily for verification and editing before allocation to the disk storage. Thus, these data entry systems are able to correct data before storing it on a magnetic disk and before its entry into the main computer system.

QUESTIONS

1. Why are I/O devices necessary for a computer system ?
2. What are peripheral devices ? Why are they so called ?
3. What is an I/O processor ? Give two synonyms for it.
4. Why are I/O devices very slow compared to the speed of primary storage and CPU ?
5. Why are punched hole I/O devices so called ?
6. Which coding system is used to represent data in 80-column card ? Why is this coding system so called ?
7. Differentiate between a zone punch and a numeric punch position for 80-column cards. How will be the letter 'E' represented on an 80-column card using these punch positions ?
8. Explain the different methods used to code data in 80-column and 96-column punched cards.

9. Explain the working of a card punch machine and a card verify machine.

10. What is a card reader ? Briefly describe the way it works.

11. Why are card readers designed to read each card twice ?

12. A 96-column card reader operates at a speed of 1000 cards per minute. Find out its data transfer rate in characters per second.

13. Give the advantages and limitations of cards as compared to tapes and disks as a data storage media.

14. Briefly describe the functioning of a paper tape punch machine and a paper tape reader.

15. Discuss the advantages and limitations of paper tapes as compared to cards as a data storage media.

16. A paper-tape reader reads at the rate of 1200 frames (characters) per second. What card reader speed is this equivalent to in cards per minute for an 80-column card reader ?

17. What is a printer ? What are the three types of printers ?

18. Differentiate between impact and nonimpact printers. Give one example of each.

19. What type of printer is most commonly used with microcomputer systems ?

20. Write short notes on :
    (a) letter quality printer
    (b) dot-matrix printer
    (c) ink-jet printer.

21. What are line printers ? Why are they so called ?

22. What is the difference between a drum printer and a chain printer ?

23. What is a page printer ? Why is it so called ? In what type of computer installations is it used ?

24. What are keyboard devices ? List out some of their characteristics.

25. What is the most popular I/O device in use today ?

26. Explain the functioning of a video display terminal.

27. What is an alphanumeric display ? A graphic display ?

28. How is a light pen used ? Is it an input or output device ?

29. Discuss some of the uses of a graphic display terminal. How can pictures displayed on a terminal screen be permanently preserved ?

30. What is a teleprinter terminal ? How may teleprinters be used ?

31. What is the purpose of a POS terminal ? What advantages are there in capturing data at the transaction source ?

32. Differentiate between a dumb, smart, and an intelligent terminal.

33. List out some of the characteristics of scanners

34. What is an optical scanner ?

35. What are the three most common types of optical scanners? What type of data does each scan ?

36. What is the difference between an optical mark reader and an optical character reader ?

37. What is MICR ? What industry is the primary user of MICR ?

38. What are the shortcomings of MICR ?

39. What is the Universal Product Code ? How is it used ?

40. What is COM ? When is it used ?

41. What are the various advantages and limitations of a COM device ?

42. What is a digitizer ?

43. What is a plotter ? What is its principal use ?

44. What is the difference between a graphic terminal and a plotter ?

45. Explain how a voice recognition system works.

46. Under what conditions should a voice response unit be considered ?

47. Voice recognition systems may be speaker-dependent or speaker-independent. How do these two systems differ ?

48. What is an offline data entry system ? In most applications, why are they preferred to an online data entry system ?

49. What is the difference between an input device and an offline data entry device ?

50. How are errors detected in input data ?

51. Explain the functioning of various offline data entry devices.

52. Give the full form of the following abbreviations: VDT, CRT, IOP, CAD, POS, OMR, OCR, UPC, MICR, and COM.

53. Assume that a CPU can add two numbers on an average in 2 microseconds (1 microsecond = 10^{-6} seconds) and a card reader can read cards at a speed of 800 cards per minute. Find the number of additions that can be performed in the time required to read a card. Use this example to support the statement that there exists a considerable mismatch in speed between the peripheral devices and the CPU.

54. Indicate whether the following peripheral devices can be used for input, output, or both :

(a) card reader
(b) line printer
(c) magnetic tape
(d) magnetic disk
(e) visual display terminal
(f) light pen visual display terminal
(g) teleprinter terminal
(h) POS terminal
(i) OCR device
(j) COM device
(k) digitizer
(l) plotter

55. How are graphs and pictures fed to a computer ?

CHAPTER 10

10. COMPUTER SOFTWARE

The terms hardware and software are frequently mentioned in connection with computers. *Hardware* is the jargon term given to the machinery itself and to the various individual pieces of equipment. It refers to the physical devices of a computer system. Thus, the input, storage, processing, control, and output devices are hardware. When the hardware is linked together to form an effective working unit we have a computer installation. In fact, what we have described so far in the previous chapters is actually the hardware of computer systems. The term `software' will be introduced in this chapter and will be discussed at length in the next few chapters.

WHAT IS SOFTWARE

It is important to note that a computer cannot do anything on its own. It must be instructed to do a desired job. Hence it is necessary to specify a sequence of instructions that a computer must perform to solve a problem. Such a sequence of instructions written in a language that can be understood by a computer is called a *computer program*. It is the program that controls the activity of processing by the computer and the computer performs precisely what the program wants it to do. The term *software* refers to the set of computer programs, procedures, and associated documents (flowcharts, manuals, etc.) that describe the programs and how they are to be used. To be precise, software means a collection of programs whose objective is to enhance the capabilities of the hardware machine.

RELATIONSHIP BETWEEN HARDWARE AND SOFTWARE

In order for a computer to produce useful output, the hardware and software must work together. Thus, there is a special relationship between hardware and software. Both are complementary to each other. Nothing useful can be done with the computer hardware on its own and software cannot be utilised without supporting hardware.

To take an analogy, a cassette player and the cassettes purchased from market are hardware. However, the songs recorded on the cassettes are its software. To listen to a particular song, first of all that song has to be recorded on one of the cassettes which should then be mounted on the cassette player and played. Similarly, to get a particular job done by a computer, the relevant software should be loaded in the hardware before processing starts. It is immediately evident that hardware is necessary but software is vital. Another important point brought out by this analogy is that software production is difficult and expensive. Hardware is a one-time expense whereas software is a continuing expense. It may also be noted that different softwares can be loaded and run on the same hardware to perform different types of jobs just as different songs can be recorded one by one on the same cassette and played using the cassette player.

TYPES OF SOFTWARE

Computer software is normally classified into two broad categories : application software and systems software. *Application software*, also known as an *application package*, is a set of one or more programs designed to carry out operations for a specified application. For example, a payroll package produces payslips as the major output and an application package for processing examination results produces marksheets as the major output along with some other statistical reports. Similarly, a program written by a scientist to solve his particular research problem is also an application software. The programs that constitute an application package are known as *application programs* and the person who prepares application programs is known as an *application programmer*.

Traditionally, application packages were limited to the general purpose functions of inventory control, production scheduling, general ledger, general accounting and payroll because these were the major application areas for which a company acquired a computer. Because there is such a great demand for these functions, nowadays packaged software supporting them is available on almost every kind of computer hardware. However, the software industry has expanded to serve many specific markets. Specific purpose application packages have also been developed for specialized areas, such as banking, hospital administration, insurance, publishing, manufacturing, science and engineering, etc. In fact, many software companies have started to offer computer systems to go along with their software as turnkey systems for specific industry needs. Development of specific purpose application packages has expanded along with the increased use of computers in non-financial operations.

Systems software, also known as a *systems package*, is a set of one or more programs, designed to control the operation of a computer system. These programs do not solve specific problems. They are general programs written to assist humans in the use of the computer system by performing tasks, such as controlling all of the operations, required to move data into and out of a computer and all the steps in executing an application program. In general, system packages support the running of other software; communicate with peripheral devices (printers, card readers, disk and tape devices, etc.); support the development of other types of software; and monitor the use of various hardware resources (memory, peripherals, CPU, etc.). Thus, systems software makes the operation of the computer system more effective and efficient. The programs included in a systems software are called *systems programs* and the person who prepares systems software is referred to as a *systems programmer*.

Systems packages offer several advantages and conveniences to application programmers and computer users in general. Good systems software allows application packages to be run on the computer with less time and effort. Without systems software, application packages could not be run on the computer system. However, the production of systems software is a complex task that requires extensive knowledge and considerable specialized training in computer science. Systems programmers, who prepare systems software, are highly trained computer specialists and important members of the computer architectural team. Because of its technical complexity, systems software is rarely developed in-house. They are normally developed and distributed by the computer manufacturers. The customer who buys or leases a computer system would usually recieve, in addition to the hardware, some software needed for the effective operation of his computer. The systems software is an indispensable part of a total computer system. Its function is to compensate for the differences that exist between the user needs and the capabilities of the hardware. A computer without some kind of systems software would be very ineffective and most likely impossible to operate.

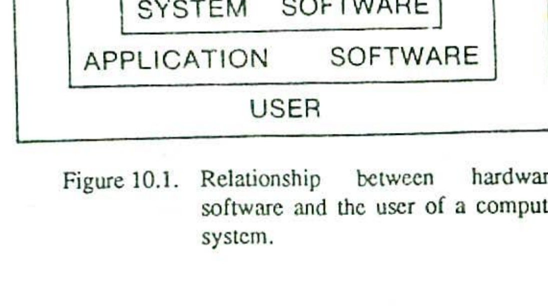


Figure 10.1. Relationship between hardware, software and the user of a computer system.

The relationship between hardware, software and the user of a computer system is shown in Figure 10.1. At the centre of any computer system is hardware and surrounding the hardware is systems software. Finally, the user interacts with application software.

ACQUIRING SOFTWARE

Computer software has evolved from an item of minor economic concern with first generation digital computers to one of major concern in todays computing systems. In the early days of computers, more than 80% of the total computer cost was devoted to hardware, but today more than 80% of the cost is for software. At one time, application and systems software were included in the purchase price of the computer. Today, however, software is usually not included in the purchase price of the computer. For most computer manufacturers the purchase price of a computer includes only the hardware along with a minimum of systems software. The customer normally has to pay extra charges for additional systems software and application software that he may wish to purchase.

Basically, there are two ways of obtaining software. One can either buy an existing package, or he can develop his own package. There are many financial options if one decides to buy a software package. It can be purchased, leased or rented, or obtained through a lease-purchase agreement. Software can be purchased from the computer manufacturers, from a software company or software house that specializes in developing and selling software. Software can also be obtained from user groups, which are groups of people or organizations that use the same computer and share software. On placement of advance order, many computer manufacturers also supply specialized application packages that are developed only for a particular user for his specific need. These packages are normally supplied along with the computer system, which is normally referred to as a *turnkey system*. If the software is to be developed in-house, that is, if the user decides to develop his own package, then some computer professionals are required to plan, develop, test, implement, and maintain the computer programs. However, development and maintenance of software is not an easy task. It is a very costly and time consuming affair. Hence, thorough analysis should be done and considerable thought should be given before one arrives at a decision of either buying or developing a software package.

FIRMWARE

Computer software in conventional systems is supplied on storage media like floppies, tapes, disks, etc. However, with the advancement in technology and the reduction in hardware cost, today software is also being made available by many computer manufacturers on read-only memory (ROM) chips. These ROM chips can be easily plugged into the computer system and they form a part of the hardware. Such programs (software) made available on hardware are known as *firmware*. Firmware often refers to a sequence of instructions (software) that is substituted for hardware. For example, in an instance where cost is more important than performance speed, the computer system architect might decide not to use special electronic circuits (hardware) to multiply two numbers, but instead write instructions (software) to cause the machine to accomplish the same function by repeated use of circuits already designed to perform addition. This software will be stored in a ROM chip of the computer system and will be executed (used) whenever the computer has to multiply two numbers. Hence, this software will be known as firmware. To be precise, firmware is software substituted for hardware and stored in read-only memory.

Initially, only systems software was supplied in the form of firmware. But today, even application programs are being supplied in firmware form. Dedicated applications are also programmed in this fashion and available in firmware. Because of the rapid improvements in memory technology, firmware is frequently a cost-effective alternative to wired electronic circuits, and its use in computer design will increase. It is expected that in the near future, firmware will make possible the cost-effective production of smart machines of all types.

QUESTIONS

1. Define the terms hardware and software.
2. What is a computer program ?
3. Hardware and software of a computer system are like two sides of a coin. Discuss.
4. Give an analogy to bring out the relationship between hardware and software of a computer system.
5. Hardware is a one-time expense whereas software is a continuing expense. Elaborate.
6. How many types of software are there ? Give two examples of each.

7. Define and distinguish between application software and systems software.

8. What type of qualification is desirable for a systems programmer and why ?

9. Highlight the importance of systems software for a computer system.

10. How does a normal user interact with the hardware of a computer system ? Describe the various in-between layers.

11. What are the different ways of acquiring software ?

12. What is a turnkey system ?

13. What is firmware and what is its importance to the computer system architect ?

14. Why is firmware gaining popularity ?

15. Differentiate between hardware, software, and firmware.