Chapter 9

Input-Output Devices

To be useful, a computer system needs to communicate with its external environment (its users). The input-output devices (abbreviated *I/O devices*) provide this capability to a computer system (see Figure 9.1). They are also known as *peripheral devices* because they surround a computer's CPU and memory. Input devices are used to enter data from outside world into primary storage, and output devices supply the results of processing from primary storage to users. A wide variety of I/O devices is now available. For a particular application, one type may be more suitable than another type. Some devices are used for both input and output functions. The goal of this chapter is to familiarize you with commonly used types of I/O devices.

Figure 9.1. Illustrating the role of I/O devices in a computer system.

It is important to note that the speed of I/O devices is very slow as compared to the speed of primary storage and CPU. This is because their speed in most cases depends on the movement of mechanical parts, and the potential for improvement in speed of such parts is limited. It is, therefore, difficult to produce I/O devices that can match processor and memory speeds, and there is a constant demand for faster and faster I/O devices.

INPUT DEVICES

An *input device* is an electromechanical device that accepts data from outside world and translates them into a form a computer can interpret. Several input devices are available today. They can be broadly classified into following categories:

1. Keyboard devices
2. Point-and-draw devices
3. Data scanning devices
4. Digitizer
5. Electronic cards based devices
6. Speech recognition devices
7. Vision based devices

The various types of input devices along with their applications are described below.

Keyboard Devices

Keyboard devices are the most commonly used input devices today. They allow data entry into a computer system by pressing a set of keys (labeled buttons) neatly mounted on a keyboard connected to a computer system. The most popular keyboard used today is the 101-keys *QWERTY keyboard* (see Figure 9.2).

Figure 9.2. The layout of keys on a QWERTY keyboard.

Point-and-Draw Devices

Interaction with computers was initially restricted mainly to text mode. However, it was soon realized that interacting with computers in text-mode is cumbersome and time-consuming. Hence, a new type of user interface, called *graphical user interface (GUI)*, was devised for interacting with computers. A GUI provides a screen with graphic icons (small images on the screen) or menus and allows a user to make rapid selections from them to give instructions to a computer (see Figure 9.3). For efficient utilization, GUI requires an input device that can be used to rapidly point to and select a graphic icon or menu item from the multiple options displayed on the screen. The keyboard, though usable, was found to be inconvenient and unsuitable for this requirement. Hence, research efforts to find a suitable input device to meet this requirement gave birth to several input devices like mouse, track ball, joystick, light pen, and touch screen. Later it was realized that many of these devices, like mouse and light pen, could also be used very effectively to create graphic elements on the screen such as lines, curves, and freehand shapes. With this new ability, these devices came to be known as point-and-draw devices. These input

devices have made computers a much more easily usable tool establishing them as a versatile tool for a wide range of users including children, illiterate citizens, and graphic designers. Some commonly used point-and-draw devices are described below.

Figure 9.3. A graphical user interface (GUI) of Microsoft® Windows desktop.

Mouse

Mouse is the most popular point-and-draw device. It is a must-have input device on modern personal computers and workstations because they support GUI as their primary user interface. A mouse is a small hand-held device that fits in a user's palm comfortably (see Figure 9.4). It rolls on a small bearing and has one or more buttons on the top. When a mouse that is connected to a user terminal is rolled on a flat surface, a graphics cursor moves on the terminal screen in the direction of the mouse's movement. Since all movements of the mouse are reproduced by the graphics cursor on the screen, you can move the graphics cursor at a menu item or an icon by moving the mouse.

Figure 9.4. A mouse.

The *graphics cursor* is displayed as a variety of symbols such as an arrow (↖), a wrist with a pointing finger (☛), etc. Depending on the application, the text and graphics cursor may be displayed on the screen at the same time. The graphics cursor, irrespective of its size and shape, has a pixel-size point that is considered the point of reference to decide where the cursor is positioned on the screen. This point is called *hot-spot* of the graphics cursor. When the hot-spot is positioned at a menu item or an icon, the graphics cursor is said to point to that menu item or icon. With a click of the mouse's button, the system can then be notified of this choice. Note that notifying the system of a particular choice, out of the various options provided by the software, is much easier with a mouse than pressing various key combinations. With proper software, a mouse can also be used to draw pictures on the screen and edit text.

The roller-ball based mouse is now being replaced with optical sensor based mouse. The optical sensor mouse has a light source with a sensor arranged in such a fashion that the light coming from the source is detected by the sensor after reflection from the surface. The on-board electronics on the mouse uses the reflection differences to calculate the direction and speed of movement and notifies the computer system. The optical sensor mouse is more sensitive, easier, and smoother to use. Another innovation in mouse is to have user-programmable buttons on the sides and the middle button on top is replaced with a wheel that can be rotated as scroll to scroll the screen display and can also be pressed as a button.

Trackball

A trackball is a pointing device similar to a roller-ball mouse. It has the roller ball also placed on the top along with the buttons (see Figure 9.5). Recall that in a roller-ball mouse the roller ball is placed in the base of the mouse. To move the graphics cursor on the screen the ball is rolled with hand. As the whole device need not be moved for moving the graphics cursor, a trackball requires less space than a mouse for operation and is often attached to or built into the keyboard. Trackballs built into the keyboard are commonly used in laptop (notebook) computers, as it is practical for laptop users in a small space. As the ball is fixed on the top, some people think of a trackball as an upside-down mouse.

Trackball comes in various shapes and forms with the same functionality. Three commonly used shapes are a ball, a button, and a square. To move the graphics cursor at a desired position on the terminal screen, the ball is rolled with hand, the button is pushed with a finger, or a finger is simply moved on the square platform.

Figure 9.5. A trackball.

Trackball is a device of choice in CAD/CAM (Computer Aided Design / Computer Aided Manufacturing) area. In designing, trackball is preferred because hand movement is mostly sufficient to move the graphical cursor and does not require any movement of equipment. This makes it easier for designers to work on large drawings and is more suitable to their style of working.

Trackball is also often used with several equipment having embedded computers. For example, an Ultrasound machine usually has a trackball that a sinologist (medical expert in sonography) can use to move the cursor (usually in cross-hair shape) to mark point of references on the image being viewed on the screen.

Joystick

A joystick is a pointing device that works on the same principle as a trackball. To make the movement of the spherical ball easier, it is placed in a socket with a stick mounted on it (see Figure 9.6). A user moves the spherical ball by the attached stick with his/her hand. The stick can be moved forward or backward, left or right, to move and position the graphics cursor at the desired position. Potentiometers are used to sense the movements. On most joysticks, a button on the top is provided to select the option currently pointed to by the cursor. The button is clicked to make this selection. Typical uses of a joystick include video games, flight simulators, training simulators, and remote control of industrial robots.

Figure 9.6. A joystick.

Electronic Pen

It is a pen-based point-and-draw device. A user holds the pen in his/her hand and points with it directly on the screen to select from the displayed menu items or icons. A user can also draw graphics directly on the screen with it. Another type of electronic pen comes with a special pad. The pen is used on the pad as an ink pen would be used on paper. Movement of electronic pen causes the graphical cursor on screen to move. Applying pressure on tip causes same action as left button-click and keeping the tip pressed for a short duration causes same action as right button-click of a mouse. Some electronic pens have a button on the side that is pressed to cause same action as right button-click of a mouse.

Touch Screen

Touch screen is the most simple, intuitive, and easiest to use of all input devices. A touch screen enables a user to choose from available options by simply touching the desired icon or menu item displayed on a computer's screen with his/her finger.

Touch screens are often used in information kiosks. An *information kiosk* is an unattended system located at a public place that stores information of public interest and allows common people to access stored information as per their requirement. For example, information kiosks may be located:

1. At an airport or a railway station to provide information to arriving passengers about hotels, restaurants, tourist spots, etc. in a city.
2. In large museums or zoos to guide the visitors to the locations of various attractions and facilities, and to caution them against things they are not supposed to do while inside.
3. In a large bank, post office, or insurance company to introduce the various types of offered services to the customers, and to guide them to appropriate counters for their specific jobs.

ata Scanning Devices

a scanning devices are input devices used for direct data entry into a computer system from source documents. me of them are also capable of recognizing marks or characters. These devices have following characteristics:

1. They eliminate the need for manual entry of data by human beings.
2. Automatic entry of data with their use improves data accuracy and increases timeliness of the information processed.
3. They demand high quality of input documents because of direct data entry from source documents. Documents that are typed poorly, have strikeovers, or have erasures are normally rejected.
4. Form design and ink specification usually becomes more critical with the use of these devices than when keyboard devices are used to key in data from forms.

a scanning devices are of many types. Commonly used ones are described below.

age Scanner

image scanner is an input device that translates paper documents into an electronic format that can be stored in mputer. The input documents may be typed text, pictures, graphics, or even handwritten material. This input e has been found to be very useful in preserving paper documents in electronic form. A copy of a document d in a computer in this manner will never deteriorate in quality or become yellow with age, and can be layed or printed, whenever desired. The stored images can even be altered and manipulated in interesting , if the computer has *image-processing software*.

e scanners come in various shapes and sizes. Two commonly used types are:

1. **Flatbed scanner.** A flatbed scanner is like a copier machine consisting of a box having a glass plate on its top and a lid that covers the glass plate (see Figure 9.7). A document to be scanned is placed upside down on the glass plate. A light source, situated below the glass plate, moves horizontally from one end to another when activated. After scanning one line, the light beam moves up a little and scans the next line. The process is repeated for all the lines. It takes about 20 seconds to scan a document of size 21 cm × 28 cm.

Figure 9.7. A flatbed scanner.

2. **Hand-held scanner.** A hand-held scanner has a set of light emitting diodes encased in a small case that can be held in hand conveniently (see Figure 9.8). To scan a document, the scanner is dragged slowly over it from its one end to the other end with its light on. The scanner has to be dragged very steadily and carefully, otherwise the conversion of the document into its equivalent bit map will not be correct. Due to this reason, hand-held scanners are used only in cases where high accuracy is not needed. They are also used when the volume of documents to be scanned is low. They are much cheaper than flatbed scanners.

Figure 9.8. A hand-held scanner.

Optical Character Recognition (OCR) Device

When image scanners are used for inputting text documents (typed or handwritten), they have following two limitations:

1. Since a scanned input document is stored as an image, instead of text, it is not possible to do any word processing of the document (the computer cannot interpret the stored document as letters, numbers, and special characters).
2. Storage space required for storing the document as an image is much more than that required for storing the same document as a text. For example, a page of printed text having 2000 characters can be stored as 2000 bytes by using the ASCII representation. A bitmap-image representation of the same document will require 10 to 15 times more storage depending on the resolution (granularity) of grid points.

OCR technology is used to overcome these limitations. In this case, the scanner is equipped with character recognition software (called OCR software) that converts the bitmap images of characters to equivalent ASCII codes. That is, the scanner first creates the bitmap image of the document and then the OCR software translates the array of grid points into ASCII text that the computer can interpret as letters, numbers, and special characters.

OCR software is extremely complex because it is difficult to make a computer recognize an unlimited number of typefaces and fonts. Hence, these software are designed to recognize texts written using standard type fonts (called OCR fonts). Two such standard fonts are OCR-A (American standard) and OCR-B (European standard). Figure 9.9 shows OCR-A fonts. Note that if the document contains italics or bold face letters, or fonts other than that for which the OCR software has been designed, the OCR software will not work effectively.

Figure 9.9. OCR-A fonts.

Optical Mark Reader (OMR)

These scanners are capable of recognizing a pre-specified type of mark made by pencil or pen. For example, in objective type tests applicants mark their choices of correct answers on a special pre-printed test scoring sheet by darkening a small square, circular, or oval shaped box by a pencil (see Figure 9.10). These answer sheets are fed directly to a computer for grading with the use of an optical mark reader.

The actual technique used by an OMR device for recognition of marks involves focusing 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) reflect the light enabling the reader to determine which responses are marked.

(a) Question sheet (b) Pre-printed answer sheet

Figure 9.10. A sample question sheet of an objective type test and its pre-printed answer sheet that is read by an OMR to grade the test.

Bar-Code Reader

Data coded in the form of small lines (known as bars) are known as bar codes. *Bar codes* represent alphanumeric data by a combination of adjacent vertical lines (bars) by varying their width and the spacing between them. They are used particularly for unique identification of all types of goods, books, postal packages, badges, tags, etc.

A bar-code reader is a device used for reading (decoding) bar-coded data. It may be a hand-held scanner, or embedded in a stationary scanner. It scans a bar-code image and converts it into an alphanumeric value that is then sent to a computer connected to the bar-code reader.

A bar-code reader uses laser-beam scanning technology. A laser beam is stroked across the pattern of bars of a bar code. Different bar codes having different patterns of bars reflect the beam in different ways that is sensed by a light-sensitive detector. Reflected light patterns are converted into electrical pulses and then transmitted to recognition logic circuits that convert it into an alphanumeric value.

There are many types of bar-coding systems. The most widely known one is the *Universal Product Code* (*UPC*). It appears on almost all retail packages in USA and now in India as well on many products. The UPC, originally used for supermarket items, is now printed on other consumer goods also. The UPC bar-code patterns are decoded as 10 digits. The first 5 of the digits identify the manufacturer or supplier of the product, and the next 5 digits identify a specific product of the manufacturer (see Figure 9.11).

Bar code readers are found commonly in supermarkets and department stores. When a customer picks up a product for purchasing and brings it to the cash counter for payment, the sales person at the counter uses a bar-code reader to scan the bar code printed on the product. The bar-code reader converts the bar code into an alphanumeric value and feeds it to a computer that looks up the price of the product, possibly updates inventory and sales records, and uses the price and description information to prepare a purchase bill for the customer. Postal delivery services also use bar codes to identify and track each packet. For example, Federal Express of USA uses a unique bar-coding system and their employees can usually tell a customer, within a matter of minutes, the current location of any packet.

Figure 9.11. An example of UPC bar code.

Magnetic-Ink Character Recognition (MICR)

MICR is similar to OCR. It is used by banking industry for faster processing of large volume of cheques handled every day by this industry. A bank cheque has bank's identification code (name, branch, etc.), account number, and cheque number pre-printed (encoded) on it by using characters from a special character set. A special ink containing particles of iron oxide (that can be magnetized) is used for pre-printing the characters on the cheque. Figure 9.12 shows a sample cheque that employs MICR technology.

Figure 9.12. A bank cheque that employs MICR technology.

When a customer presents a filled-in cheque at a bank, a bank employee manually enters (keys in) the customer-supplied information including the amount written on the cheque. This cheque is then processed by using an MICR reader-sorter that can recognize magnetic ink characters. The MICR reader-sorter reads the pre-printed data on the cheques, and sorts the cheques for distribution to other banks or for further processing.

The most commonly used character set by MICR devices is known as E13B font consisting of numerals 0 to 9 and four special characters (see Figure 9.13). Coded data in the form of these fonts are transferred from cheques to a computer by an MICR reader-sorter. As the cheques enter the reading unit, they pass through a magnetic field causing the particles in the ink to be magnetized. Read heads then interpret these characters by examining their shapes. The sorter is used to sort the cheques into different pockets according to their identification code numbers.

MICR technology speeds up data input for banking industry because cheques can be fed directly into the input device and processed automatically thereafter. Besides enabling faster processing of cheques, this technology also ensures accuracy of data entry because most of the information is pre-printed on the cheque and is fed directly to the computer. However, MICR has not been adopted by other industries because the currently supported character set has only 14 symbols (10 digits and 4 special characters). No alphabetic characters are available.

Figure 9.13. The E13B font (character set) used by MICR devices.

Digitizer

A digitizer is an input device used for converting (digitizing) pictures, maps, and drawings into digital form for storage in computers. For example, the x and y coordinates of points in a drawing may be stored in digital form. This enables re-creation of the drawing from the stored information and easy incorporation of changes in the drawing, whenever required.

A digitizer consists of a *digitizing tablet* (also known as *graphics tablet*) associated with a *stylus* (see Figure 9.14). The digitizing tablet is a flat surface that contains hundreds of fine copper wires forming a grid. Each copper wire receives electric pulses. The digitizing tablet can be spread over a working table and is connected to a computer. The stylus is like a pen or a lens-like cursor with a cross hair and button. It is connected to the tablet and can be pressed down at a point on the tablet to input the (x, y) coordinates of the point. On moving the stylus on the tablet, a cursor on computer's screen moves simultaneously to a corresponding position on the screen to provide visual feedback to the operator. This enables the operator to draw sketches directly or to input sketched drawings very easily. Inputting drawings or developing sketches by using a digitizer is further simplified by the fact that poorly sketched lines, arcs, and other graphical objects are automatically input as mathematically precise objects like straight lines and smooth curves.

Digitizers are used commonly in the area of Computer Aided Design (CAD) by architects and engineers to design cars, buildings, medical devices, robots, mechanical parts, etc. They are also used in the area of Geographical Information System (GIS) for digitizing of maps available in paper form.

Figure 9.14. A digitizer.

Electronic-card Reader

Electronic cards and their associated readers offer another means of direct data entry into a computer system. Electronic cards are small plastic cards having encoded data appropriate for the application for which they are used. An electronic-card reader, normally connected to a computer, is used to read the data encoded on an electronic card and transfer it to the computer for further processing.

Electronic cards are often issued by banks to their customers for use with *automatic teller machines* (*ATMs*). An ATM allows a customer to deposit or withdraw cash 24 hours a day without the need to interact with a bank employee. It is an unattended machine located at any place (either inside the bank or away from the bank). It is connected normally to the bank's computer. An electronic card for use in an ATM has its customer's account number and credit limit (maximum amount that he/she can withdraw in a day) encoded on the card. An ATM has an electronic-card reader associated with it. When a customer inserts his/her card into the ATM (actually the electronic-card reader of the ATM), the reader reads the data encoded on the card and transmits it to the bank's computer activating the customer's account. The customer can then carry out the desired transaction by following the instructions displayed on the screen of the ATM and by pressing a few keys on the customized keyboard or touch screen of the ATM.

Speech Recognition Devices

Speech recognition devices are input devices that allow a person to input data to a computer system by speaking to it. Hence, they make computers much easier to use. However, as a data input device, currently speech recognition systems have limited success because correct interpretation by a machine of the large number of words in the vocabulary of a language is difficult. The major difficulties are that people speak with different

accents (pronounce differently) and intonations (with different tone or pitch of the voice), and the fact that the meaning of words can vary depending on the context in which they are used. Hence, today's speech recognition systems are limited to accepting few words within a relatively small domain and can be used to enter limited kinds and quantities of data only.

Although in its infancy, speech recognition systems are already used for a wide range of applications. Some of its applications are:

1. For data input to a computer system by a person in situations where his/her hands are busy or his/her eyes must be fixed on a measuring instrument or some other object. For example, doctors in an operation room can request certain information about a patient while operating.
2. For data input by dictation of long text or passage for later editing and review.
3. For authentication of a user by a computer system based on speech input.
4. For limited use of computers by individuals with physical disabilities.

In addition to making input of data easier, speech recognition systems also provide freedom of movement to the operator because the operator is free to stand up, move around, or do some other work by hand while inputting voice data to the system.

Vision-Input System

A vision-input system allows a computer to accept input by seeing an object. Input data in this case is normally an object's shape and features in the form of an image. The idea is to simulate the capability of a human vision system in a limited sense.

A computer with a vision-input device consists of a digital camera. Following steps are taken to recognize a given object:

1. The camera is focused on the input object to take its picture.
2. The camera creates an image of the object in digital form (in 1s and 0s) so that it can be stored and interpreted by the computer.
3. The digitized image of the object is matched against similarly formed pre-stored images in the computer's image database.
4. Depending on whether a match is found or not, the system takes appropriate action.

Vision-input devices are used mainly in factories for designing industrial robots used for quality control and assembly processes. For example, a robot used for quality control may inspect objects and separate those not meeting certain quality-control specifications. Another robot may be used to inspect shapes of objects and separate objects of different shapes in different bins.

OUTPUT DEVICES

An *output device* is an electromechanical device that accepts data from a computer and translates them into a form suitable for use by outside world (users). Several output devices are available today. They can be broadly classified into following categories:

1. Monitors
2. Printers
3. Plotters
4. Screen image projector
5. Voice response system

These types of output devices along with their applications are described below.

Output devices generate computer output that can be broadly classified into following two types:

1. **Soft-copy output.** A soft-copy output is not produced on a paper or some material that can be touched and carried for being shown to others. They are temporary in nature. For example, contents displayed on a terminal screen, or words spoken out by a voice response system are soft-copy output.
2. **Hard-copy output.** A hard-copy output is produced on a paper or some material that can be touched and carried for being shown to others. They are permanent in nature and can be kept in paper files or can be looked later when the person is not using a computer. For example, output produced on paper by printers or plotters are hard-copy output.

Monitors

Monitors are the most popular output devices used today for producing soft-copy output. They display the generated output on a television like screen (see Figure 9.15). A monitor is associated usually with a keyboard and together they form a *video display terminal* (*VDT*). A VDT (often referred to as just *terminal*) is the most popular input/output (I/O) device used with today's computers. It serves as both an input and output device. The keyboard is used for input to a computer and the monitor is used to display the output from the computer. The name "terminal" comes from the fact that a terminal is at the terminus or end of a communication path.

Two basic types of monitors used today are *cathode-ray-tube* (*CRT*) and *LCD (Liquid Crystal Display) flat-panel*. CRT monitors work much like a television screen and are used with non-portable computer systems. On the other hand, LCD flat-panel monitors are thinner, lighter, and are used commonly with portable computer systems like notebook computers. With gradual reduction in price of LCD flat panel monitors, they are used increasingly with non-portable desktop computer systems also. They are also preferred because they occupy less table space.

Figure 9.15. A video display terminal consists of a monitor and a keyboard.

Printers

Printers are the most popular output devices used today for producing hard-copy output. Different types of printers are described below.

Dot-Matrix Printers

Dot-matrix printers are character printers that print one character at a time. They form characters and all kinds of images as patterns of dots. Figure 9.16 shows how various types of characters can be formed as patterns of dots. A dot-matrix printer has a print head that moves horizontally (left to right and right to left) across the paper. Print head contains an array of pins that can be activated independent of each other to extend and strike against an inked ribbon to form patterns of dots on the paper. To print a character, the printer activates the appropriate set of pins as the print head moves horizontally. For faster printing, many dot-matrix printers print both ways – while the print head moves from left to right and while it moves from right to left, on return. Such method is called *bi-directional printing*. Figure 9.17 shows a dot-matrix printer.

Figure 9.16. Formation of characters as patterns of dots.

Figure 9.17. A dot-matrix printer.

ince dot matrix printers produce printed output as patterns of dots, they can print any shape of character that a rogram can describe. They, therefore, can print many special characters, different sizes of print, and also have the ɔility to print graphics such as charts and graphs.

ot-matrix printers are impact printers because they print by hammering the pins on the inked ribbon to leave ink ıpressions on a paper. Hence, they can be used to produce multiple copies by using carbon paper or its ıuivalent. Due to impact printing, dot-matrix printers are noisy as compared to non-impact printers.

ot-matrix printers are normally slow with printing speeds ranging from 30 to 600 characters per second. owever, they are cheap in terms of both initial cost and cost of operation. Hence, they are preferred by dividuals and organizations for generating printed outputs if the speed and quality of printing are not important ctors. They are also used for applications requiring multi-copy output such as shipping forms and invoices that ly on impact printing for generating multiple copies.

kjet Printers

ɛjet printers are character printers that form characters and all kinds of images by spraying small drops of ink on ıaper. The print head of an inkjet printer contains up to 64 tiny nozzles that can be heated up selectively in a few croseconds by an integrated circuit resistor. When the resistor heats up, the ink near it vaporizes and is ejected ough the nozzle making a dot on the paper placed in front of the print head. To print a character, the printer

selectively heats the appropriate set of nozzles as the print head moves horizontally. Figure 9.18 shows an inkjet printer.

Inkjet printers produce higher quality output than dot-matrix printers do because they form characters by very tiny ink dots. A high-resolution inkjet printer has as many as 64 nozzles within a height of 7mm providing print resolution of around 360 dots per inch.

Since inkjet printers produce printed output as patterns of tiny dots, they can print any shape of characters that a program can describe. This allows the printer to print many special characters, different sizes of print, and the ability to print graphics such as charts and graphs.

Figure 9.18. An inkjet printer.

Inkjet printers are non-impact printers because they print by spraying ink on the paper. Hence, they are quieter in operation. Being of non-impact type, they cannot be used to produce multiple copies of a document in a single printing.

A color inkjet printer usually comes with two ink cartridges – black and tri-color. The tri-color cartridge contains red, blue, and yellow colors in a package that can mix appropriate amount of these colors with black from the other cartridge to get any desired color with saturation. This makes it possible to get multi-colored and photo-quality output from inkjet printers.

Inkjet printers are slower than dot-matrix printers are with printing speeds ranging from 40 to 300 characters per second. Typically, an inkjet printer is more expensive than a dot-matrix printer. They are preferred if speed of printing is not an important factor.

Drum Printers

Drum printers are line printers that print an entire line at a time. Recall that dot matrix and inkjet printers print one character at a time. Figure 9.19 shows the print mechanism of a drum printer. It consists of a solid cylindrical drum with characters embossed (raised characters) on its surface in the form of circular bands. Each band consists of all the printing characters supported by the printer in its character set. Total number of bands is equal to the maximum number of characters (print positions) that can be printed on a line. Hence, a drum printer with 132 characters per line and supporting a character set of 96 characters will have altogether 12,672 (132×96) characters embossed on its surface.

In addition to the drum, the printer has a set of hammers (one opposite each band) mounted in front of the drum in a manner that an inked ribbon and paper can be placed between the hammers and the drum. The total number of hammers is equal to the total number of bands on the drum, which is also equal to the total print positions per line.

The drum rotates at a high speed. A character is printed at a desired print position by activating the appropriate hammer when the character embossed on the band at the print position passes below it. Hence, the drum would have to complete one full revolution to print each line of output. This means that not all characters on a line are printed at exactly the same time, but the time required to print an entire line is so fast that it appears as if one line is printed at a time.

The drum of a drum printer is expensive and cannot be changed often. Hence, drum printers can print a pre-defined set of characters only in a pre-defined style embossed on the drum. Drum printers, therefore, do not have the ability to print any shape of characters, different sizes of print, and graphics such as charts and graphs.

Drum printers are impact printers because they print by hammering on a paper and inked ribbon against the characters embossed on the drum. Hence, they can be used to produce multiple copies by using carbon paper or its equivalent. Due to impact printing, drum printers are noisy in operation and often use a cover to reduce the noise level. Printing speeds of drum printers are in the range of 300 to 2000 lines per minute.

Figure 9.19. Printing mechanism of a drum printer.

Chain/Band Printers

Chain/band printers are line printers that print one line at a time. Figure 9.20 shows the print mechanism of a chain/band printer. It consists of a metallic chain/band on which all characters of the character set supported by the printer are embossed. A standard character set may have 48, 64, or 96 characters. In order to enhance printing speed, the characters in the character set are embossed several times on the chain/band. For example, the chain/band of a 64 character set printer may have four sets of 64 characters each embossed on it. In this case, the chain/band will have altogether 256 (64×4) characters embossed on it.

The printer has a set of hammers mounted in front of the chain/band in a manner that an inked ribbon and paper can be placed between the hammers and chain/band. The total number of hammers is equal to the total number of print positions. Therefore, a printer supporting 132 print positions will have 132 hammers.

The chain/band rotates at a high speed. A character is printed at a desired print position by activating the appropriate hammer when the character embossed on the chain/band passes below it. Since the character set is repeated several times on the chain/band, it is not necessary to wait for the chain/band to make a complete revolution to position the desired character in the correct print position.

Unlike the drum of a drum printer, the chain/band of a chain/band printer can be changed easily. This allows use of different fonts (styles of characters) and different scripts (languages) to be used with the same printer. Like drum printers, chain/band printers can print only pre-defined sets of characters embossed on the chain/band used with the printer. Chain/band printers, therefore, do not have the ability to print any shape of characters, different sizes of print, and graphics such as charts and graphs.

Figure 9.20. Printing mechanism of a chain/band printer.

Chain/band printers are impact printers because they print by hammering on a paper and inked ribbon against the characters embossed on the chain/band. Hence, they can be used to produce multiple copies by using carbon paper or its equivalent. Due to impact printing, chain/band printers are noisy in operation and often use a cover to reduce the noise level. Printing speeds of chain/band printers are in the range of 400 to 3000 lines per minute.

Laser Printers

Laser printers are page printers that print one page at a time. Main components of a laser printer are a laser beam source, a multi-sided mirror, a photoconductive drum, and toner (tiny particles of oppositely charged ink). To print a page of output, the laser beam is focused on the electro statically charged drum by the spinning multi-sided mirror. The mirror focuses the laser beam on the surface of the drum in a manner to create the patterns of characters/images to be printed on the page. Since the drum is photoconductive, a difference in electric charge is created on those parts of the drum surface that are exposed to the laser beam. As a result, the toner, composed of oppositely charged ink particles, sticks to the drum in the places where the laser beam has charged the drum's surface. The toner is then fused permanently

Figure 9.21. A laser printer.

on the paper with heat and pressure to generate the printed output. The drum is then rotated and cleaned with a rubber blade to remove the toner sticking to its surface to prepare the drum for next page printing. Figure 9.21 shows a laser printer.

Laser printers produce very high quality output because they form characters by very tiny ink particles. The most common laser printers have resolution of 600 dpi (dots per inch), whereas some high-end laser printers have resolution of 1200 dpi. Due to their high resolution, these printers give excellent graphics art quality.

Since laser printers produce printed output as patterns generated by the laser beam, they can print any shape of characters that a program can describe. They, therefore, can print many special characters, different sizes of print, and also have the ability to print graphics such as charts and graphs.

Laser printers are non-impact printers. Hence, they are very quiet in operation. Being of non-impact type, they cannot be used to produce multiple copies of a document in a single printing.

Although most laser printers can print in black color only because they have a single toner-drum arrangement, now even color laser printers are available at affordable price. A color laser printer, like color inkjet printer, contains four color toners, each with a drum of its own. The usage of drums and toners are same as earlier, but each drum is charged in such a way that together they produce the desired color output.

Laser printers are faster in printing speed than other printers discussed earlier. Low speed laser printers can print 4 to 12 pages per minute. High-speed laser printers are also available. Owing to their better print quality and printing speed, laser printers are more expensive than other types of printers.

Plotters

We learnt earlier that dot matrix, inkjet, and laser printers are capable of producing graphics output. However, many engineering design applications like architectural plan of a building, design of mechanical components of an aircraft or a car, etc., often require high-quality, perfectly-proportioned graphic output on large sheets. The various types of printers discussed above are not suitable for meeting this output requirement of such applications. A special type of output device, called *plotters*, is used for this purpose. Plotters are an ideal output device for architects, engineers, city planners, and others who need to routinely generate high-precision, hard-copy, graphic output of widely varying sizes. Two commonly used types of plotters are drum plotter and flatbed plotter. They are described below.

Drum Plotter

In a drum plotter, the paper on which the design is to be made is placed over a drum that can rotate in both clockwise and anti-clockwise directions to produce vertical motion. The mechanism also consists of one or more penholders mounted perpendicular to the drum's surface. The pen(s) clamped in the holder(s) can move left to right or right to left to produce horizontal motion. A graph-plotting program controls the movements of the drum and pen(s). That is, under computer control, the drum and pen(s) move simultaneously to draw designs and graphs on the sheet placed on the drum. The plotter can also annotate the designs and graphs so drawn by using the pen to draw characters of various sizes. Since each pen is program selectable, pens having ink of different colors can be mounted in different holders to produce multi-colored designs. Figure 9.22 shows a drum plotter.

Flatbed Plotter

A flatbed plotter plots a design or graph on a sheet of paper spread and fixed over a rectangular flatbed table. In this type of plotter, normally the paper does not move and the pen holding mechanism provides all types of motions necessary to draw complex designs and graphs. That is, under computer control, the pen(s) move in the required manner to draw designs and graphs on the sheet placed on the flatbed table. The plotter can also annotate the designs and graphs so drawn by using the pen to draw characters of various sizes. Provision is also there to mount more than one pen in the pen(s) holding mechanism. Since each pen is program selectable, pens having ink of different colors can be mounted in different holders to produce multi-colored designs. The plot size is restricted by the area of the bed. Some may be as small as A4 size (8"×11" page) while 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 can also etch on plastic or metal plates. In this case, the plastic or metal sheet is spread on the bed and the drawing pen has a sharp-edged needle. Figure 9.23 shows a flatbed plotter.

Figure 9.22. A drum plotter.

Figure 9.23. A flatbed plotter.

Screen Image Projector

Screen image projector is an output device used to project information from a computer on a large screen (such as a cloth screen or wall) so that a group of people can view it simultaneously. It is very useful for making presentations to a group of people with direct use of a computer.

Before such an output device was available, the contents of a presentation were prepared using a computer. The presentation material was then printed on a printer and the printout was next reproduced on overhead projector transparency sheets by using a copier machine. Finally, the presentation was made by using an overhead projector. Special marker pens had to be used for marking certain portions of the contents on the transparency sheets during the presentation.

A screen image projector simplifies this job. It can be plugged to a computer system directly, and a presenter can make a presentation to a group of people by projecting the presentation material one after another on a large screen with the help of computer's keyboard or mouse. With this facility, the presenter can also directly point to, mark, or edit certain portions of the contents of the displayed material during the presentation to make the presentation more understandable. Additionally, a full-fledged multimedia presentation with audio, video, image,

and animation can be prepared and made by using this facility to make the presentation more lively and interesting.

Screen image projectors have become common presentation equipment today. They are used commonly with portable notebook computers to setup a modern presentation facility quickly at any place with great ease. Like monitors, screen image projectors provide a temporary, soft-copy output. Figure 9.24 shows a screen image projector.

Figure 9.24. A screen image projector

Voice Response Systems

Just as a speech recognition system allows a user to talk to a computer, a voice response system enables a computer to talk to a user. A voice response system has an audio-response device that produces audio output. Obviously, the output is temporary, soft-copy output. Voice response systems are of two types – voice reproduction system and speech synthesizer. They are described below.

Voice Reproduction System

A voice reproduction system produces audio output by selecting an appropriate audio output from a set of pre-recorded audio responses. The set of pre-recorded audio responses may include words, phrases, or sentences spoken by human beings, music or alarms generated by musical instruments, or any other type of sound. The actual analog recordings of the pre-recorded sounds are converted into digital data first and then stored on a computer's disk, or in its memory chip permanently. When audio output is to be produced, the computer selects the appropriate sound from the set of pre-recorded sounds. The selected sound is converted back into analog form and then routed to a speaker to produce the audio output.

Voice reproduction systems are very useful in a wide range of applications. Their uses include:

1. Audio help for guiding how to operate a system. For example, banking industry uses voice reproduction systems in automatic teller machines to provide systematic guidance to customers on how to transact with the bank by using an ATM.
2. Automatic answering machines. For example, telephone enquiries for new telephone numbers in place of old numbers, or vacancy status of a flight or train is often taken care of by an automatic answering machine.
3. Video games are made exciting and interesting by playing an event-based sound from a set of pre-recorded sounds.
4. Talking alarm clocks. For example, every hour the clock speaks out what is the time by selecting the appropriate voice message corresponding to that hour from the set of pre-recorded voice messages. In addition, the clock may speak "its time to wake up" at the time set for alarm.
5. Talking toys and home appliances also use a voice reproduction system.
6. Often personal computers with audio facility are used for automated multimedia presentations during exhibitions.

Speech Synthesizer

A speech synthesizer converts text information into spoken sentences. To produce speech, these devices combine basic sound units called *phonemes*. From a given text information, sequence of words are combined into phonemes, amplified, and output through a speaker attached to the system. Speech synthesizers are still in their infancy because currently they can produce only limited unique sounds with only limited vocal inflections and phrasing. However, they are very useful in a wide range of applications. Their uses include:

1. For reading out text information to blind persons. For example, a recently published book may be scanned using a scanner, converted into text using OCR software, and read out to blind persons using a speech synthesizer. This allows blind persons to know the latest information published in a book as soon as it is printed, rather than wait for the book to appear in Braille.
2. For allowing those persons who cannot speak, to communicate effectively. For example, a person with this type of disability simply types the information and the speech synthesizer converts it into spoken words.
3. For translation systems that convert an entered text into spoken words in a selected language. For example, a foreigner coming to India may enter a text he/she wants to communicate to an Indian, and the speech synthesizer converts it into spoken words of the selected Indian language.

Points to Remember

1. Input-output devices (abbreviated *I/O devices*) provide the capability to a computer system to communicate with its external environment (its users). They are also known as *peripheral devices*.
2. An *input device* is an electromechanical device that accepts data from outside world and translates them into a form a computer can interpret.
3. An *output device* is an electromechanical device that accepts data from a computer and translates them into a form suitable for use by outside world (users).
4. *Keyboard devices* are the most commonly used input devices today. They allow data entry into a computer system by pressing a set of keys (labeled buttons) neatly mounted on a keyboard connected to the computer system.
5. *A graphical user interface* (*GUI*) provides a screen with graphic icons (small images on the screen) or menus and allows a user to make rapid selections from them to give instructions to a computer.
6. *Point-and-draw devices* are input devices used to rapidly point to and select a graphic icon or menu item from multiple options displayed on a screen. Many of these devices can also be used effectively to create graphic elements on the screen such as lines, curves, and freehand shapes. Some commonly used point-and-draw devices are mouse, trackball, joystick, electronic pen, and touch screen.
7. *Data scanning devices* are input devices used for direct data entry into a computer system from source documents. Some of them are also capable of recognizing marks or characters.
8. An *image scanner* is an input device that translates paper documents into an electronic format that can be stored in a computer. Input documents may be typed text, pictures, graphics, or even handwritten material.
9. An *optical character recognition* (*OCR*) *device* is a scanner equipped with character recognition software. It is used for inputting text documents and storing them in a form suitable for doing word processing of the documents. That is, a computer can interpret the stored document as letters, numbers, and special characters.
10. An *optical mark reader* (*OMR*) is a scanner capable of recognizing a pre-specified type of mark made by pencil or pen. Any input data of a choice or selection nature can be recorded for OMR input.
11. *Bar codes* represent alphanumeric data by a combination of adjacent vertical lines (called bars) by varying their width and spacing between them. A *bar-code reader* is a scanner used for reading (decoding) bar-coded data.
12. *Magnetic-ink character recognition* (*MICR*) technology is used by banking industry for faster processing of large volume of cheques. This technology also ensures accuracy of data entry because most of the information is

pre-printed on the cheque and is fed to a computer directly.

13. A *digitizer* is an input device used for converting (digitizing) pictures, maps, and drawings into digital form for storage in computers. This enables re-creation of the drawing from stored information and easy incorporation of changes in the drawing, whenever required.

14. *Electronic cards* are small plastic cards having encoded data appropriate for the application for which they are used. An *electronic-card reader* is normally connected to a computer and is used to read data encoded on an electronic card and transfer it to a computer for further processing.

15. *Speech recognition devices* are input devices that allow a person to input data to a computer system by speaking to it.

16. A *vision-input system* allows a computer to accept input by seeing an object. Input data in this case is normally an object's shape and features in the form of an image.

17. Computer output generated by output devices are of two types – soft-copy output and hard-copy output. *Soft-copy outputs* are temporary in nature and vanish after use. *Hard-copy outputs* are permanent in nature and can be kept in paper files or can be looked later when the person is not using a computer.

18. *Monitors* are the most popular output device used today for producing soft-copy output. They display the generated output on a television like screen.

19. A monitor and a keyboard are usually associated together to form a *video display terminal* (*VDT*) often referred to as just *terminal*. A terminal serves as both an input and output device. It is the most popular input/output (I/O) device used with today's computers.

20. *Printers* are the most popular output devices used today for producing hard-copy output.

21. *Dot-matrix printers* are character printers that form characters and all kinds of images as patterns of dots.

22. *Inkjet printers* are character printers that form characters and all kinds of images by spraying small drops of ink on paper.

23. *Drum printers* are line printers that print characters by striking a set of hammers on an inked ribbon and paper placed against a solid cylindrical drum with characters embossed on its surface in the form of circular bands.

24. *Chain/band printers* are line printers that print characters by striking a set of hammers on an inked ribbon and paper placed against a metallic chain/band on which all characters of the character set supported by the printer are embossed.

25. *Laser printers* are page printers that produce very high quality output by forming characters and all kinds of images with very tiny ink particles.

26. *Plotters* are an ideal output device for architects, engineers, city planners, and others who need to generate high-precision, hard-copy graphic output of widely varying sizes. Two commonly used types of plotters are drum plotter and flatbed plotter.

27. *Screen image projector* is an output device used to project information from a computer on to a large screen (such as a cloth screen or wall) so that a group of people can view it simultaneously.

28. *Voice response systems* enable computers to talk to their users. They are of two types – voice reproduction system and speech synthesizer. A *voice reproduction system* produces audio output by selecting an appropriate audio output from a set of pre-recorded audio responses. On the other hand, a *speech synthesizer* converts text information into spoken sentences.

Questions

1. Why I/O devices are necessary for a computer system?

2. What are peripheral devices? Why they are so called?

3. Differentiate between an input and output device. Can a device be used as both an input and output device? If no, explain why. If yes, give an example of such a device.

4. Why I/O devices are very slow as compared to the speed of primary storage and CPU?

5. What is an input device? Name some commonly used input devices.

6. What are keyboard devices?

7. What are point-and-draw devices? Name some commonly used point-and-draw devices.

8. What is a mouse? Explain how it is used to notify the system of a particular user choice out of a given set of choices on a monitor's screen.

9. What is a trackball? How it is different from a mouse?

10. Explain how a trackball is used to notify the system of a particular user choice out of a given set of choices on a monitor's screen.

11. What is a joystick? How it is different from a trackball? Write some uses of a joystick.

12. Explain how an electronic pen is used as an input device.

13. What is a touch screen device?

14. Write some applications for which touch screen is the most suitable input device.

15. What is an information kiosk? Write some uses of an information kiosk.

16. Write short notes on:
    (a) Mouse
    (b) Trackball
    (c) Joystick
    (d) Electronic Pen
    (e) Touch screen
    (f) Information kiosk

17. What are data scanning devices? How do they help in improving input data accuracy as compared to keyboard devices?

18. What is an image scanner?

19. Differentiate between a flatbed and a hand-held image scanner.

20. What are the limitations of an image scanner when it is used for inputting text documents? How an OCR device overcomes these limitations?

21. What is an OCR device? List some of its advantages and limitations for inputting text documents.

22. What is an OMR device? Explain the technique used by it for recognition of marks. Write some applications that make use of it.

23. What are bar codes? How does a bar-code reader read bar-coded data? Write a use of a bar-code reader.

24. What is the Universal Product Code (UPC)? Which input device is used for inputting data based on UPC?

25. What is an MICR device? Which industry is the primary user of MICR?

26. Explain how an MICR device helps in faster processing of bank cheques with greater accuracy.

27. What is the main limitation of MICR technology?

28. What is a digitizer? What are its two main components? What are its main areas of application?

29. Explain how a digitizer can be used to convert a drawing into digital form for storage in computers.

30. What is an electronic card? Write two applications where electronic cards can be used effectively.

31. What is a speech recognition device? Why do currently available speech recognition devices have limited success?

32. Write some applications of speech recognition systems.

33. What is a vision-input system? Write some applications of vision-input systems.

34. Write short notes on:
    (a) Image scanner
    (b) Bar-code reader
    (c) Digitizer
    (d) Electronic-card reader
    (e) Vision-input systems
    (f) Optical Mark Reader (OMR)
    (g) Optical Character Recognition (OCR)
    (h) Speech recognition devices
    (i) Magnetic-Ink Character Recognition (MICR)

35. Write short notes on:
    (a) Keyboard devices
    (b) Point-and-draw devices
    (c) Data scanning devices

36. What is an output device? Name some commonly used output devices.

37. Differentiate between soft-copy and hard-copy outputs.

38. Name two output devices used for producing soft-copy output and two output devices used for producing hard-copy output.

39. What is a computer terminal? Why it is so called?

40. What is a monitor device? Name the two basic types of monitors along with their relative advantages and disadvantages.

41. What is a flat panel monitor? Where it is commonly used?

42. What is a printer? What are the commonly used types of printers?

43. Differentiate between impact and non-impact printers. Write their relative advantages and disadvantages. Name few printers of both types.

44. Explain the printing mechanism of dot-matrix printers.

45. List key features and limitations of dot-matrix printers.

8. What is a mouse? Explain how it is used to notify the system of a particular user choice out of a given set of choices on a monitor's screen.

9. What is a trackball? How it is different from a mouse?

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    (b) Bar-code reader
    (c) Digitizer
    (d) Electronic-card reader
    (e) Vision-input systems
    (f) Optical Mark Reader (OMR)
    (g) Optical Character Recognition (OCR)
    (h) Speech recognition devices
    (i) Magnetic-Ink Character Recognition (MICR)

35. Write short notes on:
    (a) Keyboard devices
    (b) Point-and-draw devices
    (c) Data scanning devices

36. What is an output device? Name some commonly used output devices.

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38. Name two output devices used for producing soft-copy output and two output devices used for producing hard-copy output.

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43. Differentiate between impact and non-impact printers. Write their relative advantages and disadvantages. Name few printers of both types.

44. Explain the printing mechanism of dot-matrix printers.

45. List key features and limitations of dot-matrix printers.

46. Explain the printing mechanism of inkjet printers.
47. List key features and limitations of inkjet printers.
48. Explain the printing mechanism of drum printers.
49. List key features and limitations of drum printers.
50. Explain the printing mechanism of chain/band printers.
51. List key features and limitations of chain/band printers.
52. Explain the printing mechanism of laser printers.
53. List key features and limitations of laser printers.
54. Write short notes on:
    (a) Dot-matrix printers
    (b) Inkjet printers
    (c) Drum printers
    (d) Chain/band printers
    (e) Laser printers
55. What is a plotter? What types of users need it?
56. Explain the working mechanism of a drum plotter.
57. Explain the working mechanism of a flatbed plotter.
58. What is a screen image projector? What it is used for?
59. What is a voice response system? Write some of its typical applications.
60. What is a voice reproduction system? How does it function? Write some of its applications.
61. What is a speech synthesizer? How does it function? Write some of its applications.
62. Write short notes on:
    (a) Plotter
    (b) Screen image projector
    (c) Voice response systems
    (d) Voice reproduction system
63. Write the full forms of following abbreviations:
    (a) GUI
    (b) CAD
    (c) OCR
    (d) OMR
    (e) UPC
    (f) MICR
    (g) VDT
    (h) CRT