

UNIT 8 I/O TECHNOLOGY

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8.0 INTRODUCTION

In the previous unit, you have studied the concept of input/output interfaces and I/O techniques. The previous unit discussed three I/O techniques i.e., programmed I/O, Interrupt-driven I/O and DMA were discussed along with the evolution of I/O processor. A computer supports a number of I/O devices in order to perform data transfer with external environment. This unit provides a brief introduction to the various I/O devices such as mouse, keyboard, monitor, printer, scanner, video & sound cards etc. It also discusses the modern voice-based input devices. The unit does not attempt to provide all the details of these devices, but attempts to introduce you the characteristics, basic functions and use of the devices in the context of the processor.

8.1 OBJECTIVES

After study of this unit, the students ought to be able to:

- Explain the features of mouse and its classifications;
- List the basic characteristics, functioning and interfacing requirements of keyboard;
- Explain different types of monitors
- Explain video Cards, sound cards, and digital camera
- Explain different types of printers;
- Explain the basic characteristics of Modems and scanners;
- Explain the concept of voice-based input

8.2 MOUSE

Douglas C. Engelbart at Stanford Research Institute (now SRI International) proposed the basic concept of mouse in order to use it with computer system. Xerox Corporation is first organization which developed the first Mouse. It is hand-held hardware input pointing device, which gives user a cursor (pointing mark) on monitor screen and this cursor is used to send the input to computer system. The purpose of mouse is to detect two-dimensional movement relative to surface. Typically, mouse is available with two or three buttons but a single button is sufficient to control the movement of cursor. There exist different types of mice namely Wired, Wireless, Bluetooth, Trackball, Optical, Laser, Magic, USB etc.

The unit of mouse resolution is Counts Per Inch (CPI) which represents *the number of signals per inch of physical travel of mouse*. The value of CPI may range from 400 to 1600. The mouse also sends CPI data to computer with some frequency which is known as polling rate. The polling rate may range from 60 Hz to 1000 Hz. The large value of CPI will result in faster movement of cursor which requires sending much data to computer demanding high polling rate. Therefore, it will be difficult to control the accuracy for large value of CPI.

8.2.1 Classifications of Mice

The classifications of mice are based on connectors, number of buttons and position sensing technologies. Two classifications are discussed-

1. **Connectors:** This category deals with categorization of computer mice based on ports/physical channels which are used to connect the mouse and computers.
 - a) **Bus Mouse**-Bus was used to connect the first mouse with PC. Thus, it has been called as the bus mouse. It was used with IBM-compatible personal computers in its early days. A specialized bus interface was used to connect them with PC which was implemented via an ISA add-in card.
 - b) **Serial Mouse**-In Serial mouse, serial port was used for connection. It is basically an interface present physically on computer for communication. Bit by bit information goes in and taken out of the computer through this port. It is a male port of D-type having 9 pin (DB9M) which is found at the back of the motherboard. However, this category of mice is no longer in use.
 - c) **PS/2 Mouse**-The green colored PS/2 port is used to connect the mouse. Introduced in 1987, PS/2 uses 6-pin mini-din connector. It is the successor of serial connectors. PS/2 ports were first used in the PS/2 systems and they are still being used in modern designs. Green color of PS/2 port is for mouse and purple colored is for keyboard.
 - d) **USB Mouse**-USB mouse are same in terms of shape and appearance but the difference lies in terms of connector. They are connected to a USB port. USB stands

for universal serial bus has superseded the PS/2 ports, though some of the computers still have the PS/2 ports. This standard defines the cables, connectors and communication protocols for connection and communication between computers and attached peripheral devices. The objective of this standard was to standardize computer devices connection.

- e) **Wireless Mouse**-These are the modern mouse that does not require any cable for connection. Eliminating the clutter of cables, it provides a neat type of mouse to use. Some of its key features are- comfortable ergonomic design, improved battery life, Plug-and-Play, multi-function and wide compatibility
2. **Sensing Technology:** There are two types of mice based on sensing technologies i.e., mechanical mouse and optical mouse.
- a) Mechanical mouse has a rubber or metal ball in middle, which is used to control the movement of cursor. The sensors inside the ball detect the rotation of ball. When the ball rolls with the movement of mouse, it causes sensors to detect the rotation of ball along the two axes which consequently send signals to monitor screen. Figure 8.1(a) depicts the mechanical mouse.
 - b) Optical mice use light emitting diodes (LEDs), optical sensors and digital image processing. The optical mouse detects by sensing the changes in the reflected light. The change in reflected light is measured by analyzing the images and the cursor moves on screen accordingly. Figure 8.1(b) shows the optical mouse.

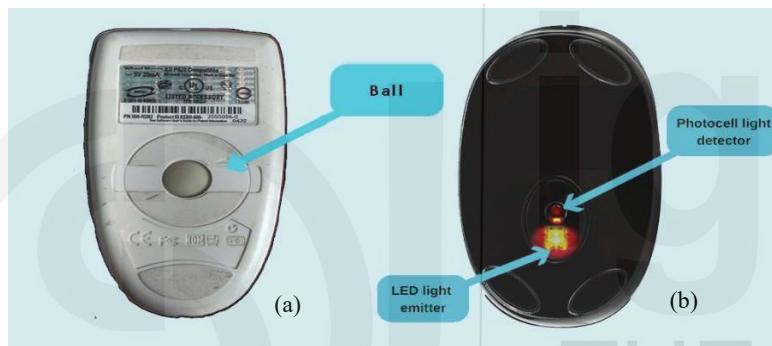


Figure-8.1: Difference between (a) Mechanical Mouse and (b) Optical Mouse

8.3 KEYBOARD

A keyboard is an input device, which is used since the inception of the computer systems. The keyboard allows manual input of alphabets, numbers, special characters, which are available as keys on a board. Figure 8.2 depicts a keyboard. In general, users use a keyboard to transfer a meaningful sequence of characters or numbers to a computer. Thus, a keyboard can be used to send input data into a computer from the external world.

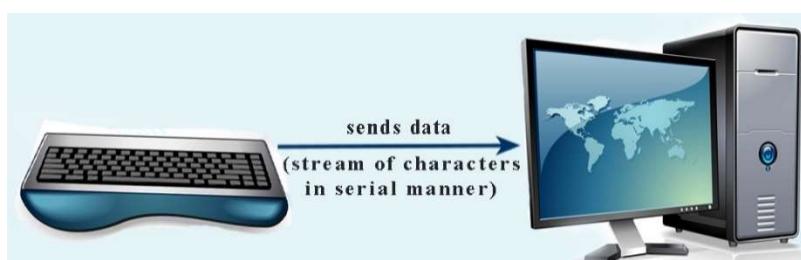


Figure-8.2: Overview of how Keyboard transfers data to the computer

8.3.1 Features of Keyboard

Some of the basic characteristics of keyboard are given as follows.

- **Keyboard Layout**

The layout defines the arrangement of the keys on the keyboard. This arrangement is mostly influenced by the typewriter. The keyboard layout is now available for many different languages of the world. A good layout is the one, which allows faster data input. Thus, in most cases, computer keyboard layout is identical to typewriter key layout, which was designed for enhancing the speed of data input. The standard keyboard layout for English is called QWERTY layout. QWERTY layout stands for the six top alphabets in the keyboard. The

QWERTY arrangement was created by Sholes, who invented typewriter. However, a computer in addition to alphabets is required to input numbers, special characters, and several shortcut commands. Therefore, keyboard has a very detailed arrangement of keys.

One popular keyboard designed by IBM for the personal computer had 101 keys. This keyboard's key layout is shown in Figure 8.3. This keyboard consists of key sets for alphabets in the middle, numeric key pad in the right for easy entry of numbers, function keys at the top name F1, F2, which are used as shortcut to various functions in different software, and a set of cursor keys to move the cursor on the screen. Later, a set of windows function keys were added to this design.

Another keyboard layout was designed by A Dvorak and William Dealey in 1936. Their layout was primarily designed for people who find typing with all fingers difficult and would like to type using only two fingers. It was expected that typing would be faster by using Dvorak-Dealey keyboard, as you can use both the hands while typing. You can find more details on this keyboard in the further readings. With the availability of newer mobile smart devices, there are many possibilities of designing new keyboards for specific areas, including better designed layout for regional scripts.

For the languages of our nation, Indic keyboard layout is a standard layout. This layout supports 12 Indian scripts.



Figure-8.3: IBM 101-key Keyboard layout

- **Keyboard Touch**

In addition to layout, the other important characteristic of a keyboard is the keyboard touch. The keys should be sensitive enough to capture the data being entered by the user. A good keyboard must be able to send data with speed. These days, in addition, to physical keyboards, touch screen keyboards are also available. Most of these keyboards provide features of predictive text and autocorrect, which facilitate data entry by the user.

- **Scan Codes**

When a key is pressed on a keyboard, it transfers the scan code relating to those keys to the processor. Scan code of every key is unique. The scan codes are used to communicate the desired data or action to the processor. A keyboard of processor is connected through interrupt driven I/O mechanism. Therefore, when a key or several keys are pressed together on the keyboard, it interrupts the processor, provided processor has enabled interrupts. The processor receives the scan code/codes and identifies the key or keys that were pressed using the scan code table stored in the ROM BIOS. In addition, the status byte that is associated with the keyboard informs the processor about the status of keys that are used as toggles, like, Caps lock, Num Lock, etc. But how does a keyboard identify that more than one keys are pressed together, such as CTRL & ALT & DEL. Interestingly, a keyboard sends two scan codes to the processor - one when key is pressed and second key is released, which were called Make and Break scan codes respectively. Thus, by knowing the timing of these make and break scan codes, processor determines, which keys are pressed together. A detailed discussion on scan codes is beyond the scope of this Unit.

8.4 MONITORS

A monitor is an output display device connected to processor and it displays the vision into the brain of the processor. It allows a user to graphically interact with the processor which is helpful to send output as well as to receive input to/from the user. Technically speaking, it is a display device which provides a graphical vision by converting the digital/analog signals into the visual form.

The monitor looks like a television set but both the devices are different with each other. The monitors have greater sharpness, lower input lag, higher refresh rates, color purity, and operate at higher frequencies in comparison to TV sets. The TV set consists of tuner or demodulator circuit to convert the signals.

Whenever users are interested to buy a monitor, they search for the better configurations in minimum possible budget. The configuration of monitors consists of display size, resolution, supported frequencies, the size of the picture tube and the type of connector used to connect to the computer. Monitors are manufactured by many manufacturers like LG, Samsung, Acer, Dell, HP, Lenovo, Sony, Asus, BenQ, etc. The monitors are available with different sizes i.e., 14'', 15'', 17'', 19'', 21.9'', 24'' or even higher. The monitors are also available with different screen form factor i.e., flat and curved screens. The monitors can be categorized into three categories based on the design technology. These categories are discussed in next sub-sections.

8.4.1 Cathode Ray Tubes

The cathode ray tubes monitors and television sets are based on the technology of Cathode ray tube (CRT). A CRT is a partly empty glass tube which consists of inert gas at low pressure. A negatively charged electrode which is known as Cathode/Electron gun is used to shoot beams of electrons at high speed towards a positively charged electrode (anode). The high-speed electrons impinge on the small phosphor coated screen. The screen consists of dots with three primary colors i.e., Red, Green and Blue. Indeed, there exists either one electron gun for the three colors (Red, Green and Blue) or one different electron gun for each color. Figure-8.4 depicts the cathode ray tube (CRT). The quality of image on CRT screen is influenced by following four factors:

1. **Phosphor coating:** The monitor screen is coated with phosphor (fluorescent material) which emits light when bombarded by electron gun. The phosphor coating is provided in inner surface of cathode ray tube. The coating affects the color and the persistence. The term persistence in the context of monitor is defined as the time for which the effect of a single hit on a dot on the monitor surface lasts.
2. **Shadow Mask/Aperture Grill:** It is the manufacturing technology for CRT monitors to produce clear and focused color images. It determines the resolution of the screen in color monitors. In shadow mask CRT, each pixel position consists of 3 phosphor color dots one for each red, green and blue. The Triad and inline arrangements are used for the alignment of color dots to produce good quality images. Another technology for same purpose is the aperture grille
3. **Electron Gun:** The electron gun must be efficient in its working. The high-quality electron gun affects the quality/sharpness of the image.
4. The screen glare and lighting of the monitor are also major factors to influence the quality of the image.

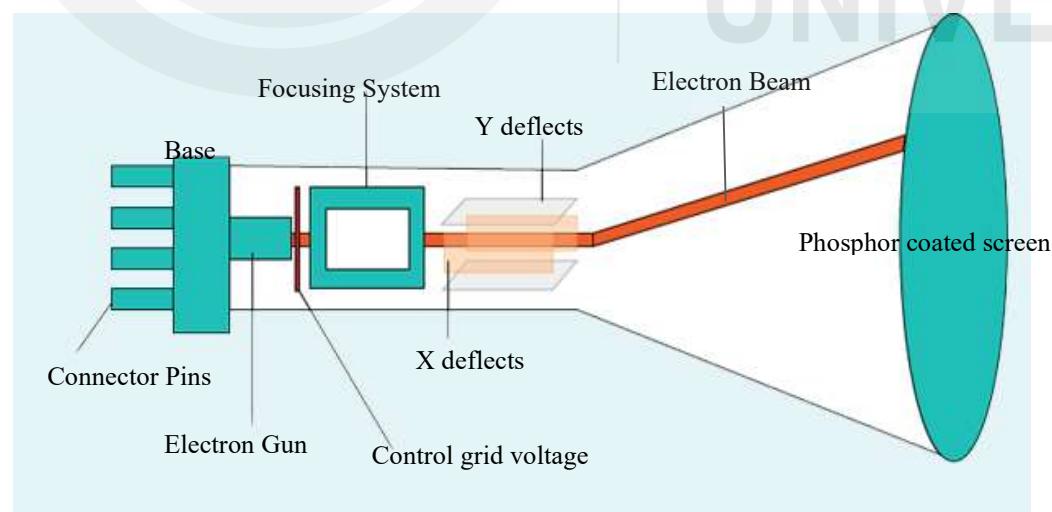


Figure-8.4: Cathode Ray Tube

8.4.2 LIQUID CRYSTAL DISPLAYS (LCDs)

LCDs were developed by the company RCA in the year 1960. An LCD is an electronically modulated optical device which employs light-modulating properties of liquid crystals combined with polarizers. The light is not emitted directly from the liquid crystals rather a

reflector is used to produce images in color or monochrome. An LCD blocks the light to display patterns. LCDs are lightweight screens and are mainly used for portable computers. They are known for low power consumption, good resolution and bright colors. The LCDs can be divided into following three categories based on display generation techniques.

1. **Reflective LCDs:** The display is generated by selectively blocking reflected light.
2. **Backlit LCDs:** The display is generated due to a light source behind LCD panel.
3. **Edgelite LCDs:** The display is generated due to a light source that is adjacent to LCD panel.

LCD Technology

To manufacture the LCD screens, Nematic technology is used. The molecules of liquid crystals (rod-shaped crystals) which are known as Nematic cells are used. Figure 8.5 depicts Nematic cells. The Nematic cells are packed (sandwich) between two thin plastic membranes. The Nematic cells have special properties i.e., these cells can change the polarity and bend of the light. The electric current is used to control these properties by applying the electric on grooves in the plastic membranes.

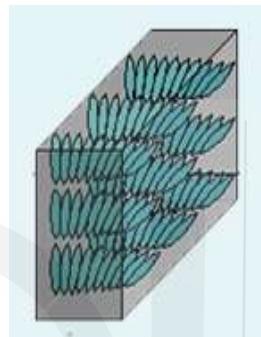


Figure-8.5: Nematic Cells

There exist two types of LCDs i.e., Passive matrix and Active matrix.

1. **Passive Matrix-** The passive matrix arrangement is most widely used technology due to low weight, high image quality, low cost and high response time. LCD panel consists of a grid of horizontal and vertical conductors. The conductors consist of Indium Tin Oxide to create a picture. Each pixel is located at the intersection of two conductors in the grid. Whenever current is passed through a pixel, it becomes dark.
2. **Active Matrix-** It employs Thin Film Transistors (TFT) and that's why known as TFT technology. In active-matrix arrangement, TFTs are arranged in a matrix on a glass surface and these TFTs are considered as pixels. These TFTs receives a small amount of white light, which is then enhanced by TFT to activate a pixel. The advantage of using TFTs is that they have faster response times, as they use smaller amount of light. However, the disadvantage of using TFTs are that they are difficult to fabricate, therefore, are costly. TFT LCD Display Technology is shown in the below Figure-8.6.

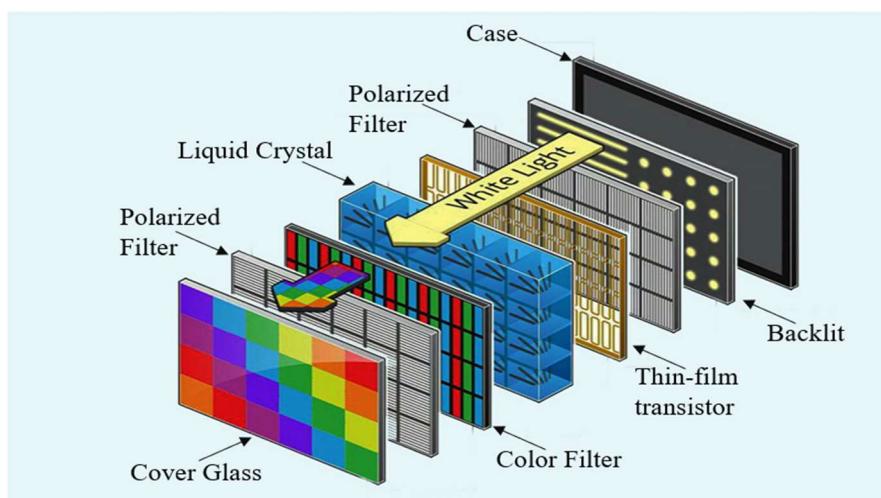


Figure-8.6: TFT LCD Display Technology

8.4.3 Light Emitting Diodes (LED)

The light-emitting diode (LED) monitors display is a flat screen, flat-panel computer monitors or television. It uses array of LEDs as pixels for displaying the videos. It is light weight and has a very short depth. LCD monitors and LED monitors differ only in terms of backlighting; typical LCD monitors uses fluorescent backlights whereas an LED monitor uses light-emitting diodes. The earlier LCD monitors used CCFL instead of LEDs to illuminate the screen. LED monitors offer many features/benefits namely slim design, flicker-free & brighter images, longer lifespan, broader dimming range, low power consumption, better color and picture quality etc. Figure 8.7 lists the benefits of LED monitors.



Figure-8.7 Benefits offered by LED monitors

Check Your Progress 1

1. Explain mechanical and optical mice.
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-
-

2. Discuss scan codes.
-
-
-

3. What are the differences between LCDs and LEDs?
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-
-

8.5 VIDEO CARDS

First, this section discusses a brief overview of graphic display technology with the primary focus on CRT monitors, before jumping to video hardware. The graphic display system is responsible for displaying bit-mapped graphics on monitor. Every image is formed using small dots which are known as *picture elements* or *pixels*. Figure 8.8 shows the pixels of an image. The description of each pixel is stored in the memory which is taken care by video system.

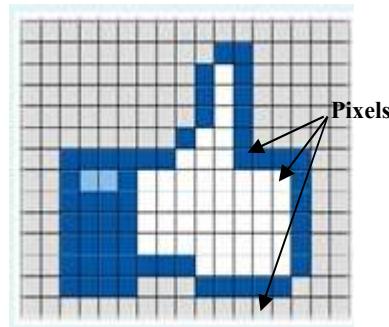


Figure-8.8 Bit-mapped Graphics Image

The display memory which is used to store the data for images is known as **frame buffer**. At any moment, the frame buffer consists of data for bit-map representation of current image on screen and the next image. The frames are read dozens of times per second and sent to the monitor using a cable in serial manner. Upon receiving the stream of data, the monitor forms and displays it on the screen by scanning raster movement from first up to down one row at a time. Based on this raster movement CRT, the monitor will illuminate its small phosphor dots. It is shown in Figure 8.9 and Figure 8.10.

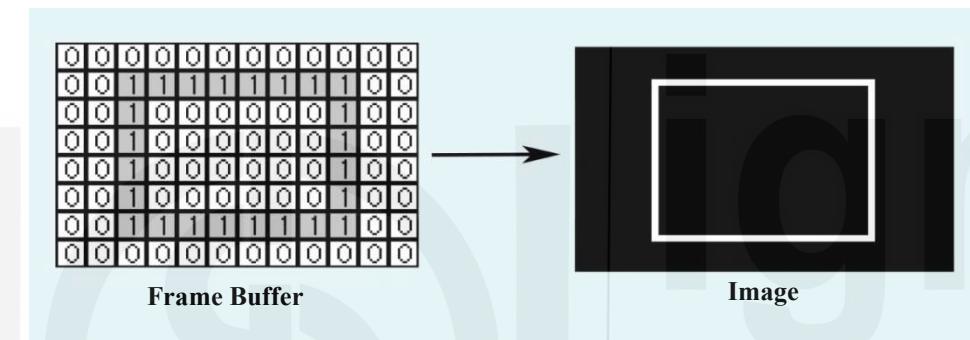


Figure-8.9: Frame Buffer and the corresponding image displayed on the system

The greater number of dots leads to better resolution of the image as well as the sharper the picture. The number of dots directly correspond to the richness of the image (or gray levels for a monochrome display) displayed by the system. The higher the number of colors, the more is the information required for each dot. Therefore, higher resolution and color depth of the system required bigger memory storage by the system to store the frame buffers.

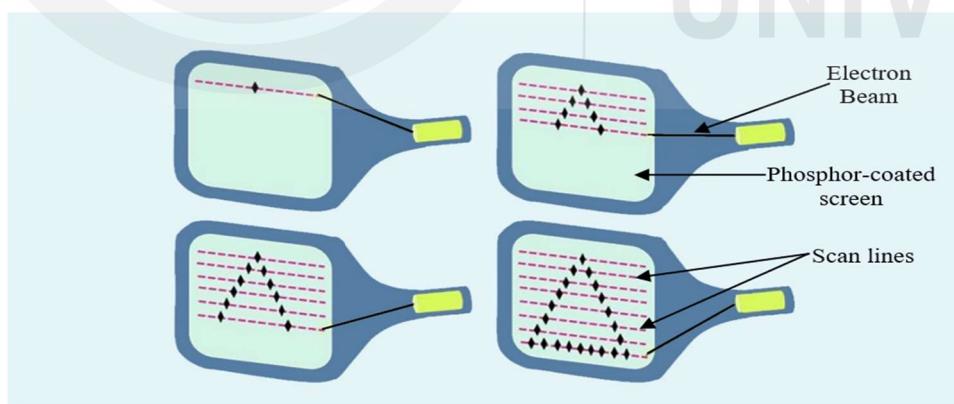


Figure 8.10: Raster Display

8.5.1 Resolution

The resolution is defined as the possible *sharpness or clarity of an image*. The resolution does not depend upon the physical characteristics of the monitor. It is measured in terms of number of pixels on a monitor. For instance, a standard VGA graphic display with resolution 640×480 consists of 640 and 480 pixels on horizontal and vertical axes respectively. In order to construct an image, different numbers of pixels are spread across both the axes of monitor screen. Higher is the resolution, sharper is the image due to large number of pixels.

The sharpness of an image on actual live-screen does not depend only on resolution but it is measured in the unit of dots-per-inch. These dots-per-inch are dependent on (i) size of the

image and (ii) resolution of the image. An image will be sharper on a smaller screen in comparison to bigger screen. For instance, an image may appear sharp on a 15" monitor and may be a little jagged on a 12" monitor display. Figure 8.11 shows a circle with different sharpness on different size monitor screens.

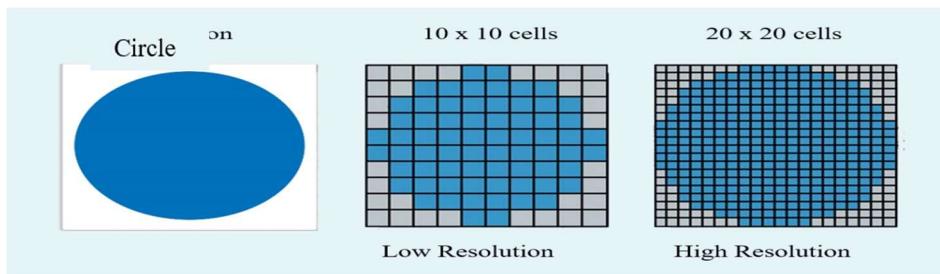


Figure-8.11: Circle with low and high resolutions

8.5.2 Color Depth

The image is constructed using stream of pixels. If the value of pixel is ‘ON’ and ‘OFF’, the pixel will be displayed in image on the screen as a pure black and white respectively. If single bit is assigned to a pixel, the image will be black and white. This system is known as **two-color system**. The pure black and white images can be converted to gray levels, which are different levels between white and black. This requires a greater number of bits to code each pixel. For instance-if you assign two bits to each pixel, four color levels are possible: White, Light Gray, Dark Gray and Black. In general, you need more than one bit to describe a pixel. Hence, one bit per pixel implies 2 colors or 2 gray-levels, 2 bits per pixel implies 4 colors or 4 gray-levels, and 3 bits per pixel implies 8 colors and so on. It means n bits per pixel imply 2^n gray-levels. For colored images color codes for the intensity of the three primary colors, viz. Red, Green and Blue, for each pixel are stored.

Color Depth can be understood as *the number of bits allocated to every pixel in order to store color code information*. Since every bit of a pixel corresponds to a specific color i.e., all bits at the same position for all pixels corresponds to the same color. Thus, the bits corresponding to same color can be regarded to form a plane and these planes are known as color planes. It is considered the color planes are stacked on top of each other which are helpful in deciding final color at each pixel. Thus, depending upon number of bits required for each pixel, there are 3 *Color Planes* (one each for Red, Green and Blue). Figure-8.12 depicts the 3-bits color display and 3 color planes.

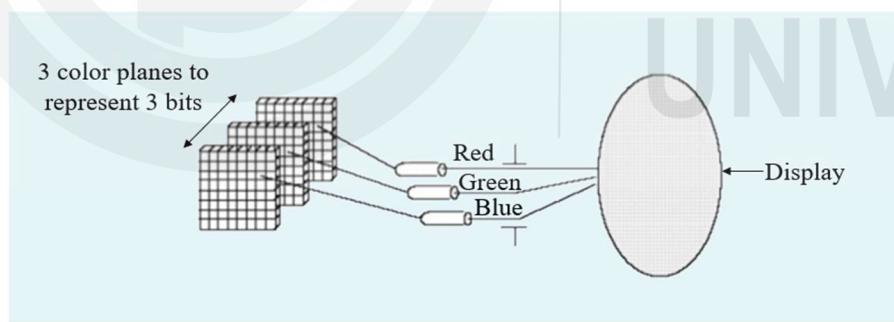


Figure-8.12: 3-bits Color Display with 3 color planes

The computer system with a 3-bit RGB color planes utilized 1 bit for each of the red, green and blue color components. Therefore, every color component can exist only in “ON” or “OFF” state. The three-bit RGB ‘ON’ or ‘OFF’ color components result in 8-colors consisting of three primary RGB colors i.e., red, green and blue; two pure colors i.e., white and black; and three complementary colors i.e., magenta, cyan, and yellow colors. The RGB values (ON” or “OFF”) of 3-bits color are given in Table 1 and the colors are displayed in Figure 8.13.



Figure-8.13: 8 possible colors for 3-bits Color Display

Table-1: 3-bit Color Display RGB values

Bit-values ('ON' or 'OFF')			Color
0	0	0	Black
0	0	1	Blue
0	1	0	Green
0	1	1	Cyan
1	0	0	Red
1	0	1	Magenta
1	1	0	Yellow
1	1	1	White

What Color depths are practically used?

If n is the color depth representing the total number of bits used to store one pixel, the number of colors will be 2^n (2 to the power n). Table 2 puts the most popular color modes.

Table 2: Popular Color Depths

Sr. No.	Color Depth(bits/pixel)	Color Mode
1	1	Monochrome
2	4	16-Colours
3	8	256-Colours
4	16	High Color
5	24	True Color

Human & Color Depth of Monitor Screen

The modern monitors can display up to a maximum of 262,144 (2^{18}) colors for 18 bits/pixel *Color Depth*. If different tones (color pitch) are allowed and eight bits are used for each RGB color, a total of 16.77 million colors (256 tones (R) x 256 tones (G) x 256 tones (B) = 16,777,216 colors) can be generated. On the other hand, human eyes are capable to distinguish maximum few million different colors. Thus, even if the monitor screens display colors more than few million, they would not be distinguished by humans. It also implies that the practical upper limit the 24-bit per pixel color depth. Since the number of possible colors produced by this color depth is more than the colors that could be distinguished by human eye, these colors are called the true colors. However, 24-bits color or true color systems have more color than possibly useful; the extra 8-bits are used by designers to store special effects information of the image. These extra bits formed a channel which is known as Alpha channel.

8.5.3 Video Memory

The video memory/frame buffer is used to store the video to be displayed. The quality of video display depends on the efficiency of the video system i.e., how quickly the frames are accessed and updated. Initially, a fixed area of RAM is allocated to the video memory. Later, video RAM along with video cards was introduced and it can be increased by placing additional video RAM under the unified memory architecture (UMA). UMA is helpful in reducing the cost of computer system. In UMA supported systems, an area of main memory is used as frame buffer/video memory which results in elimination of bus for video processing. Therefore, the computer system with UMA may be less costly.

Basically, UMA comes with on-board video card in the modern low-cost motherboards. The required resolution and color-depths are the deciding factor for the size of video memory/frame buffer. The minimum size of video memory can be calculated simply by multiplying the *Color Depths* and resolution of the monitor screen.

Let us solve a simple exercise. Assume a standard VGA monitor screen with resolution 800×600 and color depth value 8.

Number of Pixels	= $800 \times 600 = 480000$
Color Depth (8 or 2^3)	= 3-bits
Minimum Memory required	= 1,440,000 bits (180,000 bytes)
	= 180 KB

It implies that minimum RAM required for resolution 800×600 and 8 color depth is 180 KB. But the memory is available in exponential power of 2 and the next minimum size of memory is 256 KB. It implies that minimum size RAM required for resolution 800×600 and 8 color depth is 256 KB.

Now-a-days, a very odd-looking resolution i.e., 1152×864 has become popular. Could you guess why this is so? The following are the reasons behind its popularity. There are nearly one million (9,95,328) pixels for VGA with 1152×864 resolution. For color depth value 8, nearly 8 million bits or 1 MB memory is required. Further, human eyes perceive only a few million colors and this resolution is more suitable. In addition, a square pixel that has a ratio of 4: 3 allows easier programming.

Please note that the calculations shown above are not applicable for 3-D displays, which requires more memory due to the issues like “Double Buffering” and/or “Z-Buffering”.

8.5.4 Refresh Rates

The Video Controller (a special circuit) scans the frame buffer and reads rows one by one followed by sending this data in serial manner. On monitor screen, the electron beam starts scanning one-line at a time from left to right direction in order to create images. The *horizontal refresh rate or horizontal frequency* is the rate at which horizontal sweeps take place, while *vertical refresh rate or vertical frequency* is the rate at which vertical sweeps take place. The vertical frequency is also known as *refresh rate or frame rate*, as during a vertical sweep one complete frame is displayed. There exist several hundred rows in each frame and thus, horizontal frequency is hundreds of times higher than vertical frequency. The unit of horizontal frequency is KHz while the unit of vertical frequency is Hz.

Note: It is necessary to maintain the same frequencies between the monitor and video system for better quality of images. The compatible refresh rates are provided with the manual of the monitor.

8.5.5 Graphic Accelerators

An important chip associated with video card is known as Graphic Accelerator which is the replacement older technology known as *Graphic Co-Processor*. The graphic accelerator chip is a dedicated unit that executes in-built video functions of image construction and rendering, thus, releasing the microprocessor (main processor) from this work. The accelerator chips are optional but they are required due to noticeable impact on the performance of the computer, especially in graphics-intensive tasks such as- Rendering of 3D models and images, Video editing and Gaming. The graphic accelerator are needed if you need the following:

- Good support to 3-D graphics.
- Better resolution of graphics.
- Larger size of memory in the frame buffer.
- Better speed of display of drop-down menu.
- Good quality video playback.

The Graphics accelerators are widely used in industries such as- Motion pictures for special effects, Computer-aided design (CAD), Video games, 3D-effect etc.

What is a 3-D Accelerator?

The accelerator chip that has built-in ability to perform the mathematical calculations and execute the algorithms required for 3-D image generation and rendering, are called 3-D Accelerator. A 3-D image is just an illusion for human eyes which basically represents a projection of 3-D images/videos on 2-D monitor screens. This conversion takes place by projection and transparency effects, perspective effects, color depth and lighting effects. In addition, the following techniques can be used for creating 3-D images on 2-D screens: (i) Ray-Tracing, which traces the path of light rays emitted by a light source; (ii) Z-buffering, which uses a buffer to store the third axis, i.e., Z-axis positions and (iii) Double-Buffering, which uses two buffers in place of a single buffer.

8.5.6 Video Card Interfaces

A video card interface connects the video display to the computer system in order to improve the performance of the visual data you see on your screen. The video card can either be a separate component which is plugged into a slot on the motherboard of the computer or it may be integrated into the motherboard known as “onboard”. For isolated video cards, the connection is realized using either *Peripheral Connect Interface (PCI)* or *Accelerated Graphics Port (AGP)* bus.

- **PCI-** It is introduced by Intel and also known as *Peripheral Component Interconnect*. It is a high-speed common bus which is used to attach the computer peripherals to the motherboard. It is used to attach sound cards, network cards and video cards. The computers may use now some modern technologies like PCI-Express (PCIe), USB and AGP.
- **AGP-** It is also known as *Advanced Graphics Port*. It is a standard connector port used to connect the video card with the microprocessor and the main memory. It is a dedicated high-speed connection interface which is used by only graphics subsystem. AGP employs pipelining, isolated data and address buses and high-speed mode to improve the performance of graphics card.
In specific computers, the video card is directly connected with the microprocessor and may use direct memory access (DMA) I/O technique to send data from main memory to frame buffer.

8.6 SOUND CARDS

Multimedia has become an indispensable component of personnel computers to play different music files like MP3, MP4, WAV (Waveform audio file), WMA (Windows media audio), AAC (Advanced audio coding), FALC (Free lossless audio codec), OGG (The latest Free Sound format standard) etc.

The Sound card can either integrated into motherboard (built-in sound card) or connected through expansion slot. As you may study in computer networks, the analog sound waves could be converted into electrical form using electrical signals, which is used to compute the strength of sound. Usually, the analog audio signal is converted into digital audio (or digital signals) in the form of bits using sampling process. The microprocessor manipulates the digital audio bits and this data is sent to the sound card. The sound card converts this data into analog audio in order to play back through the speakers or headphones. The major functions of a modern sound card are as follows:

1. Conversion from digital sound signals to analog form to play back the sound.
2. Amplifiers to augment the strength of sound signals
3. Sound recording.
4. Sound synthesis.
5. Mixing of sound from various resources.

The three basic issues relating to sound cards are - Compatibility, Connections and Quality.

- **Compatibility:** Sound cards must be compatible for hardware as well as for software to meet the current industry standards/protocols. Some specific software like games need sound cards to be compatible with industry standards. You may refer to further readings to know about these standards.
- **Connections:** The sound card must provide different connections in order to perform various functions. It should provide MIDI port (Musical Instrument Device Interface) which allows user to produce music directly by using synthesizer circuit in the sound card. It also allows connecting a Piano keyboard to the computer system.
- **Quality:** There exist different sound cards which provide sounds with different qualities. The quality of sound differs due to the noise control, digital quality and the ranges of frequency supported by the sound card.

Check Your Progress 2

1. Explain the concept of a frame buffer in the context of Video Card interfaces.

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2. What do you understand by horizontal and vertical frequencies?

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3. Compute the minimum required video memory for 16 color depth and a monitor screen with the highest possible resolution 7680x4320.

4. Explain sound card. What are the functions of sound card?

8.7 DIGITAL CAMERA

The first digital camera was invented in the year 1975 by Steven Sasson at Eastman Kodak. Digital camera is a hardware device that takes images or record videos and stores them on memory as digital data on memory card instead of on photographic film in analog camera. In digital Camera, the images are stored in digital form and thus they can be reused later for different purposes like printing, editing etc. Since the digital camera takes images (input) and sends them to computer (output), it is considered as input as well as output device.

Figure 8.14 depicts the digital camera which is taking an image of subject (scene) under consideration. A digital camera consists of a sequence of lenses which focuses light on to a semiconductor device to create an image of a scene under consideration. The semiconductor device, in turn, records this light as digital images by using an in-built processor.

The semiconductor device is known as an Image sensor which converts light into electrical charges. Two types of Image sensors exist: Charge Coupled Devices (CCD) and Complementary Metal Oxide Semiconductor (CMOS). CCD is more popular and powerful kind of sensor in comparison to CMOS image sensors.

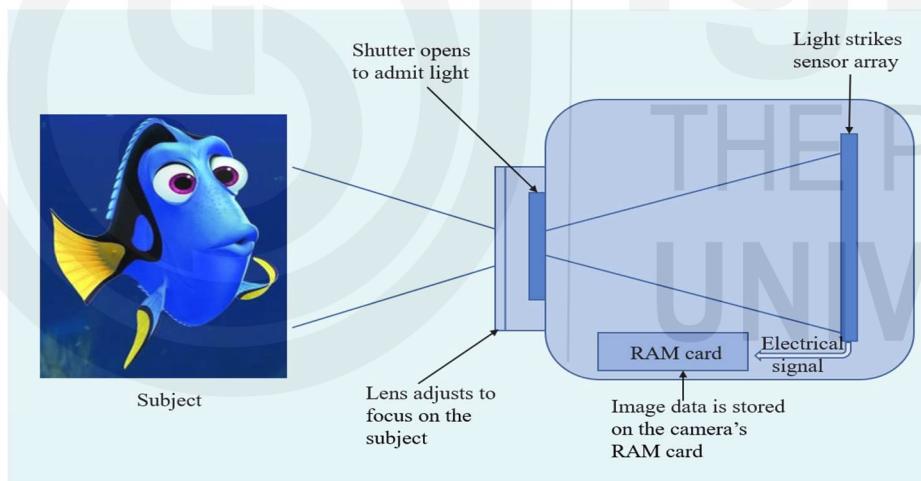


Figure-8.14: Working of a Digital Camera

The resolution (pixels) of digital camera is major deciding factor for the quality images. The higher the resolution, the better the digital camera is. The major benefits of a digital camera are as follows

- Allows user to see the videos and images immediately
- Allows user to store thousands of images/videos due to in-built memory
- Digital cameras are portable
- Allows user to edit images directly
- Allows flexibility in printing of desired images

8.7.1 Webcam

A digital camera without storage connected to computer system or network is referred as Webcam. In modern computers, the webcam can either be a separate component which is plugged into the computer or be an in-built integrated camera. In order to use webcams, it is necessary to install the required software. A webcam is an input device which is used to capture the images/videos and then send it to the computer. Webcams are used for videoconference or video calling or online meeting using Google Meet, Zoom, MS Team and others services.

8.8 Voice Based Input Device

Modern devices are capable to take human voice as input using speech recognition processes and execute applications accordingly. These devices are known as Voice Based Input devices. As compared to microphone, the speech recognition process of these devices recognizes human voice; converts it into machine-language and execute programs/applications accordingly. Figure 8.15 two devices which use speech recognition process to recognize human voice.



Figure-8.15: (a) Siri (b) Echo Dot 3 Smart Speaker with Alexa

The Voice Based Input Devices can recognize spoken words in two ways. The spoken words can either be recognized from a pre-defined vocabulary or be recognized from a known speaker after training of the input device. Whenever speaker utters a word from the pre-defined vocabulary, the Voice Based Input device may display the characters of monitor screen for verification by the speaker. However, some of these devices may process the speech without verification from the speaker. The process of speech recognition compares each uttered word with the words stored in pre-defined vocabulary table.

8.8.1 Siri

Apple Inc. offers a built-in, voice-controlled virtual assistant with most of products i.e., iPhone, iPad, Apple Watch or Mac (macOS Sierra and later) etc. This voice-controlled personal assistant is known as Siri. The users may talk to Siri as they talk to their friends. Siri allows a seamless interaction with Apple devices such that user speaks to Siri and Siri speaks to user. Siri helps users to get their job done after receiving user commands. Siri can help to open a file, send messages, open a web browser, open a website, booking a ticket, watch movies, and many other activities.

Siri works based on the Artificial Intelligence and Natural Language Processing fields. It consists of three components -Conversational interface, personal context awareness and service delegation systems. The conversational interface understands the user word-for-word manner and the semantic of text is produced using personal context awareness which is based on habit and language of the user. The service delegation helps to deliver services using built-in apps and their inner workings.

8.8.2 Alexa

Amazon offers virtual interactive voice-based AI powered digital assistant known as Alexa. This device has been designed in association with Alexa Voice Service (AVS) in order to simulate real conversations. “Alexa” is basically the “wake word” which is used to alert the device to start listening the voice to perform some tasks. Alexa employs intuitive voice commands to provide services to perform some specific tasks. Figure 8.15(b) depicts the Amazon Alexa. It is available as Echo speakers, smart thermostats, lamps and lights, and right on your phone through the Alexa app. Alexa can do quick math, play music, check news and weather updates, read emails and control many of the smart products.

Alexa also works based on the Artificial Intelligence and Natural Language Processing fields. It Alexa consists of speakers, microphone and a processor which is used to activate the device. It receives input and sends it to cloud where Alexa Voice services (AVS) interprets and understands the user input. Accordingly, AVS sends the appropriate output back to user device. The internet connection is the basic requirement to use Alexa.

8.9 PRINTERS

Printers are devices that accept textual and graphical contents as output from a computer system and print contents on paper in a controlled manner. The text and photographic images are produced by printers. Printers differ in technology used, memory, speed, resolution, color supported, size, hardware compatibility, cost and others factors. The present-day printer technologies include the dot matrix printer, Inkjet or tank printers, Laser Printers etc. to serve different needs. The available printers can be divided into two classifications-Impact and Non-impact printers. Figure 8.16 shows the classifications of printers.

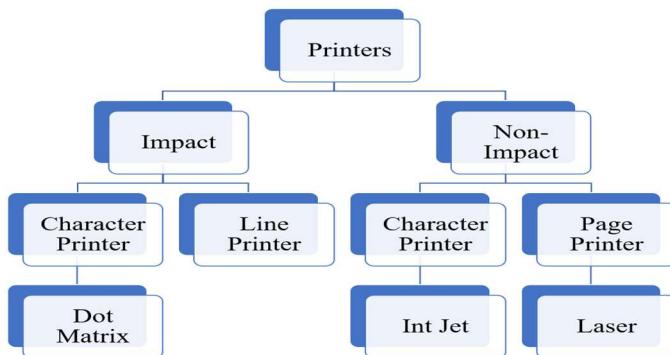


Figure-8.16: Classification of Printers

8.9.1 Impact Printers

Impact printer uses mechanical components for printing i.e., physical contact between printing head and paper. In order to print, the characters and graphics are produced on a paper by striking. They produce banging noise during printing. Impact printers can be divided further into two categories-Character and line printers. The character printers print only one at a time by striking on ribbon whereas line printers print one line at time. The line printers are fast and costly printer in comparison to character printers. Different types of impact printers are line printers, dot-matrix printers and, daisy-wheel printers.



(a)



(b)

Figure-8.17: (a) Dot-matrix printer (b) Local Railway ticket

Dot Matrix Printer

A Dot Matrix Printer (DMP) employs fixed number of pins to print on paper. The print head with many pins runs back and forth on the page and prints by striking against a sooted cloth ribbon in order to make a mark on paper. In DMP, the characters are using matrix of dots and the printed character is basically an accumulation of several dots on the paper. Therefore, the arbitrary font or graphics will be generated in each printing. Figure 8.17 shows a DMP and the local railway ticket printed by DMP.

8.9.2 Non-Impact Printers

In non-impact printer, no mechanical moving component is employed for printing. These printers don't strike or impact the ribbon for print. The technologies used by non-impact printers are chemical, inkjet, electrostatic, xerographic and laser. These printers work silently. Non-impact printers can be further divided into two categories-Character and Page printers. The non-impact character printers spray tiny drops of ink on to the without striking/physical contact with paper. The page printers print one full page at once. Different types of non-impact printers are inkjet, photo, and laser printers.

Laser Printer

Laser printers are very common page printers and print one page at once. Laser printers employ a focused light beam to transfer image or text onto paper. The modern laser printer use Resolution Enhancement Technology (RET) which is introduced by Hewlett-Packard. This technology smoothes the edges of character, diagonal lines etc. to produce better quality printouts. To produce high quality print, the basic requirement is the memory which increases as a square of resolution i.e., dots per inch (DPI). For 600 dpi, approximately 3.5 MB (600x600 bits) memory is required whereas 14 MB (1200x1200 bits) is required for 1200 dpi. Figure 8.18 depicts a single function monochrome laser printer.



Figure-8.18: Single function Monochrome Laser Printer

8.10 SCANNERS

A scanner is an electronic device which is used to capture images from tangible sources like photographic images, paper, posters, slides and others. The scanner converts the captured images into electronic form and stores them in computer memory in order to view/modify later. The scanner employs light sensors arranged in the form of an array in scan-able area. The light sensors detect differences in brightness of reflections from an image and then scan the source.

The existing scanners differ in many factors such as compatibility, resolution, support for different media and interfaces, etc. Two popular types of scanners are - *Flatbed Scanners* and *Handheld Scanners*.

Flatbed Scanners are used to scan high-resolution tangible images into detailed and sharp electronic images. The images are placed on a flat glass tray and movable sensors are used to scan the images. Figure 8.19(a) shows a flatbed scanner. Handheld scanners are used to scan the physical documents, and require good hand control for high quality scanning. These are the most portable and cheapest scanners and shown in Figure-8.19(b).

Scanning is used for many different applications. The scanners are used as Magnetic Ink Character Recognition (MICR) scanner in order to scan cheques and Bar-Code readers to identify different objects. One more application is *Optical Recognition of Characters (OCR)*. The *OCR* software use character/pattern matching algorithms to recognize characters and converts the scanned text to a text file. The *OCR* technology is very much useful in digitizing the ancient text written in old scripts.



Figure-8.19: (a) Flatbed Scanner (b) Handheld Scanner

8.10.1 Resolution

The resolution of scanner is the quality of image achieved by scanner. It is measured in *dots per inch (dpi)* and it indicates the number of dots per inch scanned horizontally and vertically.

It implies that the more is the dpi of a scanner, the more details a scanned electronic image will have. The scanned file size increases with increased resolution. There are various ways to measure the resolution.

Optical Resolution - The upper resolution limit of a scanner which is used to scan the images is known as optical resolution (hardware resolution). For example- if the optical resolution of a scanner is 300 dpi, it means 90000 (300x300) pixels per square inch can be captured by the scanner. The scanners may be available with optical resolutions of 300, 600, 1200, 2400 dpi or even more.

Interpolated Resolution- The resolution of image can be augmented using interpolation algorithms and this resolution is known as Interpolation resolution. The interpolation technique employing complex algorithms is used to add intermediate pixels based on the properties of surrounding pixels. The interpolation technique results in increased size of scanned images but it provides smoother and high-quality images without adding any additional information. For instance- if the optical and interpolated resolutions are 300x300 dpi and 4800x4800 dpi respectively. This implies 90000 pixels per square inch can be captured by the scanner while the interpolation algorithm can add 15 pixels between every pair of pixels to increase the dpi of image.

8.11 MODEMS

Modem (i.e., modulator-demodulator) is a device that connects two computers using telephone lines in order to exchange data with each other. The modem receives digital signals from computer, puts them into analog circuit by modifying a constant wave (known as carries) and then analog signals are transmitted over the telephone lines. This process is known as modulation. It occurs whenever user connects to the Internet. Demodulation is the inverse process of modulation in which the digital signals are derived from the modulated wave. It occurs whenever user receives data from a website, which is then displayed by your browser. Figure 8.20 shows the process of modulation and demodulation performed by the modem. You may refer to further readings for more details on modulation and demodulation techniques.

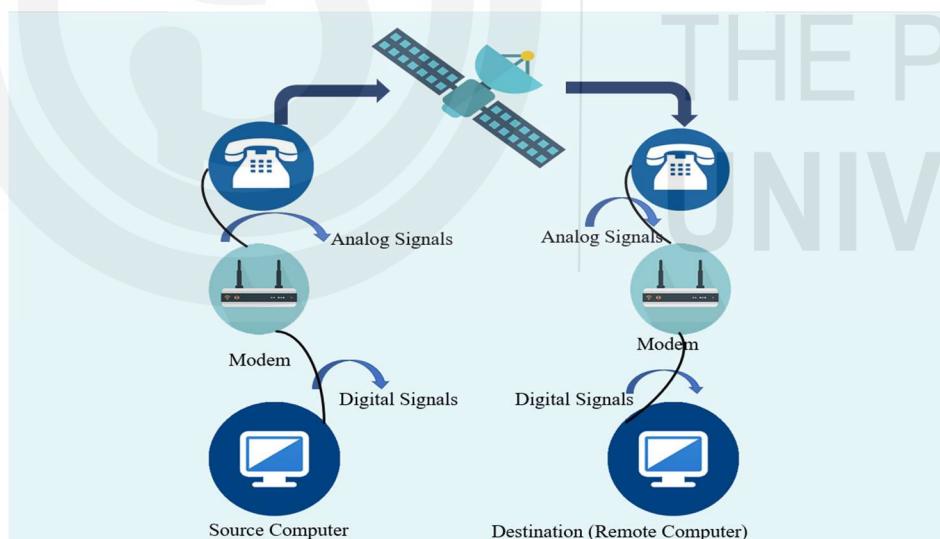


Figure-8.20: Modulation and Demodulation process by Modem

Check Your Progress 3

1. Explain webcam and its major benefits.

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2. How characters are recognized by voice-based input devices?

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3. Compare impact and non-impact printers.

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4. Explain Interpolated resolution.

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5. How many pixels can be captured by a scanner with 600 dpi optical resolution?

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8.12 SUMMARY

This unit discussed several input/output devices and the technologies behind them. This unit covers different input device along with different components or types or features. It is discussed Mouse and classifications of Mice, Keyboard along with its features, voice-based input devices, scanners and webcam its different types. This unit also discussed output devices along with other components or types or features. It discussed computer monitors with three different categories i.e., CRT, LCD and TFT screens. The printers with their different categories have also been discussed. The video cards have also been discussed with their characteristics like resolution, color depth, video memory, refresh rates, graphic accelerators and video card interfaces. It also discussed sound cards with its functions and different characteristics. At last, the modem device is discussed in brief manner.

8.13 SOLUTIONS/ ANSWERS

Check Your Progress 1

1. Mechanical mouse has a rubber or metal ball in middle, which is used to control the movement of cursor. The sensors inside the ball detect the rotation of ball. When the ball rolls with the movement of mouse, it causes sensors to detect the rotation of ball along the two axes which consequently send signals to monitor screen. Figure 8.1(a) depicts the mechanical mouse.

Optical mice use light emitting diodes (LEDs), optical sensors and digital image processing. The optical mouse detects by sensing the changes in the reflected light. The change in reflected light is measured by analyzing the images and the cursor moves on screen accordingly. Figure 8.1(b) shows the optical mouse.

2. Scan Codes-When a key is pressed on a keyboard, it transfers the scan code relating to those keys to the processor. Scan code of every key is unique. The scan codes are used to communicate the desired data or action to the processor. A keyboard of processor is connected through interrupt driven I/O mechanism. Therefore, when a key or several keys are pressed together on the keyboard, it interrupts the processor, provided processor has enabled interrupts. The processor receives the scan code/codes and identifies the key or keys that were pressed using the scan code table stored in the ROM BIOS.
3. LCD monitors and LED monitors differ only in terms of backlighting; typical LCD monitors uses fluorescent backlights whereas an LED monitor uses light-emitting diodes. The earlier LCD monitors used CCFL instead of LEDs to illuminate the screen.

Check Your Progress 2

1. The display memory which is used to store the data for images is known as frame buffer. At any moment, the frame buffer consists of data for bit-map representation of current image on screen and the next image. The frames are read dozens of times per second and sent to the monitor using a cable in serial manner. Upon receiving the stream of data, the monitor forms and displays it on the screen by scanning raster movement from first up to down one row at a time. Based on this raster movement CRT, the monitor will illuminate its small phosphor dots.
2. Refer text 8.5.4
3. The minimum required video memory is computed as follows-

Number of Pixels	$= 7680 \times 4320 = 33,177,600$
Color Depth (16-colours = 2^4)	= 4-bits
Minimum Memory	= 132,710,400 bits (16,588,800 bytes)
	= 16,200 KB = 15.82 MB

4. Sound card is used to convert digital audio data into analog audio in order to play back through the speakers or headphones. The Sound card can either integrated into motherboard (built-in sound card) or connected through expansion slot. The major functions of a modern sound card are as follows:
 - a) Conversion from digital sound signals to analog form to play back the sound.
 - b) Amplifiers to augment the strength of sound signals
 - c) Sound recording.
 - d) Built-in synthesizer
 - e) Sound mixer circuits.

Check Your Progress 3

1. A digital camera without storage connected to computer system or network is referred as Webcam. In modern computers, the webcam can either be a separate component which is plugged into the computer or be an in-built integrated camera. The webcam can be used for video conference or video calling or online meeting using Google Meet, Zoom, MS Team and others services.
2. These devices recognize spoken words in two ways. The spoken words can either be recognized from a pre-defined vocabulary or be recognized from a known speaker after training of the input device. Whenever speaker utters a word from the pre-defined vocabulary, the Voice Based Input device may display the characters on monitor screen for verification by the speaker. However, some of these devices may process the speech without verification from the speaker.
3. Impact printer uses mechanical components for printing i.e., the characters and graphics are produced on a paper by striking whereas non-impact printer don't strike or impact the ribbon to print on paper. Impact printers produce banging noise during printing while non-impact printers work silently.
4. Refer text 8.10.1
5. The scanner can capture 360000 pixels per square inch