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Introduction

What is Computer Graphics?

- **It is the technology for presenting information.**

- **It is the branch of computer science which mainly deals with the formation, manipulation, storage and display of the image , adding additional information and graphical effects such as shading, tilting, filling of colors, morphing etc.**

Functions of Computer Graphics

1. Creation of object by taking data from input coordinates or by free hand or specific input from keyboard.

2. Scanning from existing drawing.

3. Manipulation such as correction, modification, changing shapes, size, color etc.

4. Production(mainly printing and plotting)

Characteristics of Computer Graphics

- **Interactive nature and preview capability of computer processing systems**

- **CG provides joy and adventure in the form of cartoon movies and video games.**

- **High Resolution displays**

- **To run the packages , it requires proper training.**

- **The final picture displayed is the net result of creativity inside the human beings.**

Applications of Computer Graphics

- **Building design and construction:** It provides very useful tools for generating architect's drawings and visualizing structures. Computer can make various images of building from different angles.

- **Electronic design:** The design of PCB's were earlier done by hand but now a days, engineers work on the video screen and designs the PCB and generate hardcopy output for further reference.

Applications of Computer Graphics

- **Mechanical design:** As machines are simply complex arrangement of mechanical parts. Constructive solid geometry technique is used to design different parts on computer using graphics software.
- **Entertainment and animation:** Computers are used in making cartoon animation films.

Applications of Computer Graphics

- **Cartography:** CG is used to produce accurate and schematic representation of geographical and other natural phenomena from measurement data. For eg. Graphics maps, oceanographic charts, weather maps, population density maps etc.

- **Arts and commerce:** CG is used to produce pictures that express a message and attract attention like teleshops, transportation, hotels etc.

Applications of Computer Graphics

- **Aerospace industry:** Aircraft designer use computers to simulate the airflow over wings. The air pattern around the wings are displayed on the graphics monitor. Simulated software are also used to train the pilots.

- **Medical technology:** Computerized Axial Tomography(CAT)is used to compose the three dimensional model of the brain by taking multiple X-rays of it.

Applications of Computer Graphics

- **Graphic/Data Representation:** Graphic representation is helpful in all areas- from catching person's attention through an advertisement, creating histograms, bar and pie charts.

Classification of Applications Areas

All the applications may be categorized into the following four groups according to the manner of representation:

1. **Dimensional**

The images of objects can be represented in either 2D or 3D form. Examples of 2D representations are line drawings, gray scale images and color images.

Classification of Applications Areas

2. Type of Interaction

Type of interaction determines the user's degree of control over an image. Example are offline plotting, interactive plotting, real-time animation graphics and interactive designing.

Offline plotting is done with a predefined database produced by other application programs.

In interactive plotting, the user controls graphics by changing the parameters of the object.

In real time application graphics, the user controls the graphics in real time, with predefined data or real time calculation such as graphics systems are used in scientific visualization and flight simulatiors.

Classification of Applications Areas

3. Role of Picture

In one application, the graphics used is the end product as in case of cartography, animation and art works. In another application CAD, the drawing is merely a representation of the geometric properties of the object being designed and anlyzed.

4. Logical or Temporal Relationship

The relationship between the objects and their pictures may be logical or temporal. For example: the user may deal with only one picture at a time or user may deal with a time varying sequence of related pictures.

Display Devices

- **Video Display Devices**

  Video monitors are the primary output devices in a graphics system and the operation of these monitors is based on standard cathode-ray-tube (CRT) design.

1. Refresh Cathode Ray Tube
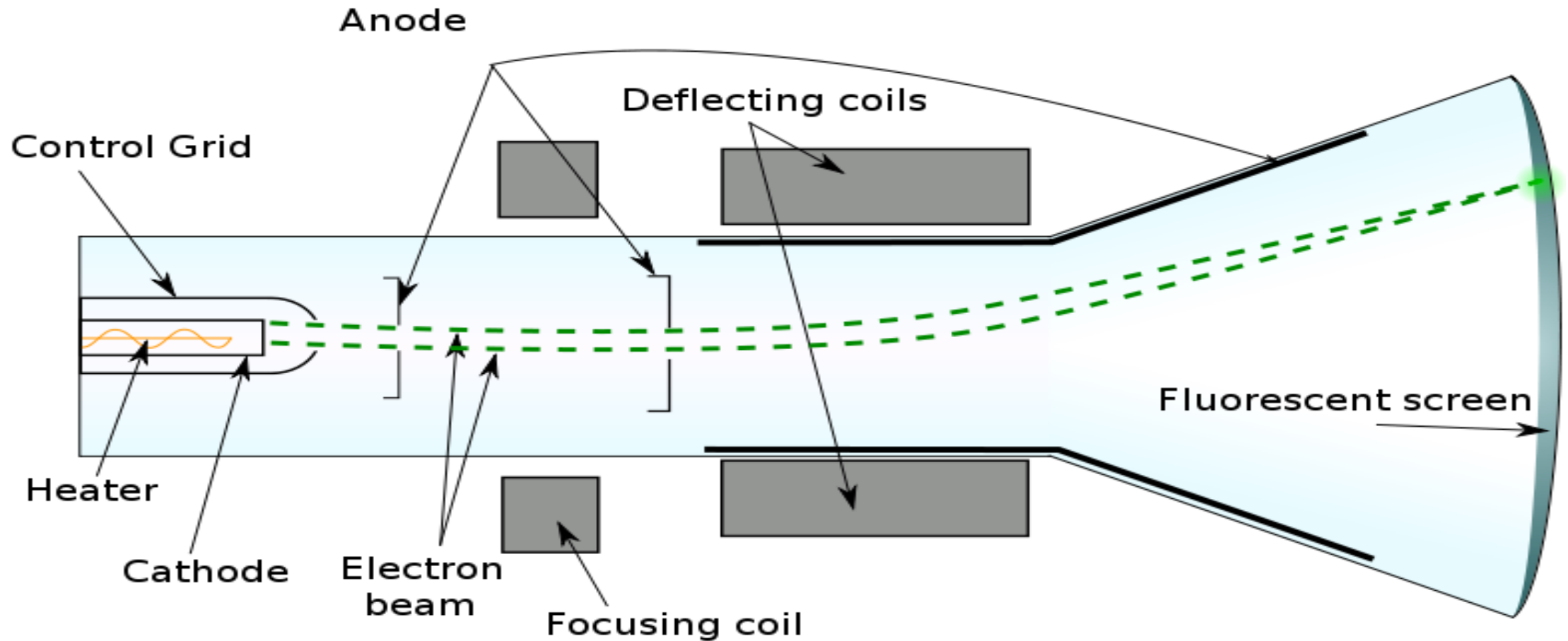
Fig.: Basic design of a magnetic deflection CRT

1. Refresh Cathode Ray Tube Contd..

- **A CRT is an evacuated glass bottle, with a heating element on one end and a phosphor coated screen on the other. When a current flows through this heating element, called a filament, the conductivity of the metal filament is reduced due to the high temperature.**

- **A beam of electrons or cathode rays emitted by an electron gun passes through focusing and deflection systems that direct the beam towards specified position on the phosphor coated screen.**

- **The phosphor then emits a small spot of light at each position contacted by the electron beams, but this light fades very rapidly.**

1. Refresh Cathode Ray Tube Contd..

- **Therefore to maintain the picture on the screen or to keep the phosphor glowing, we can redraw the picture rapidly by quickly directing the electron beam back over the same points. This type of display is called *Refresh CRT.***

- *The Electron gun in CRT consists of*
    - *1. The heated metal cathode*
    - *2. A control grid*

- **The intensity of the electron beam is controlled by setting voltage levels on the control grid which is a metal cylinder that fits over the cathode. The CRT is refreshed to avoid flicker at least 60HZ, but exact number depends upon the image intensity, ambient lightning and wavelength, size of the screen**

1. Refresh Cathode Ray Tube Contd..

- **Intensity level for individual screen positions can be specified with graphics software commands.**
- **The focusing system in a CRT is needed to focus the electron beam to converge into a small spot, as it strikes the phosphor otherwise the electron will repel each other and the beam would spread out as it approaches the screen.**
- **Focusing is accomplished with either electric or magnetic fields.**
- **Electrostatic focusing is commonly used in television and computer graphics monitors.**

1. Refresh Cathode Ray Tube Contd..

- **Additional focusing hardware is used in high precision systems to keep the beam in focus at all screen positions.**

- **Persistence: Different kinds of phosphors are available for use in CRT, besides color a major difference between phosphors is their persistence. Therefore persistence is defined as how long the electrons continue to emit light after the CRT is removed. We can further refine persistence as the time it takes the emitted light from the screen to decay to one tenth of its original intensity. Lower persistence phosphors require higher refresh rates, the graphics monitors are constructed with persistence range of 10 to 60 microseconds.**

1. Refresh Cathode Ray Tube Contd..

- **Resolution:** The maximum no. of points that can be displayed without overlap on a CRT is referred to as the resolution. The resolution of a CRT is dependent on the type of phosphor, the intensity to be displayed and the focusing and deflection systems. The typical resolution of on high quality systems is **1280X1024.The** high resolution systems are often referred to as High definition systems. The resolution Is measured in terms of number of scan lines ,the number of pixels per scan lines and number of bits per pixel.

# 1. Refresh Cathode Ray Tube Contd..

- **Aspect Ratio: The ratio of vertical points to the horizontal points necessary to produce equal length lines in both the directions on the screen is called aspect ratio. Aspect ratio = ¾ means: vertical line with 3 points is equal in length to horizontal line of 4 points.**

2. Raster Scan Display

- **Raster is an acronym of matrix. In a Raster Scan system, the electron beam is swept across the screen , one row at a time from top to bottom.**

- **As the electron beam moves across each row the beam intensity is turned on or off to create a pattern of illuminated spots.**

- **Refresh buffer or Frame buffer: The picture definition is stored in a memory area called refresh buffer. This memory area holds the set of intensity values for all screen points. Stored intensity values are then retrieved from the refresh buffer and painted on the screen one row at a time.**

2. Raster Scan Display

Contd..

(a)   (b)

(c)   (d)
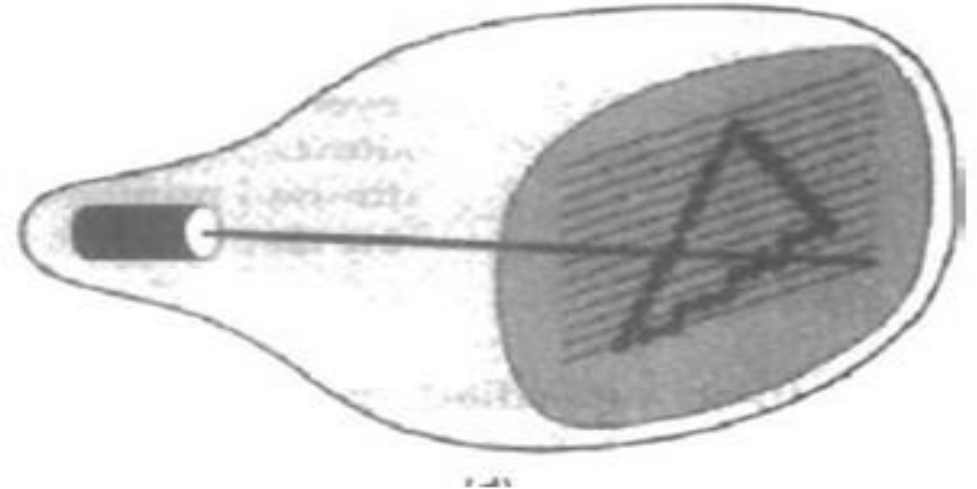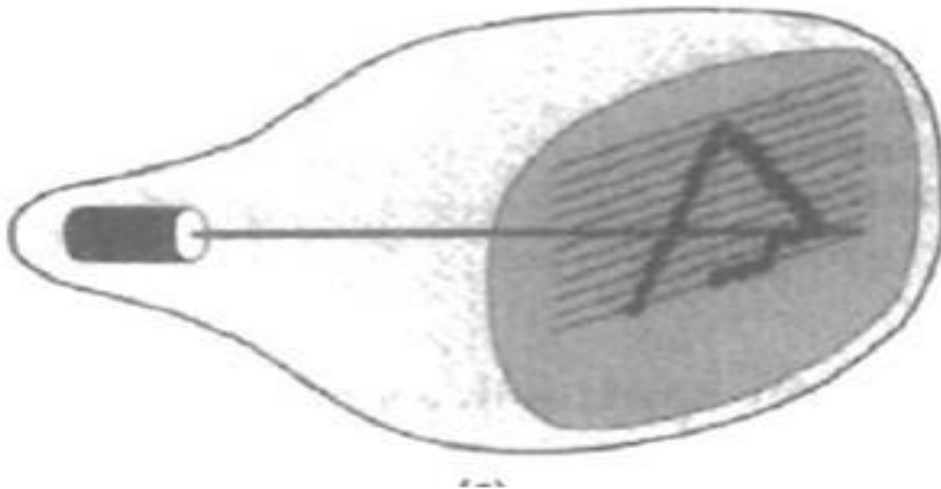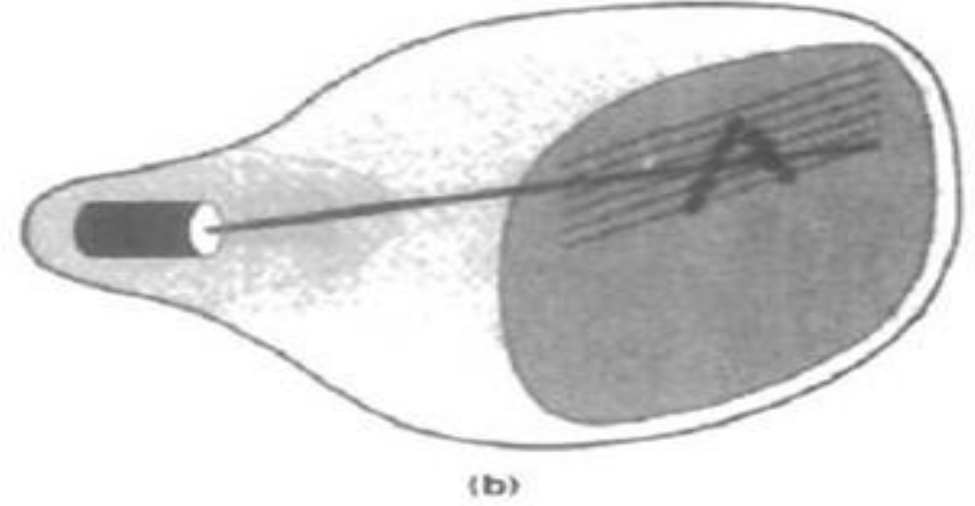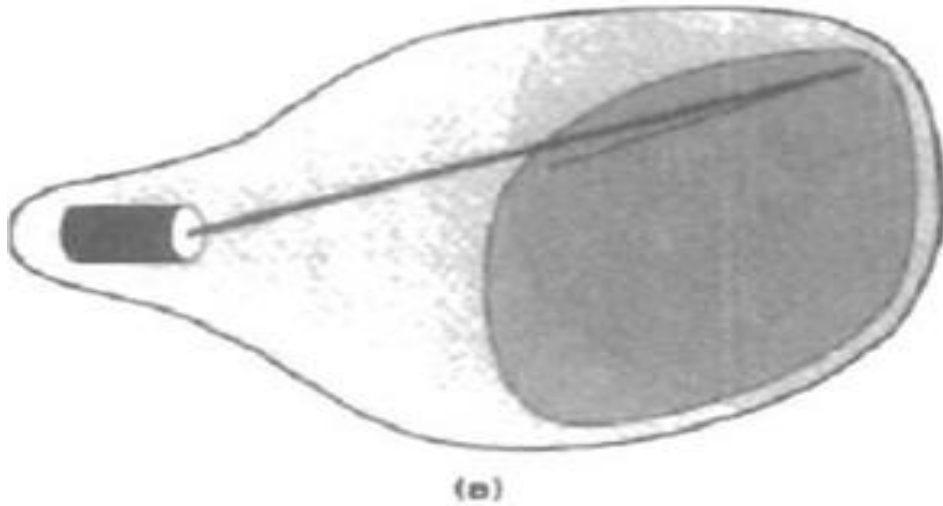
2. Raster Scan Display Contd..

- **It is well suited for realistic display of scenes and television sets and printers.**
- **In black and white system each screen pt. is either on or off, so only a bit per pixel is needed to control the intensity of screen positions.**
- **But additional bits are required to display variation in color and intensity .**
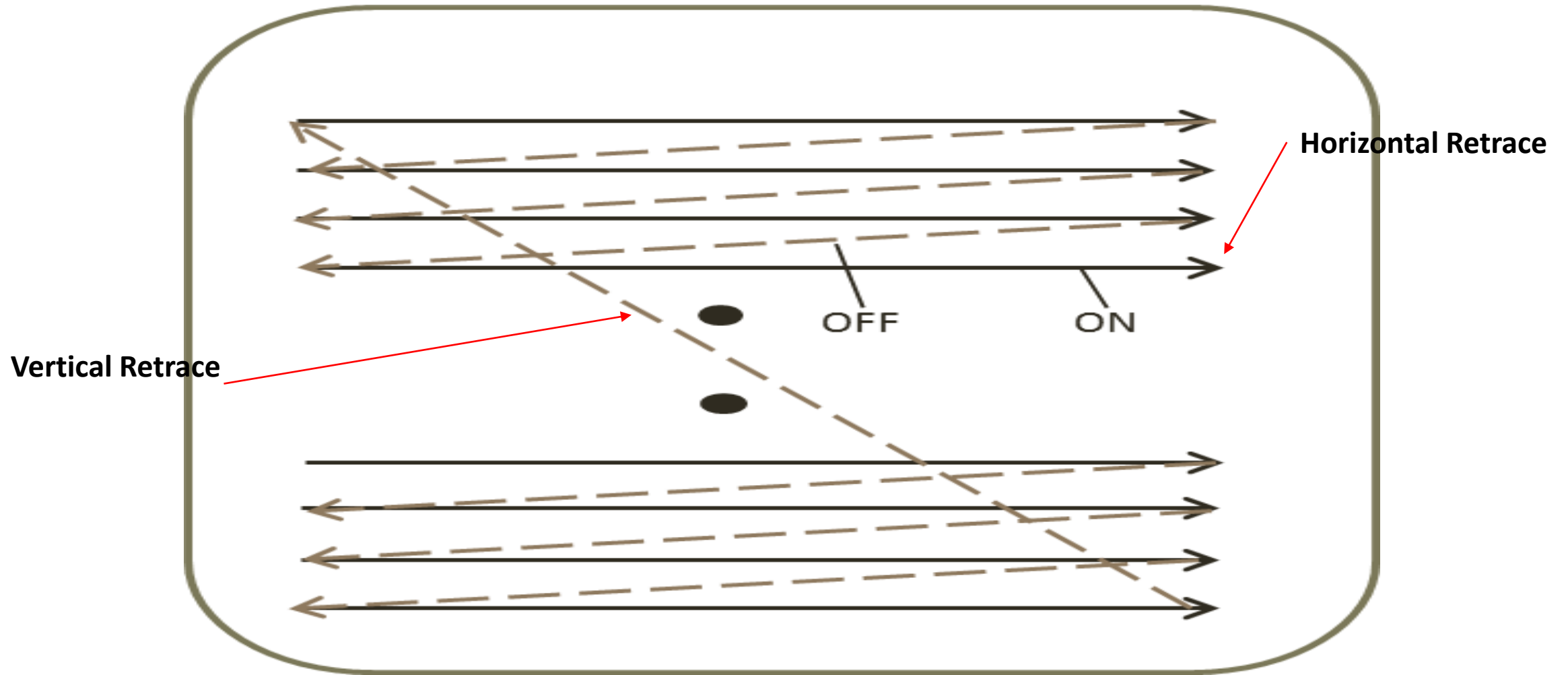
2. Raster Scan Display Contd..

- **In black & white systems frame buffer is called a bitmap whereas for systems with multiple bits are known as pixmap.**
- **Refreshing rate: The frequency at which the content of the frame buffer is sent to display monitor is called refreshing rate.**

2. Raster Scan Display Contd..

- **Horizontal Retrace:** The return of the electron beam to the left of the screen after refreshing each scan line is called horizontal Retrace.

- **Vertical Retrace:** At the end of each frame , the electron beam returns to the top left corner of the screen to begin the next frame is known as vertical retrace.

2. Raster Scan Display Contd..

2. Raster Scan Display Contd..

- **Interlacing: On some raster scan systems, each frame is displayed in two passes using an interlaced refresh procedure.**
- **Pass-I: In the first pass, the beam swaps across every other scan line from top to bottom.**
- **Pass-II: Then after the vertical retrace, the beam sweeps out the remaining lines.**
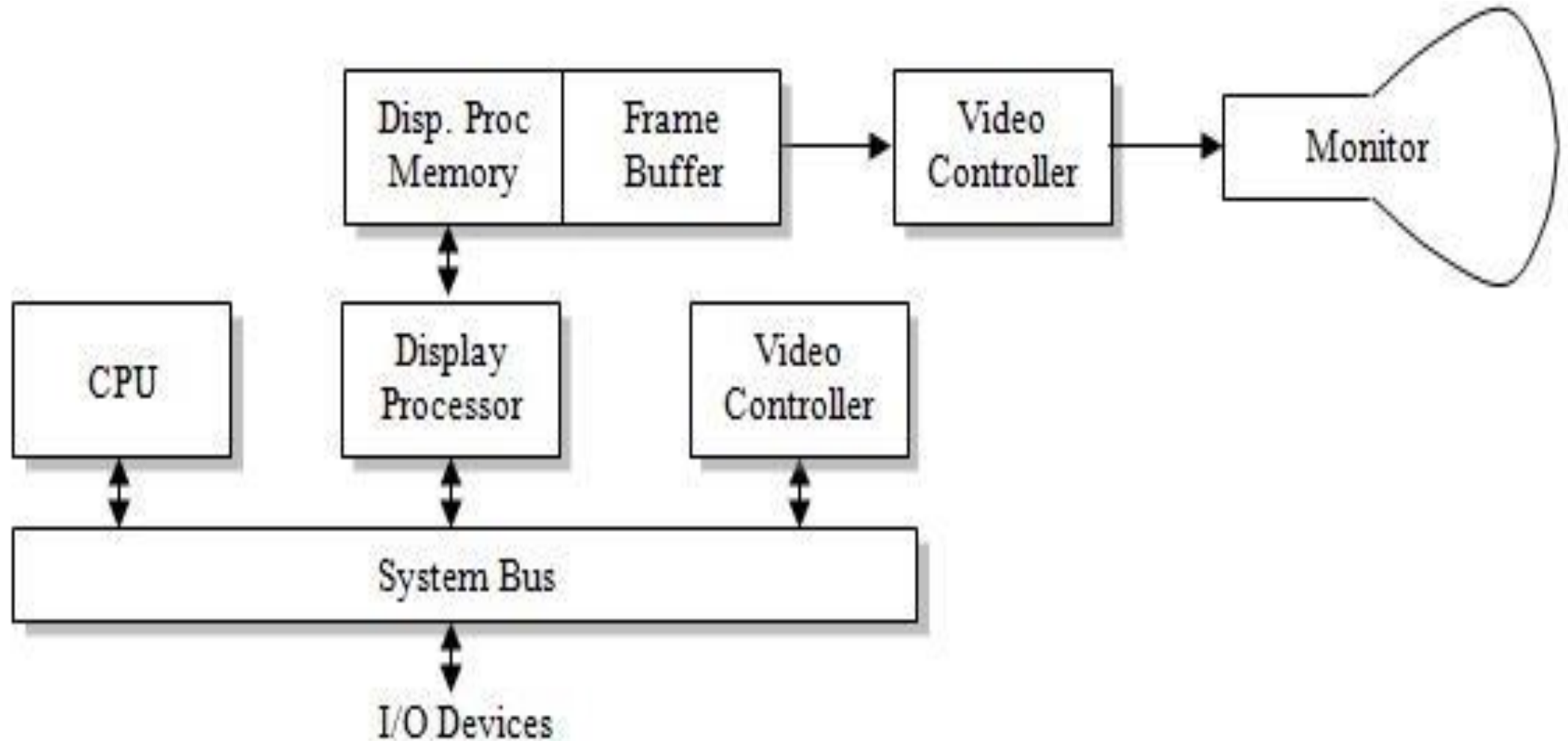
2. Raster Scan Display Contd..

- **Interlacing helps us to see the entire screen displayed in one half the time, it would have taken to swap across all the lines at once from top to bottom.**

- **Advantage: This is an effective technique for avoiding flicker, providing that adjacent scan lines contain similar display information.**

Architecture of a Simple Raster Graphics system Contd..

Architecture of a Simple Raster Graphics system   Contd..

- Interactive raster-graphics systems typically employ several processing units. In addition to the CPU, a special purpose processor called the video controller or display controller is used to control the operation of the display device.

- The figure shows the organization of a raster system. The frame buffer can be anywhere in the system memory, and the video controller access the frame buffer to refresh the screen.

Architecture of a Simple Raster Graphics system Contd..

Video Controller

- A fixed area of the system memory is reserved for the frame buffer, and the video controller is given direct access to the frame buffer memory. The co-ordinates of the graphics monitor starts at the lower left screen corner. Positive x values increasing to the right and y values increasing from bottom to top.

- The diagram shows the refresh operation of video controller. Two registers are used to store the co-ordinates of the screen pixels. Initially x=0 and y=ymax. The value stored in the frame buffer corresponding to this pixel position is retrieved. And the x value is incremented by 1 and the corresponding y value is retrieved, like that the pixel values are retrieved line by line. Once the last pixel is reached again the registers are reset to initial value to repeat the process.

Architecture of a Simple Raster Graphics system Contd..

Display Processor

- The purpose of the display processor or graphics controller is to free the CPU from the graphics chores. In addition to the system memory a separate display processor memory area can also provided.

- A major task of the display processor is digitizing a picture definition given in an application program into a set of pixel-intensity values for storage in the frame buffer. This digitization process is called scan conversion. Lines and other geometric objects are converted into set of discrete intensity points. Characters can be defined with rectangular grids, or they can be defined with curved outlines.

- To reduce the memory space required to store the image information, each scan line are stored as a set of integer pairs. One number of each pair indicates an intensity value, and the second number specifies number of adjacent pixels the scan line that is also having same intensity. This technique is called run-length encoding.

Architecture of a Simple Raster Graphics system   Contd..

- **Video Controller: It is a special purpose processor in an interactive raster graphics system. It is used to control the operation of display devices.**

- **The Frame buffer can be anywhere in system memory and the video controller accesses the frame buffer to refresh the screen.**

- **After cycling through all the scan lines & pixels, video controller resets its registers to the first pixel position on the top of the scan line.**
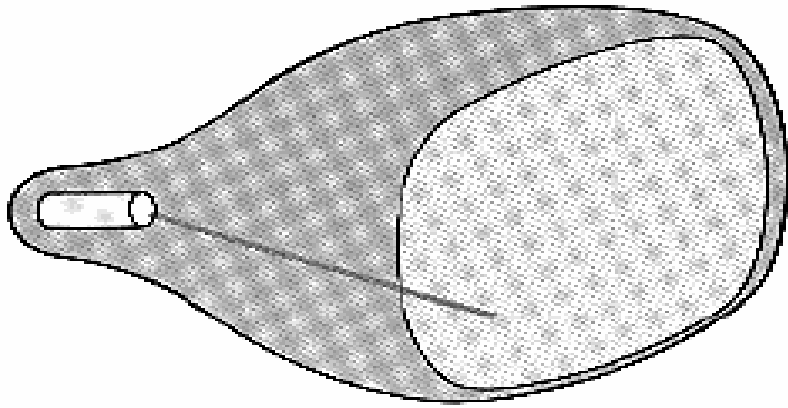
3. Calligraphic or Random Scan Display Systems

- **In a random scan display unit, the CRT has the electron beam directed only to the parts of the screen where a picture is to be drawn.**

- **They are also called vector/stroke writing/ calligraphic displays.**

- **The component lines of a picture can be drawn & refreshed by a random scan system in a specified order.**

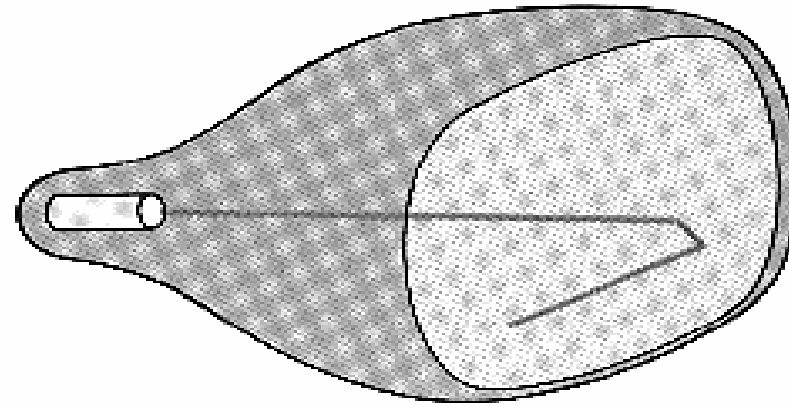# 3. Calligraphic or Random Scan Display Systems

- **A pen plotter operates in a similar way and is an example of a random scan.**

- **Refresh rate in a random scan display depends upon the no. of lines to displayed.**

- **Picture definition is now stored as a set of line drawing commands in an area of memory referred to as refresh display file/ display list/ display program/ refresh buffer.**

Calligraphic or Random Scan Display Systems Contd..

(a)

(b)
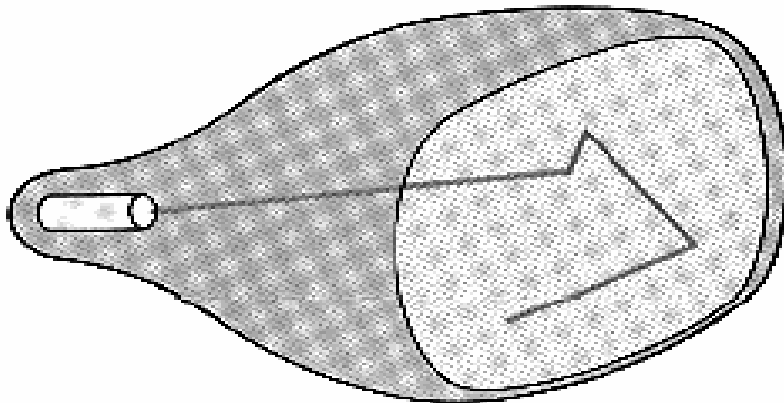
(c)
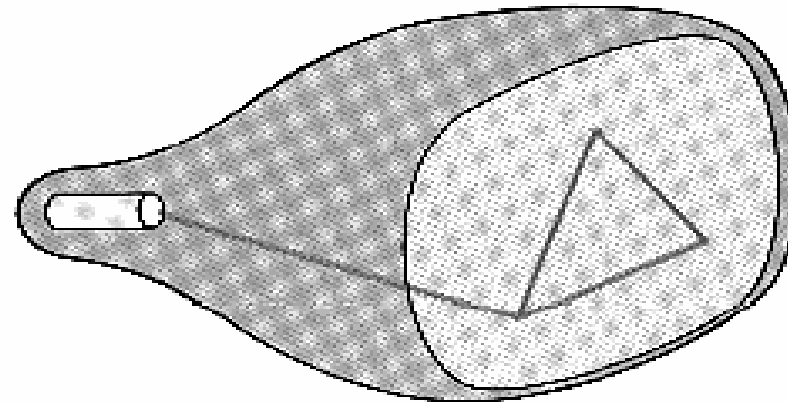
(d)

Calligraphic or Random Scan Display Systems   Contd..

- **According to the commands in a display file, each component of line is drawn and system cycles back to the first line command in the list.**

- **Random Scan systems are designed to draw all the component lines of a picture 30 to 60 times per second.**

- **It is designed for line drawing applications and can not be used to display realistic shaded scenes.**

Architecture of a Simple Random Scan system   n Contd..
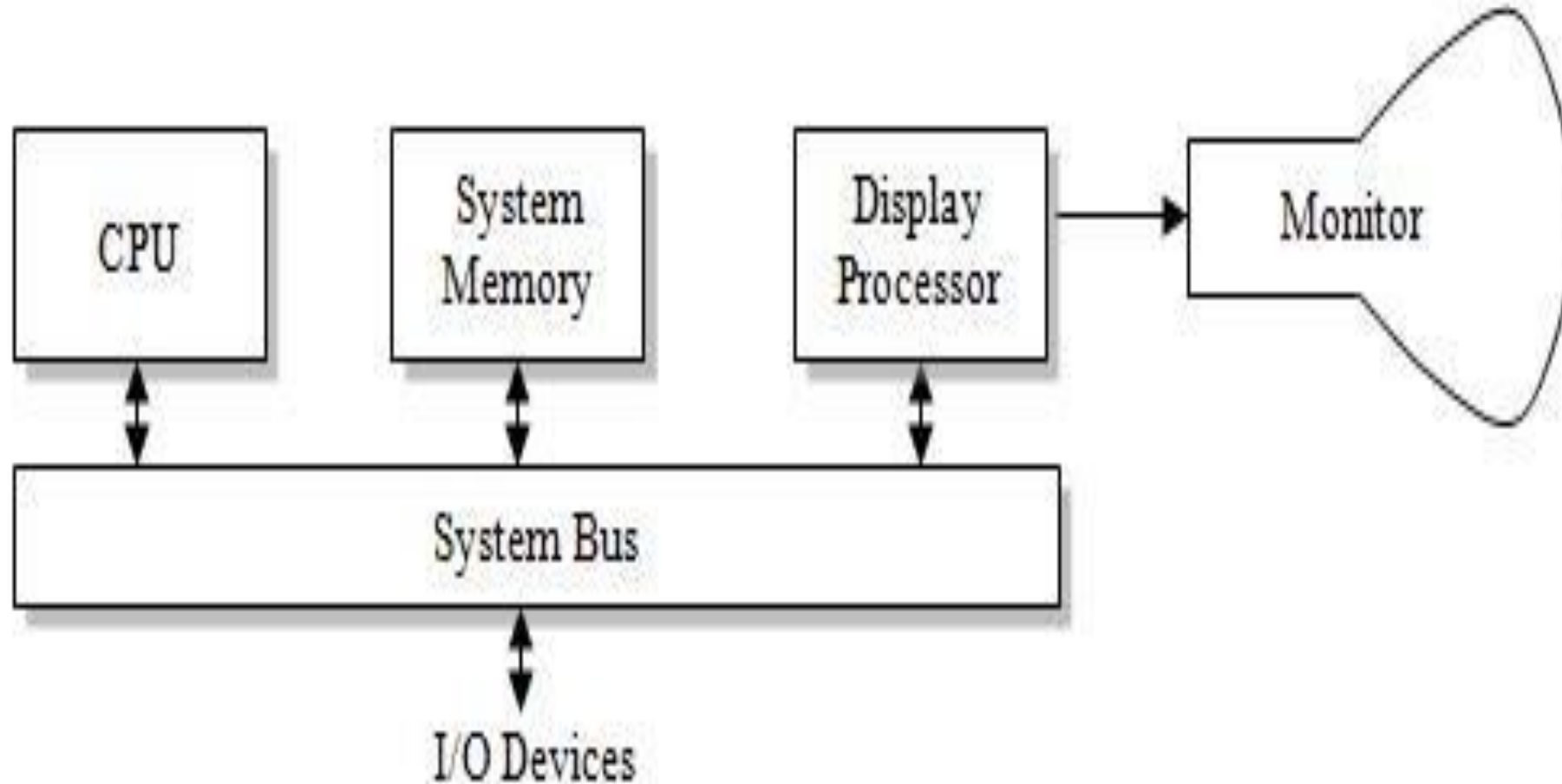
Architecture of a Simple Random Scan system   Contd..

- An application program is input and stored in the system memory along with a graphics package.

- Graphics commands in the program are translated by the graphics package into a display file stored in the system memory.

- This display file is then accessed by the display processor to refresh the screen.

Architecture of a Simple Random Scan system   Contd..

- The display processor cycles through each command in the display file program once during every refresh cycle. Sometimes the display processor in a random-scan system is refreshed to as a display processing unit or a graphics controller.

- Graphic patterns are drawn on a random scan system by directing the electron beam along the component lines of the picture.

Architecture of a Simple Random Scan system   Contd..

- Lines are defined by the values for their co-ordinate endpoints, and these input co-ordinate values are converted to x and y deflection voltages. A scene is then drawn one line at a time by positioning the beam to fill in the line between specified endpoints.

Difference between Random Scan and Raster Scan Displays

Random scan display	Raster scan display
It has high resolution.	It has low resolution.
It is more expensive.	It is less expensive.
Any modification if needed is easy.	Modification is tough in Raster scan systems.
Solid pattern is tough to fill.	Solid pattern is easy to fill.
Refresh rate depends on resolution.	Refresh rate does not depends on resolution.
Every time when a picture is drawn only the area where picture is drawn is refreshed.	Every time when a picture is drawn the whole screen is refreshed.

Difference between Random Scan and Raster Scan Displays

Random scan display	Raster scan display
Beam Penetration comes under it.	Shadow mask technique comes under it.
It does not use interlacing method.	It uses interlacing.
It is restricted to line drawing application.	It is suitable for realistic displays.

4. Color CRT Monitors

- **A color CRT monitor displays color picture by using a combination of phosphors that emit different colored light. By combining the emitted light a range of colors can be generated.**

- **Two basic methods for producing color displays are:**
  - **Beam Penetration Method**
  - **Shadow-Mask Method**

4. Color CRT Monitors   Contd..

- **Beam Penetration Method**

Random scan monitors use the beam penetration method for displaying color picture. In this, the inside of CRT screen is coated two layers of phosphor namely red and green. A beam of slow electrons excites only the outer red layer, while a beam of fast electrons penetrates red layer and excites the inner green layer. At intermediate beam speeds, combination of red and green light are emitted to show two additional colors- orange and yellow.

4. Color CRT Monitors   Contd..

- **Advantage**

Less expensive

- **Disadvantages**

(a) Quality of images are not good as comparable with other methods

(b) Four colors are allowed only

4. Color CRT Monitors   Contd..

- **Shadow Mask Method**

Raster scan system are use shadow mask methods to produced a much more range of colors than beam penetration method. In this, CRT has three phosphor color dots. One phosphor dot emits a red light, second emits a green light and third emits a blue light. This type of CRT has three electrons guns and a shadow mask grid as shown in figure:

4. Color CRT Monitors   Contd..
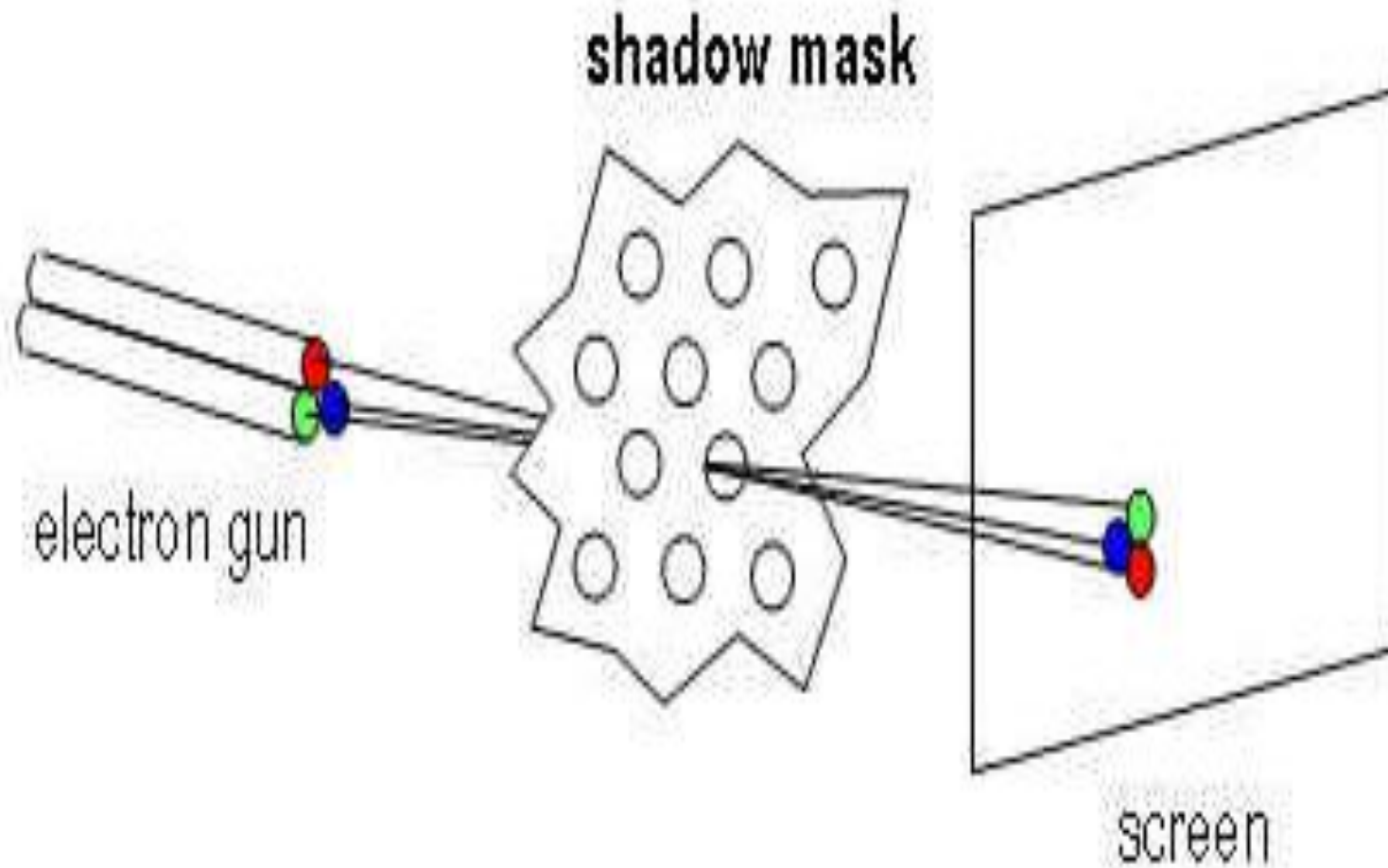
4. Color CRT Monitors   Contd..

Shadow mask method(Contd….):

- **Delta delta shadow mask method is commonly used in Color CRT systems. The steps in shadow mask method:**

- **The three electron beams are deflected and focused as a group onto the shadowmask, which contains a series of holes aligned with the phosphore dot patterns.**

4. Color CRT Monitors   Contd..

- **Shadow mask method(Contd….):**
- **When the three beams pass through a hole in the shadow mask, they activate a dot which appear as a small color spot on the screen.**
- **We obtain color variations in a shadow mask CRT by varying the intensity levels of the three electron beams.**

4. Color CRT Monitors   Contd..

- **A white area is a result of all three dots with equal intensity while yellow is produced with green and red dots and so on.**

- **Advantages: produce realistic images, produce different colors and shadows scenes.**

- **Disadvantages**
  - **low resolution**
  - **expensive**
  - **electron beam directed to whole screen**

5. Direct View Storage Tubes (DVST)

- DVST terminals use Random Scan application to generate the image on CRT screen.

- It is an alternative method of maintaining image. To maintain a screen image , information is stored inside the CRT instead of refreshing the screen.

- Storage grid-It stores picture information as a charge distribution just behind the phosphor –coated screen.

5. Direct View Storage Tubes (DVST)

Two electron guns are used

1. **Primary gun stores the picture pattern.**
2. **Flood gun maintains the picture display.**
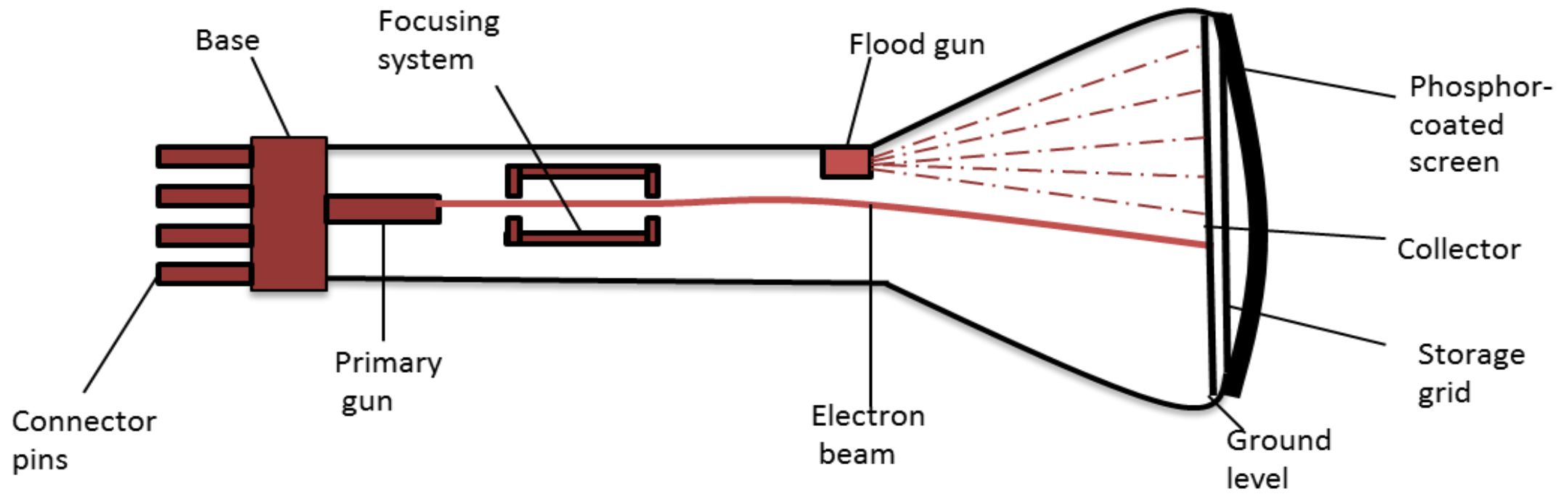
Direct View Storage Tubes (DVST) Contd..

- **Advantages**
  1. It can let the picture display for long time
  1. Refreshing is not required.
  2. Very complex pictures can be displayed at very high resolution. Without flicker.
  3. It is good for static picture only.
  4. It has flat screen.

Direct View Storage Tubes (DVST) Contd..

- **Disadvantages**
  1. **Not suitable for dynamic images.**
  2. **Do not display colors.**
  3. **To make a small change in pic. There is need to redraw entire picture.**

6. Flat Panel Displays

- These are also known as Gas-Discharge displays.
- It refers to a class of video devices that have reduced volume, weight and power requirements compared to a CRT.
- They are thinner than CRT's
- There are two categories :

➢**Emissive display**:

- These are the devices that convert electrical energy into light. Example: Plasma panels , thin film electro luminescent displays and L.E.D .

➢ **Non Emissive displays**:

- These use optical effects to convert sunlight or light from some other source into graphics patterns. Example: LCD

6. Flat Panel Displays

Contd..

- Plasma Panels: They Consists of two plates and are constructed by filling the region b/w two glass plates with a mixture of gases (neon, xenon or helium).This material is sensitive to light and the frame buffer/refresh buffer stores the pixel value.

Advantages:

- Refreshing is not required.

- Produces a very steady image, totally free of flicker.

- Less bulky than CRT.

- Available in black and white as well as color displays.

- Light weight.

- Hanged on a wall.

- Wear them on wrist.

- Selective parts of image can be erased or update.

6. Flat Panel Displays Contd..

- Plasma Panels

Disadvantages:
- Refresh rate is only 60 bits/second, so not suitable for animations.

- They are slow devices.

- Costlier than CRTs.

- It requires complex addressing and wiring.

6. Flat Panel Displays Contd..

- **LED(Light Emitting Diode)**

It is a type of emissive device. In an LED, a matrix diode is organized to form the pixel positions in the displays and picture definition is stored in a refresh buffer and converted to voltage levels that are applied to the diodes to produce light patterns in the display.

6. Flat Panel Displays Contd..

- **LCD(Liquid Crystal Display)**

These are the devices that produce a picture by passing polarized light from the surroundings or from an internal light source through liquid crystal material that transmits light.

Advantages of LCD:

Low power consumption, small in size and cost is low.

Disadvantages of LCD:

- LCDs are temperature dependent.

- LCDs don't emit light as a result the image has very little contrast.

- Resolution is not as good as that of a CRT.

Reason of replacing LCDs with LEDs

LED displays are the technological advancement of LCD displays. LED displays are, LCD displays with LED backlight to power up the LCD panel. It means that LEDs are placed behind or around the LCD panel to enhance the luminosity and video definition of the monitor screen. The major difference between LCD and LED displays are as follows:

- **Contrast:** Contrast and black level of the LED screen is better than the LCD screens because of the liquid crystals cannot stop 100% of the backlight from cold cathode backlight and hence when the black screen is to be shown on the monitor, it is not completely black.

- **Color Accuracy:** Color accuracy for direct and edge LED displays and LCD displays are almost same but the RGB LEDs display has quite better color accuracy.

Reason of replacing LCDs with LEDs

- **Viewing Angle:** If the viewing angle of the display is much wider than thirty degrees from the center then the contrast ratio of the image is diminished in LCD. This affects the eyes while this disadvantage is overcome by LED. LEDs have a wider viewing angle, which means the image is still clear when viewed from the side.

- **Power:** More power is consumed by the local dimming LED display than LCD. Hence it will be wise and economic to either compromise with energy bill or good quality picture.

- **Use of Mercury:** LED displays don not use mercury(used in cathode lamps in LCD backlight) so they are environment friendly.

- **Size:** The size of edge and RGB than the LCD monitors is slightly thinner than the LCD monitors.

- **Price:** Price becomes a major factor when comparing LCD and LED TVs. LED displays yield a higher price tag.

Input Devices

A piece of computer hardware that is used to enter and manipulate information on a computer. Basic input devices include the following:

- **Keyboard**
- **Mouse**
- **Digitizer**
- **Trackball**
- **Touch Screens**
- **Light Pens**
- **Microphones**
- **Bar code readers**
- **Joysticks**
- **Scanners**
- **Voice Systems**

Keyboard

- The keyboard is the most common input device for entering numeric and alphabetic data in to a computer system by pressing a set of keys which are mounted on the keyboard, which is connected to computer system.

- The keys on computer keyboards are often classified as follows:

- Alphanumeric Keys - letters and numbers.

- Punctuation Keys - comma, period, semicolon, and so on.

- Special Keys - function keys, control keys, arrow keys, Caps Lock key, and so on.

Mouse

- A mouse is a small device that a computer user pushes across a desk surface in order to point to a place on a display screen and to select one or more actions to take from that position.

- A mouse consists of
  1. A metal or plastic housing or casing
  2. A ball that sticks out of the bottom of the casing and is rolled on a flat surface
  3. One or more buttons on the top of the casing
  4. A cable that connects the mouse to the computer.

  As the ball is moved over the surface in any direction, a sensor sends impulses to the computer that causes a mouse-responsive program to reposition a visible indicator (called a cursor) on the display screen. The positioning is relative to some variable starting place. Viewing the cursor's present position, the user readjusts the position by moving the mouse. The most conventional kind of mouse has two buttons on top: the left one is used most frequently.

Digitizer

- A graphics tablet (or digitizing tablet, graphics pad, drawing tablet) is a computer input device that allows one to hand-draw images and graphics, similar to the way one draws images with a pencil and paper. These tablets may also be used to capture data or handwritten signatures.

- A graphics tablet (also called pen pad or digitizer) consists of a flat surface upon which the user may "draw" an image using an attached stylus, a pen-like drawing apparatus. The image generally does not appear on the tablet itself but, rather, is displayed on the computer monitor. Some tablets however, come as a functioning secondary computer screen that you can interact with directly using the stylus.

- Some tablets are intended as a general replacement for a mouse as the primary pointing and navigation device for desktop computers.

Light Pen

- A Light Pen is a pointing device shaped like a pen and is connected to a VDU. The tip of the light pen contains a light-sensitive element which, when placed against the screen, detects the light from the screen enabling the computer to identify the location of the pen on the screen. Light pens have the advantage of 'drawing' directly onto the screen, but this can become uncomfortable, and they are not as accurate as digitizing tablets.

Touch Screen

- A touch screen is a display which can detect the presence and location of a touch within the display area. The term generally refers to touch or contact to the display of the device by a finger or hand.

- Touch screens can also sense other passive objects, such as a stylus. However, if the object sensed is active, as with a light pen, the term touch screen is generally not applicable. The ability to interact directly with a display typically indicates the presence of a touch screen.

- The touch screen has two main attributes.
  - First, it enables one to interact with what is displayed directly on the screen, where it is displayed, rather than indirectly with a mouse or touchpad.
  - Secondly, it lets one do so without requiring any intermediate device, again, such as a stylus that needs to be held in the hand.

  Such displays can be attached to computers or, as terminals, to networks. They also play a prominent role in the design of digital appliances such as the personal digital assistant (PDA), satellite navigation devices, mobile phones, and video games.

Image Scanners

- A scanner is a device that optically scans images, printed text, handwriting, or an object, and converts it to a digital image. Common examples found in offices are variations of the desktop (or flatbed) scanner where the document is placed on a glass window for scanning.

- Hand-held scanners: Here the device is moved by hand, have evolved from text scanning.

- 3D scanners: These are used for industrial design, reverse engineering, test and measurement, orthotics, gaming and other applications.

- Mechanically driven scanners that move the document are typically used for large-format documents, where a flatbed design would be impractical.

Image Scanners

- Types of Image Scanners:
  1. Modern Scanners use Charge-coupled device (CCD) or a Contact Image Sensor (CIS) as the image sensor, whereas older drum scanners use a photomultiplier tube as the image sensor.
  2. A rotary scanner, used for high-speed document scanning, is another type of drum scanner, using a CCD array instead of a photomultiplier.
  3. Planetary scanners take photographs of books and documents
  4. 3D scanners are used for producing three-dimensional models of objects.
  5. Digital camera scanners, which are based on the concept of reprographic cameras. Due to increasing resolution and new features such as anti-shake, digital cameras have become an attractive alternative to regular scanners. While still having disadvantages compared to traditional scanners (such as distortion, reflections, shadows, low contrast), digital cameras offer advantages such as speed, portability, gentle digitizing of thick documents without damaging the book spine.

  Note: New scanning technologies are combining 3D scanners with digital cameras to create full-color, photo-realistic 3D models of objects.

Voice Systems

- voice input device: A device in which speech is used to input data or system commands directly into a system. Such equipment involves the use of speech recognition processes, and can replace or supplement other input devices. Some voice input devices can recognize spoken words from a predefined vocabulary, some have to be trained for a particular speaker.

- Speech recognition (also known as automatic speech recognition or computer speech recognition) converts spoken words to machine-readable input (for example, to key presses, using the binary code for a string of character codes). The term "voice recognition" is sometimes incorrectly used to refer to speech recognition, when actually referring to speaker recognition, which attempts to identify the person speaking, as opposed to what is being said. Confusingly, journalists and manufacturers of devices that use speech recognition for control commonly use the term Voice Recognition when they mean Speech Recognition.

Joystick

- A joystick is an input device consisting of a stick that pivots on a base and reports its angle or direction to the device it is controlling. Joysticks are often used to control video games, and usually have one or more push-buttons whose state can also be read by the computer. A popular variation of the joystick used on modern video game consoles is the analog stick.

- The joystick has been the principal flight control in the cockpit of many aircraft, particularly military fast jets, where center stick or side-stick location may be employed.

- Joysticks are also used for controlling machines such as cranes, trucks, underwater unmanned vehicles. Miniature finger-operated joysticks have been adopted as input devices for smaller electronic equipment such as mobile phone.

Trackball

- A trackball is a pointing device consisting of a ball held by a socket containing sensors to detect a rotation of the ball about two axes—like an upside-down mouse with an exposed protruding ball. The user rolls the ball with the thumb, fingers, or the palm of the hand to move a cursor. Large tracker balls are common on CAD workstations for easy precision. Before the advent of the touchpad, small trackballs were common on portable computers, where there may be no desk space on which to run a mouse. Some small thumb balls clip onto the side of the keyboard and have integral buttons with the same function as mouse buttons.

- The late 1990s replacement of mouse balls by direct optical tracking put trackballs at a disadvantage and forced them to retreat into niches where their distinctive merits remained more important. Most trackballs now have direct optical tracking which follows dots on the ball.

- As with modern mice, most trackballs now have an auxiliary device primarily intended for scrolling.

Output Devices

Hard Copy Devices

Hard copy devices or output devices accept data from a computer and converted them into a form which is suitable for use by the user.

- Basic output devices include the following:
  - Monitors
  - Printers
  - Plotters

Printers

- Printers are the most commonly used output devices for producing hard copy output.
- The various types of printers in used today are as follows:
  - Dot-Matrix Printers
  - Inkjet Printers
  - Drum Printers
  - Laser Printers

Printers

Dot-Matrix Printers

- A dot matrix printer or impact matrix printer is a type of computer printer with a **print head** that runs back and forth, or in an up and down motion, on the page and prints by impact, striking an ink-soaked cloth ribbon against the paper, much like a typewriter. Unlike a typewriter or daisy wheel printer, letters are drawn out of a dot matrix, and thus, varied fonts and arbitrary graphics can be produced. Because the printing involves mechanical pressure, these printers can create carbon copies and carbonless copies.

- Each dot is produced by a **tiny metal rod**, also called a "wire" or "pin", which is driven forward by the power of a tiny electromagnet or solenoid, either directly or through small levers. Facing the ribbon and the paper is a small guide plate (often made of an artificial jewel such as sapphire or ruby) pierced with holes to serve as guides for the pins. The moving portion of the printer is called the print head, and when running the printer as a generic text device generally prints one line of text at a time. Most dot matrix printers have a single vertical line of dot-making equipment on their print heads; others have a few interleaved rows in order to improve dot density.

Printers

Inkjet Printers

- Inkjet printers form characters and images by spraying small drops of ink on to the paper. They are the most common type of computer printer for the general user due to their **low cost**, **high quality of output**, **capability of printing in different colors**, and **ease of use**.

- The dots are extremely small, so small that they are tinier than the diameter of a human hair (70 microns).

- The dots are positioned very precisely, with resolutions of up to 1440x720 dots per inch.

- The dots can have different colors combined together to create photo-quality images.

Printers

Laser Printers

- A type of printer that utilizes a laser beam to produce an image on a drum. The light of the laser alters the electrical charge on the drum wherever it hits. The drum is then rolled through a reservoir of toner, which is picked up by the charged portions of the drum. Finally, the toner is transferred to the paper through a combination of heat and pressure. This is also the way copy machines work.

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

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

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

Plotters

- A plotter is a printer that interprets commands from a computer to make line drawings on paper with one or more automated pens.

- Unlike a regular printer, the plotter can draw continuous point-to-point lines directly from vector graphics files or commands.

- Plotters were the first type of printer that could print with color and render graphics and full-size engineering drawings. As a rule, plotters are much more expensive than printers. They are most frequently used for CAE (computer-aided engineering) applications, such as CAD (computer-aided design) and CAM (computer-aided manufacturing).

- A plotter consists of an arm that moves across the paper on which the diagram or graph needs to be drawn . A pen moves along the arm and the arm itself moves relative to the paper. A combination of the two thus provides movement along the horizontal and vertical axes.

- There are a number of different types of plotters:
  - A drum plotter
  - A flatbed plotter

Plotters

Drum Plotters

- It draws on paper wrapped around a drum which turns to produce one direction of the plot, while the pens move to provide the other direction.

- In this plotter the pen moves in the horizontally and the drum rolls on the other axis. Generally it is a graphical output device, and it is generally used to plot drawings.

- It is very good for line drawings but it is very slow. Here the pen moves in x-axis and the paper moves on y-axis.

Plotters

Flatbed Plotters

- This is a plotter where the paper is fixed on a flat surface and pens are moved to draw the image. This plotter can use several different color pens to draw with. The size of the plot is limited only by the size of the plotter's bed.