DISPLAY DEVICES
DEFINITION

• A **display device** is a device for visual or tactile presentation of images (including text) acquired, stored, or transmitted in various forms.

Ex : Computer monitor, TV screen.

• Also known as an **information display**
MONITOR TECHNOLOGIES

• CRT  Cathode Ray Tube

• LCD  Liquid Crystal Display
  – TFT Thin Film Transistor

• PLASMA Technology
RELATED TERMINOLOGIES

- Pixel
- Resolution
- Display Size
- Viewing Angle
- Response time
- Brightness
PIXEL

- Picture Element
- It is the smallest element forming an image.
RESOLUTION

• No. of pixels per unit video display

• Video Graphics Array (VGA):
  – 720 pixels across by 400 pixels down in text mode
  – 640 pixels across by 480 pixels down in graphics mode.
DISPLAY SIZE

- Measured as distance from one corner to the diagonally opposite corner.
- Usually measured in INCHES.
VIEWING ANGLE

• It is angle from which the screen can be seen from side.
• It is larger for CRT as compared to LCD
RESPONSE TIME

• The minimum time necessary to change a pixel's color or brightness.
BRIGHTNESS

- The amount of light emitted from the display (more specifically known as luminance).
CRT: DEFINITION

• A CRT is a glass tube that is narrow at one end and opens to a flat screen at the other end.
CRT: STRUCTURE

• Narrow end of CRT contains
  – a single electron gun for single-color monitor
  – Three electron guns for a color monitor—one each for three primary colors: red, green, and yellow.

• The display screen is covered with tiny phosphor dots.
CRT : PRINCIPLE

• CRT display works on:
  ➢ Electron emission
    Electrons are emitted from the Cathode tube.
  ➢ Phosphorescence
    It is the emission of visible light, when electron beam strikes Phosphor material.
CRT

Cathode

Accelerating system

Deflection system

Control Grid

Focussing system

Phosphor on inner surface

Interior metallic coating at high positive voltage
MAIN PARTS OF CRT

E GUN

- Produces constant stream of electrons

Control Grid

- Sets intensity of spot on screen \((\text{the more negative the control grid voltage the fewer electrons pass through})\)

Focusing System

- Forces e-beam into narrow stream (otherwise repel)

Deflection Coils

- Indicates target phosphor spot

High positive V coating

- 15-20,000 V Accelerates e-beam to screen
**Electron Gun**- The Primary components of an electron gun in a CRT are *heated metal cathode and a control grid*. Heat is supplied to cathode by directing a current through a coil of wire, called filament, inside the cylindrical cathode structure. This causes the electrons to be “boiled off” the hot cathode surface. In vacuum inside the CRT envelop, the free negatively charged electrons are accelerated towards the phosphor coating by a high positive voltage.

**Control Grid**- Intensity of electron beam is controlled by setting the voltage levels on the control grid, which is a metal cylinder fit over the cathode.

- A high negative voltage on control grid will shut off the beam by repelling the electron whereas a smaller negative voltage on control grid simply decreases the number of electrons passing through.

- Amount of light emitted depends on electrons striking the screen, brightness of display is controlled by varying the voltage on control grid.
• **Deflection System** - As with focusing, deflection of electron beam can be controlled either with electric or with magnetic fields.
  – Two pairs of coils are used, with the coils in each pair mounted on opposite sides of neck of CRT envelop. One pair is mounted on top and bottom of the neck and the other pair is mounted on opposite sides of the neck.
  – Horizontal deflection is accomplished with one pair of coils and vertical deflection by the other pair.
  – In electrostatic deflection, two pairs of parallel plates are mounted inside the CRT envelop. One pair is mounted horizontally to control vertical deflection and other is mounted vertically to control the horizontal deflection.
• Spots of light are produced on screen by transfer of CRT beam energy to phosphor. When the electrons in beam collide with phosphor coating, they are stopped and their kinetic energy is absorbed by the phosphor.
• Part of beam energy is converted by friction into heat energy and the remainder causes electrons in phosphor atoms to move up to higher quantum energy levels.
• The excited phosphor electrons begin to drop back to their stable ground state, giving up their extra energy as small quantum of light energy. The glow on screen is the combined effect of all electron emissions.
• The frequency of light (color) emitted by phosphor is proportional to energy difference between the excited quantum state and the ground state.
CRT DISPLAY: ADVANTAGES

• Offers greater resolution.
• Widest viewing angle when compared to any other technology.
• It is cheap as compared to LCD, PLASMA displays.
CRT DISPLAY: DISADVANTAGES

• Thickness is much larger as compared to LCD, PLASMA display.

• Cannot be used for smaller displays like watches.
  - View area is less than the offered monitor size.
  - It is more heavier.
Vector and Raster

Two common techniques are used to draw the graphic on the screen using CRT display.
  - Vector and Raster

- **Vector** was developed in the mid-sixties and was in common use until the mid-eighties

- **Raster** was developed in the early seventies and today has mostly replaced vector based systems
Raster Scan Displays

• The most common type of graphics monitor employing a CRT is the raster scan display.
• 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 (one scan line), the beam intensity is turned on and off to create a pattern of illuminated spots.
• Picture definition is stored in a memory area called, refresh buffer or frame buffer in the form of intensity values for all screen points.
• Stored intensity values are retrieved from the buffer and painted on screen one row (scan line) at a time.
• Each screen point is referred to as a ‘pixel’
• In black and white systems, each screen point is either on or off requiring one bit per pixel to control the intensity of screen positions.
• For colored systems, upto 24 bits per pixel are required in high quality systems

**The capability of raster scan system to store intensity information for each screen point makes it well suited for the realistic display of scenes containing subtle shading and color patterns**
• Refreshing of screen is carried out at the rate of 60 to 80 frames per second. Unit of refresh rate is cycles per second or hertz

• At the end of each of scan line, the electron beam returns to left side of the screen to begin displaying the next scan line. The return to left of screen after refreshing each scan line, is called the \textbf{horizontal retrace} of the electron beam.

• At the end of each frame, the electron beam returns to the top left corner of the screen to begin the next frame. This is called the \textbf{vertical retrace}.
Interlaced Raster Scan System

• On some raster scan systems, each frame is displayed in two passes using an interlaced refresh procedure.
• In the first pass, the beam sweeps across every other scan line from top to bottom.
• In second pass, after the vertical retrace, the beam sweeps out the remaining scan line.

Interlacing of the scan lines in this way allows us to see the entire screen displayed in one-half of the time it would take to sweep across all the lines at once from top to bottom. Interlacing is primarily used with slower refreshing rates. This is an effective technique for avoiding flicker, providing that adjacent scan lines contain similar display information.
Vector (Random) Scan Displays

- Other type of graphic monitor employing CRT is the random scan system.
- When operated as random scan display unit, a CRT has the electron beam directed only to the parts of screen where a picture is to be drawn.
- The electron beam directly draws the picture
- Random scan monitors draw a picture one line at a time and for this reason are also referred to as vector display systems or calligraphic displays
- Refresh rate depends the number of lines to be drawn.
- The picture definition is stored as a set of line-drawing commands in the memory called the refresh display file—also known as display list, display program or refresh buffer
• To display the picture, the system cycles through the set of commands in the display file drawing each component line in turn.
• After all line drawing commands have been processed, the system cycles back to the first line command in the list.
• Random scan displays are designed to draw all the component lines of a picture 30 to 60 times a second.
• The component lines of the picture can be drawn and refreshed by a random scan system in any specified order. A pen plotter operates in similar way and is an example of a random scan hard copy device.
Advantages
• High resolution
• Easy animation
• Requires little memory (just display program)
• Good for line-drawing applications CAD
• Also *good for smooth curved surfaces*
  – e.g. oscilloscope

Disadvantages
• Limited colour capability
• Flicker occurs as complexity of image increases.
• Not good for shading etc
Colour CRTs

- Colour CRTs mix red, green, blue to get coloured pixel.
  - Pixel is divided into phosphor dots for red, green, blue colours (triads).

![Delta Arrangement | In-line Arrangement](image)

- For each colour there is a separate electron gun.
  - Intensity of single colour is determined by voltage for beam (determined by digital to analog conversion).
Two basic techniques used for producing color CRT displays are:

- **Beam penetration Method** (Used mainly in random scan systems)
- **Shadow-mask Method** (Used in raster scan systems)
Beam-Penetration Method

- In Beam penetration method, two layers of phosphor, usually red and green, are coated onto the inside of CRT screen, and displayed color depends on how far the electron beam penetrates into the phosphor layer.

- Slow electron Beam excites only the outer red layer

- Very fast electron beam penetrates through red and excites the inner green layer.

- Intermediate beam speeds produce combination of red and green light to show two additional colors, orange and yellow.
Limitations

• It is an inexpensive way to produce color in random scan monitors, but only four colors are possible

• Quality of picture is not as good as with other methods
**Shadow Mask Colour CRT**

- **Shadow mask**: a metal plate with small holes
  - Ensures that electrons from the appropriate beam only reach the corresponding colour phosphor dot

![Diagram of Shadow Mask Colour CRT]

**Delta Arrangement | In-line Arrangement**
Shadow-mask method

• Commonly used in raster scan systems
• Produce much wider range of colors than beam penetration method
• Three phosphor color dots at each pixel position. One phosphor dot emits red light, another emits green light and third emits blue light.
• The CRT has three electron guns, one for each color dot and a shadow-mask grid just behind the phosphor coated screen.
• Color variations are obtained by varying the intensity levels of three electron beams

Two types of arrangements are there for shadow-mask method
• Delta-delta arrangement
• In-line arrangement
**delta-delta Arrangement**

- In delta-delta arrangement, the three phosphor dots are arranged in the form of a triad.
- Three electron beams are deflected and focused as a group on to the shadow mask containing a series of holes aligned with the phosphor dot pattern.
- Three beams, when pass through a hole in shadow mask, activate the dot triangle, which appears as a small color spot on screen.
- The phosphor dots in triangle are arranged so that each electron beam can activate only its corresponding color dot when it passes through the shadow mask.
In-line Arrangement

- In In-line arrangement, three electron guns, and corresponding red-green-blue color dots on screen, are aligned along one scan line instead of in a triangular pattern.

- Easier to keep in alignment and is commonly used in high resolution color CRTs.
• Color variations in a shadow mask CRT are produced by varying the intensity levels of three electron beams e.g. by turning off the red and green guns, we get only the color coming from blue phosphor. The color produced depends on the excitation of red, green and blue phosphors.
Direct View Storage tube (DVST)

- A Direct-View Storage tube is a type of CRT that stores the picture information as a charge distribution just behind the phosphor coated screen.
- Two electron guns are used in DVST
  - Primary gun – used to store the picture pattern
  - Flood gun – used for maintaining the picture display
- Advantages:
  - No Constant Refresh Required
  - Very complex pictures can be displayed at very high resolutions without flicker
- Disadvantages:
  - To update any part of image must redraw all parts of image
  - Ordinarily, do not display colour
FLAT PANEL DISPLAYS

• Flat-Panel Display refers to a class of video devices that have reduced volume, weight and power requirements compared to CRT.
• There are two categories of flat panel displays:
  • Emissive Displays
  • Non-Emissive Displays
• **Emissive Displays** (or emitters) are devices that convert electrical energy into light. Plasma Panel, thin-film electroluminescent displays and light emitting diodes are examples of emissive displays.
• **Non-emissive** displays (or non-emitters) use optical effects to convert sunlight or light from some other source into graphics pattern e.g Liquid Crystal Display
A liquid crystal display is a thin, flat display device made up of any number of pixels arrayed in front of a light source or reflector. It uses very small amounts of electric power, and is suitable for use in battery-powered electronic devices.
Liquid crystals are organic compounds, whose macroscopic behaviour resemble that of liquid but show physical properties of crystals.

They have characteristics like: rod-like molecular structure, rigidness of the long axis, and strong dipoles and/or easily polarizable constituents.

The distinguishing characteristic of the liquid crystalline state is the tendency of the molecules to point along a common axis, called the director.
Figure 2-15
CHARACTERISTICS:

- Solid
- Liquid Crystal
- Liquid
LCD : CONSTRUCTION

• Each pixel of an LCD consists of a layer of molecules aligned between two transparent electrodes, and two polarizing filters, whose axes are perpendicular.

• Orientation of the liquid crystal molecules is determined by the alignment at the surfaces.
Liquid Crystal Display (LCD)

- Six Layers

Reflective Layer  Horizontal Polarizer  Horizontal Grid Wires  Liquid Crystal Layer  Vertical Grid Wires  Vertical Polarizer

Viewing Direction
A subpixel of a color LCD
LCD : WORKING

• Before applying Electric field, the molecules arrange themselves in a helical structure, or twist.
• When a voltage is applied across the electrodes, a torque acts to align the liquid crystal molecules parallel to the electric field, distorting the helical structure.
• This reduces the rotation of the polarization of the incident light.
LCD : CLASSIFICATION

• Transmissive displays:
  It is illuminated from the back by a backlight and viewed from the opposite side (front). Ex: Computer display.

• Reflective displays:
  It is illuminated by external light reflected by a diffusing reflector behind the display. Ex: Calculator.
LCD : USES

• LCDs with a small number of segments, are used in digital watches and pocket calculators
• Small monochrome displays in personal organizers, or older laptop screens
• High-resolution color displays such as modern LCD computer monitors and televisions
TFT TECHNOLOGY

• TFT stands for THIN FILM TRANSISTOR.

• A thin film transistor (TFT) is a special kind of field effect transistor made by depositing thin films for the metallic contacts, semiconductor active layer, and dielectric layer.
TFT DISPLAY : DEFINITION

- TFT-LCD (Thin Film Transistor Liquid Crystal Display) is a variant of liquid crystal display (LCD) which uses thin film transistor (TFT) technology to improve image quality.
- TFT is usually synonymous with LCD.
TFT DISPLAY : MATERIALS

• Most TFTs are not transparent themselves, since many of them are based on hydrogenated amorphous silicon (a-Si:H), whose bandgap is assumed to be less than that of crystalline silicon (1.12 eV).

• Indium tin oxide (ITO) is usually employed for the electrodes.
TFT TECHNOLOGY: CONSTRUCTION

• A transistor switch which allows each pixel to be individually controlled.

• Each pixel is a small capacitor with a transparent ITO [indium tin oxide] layer at the front, a transparent layer at the back, and a layer of insulating liquid crystal between.
TFT DISPLAY : WORKING

• The pixels are arranged in rows and columns which reduce the connection count to thousands.
• If all the pixels in one row are driven with a positive voltage and all the pixels in one column are driven with a negative voltage.
• A transistor switch allows each pixel to be individually controlled
TFT DISPLAY : ADVANTAGES

• Fast response time has been a great feature of TN displays.
• Lower cost of production
• Less noise or glitter seen on the panel surface
TFT DISPLAY : DISADVANTAGES

• The TFT display suffers from limited viewing angles, especially in the vertical direction.

• They are unable to display the full 16.7 million colors (24-bit truecolor) available from modern graphics cards.
A **plasma display panel (PDP)** is a type of flat panel display now commonly used for large TV displays (typically above 37-inch or 940 mm).
The xenon and neon gas in a plasma television is contained in hundreds of thousands of tiny cells positioned between two plates of glass.

Long electrodes are also sandwiched between the glass plates, in front of and behind the cells.

Cells are covered with a magnesium oxide protective layer.
PLASMA DISPLAY : WORKING

• Control circuitry charges the electrodes that cross paths at a cell,
• This creates a voltage difference between front and back and causing the gas to ionize and form a plasma.
• As the gas ions rush to the electrodes and collide, photons are emitted.
• In color panels, the back of each cell is coated with a phosphor. The ultraviolet photons emitted by the plasma excite these phosphors to give off colored light
PLASMA DISPLAY: CHARACTERISTICS

• The display panel is only about 6 cm (2½ inches) thick, and total thickness less than 10 cm.
• They can be produce fairly large sizes, up to 262 cm (103 inches) diagonally.
• Bright scenes (say a football game) will draw significantly more power than darker scenes.
• Their lifetime is estimated at 60,000 hours
PLASMA DISPLAY : ADVANTAGES

• Supports large displays, up to 103 inches diagonally.
• Overall thickness of monitor is less than 10 cm. and can be installed on a wall.
• Faster response time,
• Greater color spectrum,
• Wider viewing angle
PLASMA DISPLAY : DISADVANTAGES

• They are costly as compared to CRT, LCD displays.

• Burn-in problem.

Static images can leave a permanent mark on the screen. This is why a plasma TV should not be used as a computer monitor or video game display.
Raster Scan Systems

- Interactive raster scan systems typically employ several processing units. In addition to CPU, a special purpose processor called video controller or display controller, is used to control the operation of the display device. The frame buffer is accessed by the video controller repeatedly to refresh the screen.

- The frame buffer locations and corresponding screen positions are referenced in Cartesian coordinates. The coordinate origin is referenced at the upper left corner of the screen. The scan lines are labeled from 0 at the top of screen to $y_{\text{max}}$ at the bottom. Along each scan line screen pixel positions are labeled from 0 to $x_{\text{max}}$.

- Two registers are used to store the coordinates of the screen pixels. Initially the x and y registers are set to 0. The value stored in the frame buffer for this pixel is retrieved and used to set the intensity of the CRT beam. x register is incremented by 1 and the process is repeated for the next pixel till the last pixel on top scan line is processed. X register is again set to 0 and y register is incremented by 1. After cycling through all pixels along the bottom scan line the video controller resets the registers to first pixel position on top scan line and refresh process starts over.

- To speed up the pixel processing, video controller can retrieve multiple pixel values in one pass. The multiple pixel values are then stored in a separate register and are used to control the CRT beam intensity for a group of adjacent pixels. When that group of pixel values are processed, next block of pixel values are retrieved from the frame buffer.
Display Processor Architecture

Raster-graphics system with display processor

CPU  Display Processor  System Memory  System Bus  I/O Devices

Display Processor Memory  Frame Buffer  Scan Controller  Display
Random Scan Systems

- In random scan systems, an application program is input and stored in the system memory along with a graphics package. Graphics commands in the application program are translated by 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. The display processor cycles through each command in the display file program once during every refresh cycle. Graphics patterns are drawn on random scan systems by directing the electron beam along the component lines of the picture. Lines are defined by the values of their coordinate end points and these input coordinate 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 the specified endpoints.
Random Scan System

CPU -> System Memory -> Display Processor -> Monitor

I/O Devices

System Bus