JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

Year & Semester – III / V

Subject – Computer Graphics and Multimedia (5IT4-04)

Presented by – Dr. Smita Agrawal(Professor, Department of Information Technology)

Ist Lecture

VISSION AND MISSION OF INSTITUTE

Vision:

To become a renowned centre of outcome based learning, and work towards academic, professional, cultural and social enrichment of the lives of individuals and communities.

Mission:

- Focus on evaluation of learning outcomes and motivate students to inculcate research aptitude by project based learning.
- Identify areas of focus and provide platform to gain knowledge and solutions based on informed perception of Indian, regional and global needs.
- Offer opportunities for interaction between academia and industry.
- Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders can emerge in a range of professions.

VISSION AND MISSION OF DEPARTMENT

Vision:

To establish outcome based excellence in teaching, learning and commitment to support IT Industry.

Mission:

M1: To provide outcome based education.
M2: To provide fundamental & Intellectual knowledge with essential skills to meet current and future need of IT Industry across the globe.
M3: To inculcate the philosophy of continues learning, ethical values & Social Responsibility

Unit-I: Introduction

Objectives:

- This course provides an introduction to the principles of computer graphics.
- This course will consider methods for modeling 2-D and 3-D objects and efficiently generating photorealistic renderings on color raster graphics devices.
- The emphasis of the course will be placed on understanding how the various elements that underlie computer graphics (algebra, geometry, algorithms and data structures, optics, and photometry) interact in the design of graphics software systems.
- It also introduces brief introduction about multimedia and animation.

Unit-I: Introduction

Scope:

- **Computer Graphics Technology** is used across a range of industries. Computer graphics technology professionals use their knowledge and technical skills in graphic design and animation to design and create layouts, Web pages, and multimedia productions.
- **Multimedia Technology** is all about imparting information through use of computers by integrating various mediums like image, sound, text and videos. This field has gained popularity due to the varied palate of career opportunities it can offer.

Unit-I: Introduction

Scope:

- **Work opportunities for quality animators** and related professionals like Graphic Designer, Multimedia Developer and Game Developer, Character Designers, Key Frame Animators, 3D Modelers, Layout Artists etc. exists in following sectors at large-
    - Advertising
    - Online and Print News Media
    - Film & Television
    - Cartoon production
    - Theater
    - Video Gaming
    - E-learning

Unit-I: Introduction

Scope:

- Opportunities exists both with government as well as private sector enterprises.
- Animation itself is an industry, and as industry it's on boom.
- There exist numerous animation houses both in India and abroad who work for clienteles.
- An animator and multimedia professional can also work as freelancer or start his / her own enterprise given he / she has entrepreneurial skills and funds for investments.
- Animators work in various capacities.

Unit-I: Introduction

Outcome:

After completion of this course, students will be able to:

- Understand the basic concepts, importance, applications of Computer Graphics also they will be able to understand working principle of display devices.
- Interpret mathematical foundation to learn graphics algorithms to draw various shapes such as line, circle, ellipse, and curves on monitor.
- Learn methods for modeling 2-D and 3-D objects such as transformation, clipping , viewing and rendering techniques.
- Design animation sequences, as well as recursively defined curves such as Koch curves, C curves and many more.

IInd Lecture

Unit-II: Basics of Computer Graphics

- Introduction about Computer Graphics
- Applications
- Display Devices
- Input Devices
- Graphics Software & Standards

Unit-II: Basics of Computer Graphics

Introduction about Computer Graphics:

- **Computer Graphics** is a branch of Computer Science that deals with generating images with the aid of Computers.
- Today, Computer Graphics is a core technology in digital photography, film, video games, cell phone and computer displays, and many specialized applications.
- A great deal of specialized hardware and software has been developed, with the displays of most devices being driven by Computer Graphics hardware. It is a vast and recently developed area of Computer Science.

Unit-II: Basics of Computer Graphics

- It is also used for processing image data received from the physical world.
- Computer Graphics development has had a significant impact on many types of media and has revolutionized animation, movies, advertising, video games and graphic design in general.
- Although early applications in engineering and science had to rely on expensive and cumbersome equipment, advances in computer technology have made interactive computer graphics a practical tool.
- Today, we find computer graphics used routinely in such diverse areas as science, engineering, medicine, **business,** industry, government, art, entertainment, advertising, education, and training.

Unit-II: Basics of Computer Graphics

Following are the uses and applications of Computer Graphics:

- **Computer Aided Design**
- **Presentation Graphics**
- **Computer Art**
- **Entertainment**
- **Education and Training**
- **Visualization**
- **Image Processing**
- **Graphical User Interfaces**

Unit-II: Basics of Computer Graphics

Display Devices:

1. **Cathode Ray Tube**
2. Random Scan and Raster Scan
3. Color CRT Monitors
4. Direct View Storage Tubes
5. Flat Panel Display

Overview (Display Devices)

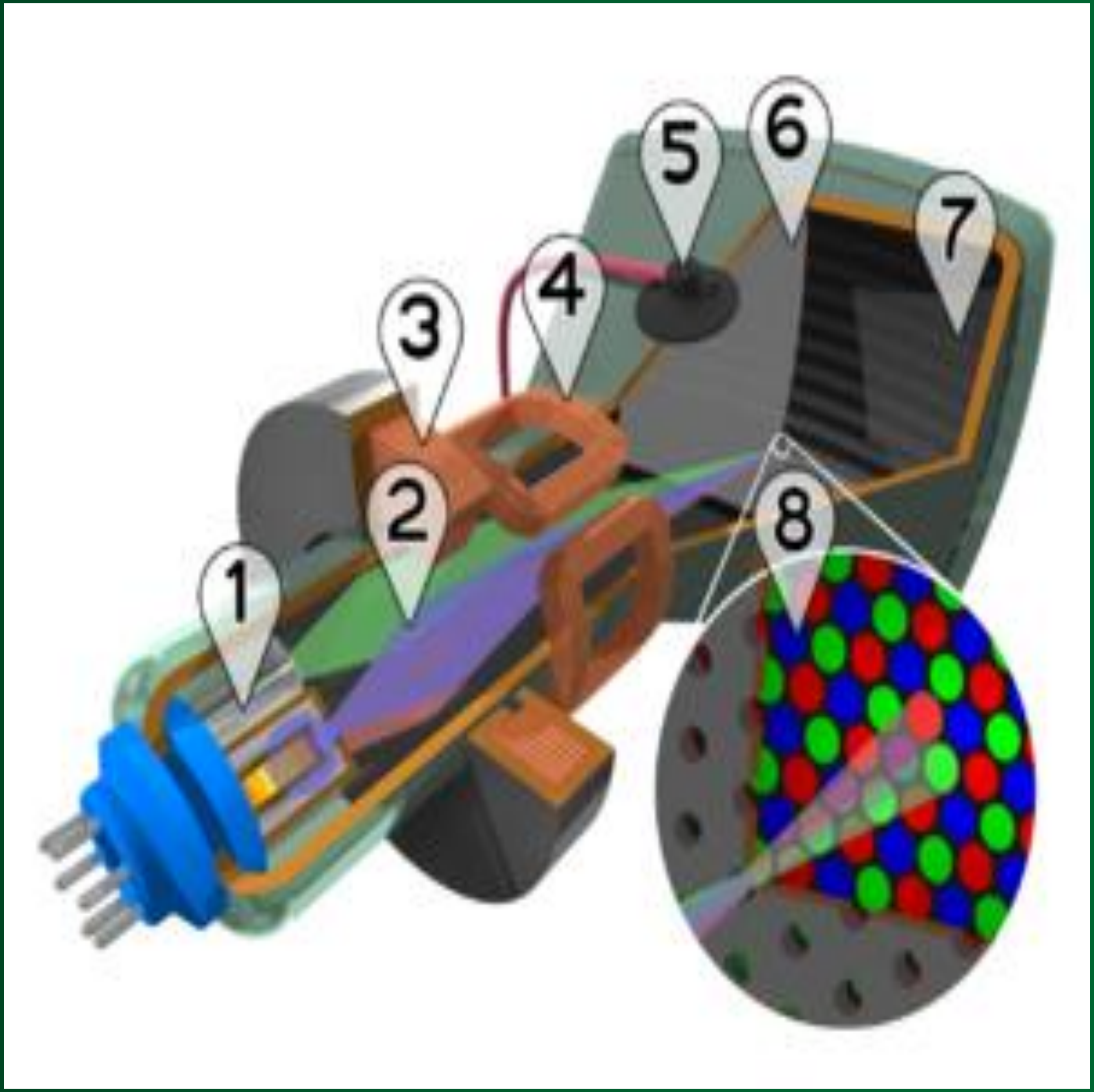
- The display systems are often referred to as **Video Monitor** or **Video Display Unit** **(VDU).**
- The primary output device in a graphics system is a monitor.

Video Monitor

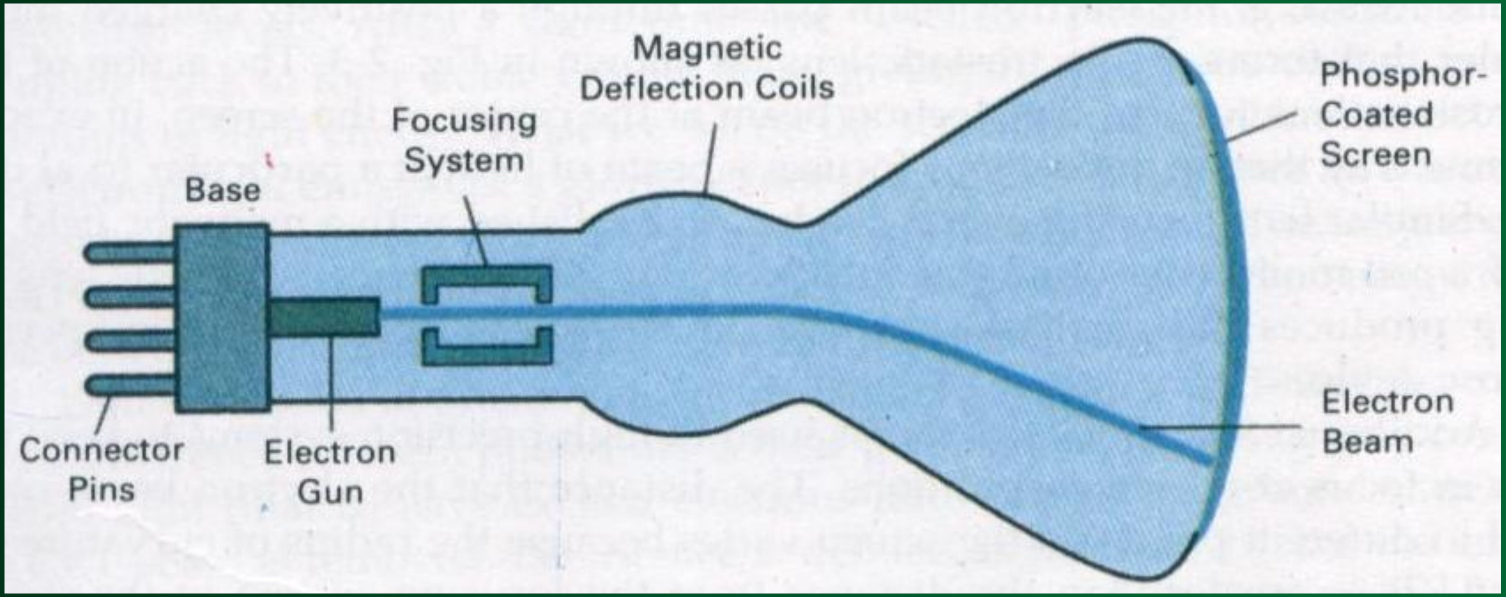
Cathode **R**ay **T**ube

(**CRT**)

1. Electron Guns
2. Electron Beams
3. Focusing Coils
4. Deflection Coils
5. Anode Connection
6. Shadow Mask
7. Phosphor layer
8. Close-up of the phosphor coated inner side of the screen



Cathode Ray Tube (CRT)

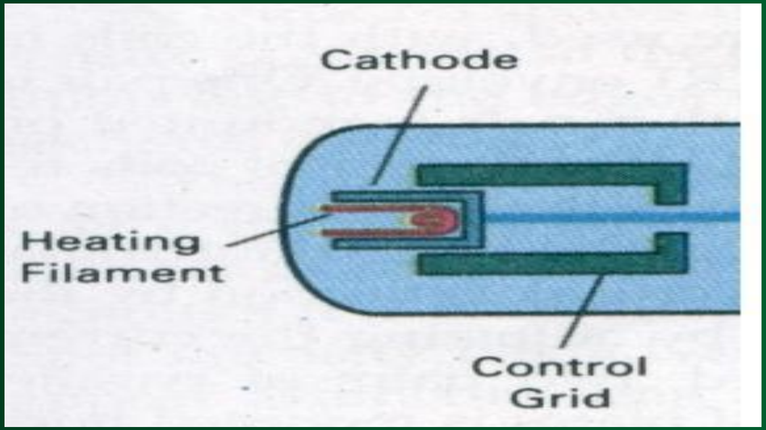


Refresh CRT

- Light emitted by the Phosphor fades very rapidly.
- **Refresh CRT:** One way to keep the phosphor glowing is to redraw the picture repeatedly by quickly directing the electron beam back over the same points.

Electron Gun

- Heat is supplied to the cathode by the **filament**.

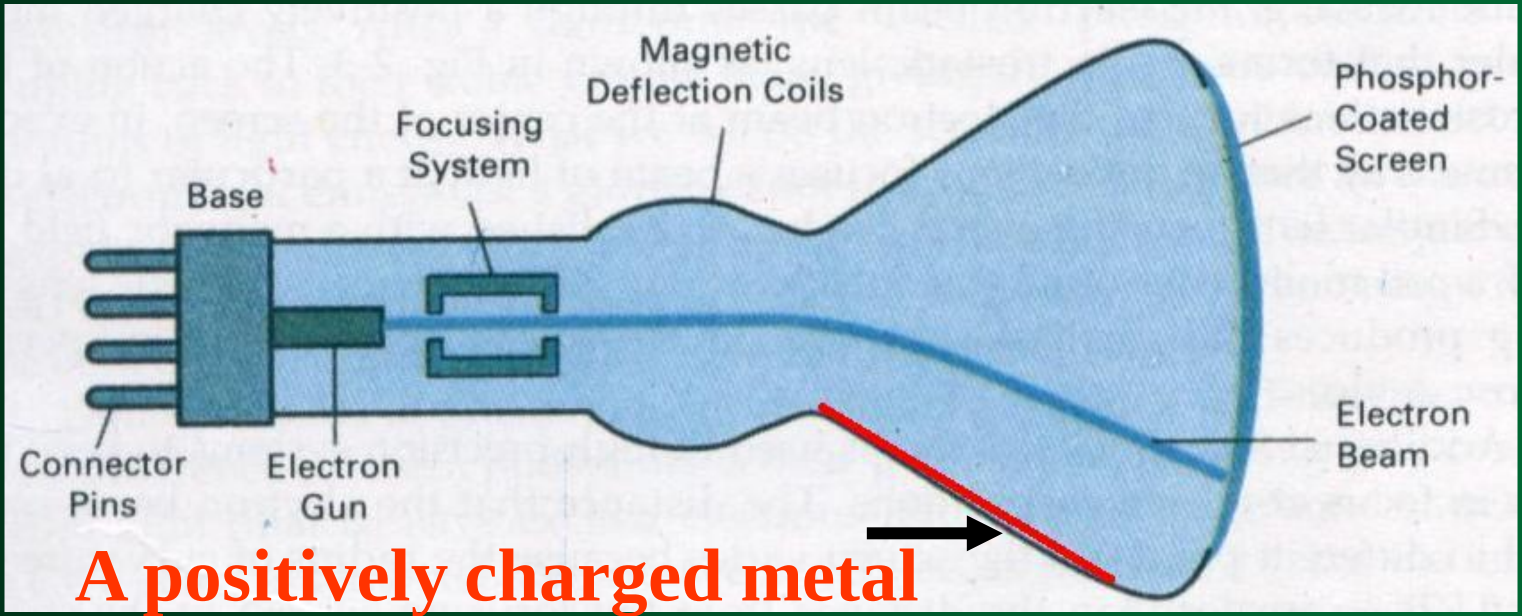


Electron Gun

- The free electrons are then accelerated toward the phosphor coating by a **high positive voltage**.

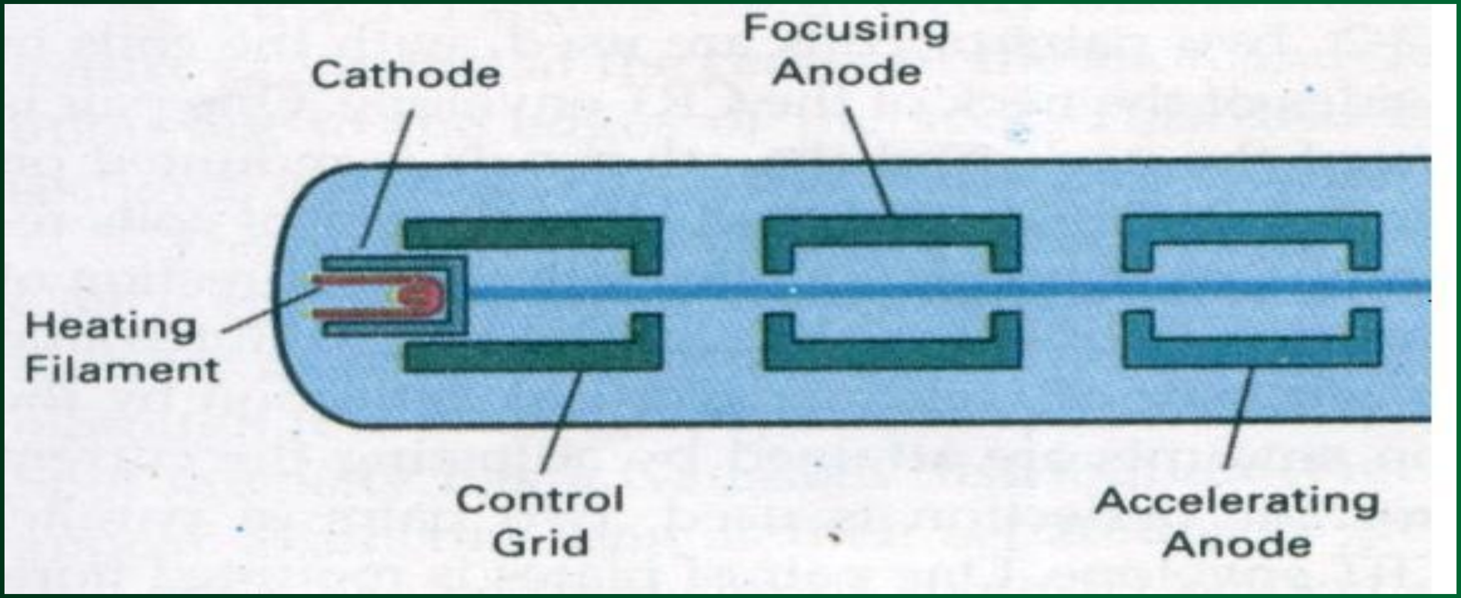
High Positive Voltage

- **A positively charged metal coating** on the inside of the CRT envelope near the phosphor screen.



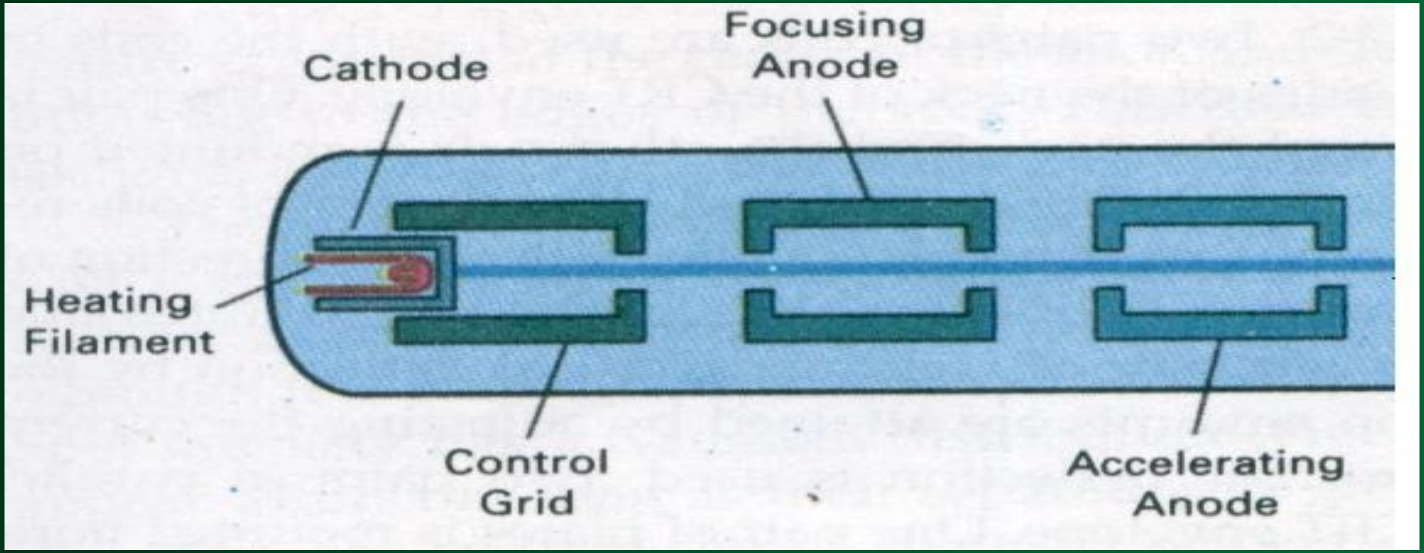
High Positive Voltage

- An accelerating **anode** .



Electron Gun

- **Intensity** of the electron beam is controlled by setting voltage level on the control grid.



Electron Gun

- **A smaller negative voltage** on the control grid simply decrease the number of electrons passing through.

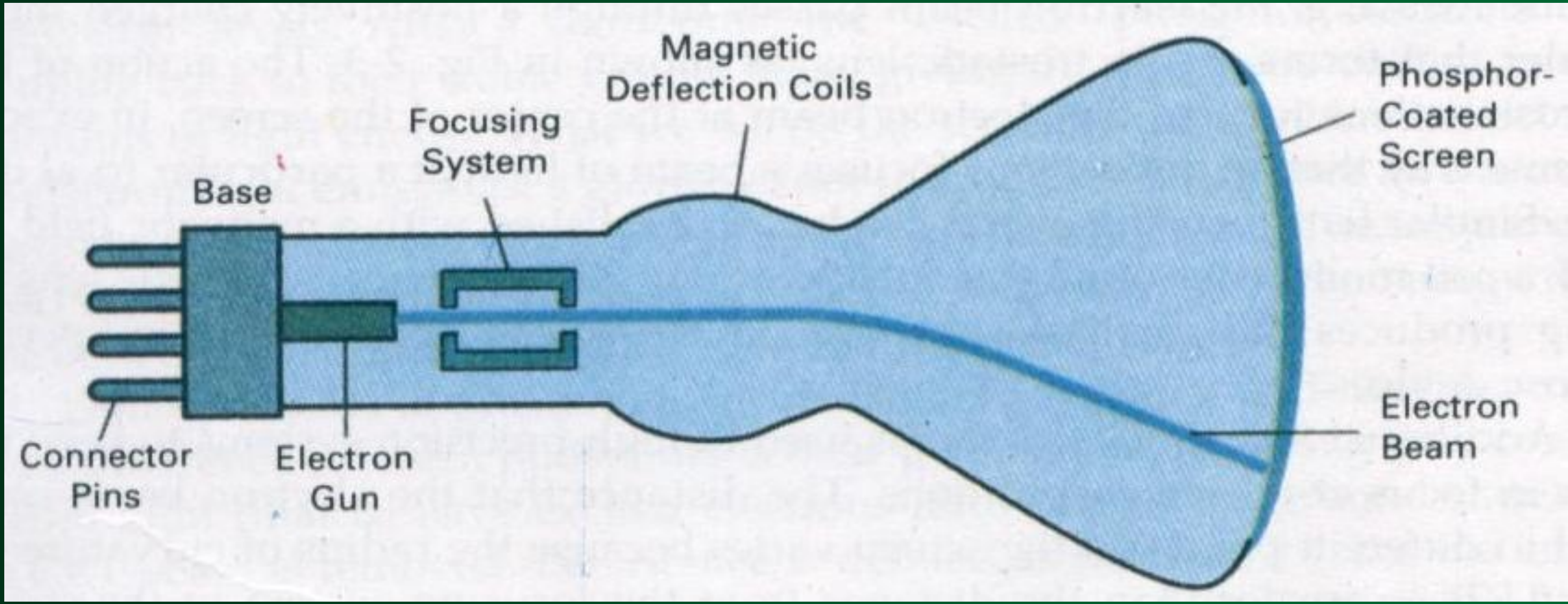
Focusing System

- The **focusing system** is needed to force the electron beam to converge into a small spot as it strikes the phosphor.

- **Electrostatic focusing** is commonly used in computer graphics monitor.

Focusing System

- With electrostatic focusing, the electron beam passes through a positively charged metal cylinder that forms an **electrostatic lens**.



Focusing System

- Similar lens focusing effects can be accomplished with a **magnetic field** set up by a coil mounted around the outside of the CRT envelope.

Focusing System

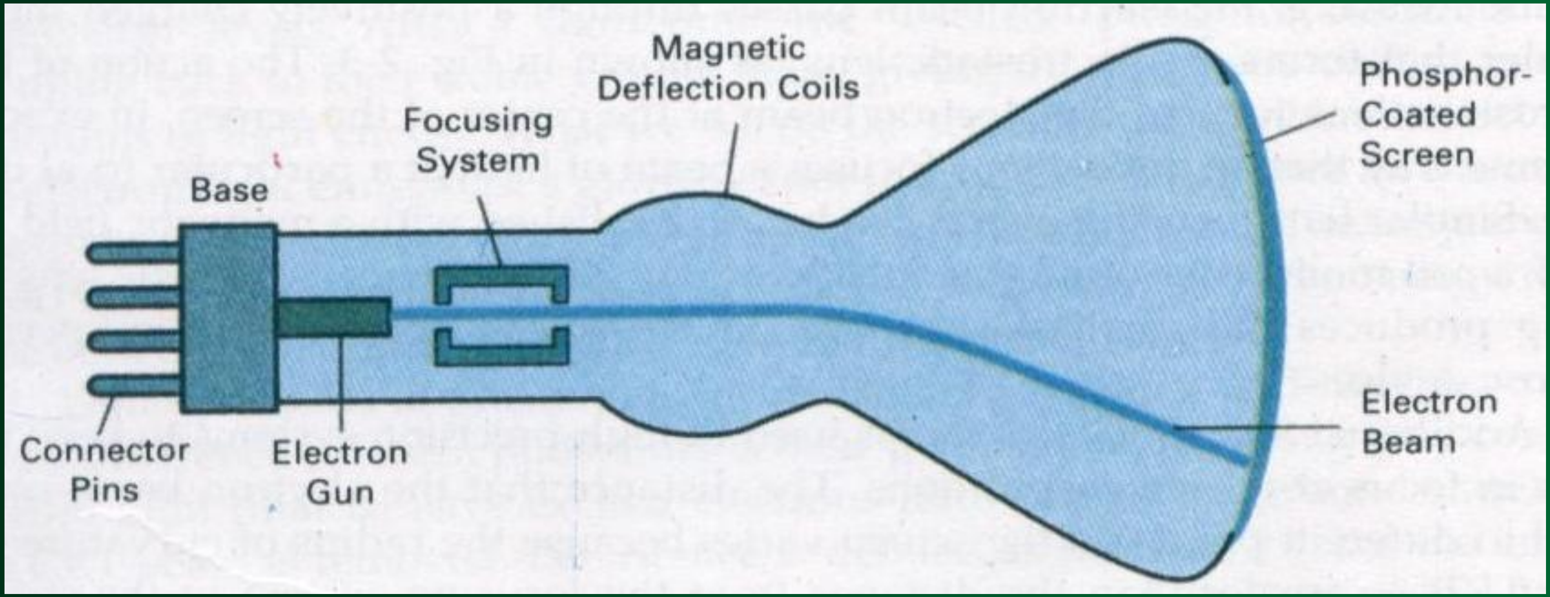
- The **distance** that the electron beam must travel to different points on the screen **varies** because the **radius of curvature** for most CRTs is ***greater*** than the distance from the focusing system to the screen center.

Focusing System

- The electron beam will be focused properly only at the **center** of the screen.
- As the beam moves to the **outer edges** of the screen, displayed images become ***blurred***.
- **Dynamically focusing lens** work based on beam position.

Deflection Systems

- Deflection of the electron beam can be controlled either with **electric fields** or with **magnetic fields**.
- The magnetic deflection coils mounted on the outside of the CRT envelope.

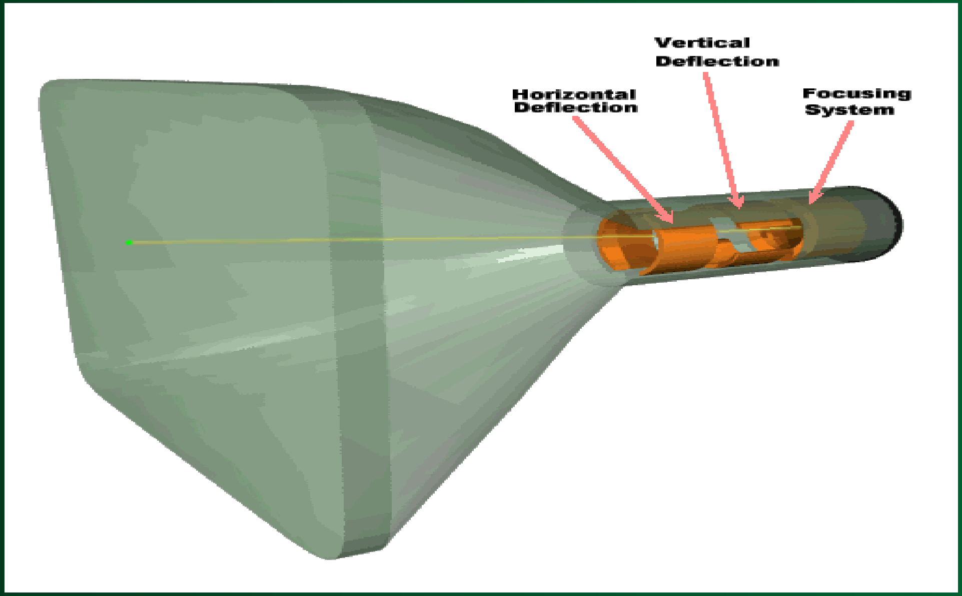


Deflection Systems

- **Two pairs of coils** are used, with the coils in each pair mounted on opposite sides of the neck of the CRT envelope.

Deflection Systems

- One pair is mounted on the top and bottom of the neck, and the other pair is mounted on opposite sides of the neck.



Deflection Systems

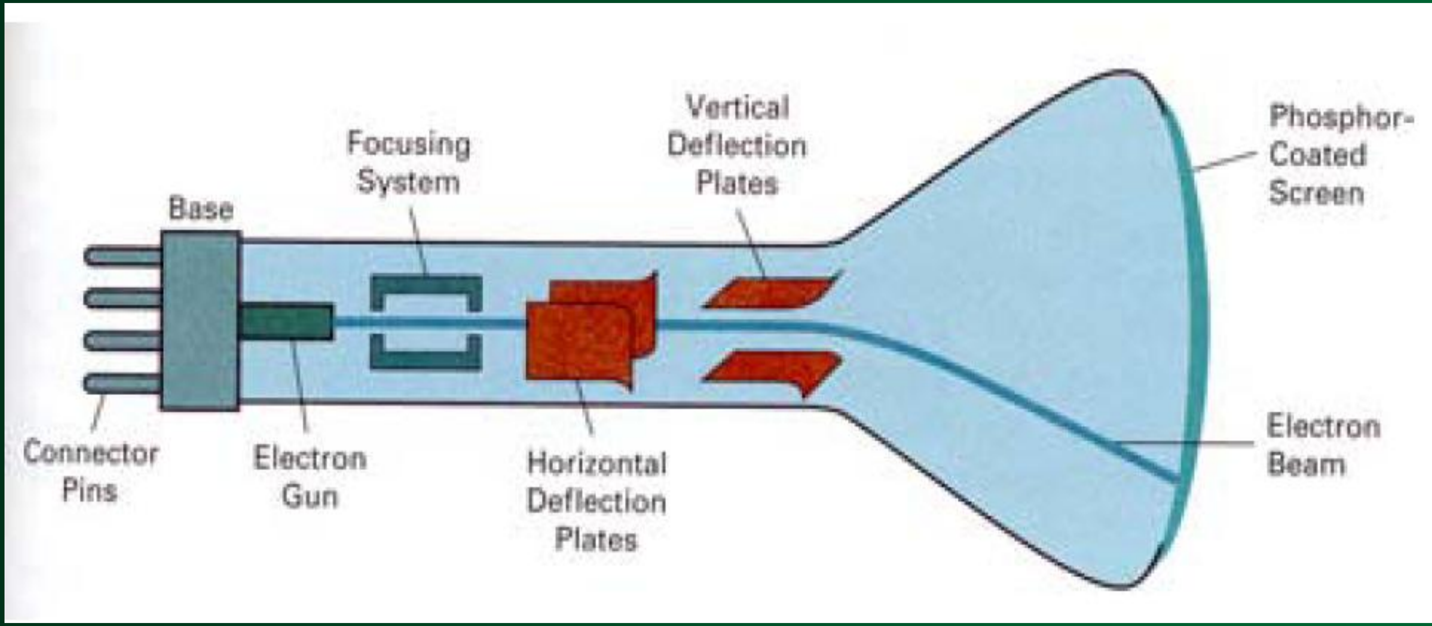
- **Horizontal deflection** is accomplished with one pair of coils, and **vertical deflection** by the other pairs.
- The proper deflection amounts are attained by adjusting the **current** through the coil.

Deflection Systems

- **Electrostatic deflection:** Two pairs of parallel plates are mounted inside the CRT envelope.

Deflection Systems

- One pair of plates is mounted horizontally to control the **vertical deflection**, and the other pair is mounted vertically to control **horizontal deflection**.



Spots of Light

- **Spots of lights** are produces on the screen by the transfer of the CRT beam energy to the phosphor.

- Part of the beam energy is converted into heat energy.

Spots of Light

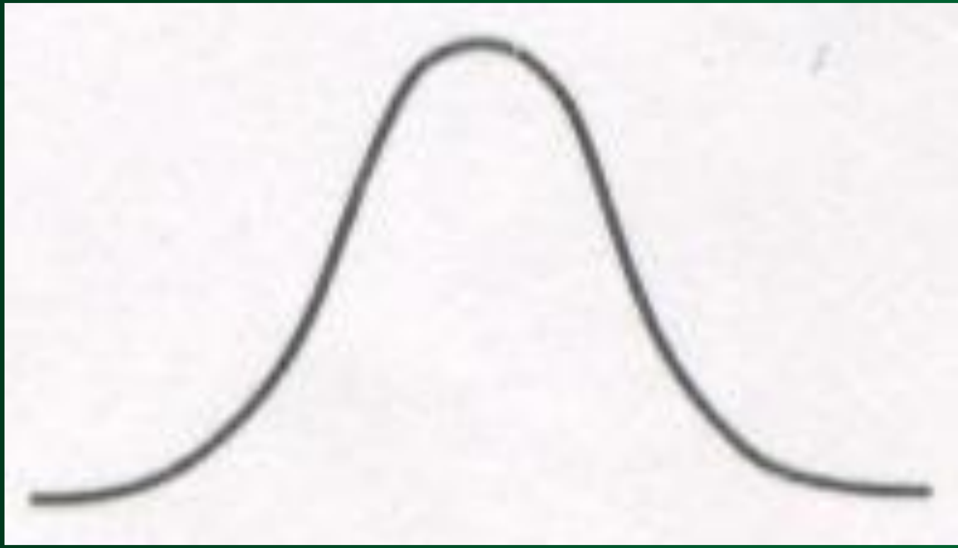
- The **excited** phosphor electrons begin dropping back to their stable ground state, giving up their extra energy as small quantum of **light energy**.

Persistence

- **Persistence** :The time it takes the emitted light from the screen to decay to one-tenth of its original intensity.

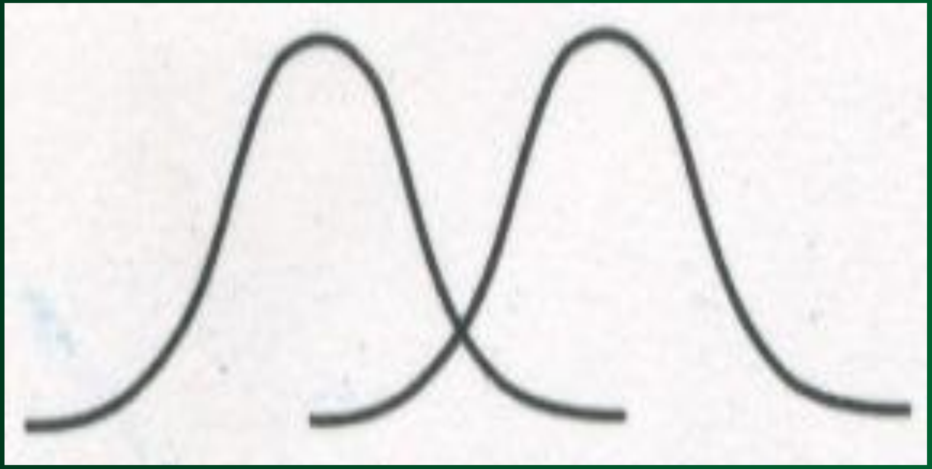
Intensity Distribution

- The intensity is greatest at the center of the spot, and decrease with Gaussian distribution out to the edges of the spot.



Resolution (Spots of Light)

- **Resolution:** The maximum number of points that can be displayed without overlap on a CRT.



Overlap

Resolution (Spots of Light)

- Resolution of a CRT is dependent on:

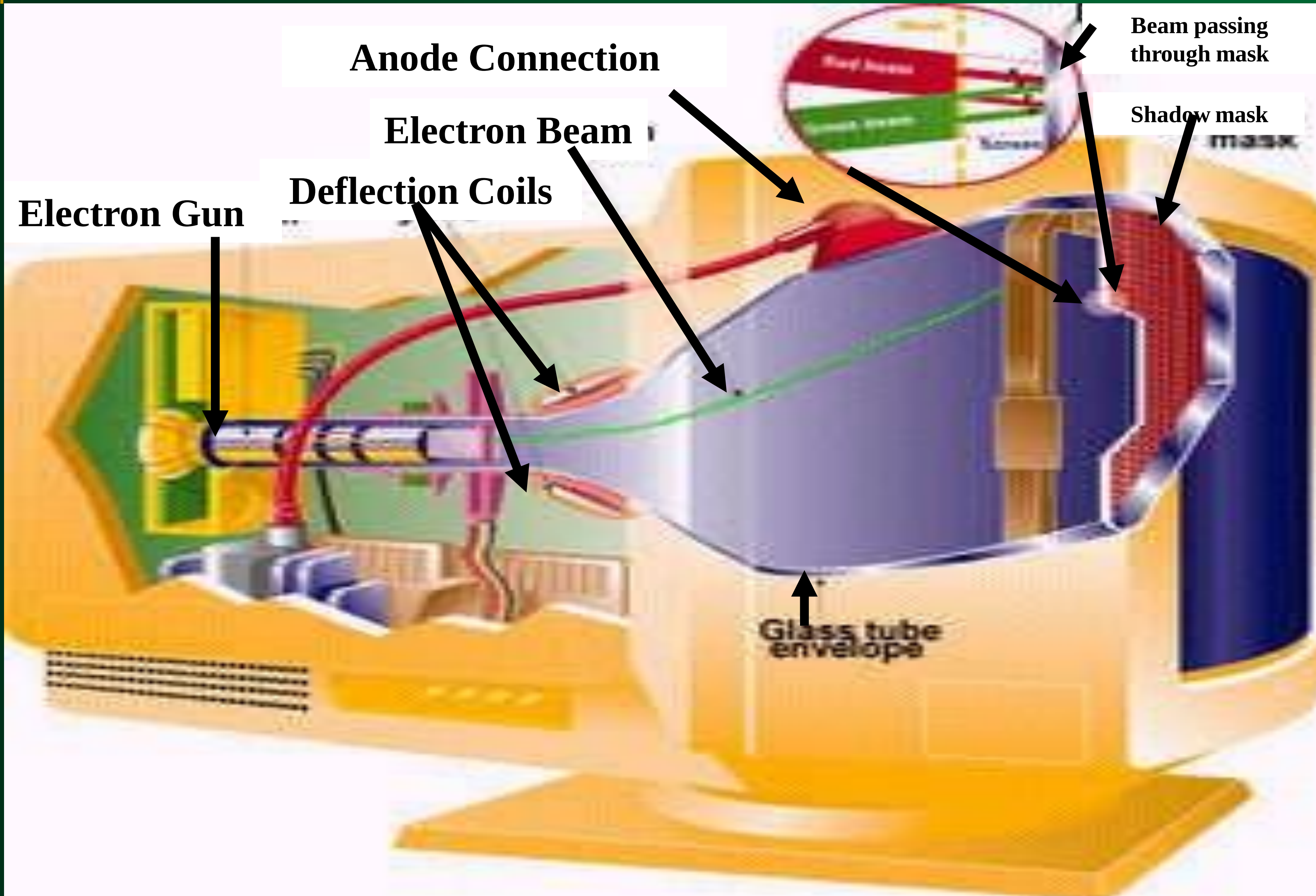
- **The type of phosphor**
- **The intensity to be displayed**
- **The focusing and deflection systems.**

Typical resolution: 1280 by 1024

Aspect Ratio

- **Aspect Ratio:** This numbers gives the ratio of vertical points to horizontal points necessary to produce equal length lines in both directions on the screen.

Cathode Ray Tube (CRT)

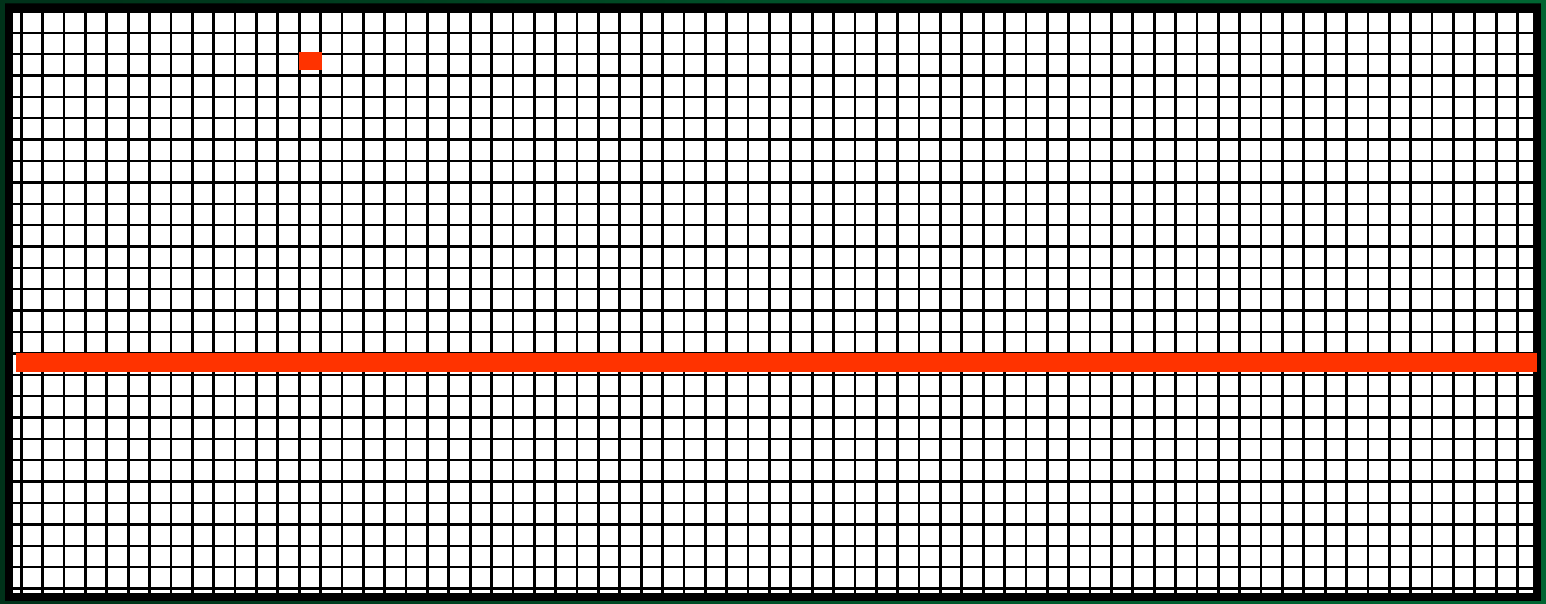


IIIrd Lecture

Raster Scan Displays

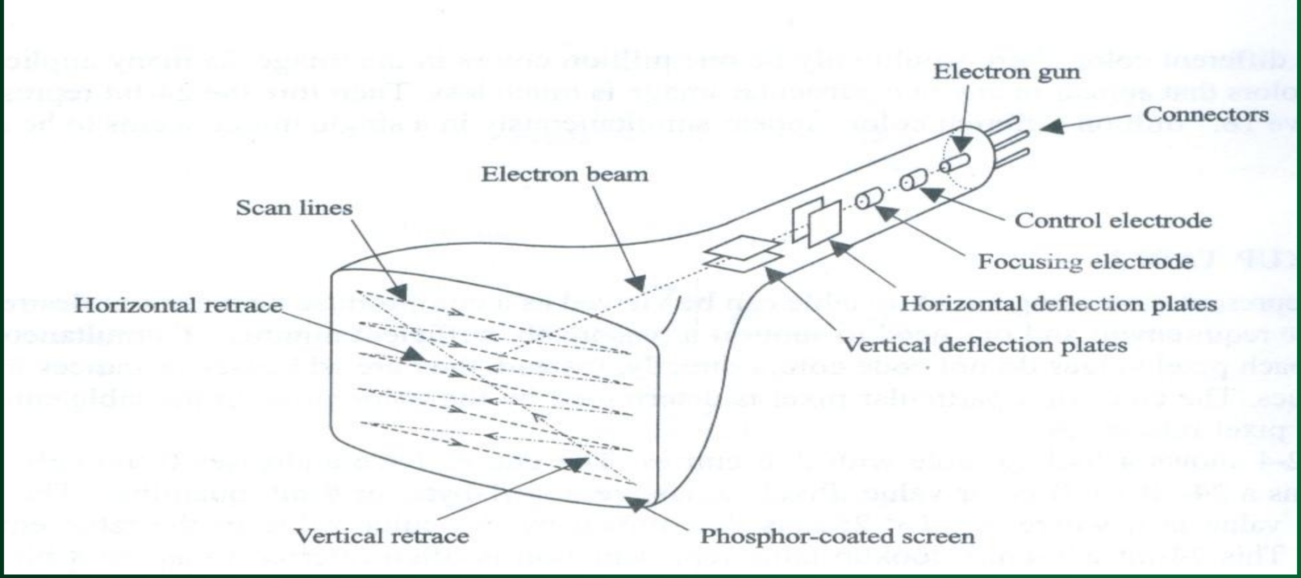
Raster Scan Displays

- **Raster:** A rectangular array of points or dots
- **Pixel:** One dot or picture element of the raster
- **Scan Line:** A row of pixels



Raster Scan Displays

- In a raster scan system, the electron beam is swept across the screen, one row at a time from top to bottom.

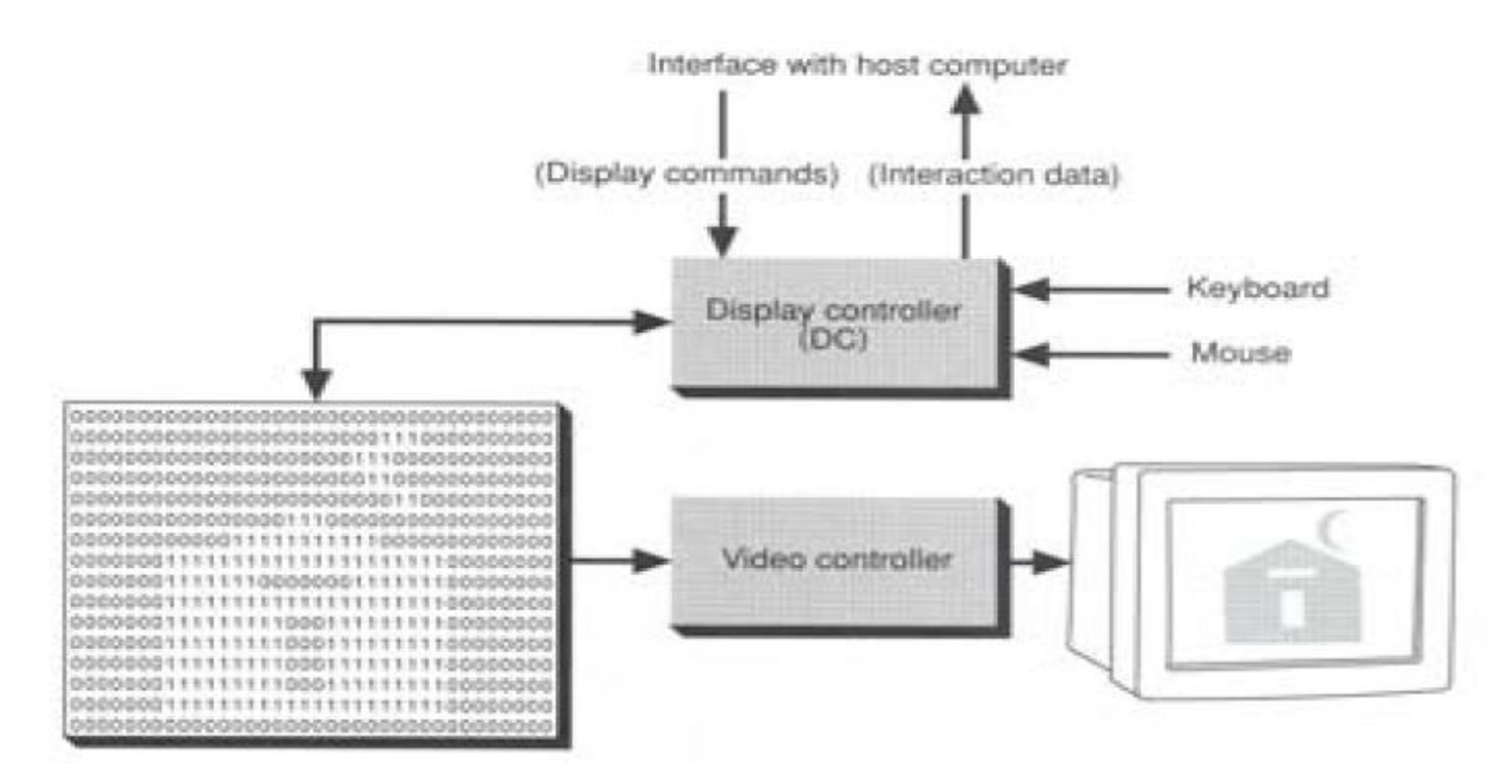


Raster Scan Displays

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

Raster Scan Displays

- Picture definition is stored in a memory area called the **refresh buffer** or **frame buffer**.

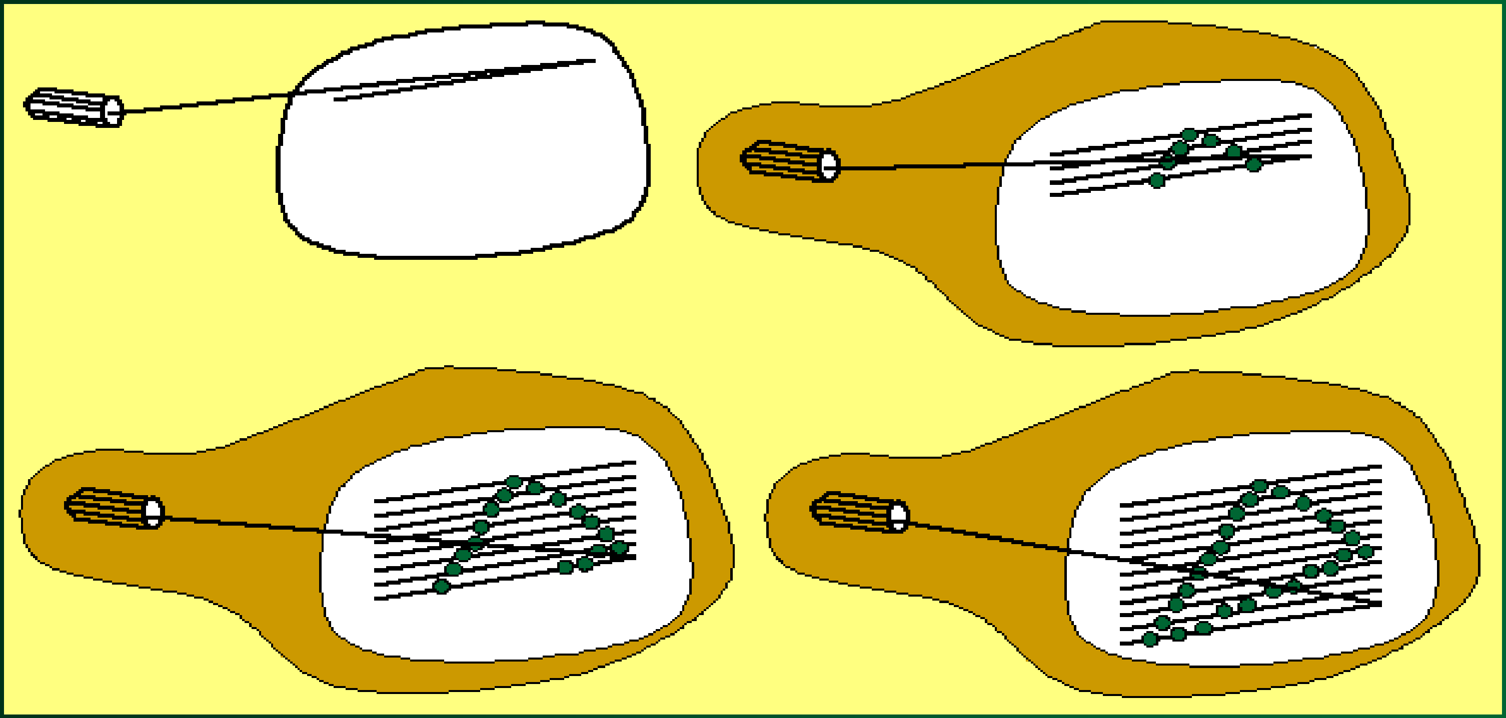


Raster Scan Displays

- **Refresh buffer** or **frame buffer:** This memory area holds the set of intensity values for all the screen points.

Raster Scan Displays

- Stored intensity values then retrieved from refresh buffer and "**painted**" on the screen one row (**scan line**) at a time.



Raster Scan Displays

- Intensity range for pixel positions depends on the capability of the raster system.
- A black-and-white system: each screen point is either on or off, so only **one bit** per pixel is needed to control the intensity of screen positions.

Raster Scan Displays

- On a black-and-white system with one bit per pixel, the frame buffer is called **bitmap**.

- For system with multiple bits per pixel, the frame buffer is called **pixmap**.

Raster Scan Displays

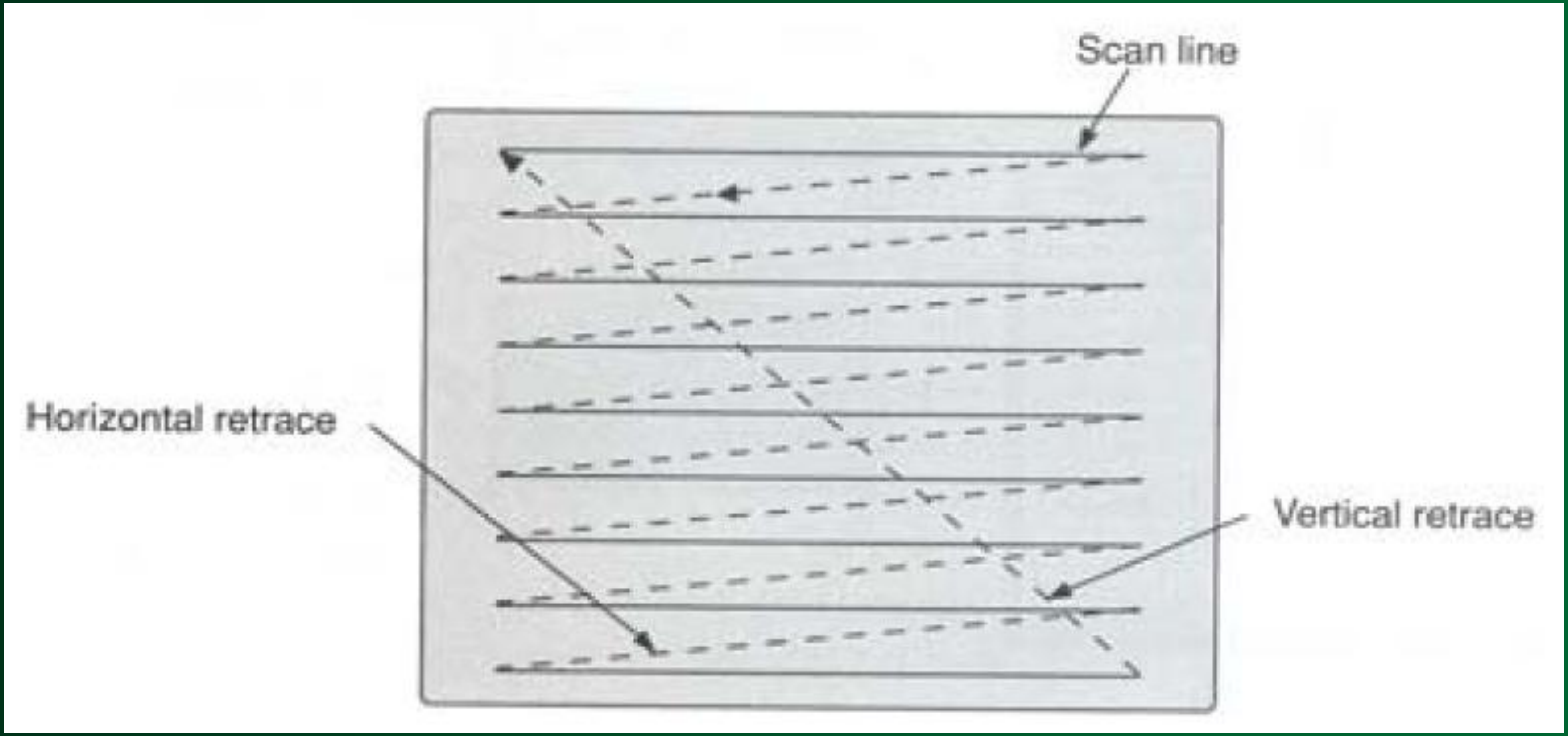
- Sometimes, refresh rates are described in unit of cycles per second, or Hertz (**HZ**)

Raster Scan Displays

- Refreshing on raster scan displays is carried out at the rate 60 to 80 frame per second.

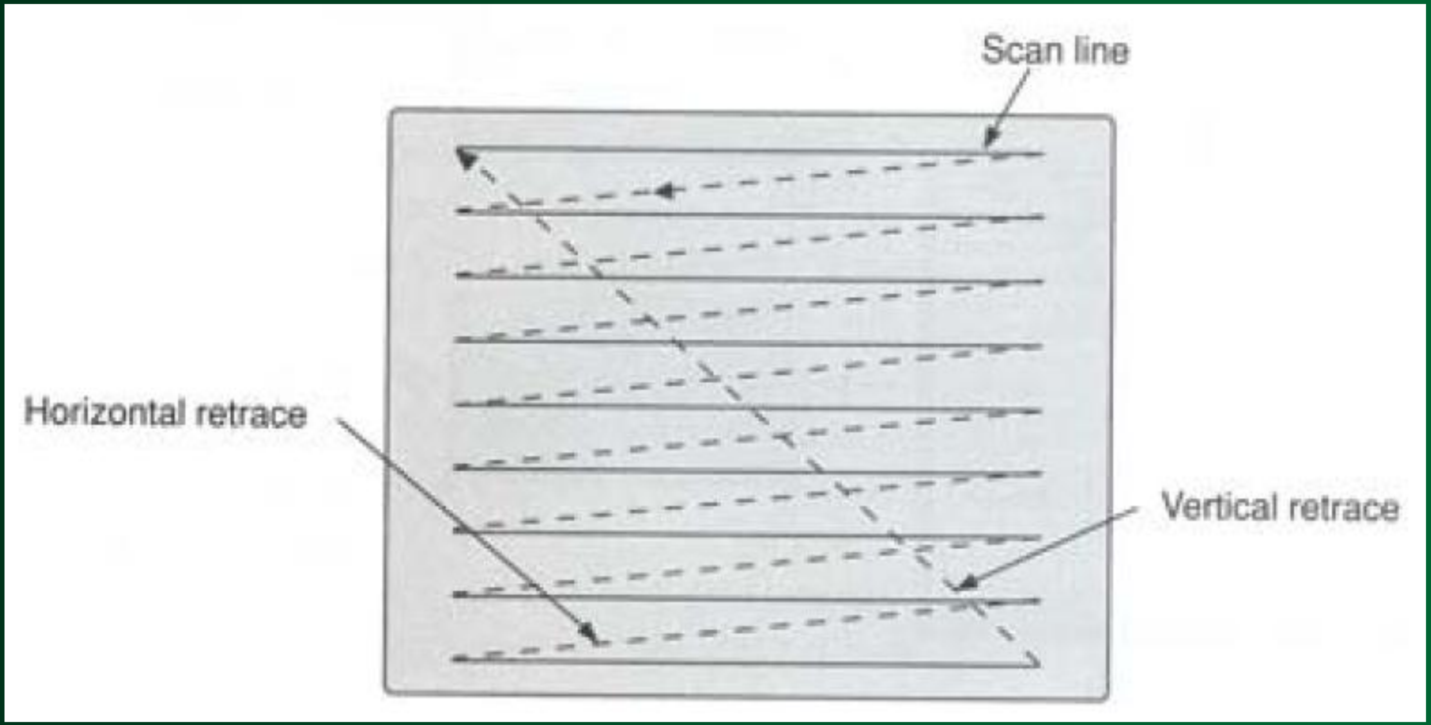
Raster Scan Displays

- **Horizontal retrace**: The return to the left of the screen, after refreshing each scan line.



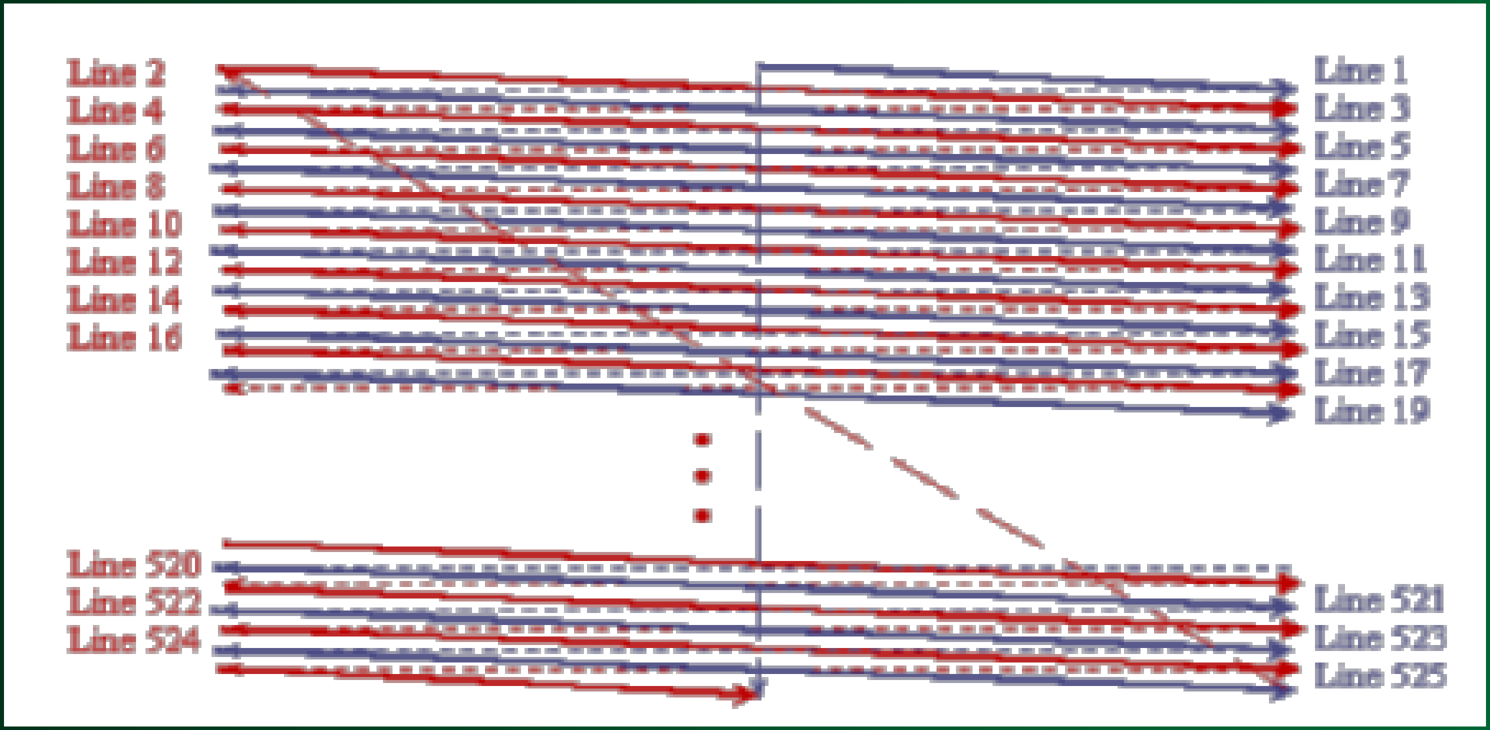
Raster Scan Displays

- **Vertical retrace**: At the end of each frame (displayed in 1/80th to 1/60th of a second) the electron beam returns to the top left corner of the screen to begin the next frame.



Interlacing

- On some raster systems (TV), each frame is displays in two passes using an **interlaced refresh procedure**.



Interlacing

- On an older, 30 frame per-second, noninterlaced display, some flicker is noticeable.
- With interlacing, each of the two passes can be accomplished in 1/60th of a second.

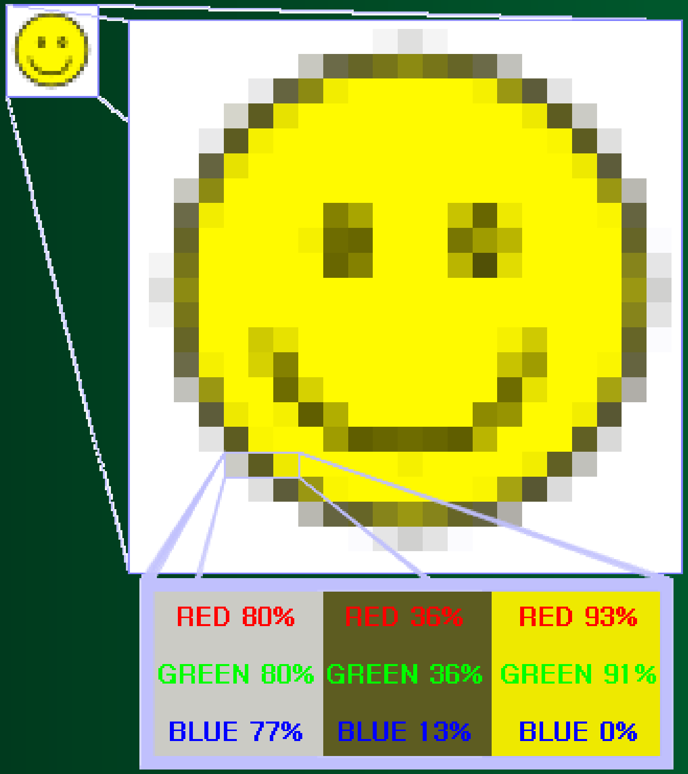
An effective technique for avoiding flicker

Raster image

- The **quality** of a raster image is determined by the total number pixels (**resolution**), and the amount of information in each pixel (**color depth**)

Raster image

- Raster graphics cannot be **scaled** to a higher resolution without loss of apparent quality.



Random Scan Displays

Random Scan Displays

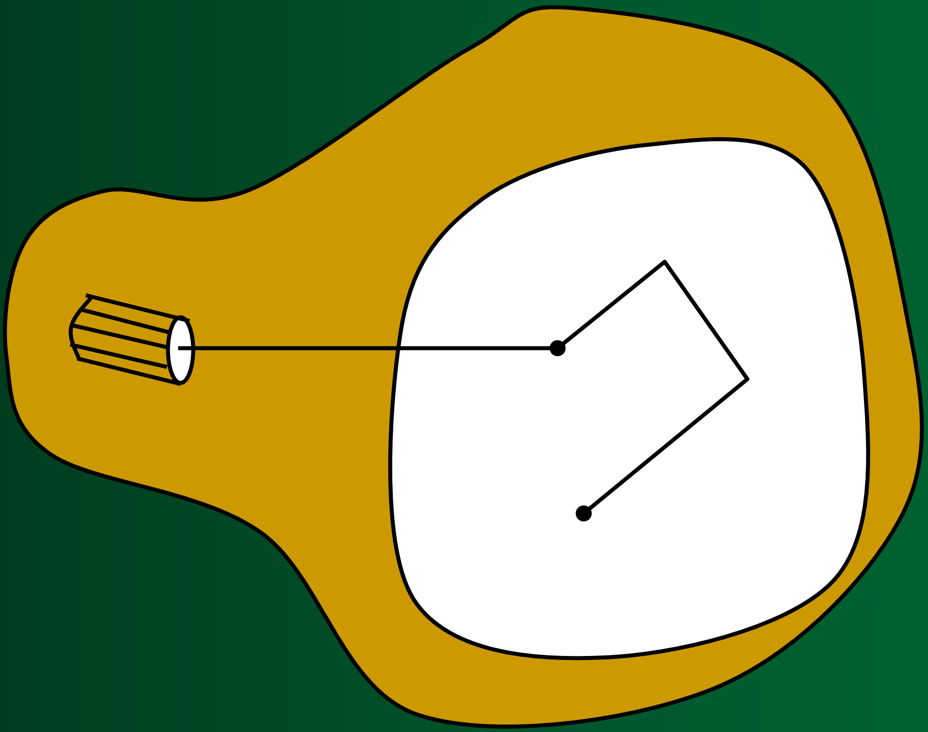
- Random scan display is the use of geometrical primitives such as points, lines, curves, and polygons, which are all based upon **mathematical equation**.
- Raster Scan is the representation of images as a collection of **pixels** (dots)

Random Scan Displays

- In a random scan display, a CRT has the electron beam directed only to the **parts of the screen** where a picture is to be drawn.
- Random scan monitors draw a picture one line at a time (**Vector** display, **Stroke –writing** or **calligraphic** displays).

Random Scan Displays

- The component lines of a picture can be drawn and refreshed.



Random Scan Displays

- **Refresh rate** depends on the number of lines to be displayed.

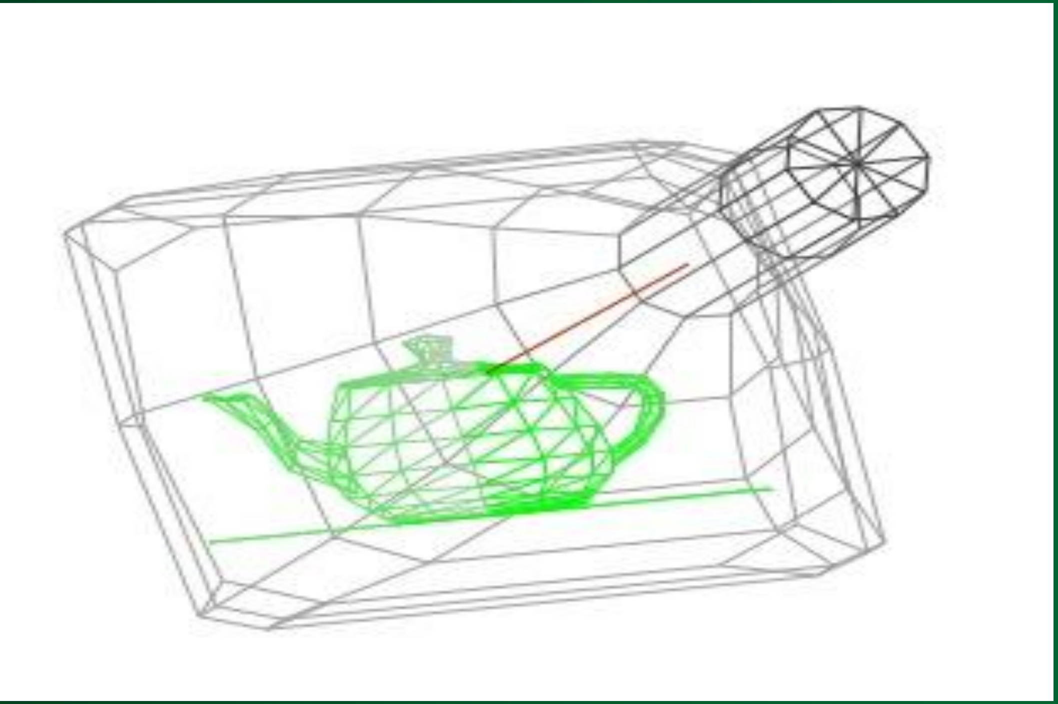
- Picture definition is now stored as a line-drawing commands an area of memory referred to as **refresh display file** (**display list**).

Random Scan Displays

- To display a picture, the system cycle through the **set of commands** in the display file, drawing each component line in turn.

Random Scan Displays

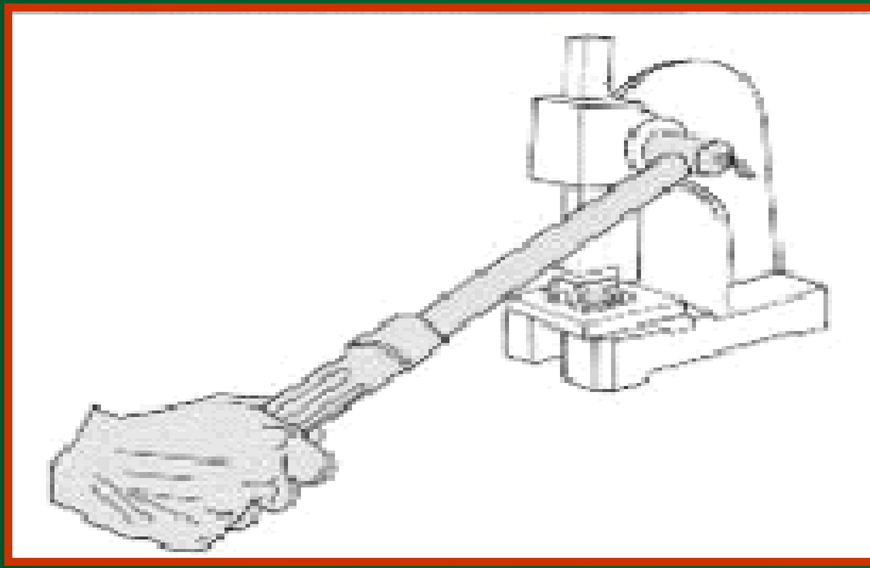
- Random scan displays are designed to draw all the component lines of a picture 30 to 60 times each second.



IVth Lecture

Random Scan Displays

- Random scan displays are designed for **line-drawing applications** and can not display realistic shaded scenes.



Random Scan Displays

Color CRT Monitors

Color CRT Monitors

- A CRT monitor displays color pictures by using a combination of phosphors that emit different ***color*** lights.

Methods

1. **Beam Penetration**

2. **Shadow Mask**

Beam Penetration Method

Beam Penetration Method

- Two layers of ***phosphor*** (**red** and **green**) are coated onto the inside of the CRT screen.

- The display color depends on how far the electron beam **penetrates** into the phosphor layers.

Beam Penetration Method

- The speed of the electrons, and the screen color at any point, is controlled by the beam **acceleration voltage.**

The beam penetration method:

- Used with random scan monitors
- Only four colors are possible (**red**, **green**, **orange**, and **yellow**).
- Quality of pictures is not as good as with other methods.

Shadow Mask Method

Shadow Mask Method

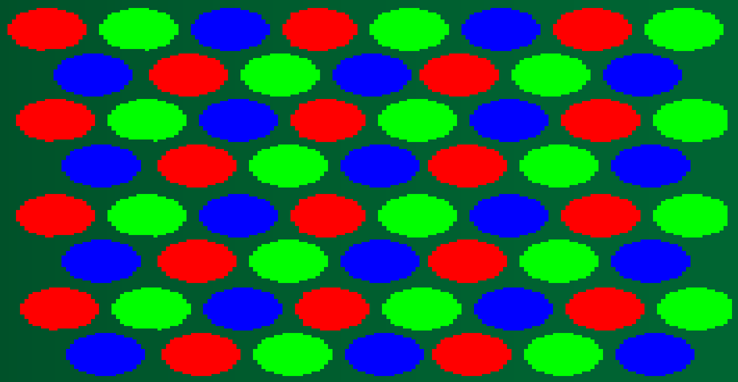
The color CRT has:

- Three color ***phosphor*** dots (**red**, **green** and **blue**) at each point on the screen

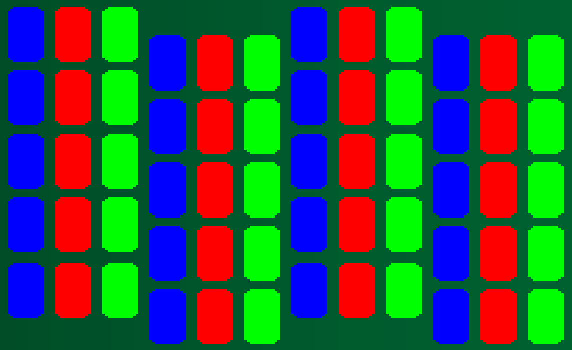
- Three ***electron guns***, each controlling the display of red, green and blue light.

Shadow Mask Method

Delta Method:

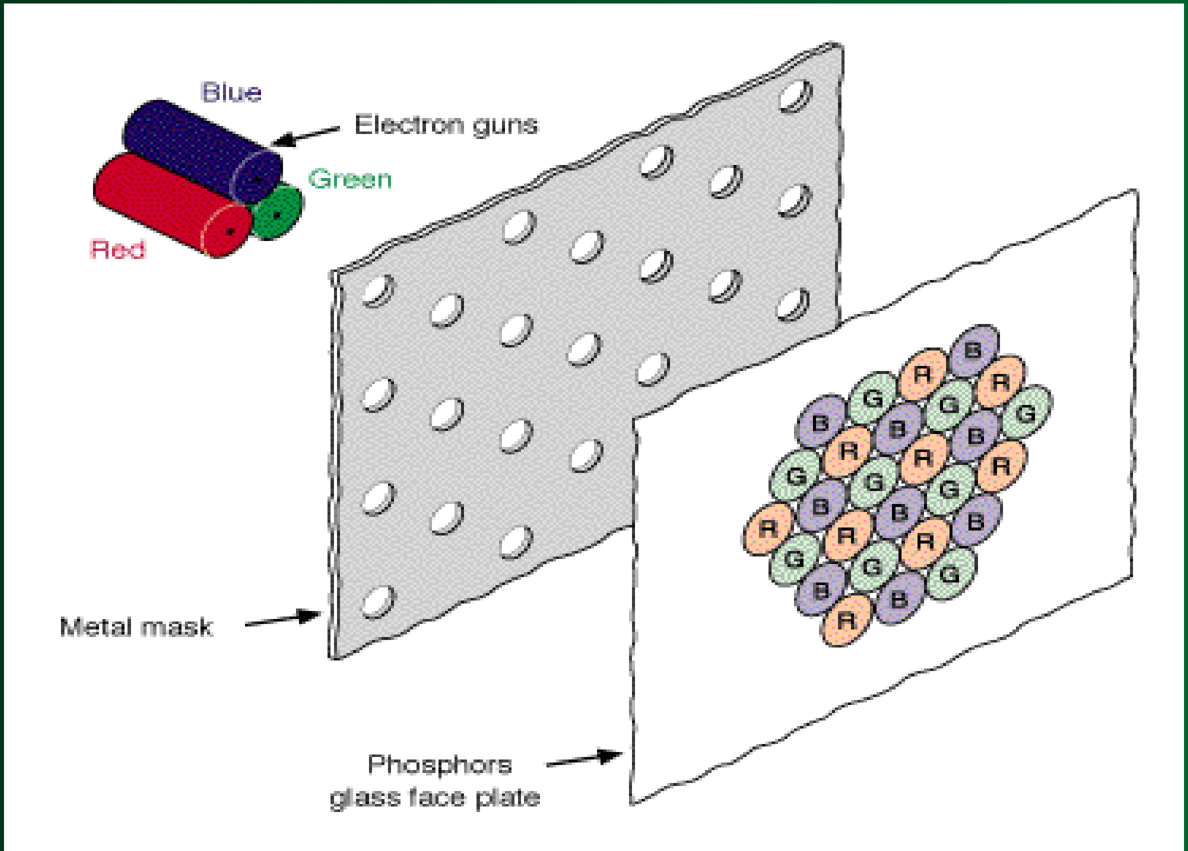


In-line Method:



Shadow Mask Method

The delta-delta method:



Shadow Mask Method

The delta-delta method:

- DeltaDelta shadow-mask method, commonly used in color **CRT** systems.

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

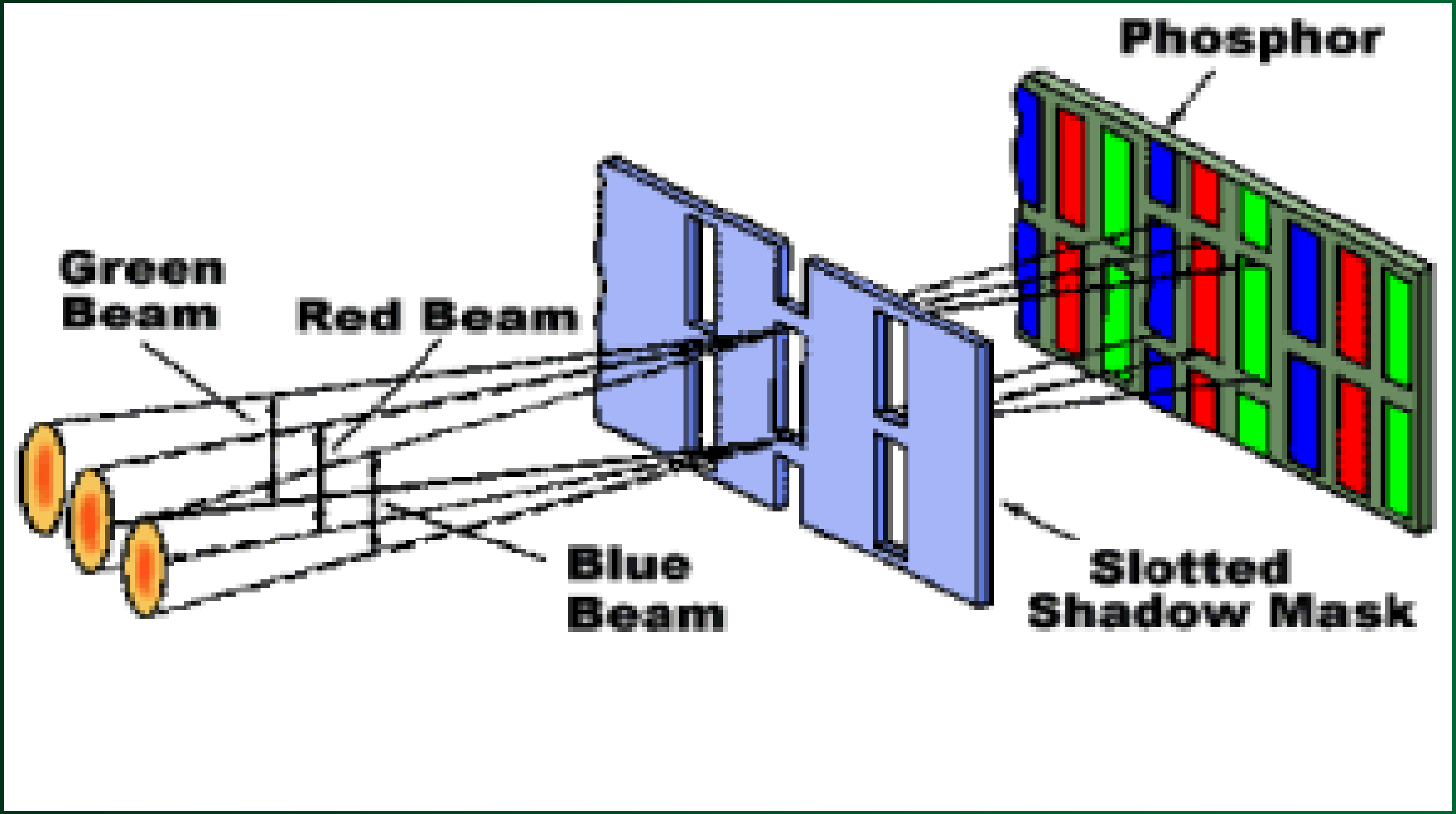
Shadow Mask Method

The delta-delta method:

- When the three beams pass through a hole in the shadow mask, they activate a dot triangle, which appears as a small color spot on the screen.
- The phosphor dots in the triangles are arranged so that each electron beam can activate only its corresponding color dot when it passes through the shadow mask.

Shadow Mask Method

The in-line method:



Shadow Mask Method

The in-line method:

- Another configuration for the three electron guns is an ***in-line*** arrangement in which the three electron guns, and the corresponding red-green-blue color dots on the screen, are aligned along one scan line instead of in a triangular pattern.

Shadow Mask Method

The in-line method:

- This in-line arrangement of electron guns is easier to keep in alignment and is commonly used in high-resolution color CRTs.
- We obtain color variations in a shadow-mask CRT by varying the intensity level of three electron guns.

Shadow Mask Method

- We obtain color variations by varying the **intensity** levels of the three electron beam.

Shadow Mask Method

Shadow mask methods are:

- Used in raster scan system (including color TV).
- Shadow-mask methods **are** commonly **used** in raster scan systems (including color **TV)** because they produce a much wider range of colors than the beam penetration method.
- Designed as ***RGB*** monitors.

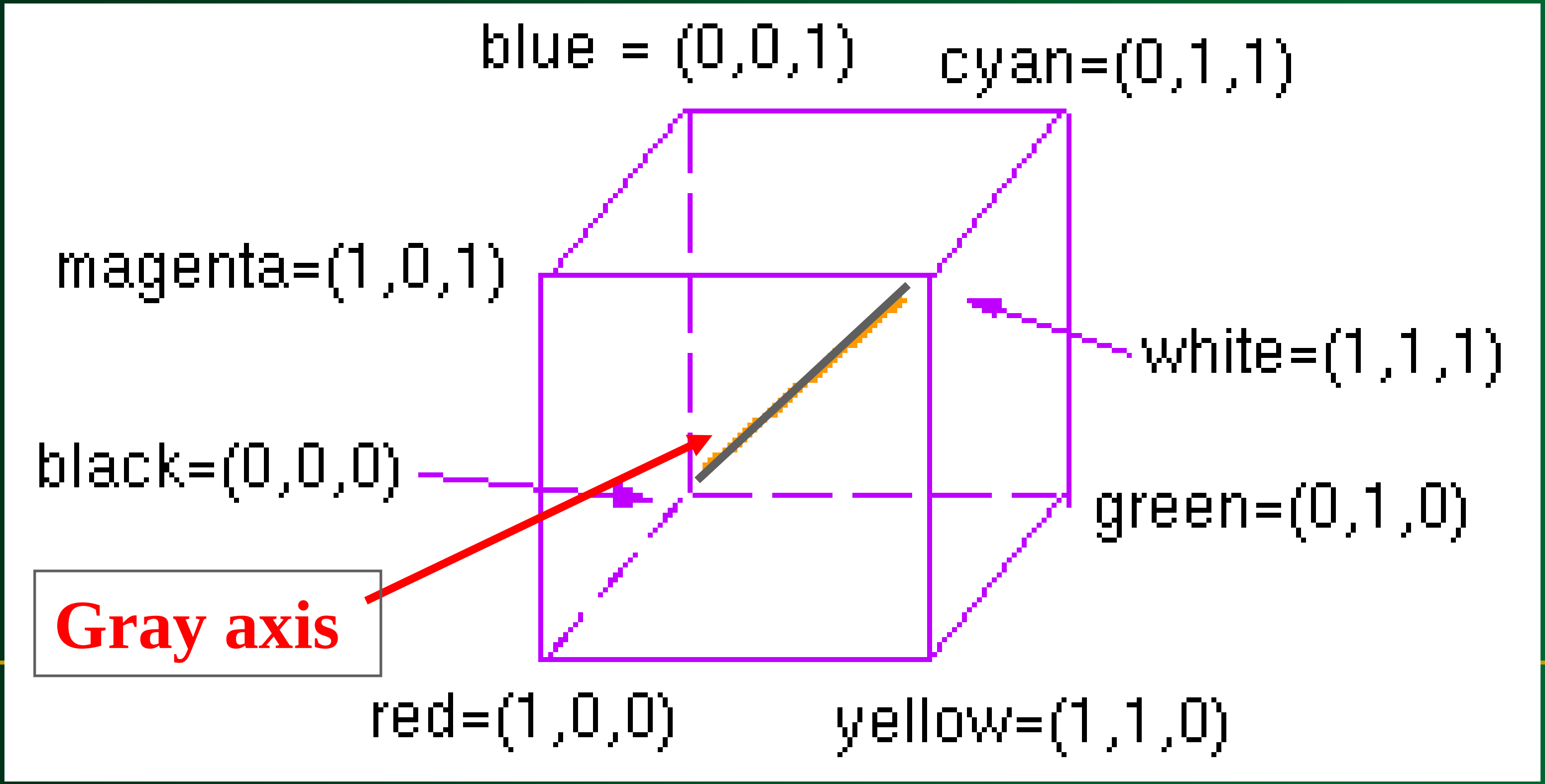
Shadow Mask Method

- High quality raster graphics system have **24** bits per pixel in the frame buffer (a **full color** system or a **true color** system)

Color Models

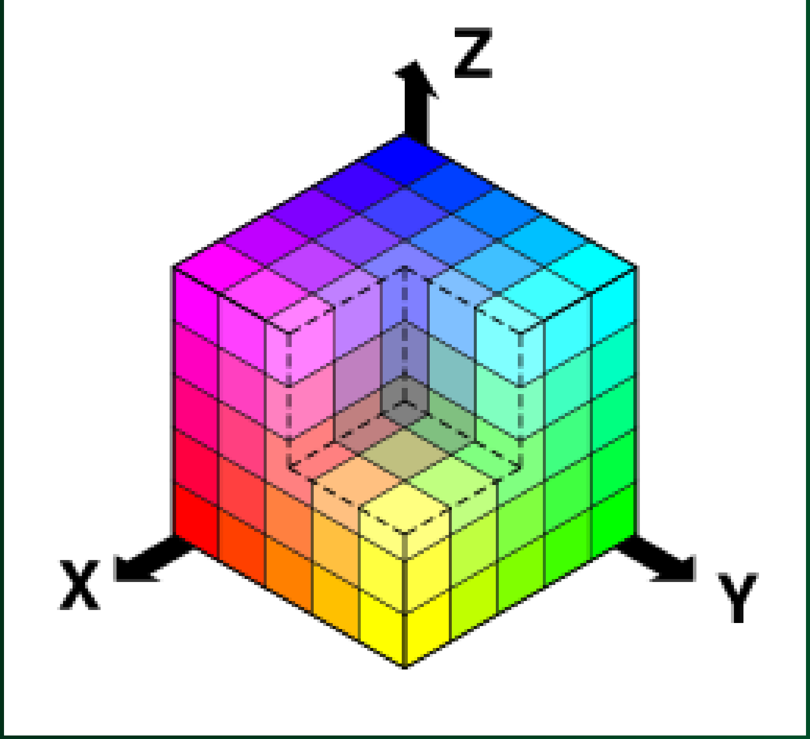
The RGB Color Model

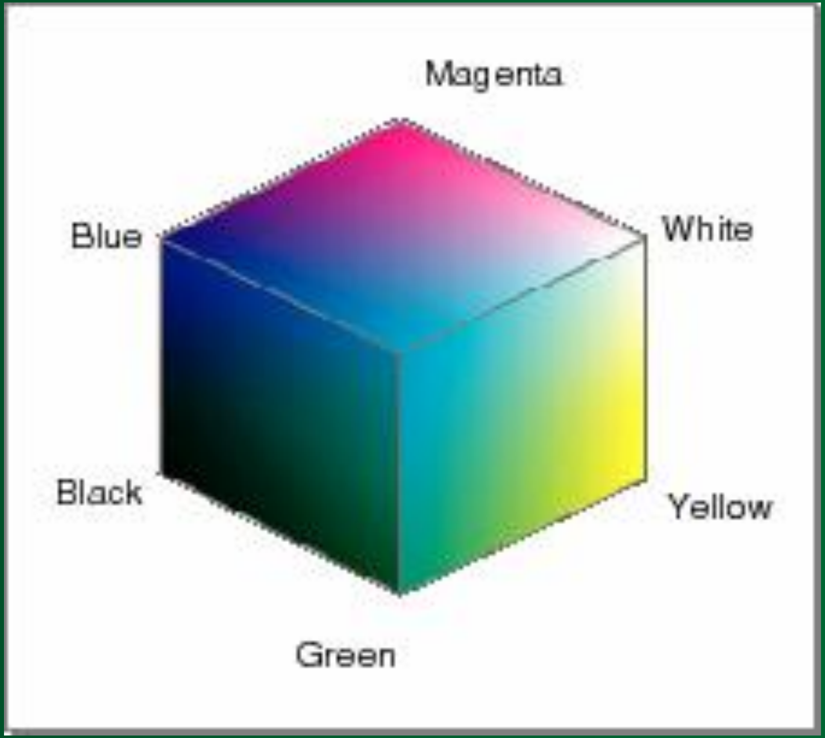
- ***R***, ***G***, and ***B*** represent the colors produced by ***red***, ***green*** and ***blue*** phosphors, respectively.



RGB Color Model

RGB color space





CMY Color Model

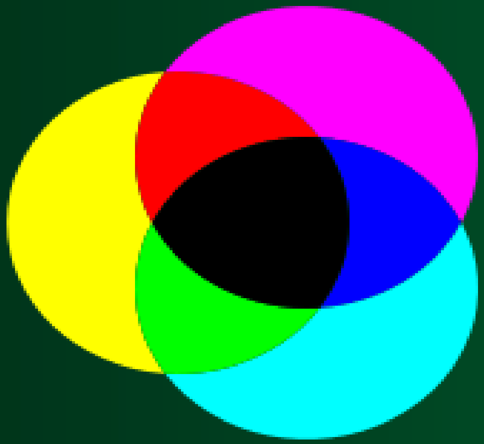
CMY (short for Cyan, Magenta, Yellow, and key) is a subtractive color model.

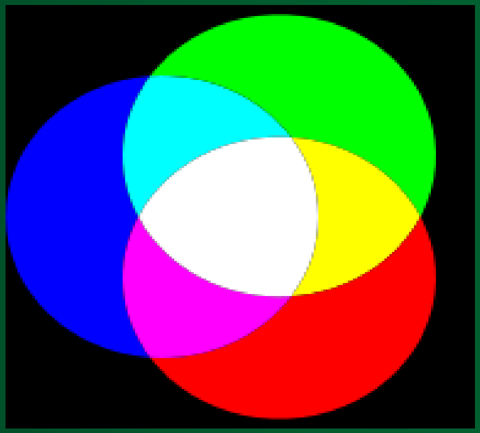
Colors are subtractive

C	M	Y	Color
0.0	0.0	0.0	White
1.0	0.0	0.0	Cyan
0.0	1.0	0.0	Magenta
0.0	0.0	1.0	Yellow
1.0	1.0	0.0	Blue
1.0	0.0	1.0	Green
0.0	1.0	1.0	Red
1.0	1.0	1.0	Black
0.5	0.0	0.0	
1.0	0.5	0.5	
1.0	0.5	0.0	

CMY Color Model

$$\begin{pmatrix} C \\ M \\ Y \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$





Color Depth, Bit Depth

- The number of discrete intensities that the video card is capable of generating for each color determines the maximum number of colors that can be displayed.

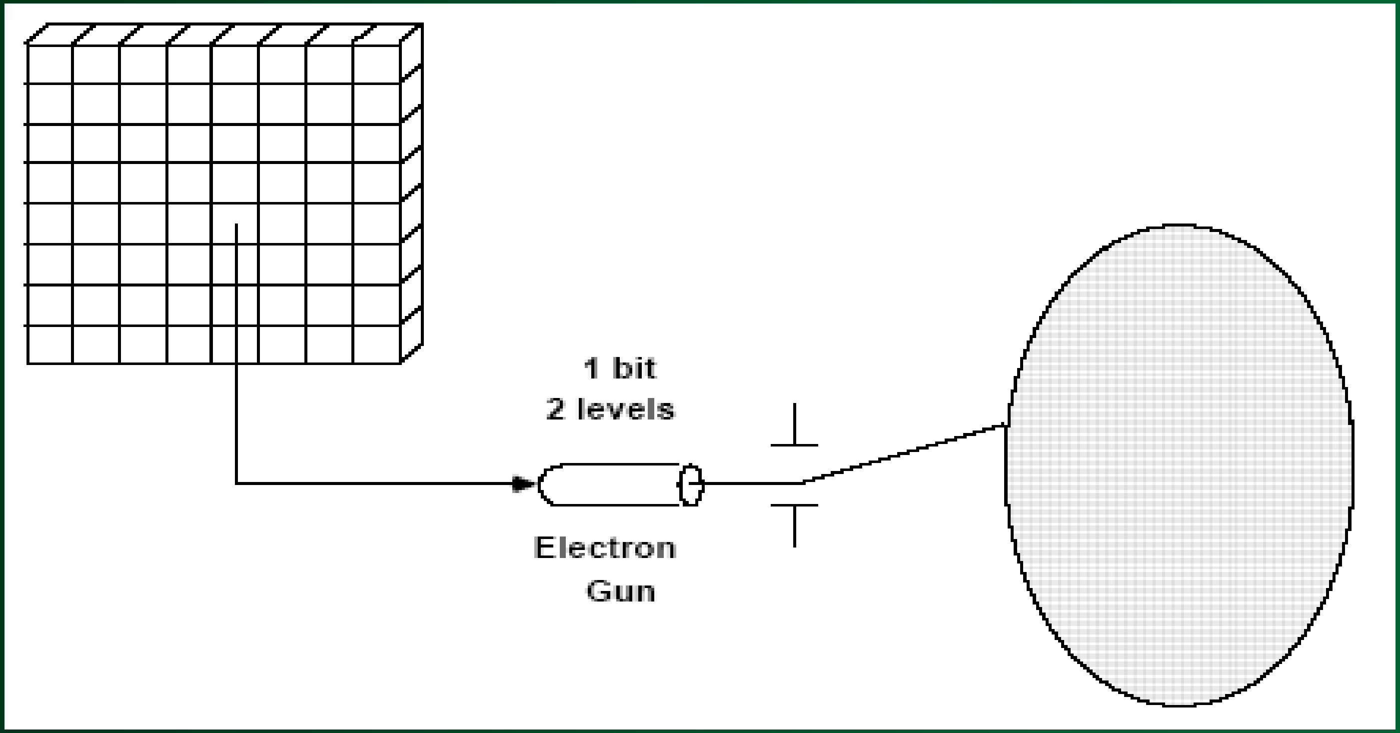
- The number of memory bits required to store color information (intensity values for all three primary color components) about a pixel is called **color depth** or **bit depth**.

Color Depth, Bit Depth

- A minimum of one memory bit (color depth=1) is required to store intensity value either 0 or 1 for every screen pixel.
- If there are n pixels in an image a total of n bits memory used for storing intensity values (in a pure black & white image)

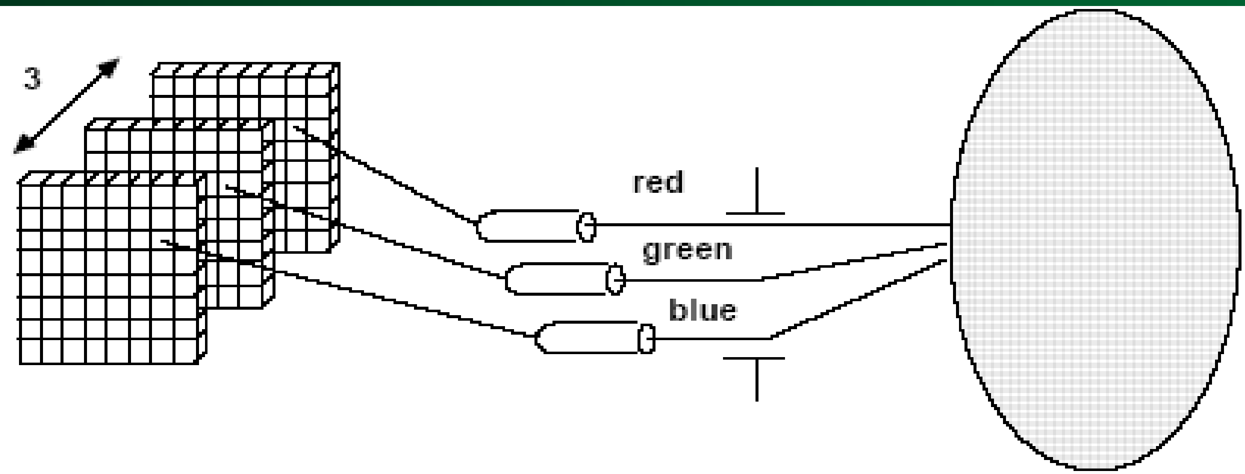
Bit Plane

- The block of memory which stores (or is mapped with) intensity values for each pixel (B& W image) is called a **bit plane** or **bitmap**.



3Bit color display

- Color or gray levels can be achieved in the display using additional bit planes.



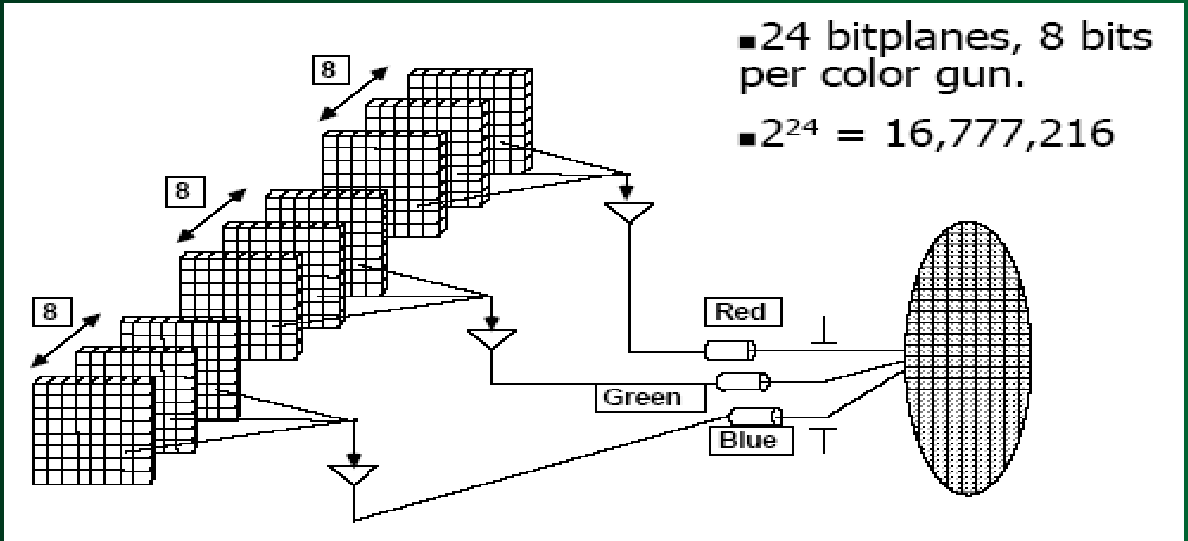
COLOR:	black	red	green	blue	yellow	cyan	magenta	white
R	0	1	0	0	1	0	1	1
G	0	0	1	0	1	1	0	1
B	0	0	0	1	0	1	1	1

N Bit Planes

- The result for n bits per pixel (color depth=n) is a collection of n bit planes (2^n colors or gray shades at every pixel)

True Color

- For **true Color three bytes** of information are used, one for each of the red, blue and green signals that make a pixel.
- A byte can hold 256 different values and so 256 intensities setting are possible for each electron gun which mean each primary color can have 256 intensities (**256*256* 256 color possible**)



High Color

- For **high Color two bytes** of information are used, to store the intensity values for all three color.
- This is done by dividing 16 bits into 5 bits for blue, 5 bits for red and 6 bits for green. This means 32(=2^5) intensities for blue, 32 (=2^5) for red, and 64 (=2^6) for green.
- Loss of visible image quality.

256 color mode

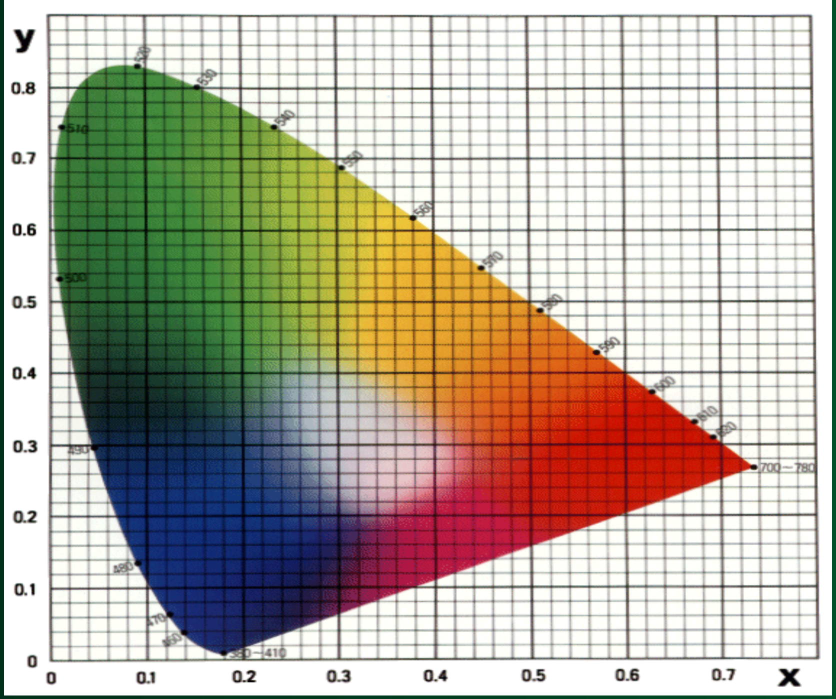
- The PC uses only 8 bits, 2 bits for blue and 3 each for green and red.
- Most of the colors of a given picture are not available.
- A ***palette*** or ***look-up table*** is used here.

Color Palette

- A palette is a separate memory block (in addition to the 8 bit plane) created 256 different colors.
- Each color is defined using the standard 3 byte color definition that is used in true color.
- The intensity values for each of the three primary color component can be anything between 0 and 255 in each of the table entries.

Color Palette

- The intensity values for each of the three primary color component can be anything between 0 and 255 in each of the table entries.

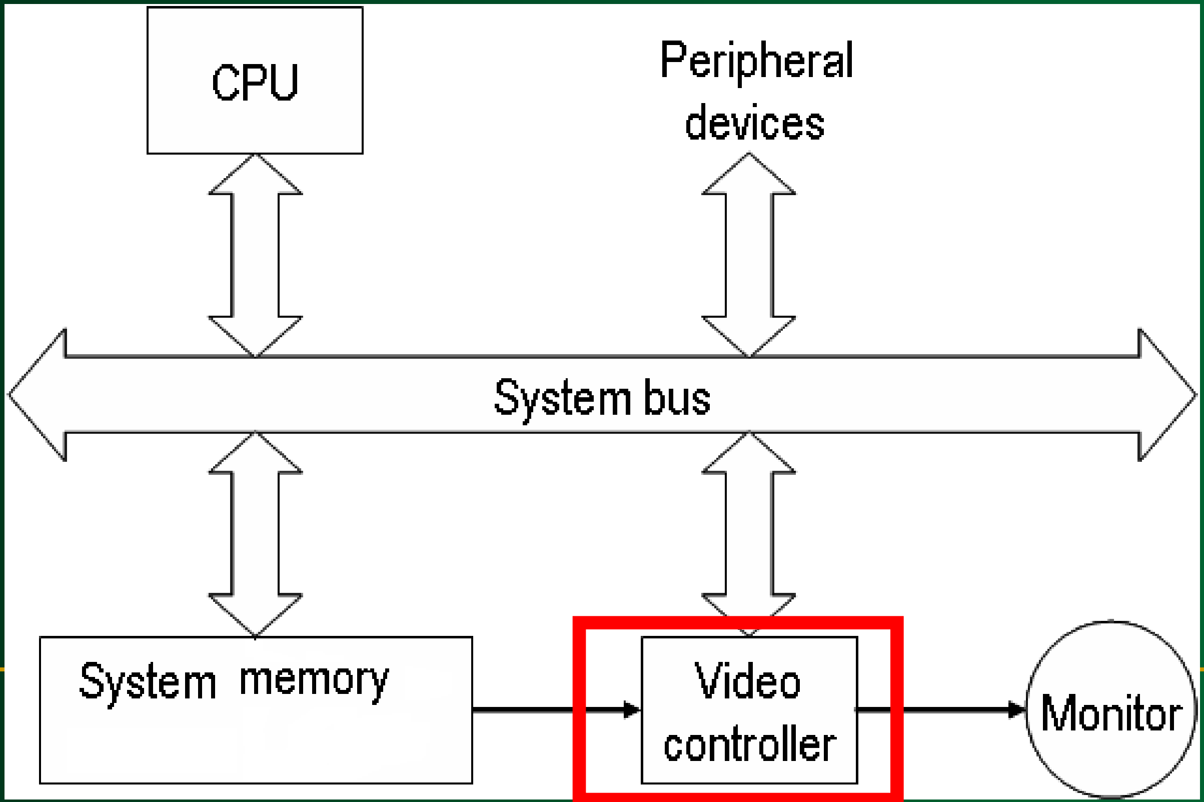


Total number of colors available called **color palette**.

Raster Scan Systems

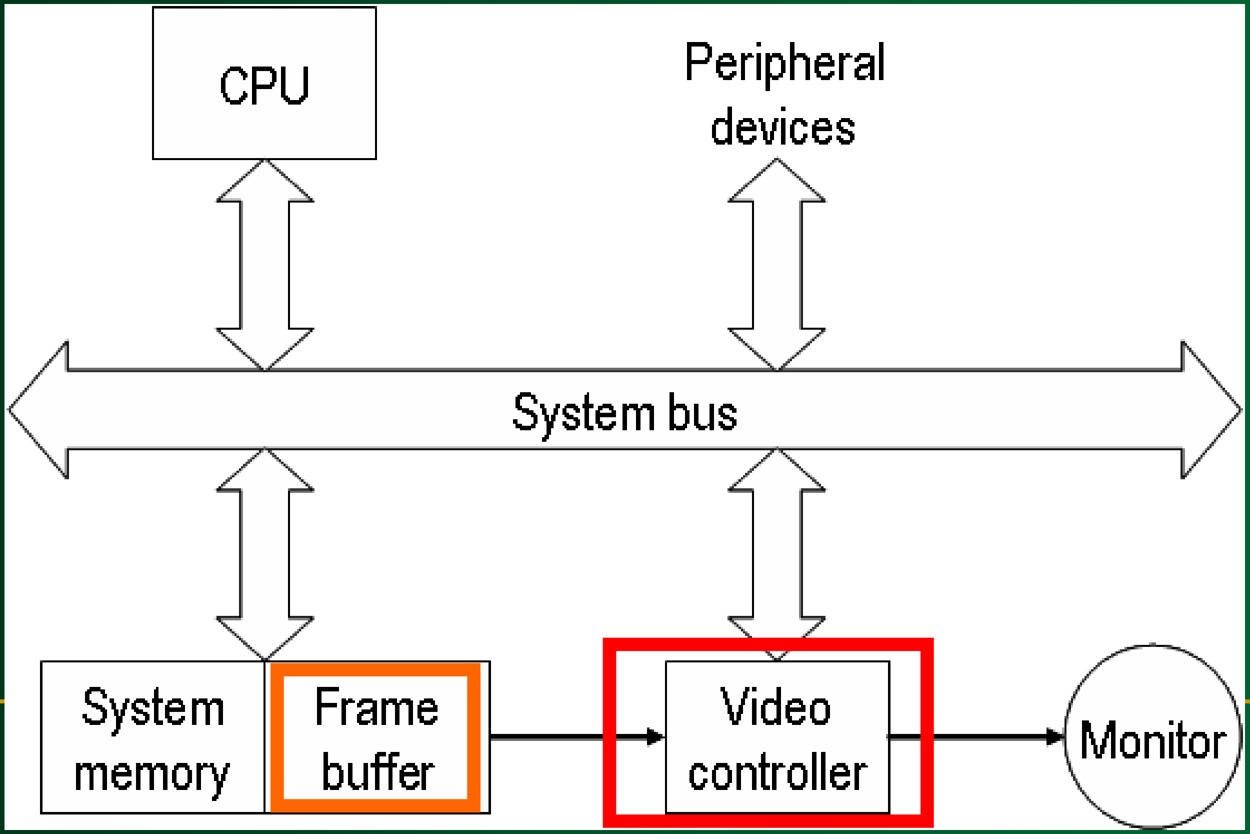
Raster Scan Systems

- In addition to the central processing unit (CPU), a special processor, called the **video controller** or **display controller**, is used to control the operation of the display device.



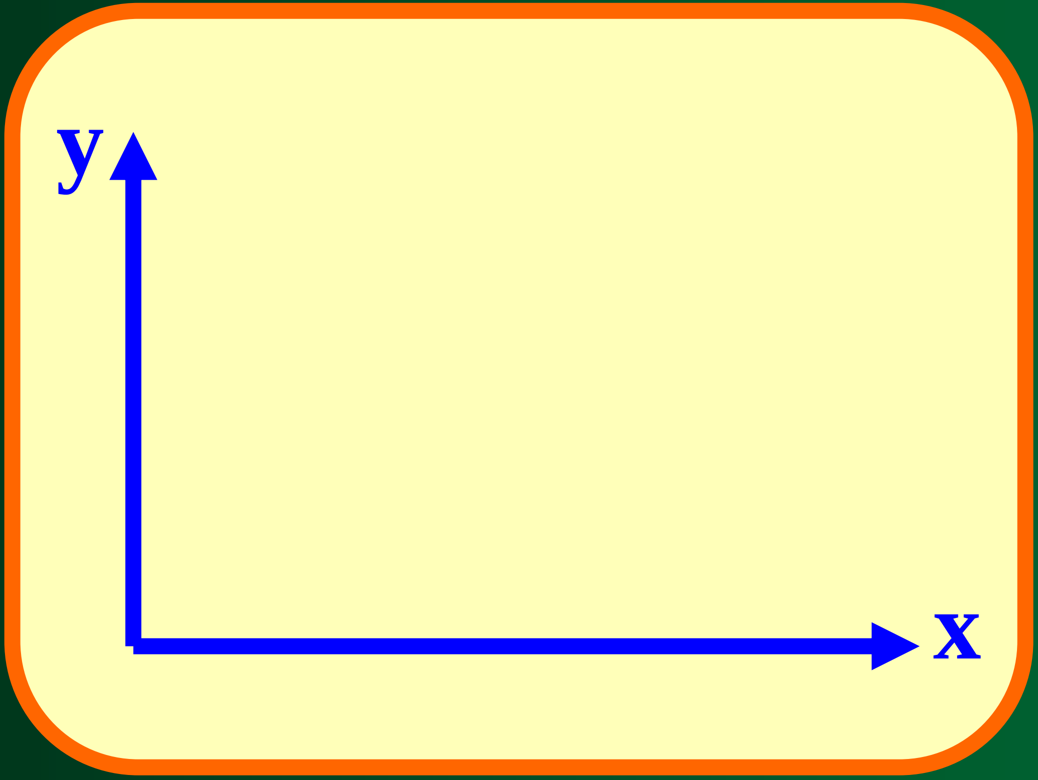
Video Controller

- 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.



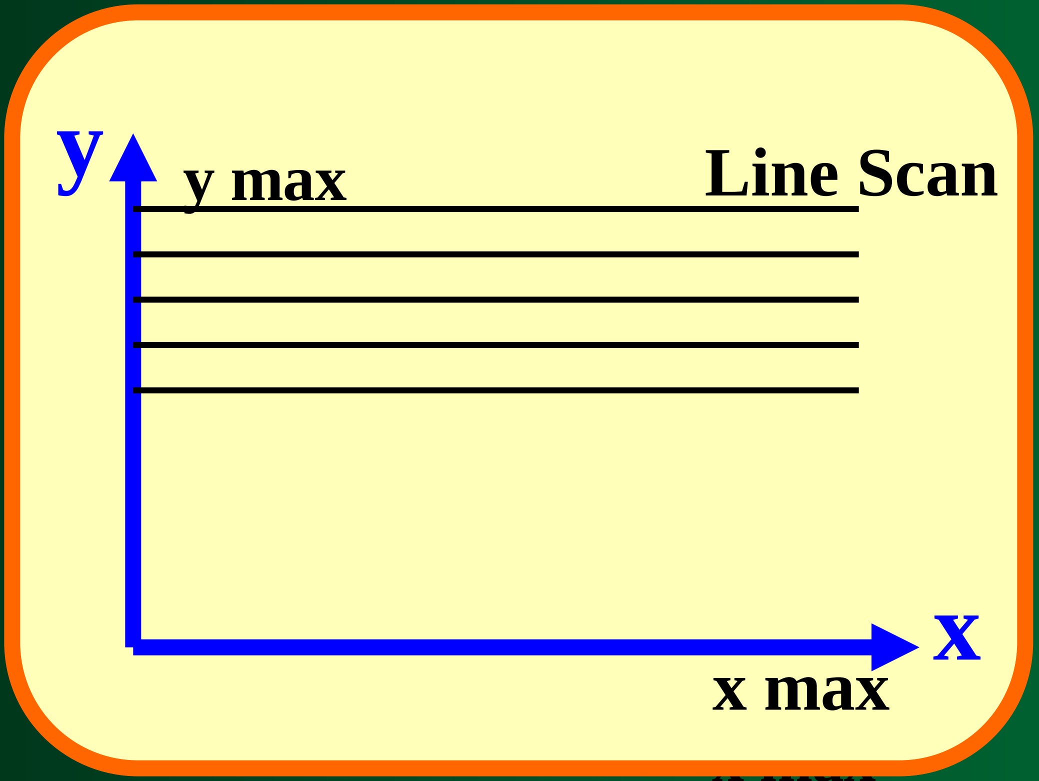
Video Controller

- **Frame buffer** location, and the corresponding screen positions, are referenced in Cartesian coordinates.



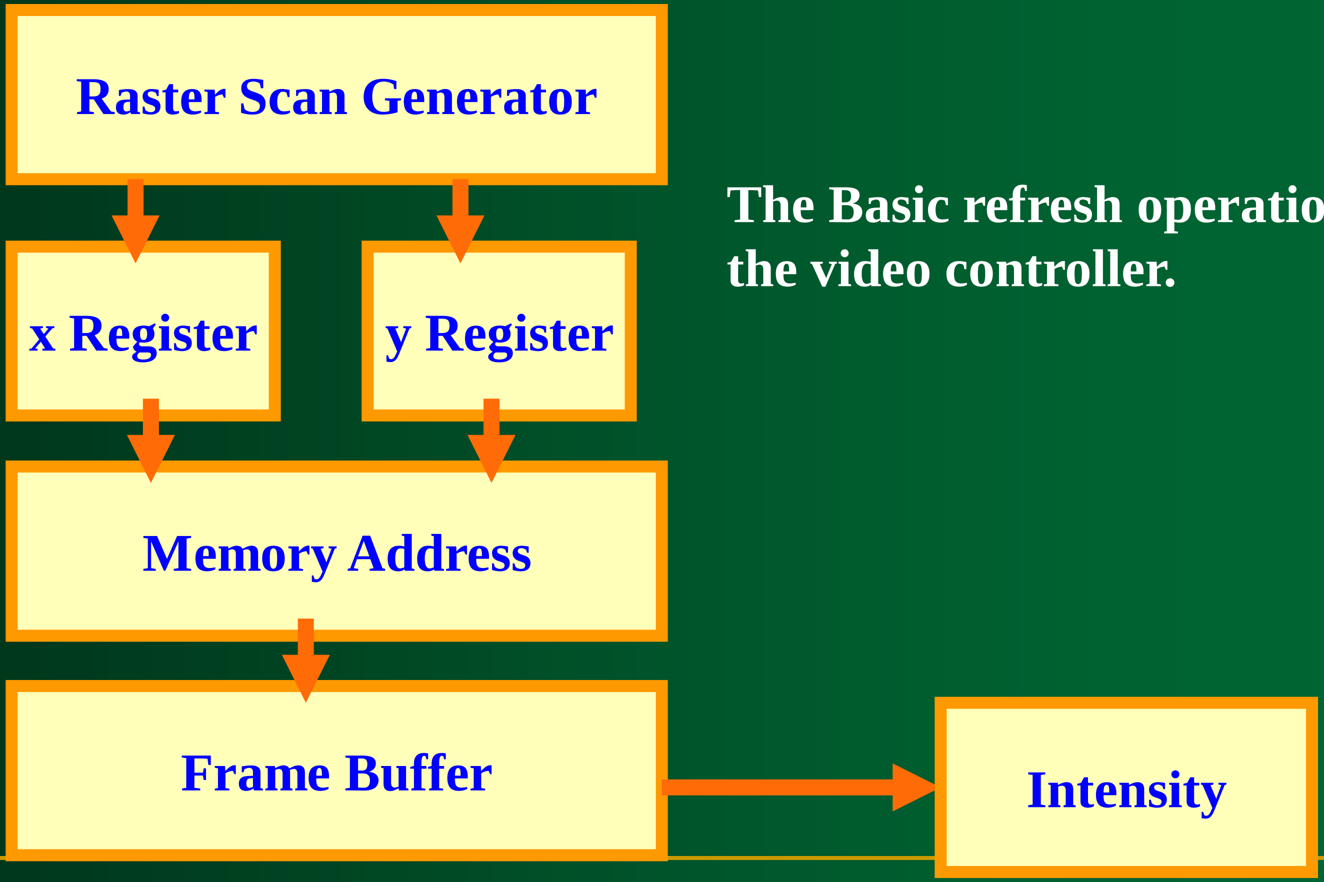
Video Controller

- **Scan lines** are then labeled from y_{max} at the top of the screen to 0 at the bottom. Along each scan line, screen **pixel** positions are labeled from 0 to x_{max}.



Video Controller

- Two registers are used to store the coordinates of the screen pixels.



The Basic refresh operation of the video controller.

Video Controller

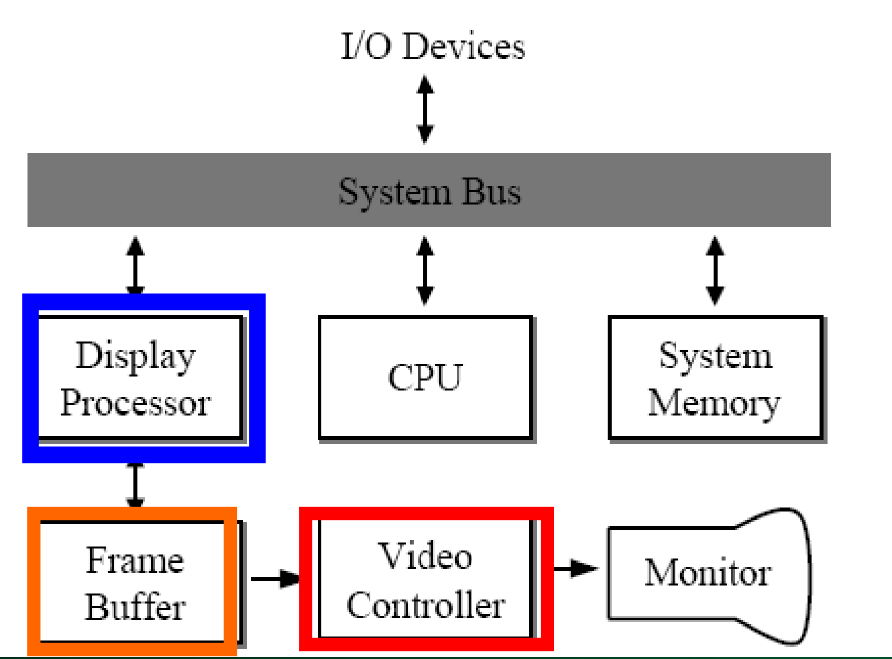
Some of operations can be performed by the Video Controller:

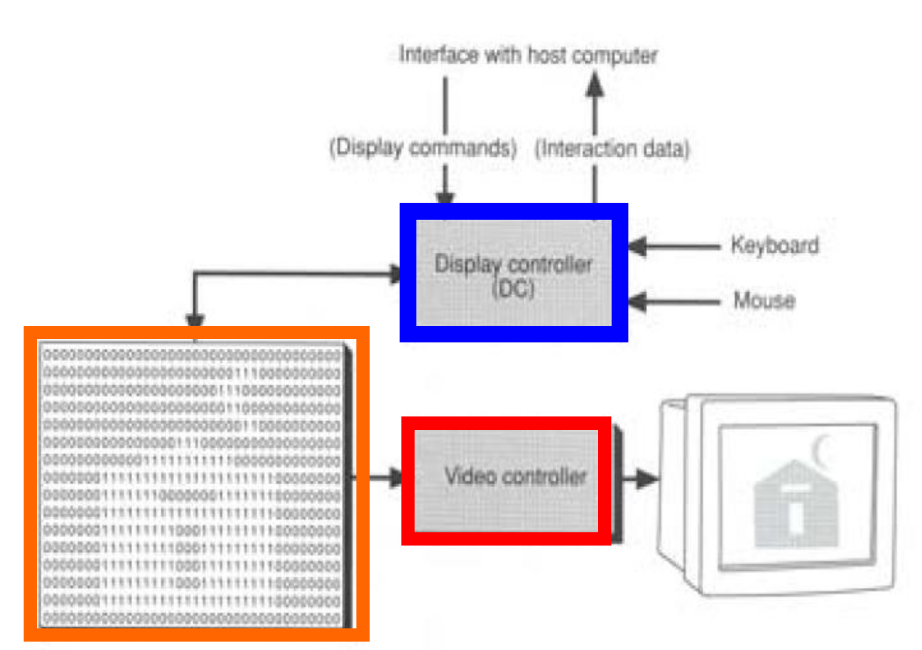
- Refreshing operation
- Transformation (Areas of the screen can be enlarged, reduces, or moved during the refresh cycles)

Raster Scan Display Processor

Raster Scan Display Processor

- A raster system containing a separate **display processor** (graphics controller, display coprocessor)
- The purpose of the **DP** is to free the CPU from the graphics chores.





DP

- A major task of the display processor is **Scan Conversion.**

- **Scan Conversion: is digitizing a picture definition given in an application program into a set of pixel intensity values for storage in the frame buffer.**

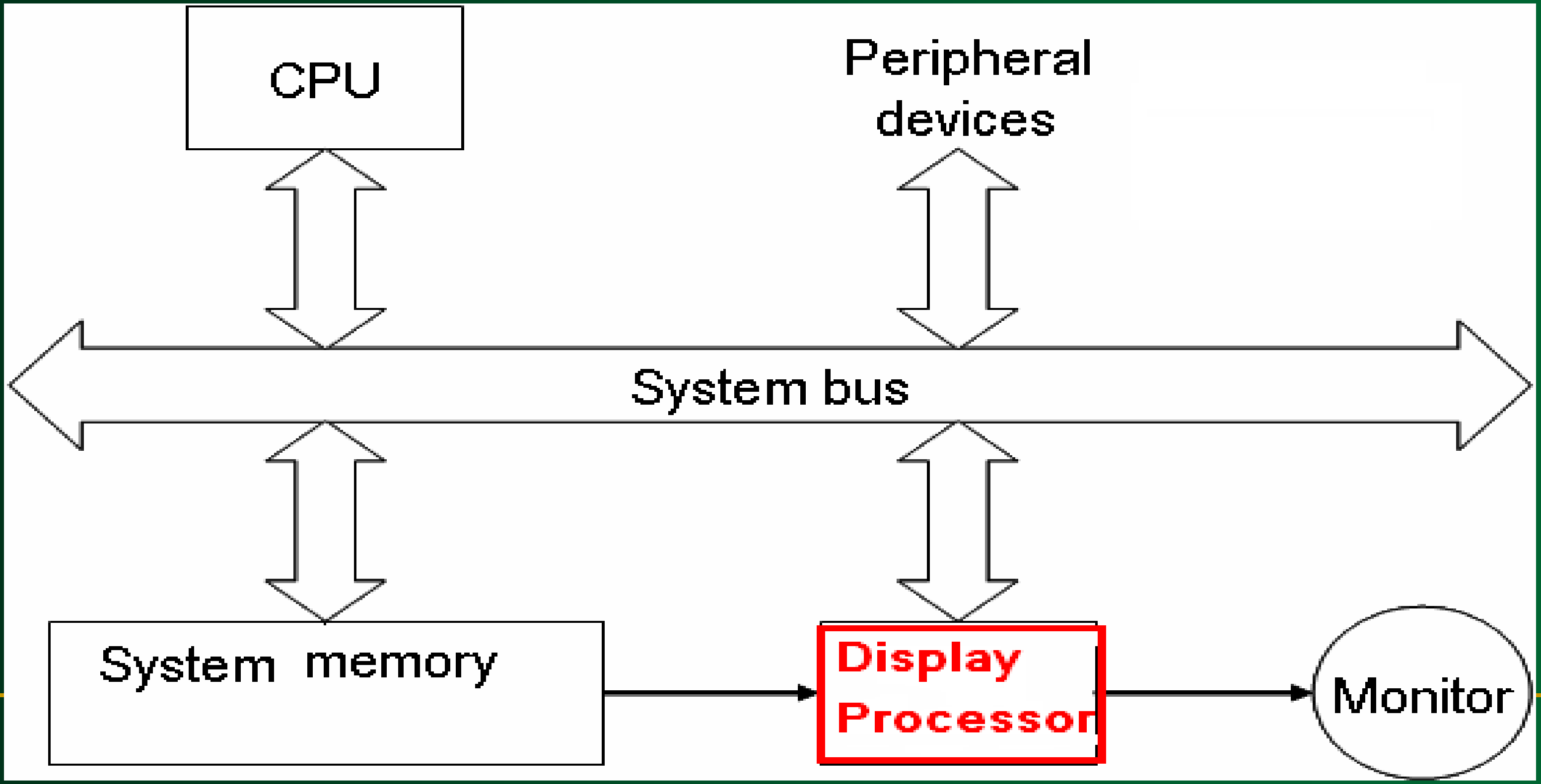
DP

- Generation various line styles (dashed, dotted, or solid)
- Displaying color areas
- Performing certain transformation and manipulation on display objects.

Random Scan Systems

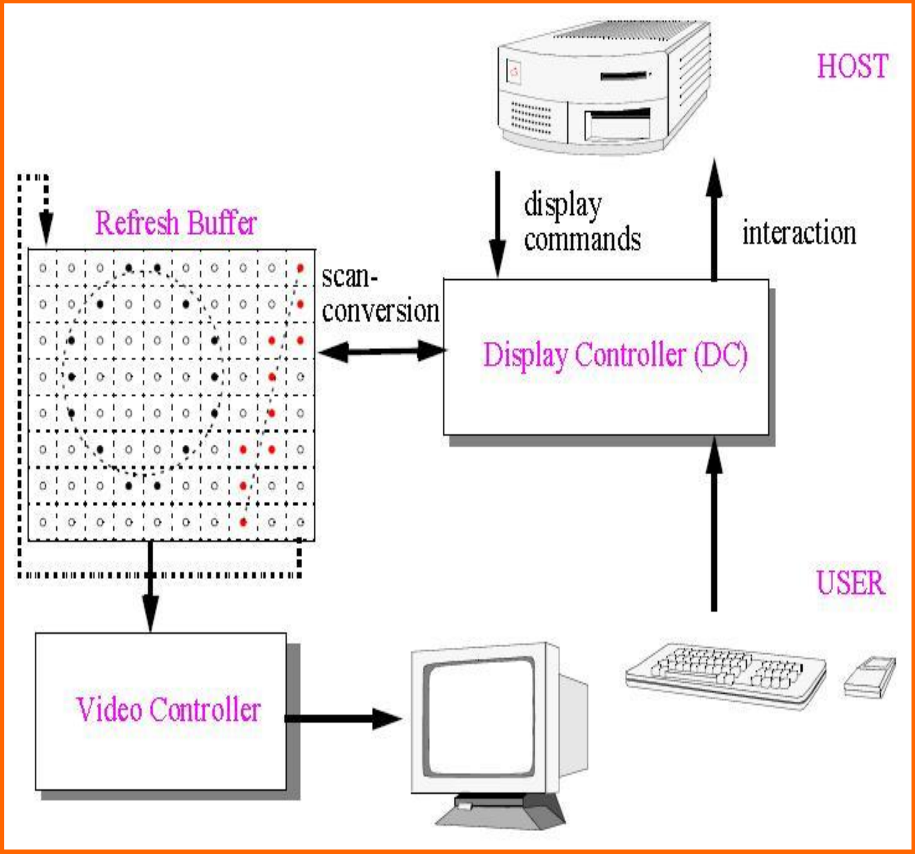
Random Scan System

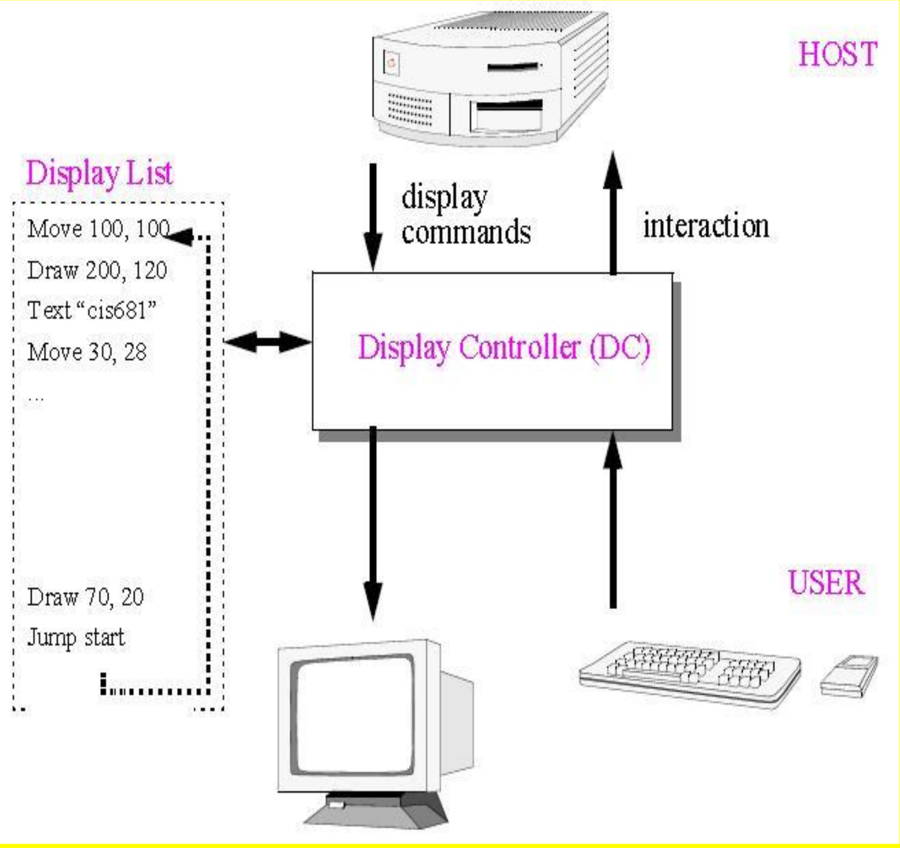
- Graphic commands are translated by the graphics package into a display file stored in the system memory.
- This file is then accessed by the **display processor unit** (**DPU**)(graphic controller) to refresh the screen.



Raster Scan System

Random Scan System





DIRECT VIEW STORAGE TUBE

Direct View Storage Tube

- An alternative method for maintaining a screen image is to store the picture information inside the CRT instead of refreshing the screen.
- A direct-view storage tube (DVST) stores the picture information as a charge distribution just behind the phosphor-coated screen.
- Two electron guns are used in a DVST. One, the primary gun, is used to store the picture pattern; the second, the flood gun, maintains the picture display.

Direct View Storage Tube

Advantages:

A DVST monitor has both disadvantages and advantages compared to the refresh CRT. Because no refreshing is needed, very complex pictures can be displayed at very high resolutions without flicker

Direct View Storage Tube

Disadvantages:

- Disadvantages of DVST systems are that they ordinarily do not display color and that selected parts of a picture cannot he erased.
- To eliminate a picture section, the entire screen must be erased and the modified picture redrawn.

Direct View Storage Tube

Disadvantages:

- The erasing and redrawing process can take several seconds for a complex picture.
- For these reasons, storage displays have been largely replaced by raster systems.

Flat Panel Displays

Flat Panel Displays

- A class of video devices that have reduce volume and weight compared to a CRT.

- A significant feature of flat panel displays is that they are **thinner** than CRTs.

Flat Panel Displays

Current uses for flat panel displays:

- Small TV monitors
- Calculators
- Pocket video games
- Laptop computers
- Advertisement boars in elevators

Flat Panel Displays

Flat panel displays:

- **Emissive** or **Emitters** Displays

- **Non-emissive** or **Non-emitters** Displays

Emissive (or Emitters) Displays

- Emissive displays convert **electrical energy** into light.
- Examples: Plasma panel, thin-film electroluminescent displays, Light-Emitting Diodes (LED) and flat CRT.

Non-Emissive (or Non-Emitters) Displays

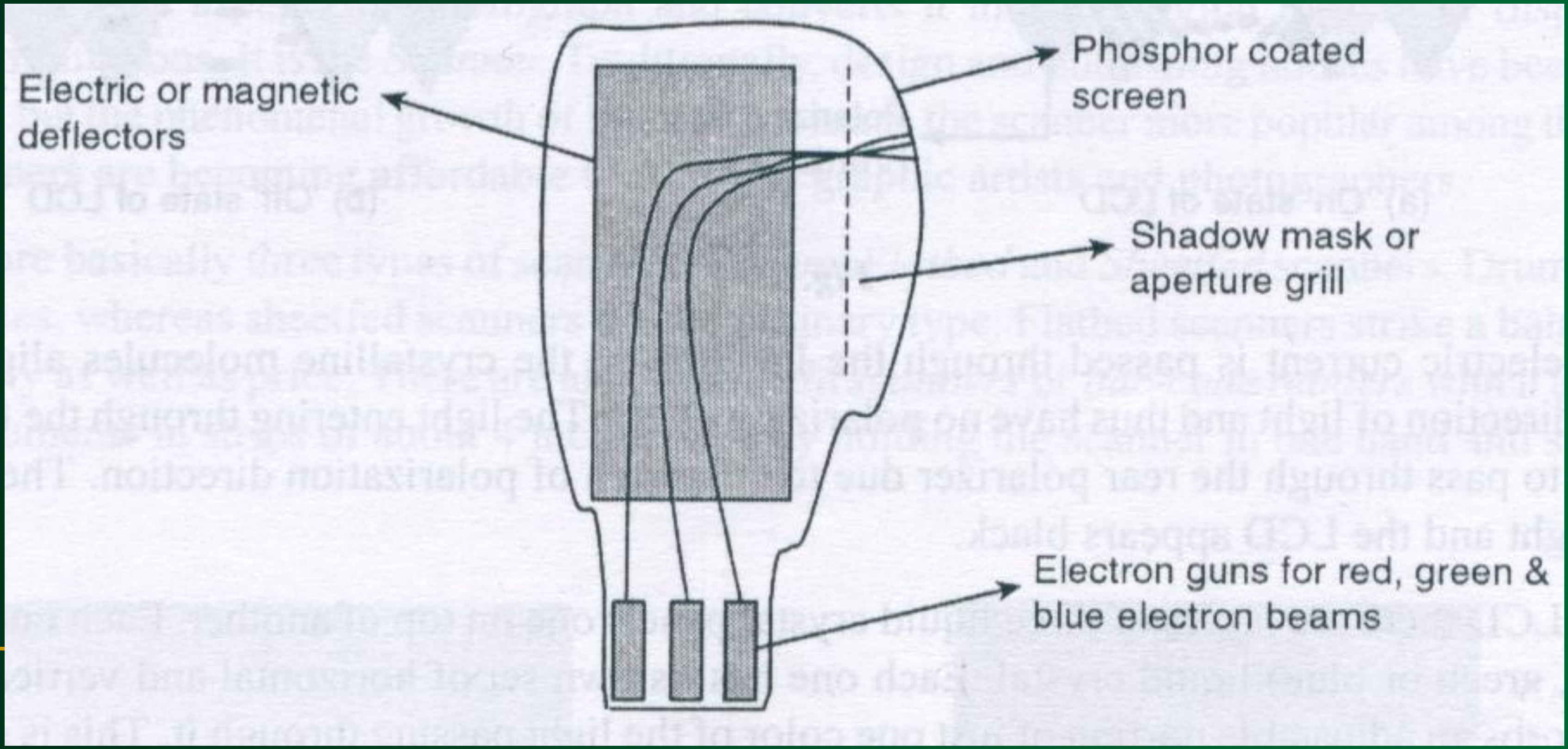
- Use **optical effects** to convert sunlight or light from some other source into graphics pattern.

  - Example: **L**iquid-**C**rystal **D**evice (**LCD**)

Flat CRT

Flat CRT

- Electron beams are accelerated parallel to the screen, then deflected 90° to the screen.



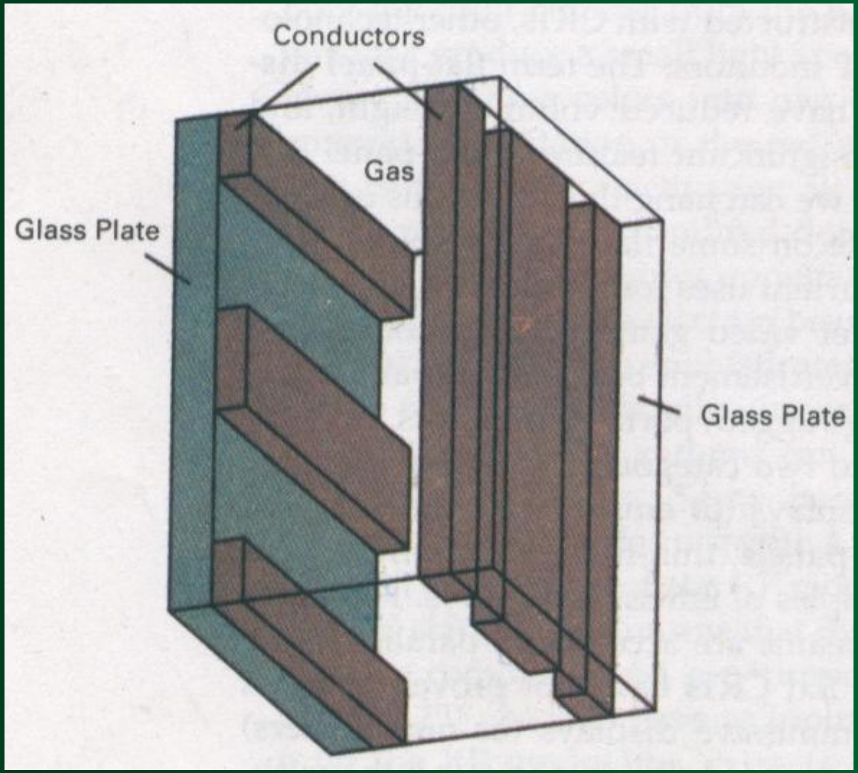
Plasma Panel

Plasma Panel

- A **layer of gas** (usually neon) is sandwiched between two glass plates.

Plasma Panel

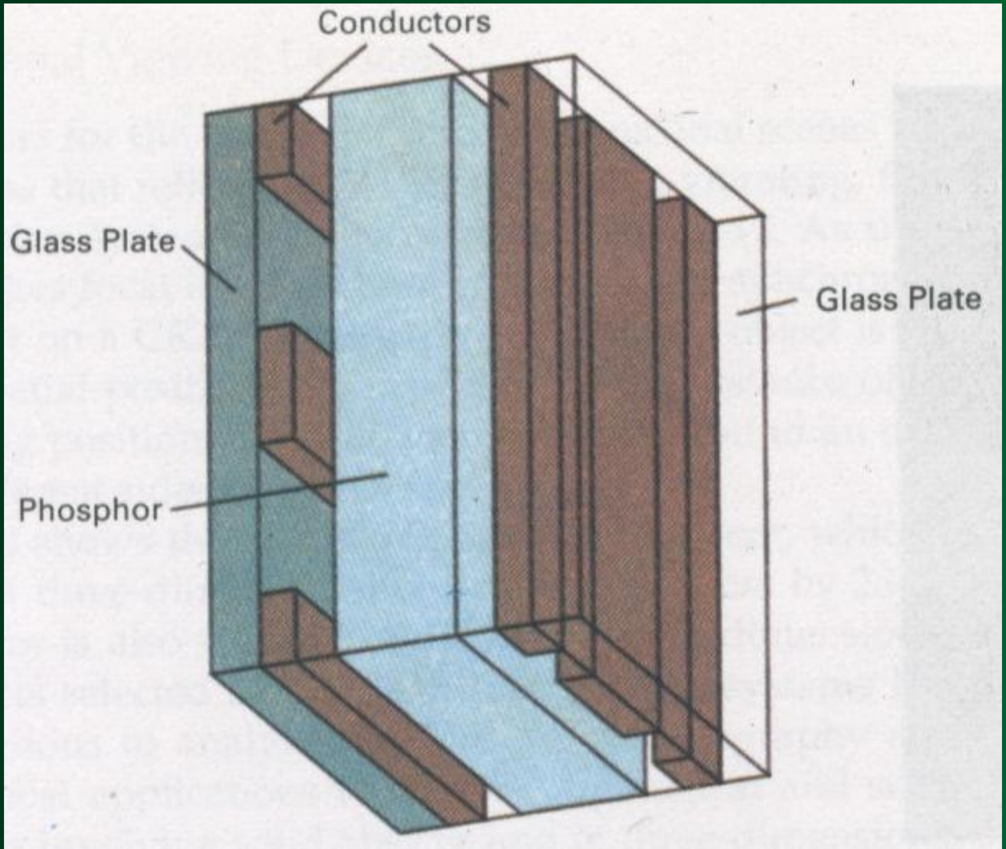
- By applying high voltage to a pair of horizontal and vertical conductors, a small section of the gas (tiny neon bulb) at the intersection of the conductors break down into glowing plasma of electrons and ions.



Thin Film Electroluminescent

Thin Film Electroluminescent

- The region between the glass plates is filled with a phosphor, such as zinc sulfide doped with manganese.



Light Emitting Diode (LED)

Light Emitting Diode (LED)

- A matrix of **diodes** is arranged to form the pixel positions in the display, and picture definition is stored in a refresh buffer.

- Information is read from the refreshed buffer and converted to voltage levels that are applied to the diodes to produce the light patterns in the display.

Liquid Crystal Displays (LCD)

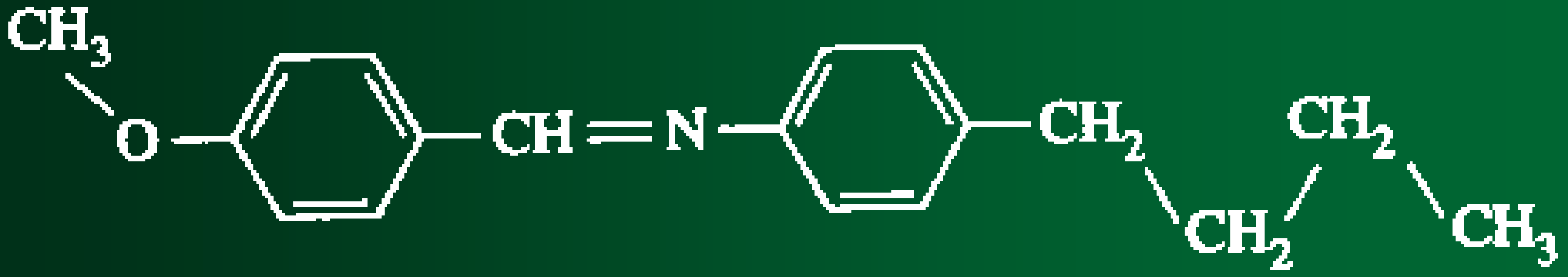
Liquid Crystal Displays (LCD)

- Used in small systems, such as calculators, laptop computers.

- Produce a picture by passing polarized light (from the surrounding or from an internal light source) through a liquid-crystal material that can be aligned to either block or transmit the light.

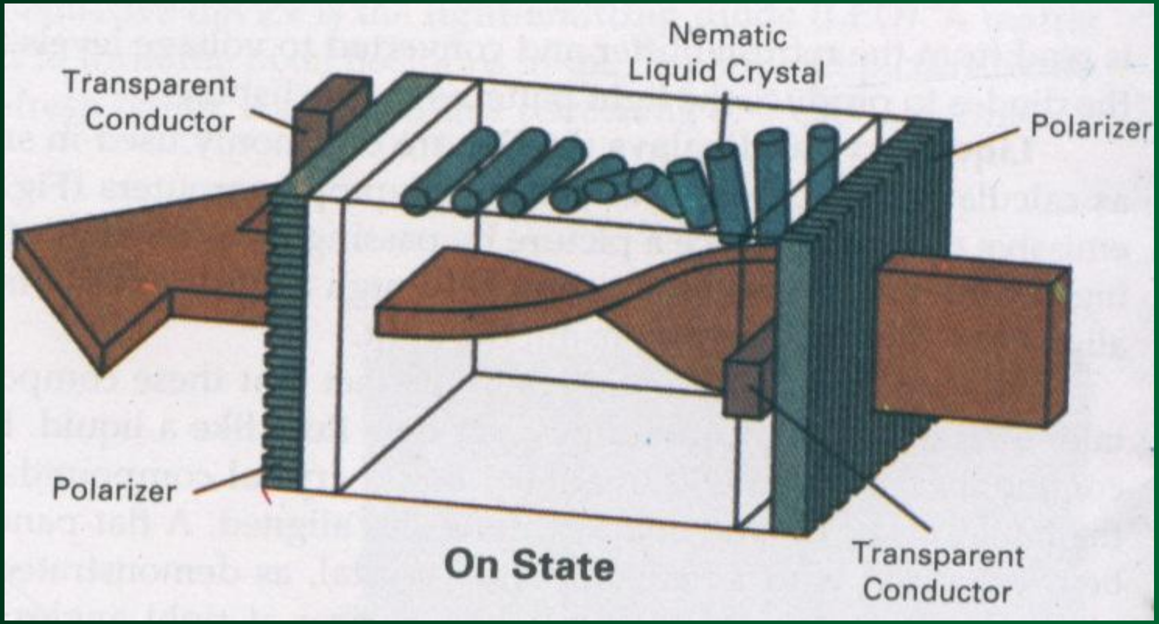
Liquid Crystal Displays (LCD)

- **Liquid crystal:** These compounds have a crystalline arrangement of molecules, yet they flow like a liquid.



Liquid Crystal Displays (LCD)

- Two glass plates, each containing a light polarizer at right angles to the other plate, sandwich the liquid crystal materials.
- Rows of horizontal transparent conductor & columns of vertical conductors (put into glass plates)

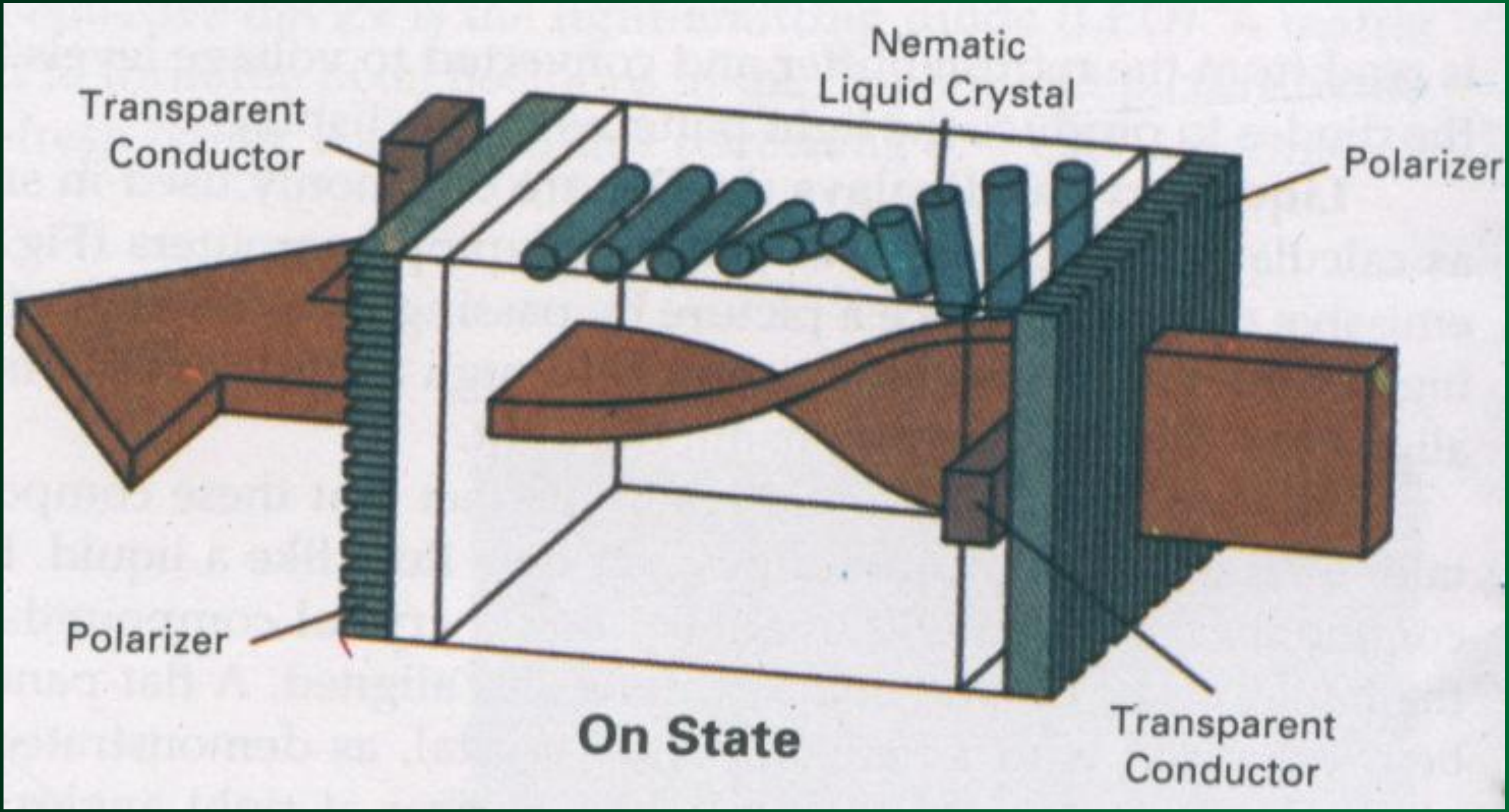


Liquid Crystal Displays (LCD)

- Polarized light passing through the material is ***twisted*** so that it will pass through the opposite polarizer.

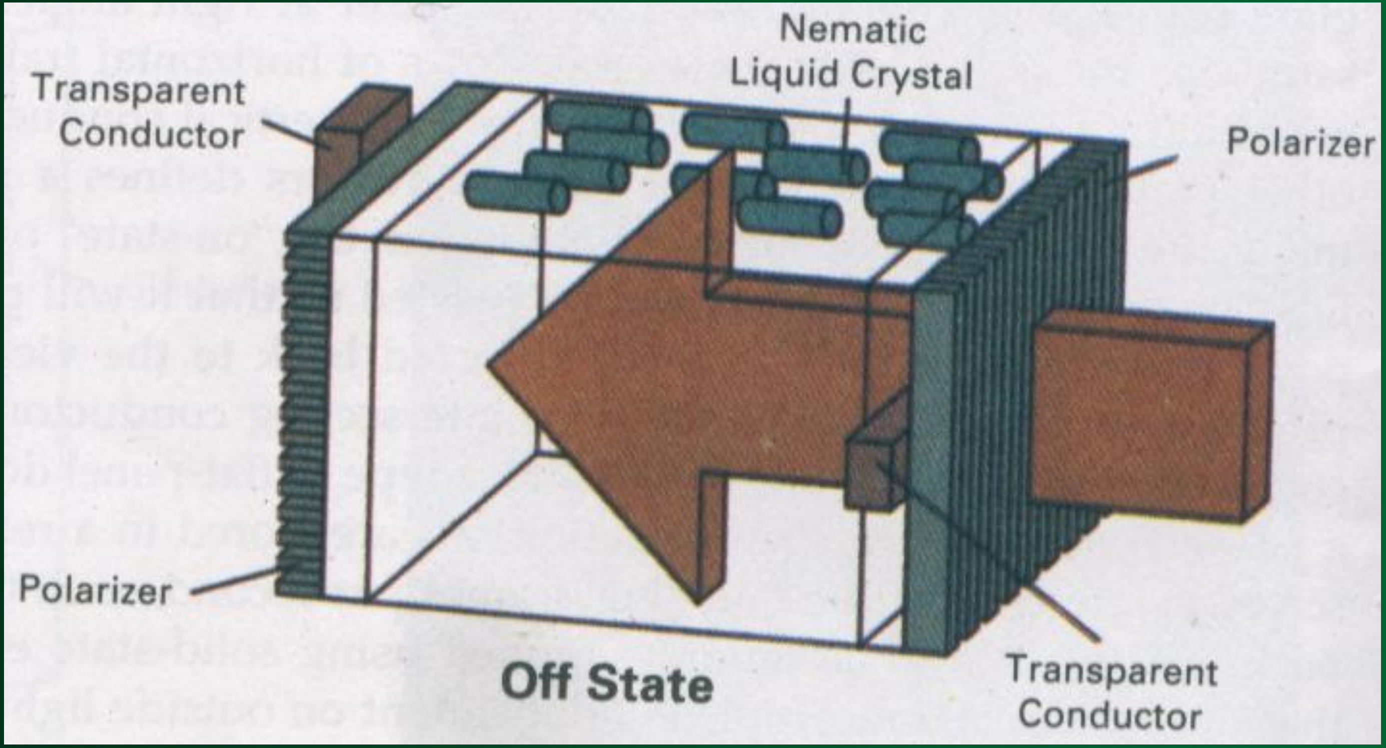
- The light is then reflected back to the viewer.

Liquid Crystal Displays (LCD)

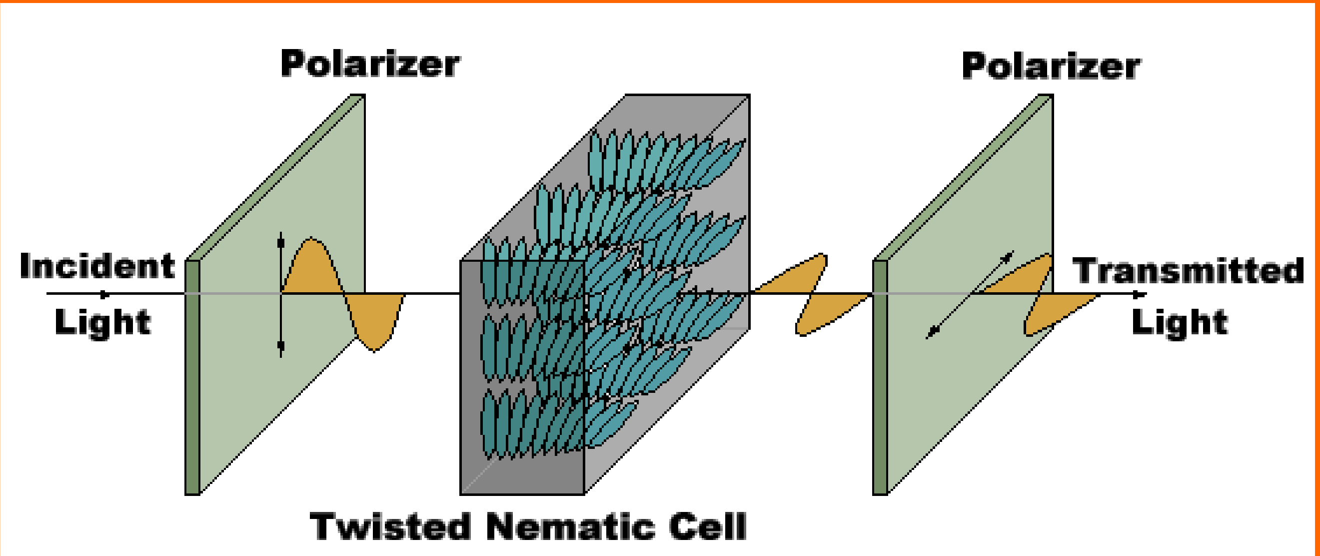


Liquid Crystal Displays (LCD)

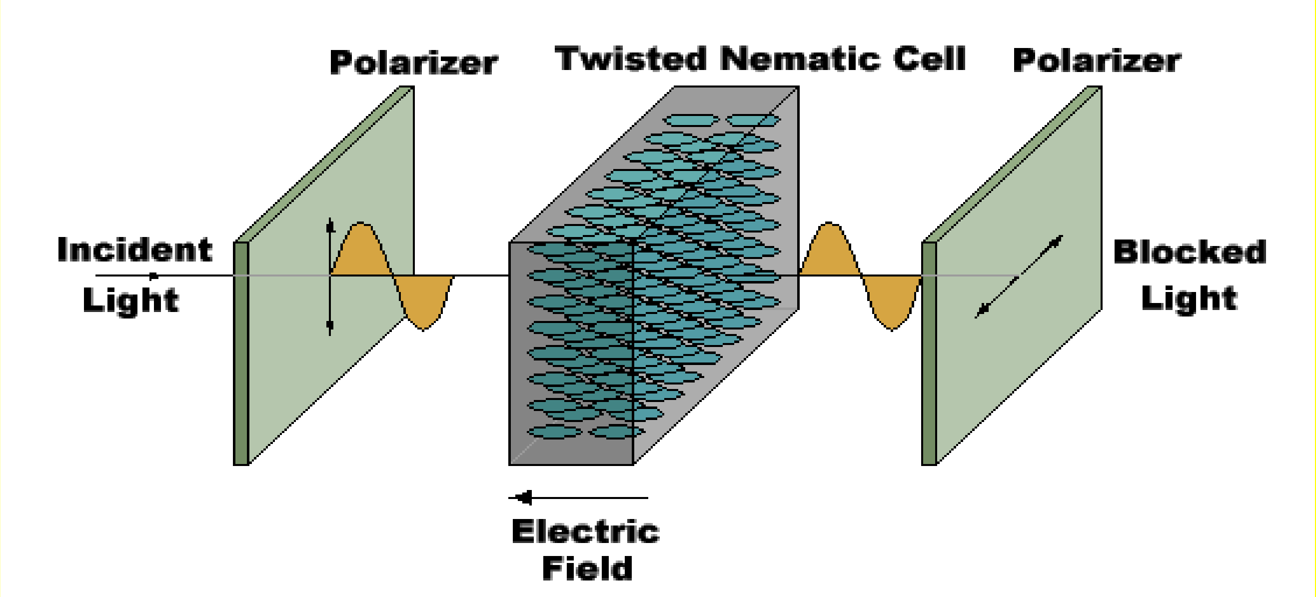
- To turn off the pixel, we apply a voltage to the two intersecting conductor to align the molecules so that the light is not twisted.



Liquid Crystal Displays (LCD)



On State



Off State

Input Devices

- Locator Devices
- Keyboard
- Scanner
  - Images
  - Laser
- Cameras (research)

Locator Devices

When queried, locator devices return a position and/or orientation.

- Mouse (2D and 3D)
- Trackball
- Joystick (2D and 3D)

Locator Devices

When queried, locator devices return a position and/or orientation.

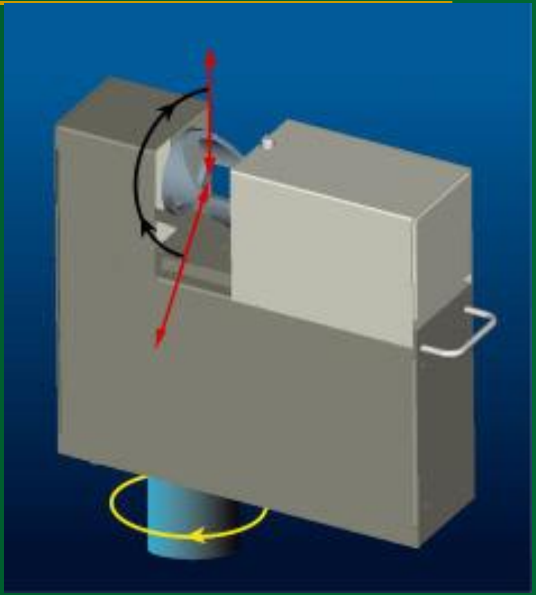
- Tablet
- Virtual Reality Trackers
  - Data Gloves
  - Digitizers

Keyboard

- Text input
  - List boxes, GUI
  - CAD/CAM
  - Modeling
- Hard coded
  - Vertex locations are inserted into code

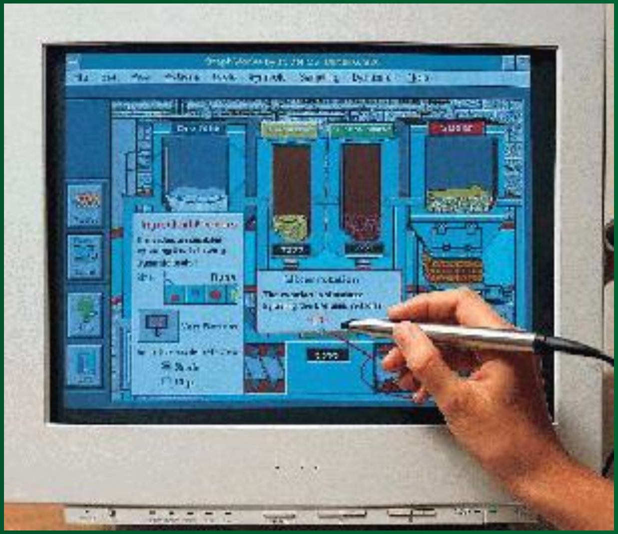
Scanners

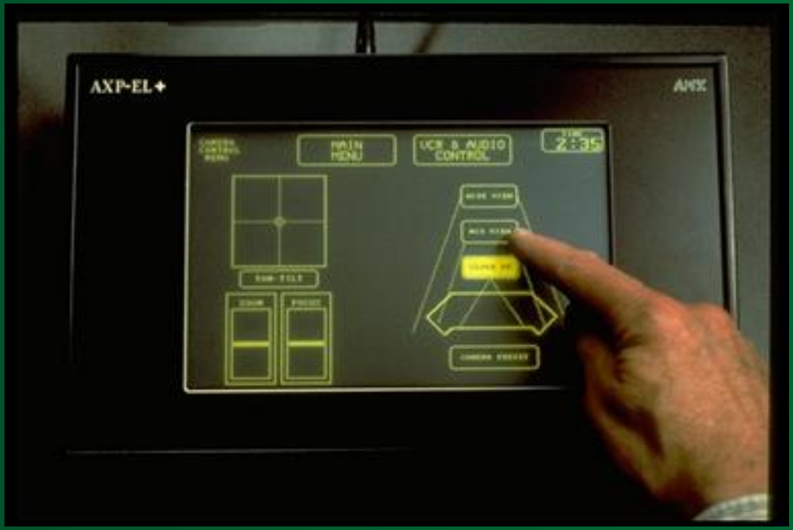
- Image Scanners - Flatbed, etc.
  - What type of data is returned? Bitmap
- Laser Scanners - Deltasphere
  - Emits a laser and does time of flight. Returns 3D point
- Camera based - research
  - Examine camera image(s) and try to figure out vertices from them.



Many others

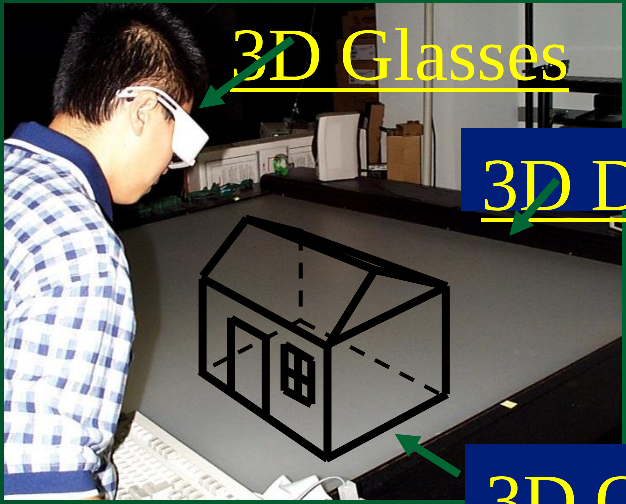
- Light Pens
- Voice Systems
- Touch Panels
- Camera/Vision Based
- Which is best?

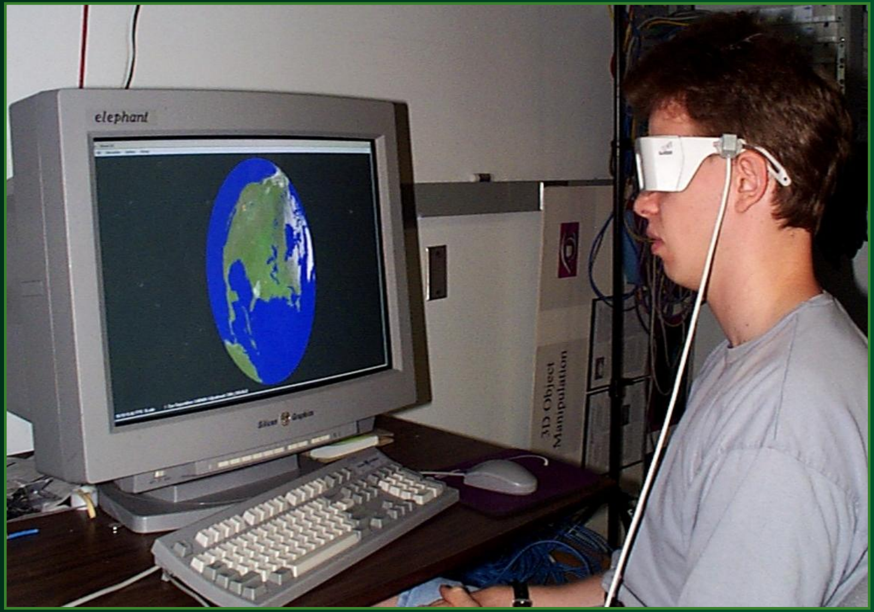




Displays in Virtual Reality

- Head-Mounted Displays (HMDs)
  - The display and a position tracker are attached to the user's head
- Head-Tracked Displays (HTDs)
  - Display is stationary, tracker tracks the user's head relative to the display.
  - Example: CAVE, Workbench, Stereo monitor


3D Glasses
3D Display
3D Object


elephant
3D Object Manipulation

References:

1. Donald Hearn, M. Pauline Baker.
Computer Graphics ebook (pdf) C-Version
Page. No: 4 to 79

Query??