INTRODUCTORY CONCEPTS

COMPUTER GRAPHICS is the art and science of using the computer to make images.

Study of methods (artistic, mathematical, algorithmic, software) and systems (mechanical, electronic, hardware) to create, control and manipulate pictorial data on the computer.

Computer graphics application

WHAT WILL WE LEARN IN THE COURSE?

Basic concepts of CG

Drawing in 2D and 3D

Colouring Pixels

Modelling

- Lines, Polygons
- Curves, Surfaces
- Modelling transformations
- Hidden Surfaces
- Viewing transformations

Rendering

- Shading
- Lighting models
- Texture mapping
- Ray Tracing

TYPICAL CG APPLICATIONS…

Computer-Aided Design

Presentation Graphics

Computer Art

Entertainment

Education and Training

Visualization

Image Processing

Graphical User Interfaces

EXAMPLE OF COMPUTER GRAPHICS PACKAGES:

LOGO

COREL DRAW

AUTO CAD

3D STUDIO

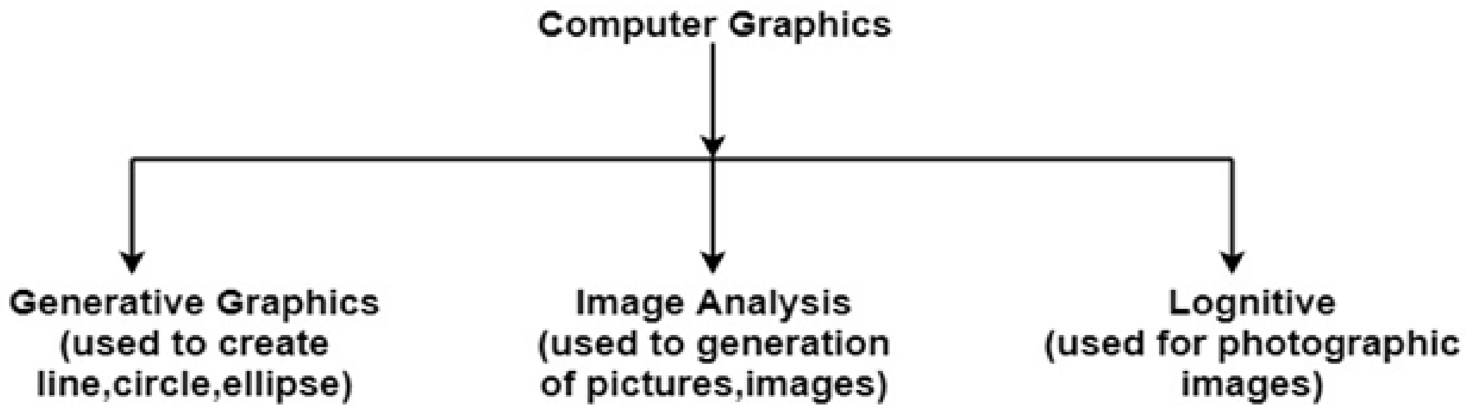
CORE

GKS (Graphics Kernel System)

PHIGS

CAM (Computer Graphics Metafile)

CGI (Computer Graphics Interface)



Interactive and Passive Graphics

(a) Non-Interactive or Passive Computer Graphics:

In non-interactive computer graphics, the picture is produced on the monitor, and the user does not have any controlled over the image, i.e., the user cannot make any change in the rendered image.

One example of its Titles shown on T.V.

Non-interactive Graphics involves only one-way communication between the computer and the user, User can see the produced image, and he cannot make any change in the image.

(b) Interactive Computer Graphics:

In interactive Computer Graphics user have some controls over the picture, i.e., the user can make any change in the produced image.

One example of it is the ping-pong game.

WHY COMPUTER GRAPHICS USED?

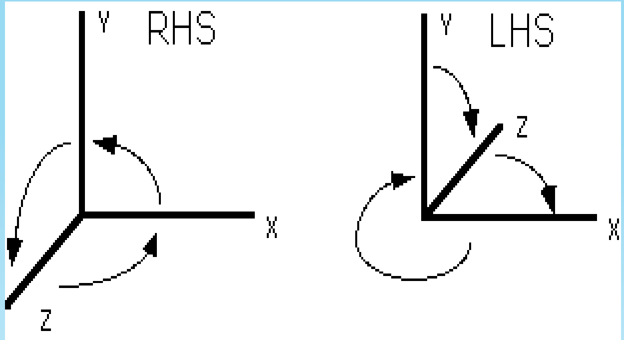
COORDINATE SYSTEM

In a 2-D coordinate system the X axis generally points from left to right, and the Y axis generally points from bottom to top. (Although some windowing systems will have their Y coordinates going from top to bottom.)

When we add the third coordinate(3-D), Z, we have a choice as to whether the Z-axis points into the screen or out of the screen:

Right Hand Coordinate System (RHS): Z is coming out of the page

Counterclockwise rotations are positive
if we rotate about the X axis : the rotation Y->Z is positive
if we rotate about the Y axis : the rotation Z->X is positive
if we rotate about the Z axis : the rotation X->Y is positive

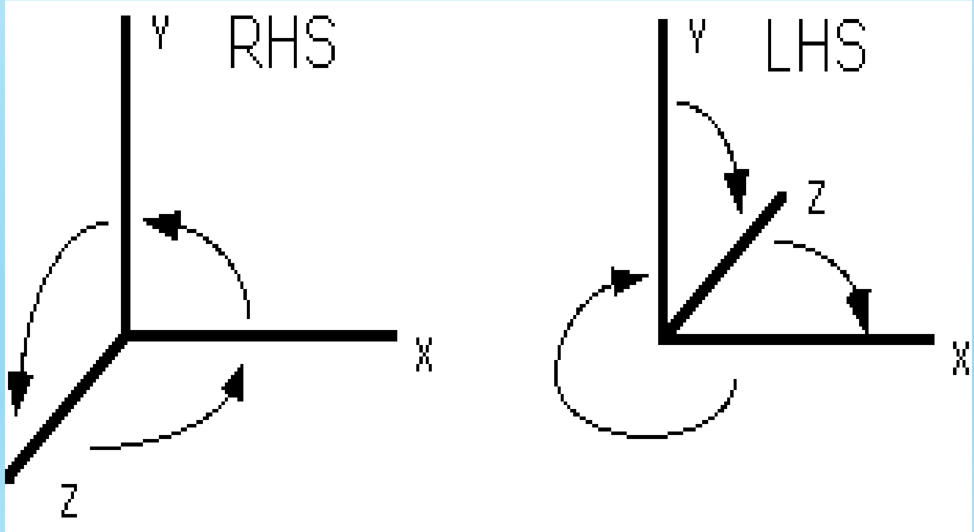


Left Hand Coordinate System (LHS):Z is going into the page

Clockwise rotations are positive
if we rotate about the X axis : the rotation Y->Z is positive
if we rotate about the Y axis : the rotation Z->X is positive
if we rotate about the Z axis : the rotation X->Y is positive

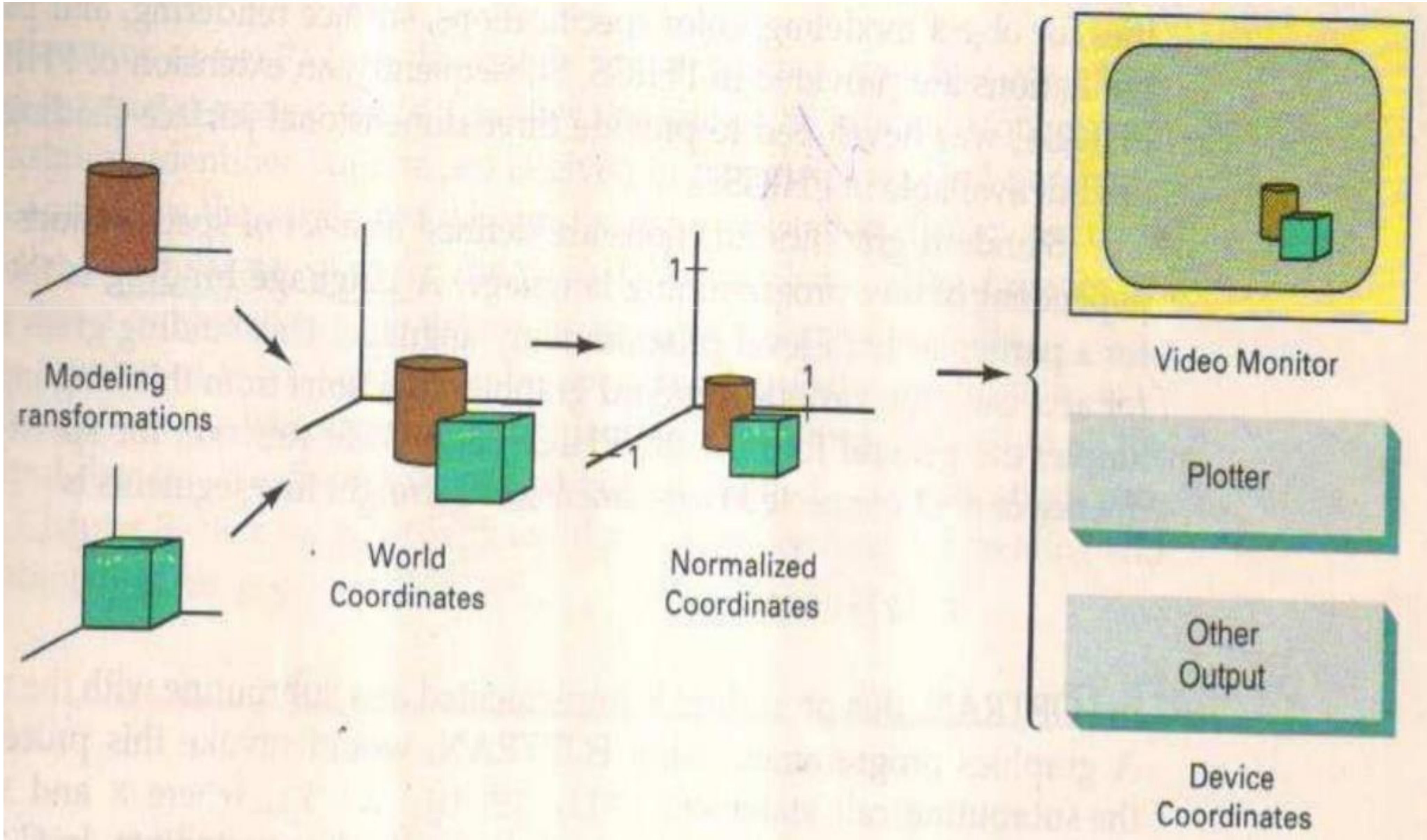
so basically its the same thing ...

OpenGL generally uses a right-hand coordinate system.



The different coordinate representations in graphics packages are:

- **Modeling coordinate**
  - Construct the shape of individual objects such as trees, furniture, in a scene within separate coordinate reference frames called modeling coordinates or local coordinates or master coordinates.
- **World coordinate**
  - Once individual object shapes have been specified we can place objects into appropriate position within the scene using a reference frame called world coordinates.
- **Device coordinate**
  - The world coordinate description of the scene is transferred to one or more output device reference frames for display.
  - These display coordinate systems are referred as device coordinate or screen coordinate.
  - **Normalized device coordinate – between range 0-1.**



Modeling
ransformations
World
Coordinates
1
1
1
Normalized
Coordinates
Video Monitor
Plotter
Other
Output
Device
Coordinates

GRAPHICS SYSTEMS

Cathode Ray Tube (CRT)
Random Scan vs Raster Scan
Color CRT Monitors
Direct View Storage Tubes
Flat Panel Display

GRAPHICS INPUT AND OUTPUT DEVICES…

INPUT DEVICES SPECIALLY DESIGNED FOR INTERACIVE INPUT

- Mouse
- Trackball
- Space ball
- Joystick
- Digitizers
- Dials
- Button Boxes.

INPUT DEVICES USED IN PARTICULAR APPLICATIONS

Data Gloves

Touch Panels

Image Scanners

Light Pens

Voice Systems

OUTPUT DEVICES…

- Monitors
- Graphic Plotter
- Printer

VIDEO DISPLAY DEVICES

- Monitors
  - There are two kinds of viewing screen used for monitors.
    - Cathode-Ray Tube (CRT)
      - The CRT display is made up of small picture elements called pixels. The smaller the pixels, the better the image clarity or resolution.
    - Flat-Panel Display
      - **Emissive Displays** – Emissive displays are devices that convert electrical energy into light. For example, plasma panel and LED (Light-Emitting Diodes).
      - **Non-Emissive Displays** – Non-emissive displays use optical effects to convert sunlight or light from some other source into graphics patterns. For example, LCD (Liquid-Crystal Device).

CRT DISPLAY

- Cathode Ray Tube : The primary output device in a graphical system is the video monitor.
- A cathode ray tube (CRT) is a specialized vacuum tube in which images are produced when an electron beam strikes a phosphorescent surface.
- It modulates, accelerates, and *deflects electron beam(s)* onto the screen to create the images.
- Most desktop computer displays make use of CRT for image displaying purposes.
- Types of CRT Display devices
  - DVST : Direct View Storage Tube
  - Random /calligraphic scan display systen
  - Raster/refresh scan display system

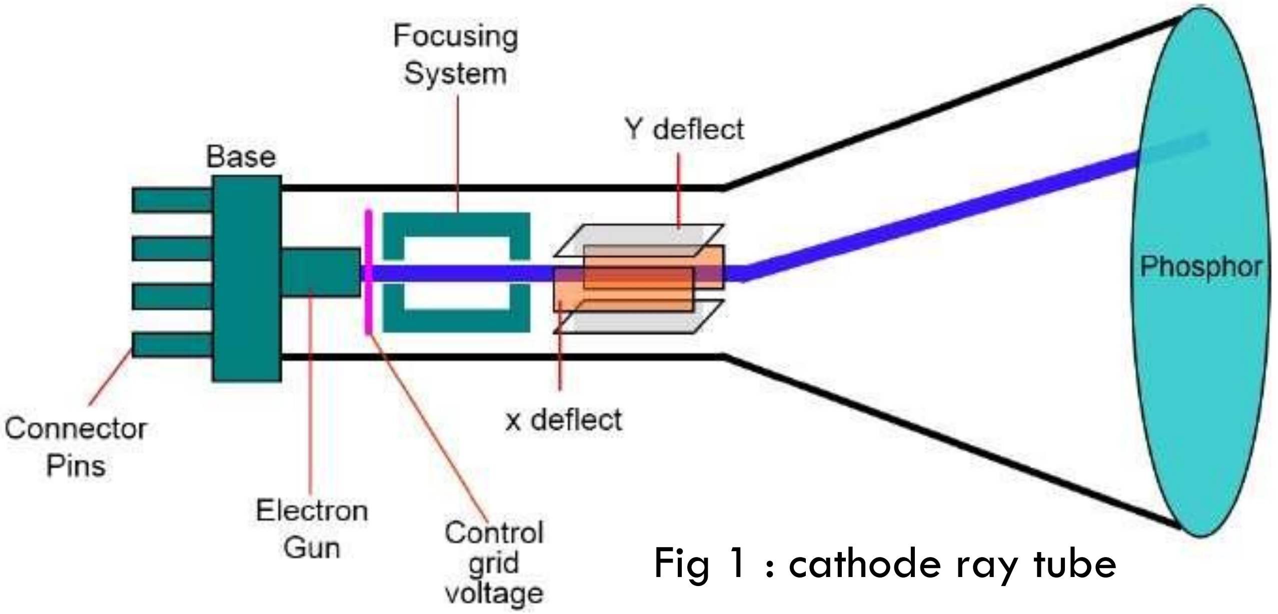


Fig 1 : cathode ray tube

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.

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

Each screen point is referred to as a **pixel /picture element/pel**

Picture definition is stored in memory area called the **Refresh Buffer** or **Frame Buffer**.

Frame Buffer is also known as **Raster or bit map.**

This memory area holds the set of intensity values for all the screen points.

Stored intensity values are then retrieved from the refresh buffer and "painted" on the screen one row *scanline* at a time.

Beam refreshing is of two types. First is **horizontal retracing** and second is **vertical retracing**.

When the beam starts from the top left corner and reaches the bottom right scale, it will again return to the top left side called at vertical retrace.

Then it will again more horizontally from top to bottom call as horizontal retracing shown in fig:

At the end of each scan line, the electron beam returns to the left side of the screen to begin displaying the next scan line.

Raster Scan provides a refresh rate of 60 to 80 frames per second.

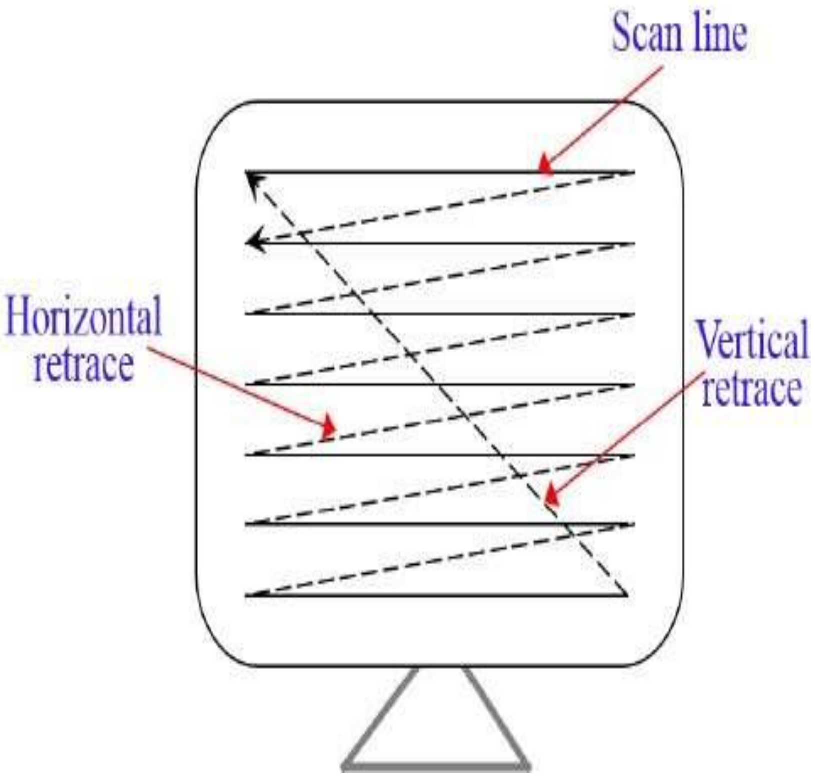


Fig 2 : Raster scan

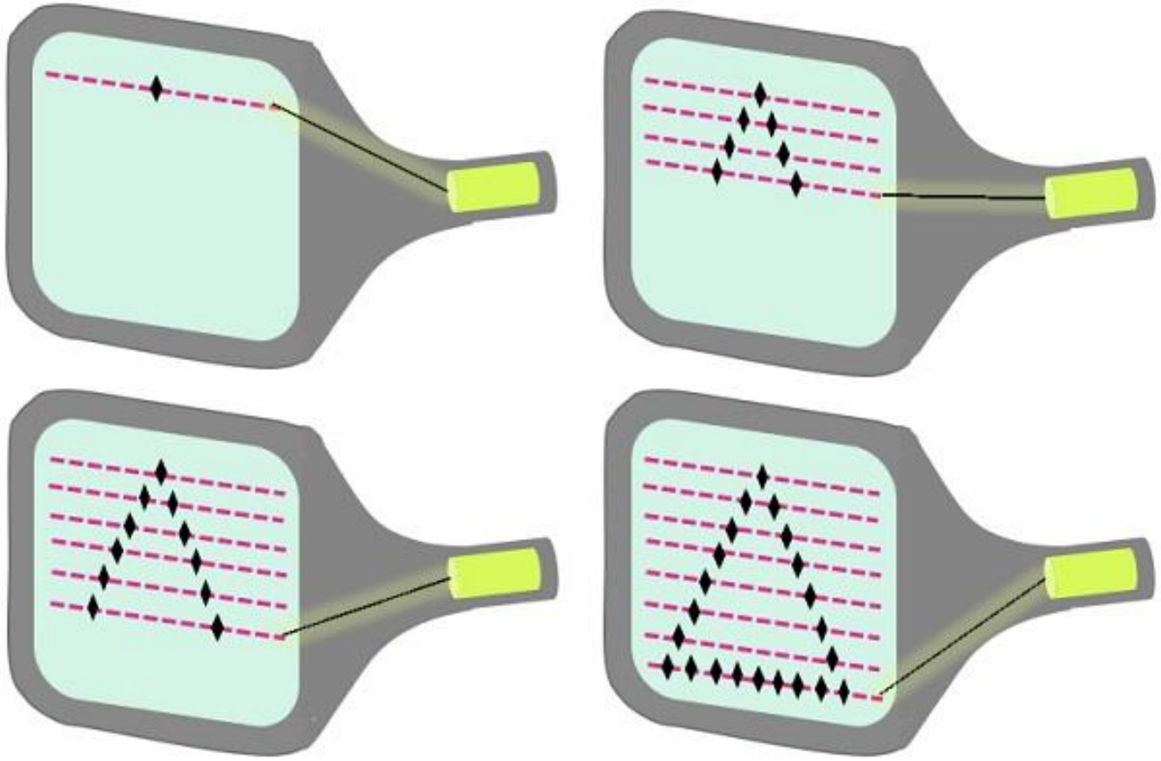


Fig 3 : **Raster Scan**: A raster scan system displays an item as a group of separate points along each screen line

TYPES OF SCANNING OR TRAVELLING OF BEAM IN RASTER SCAN

- Interlaced Scanning
- Non-Interlaced Scanning

In Interlaced scanning, each horizontal line of the screen is traced from top to bottom. Due to which fading of display of object may occur.

This problem can be solved by Non-Interlaced scanning.

In Non-Interlaced scanning first of all odd numbered lines are traced or visited by an electron beam, then in the next circle, even number of lines are located.

For non-interlaced display refresh rate of 30 frames per second used. But it gives flickers.

For interlaced display refresh rate of 60 frames per second is used.

RANDOM SCAN DISPLAY

In this technique, the electron beam is directed only to the part of the screen where the picture is to be drawn rather than scanning from left to right and top to bottom as in raster scan.

It is also called **vector display, stroke-writing display,** or **calligraphic display.**

Random Scan System uses an electron beam which operates like a pencil to create a line image on the CRT screen.

The picture is constructed out of a sequence of straight-line segments. Each line segment is drawn on the screen by directing the beam to move from one point on the screen to the next, where its x & y coordinates define each point.

After drawing the picture. The system cycles back to the first line and design all the lines of the image 30 to 60 time each second.

Picture definition is stored as a set of line-drawing commands in an area of memory referred to as the **refresh display file.**

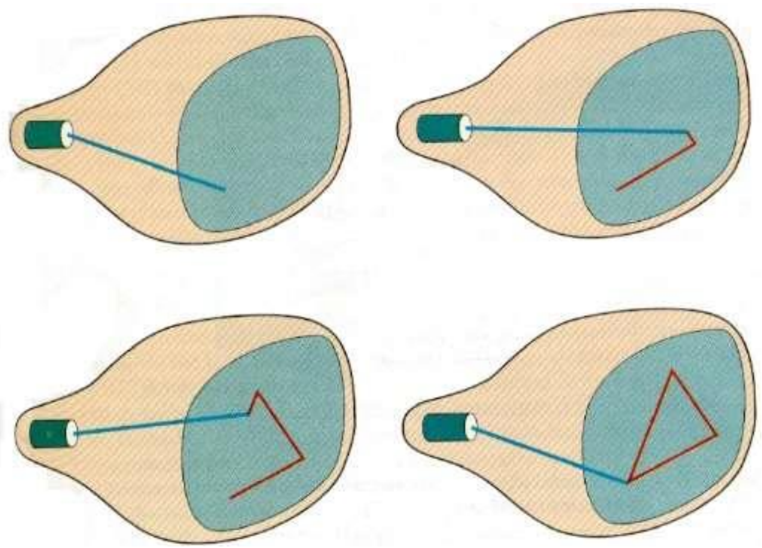


Fig 4 : Random scan

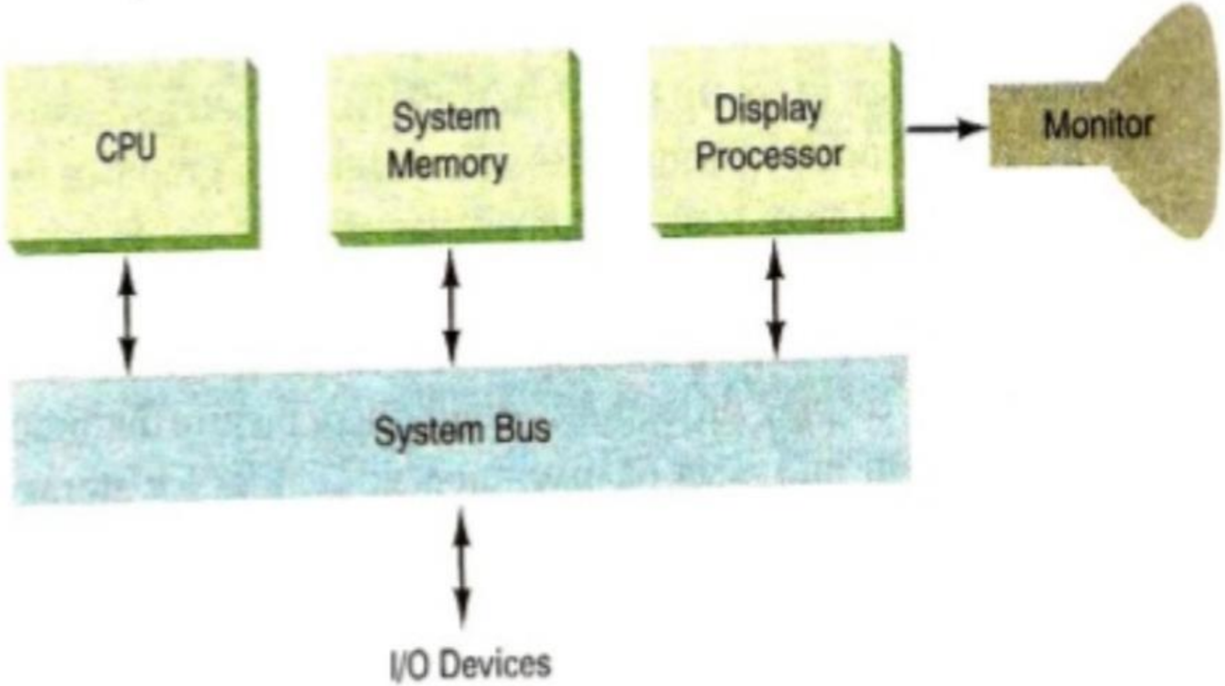


Fig 5: Architecture of simple random-scan display device

CALLIGRAPHIC OR RANDOM SCAN DISPLAY SYSTEM

Refresh Buffer/Frame Buffer : memory area allocated to store display list or display program for the display processor to draw the picture.

The **display processor** interprets the commands in the refresh buffer for plotting

The display processor must cycle through the display list to refresh the phosphor

- The display program has commands for point- , line–, and character plotting

The display processor sends digital and point coordinate values to a vector generator
• The vector generator converts the digital coordinate values to analog voltages for the beam-deflection circuits

• The beam-deflection circuits displace the electron beam for writing on the CRT's phosphor coating

• Recommended refresh rate is 40 – 50 Hz.

• Scope of animation with segmentation – mixture of static and dynamic parts of a picture

DVST (DIRECT VIEW STORAGE TUBE)

Storage tube : it is a CRT with long persistence phosphor.

The term "storage tube" refers to the ability of the screen to retain the image which has been projected against it, thus avoiding the need to rewrite the image constantly.

It uses the random scan approach to generate the image on the CRT screen.

Function of guns: Two guns are used in DVST

Primary guns: It is used to store the picture pattern.

Flood gun or Secondary gun: It is used to

maintain picture display.

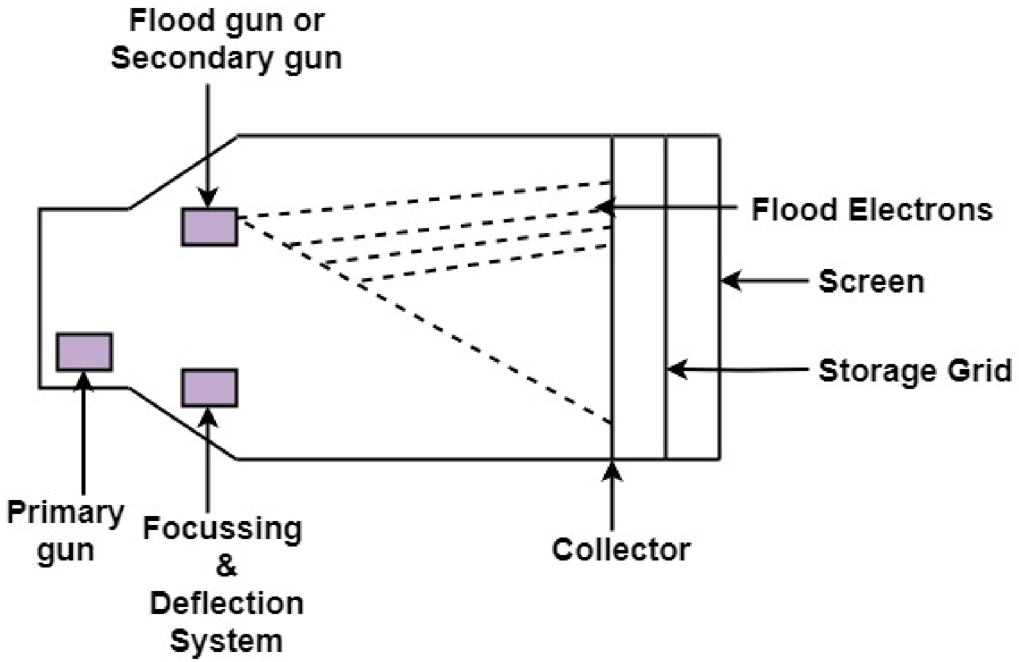


Fig 6: Direct View Storage Tube

ADVANTAGES AND DISADVANTAGES OF RANDOM RASTER SCAN AND DVST DISPLAY

Random Scan Display

Advantages:

A CRT has the electron beam directed only to the parts of the screen where an image is to be drawn.

Produce smooth line drawings.

High Resolution

Disadvantages:

Random-Scan monitors cannot display realistic shades scenes.

Raster Scan Display

Advantages:

Realistic image

Million Different colors to be generated

Shadow Scenes are possible.

Disadvantages:

Low Resolution

Expensive

DVST Display

Advantage:

No refreshing is needed.

High Resolution

Flicker free display

Cost is very less

Disadvantage:

It is not possible to erase the selected part of a picture.

It is not suitable for dynamic graphics applications.

If a part of picture is to modify, then much time is consumed.

REFRESH AND RASTER SCAN DISPLAY SYSTEM

Unlike DVST and random-scan which were line-drawing devices , refresh CRT is a point-plotting device.

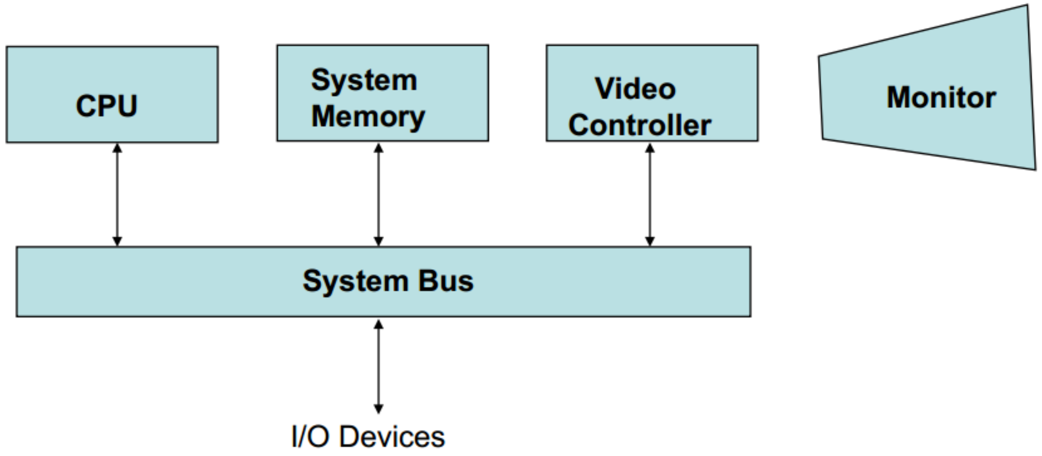


Fig 7: **Architecture of Simple Raster graphics system**

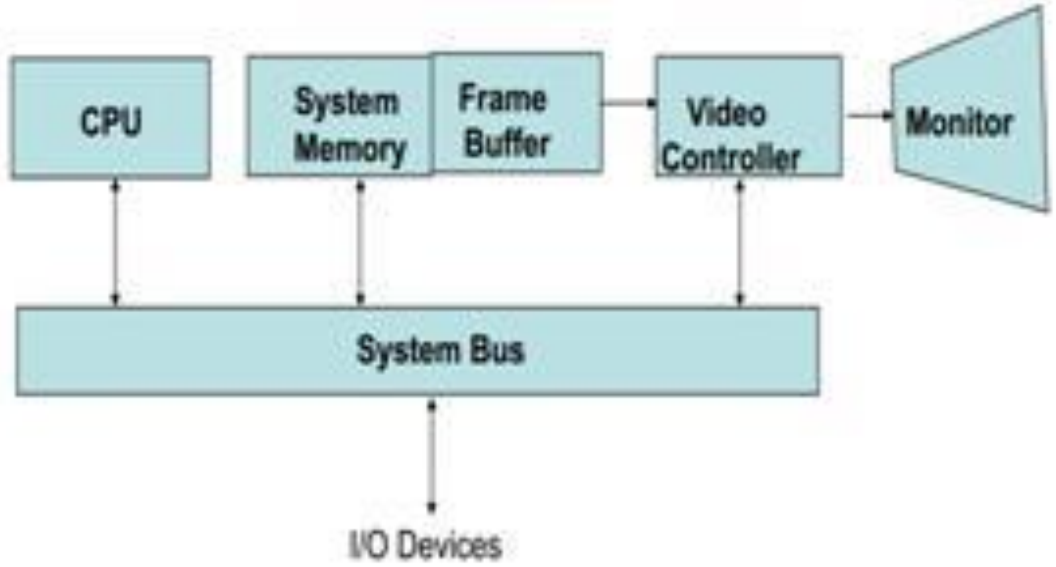


Fig 8: **Architecture of Raster system with a fixed portion of the system memory reserved for the frame buffer**

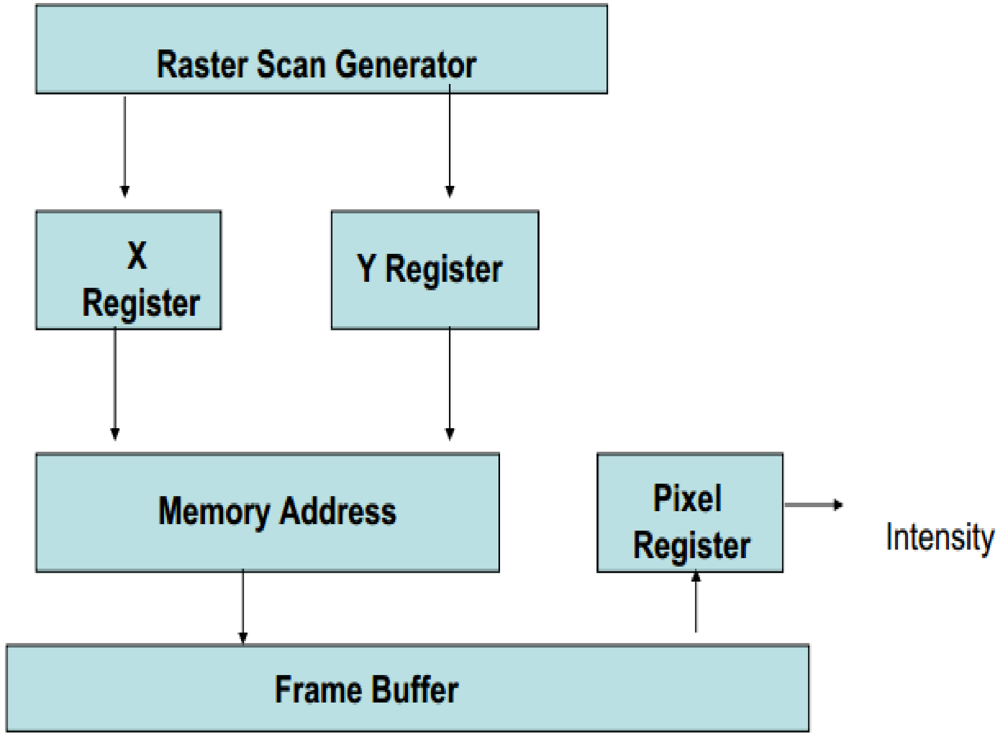


Fig 9: **Basic Video Controller Refresh Operation**

To speed up pixel processing video controllers can retrieve multiple pixel values from the refresh buffer on each pass. The multiple pixel intensities are then stored in a separate register and used to control the CRT beam intensity for a group of adjacent pixels. When this group of the pixel has been processed the next block of pixel values is retrieved from the frame buffer.

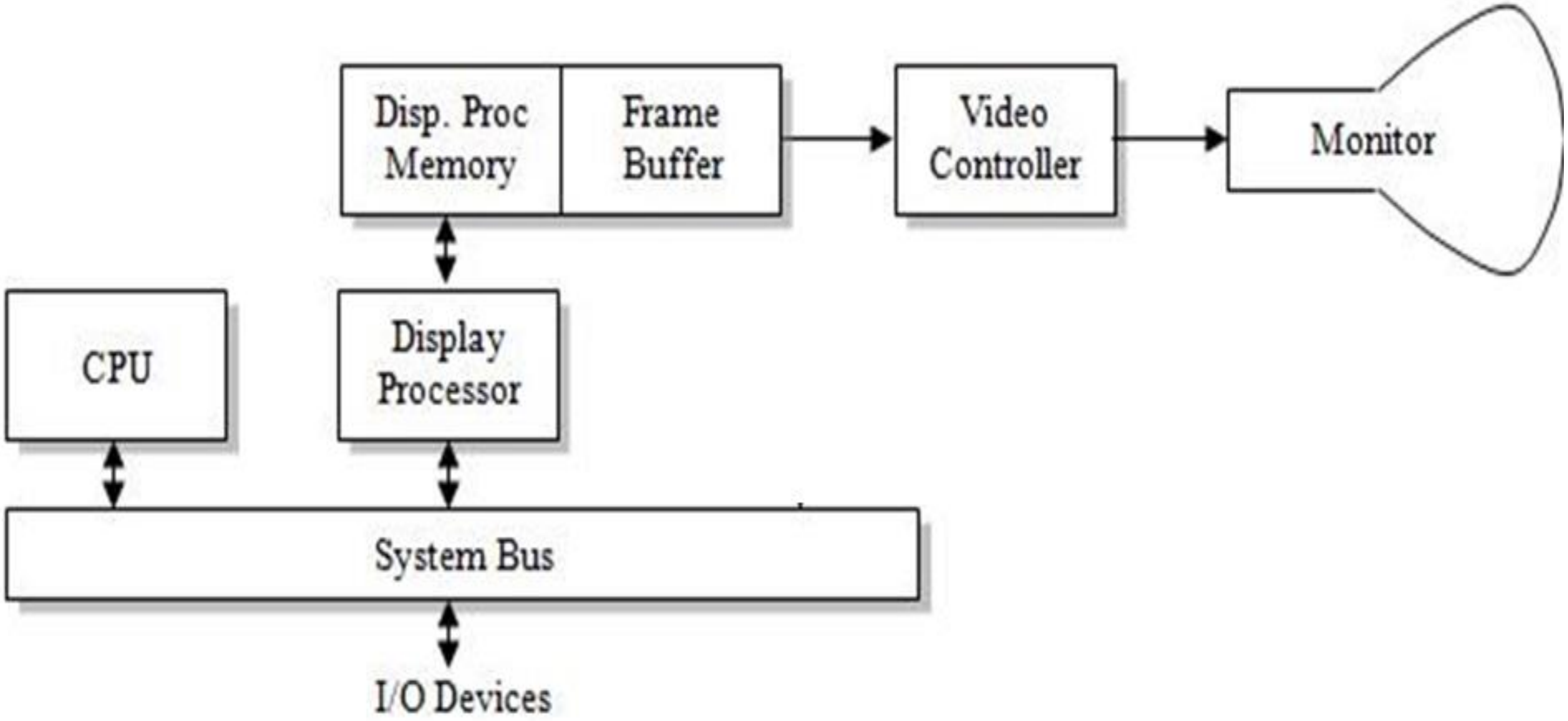


Fig 10: Architecture of a raster-graphics system with a display processor

REFRESH RATE , VIDEO BASICS AND SCAN CONVERSION

A typical example :

If one uses a 512x512 element raster display, then 2^{18} bits are necessary in a **single bit plane (one-bit**-per-pixel image).

Memory size required: 32 KB

A DAC (digital-to-analog converter) is used to convert the bit value (0, 1) to analog signals for refreshing the screen

Memory size required for N-bit plane gray level frame buffers:

(Several **bit planes** may be used in conjunction to give more **bits** per pixel)

N	Size in KB
3	96
8	256
24	768

Table 1: N-bit plane and corresponding memory size of frame buffer

NUMERICAL EXAMPLE 1:

If one uses a 1024x1024 high resolution CRT:

N	Display colour	Memory size
1	?	?
8	?	?

Refresh rate of a CRT is the number of times the image is drawn on the screen per second.

- Reducing refresh rate increases flicker.

Refresh rate to avoid flickering – 60 Hz

If one uses a 1024x1024 high resolution CRT:

N	Display colour	Memory size
1	Black and White	128 KB
8	256 colours	1 MB
24	16 million colours	3 MB
32	16 million colours	4 MB

Table 2: N-bit plane , colors displayed and corresponding memory size of frame buffer

Even 32 bits per pixel with 1280x1024 pixels raster are available.

Horizontal scan rate is the number of scan lines the circuit drives a CRT display per second = refresh rate x number of scan lines

Resolution of the screen depends on spot size

CRT resolution is not a function of bitmap resolution

For larger spot size, resolution decreases

Horizontal resolution depends on spot size and beam switching (ON/OFF) speed

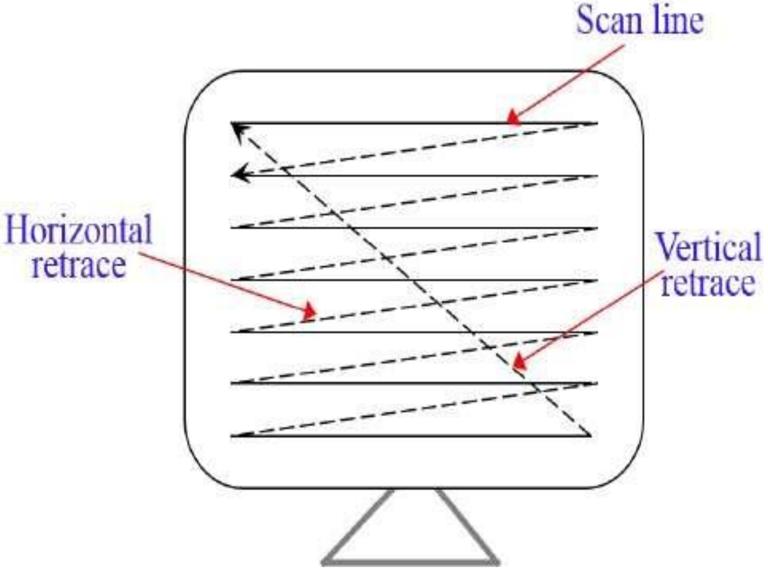
Bandwidth of the display: The rate at which the beam can be turned OFF to ON and vice-versa.

For N pixels per scan line, it is necessary to turn the electron gun at a maximum rate of: N/2 times ON and N/2 times OFF; This will create alternate black and white lines on the screen.

NTSC (American Standard Video) has 525 horizontal lines with a frame rate of 30 fps.

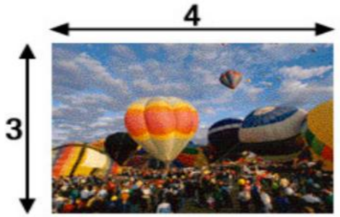
Viewing aspect ratio is 4:3

- Each frame has two fields, each containing half the picture.
- Fields are interlaced or interwoven
- Fields are presented alternately every other 1/60-th of a sec.
- One field contains odd scan lines (1,3,5,...)
- The other contains even scan lines (2,4,6,...)
- Two types of retrace after every field : (Interlacing scan lines on a raster scan display)



First, all points on the even-numbered (solid) scan lines are displayed; then all points along the odd-numbered (dashed) lines are displayed

Aspect ratio is the relationship of the width of a video image compared to its height. The two most common aspect ratios are 4:3 and 16:9.



SCHEMATIC OF A 7-LINE INTERLACED SCAN LINE PATTERN.

The odd field begins with line 1. The horizontal retrace is shown dashed. The odd field vertical retrace starts at the bottom center. The even field vertical retrace starts at the bottom right.

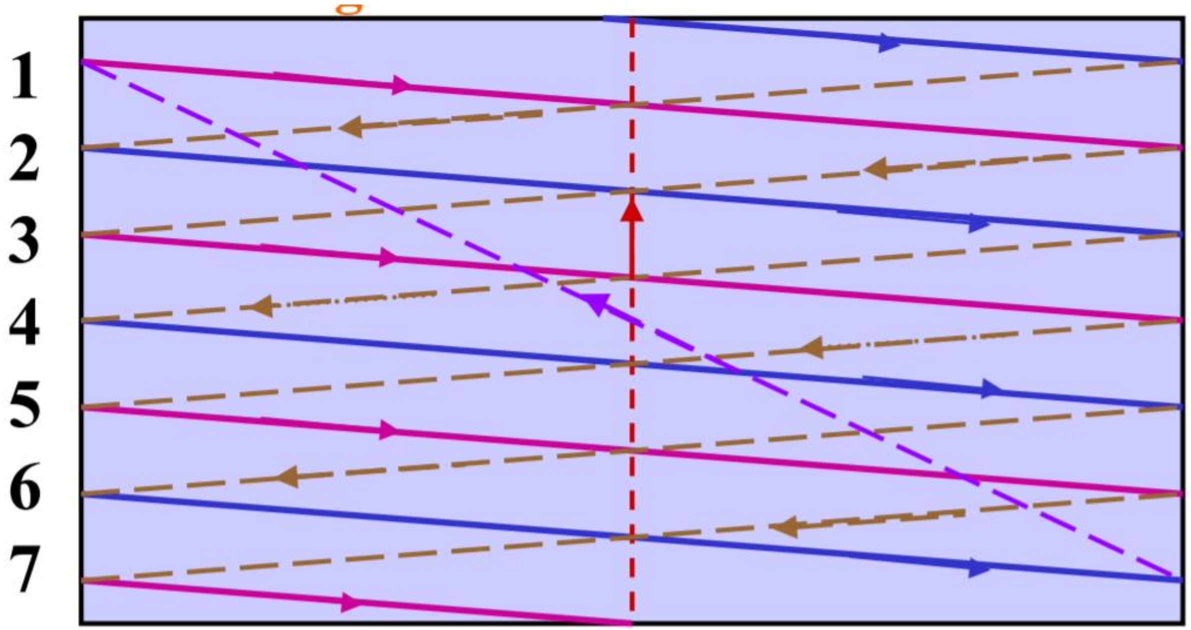


Fig 11 : 7-line interlaced scan line pattern

Horizontal retrace - As the electron beam reaches the right edge of the screen, it is made invisible and rapidly returns to the left edge

- Time taken for horizontal retrace is typically **17%** allotted for a scan line.
- After odd field scan conversion is complete, the beam is at the bottom center of the screen.
- After even field scan conversion is complete, the beam is at the bottom right of the screen.
- Odd field vertical retrace returns the beam (switched OFF) to the top center of the screen
- Even field vertical retrace returns it to the upper left corner of the screen

Two fields are presented alternately for each frame. So we present 60 fields per second.

Let the time available for each scan line be T.

- Thus, we have: T * 525 * 30 = 1 sec.

- Thus, T = 63.5 ms/scan-line

- This includes the vertical retrace time.

- When we consider the horizontal retrace time, the actual time to display all pixels in a scan line (time to scan from left to right only): T' = 0.83*T = 53 ms .

- Considering 4:3 aspect ratio,

the number of pixels per scan line = 483*4/3 = 644

- **Thus, time available for the beam to access and display a pixel = 82.3 ns (nano-second)**

NUMERICAL EXAMPLE 2:

Find pixel access time for the following:

Frame Rate	Display Resolution	Pixel Access Time
30	512 X 512	?
25	500 X 625	?
60	1000 X 1000	?
60	1024 X 1024	?

N-BIT PLANE GRAY LEVEL FRAME BUFFER

Choice of the number of gray scales and colors depend on the value of N (bit plane size)

N	Display colour
1	Two colours
3	8 gray scales or colors
8	256 gray scales or colors
24	16 million colors

For colored displays (raster-scan), three separate color guns must be used.

Each bit/byte plane drives a color gun.

A SINGLE BIT-PLANE BLACK & WHITE FRAME BUFFER RASTER CRT GRAPHICS DEVICE.

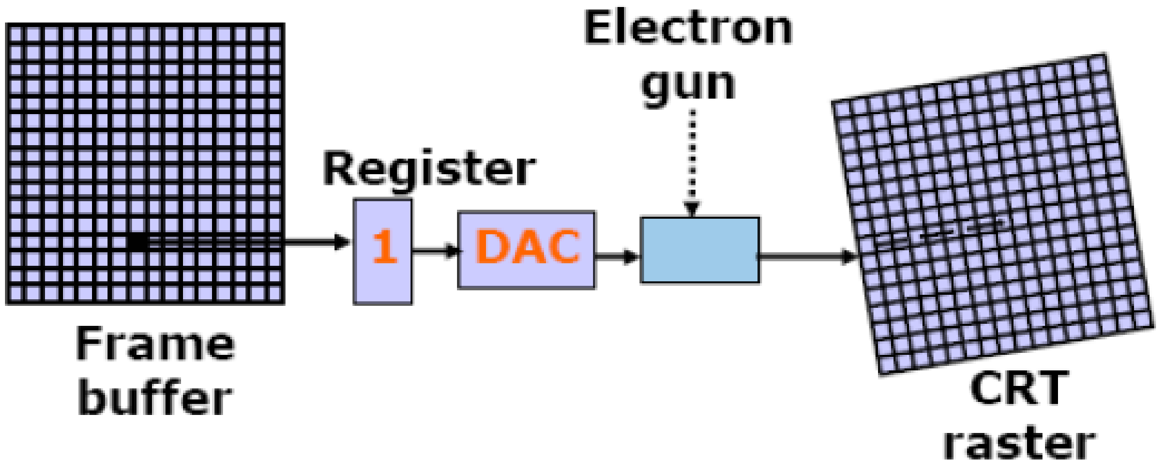


Fig 11 : **A single bit-plane black white frame buffer raster CRT graphics device**

AN N-BIT PLANE GRAY LEVEL FRAME BUFFER

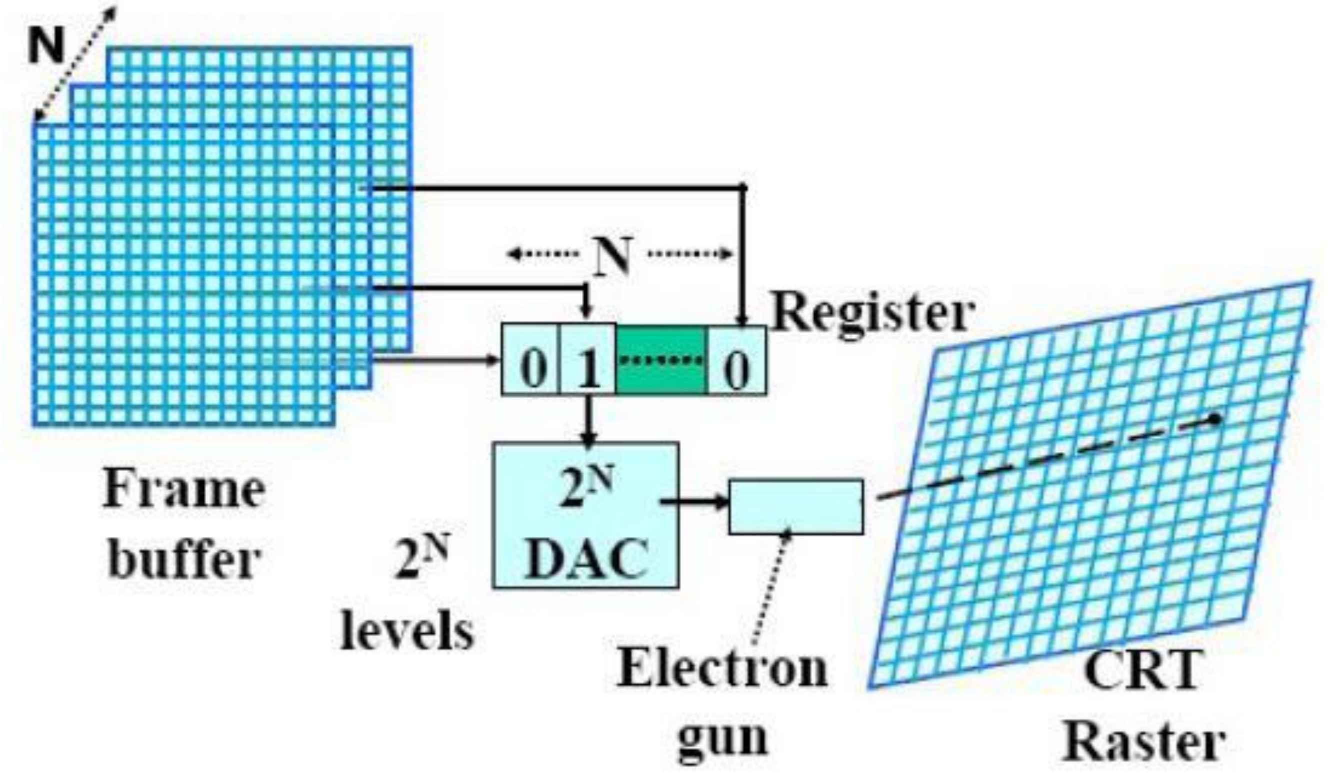


Fig 12 : **An N- bit plane gray level frame buffer**

SIMPLE COLOR FRAME BUFFER (N=3)

*3 different colour guns
3 different one-bit
registers (0/1)
3 different DAC

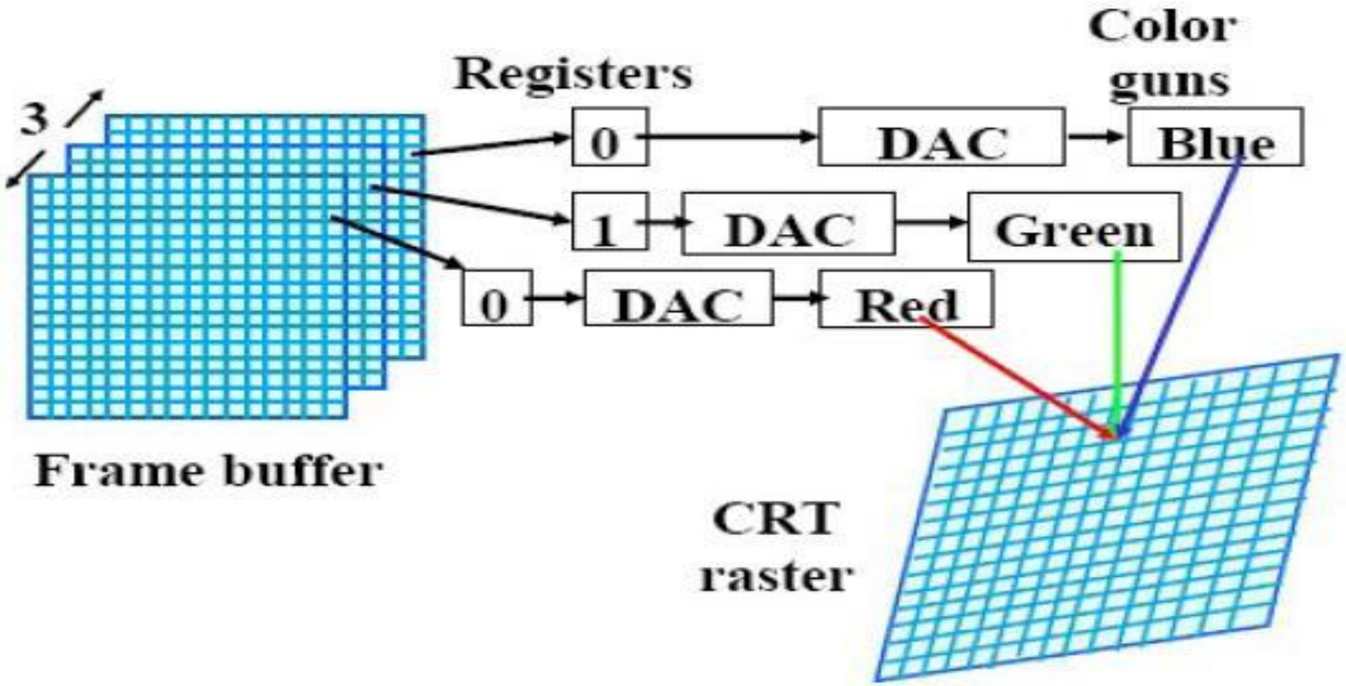


Fig 13 : **Simple Color buffer**

IN CASE OF ONE-BIT FOR EACH COLOR FRAME BUFFER, WE GET 8 COLORS AS:

COLOR	RED	GREEN	BLUE
BLACK	0	0	0
BLUE	0	0	1
GREEN	0	1	0
CYAN	0	1	1
RED	1	0	0
MAGENTA	1	0	1
YELLOW	1	1	0
WHITE	1	1	1

COLOR CRT MONITORS

The CRT Monitor display by using a combination of phosphors.

The phosphors are different colors.

There are two popular approaches for producing color displays with a CRT are:

1. Beam Penetration Method
2. Shadow-Mask Method

BEAM PENETRATION METHOD

The Beam-Penetration method has been used with random-scan monitors.

In this method, the CRT screen is coated with two layers of phosphor, red and green and the displayed color depends on how far the electron beam penetrates the phosphor layers.

This method produces four colors only, red, green, orange and yellow.

A beam of slow electrons excites the outer red layer only;

hence screen shows red color only.

A beam of high-speed electrons excites the inner green layer.

Thus screen shows a green color.

SHADOW-MASK METHOD:

Shadow Mask Method is commonly used in Raster-Scan System because they produce a much wider range of colors than the beam-penetration method.

It is used in the majority of color TV sets and monitors.

Construction: A shadow mask CRT has 3 phosphor color dots at each pixel position.

One phosphor dot emits : red light ; Another emits : green light ; Third emits : blue light

This type of CRT has 3 electron guns, one for each color dot and a shadow mask grid just behind the phosphor coated screen.

Shadow mask grid is pierced with small round holes in a triangular pattern.

Figure shows the delta-delta shadow mask method commonly used in color CRT system.

Working:

Triad arrangement of red, green, and blue guns.

The deflection system of the CRT operates on all 3 electron beams simultaneously; the 3 electron beams are deflected and focused as a group onto the shadow mask, which contains a sequence of holes aligned with the phosphor- dot patterns.

When the three beams pass through a hole in the shadow mask, they activate a dotted triangle, which occurs as a small color spot on the screen.

The phosphor dots in the triangles are organized so that each electron beam can activate only its corresponding color dot when it passes through the shadow mask.

Inline arrangement: Another configuration for the 3 electron guns is an Inline arrangement in which the 3

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

This inline arrangement of electron guns in easier to keep in alignment and is commonly used in high-resolution color CRT's.

Figure 14 shows operation of a delta-delta, shadow-mask CRT. Three electron guns, aligned with the triangular color-dot patterns on the screen, are directed to each dot triangle by a shadow mask.

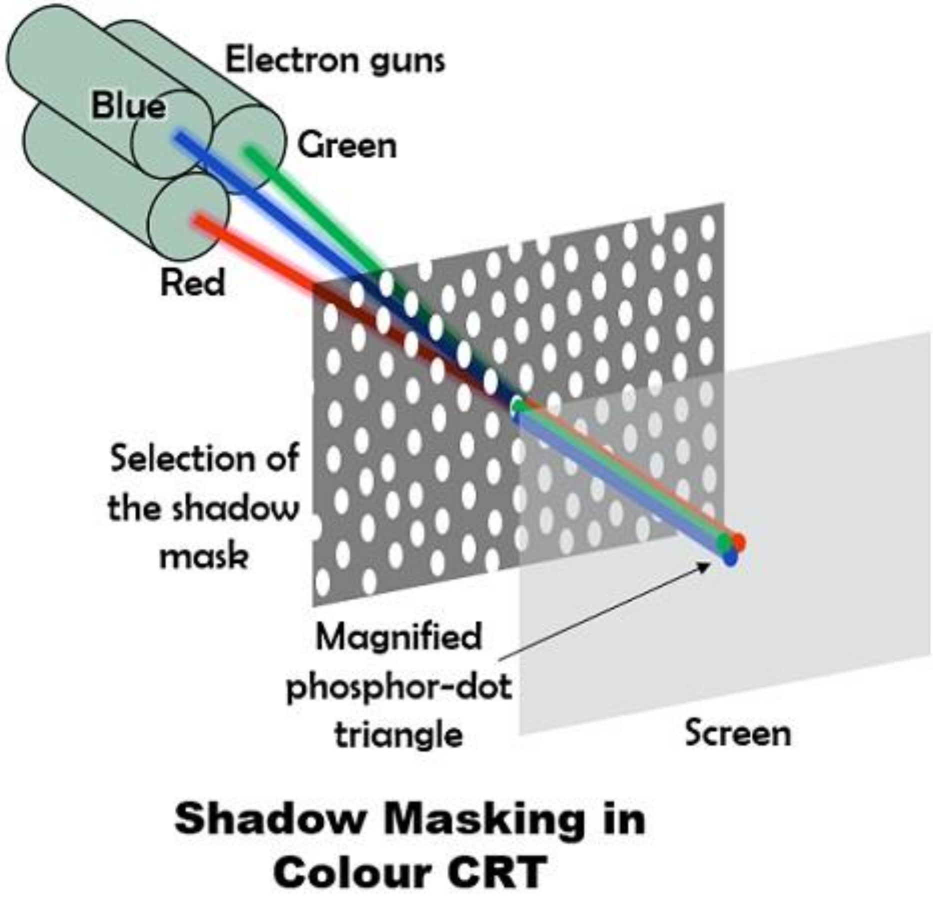


Fig 14 : Delta-delta shadow mask method

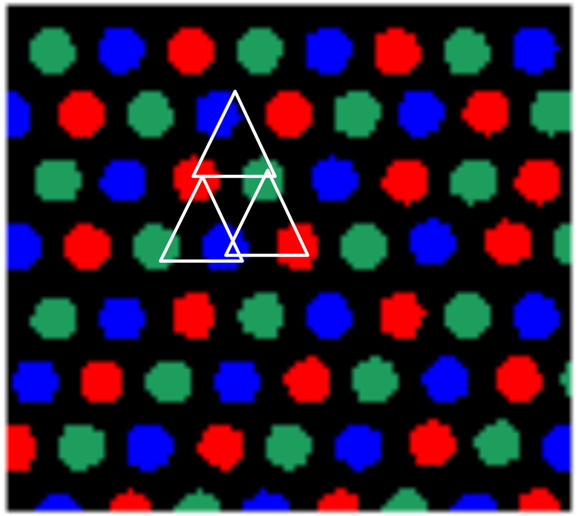


Fig 15 : Phosphorus dot pattern for shadow mask

A 24-BIT-PLANE COLOR FRAME BUFFER

Typically 8-bit planes per color is used, which gives a 24-bit plane frame buffer

• Each group of bit-planes drives an 8-bit DAC

• Each group generates 256 shades of intensities of red, green or blue

• Hence we obtain $2^{24} = 16,777,216$ possible colors.

• This is called a **FULL COLOR FRAME BUFFER**

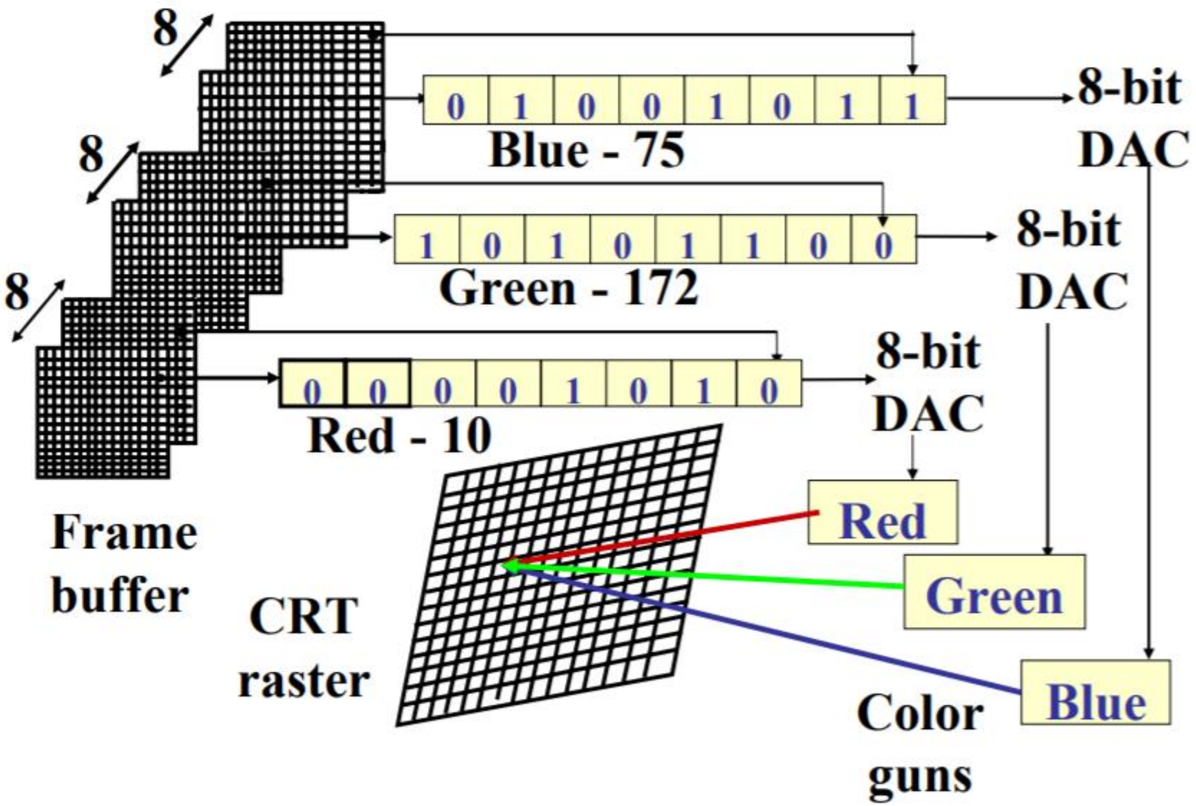


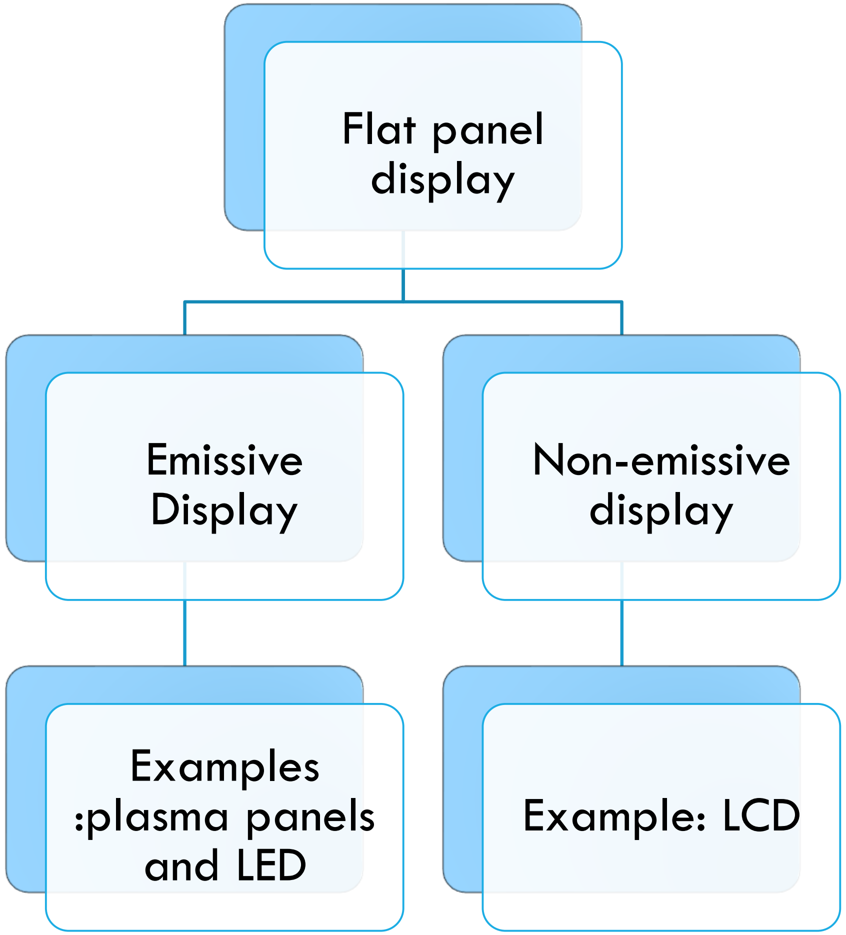
Fig 16 : 24-bit-plane color frame buffer

FLAT PANEL DISPLAY

The Flat-Panel display refers to a class of video devices that have reduced volume, weight and power requirement compare to CRT.

Emissive Display: The emissive displays are devices that convert electrical energy into light.

The Non-Emissive displays use optical effects to convert sunlight or light from some other source into graphics patterns.



LCD (LIQUID CRYSTAL DISPLAY)

LCD is made up of 6 layers :

1. vertical polarizer plane;
2. layer of thin grid wires;
3. layer of LCDs;
4. layer of horizontal grid wires;
5. horizontal polarizer;
6. finally a reflector.

• LCD material is made up of long crystalline molecules;

When the crystals are in an electric field, they all line up in the same direction.

• Active matrix panels have a transistor at each grid point (X, Y).

Crystals are dyed up to provide color.

Transistors act as memory, and also cause the crystals to change their state quickly.

• LCD displays are low cost, low weight, small size and low power consumption

The display contains two polarizers, aligned 900 to each other.

• With the display in its OFF (or twisted) state, light entering the display is plane polarized by the first polarizer.

• This polarized light passes through the liquid crystal sandwich and then through the second polarizer and is reflected back to the display.

• Turning the pixel ON (by applying and electric field) causes the crystal to untwist.

• Light now passing through the liquid crystal sandwich is now absorbed by the second polarizer. The pixel now appears dark.

Displays are of two types – plasma/gas discharge or Electroluminescent.

All flat panel displays are raster refresh displays.

A flat CRT is obtained by initially projecting the beam parallel to the screen and then reflecting it through 90o.

Reflection of the electron beam reduces the depth of the CRT bottle and hence the display.

Plasma displays like LCDs are also called active matrix displays.

The required voltage or current to control the pixel illumination is supplied using a thin-film transistor or diode.