Interactive Computer Graphics (COM524T)

Video Display Devices

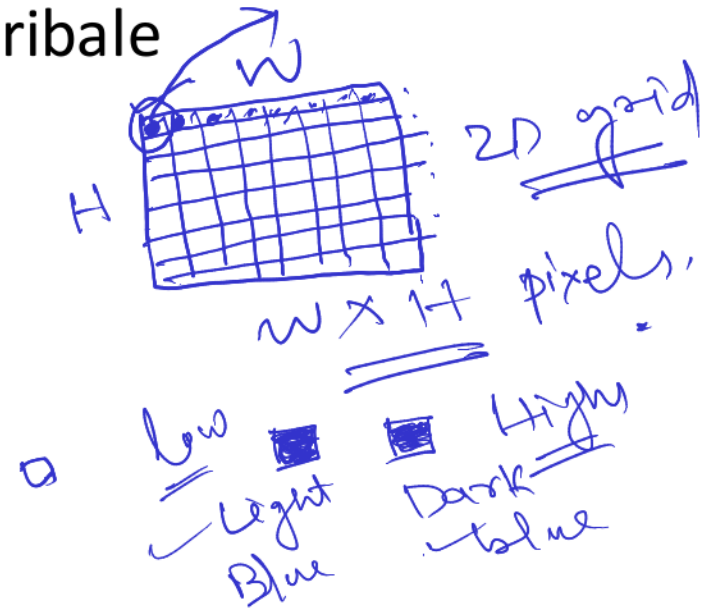
Dr. Ram Prasad Padhy, IIITDM Kancheepuram

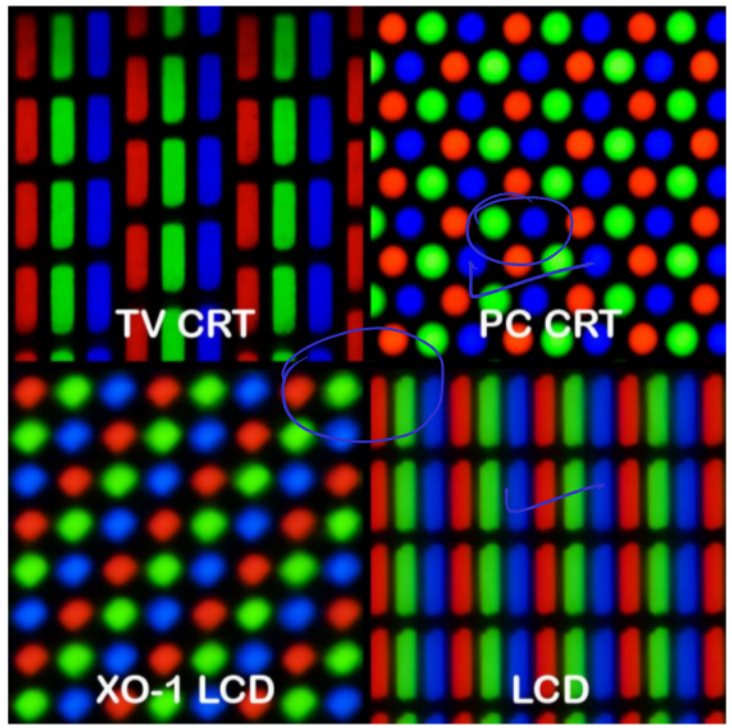
Topics to Learn

- What is PIXEL?
- Image Resolution: PPI/Pixel Density
- Aspect Ratio
- Cathode Ray Tube (CRT)
- Vector Scan Display/ Random Scan Display
- Raster Scan Display
- Difference between Vector and Raster Displays

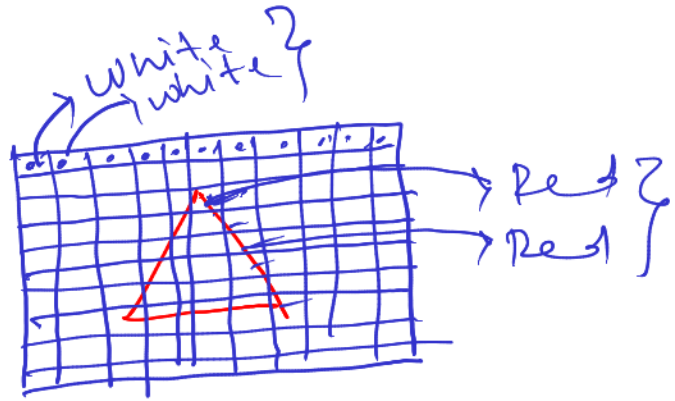
PIXEL

- Picture element
- In digital imaging, it is the smallest item of information in an image
- Arranged in 2D grid (row and column) --> dots/squares/rectangles
- It is the smallest unit of display on a video monitor
- Intensity of each pixel is varibale





PIXEL



R, G, B

255, 0, 0 → Red

220, 10, 10 → ~~light~~ Red
Dark

PIXEL

3 component / 3 layers

RED (R) — 8 bits (1 Byte)

GREEN (G) — 8 bits (1 Byte)

BLUE (B) — 8 bits (1 Byte) = 24 bits (3 Bytes)

8 bits → 256 (2^8) → [0, $2^8 - 1$]

(Binary system) → 256 shades → [0, 255]

PIXEL

RED → 256 , Green → 256 , Blue → 256

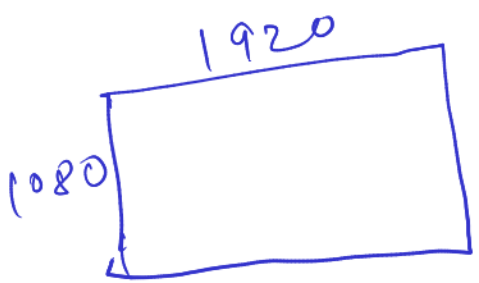
↓ ↓ ↓

[0, 255] [0, 255] [0, 255]

Total shades = $256 \times 256 \times 256 = 256^3 = 16.7$ million color shades

* composite of all the 3 components, gives the final color to the pixel.

Image : 1920×1080 pixels.



W H

image size = $1920 \times 1080 \times 3$ Bytes

$= 6415200$ Bytes ≈ 6.41 MB

10^3

10^{-6}

Image Resolution

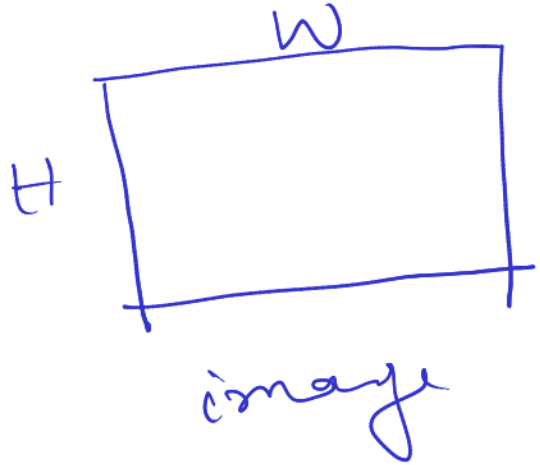
↳ W x H → Resolution

1920 x 1080 → FHD (Full HD)

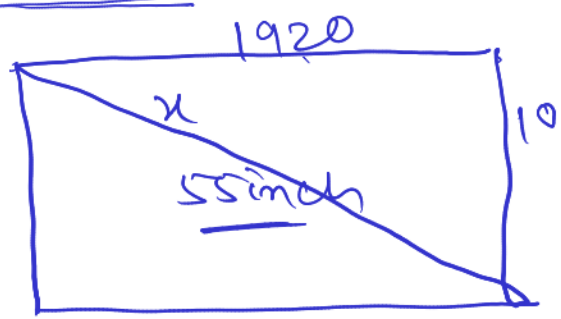
1280 x 720 → HD

4K ← 4096 x 2160 → UHD (Ultra HD)

4K ← 3840 x 2160 → QHD (Quad HD)



Pixel Density ←



55 inch TV

→ Pixel density ← (Pixel per inch PPI)

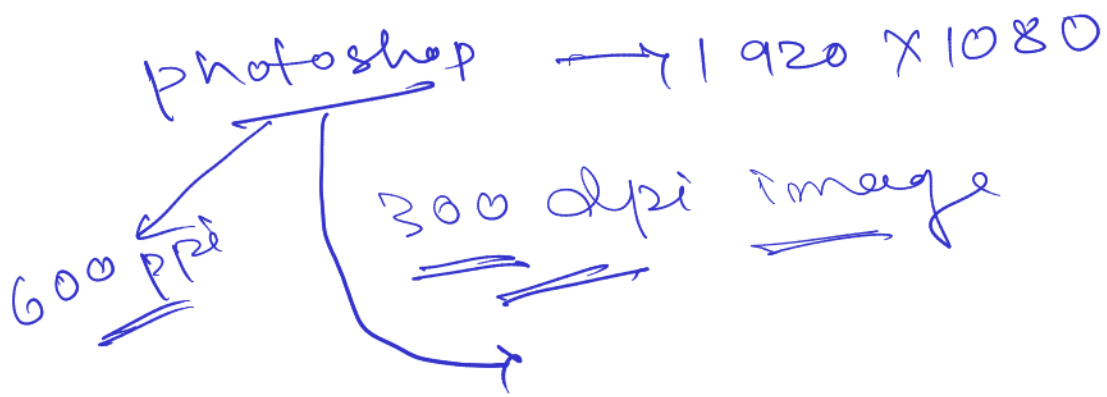
$x^2 = 1920^2 + 1080^2$

$\Rightarrow x = 2205$ pixels.

$PPI = \frac{2205}{55} = 40.09$ PPI

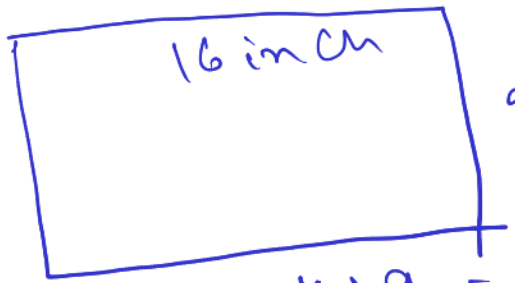
Image Resolution

dpi = dots per inch or pixel per inch



Aspect Ratio

* Ratio of width to height of a device



AR = 16:9 = 1.77

Q1 Find out the AR for all known resolution.

1920 x 1080 → FHD 1080, UHD, HD, 720 ← 1280 x 720 @ HD

SD - 480 ↓ Standard definition (SD)

640 x 480 → CD

SD - 480 : 720 x 480 → DVD

2K → 2048 x 1080

2K → 2560 x 1440

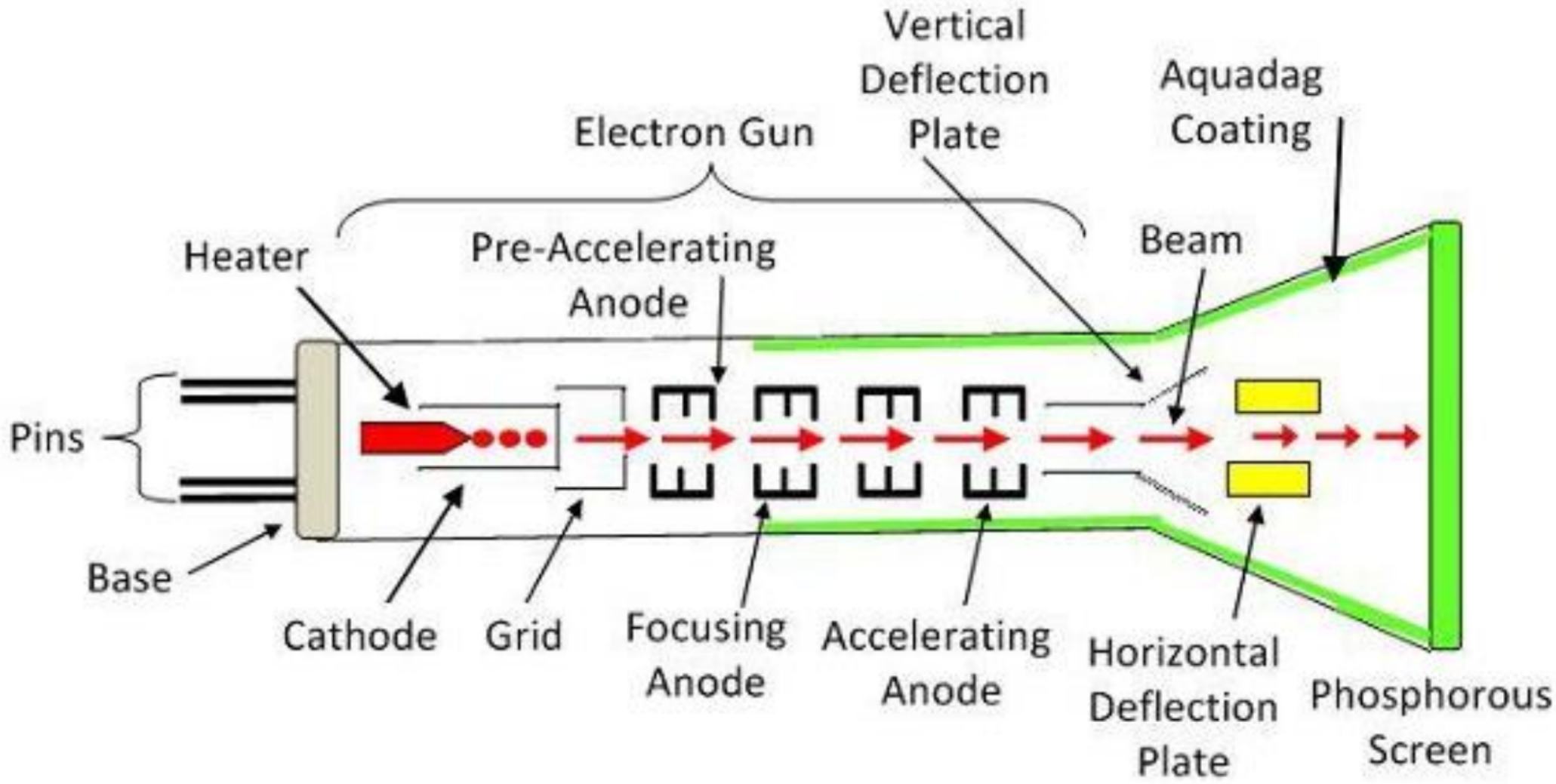
Self-study

- Different color models and their conversion (e.g. RGB, CMYK, HSV etc.)
- How color image is printed on a printer? CMYK

Cathode Ray Tube (CRT)

- The CRT is a **display screen** which produces images in the form of the **video signal.**
- It converts electrical signal (voltage and current) into video signal.
- It is a type of vacuum tube which displays images when the electron beam through **electron gun** strikes on the **phosphorescent surface**.
- In other Words, the CRT **generates** the beams, **accelerates** it at high velocity and **deflect** it for creating the images on the **phosphorous screen** so that the beam becomes **visible.**

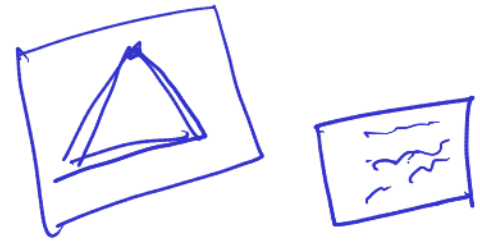
Cathode Ray Tube (CRT)



Cathode Ray Tube (CRT)

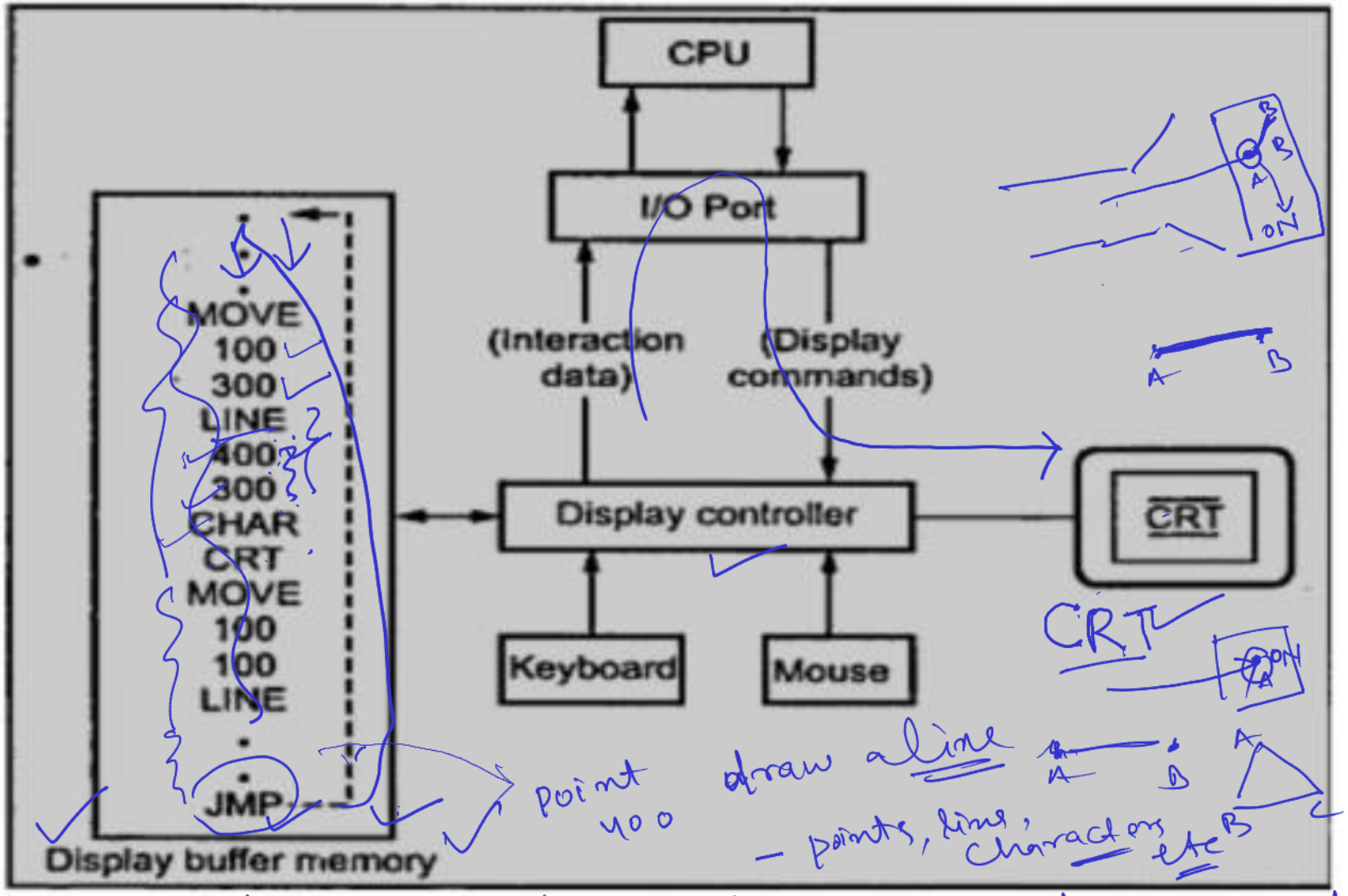
- **Cathode** emits electrons (e-) when it gets heated by the heater
- **Grid** focuses and passes the electron beam at a high speed
- **Pre-accelerating anode --> Focussing anode --> Accelerating anode**: Provide path to electron
- **Vertical deflection plate**: It deflects the e- beam in up and down direction on the screen
- **Horizontal deflection plate**: It deflects the e- beam in the right and left direction
- **Aquadag coating:** If e- comes out of their path, it repels and healps the e- to come agaiun to th focusing path
- **The display screen is coated with phosphor**
- Metal used in the screen is zinc sulphate or zinc tungston or zinc oxide
- Cathode is of Nickle cylinder coated with oxide → Barium
- **Electron gun:** Heater + Cathode + Grid + Assembly of anodes

Vector Scan Display (VSD)



- It is also known as Random Scan Display or Calligraphic Display or Stroke-writing Display
- It is a technique used for producing images on the screen
- It is called vector displays, as it draws picture one line at time.
- Electron beam is directed only to the areas of screen where a picture has to be drawn.
- It can draw and refresh component lines of a picture in any specified sequence.
- Pen plotter is an example of random-scan displays.
- The number of lines regulates refresh rate on random-scan displays
- An area of memory called **refresh display files** stores picture definition as a set of line drawing commands. The system returns back to first line command in the list, after all the drawing commands have been processed.

Vector Scan Display (VSD)



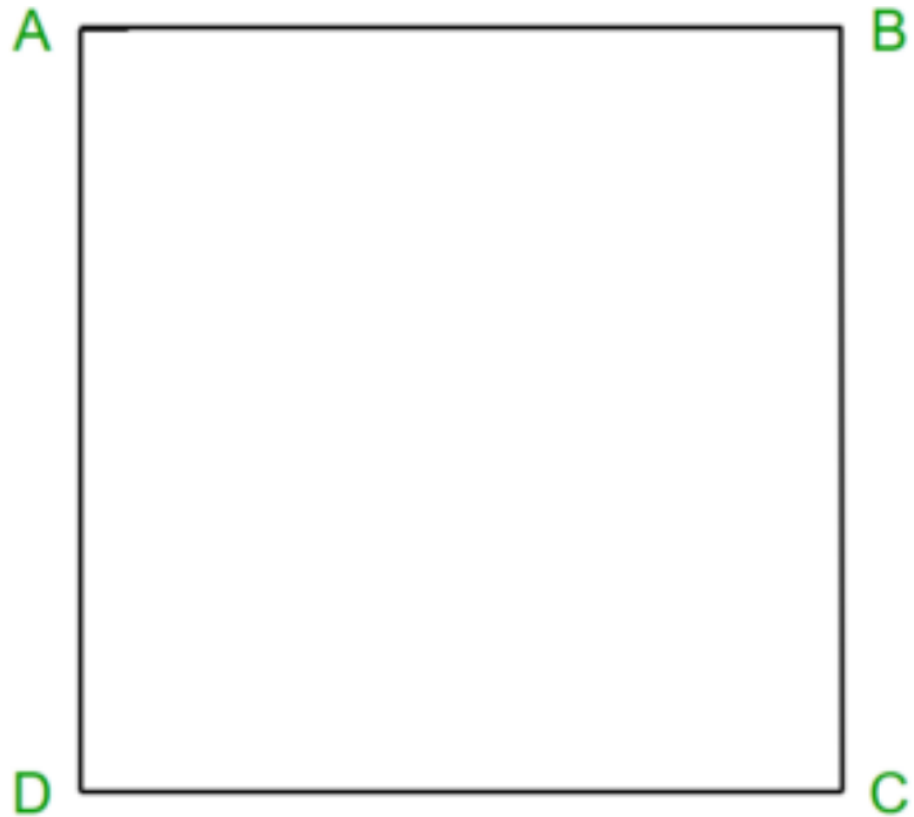
- Faster refreshing can burn the phosphor. To avoid this every refresh cycle is delayed to prevent refresh rate greater than 60 frames per second.

Refresh Rate : No. of times the screen refreshes per second.

Vector Scan Display (VSD)

Suppose we want to display a square ABCD on the screen. The commands will be:

- Draw a line from A to B
- Draw a line from B to C
- Draw a line from C to D
- Draw a line from D to A

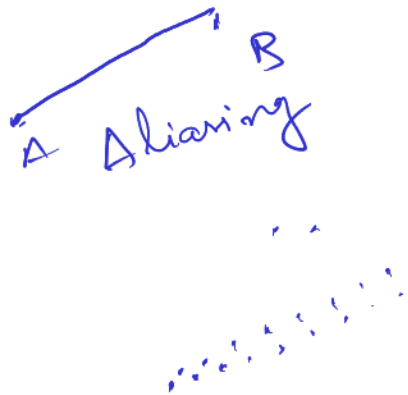


Vector Scan Display (VSD)

Vector-Scan Display Processors:

- Input in the form of an application program is stored in the system memory along with graphics package.
- Graphics package translates the graphic commands in application program into a display file stored in 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.
- Sometimes the display processor in a vector-scan is referred as *Display Processing Unit / Graphics Controller*.

Vector Scan Display (VSD)



Advantages:

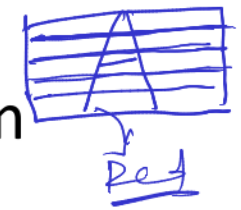
- Higher resolution as compared to raster scan display.
- Produces smooth line drawing.
- Less Memory required.

Disadvantages:

- Realistic images with different shades cannot be drawn.
- Colour limitations. → y different intensities.

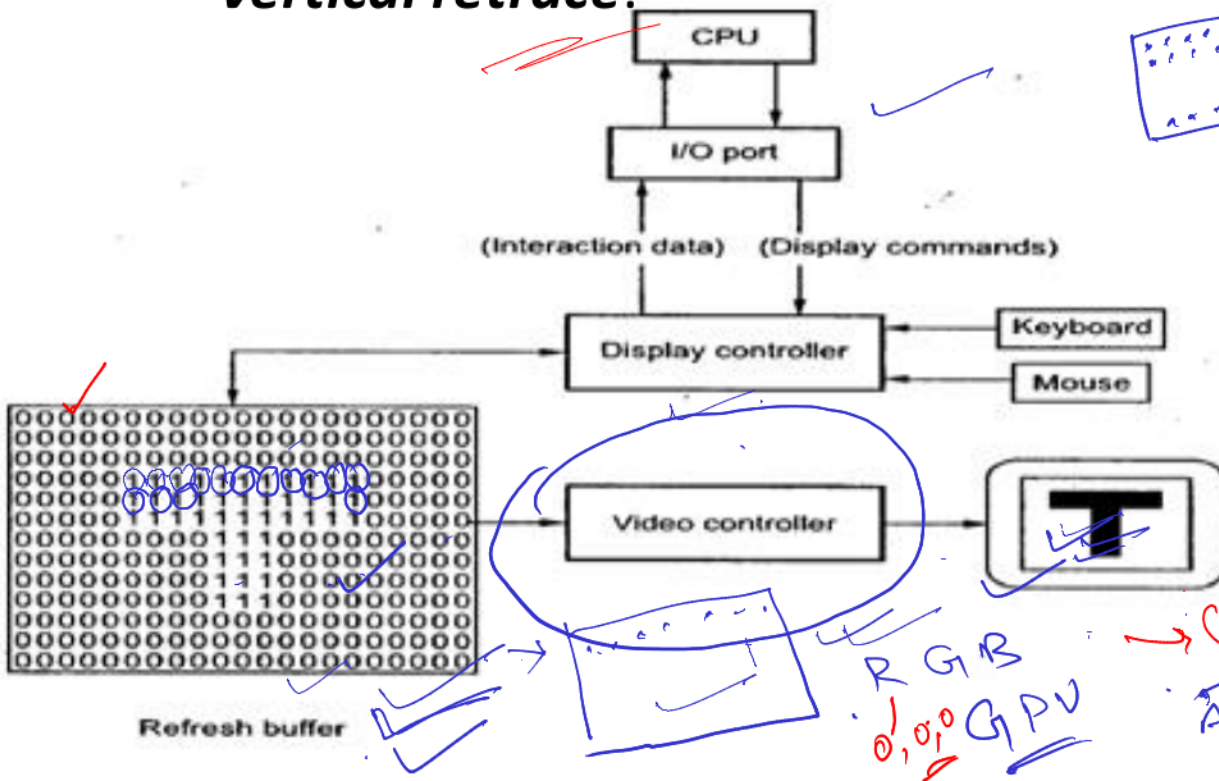
Raster Scan Display (RSD)

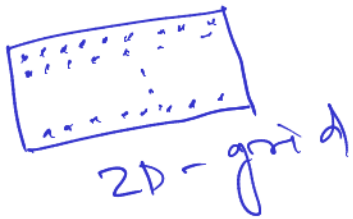
- **Raster Scan Displays** are most common type of graphics monitor which employs CRT. It is based on television technology.
- In raster scan system electron beam sweeps across the screen, from top to bottom covering one row at a time.
- A pattern of illuminated pattern of spots is created by turning beam intensity on and off as it moves across each row.
- A memory area called **refresh buffer or frame buffe**r stores picture definition. This memory area holds intensity values for all screen points.
- Stored intensity values are restored from frame buffer and painted on screen taking one row at a time. **Each screen point is referred to as pixels.**
- In raster scan systems refreshing is done at done at a rate of 60-80 frames per second. **Refresh rates are also sometimes described in units of cycles per second / Hertz (Hz).**

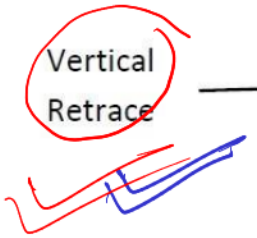


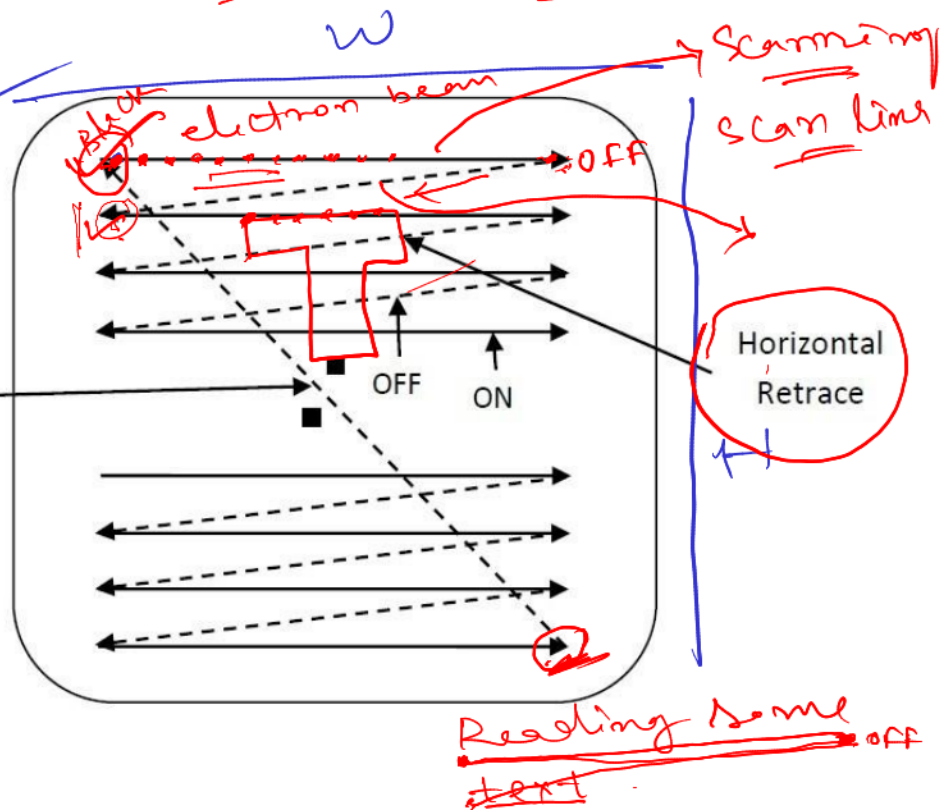
Raster Scan Display (RSD)

- At the end of each scan line, electron beam begins to display next scan line after returning to left side of screen. The return to the left of screen after refresh of each scan line is known as ***horizontal retrace*** of electron beam. At the end of each frame electron beam returns to top left corner and begins the next frame. It is known as ***vertical retrace***.

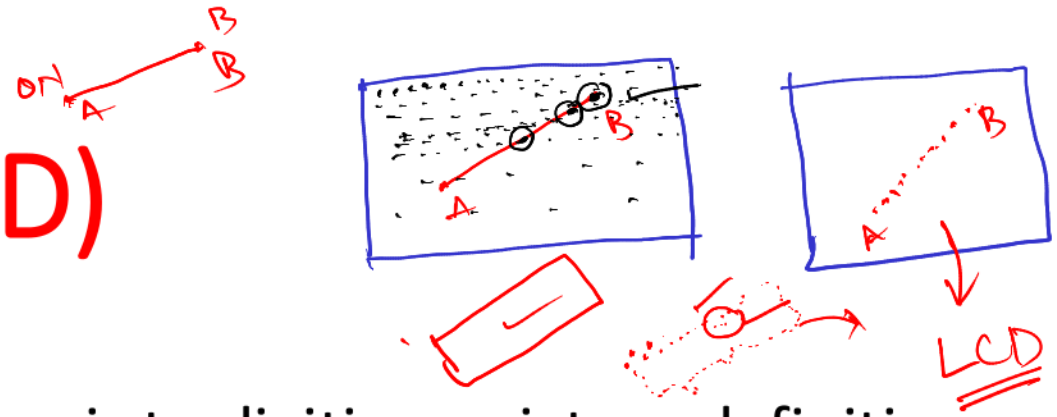








Raster Scan Display (RSD)



Raster-Scan Display Processor:

- An important function of display process is to digitize a picture definition given in an application program into a set of pixel-intensity values for storage in refresh buffer. This process is referred to as **scan conversion**.
- The purpose of display processors is to relieve the CPU from graphics jobs.
- Display processors can perform various other tasks like: creating different line styles, displaying color areas, etc.
- Typically display processors are utilized to interface input devices, such as mouse, joysticks.

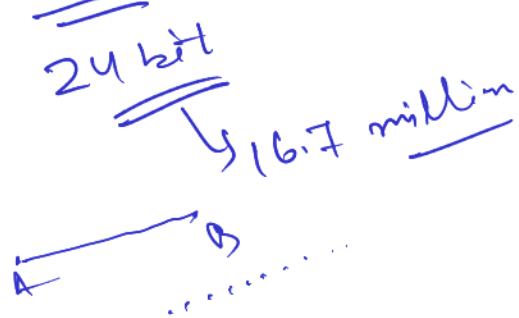
Raster Scan Display (RSD)

Advantages:

- Real life images with different shades can be displayed.
- Color range available is bigger than random scan display.

Disadvantages:

- Resolution is lower than random scan display.
- More memory is required.
- Data about the intensities of all pixel has to be stored.



VSD vs RSD

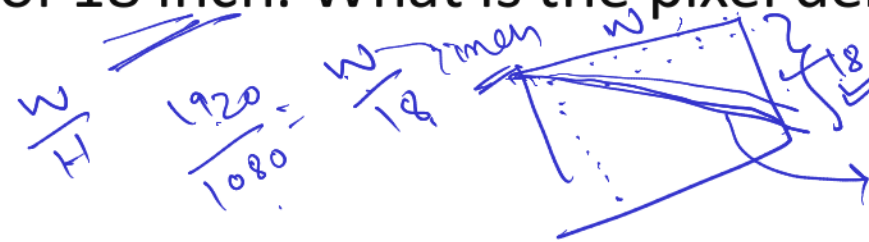
Vector Scan Display	Raster Scan Display
The resolution of vector scan is higher than raster scan.	While the resolution of raster scan is lesser or lower than random scan.
It is costlier than raster scan.	While the cost of raster scan is lesser than vector scan.
In vector scan, any alteration is easy in comparison of raster scan.	While in raster scan, any alteration is not so easy .
In vector scan, interweaving is not used.	While in raster scan, interweaving is used.
In vector scan, mathematical function is used for image or picture rendering.	While in which, for image or picture rendering, raster scan uses pixels.
It is suitable for applications requiring polygon drawings.	It is suitable for creating realistic scenes.

Self-study

- **Functioning of LED, LCD displays and their difference**

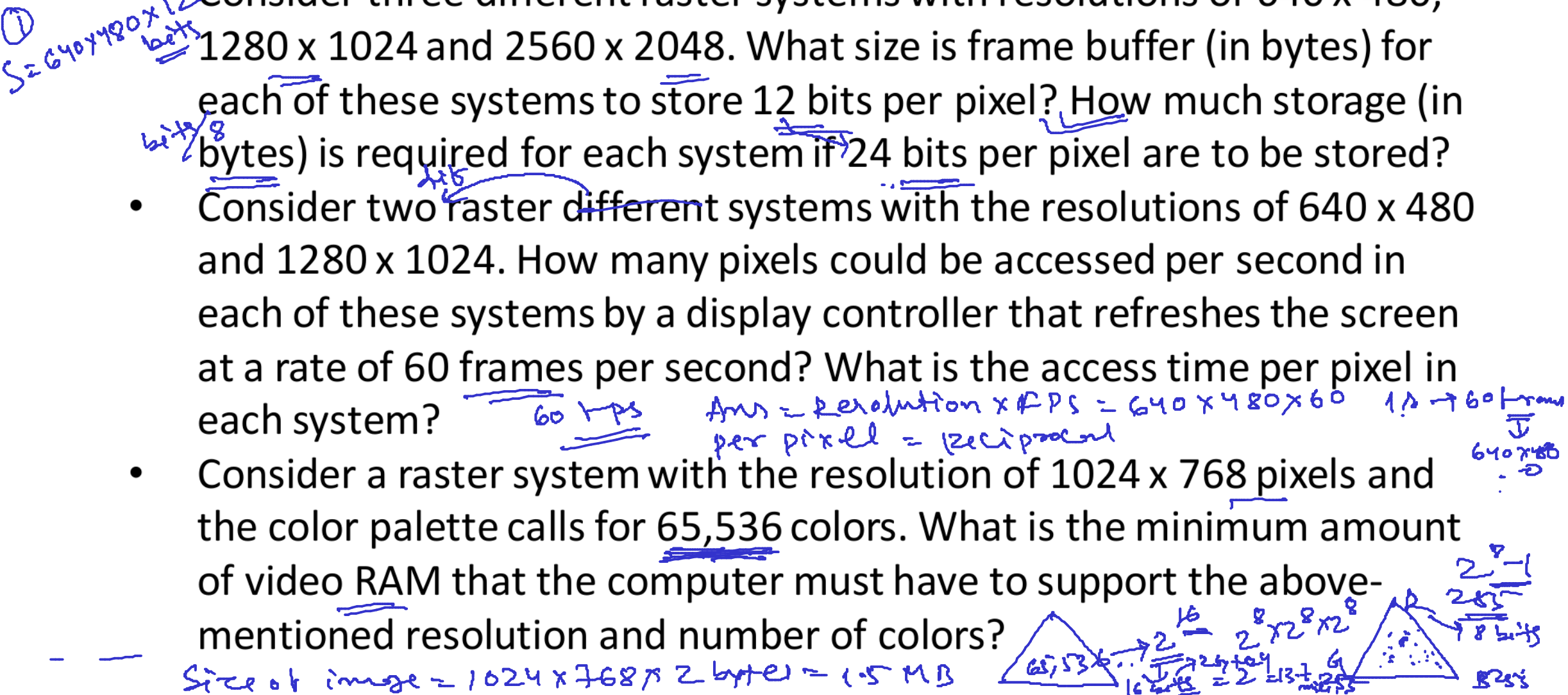
Numerical Questions

- Suppose an image to be printed is in RGB color model. But, the printer has CMY tuners. What will be the CMY values calculated by the printer for RGB: (100, 120, 195). Assume the maximum intensity value for a RGB pixel is 255.
- Suppose the refresh rate for a display system with resolution 1280 x 720 is 60 frames per second. How much time does it require to display a single pixel (answer should be in miliseconds) on the screen?
- What is the size of an image (in KB) if the image is 1920 x 1080 color image with 16 bits to store each of R, G, B values. Consider direct coding.
- Suppose a display system with 1920 pixels in width and 1080 pixels in height has a height of 18 inch. What is the pixel density for the display system?



Numerical Questions

- Consider three different raster systems with resolutions of 640 x 480, 1280 x 1024 and 2560 x 2048. What size is frame buffer (in bytes) for each of these systems to store 12 bits per pixel? How much storage (in bytes) is required for each system if 24 bits per pixel are to be stored?
- Consider two raster different systems with the resolutions of 640 x 480 and 1280 x 1024. How many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 60 frames per second? What is the access time per pixel in each system?
- Consider a raster system with the resolution of 1024 x 768 pixels and the color palette calls for 65,536 colors. What is the minimum amount of video RAM that the computer must have to support the above-mentioned resolution and number of colors?



Numerical Questions

- Find out the time required to scan one row of screen if the screen resolution is 20MP (mega pixel), aspect ratio 5/4 and refresh frequency is 30Hz.
- How much time is spent scanning across each row of pixels during screen refresh on a raster system with resolution of 1280 X 1024 and a refresh rate of 60 frames per second?
- Assuming that a certain full color (24 bit per pixel) RGB raster system has a 512 by 512 frame buffer, how many distinct color choices (intensity levels) would be available?
- How long would it take to load a 640x480 frame buffer with 12bits per pixel, if 10^5 bits can be transferred per second?

(1)

RGB → CMY

$$C = \frac{255 - R}{255}$$

RGB → [0, 1]

R, G, B → [100, 120, 195]

$$R' = \frac{R}{255} = 0.39 \qquad G' = \frac{G}{255} = 0.47 \qquad B' = \frac{B}{255} = 0.76$$

$$K = 1 - \max(R', G', B') = 1 - 0.76 = 0.24$$

$$C = 1 - \frac{R'}{1-K} = \frac{1 - R' - K}{1-K} = 0.488$$

$$M = 1 - \frac{G'}{1-K} = \frac{1 - G' - K}{1-K} = 0.384$$

$$Y = 1 - \frac{B'}{1-K} = \frac{1 - B' - K}{1-K} = 0$$

(2) R.R = 60 fps frames/seconds.

1 second → 60 frames are displayed.

$= 60 \times 720 \times 1280$ pixels.

$\therefore$ 1 pixel $= \frac{1}{60 \times 720 \times 1280}$ seconds $= 1.8 \times 10^{-5}$ ms

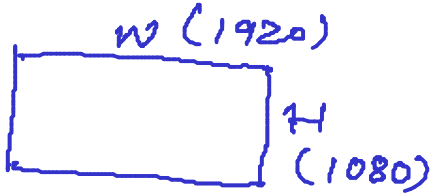
(3) Resolution → 1920 × 1080. Each of R, G, B → 16 bits.

W × H

→ 2 bytes.

$\therefore$ Size of an image = 1920 × 1080 pixels.

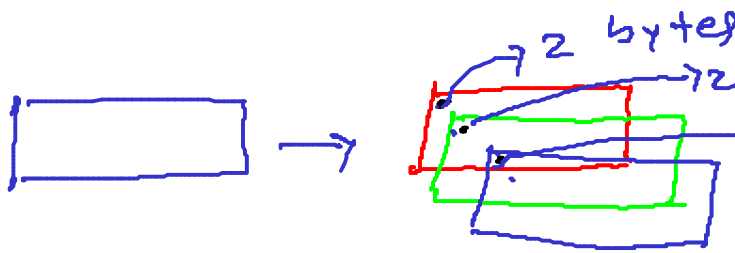
No. of pixels. =



$10^{-3} = 1000$

1 KB = 1024 bytes

Each pixel size = 2 × 3 = 6 bytes.



1 pixel = 3 components

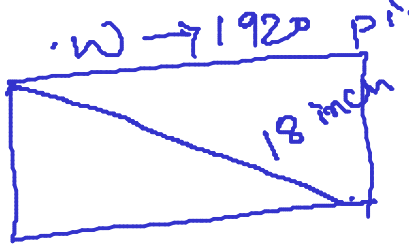
= R, G, B

2 2 2

$\therefore$ Size of image = 1920 × 1080 × 6 bytes = 12441600 bytes.

= 12150 KB = 11.86 MB

(4)



$W \times H = 1920 \times 1080$

$H = 18$ inch

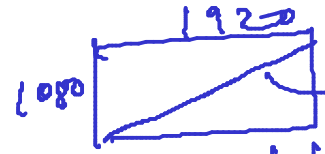
Pixel density = pixels per inch = PPI

$P.D = \frac{\text{No of pixels along width}}{\text{width}}$

$= \frac{\text{No of pixels along height}}{\text{height}}$

$\frac{W}{H} = \frac{1920}{1080}$

$\Rightarrow \frac{W}{18} = \frac{1920}{1080} \Rightarrow W = 32$ inch.



Size of the D.S = 55 inch

Length of the diagonal $= \sqrt{W^2 + H^2} = \sqrt{32^2 + 18^2}$

$= 36.71$ inch.

No. of pixels along the diagonal $= \sqrt{1920^2 + 1080^2}$

$= 2202.91$ pixels.

≈ 2203 pixel

Pixel density $= \frac{\text{No. of pixels along the diagonal}}{\text{Length of the diagonal}}$

$= \frac{2202.91}{36.71} \approx 60$ PPI ✓