DISPLAY DEVICES

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Overview

1. Computer Graphics Devices
2. Types of CRT Display devices
   - DVST
   - Random Scan or Vector Graphics System
   - Raster Scan Display System
     - Refresh Rate, Video basics and Scan Conversion
     - Display system with N-bit plane gray level Frame buffer
     - Display system with N-bit plane colour Frame buffer
3. Flat Panel Display Systems

Computer Graphics Devices

- Examples of Computer Graphics Devices
  - Input Devices: Video digitizers, scanners, keyboard, joystick, mouse, touch screen, etc.
  - Output Devices: CRT, plotters, data matrix, laser printers, Films, flat panel devices, etc.
  - Processing/controlling devices: VGA/EGA/CGA/SVGA/, VDC, VDP, GPU
- Let us discuss **CRT monitor**

Types of CRT display devices

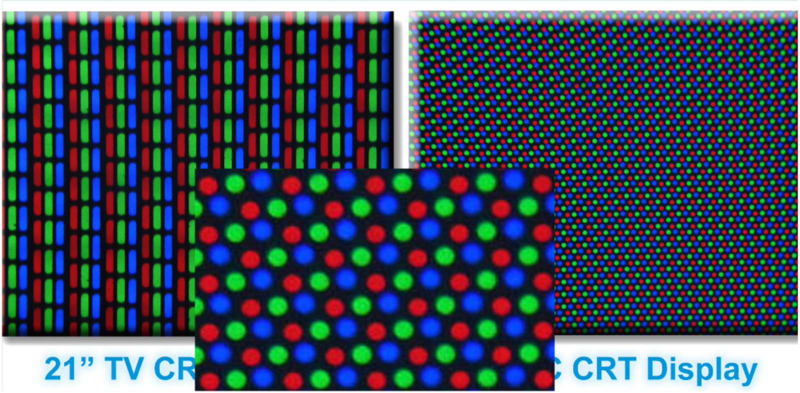
- DVST (Direct View Storage Tube)
- Calligraphic or Random Scan display system
- Refresh and raster scan display system

DVST - Direct View Storage Tube

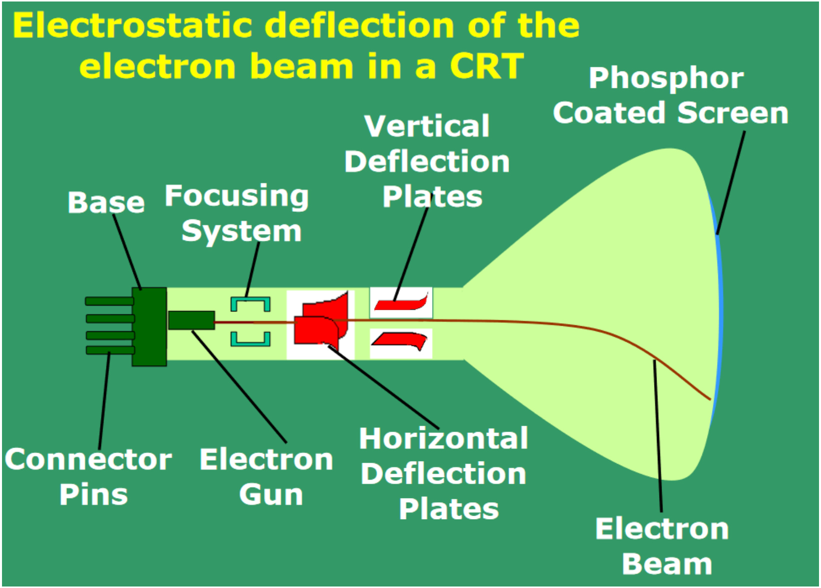
- Three types of phosphors used to generate arbitrary colour when electrons hit the phosphor
- One type will glow in red
- The second type will glow in green
- The third type will glow in blue

DVST - Direct View Storage Tube (cont.)

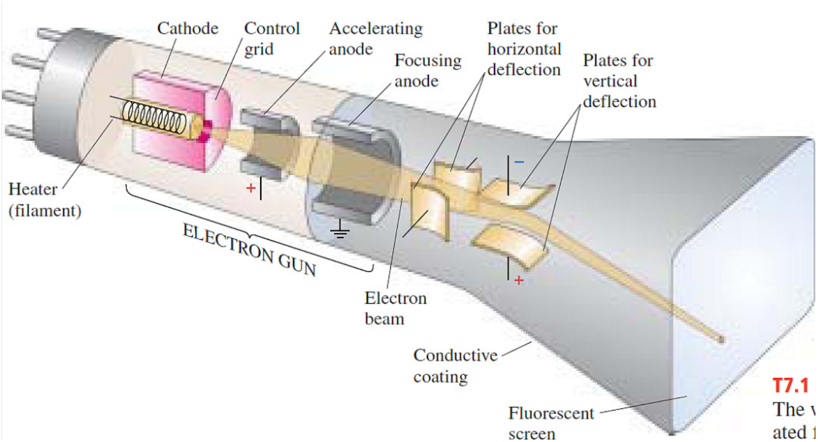
The coating of Phosphors behind the visible screen.



DVST - Direct View Storage Tube (cont.)



DVST - Direct View Storage Tube (cont.)



DVST - Direct View Storage Tube (cont.)

- Screen has a storage mesh in which the phosphor is embedded
- It uses long persistence phosphor
- Provides flicker-free display
- line is drawn
- No refreshing necessary
- A slow moving electron beam draws a line on the screen

Drawbacks

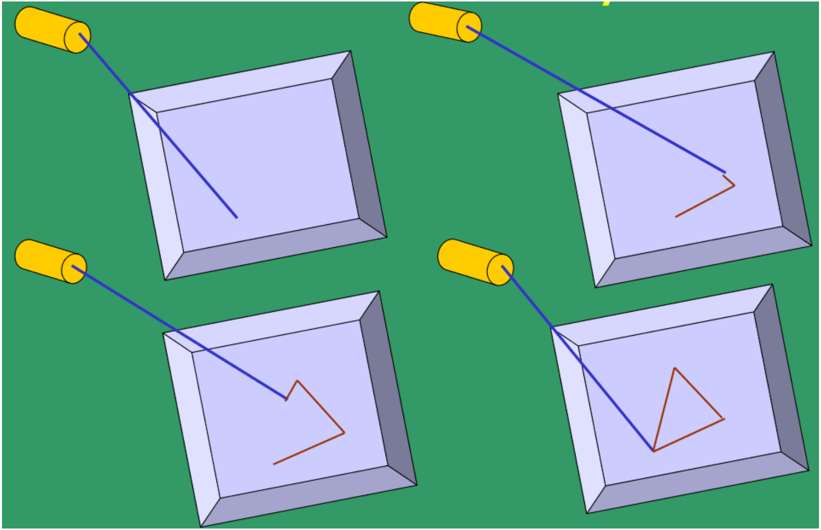
- Slow process of drawing – typically a few seconds are necessary for a complex picture
- Image stays on the screen for several seconds
- Not suitable for animation

Calligraphic or Random Scan display system or Vector graphics system

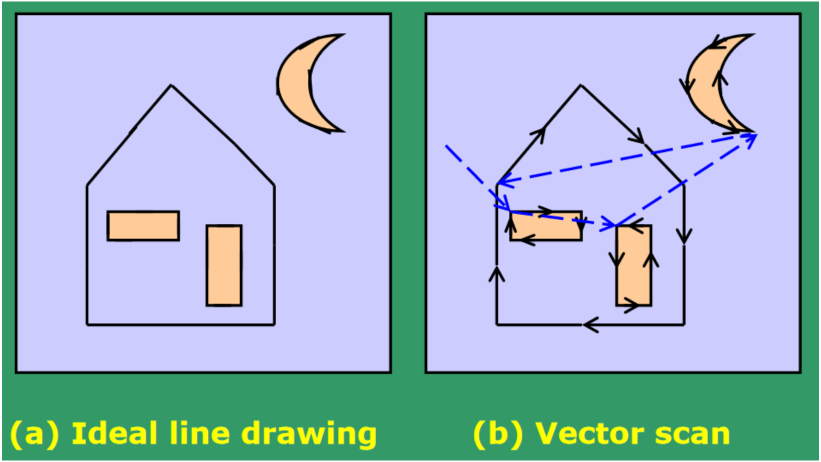
- Lines are drawn
- Characters are made of sequences of strokes (or short lines)
- Vectored – electron beam is deflected from end-point to end-point
- Random scan - Order of scanning(drawing) lines can be arbitrary
  -To draw a particular line, no precondition is imposed
- Phosphor has short persistence – decays in 10-100 μ s
- Recommended refresh rate is 60 Hz. or more
- Animation is possible

Calligraphic or Random Scan display system or Vector graphics system (cont.)

Random-scan display system draws a set of lines in any order.



Calligraphic or Random Scan display system or Vector graphics system (cont.)



Calligraphic or Random Scan display system or Vector graphics system (cont.)

- Phosphor's Fluorescence is the light emitted while the phosphor is being struck by electrons
- Quantum of Phosphor's Fluorescence is directly proportional to the number of electrons hit the Phosphor
- Phosphor's persistence is defined as the time from the removal of excitation to the moment when phosphorescence has decayed to 10% of the initial light output (decay is exponential).
  - long persistence : several seconds (used in DVST display)
  - short persistence : 10-60 μs(Used in Vector display)

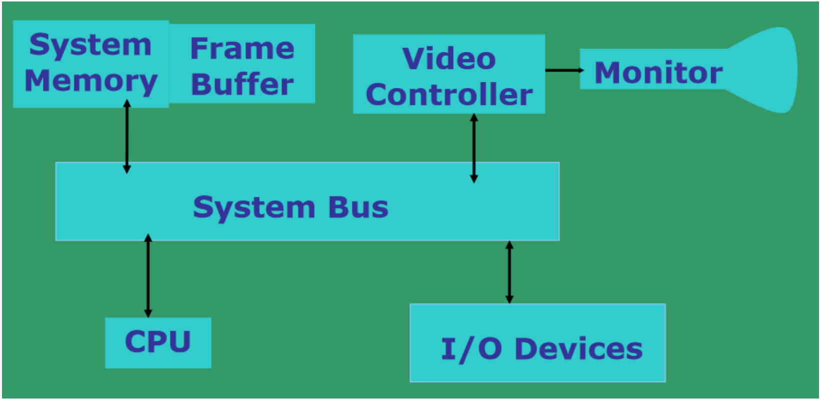
Raster scan display system

- Raster: 2D array of cells, where each cell is a pixel
- Raster scan display displays each pixel in the 2D array of cells
- Electron gun fires electron only on the specific pixel location
- Electron gun start and stop firing at each pixel
- Unlike DVST and random-scan which were line-drawing devices, Raster scan display is a point-plotting device
- Refresh buffer (also called frame buffer) stores the drawing primitives in terms of pixels(location, value)
- Used in television screens

Raster scan display system (cont.)

Architecture of a simple raster graphics system

- Video (Display) controller(VDC) is a necessary hardware in raster scan display system
- VDC is also called as graphics card or video card
- Video Display Processor(VDP), an extended hardware from VDC, can also be used
- GPU, extended hardware from VDP, can also be used



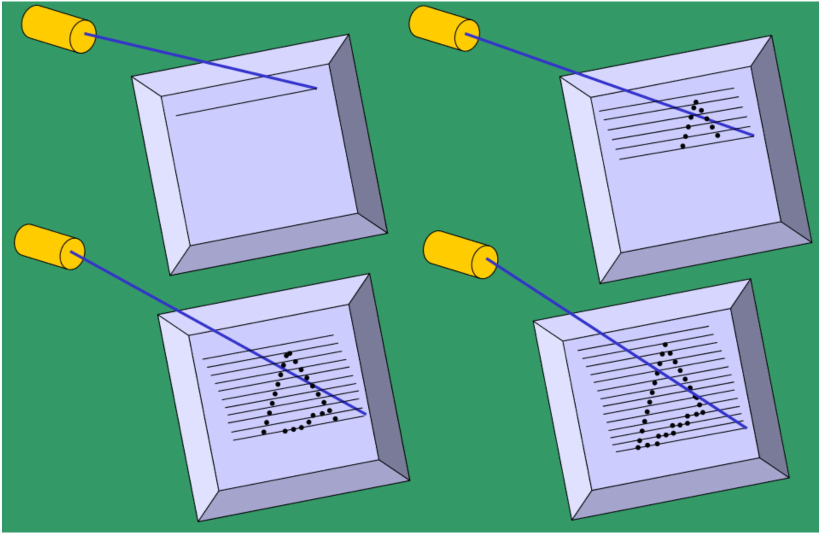
System Memory
Frame Buffer
Video Controller
Monitor
System Bus
CPU
I/O Devices

Raster scan display system (cont.)

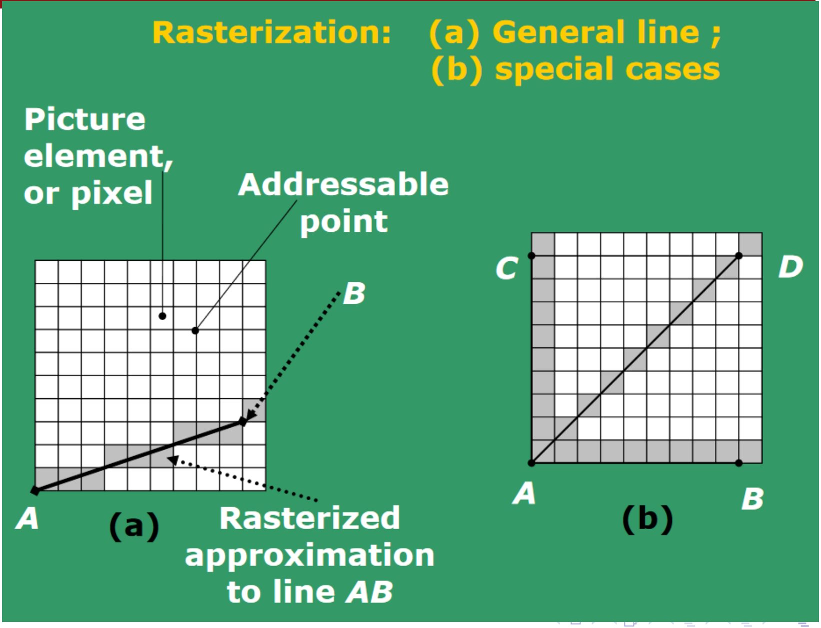
- Entire screen is a matrix of pixels
- Each pixel brightness can be controlled
- Each point is an addressable point in screen
- Line cannot be drawn directly from one point to another
- This causes the effect of ‘aliasing’, ‘jaggies’or ‘staircase’ effect

Raster scan display system (cont.)

Raster-scan display system draws a discrete set of points



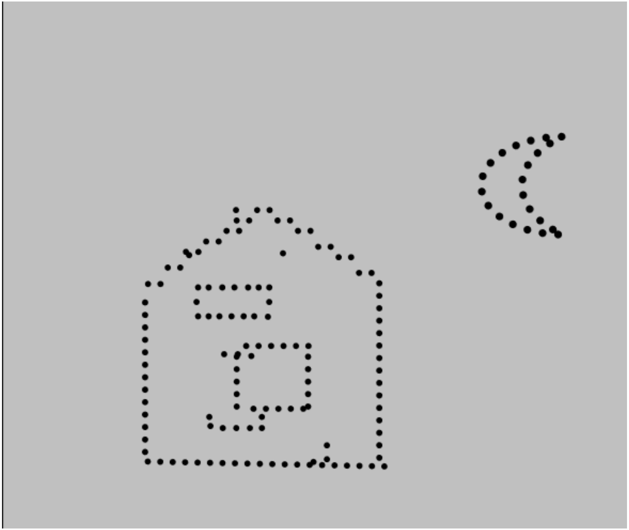
Raster scan display system (cont.)



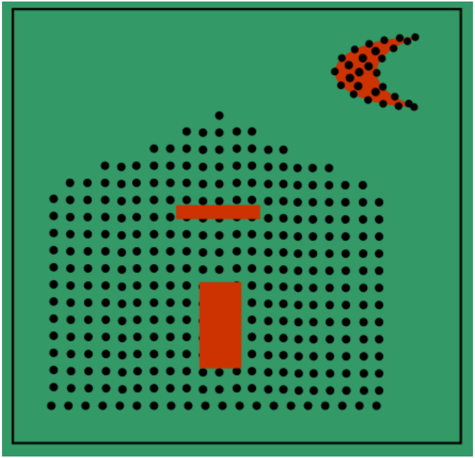
- Raster is a matrix of pixels representing the entire screen area
- Entire image is scanned out sequentially by the video controller (one raster line at a time)
- The lines are scanned from top to bottom and then back to the top
- The intensity of the beam decides the brightness of the pixel
- At least one memory bit for each pixel (called bit-plane)

Refresh Rate, Video basics and Scan Conversion (cont.)

Raster scan with outline primitive



Raster scan with filled primitive



Refresh Rate, Video basics and Scan Conversion (cont.)

Raster Size:

- If one uses a 512x512 element raster display, then 2^{18} bits are necessary in a single bit plane. Memory size required:32 KB
- Memory size required for N-bit plane gray level frame buffers:

N	Size in KB
3	96
8	256
24	768

Refresh Rate, Video basics and Scan Conversion (cont.)

- Refresh rate to avoid flickering – 60 Hz
- If one uses a 1024x1024 high resolution CRT:

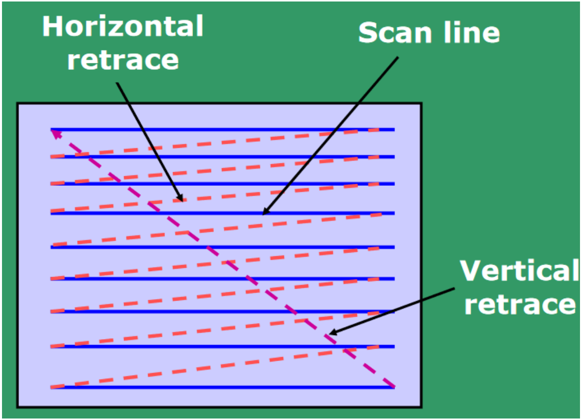
N	Display Color	Memory Size
1	Black & White	128 KB
8	256 colors	1 MB
24	16 million colors	3 MB
32	16 million colors	4 MB

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

Refresh Rate, Video basics and Scan Conversion (cont.)

- **Refresh rate** of a CRT is the number of times the image is drawn on the screen per second.
- Reducing refresh rate increases flicker.
- **Horizontal scan rate** is the number of scan lines displayed per second = refresh rate x number of scan lines
- Resolution of the screen depends on dot(pixel) size
- For larger spot size, resolution decreases

Raster Scan

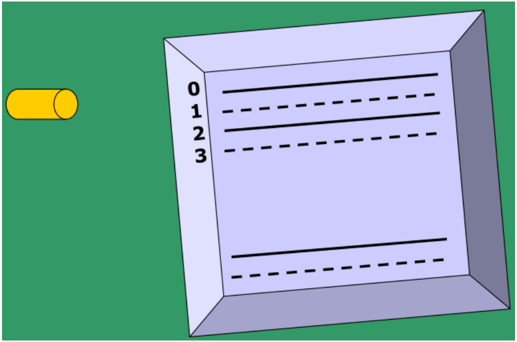


Refresh Rate, Video basics and Scan Conversion (cont.)

- NTSC (American Standard Video) has 525 horizontal lines with a frame rate of 30 fps.
- 525 horizontal lines include 483 physical horizontal lines and 42 virtual lines
- Why virtual lines: Time taken for vertical retrace is equal to time required to draw 42 horizontal lines
- 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

Refresh Rate, Video basics and Scan Conversion (cont.)

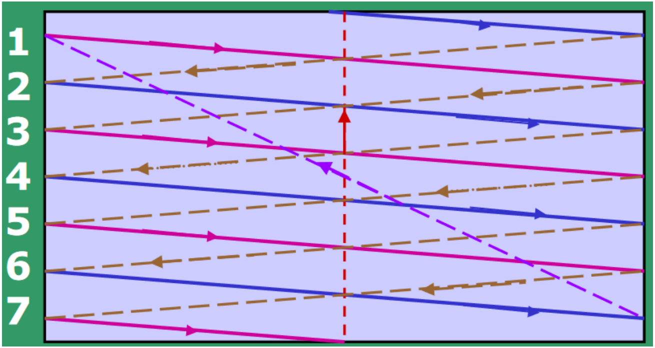
- Interlacing scan lines on a raster scan display
- First, all points on the even-numbered (solid)scan lines are displayed
- then all points along the odd-numbered (dashed) lines are displayed



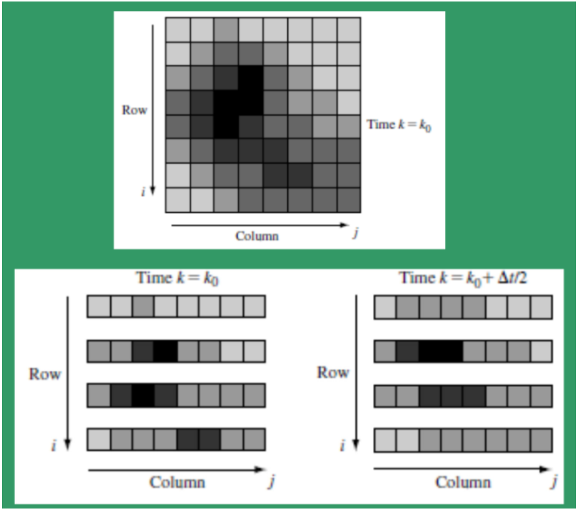
Refresh Rate, Video basics and Scan Conversion (cont.)

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.



Refresh Rate, Video basics and Scan Conversion (cont.)



Refresh Rate, Video basics and Scan Conversion (cont.)

- 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 time required for one scan line is calculated as total time taken for drawing the scan line and the time taken for one horizontal retrace
- 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

Refresh Rate, Video basics and Scan Conversion (cont.)

What is the time taken to draw a horizontal line as per NTSC standards

- Let T be the total time taken for one scan line and one horizontal trace.
- As in 1 sec, 30 frames are displayed, 1 sec = 30 * ((Time taken for drawing horizontal lines + time for horizontal traces) + time vertical trace)
- Thus 1 sec = 30*(483 T + 42 T) sec
- Thus, T = 63.5 μs/scan-line.
- As 17 % of time is spent for horizontal retrace, the time to display all pixels in a scan line (time to scan from left to right only):T' = 0.83*T = 53 μs.

What is the time taken to display one pixel as per NTSC standards

Refresh Rate, Video basics and Scan Conversion (cont.)

- As aspect ratio in NTSC is $4/3$ and number of physical horizontal lines is 483, $4/3 = w/483$ (sine aspect ratio is w/h)
- Thus the number of columns $= w = 4/3 * 483 = 644$
- Since time taken for drawing one horizontal line(excluding horizontal retrace) is 53 μs, time taken to display one pixel $= 53/644\ \mu$ s $=$ 82.3 ns

Refresh Rate, Video basics and Scan Conversion (cont.)

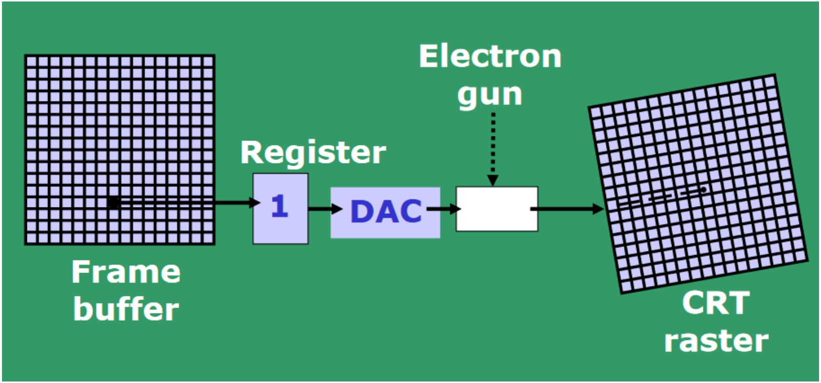
Some examples of pixel access times:

Frame Rate	Image size	Pixel Access Time
30	512 x 512	105 ns
25	500 x 625	105 ns
60	1000 x 1000	26 ns
60	1024 x 1024	24 ns
90	3840 x 2400	?? ns

- Number of gray scales and colors depend on the value of N (bit plane size)
  - When N = 1, two gray scales (B&W)
  - When N = 3, 8 gray scales
  - When N = 8, 256 gray scales
  - For colour Image, when N = 24, 16 million colors
- For colored displays (raster-scan), three separate color guns must be used.

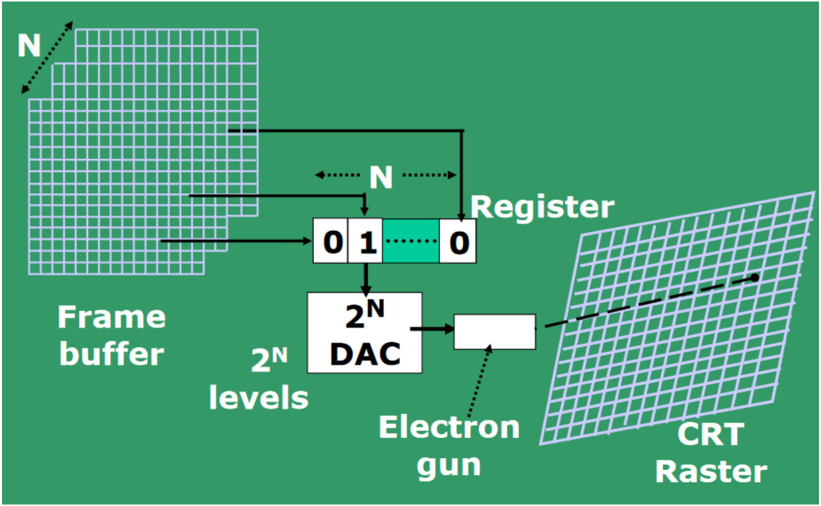
Display system with N-bit plane gray level Frame buffer (cont.)

A single bit-plane black & white frame buffer raster CRT graphics device.



Display system with N-bit plane gray level Frame buffer (cont.)

An N-bit plane gray level frame buffer



Display system with N-bit plane colour Frame buffer

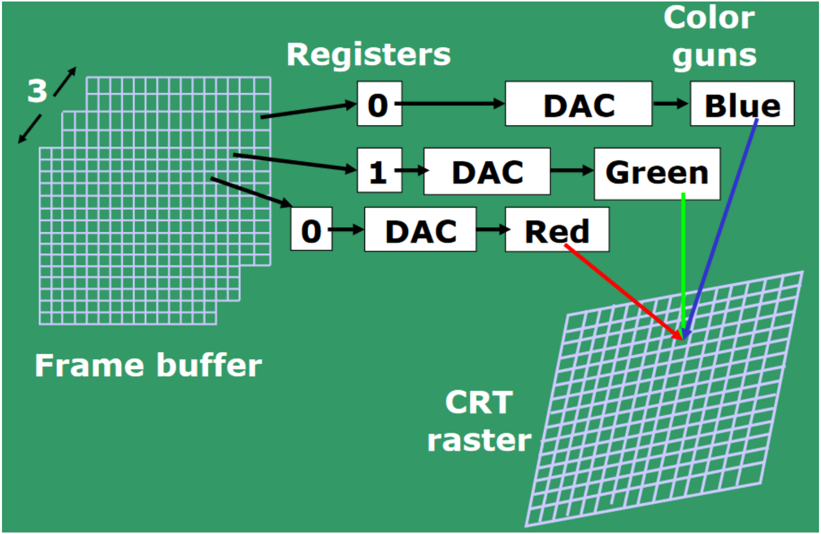


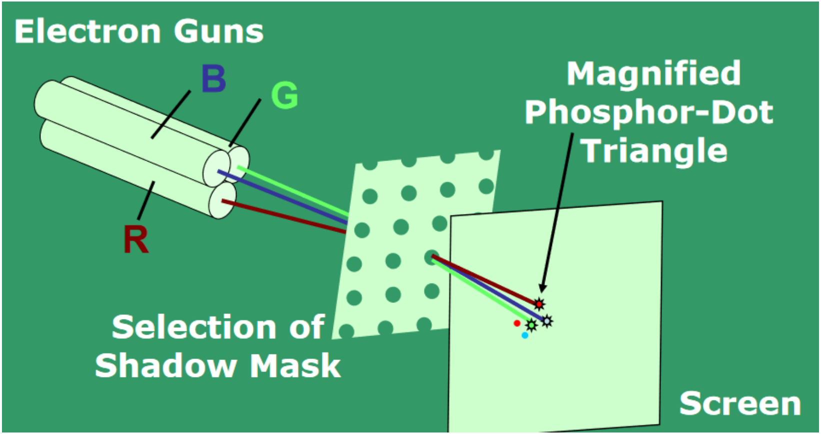
Figure 1: When N=3, $R, G, B \in \{0, 1\}$

Display system with N-bit plane colour Frame buffer (cont.)

In case of one-bit for each color frame buffer, we get 8 colors as:

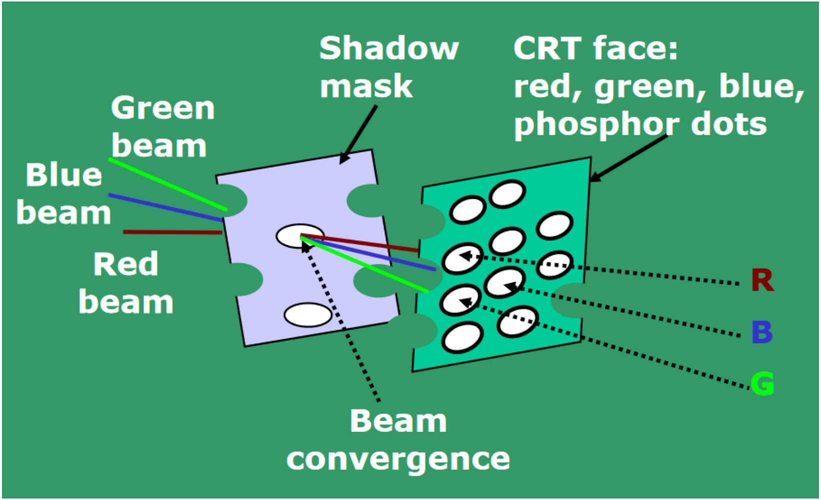
COLOR	RED	GREEN	BLUE
BLACK	0	0	0
BLUE	0	0	1
GREEN	0	1	0
CYAN	0	1	1
RED	1	0	0
MAGENTA	1	0	1
YELLOW	1	1	0
WHITE	1	1	1

Three electron guns, aligned with the triangular color-dot patterns on the screen, are directed to each dot triangle by a shadow mask.



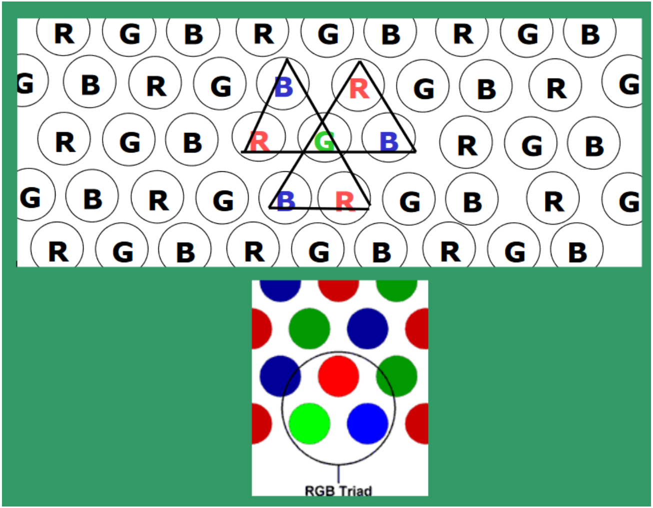
Electron Guns and Shadow Mask in CRT Display (cont.)

Color CRT electron gun and shadow mask arrangement

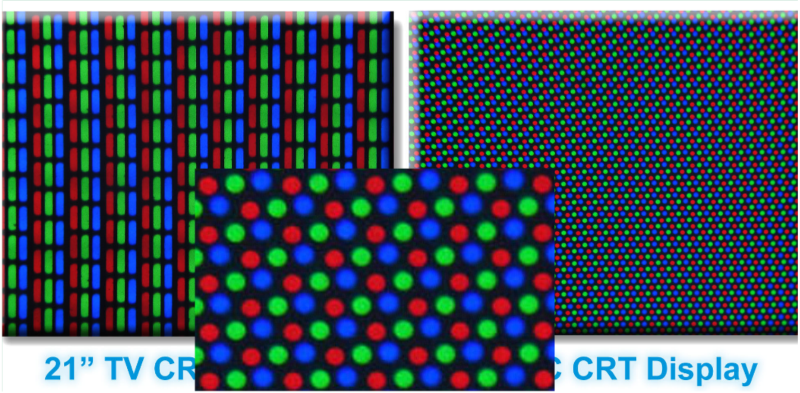


Arrangement of Phosphorus dots in CRT display

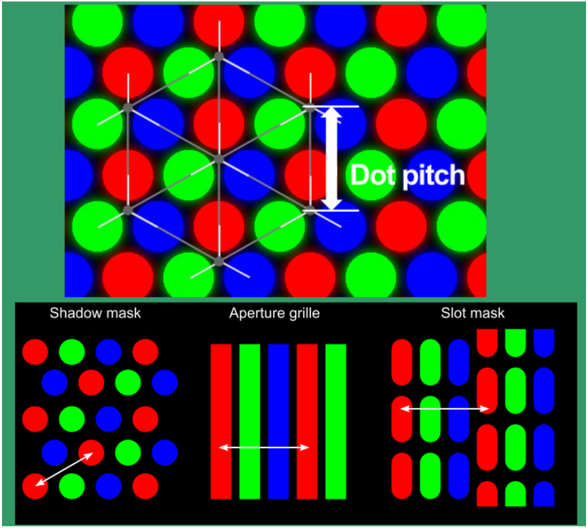
Efficient arrangement of Phosphorus dots in CRT display



Coating of phosphor



Arrangement of Phosphorus dots in CRT display (cont.)



Display Standards

Display Standard	Resolution	Ratio	Dot Pitch(mm)	Pixels	Pixels Per Inch
QWXGA	2048x1152	16:9	0.249	2.4M	102.2
QXGA	2048x1536	4:3		3.1M	
WQXGA	2560x1600	16:10	0.25	4.1M	101.6
QSXGA	2560x2048	5:4		5.2M	
WQSXGA	3200x2048	25:16		6.6M	
QUXGA	3200x2400	4:3		7.7M	
WQUXGA	3840x2400	16:10	0.125	9.2M	203.2

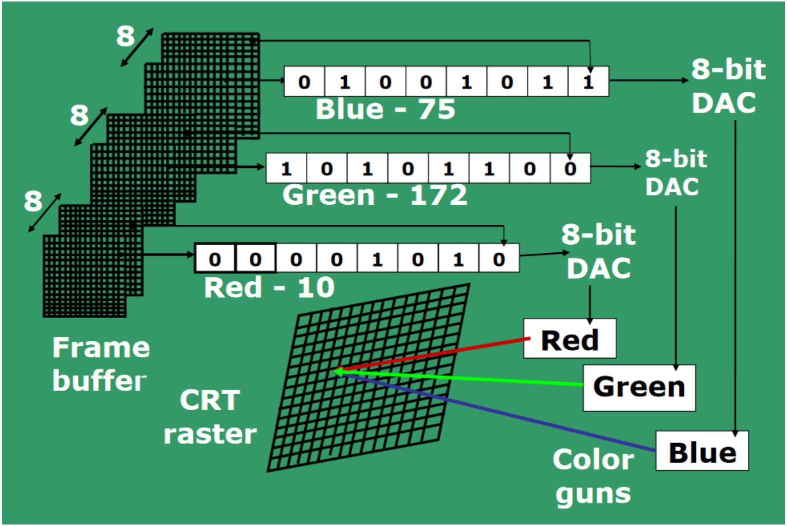
The dot pitch of FLC displays (Ferro Liquid Crystal) can be as low as 0.012 mm

Display system with Full Colour 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 224= 16,777,216 possible colors.
- This is called a **FULL COLOR FRAME BUFFER**

Display system with Full Colour Frame Buffer (cont.)

A 24-bit-plane color frame buffer

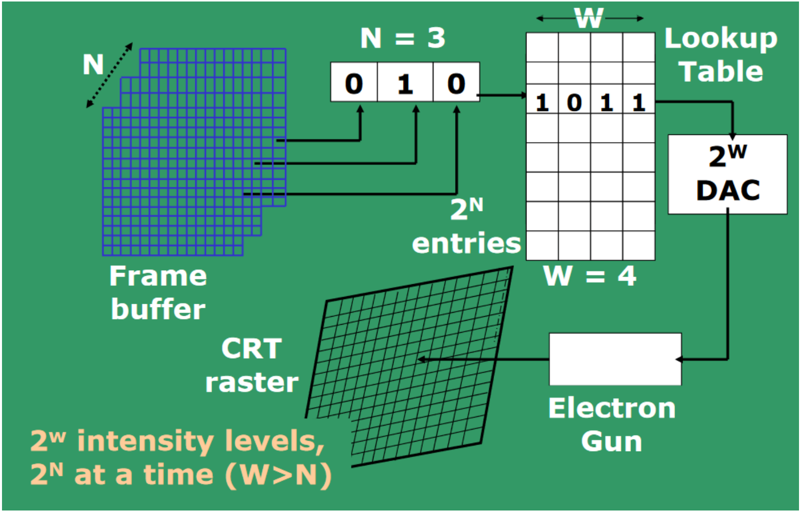


Display system with Look-up-table based colour Frame Buffer

Use of

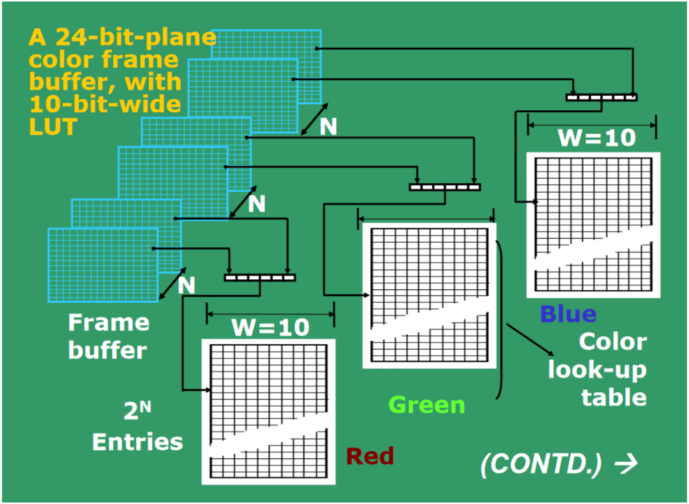
- One LUT (Look-up-table) for storing colours/gray levels
- Typically W $>$ N, where W is width of LUT, N is the number bit planes
- The N-bit register content acts as an index into the lookup table
- Thus out of 2^W possible intensities, that are available, only 2^N different intensities are usable at any time
- The programmer must choose 2^N different intensities, based on his requirement, and load the LUT (addressable in memory) before use

An N-bit-plane colour buffer with a W-bit-wide lookup table.

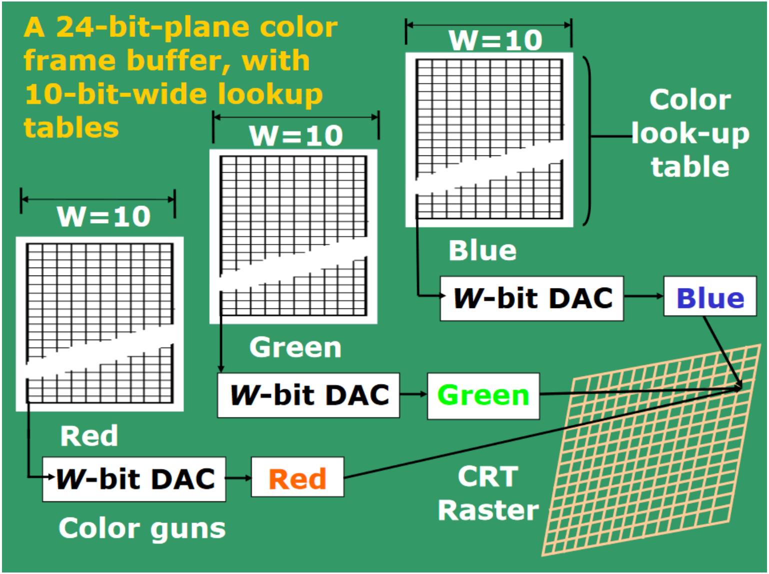


Display system with Look-up-table based colour Frame Buffer (cont.)

An N-bit-plane colour buffer with a 3 W-bit-wide lookup tables

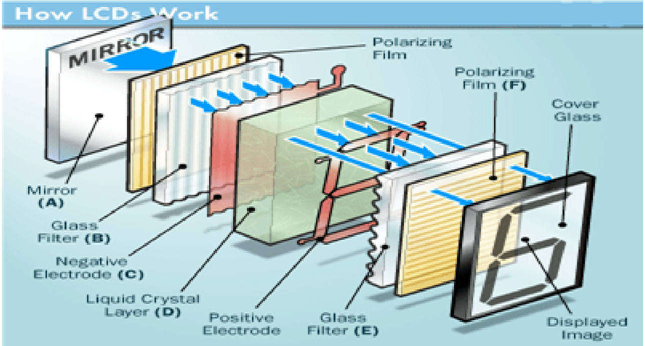


Display system with Look-up-table based colour Frame Buffer (cont.)



FLAT PANEL DISPLAYS

- Flat panel displays are low cost, low weight, small size and low power consumption
- Use of CRT display decreases, but flat panel display increases
- All flat panel displays are raster refresh displays.
- voltage to control the pixel illumination is supplied using a thin-film transistor or diode.


How LCDs Work
MIRROR
Polarizing Film
Polarizing Film (F)
Cover Glass
Mirror (A)
Glass Filter (B)
Negative Electrode (C)
Liquid Crystal Layer (D)
Positive Electrode
Glass Filter (E)
Displayed Image

- LCD is made up of layers such as vertical polarizer plane; layer of thin grid wires(also called as electrode); layer of LCDs; layer of horizontal grid wires; horizontal polarizer; and 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.

FLAT PANEL DISPLAYS (cont.)

- The display contains two polarizers, aligned 90 degree 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.

Acknowledgements

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Thank You! :)