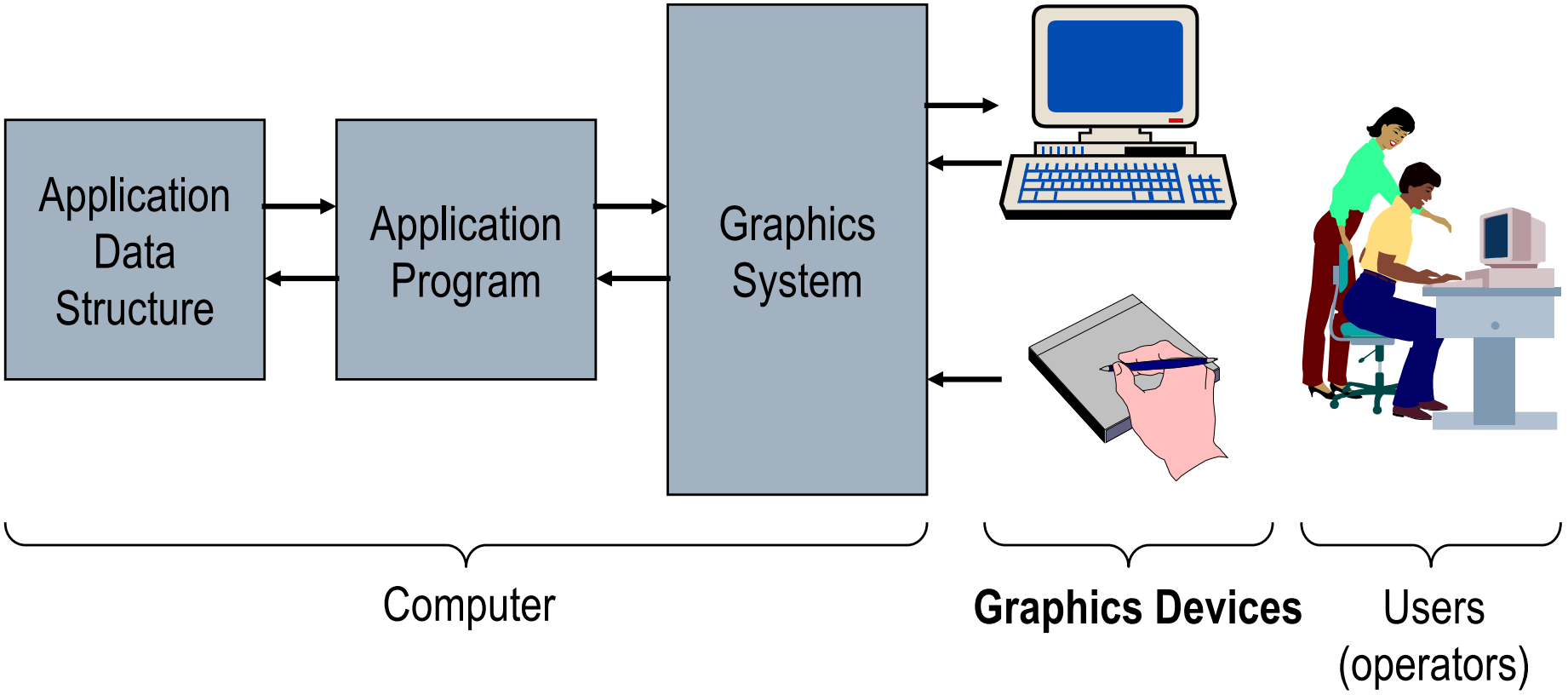
Graphical Devices (1)

Contents

1. Output devices
   - Hardcopy technology
   - Display technology
   - Raster system architectures
2. Input devices

Programmer's Model of Interactive CG



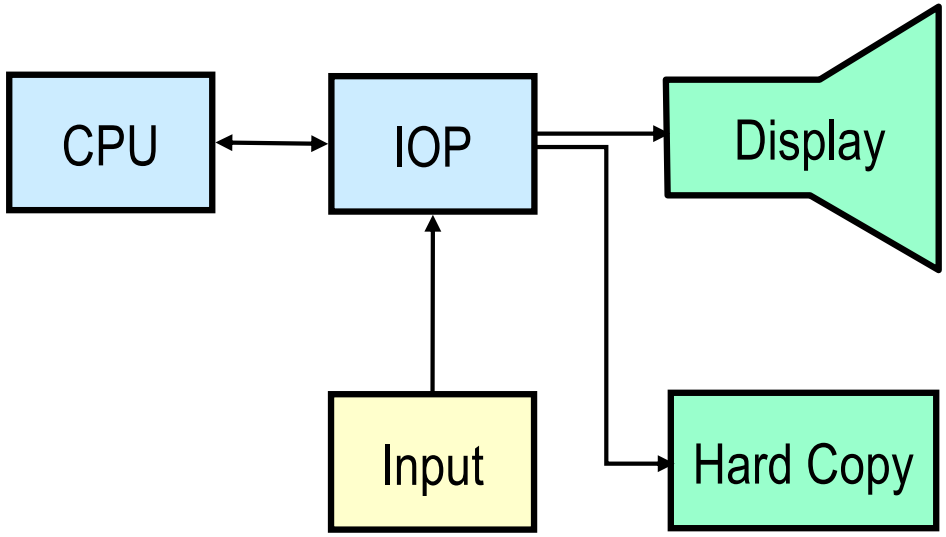
- Graphics Models - Application Data Structures
- Application Programs
- Graphics Systems
- Graphics Devices

Graphical device types

- Output device
  - Graphics display, printer, plotter etc.
- Input device
  - Logical
    - locator, stroke, string, valuator, choice, pick
  - Physical
    - mouse, trackball, joystick, scanner, keyboard, etc
- Interactive device
  - Graphics console, graphics tablet, head mounted display, etc.

Device components

- Input Output Processor
  - Communicates with CPU
  - Scan converts the output primitives
  - Refreshing screen
  - Interfacing with interactive input devices
  - Raster operations
  - Character generation
  - Additional functions

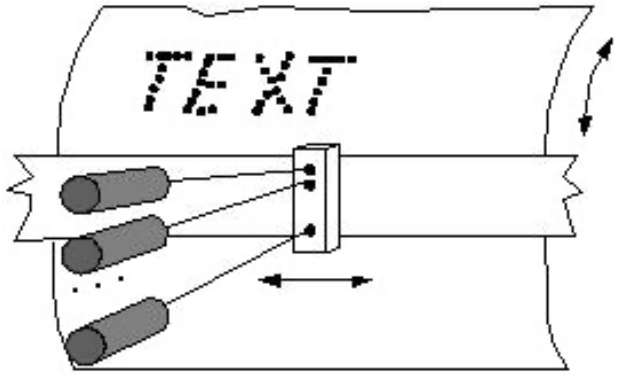


Output devices

- Hardcopy technologies:
  - dot matrix printer
  - pen plotter
  - desk-top plotter
  - electrostatic plotter
  - laser printer
  - ink-jet printer
  - thermal transfer printer
- Display technologies:
  - monochrome and color CRT (Cathode Ray
  - direct-view storage tube (DVST)
  - liquid-crystal display (LCD)
  - plasma panel
  - electroluminescent display (ELD)
- Raster-scan display systems
  - simple raster display system
  - peripheral display processor
  - additional display processor
  - integrated display processor

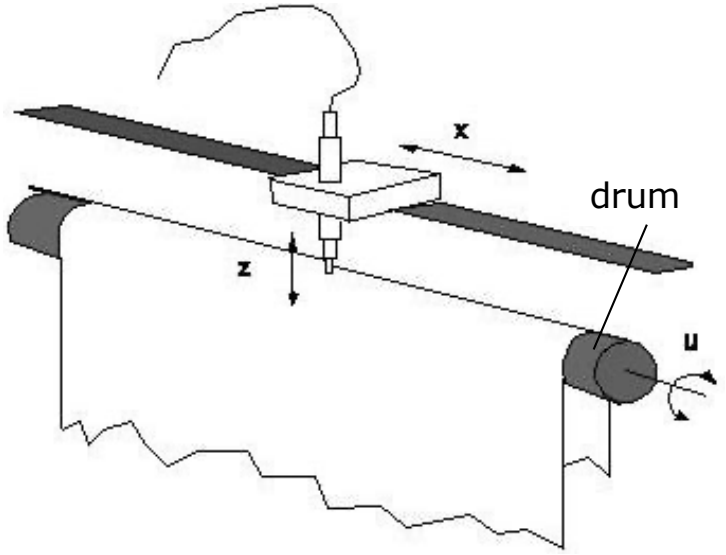
Dot matrix printer

- Raster output device
- Requires scan conversion of vector images for printing
- Head of pins
- Each pin is individually fired
- Bw and colored ribbons



Pen plotter

- Flatbed plotter
  - Paper held down on the table
    - Electrostatic charge
    - Vacuum
    - Stretch tightly
  - Pen
    - Drawing by bw or colors
    - Knife blade for scribing
    - Light source for exposing photographic negatives
- Drum plotter



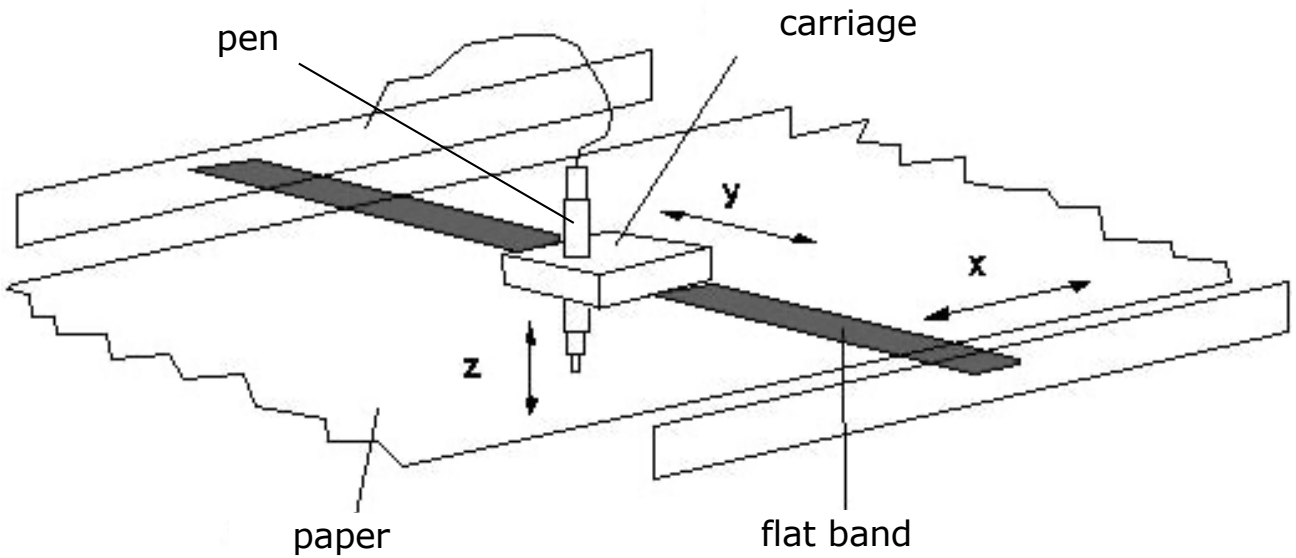
Pen plotters include a microcontroller

- Accepts graphics commands:

draw line, move, draw circle, etc.

- Decomposes the output primitives into incremental pen movements:

Δx, Δy, z, Δu etc.

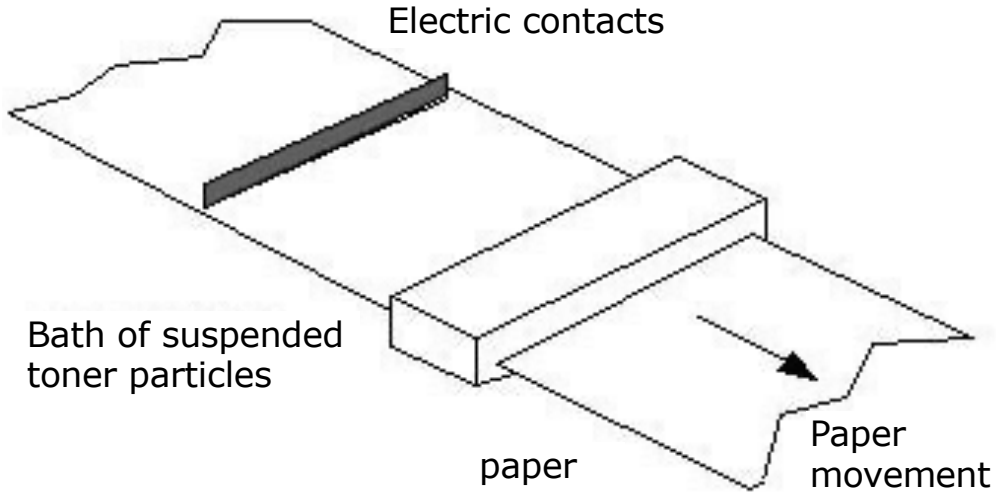


Electrostatic plotter

1. The plotter places a negative charge in parts that are to be black
2. Flows positively charged black toner over the paper
3. Toner particles adhere to the paper

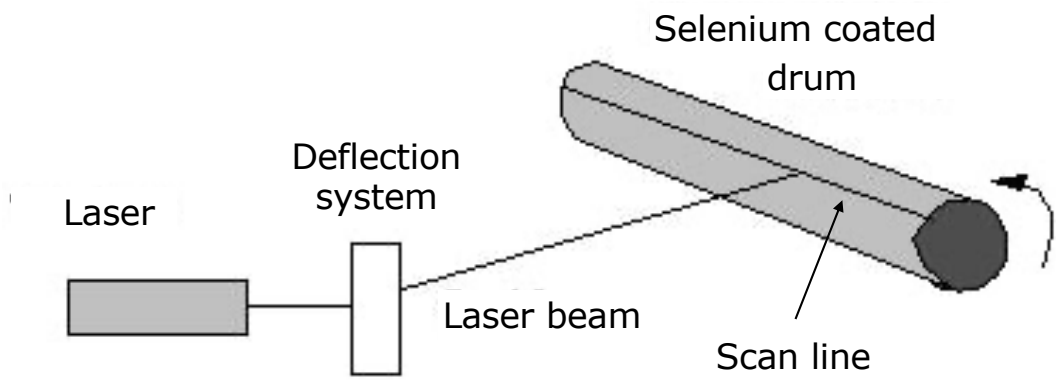
Color plotter

- Multiple passes for fundamental colors
- Colors: black, cyan, magenta, and yellow toners
- One pass, multiple heads



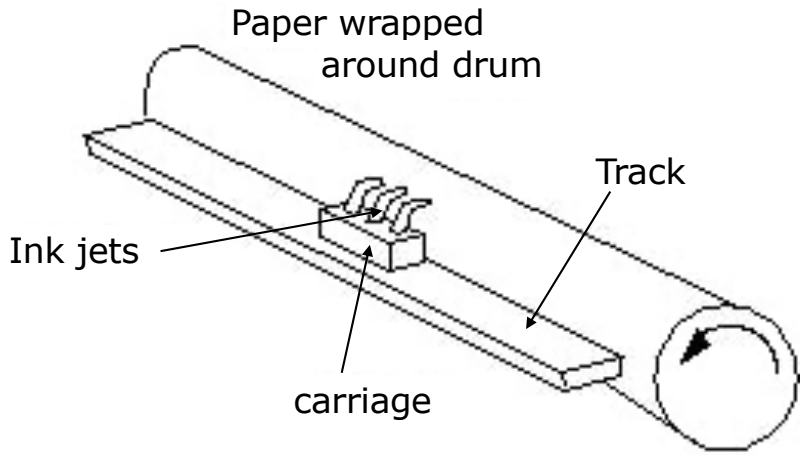
Laser printer

1. Drum is positively charged
2. Laser beam scans the rotated drum
3. Areas hit by the laser beam lose the charge
4. Positive charge remains only on the parts that are to be black
5. Negative powdered toner adheres to the positive areas on the drum
6. The toner is transfered onto the blank paper
7. Color xerography repeats the process for each primary color



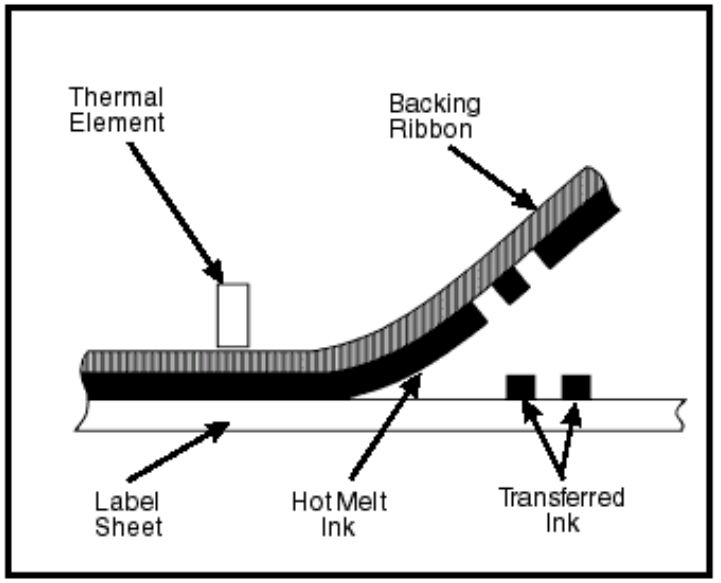
Ink-jet printer

- Primary colors: cyan, magenta, yellow
- Ink jets onto the head (carriage)
- Some ink-jet printers accept video input



Thermal transfer printers

- Heating nibs transfer pigments from colored wax paper to plain paper
- Wax paper and plain paper are drawn together over a strip of heating nibs
- Color printing: wax paper is on a roll of alternating cyan, magenta, yellow, and black strips, each of a length egual to the paper size
- Time: 1 min / image
- Usage:
  - barcode labels
  - cloth labels (e.g. shirt size)
  - Printing plastic labels



Thermal Transfer Printing

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  - simple raster display system
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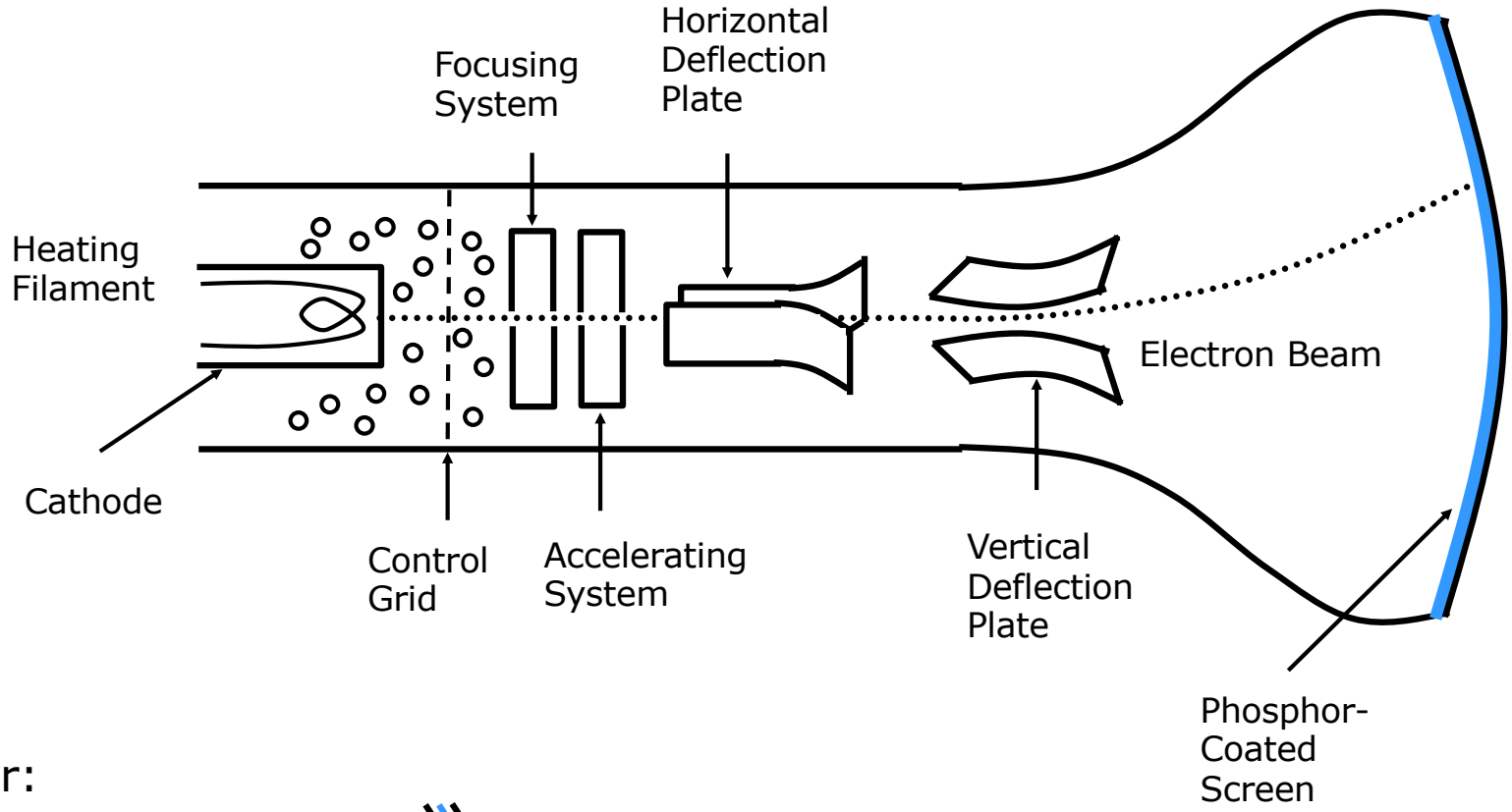
Cathode Ray Tube (CRT)

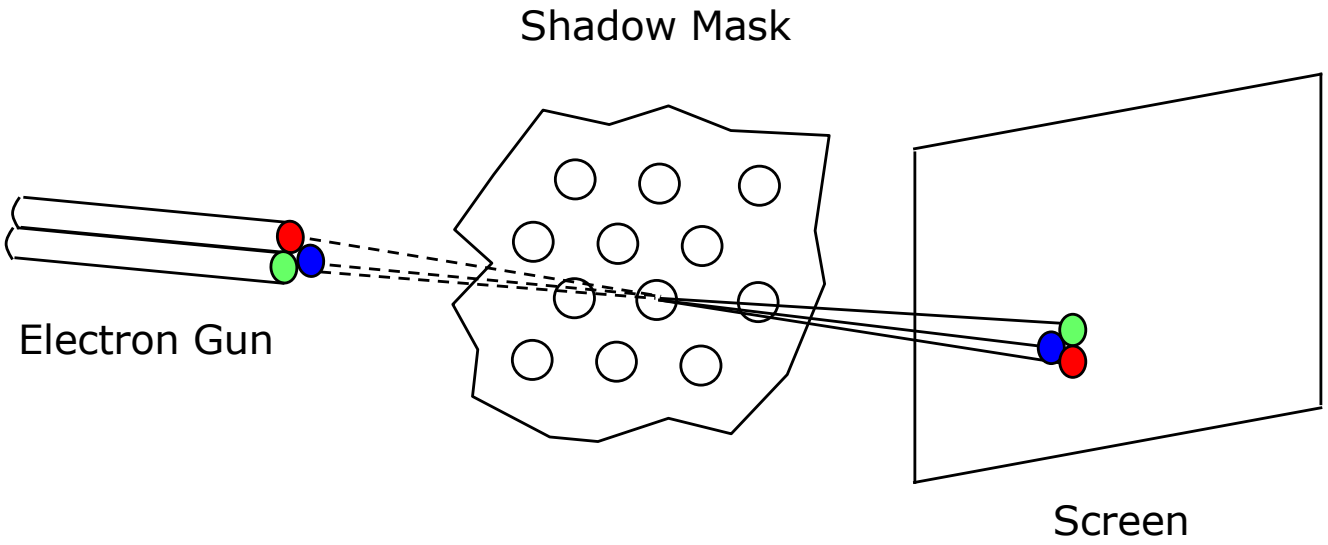


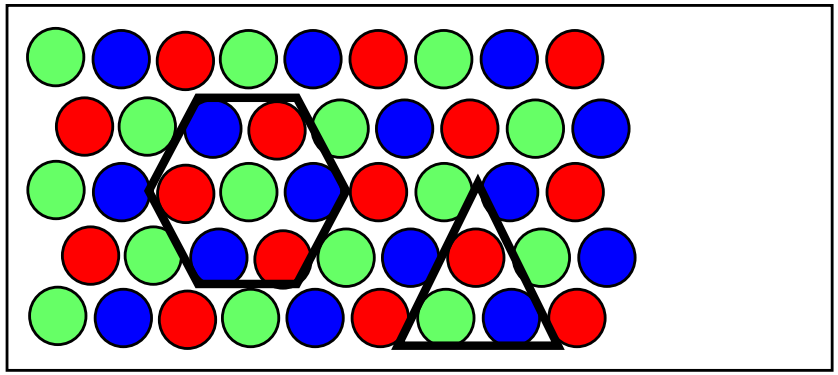
Color:

Beam Penetration

Shadow Mask

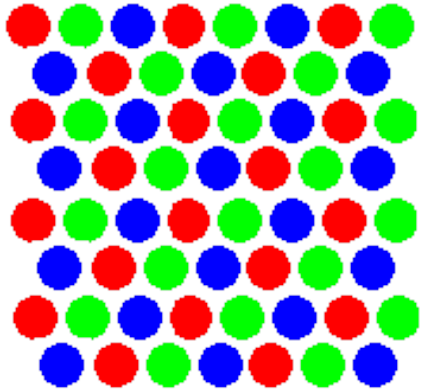
Color CRT (Shadow Mask)

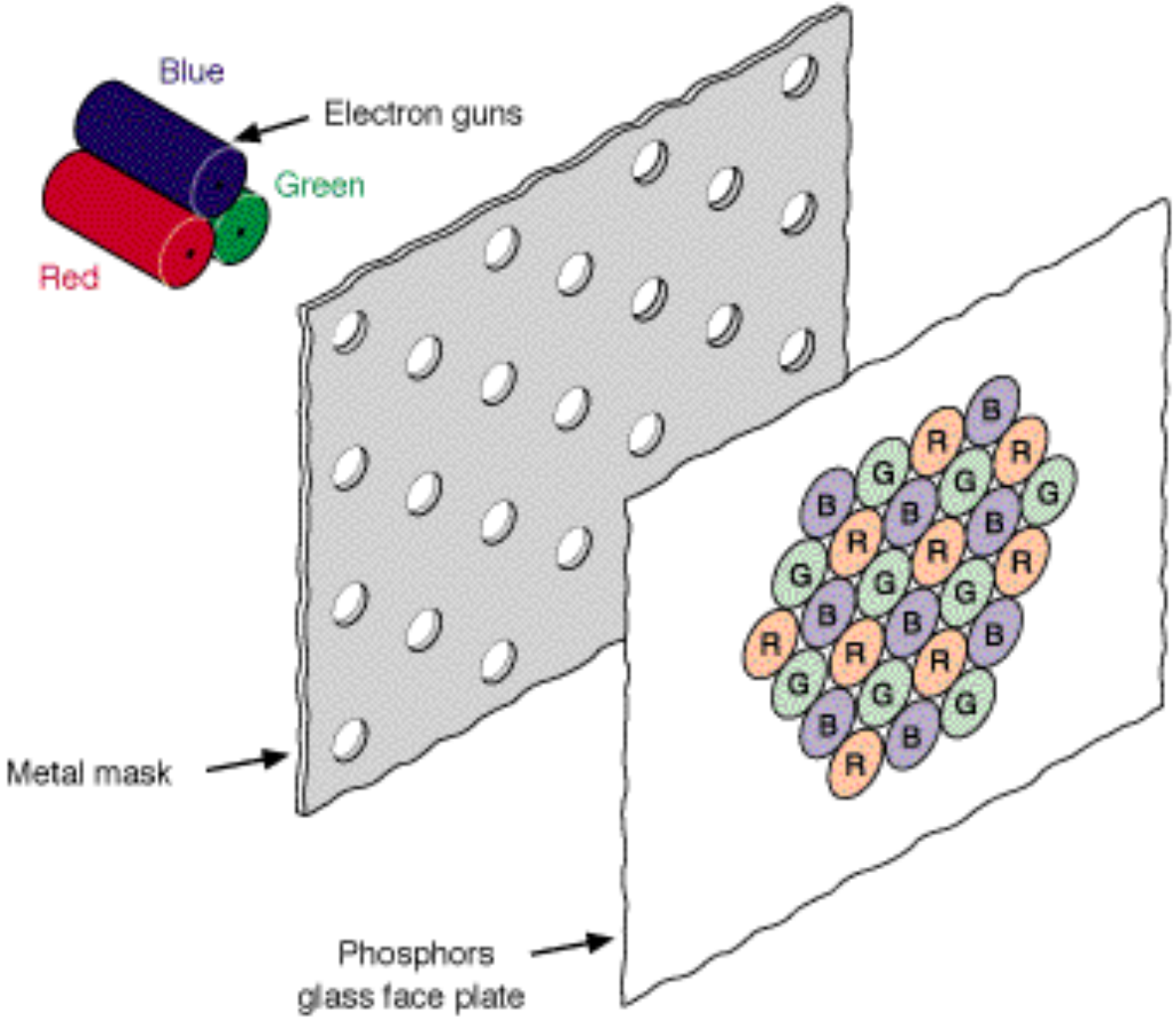




Phosphor dot pattern

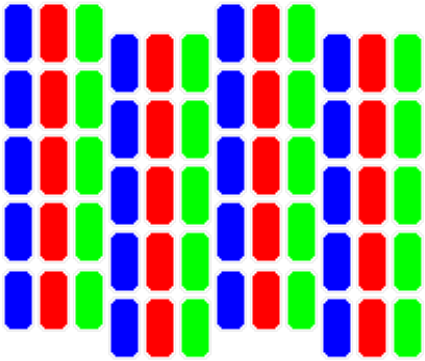
Delta electron gun arrangement

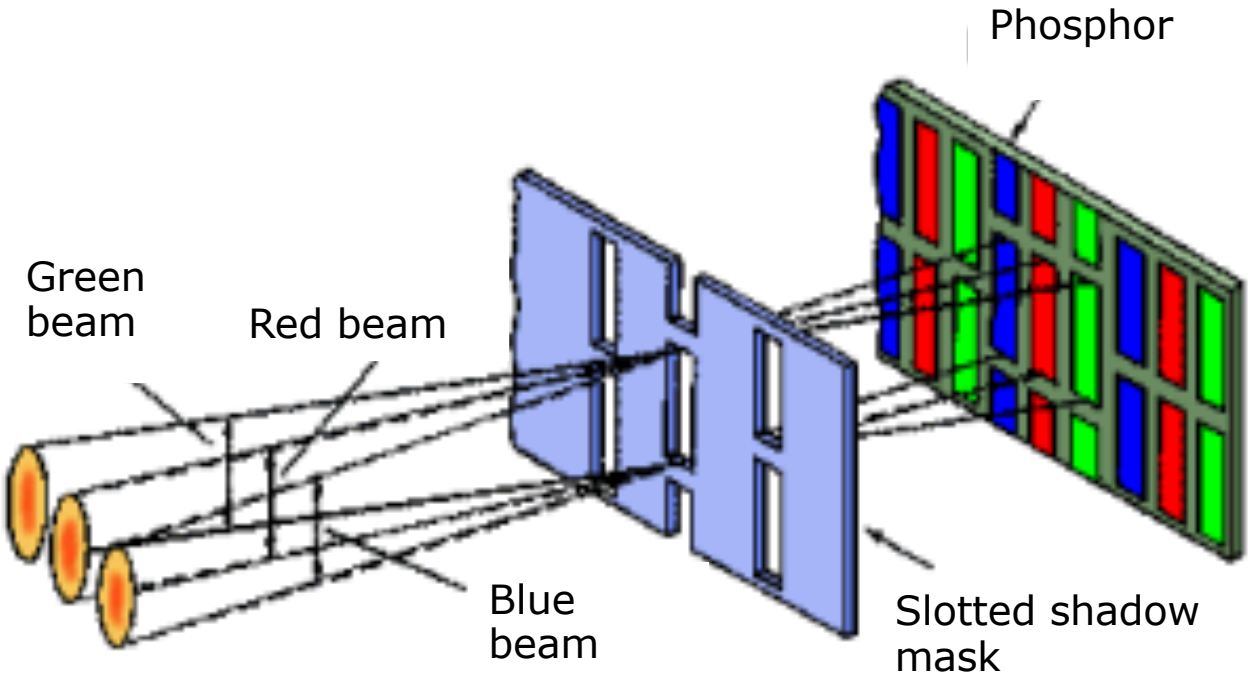




In-line electron gun arrangement

Phosphor pattern of stripped picture tube

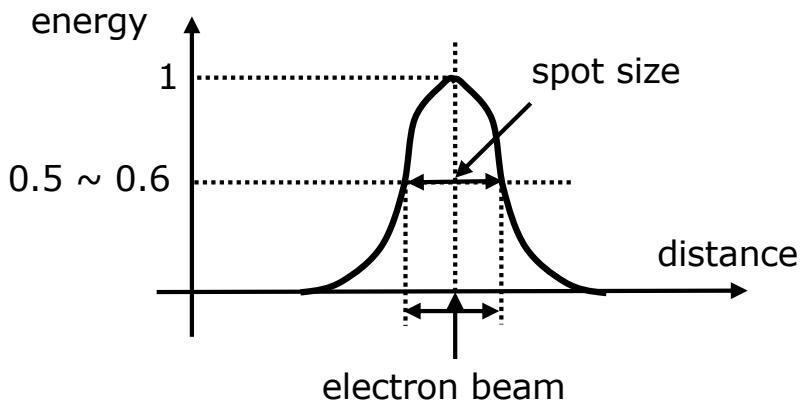


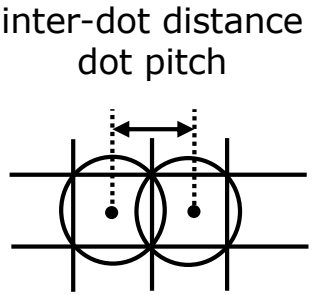


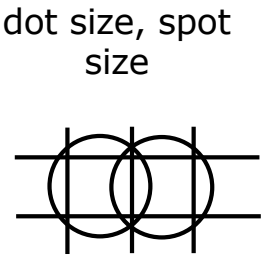
CRT - characteristics

- Persistence
  - How long a phosphor continues to emit light after the electron beam is removed (less than 1/10 of its original intensity)
  - Gives: Refresh rate, image modification rate, animation
  - Issue: Picture complexity

- Sharpness

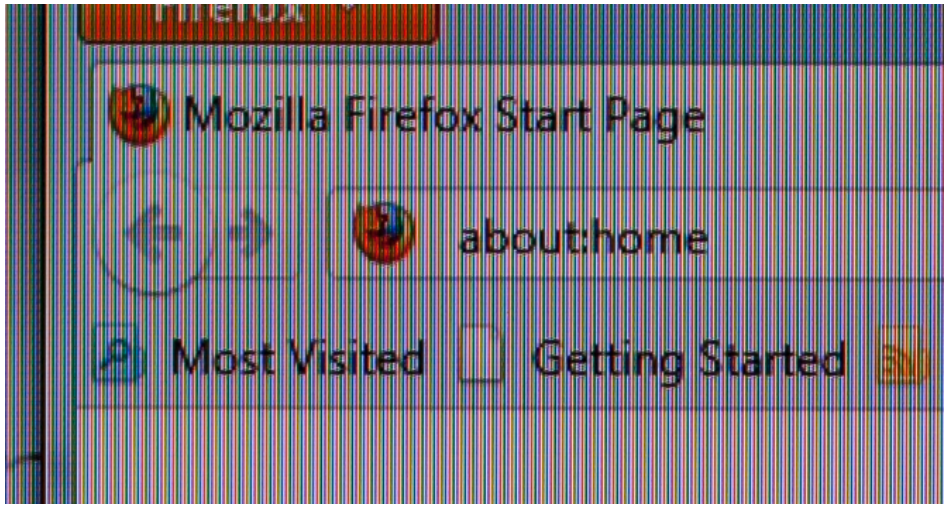


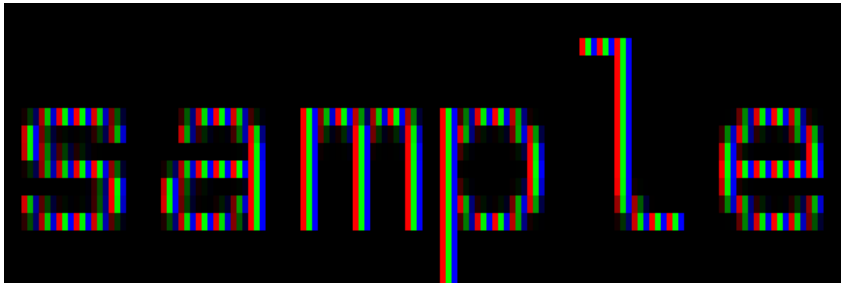




Monitor persistance

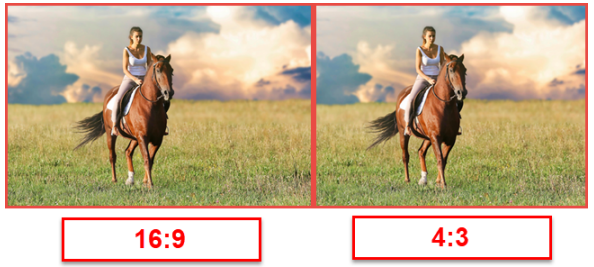
Sharpness

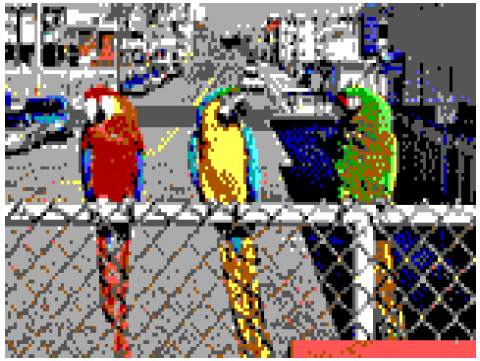

Mozilla Firefox Start Page
about:home
Most Visited
Getting Started

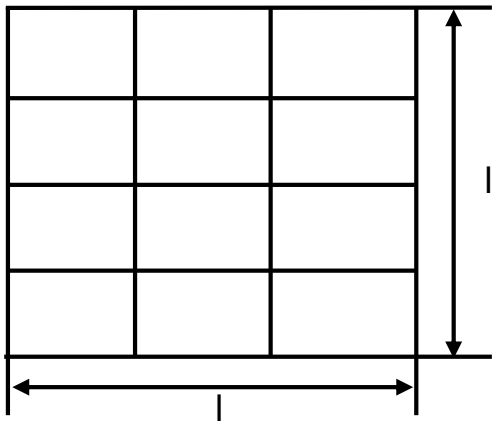

sample

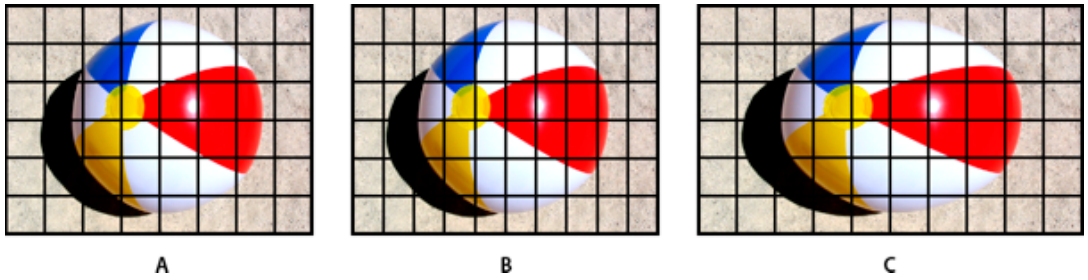
CRT - characteristics

- Resolution
  - 1 / spot size
  - # of points / scan line
  - # of lines / frame
- Addressability
  - 1 / inter-dot distance
- Aspect ratio
  - horizontal to vertical points to produce equal length of lines in both direction on screen, e.g. 3/4 = 0.75



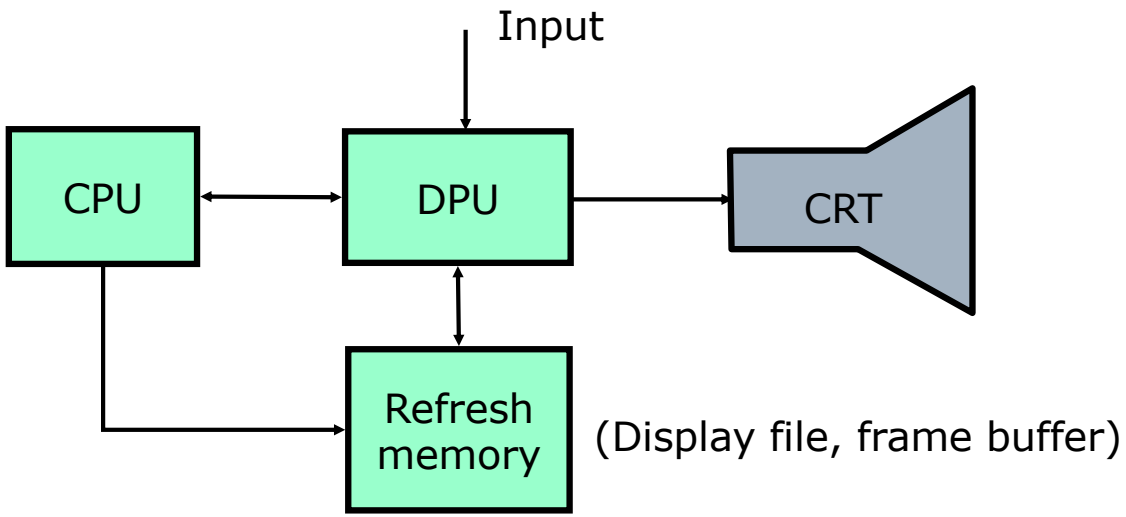






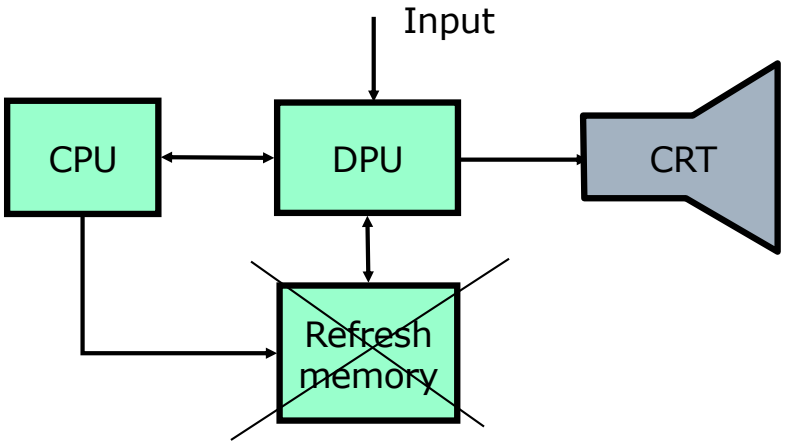
Refresh CRT

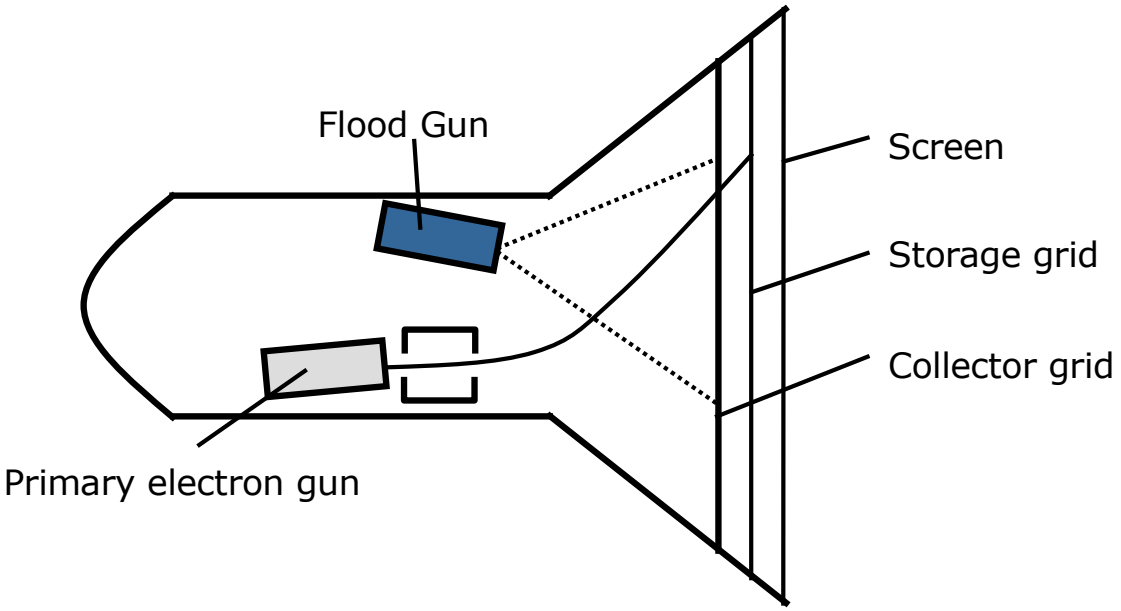
- Refresh memory
  1. Vector image: graphics commands (display file)
     Issue: the size of the refresh memory limits the complexity of the picture
  2. Raster graphics: bitmap matrix (frame buffer)

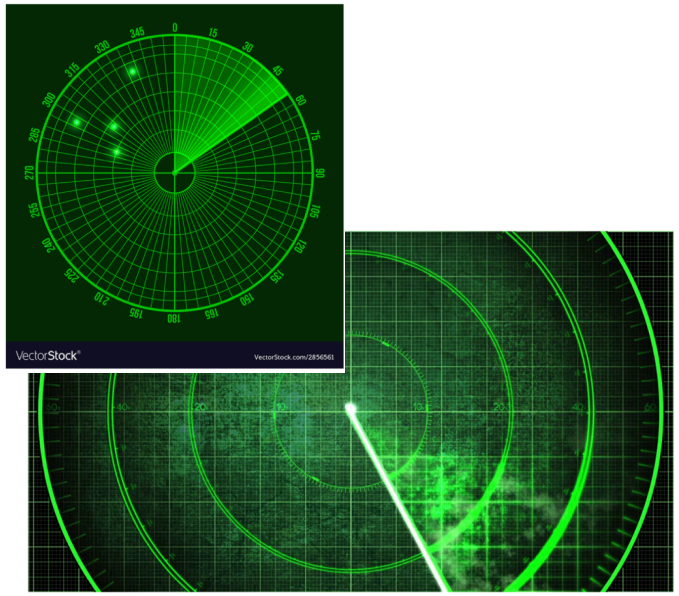


Direct View Storage Tube (DVST)

- Image persistance, flicker free
- Always delete and redraw the entire image
- High voltage to delete the screen

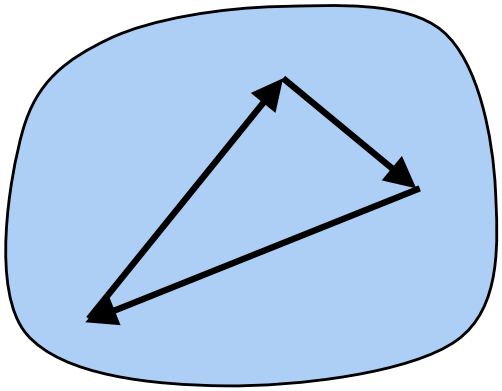


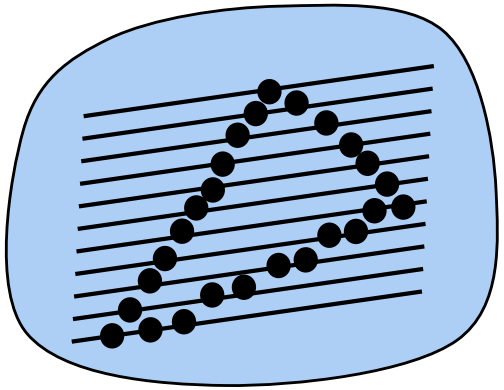




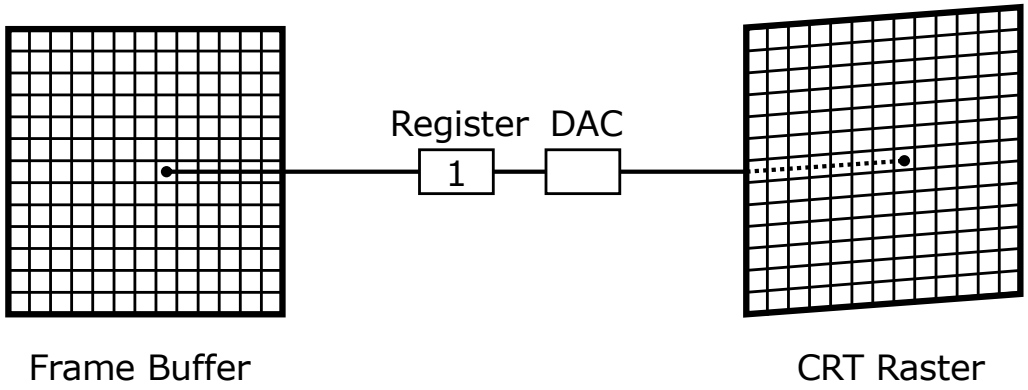
Vector vs raster graphics

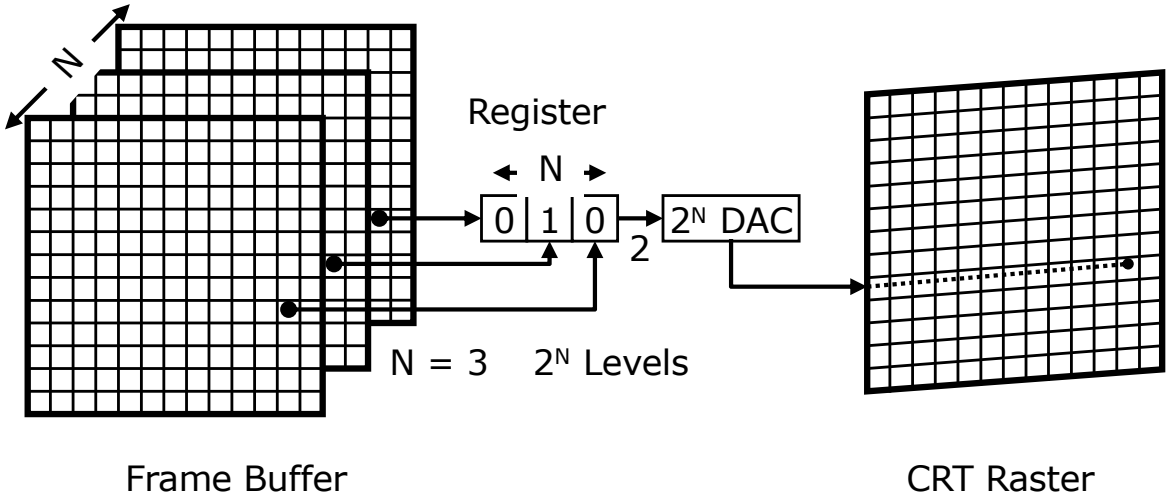
- Vector graphics
  - Application software controls the graphics primitives: point, line, polyline
  - Display processor builds the image as a sequence of vectors
  - Limited image complexity
- Raster graphics
  - Application software controls pixels in refresh buffer
  - Display processor just refresh the screen
  - No limited image complexity



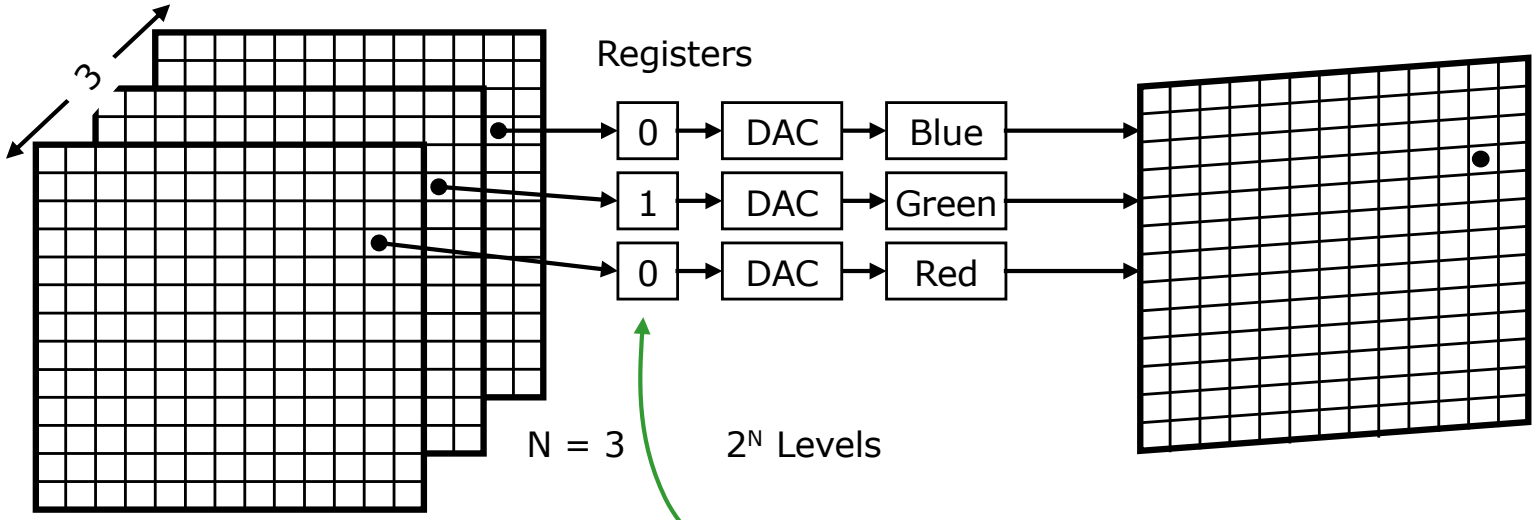


Frame buffer – gray levels



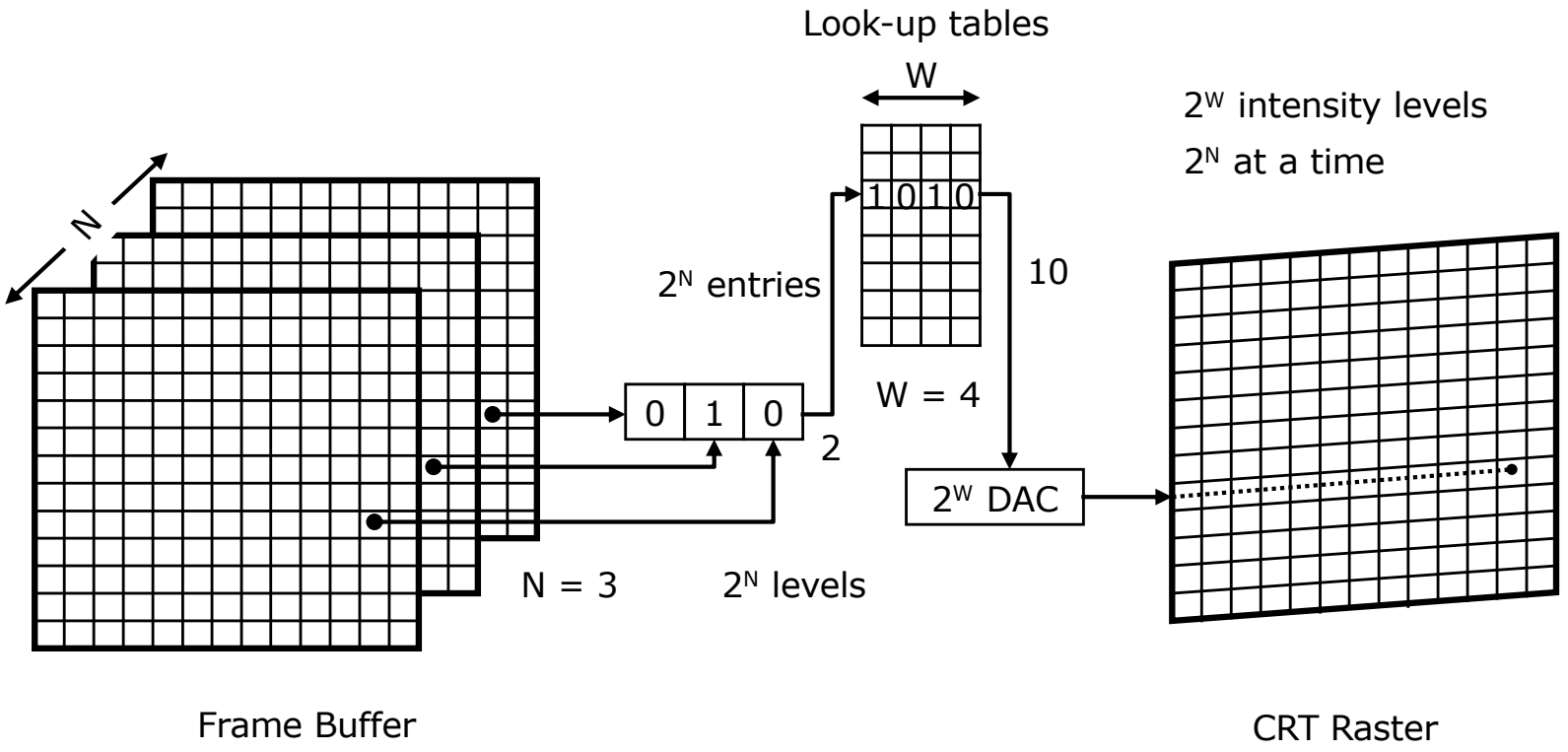


Color planes



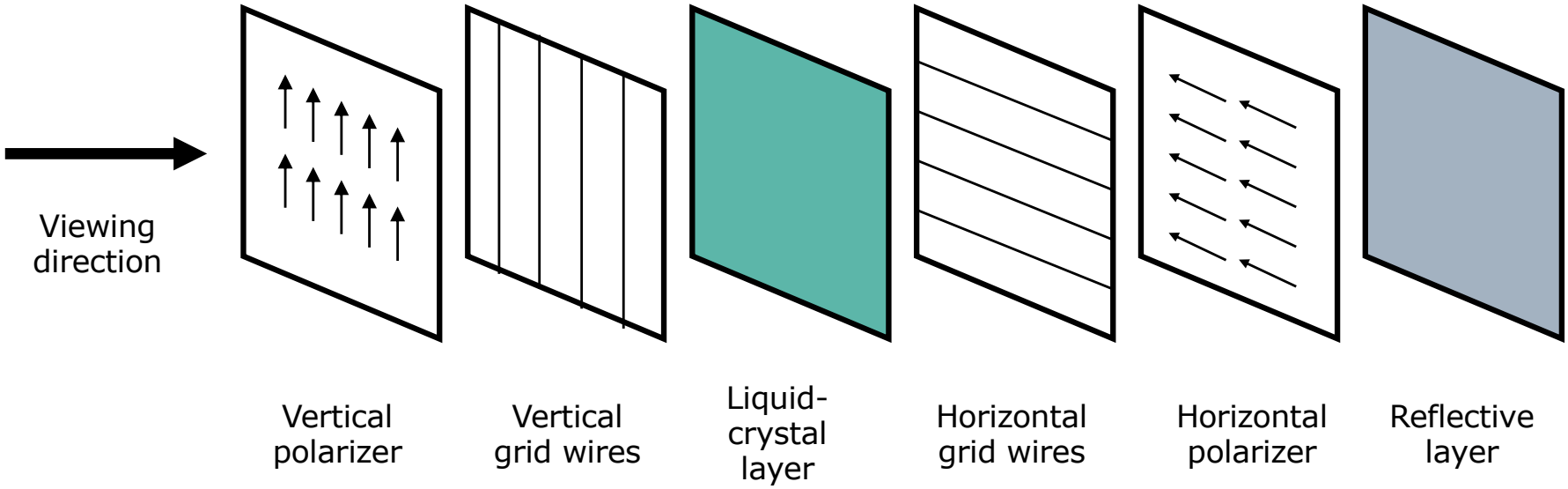
	Red	Green	Blue	
Black	0	0	0	
Red	1	0	0	
Green	0	1	0	
Blue	0	0	1	
Yellow	1	1	0	
Cyan	0	1	1	
Magenta	1	0	1	
White	1	1	1	

Color palette in Look-up tables

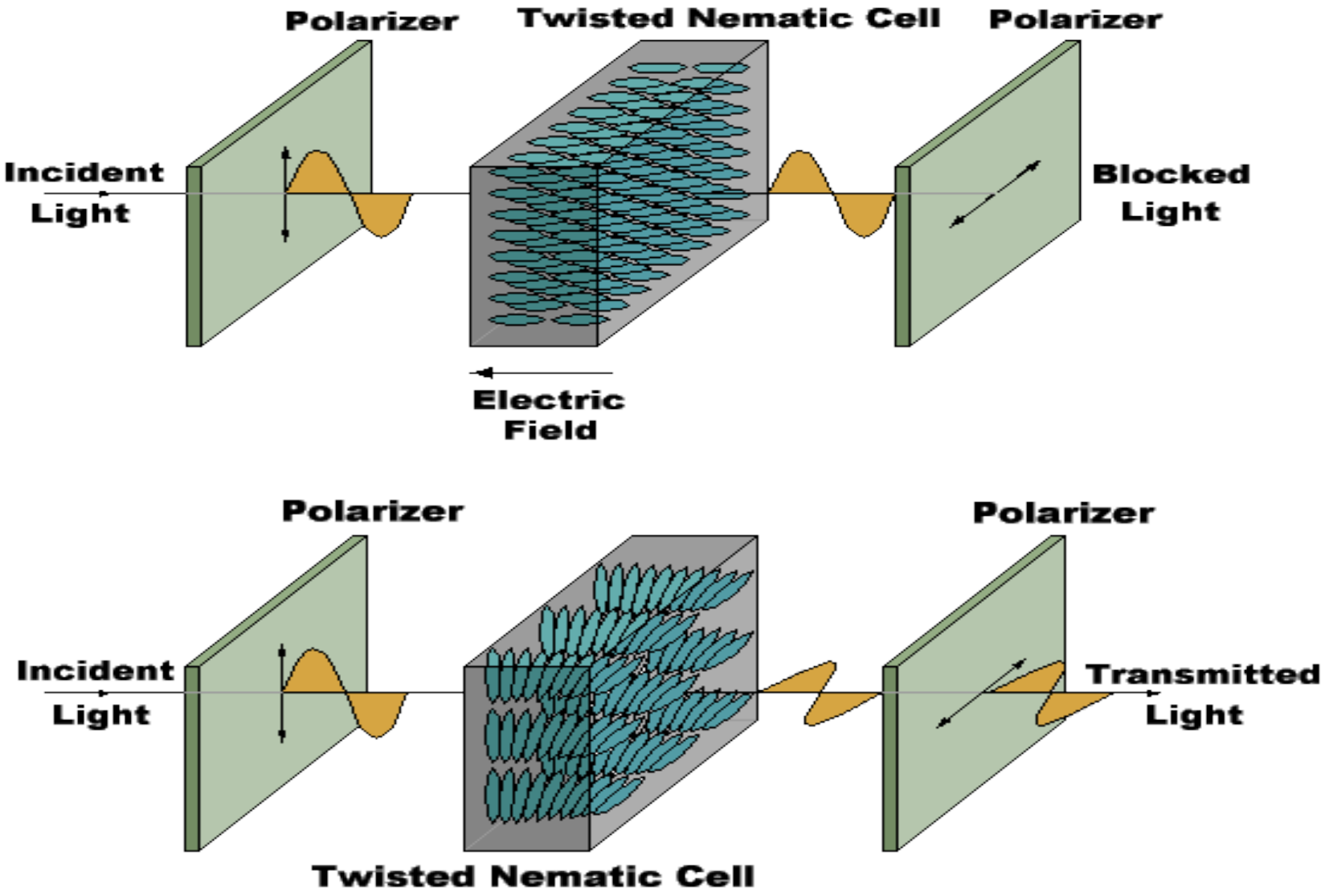


Liquid Crystal Displays (LCD)

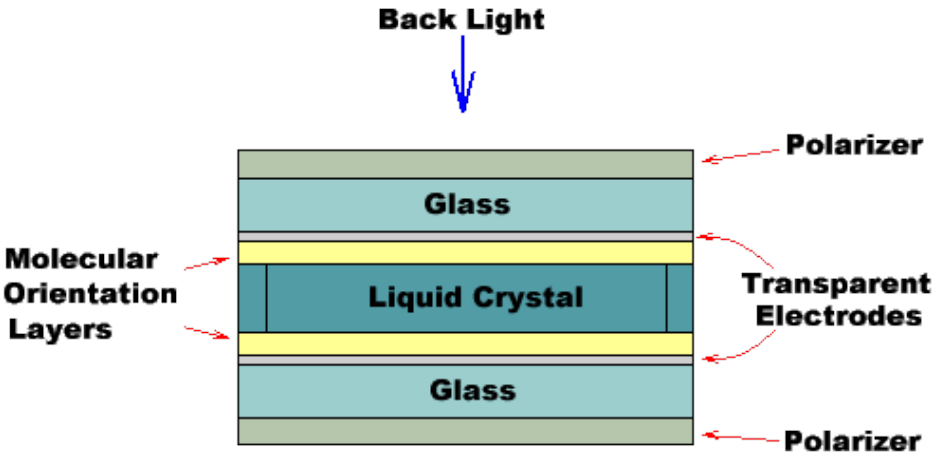
- Most popular alternative to the CRT is the Liquid Crystal Display (LCD)
- Organic molecules
  1. In the absence of external forces, tend to align themselves in crystalline structures. In their unexcited or crystalline state the LCDs rotate the polarization of light by 90 degrees.
  2. When an external force is applied they will rearrange themselves as if they were a liquid. In the presence of an electric field, LCDs the small electrostatic charges of the molecules align with the impinging E field.
- External force: heat (i.e. mood rings), electromagnetic field.
- The LCD's transition between crystalline and liquid states is a slow process.



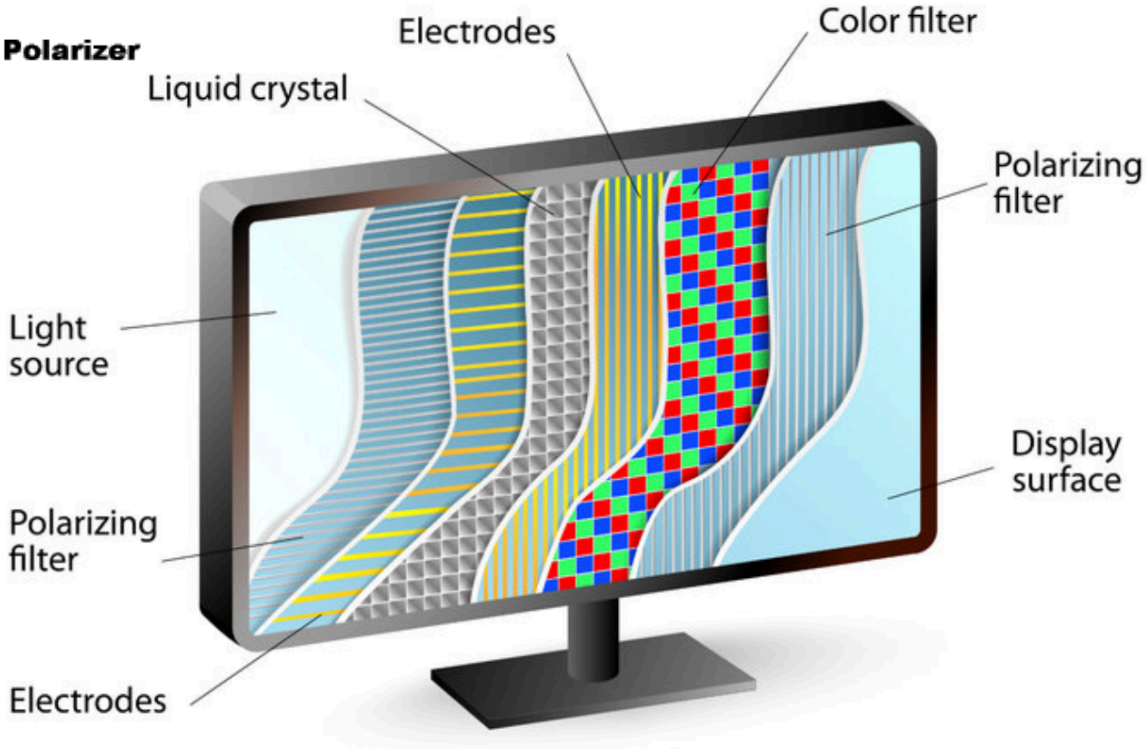
LCD – twisted nematic cells



LCD screen structure



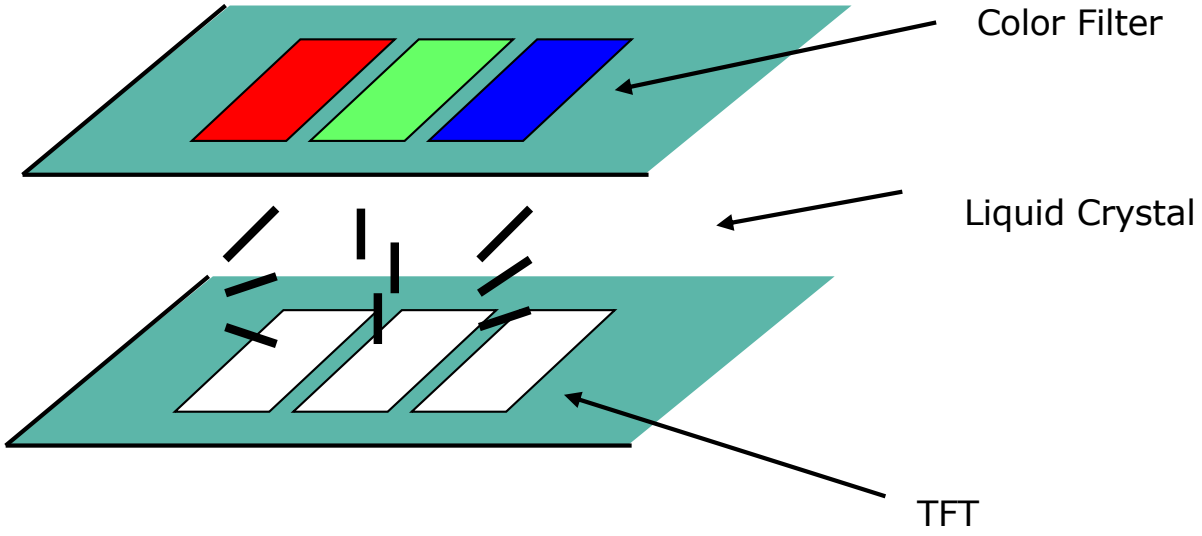
Color dispaly needs three color filters: red, green, blue, that block all light other than that color from coming through.



Color TFT (Thin Film Transistor) LCD

- TFT (Thin Film Transistor) or Active Matrix LCD
  - There is a transistor at each grid point
  - Cause the crystals to change their state quickly
  - Control the degree to which the state has been changed
  - Hold the state until it changes

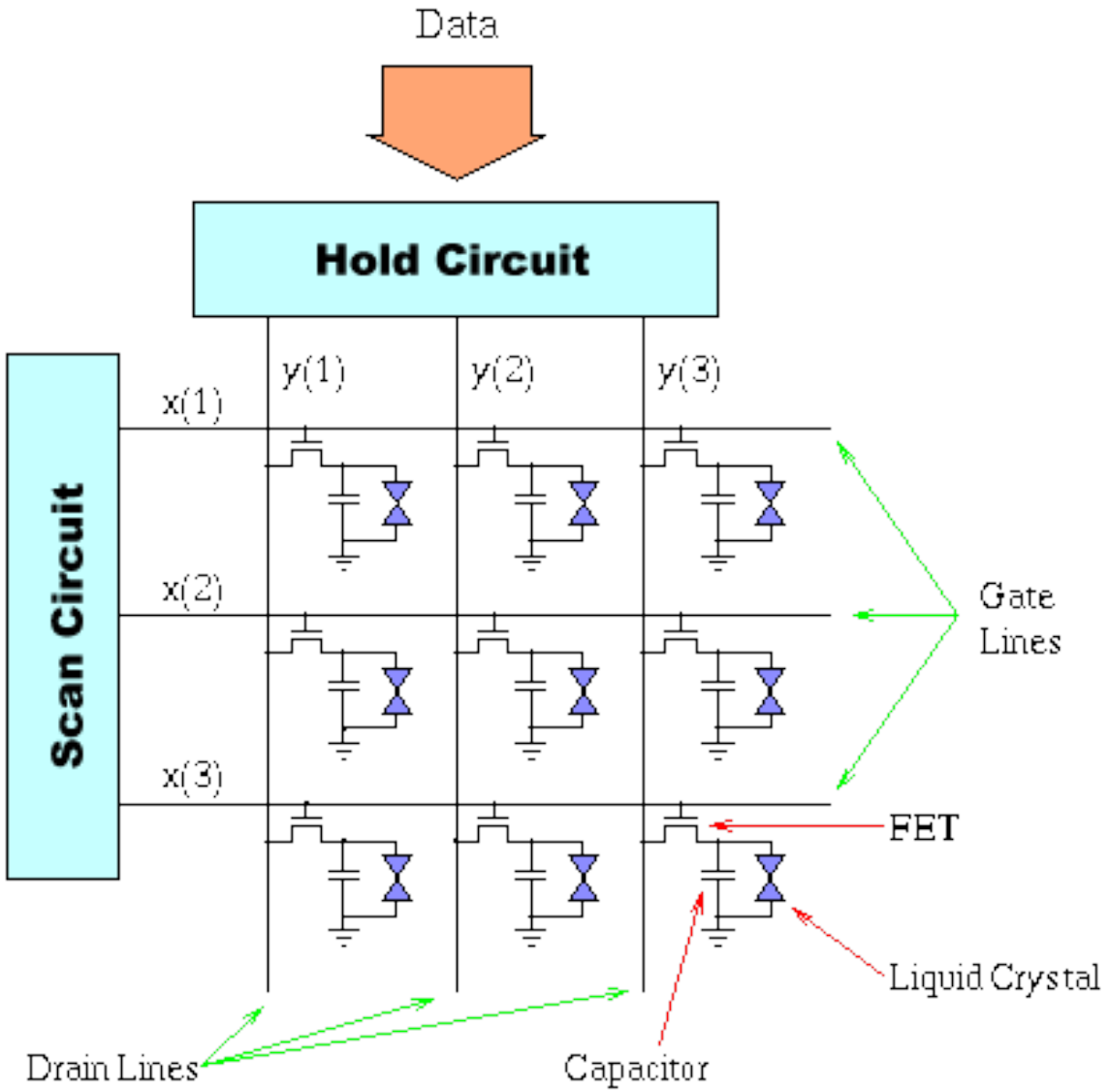
Color cell



TFT

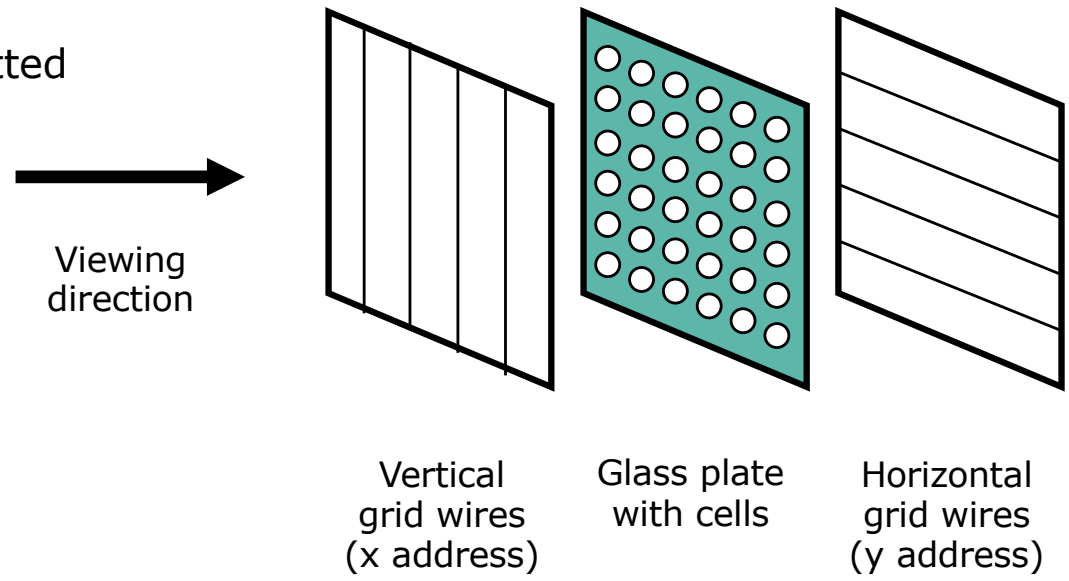
- VGA screens need 921,000 transistors (640 x 480 x 3)

- 1024 x 768 needs 2,359,296 transistors (1024 x 768 x 3)

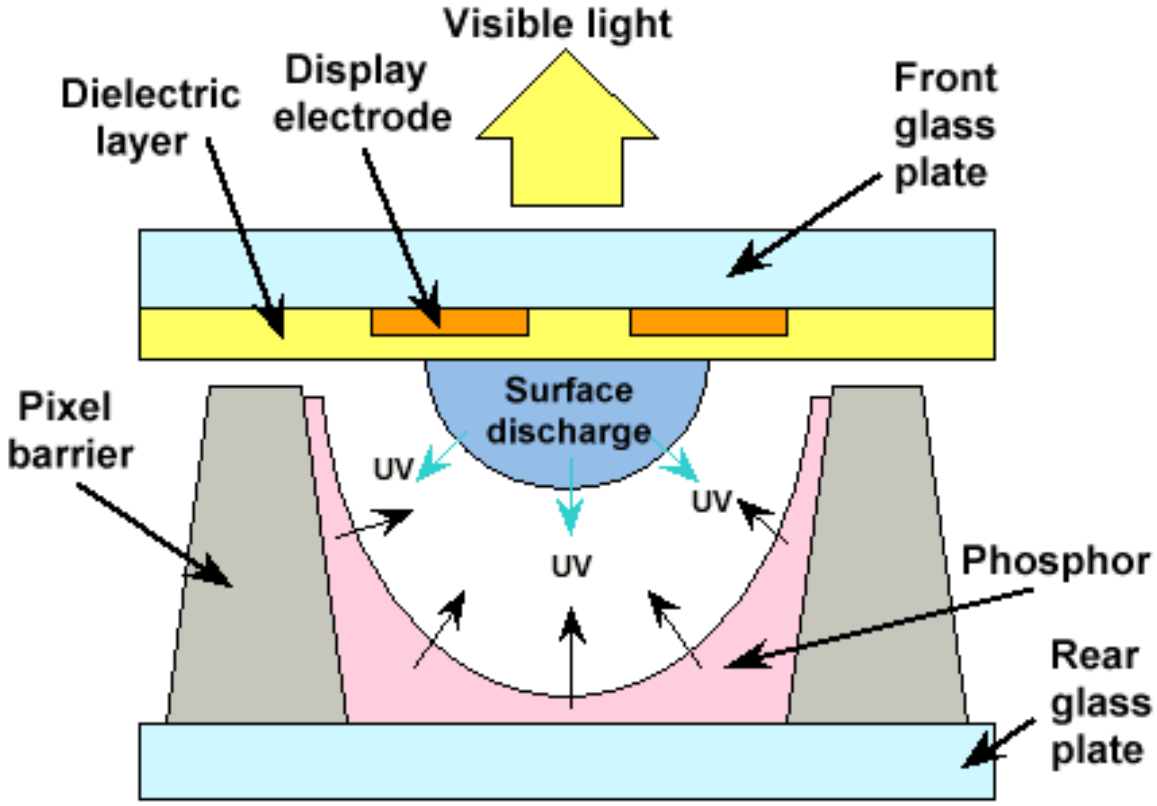


Plasma display panel (PDP)

- Three layers
- Horizontal and vertical grid wires
- Glass plate with cells (neon bulbs, fluorescent tubes). E.g. 50-125 cells / inch
- Bulb state
  - On: High-voltage discharge excites gas mixture (He, Xe).
    - It fires the bulb that glows. Low voltage sustains the state.
    - Remains on till an explicit command turns it off.
  - Off: bulbs do not glow. They are transparent.
- Turns on/off in less than 15 μs
- Does not need refresh buffer
- Flat and transpartent panel
- Upon relaxation UV light is emitted
- UV light excites phosphors



PDP Structure



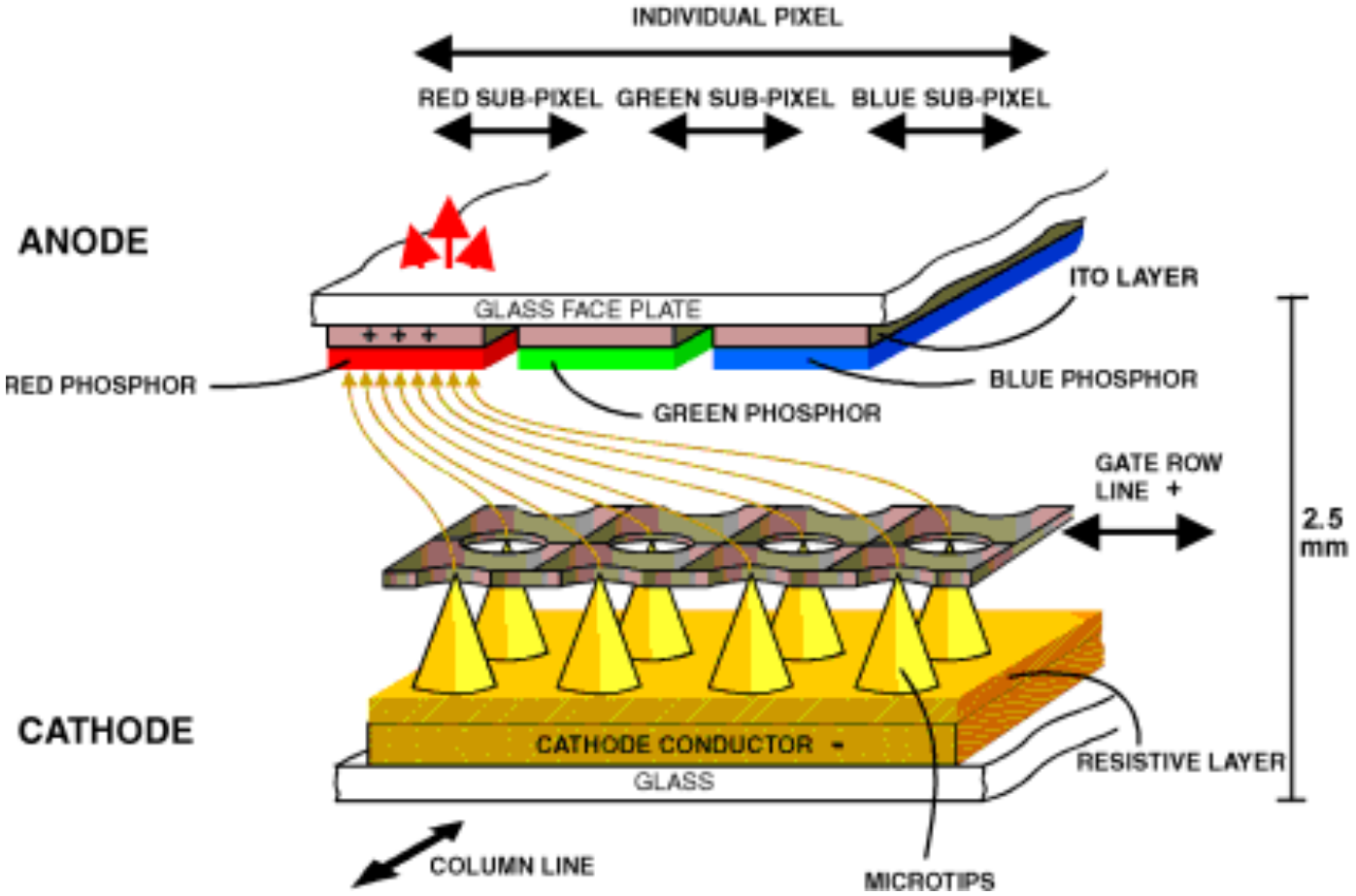
Plasma display panel

- Promising for large format displays
- Large viewing angle
- Less efficient than CRTs
- Not as bright
- More power
- Large pixels (~1mm compared to 0.2mm for CRT)

Field Emission Display (FED)

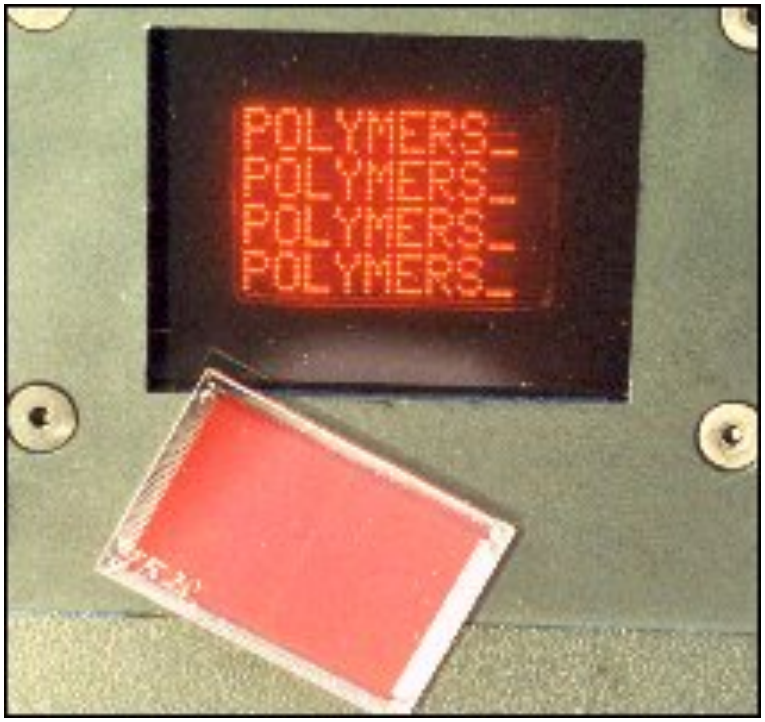
- Works like a CRT with multiple electron guns at each pixel
- Uses modest voltages applied to sharp points to produce strong E fields
- Reliable electrodes proven difficult to produce
- Limited in size
- Thin but requires a vacuum

FED cell structure

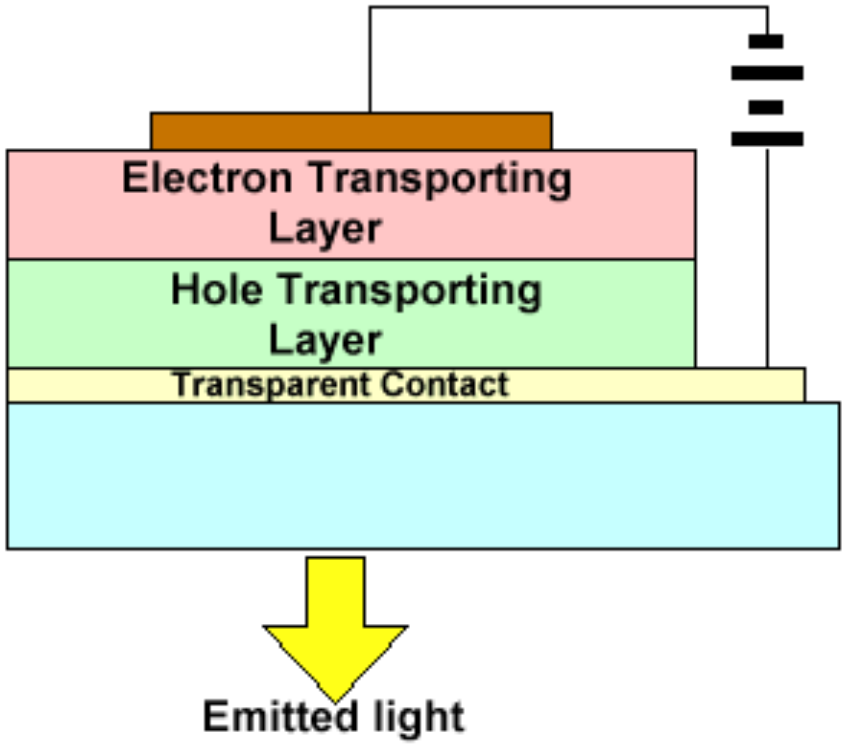


Organic Light Emitting Diode (OLED)

- Function is similar to a semiconductor LED
- Thin-film polymer construction
- Potentially simpler processing
- Transparent
- Flexible
- Can be vertically stacked
- Excellent brightness
- Large viewing angle
- Efficient (low power/low voltage)
- Fast (< 1 μs)
- Can be made large or small
- Tend to breakdown



OLED structure



Over head projectors

- CRT projector

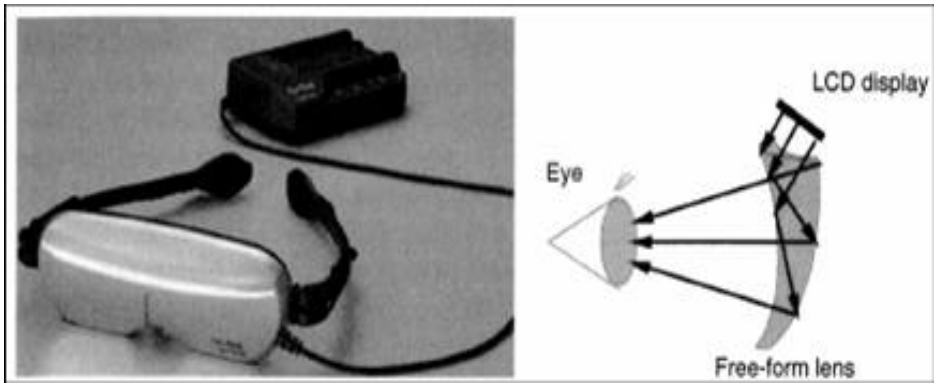
- LCD projector

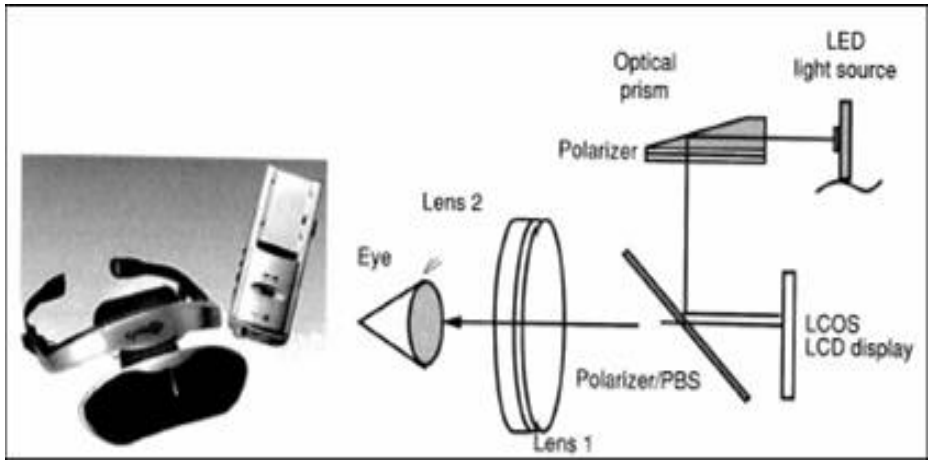
- Digital Light Processing (DLP)

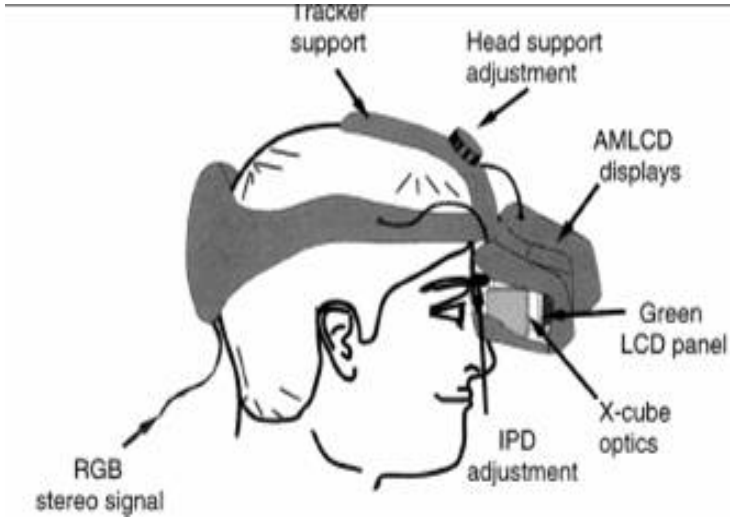
Head Mounted Display (HMD)

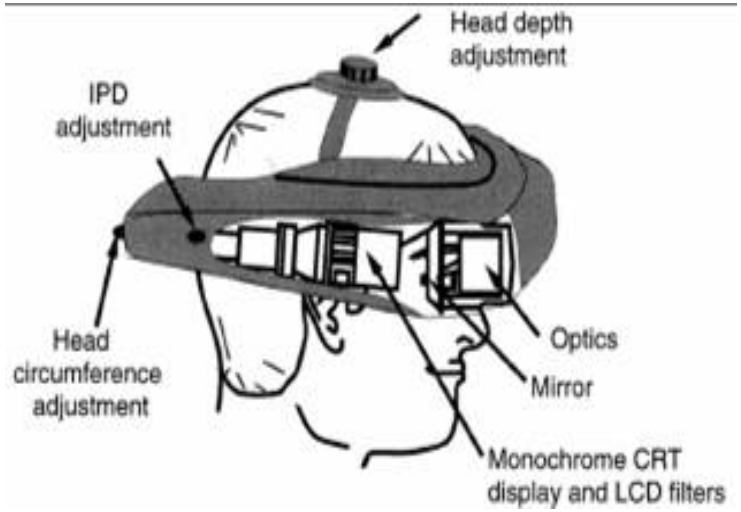
- Use two small screens placed just in front of each eye
- The virtual objects are placed at 1-5 m in front of the user
- Resolutions greater than 1024x768
- Technology:
  - LCD (Liquid Crystal Display) – for commercial use
  - CRT (Cathode Ray Tube) – professional use, high resolution

HMD - examples



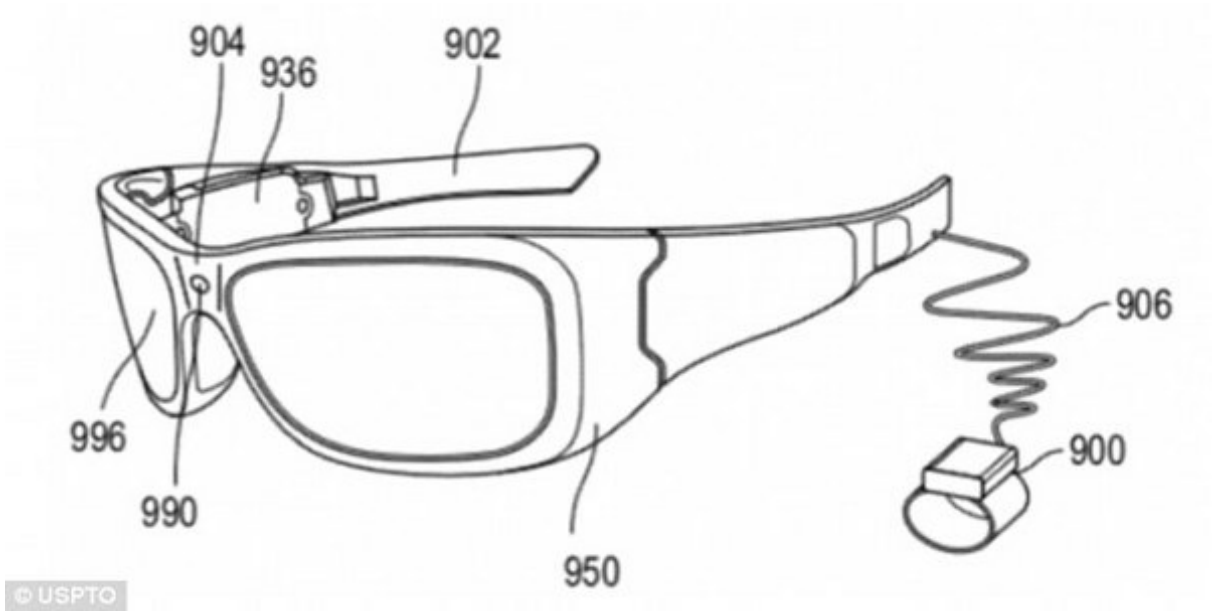






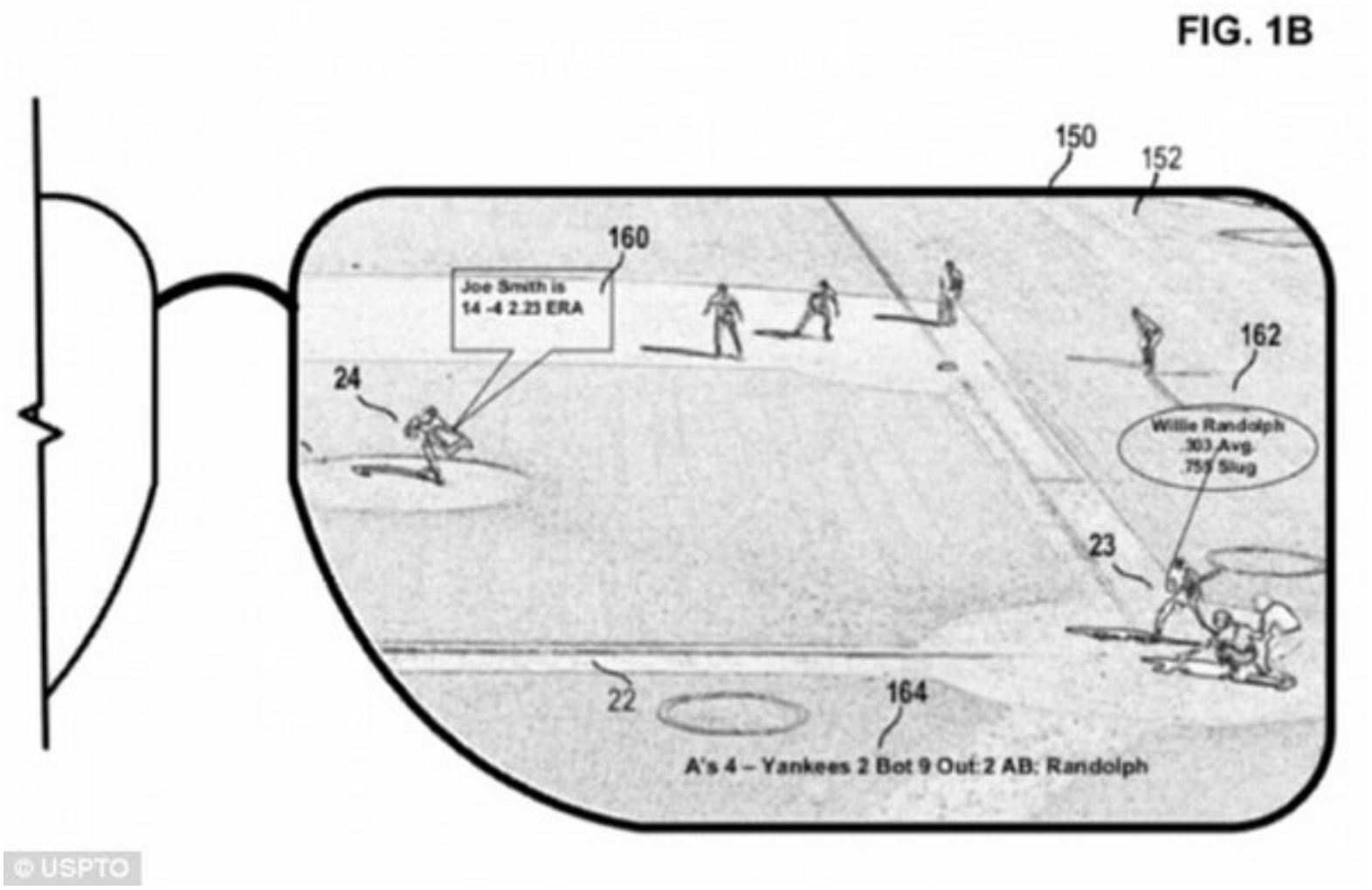
Glasses – Augmented Reality

Glasses - Real augmentation



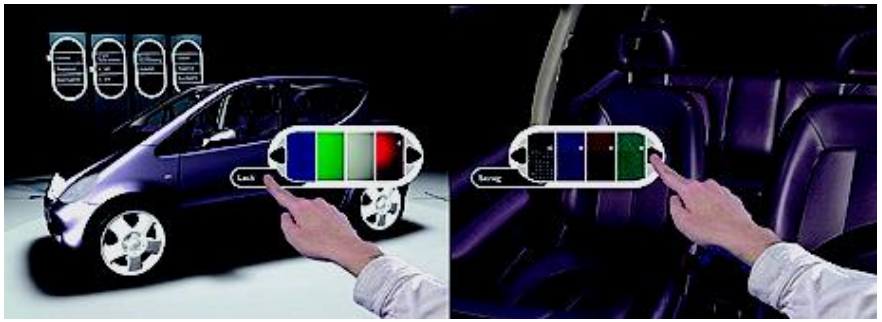
- Controlled by voice and head movement
- Operations: navigation over Internet, video call, listen music, write notices, etc.

Glasses - Real augmentation



Binocular Omni-Orientation Monitor (BOOM)

- Head-coupled stereoscopic display device
- Screens and optical system are housed in a box that is attached to a multi-link arm
- Sensors in the links of the arm that holds the box

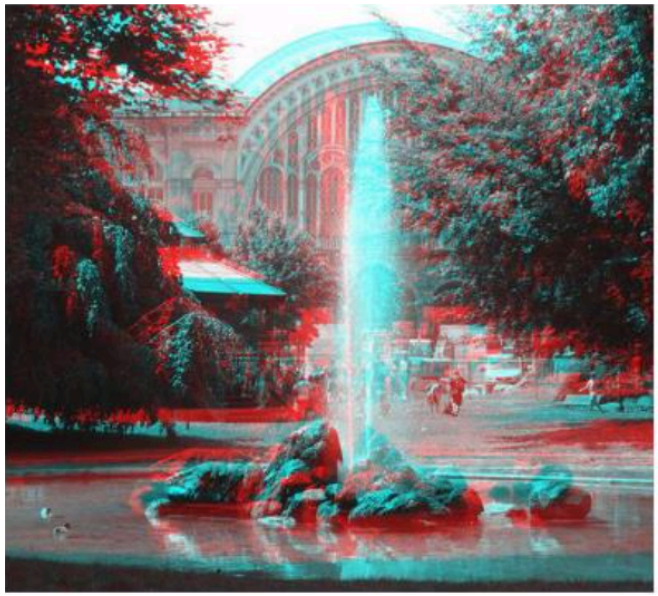


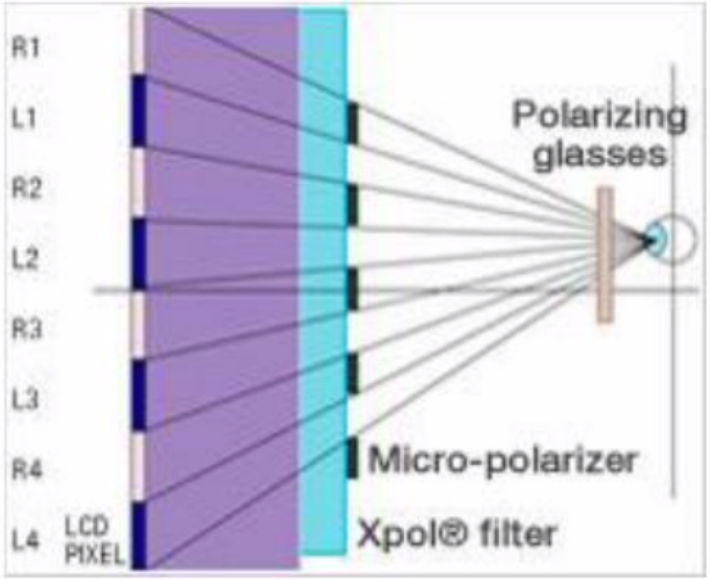
Stereoscopic view

- Stereo pairs
- Based on providing view for left and right eye separately by various techniques:
  1. By glasses
  2. Autostereoscopic

Stereoscopic view

- Color filters - red and green glasses
- Polarizing filters - polarized glasses



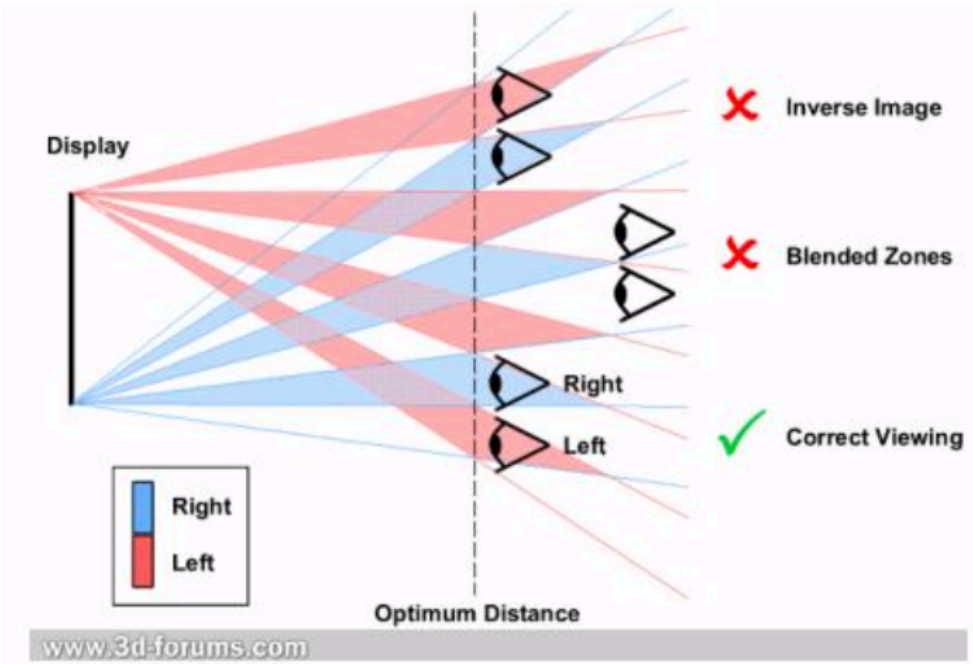


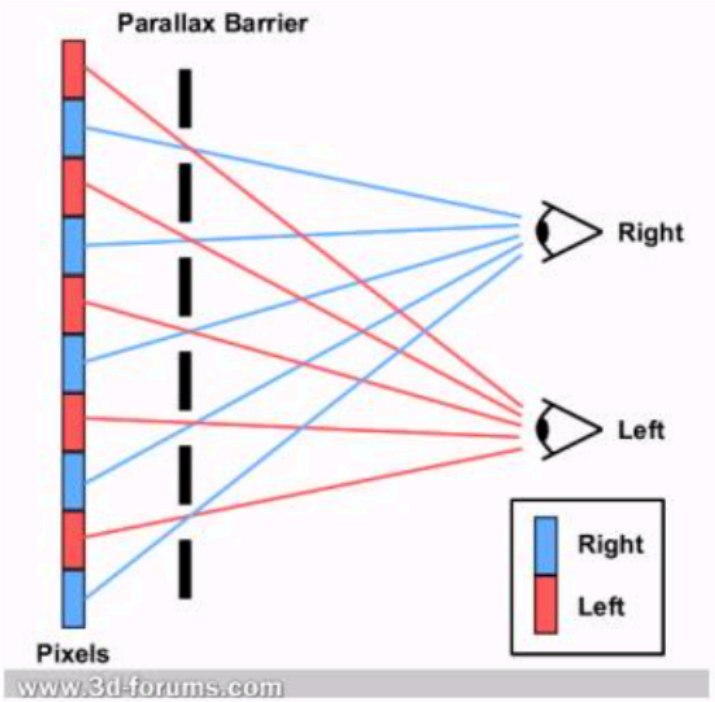
Stereoscopic view

- Shutter glasses - block one eye at a time sync with display. Requires high speed display. Glasses have active components.

Stereoscopic view

- Autostereoscopic - each eye of the viewer sees the different image from the same display without use of glasses. Binocular with one viewing position and multi-view with several viewing positions
- Parallax barrier – series of vertical aperture slits are placed in front of the screen that control witch part of the screen each eye sees





Stereoscopic view

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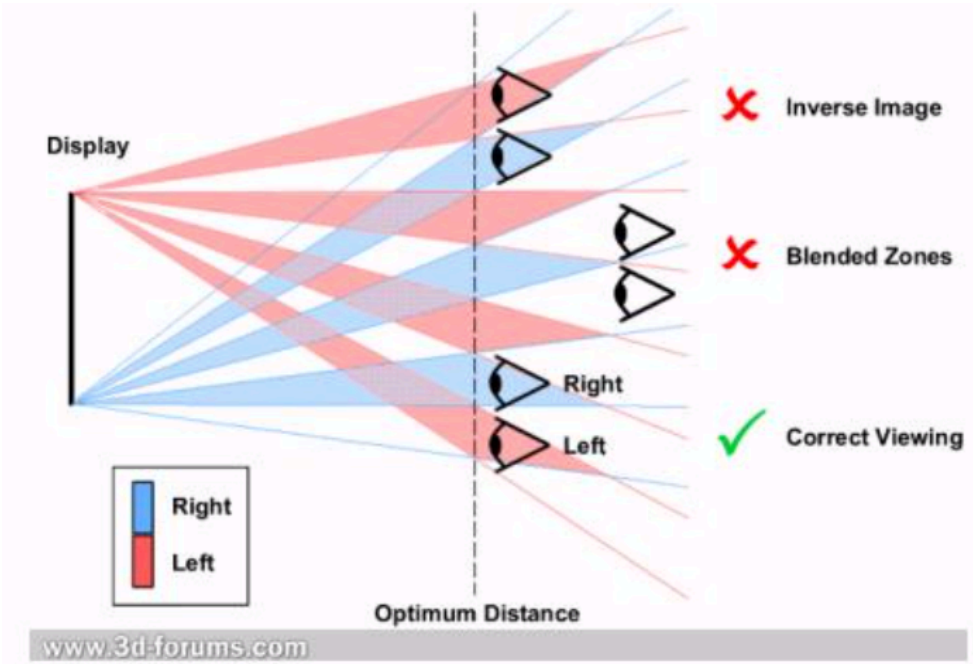
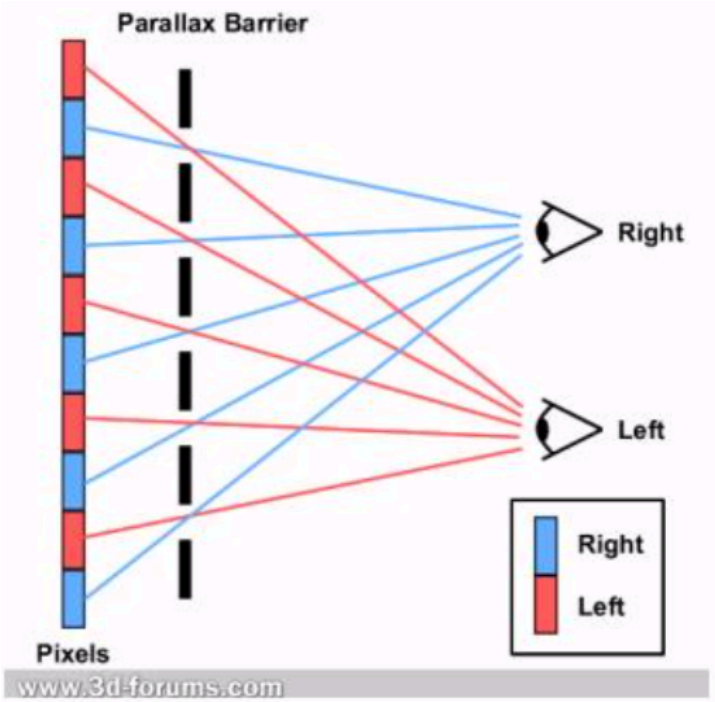
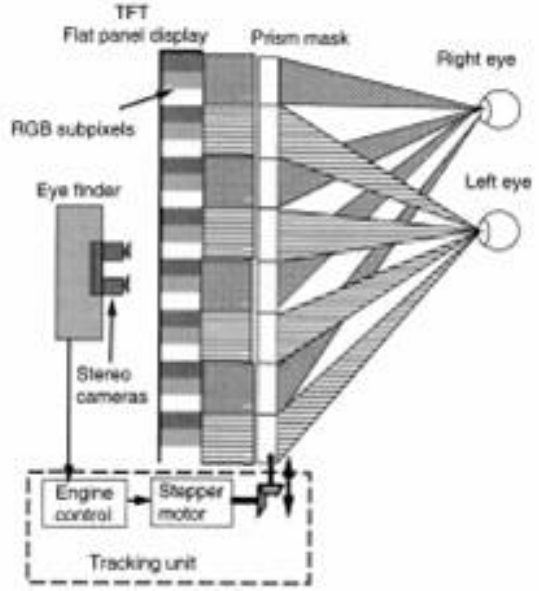




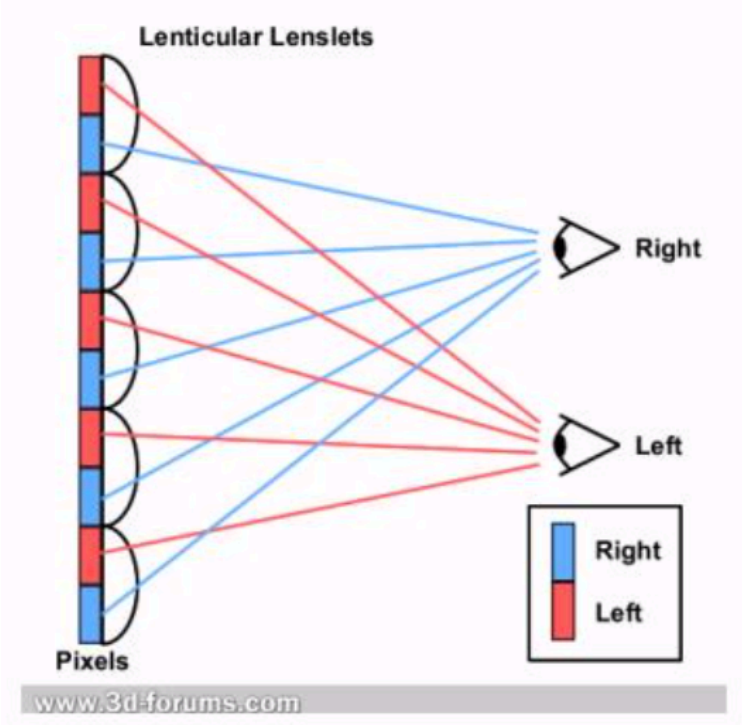
Stereoscopic view

- Prismatic
  - Passive – do not track the viewer's head
  - Active – track the viewer's head and adjusts the column of the pixels. The separation of the columns is achieved by a prismatic mask placed on the display



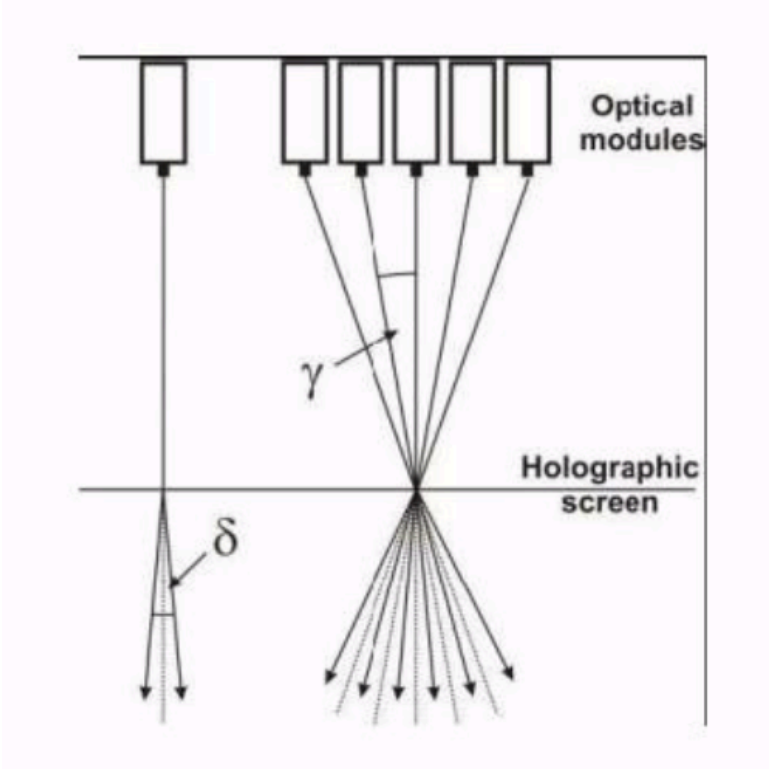
Stereoscopic view

- Lenticular – thousands of tiny lenses placed in front of regular LCD screen. Each eye can focus on different set of sub pixels on LCD element
- Head tracking – by tracking viewer's head the display optics are kept so that viewer's eyes stay in stereoscopic area



Stereoscopic view

- Holographic – photography technique that records image on three dimensions. Each point of the holographic screen emits light beams of different color and intensity to various directions. Cannot be done in real-time for video

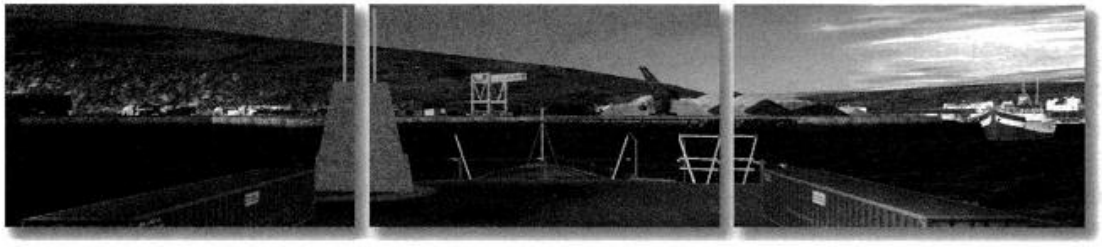


Large displays

- Graphic display that presents a virtual scene to be viewed simultaneously by multiple users close to the display:
  - Monoscopic images
  - Stereoscopic images
- Based on monitors
- Based on projectors

Large displays based on monitors

- The alternative is to use several adjacent monitors.
- Problems occur with high-speed simulation when there are interruptions between images on adjacent monitors.

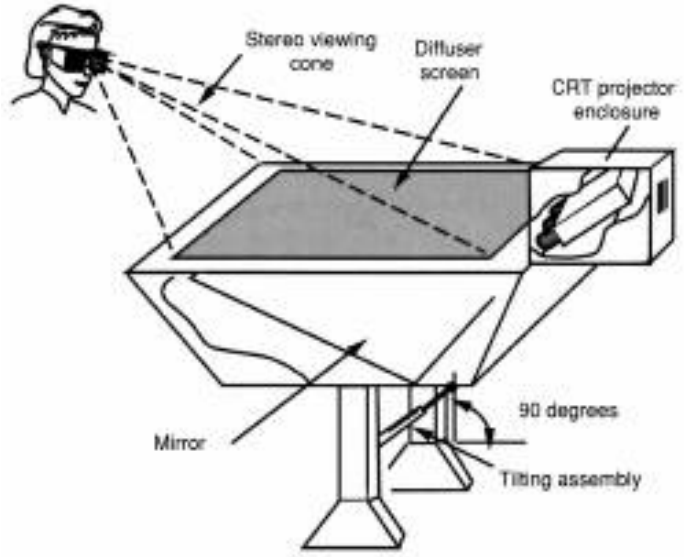


Large displays based on projectors

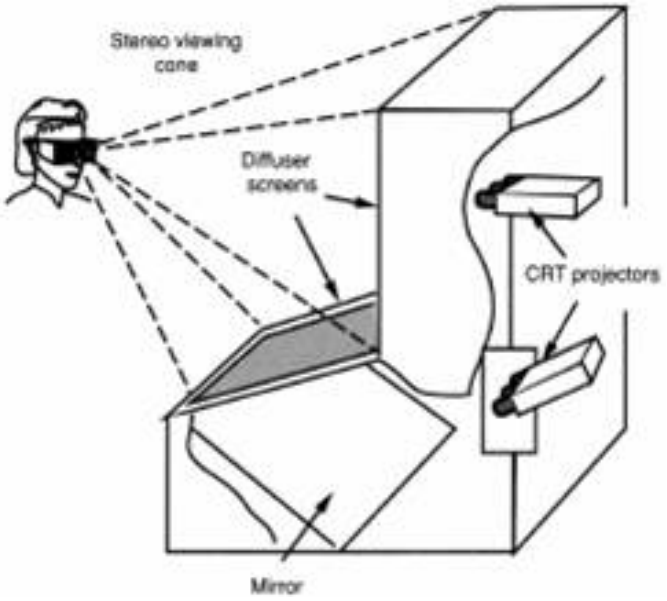
- LVD (Large Wall Display)
- It is the optimal solution to allow more users to attend an RV simulation
- A CRT projector uses 3 R, G, B tubes for a high resolution image (1280x1024) at 120 Hz
- When operating in stereo mode by sequencing the frame, the number of scan lines is divided into 2, the user seeing a stereo image at 60 Hz
- Requires special CRT tube with low persistence time, otherwise the stereo effect is lost by simultaneously displaying images
- Disadvantages:
  - High cost
  - Inability to design bright images (200-300 lumens)

Large displays based on projectors

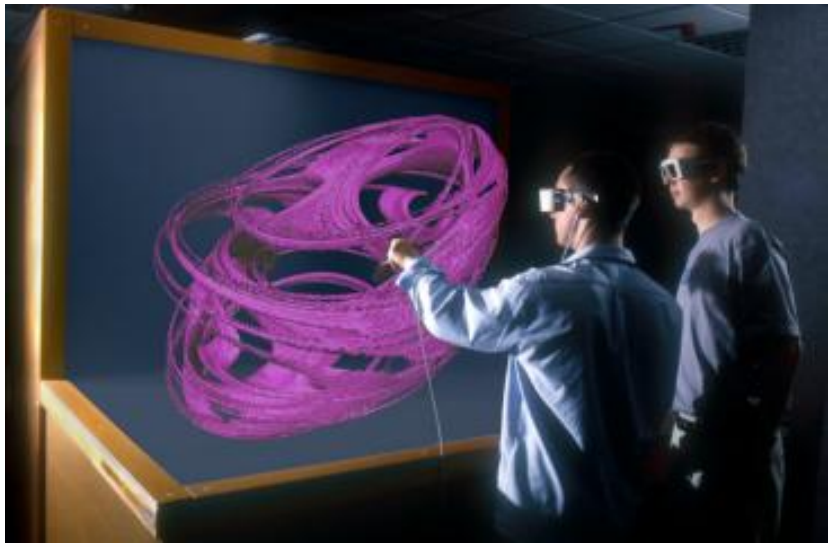
- Projects the 3D scene on a horizontal screen
- The 3D scene can view by using active glasses
- Tall objects will be cut on the opposite side of the user



- The alternative could be the L-shape screen
- 2 projectors for the 2 surfaces
- Increased size of the seen scene
- The image can be distorted for the users without tracker

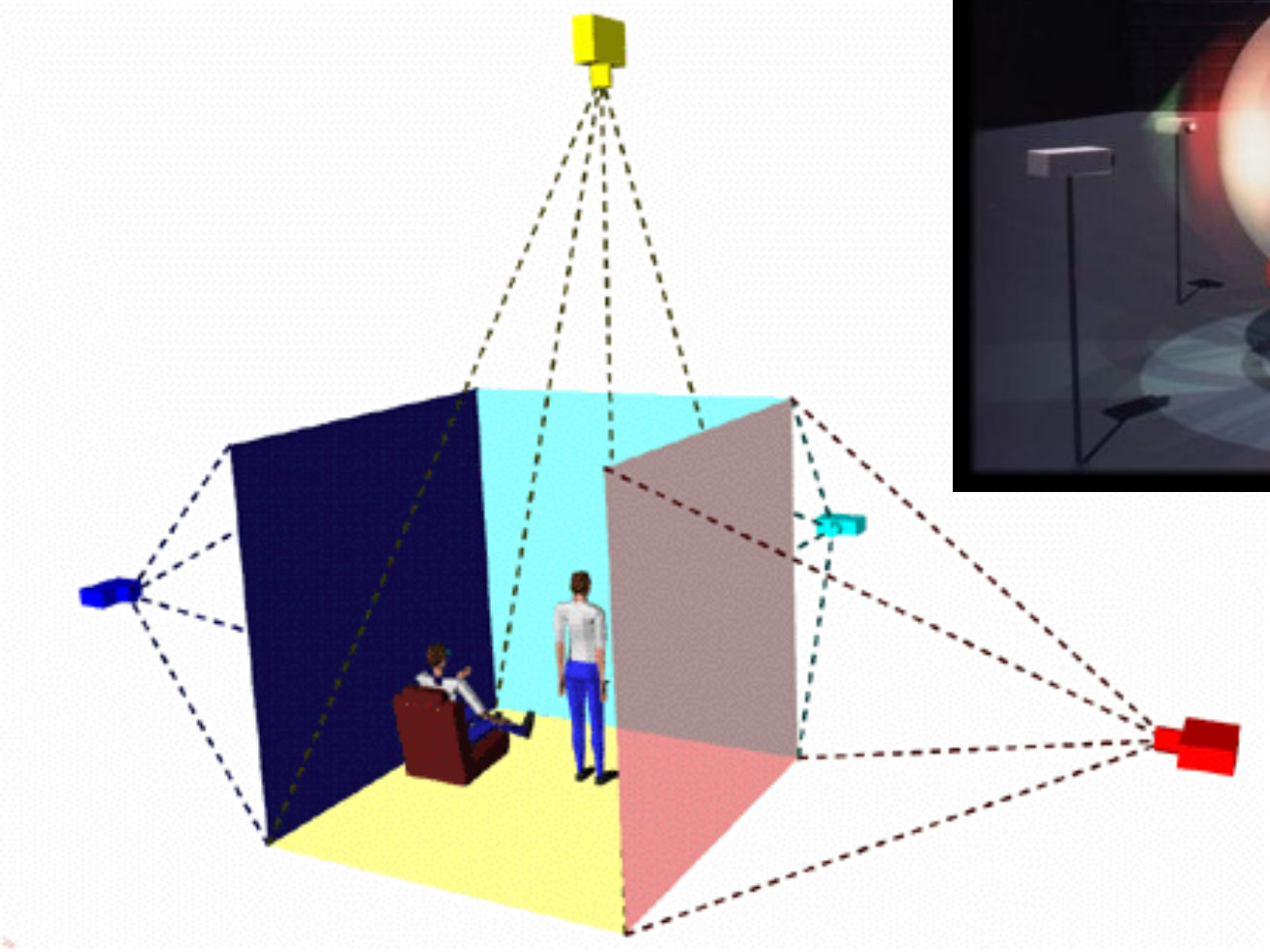


Workbench



- VR PluraView is a passive virtual reality stereo monitor. Interaction with 3D stereo models and content across all axes. Zoom, rotate and incline without a mouse, either via head tracking and / or using tracking-balls or a 3D pen.

Cave Automatic Virtual Environment (CAVE)

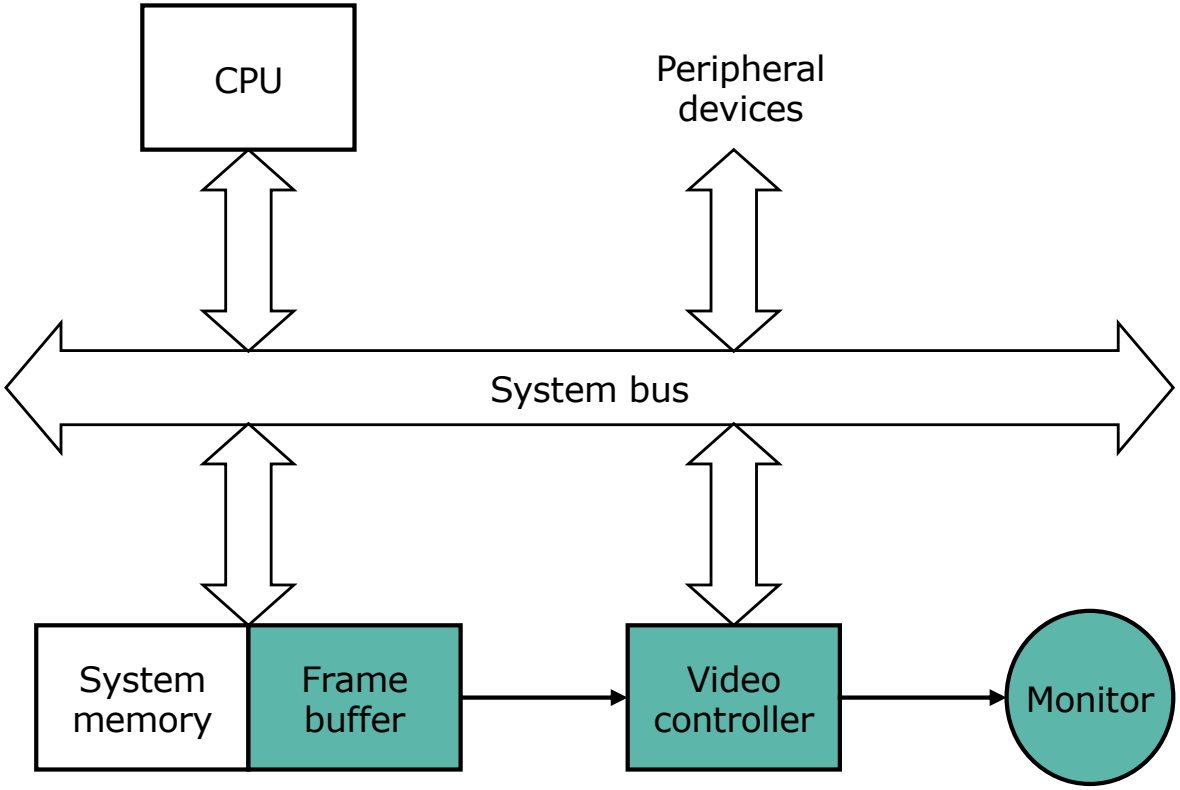


Output devices

- Hardcopy technologies:
  - dot matrix printer
  - pen plotter
  - desk-top plotter
  - electrostatic plotter
  - laser printer
  - ink-jet printer
  - thermal transfer printer
- Display technologies:
  - monochrome and color CRT (Cathode Ray
  - direct-view storage tube (DVST)
  - liquid-crystal display (LCD)
  - plasma panel
  - electroluminescent display (ELD)
- Raster-scan display systems
  - simple raster display system
  - peripheral display processor
  - integrated display processor

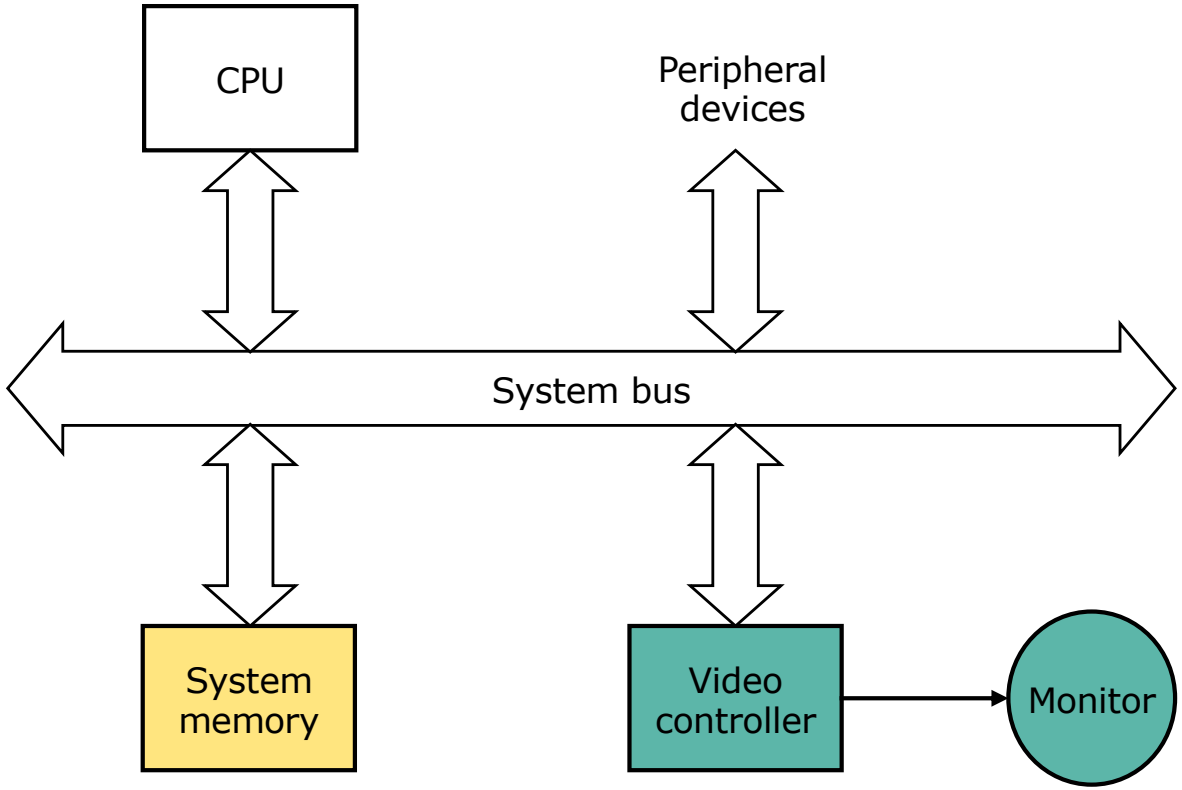
Simple Raster Display System with Dual Port Memory

- Frame buffer – dedicated portion of the system memory
- Dual port memory
- Video controller accesses directly the system memory



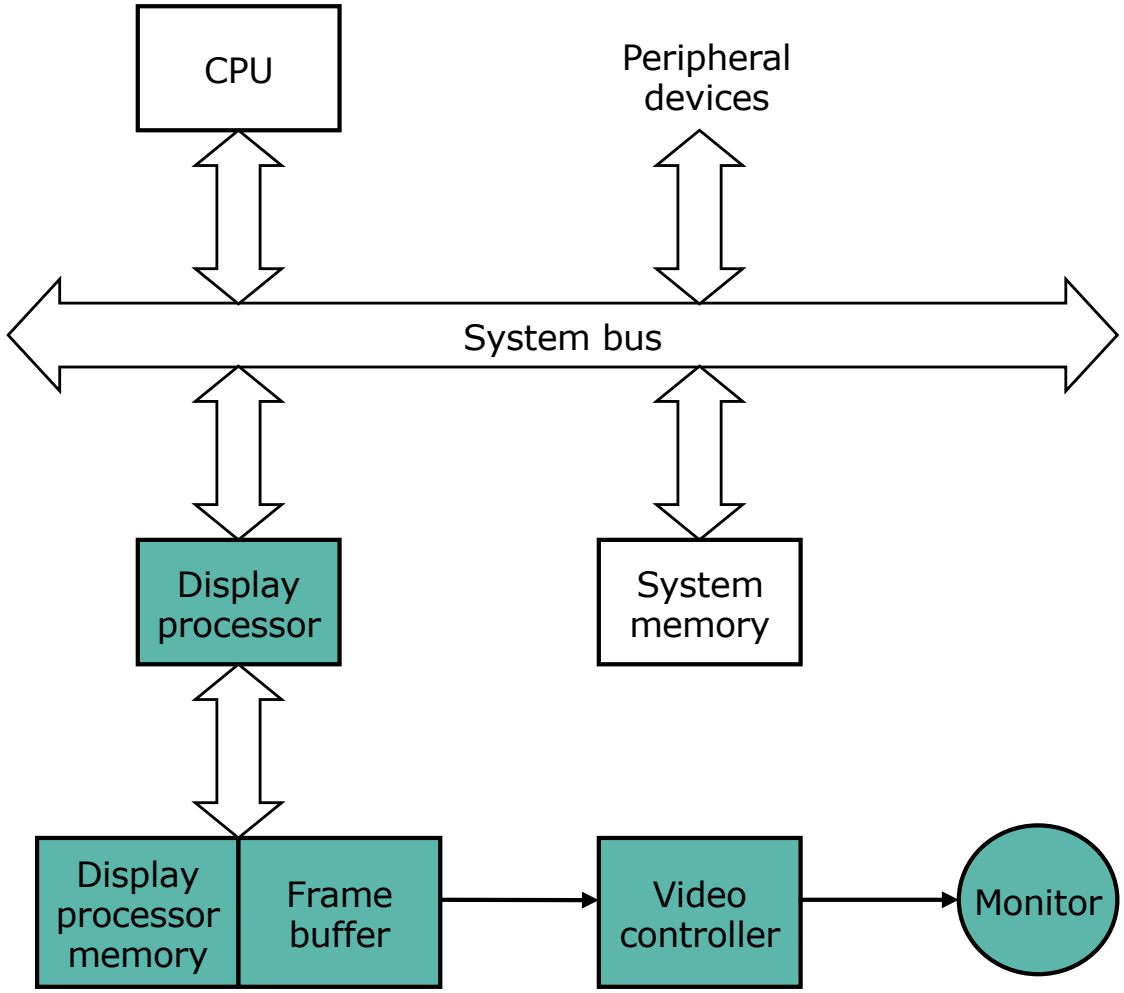
Simple Raster Display System

- Frame buffer – anywhere in the system memory
- Video controler accesses the memory through the system bus



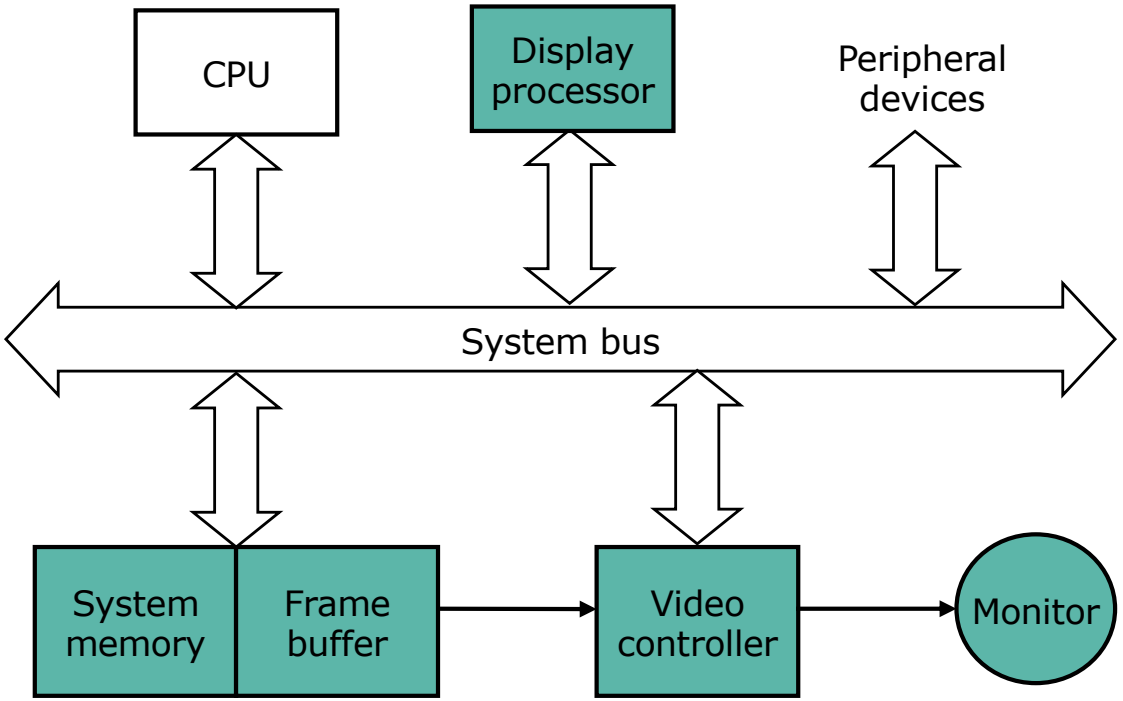
Raster Display System with Peripheral Display Processor

- System memory:
  - Application program
  - Graphics package
  - Operating system
- Display processor:
  - Raster operations
  - Scan conversion
  - Double-buffering
  - I/O transfer on the system bus



Raster Display System with Integrated Display Processor

- Cache memories
- Video RAM (VRAM)
  (read out all pixels on a scan line in one cycle)



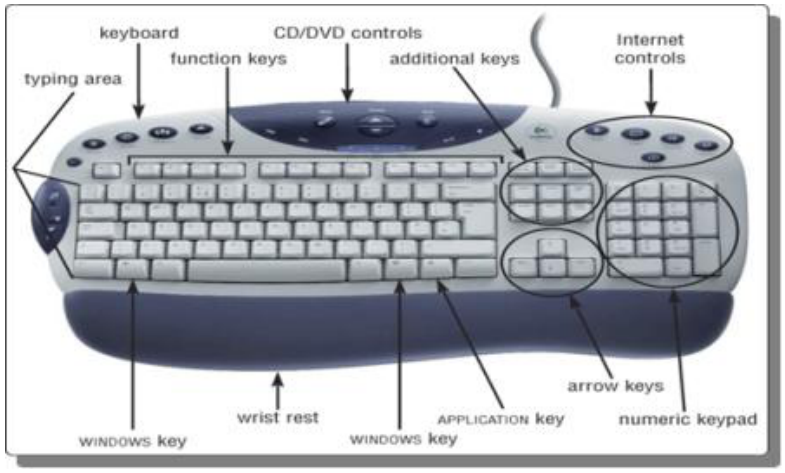
Input devices

- Logical input device
  - Locator
  - Valuator
  - Choice
  - String
  - Pick
  - Stroke
- Physical devices:

locator:	graphic tablet, joystick
valuator:	analog to digital converter, potentiometer
choice:	keyboard, set of buttons (function keys)
pick:	light-pen
string:	keyboard
stroke:	mouse, track-ball

Keyboard

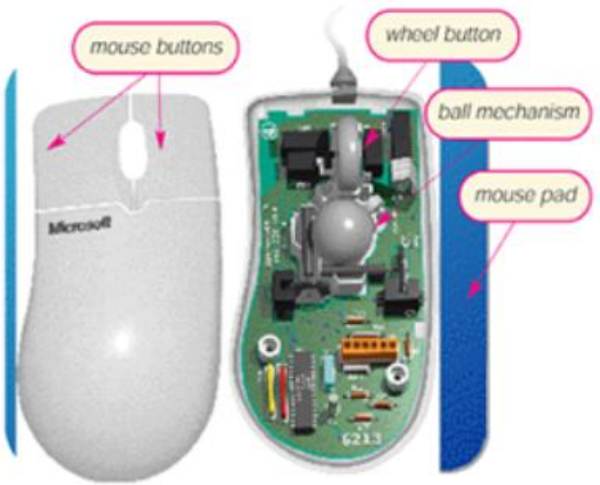
- Text

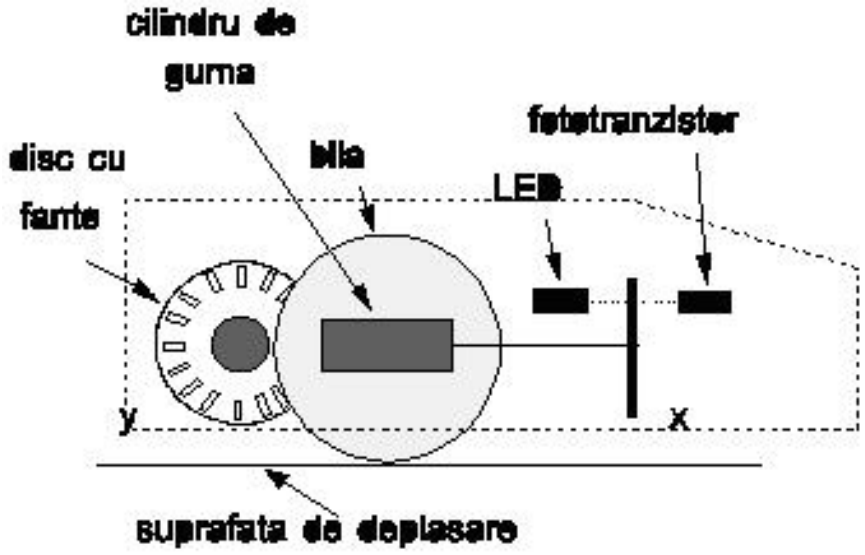


Mouse

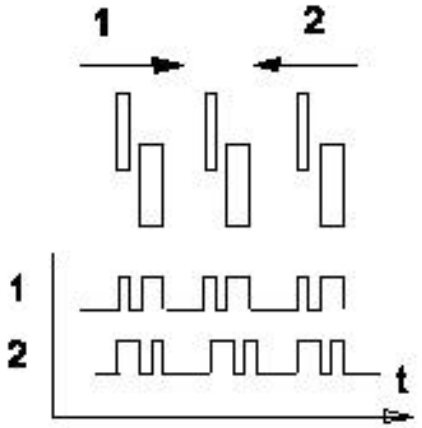
- Stroke

- a) Mouse with ball
- b) Disk with asymmetrical cuttings,
  1 – rotation sense from left to right,
  2 – rotation sense from right to left.
- c) Optical mouse



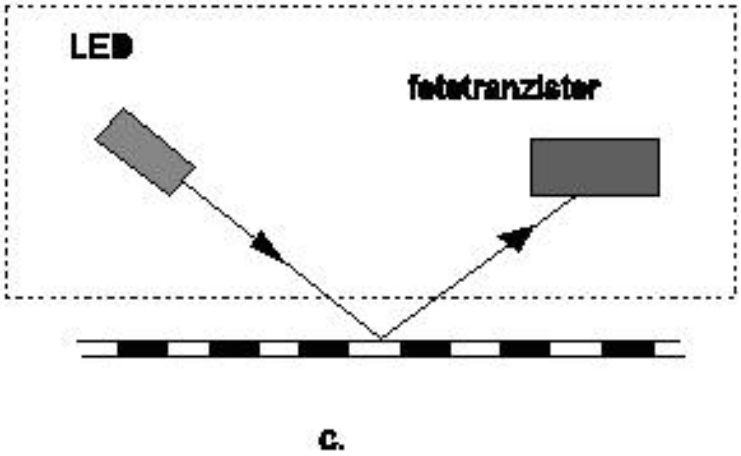


a.

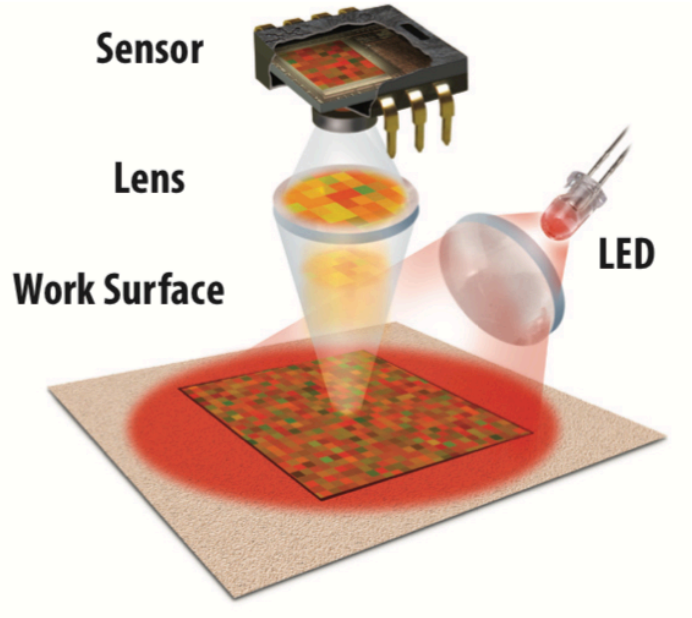


b.

Optical Mouse

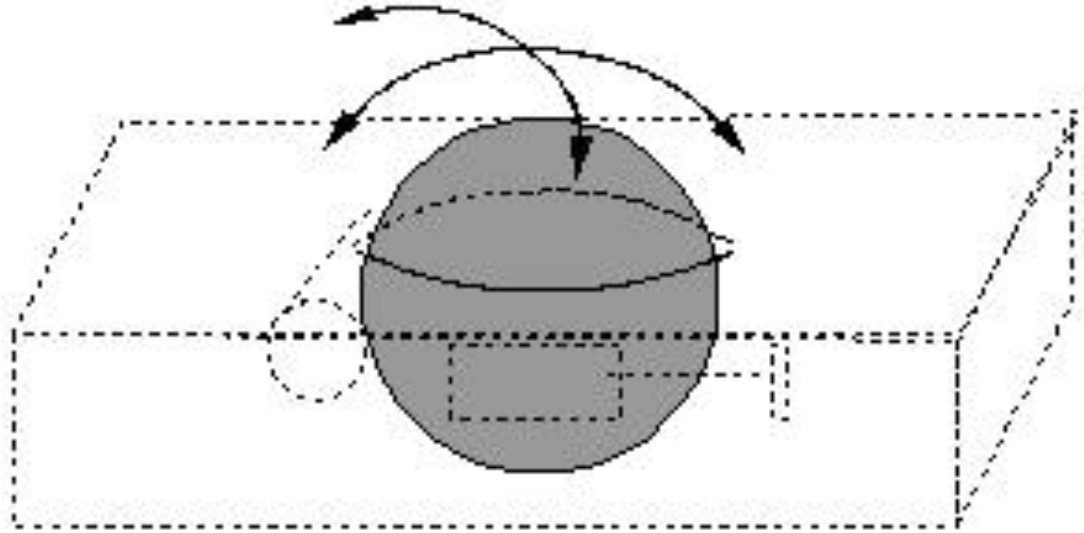


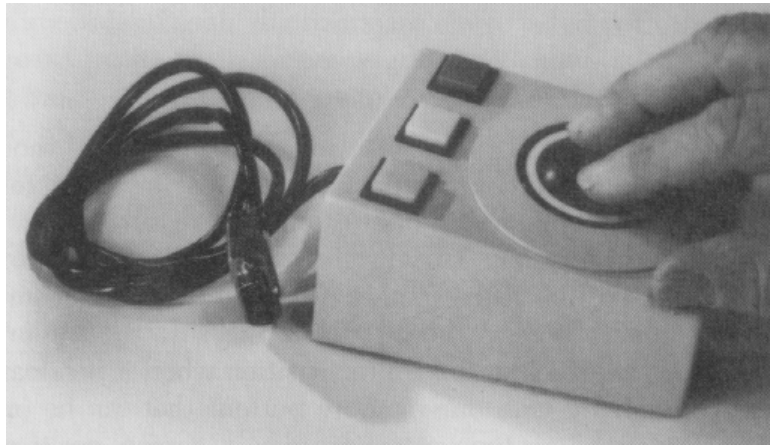
c.



Track-ball

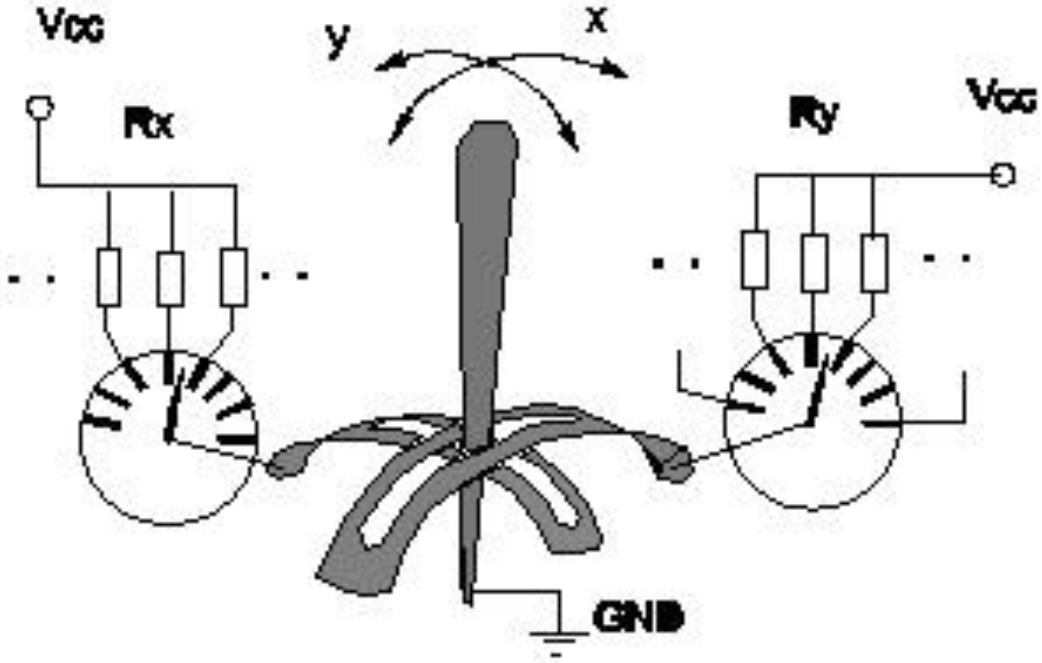
- Stroke

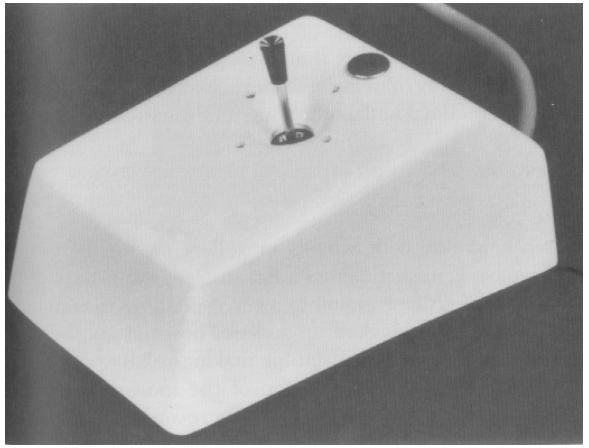




Joystick

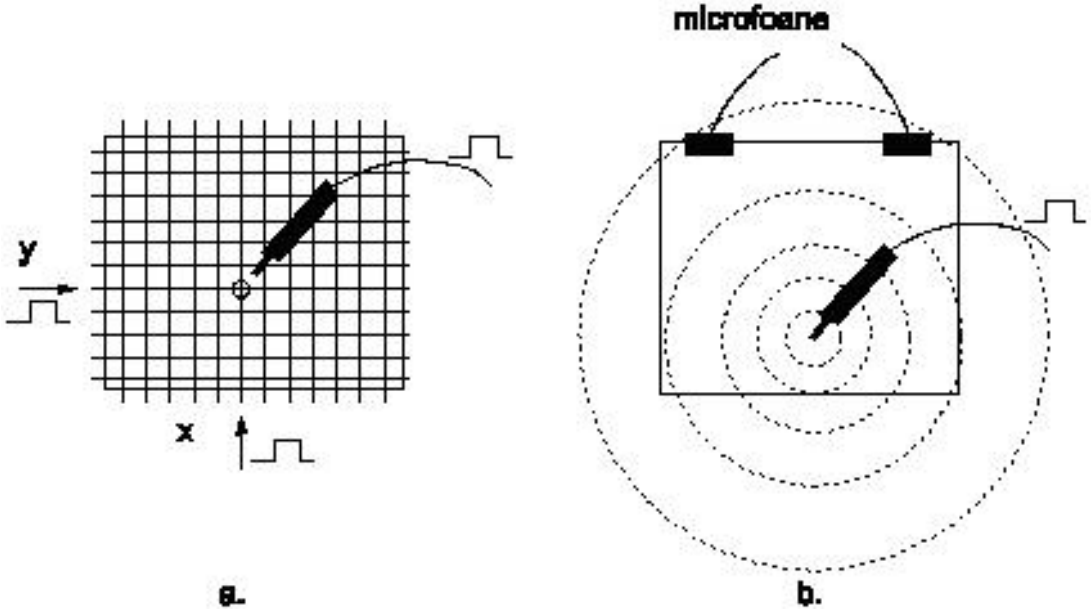
- Locator

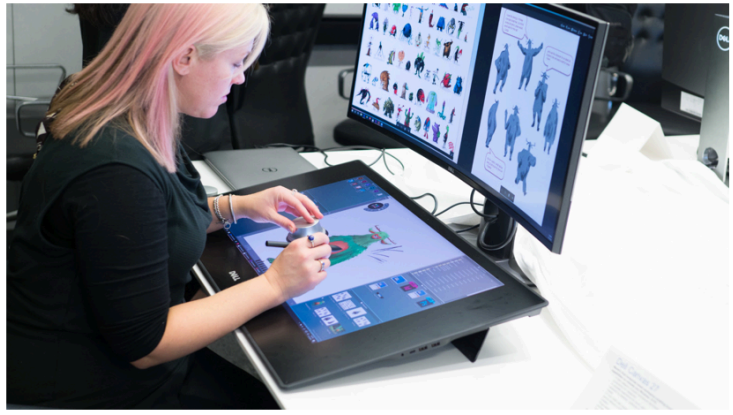




Graphic tablet

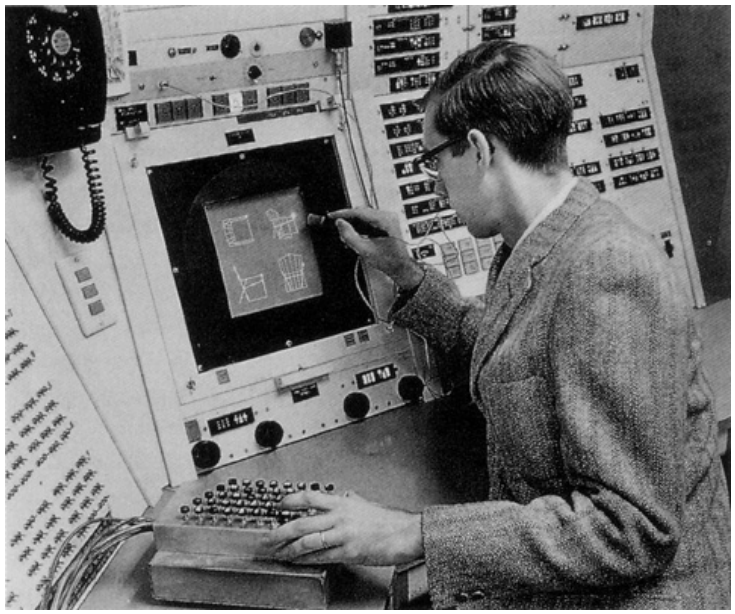
- Locator
- Graphic Tablet
  a) Active tablet, passive pen.
  b) Acoustic active pen, tablet with microphones.

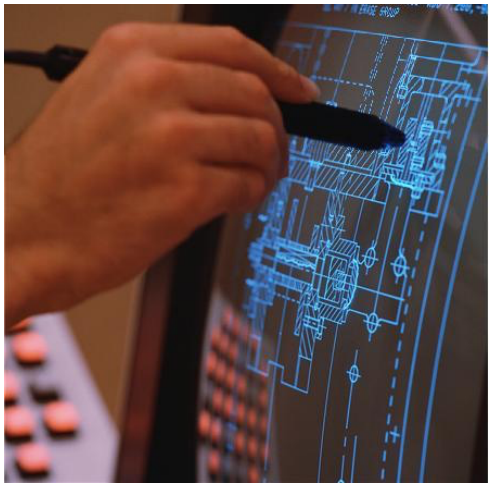


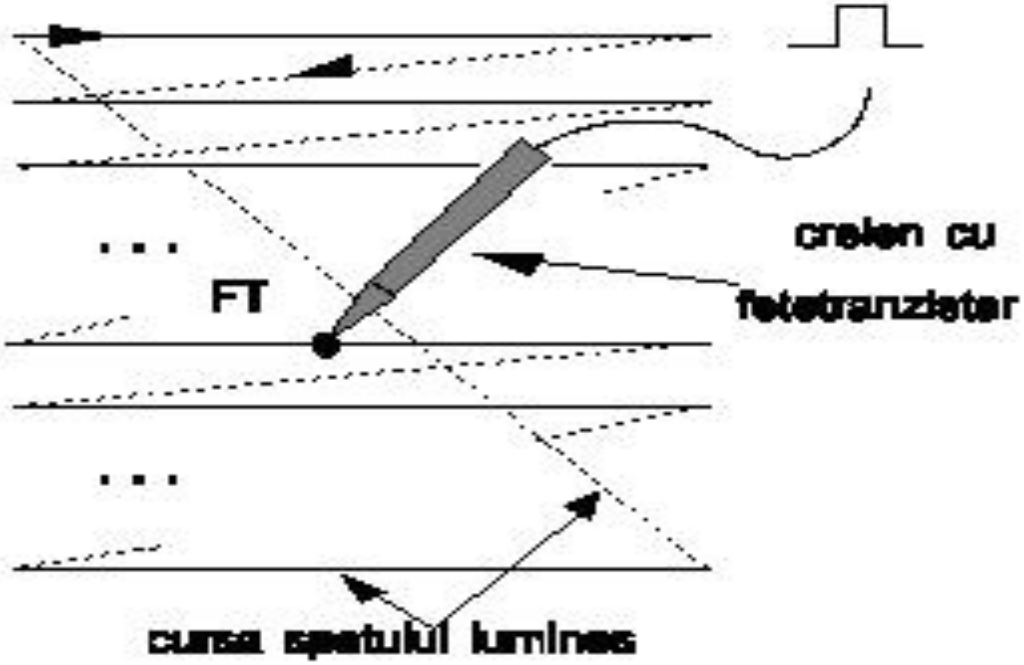


Light pen

- Pick

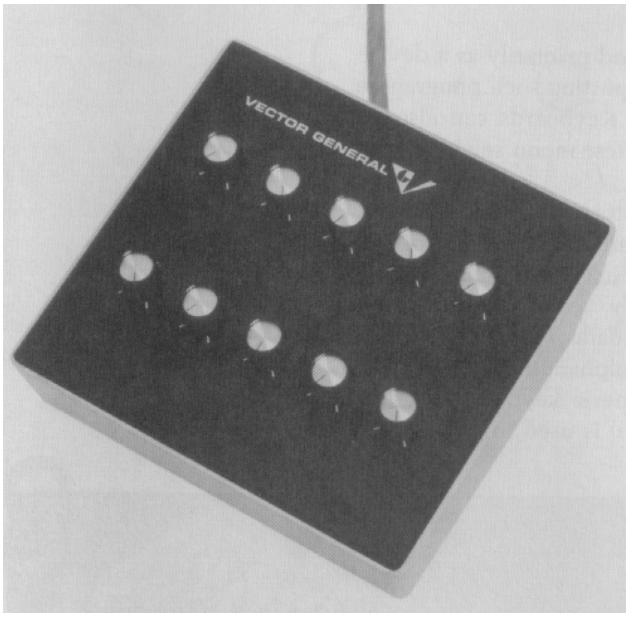






Potentiometer, Dials

- Value



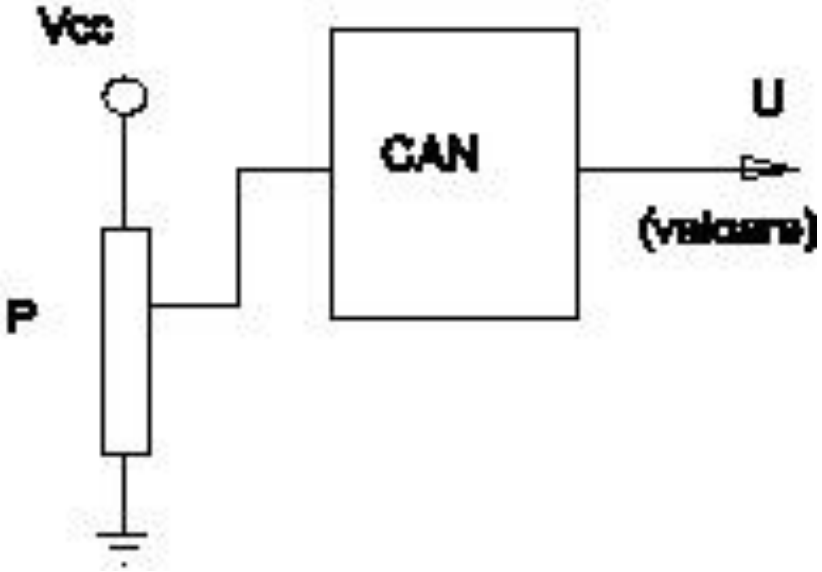
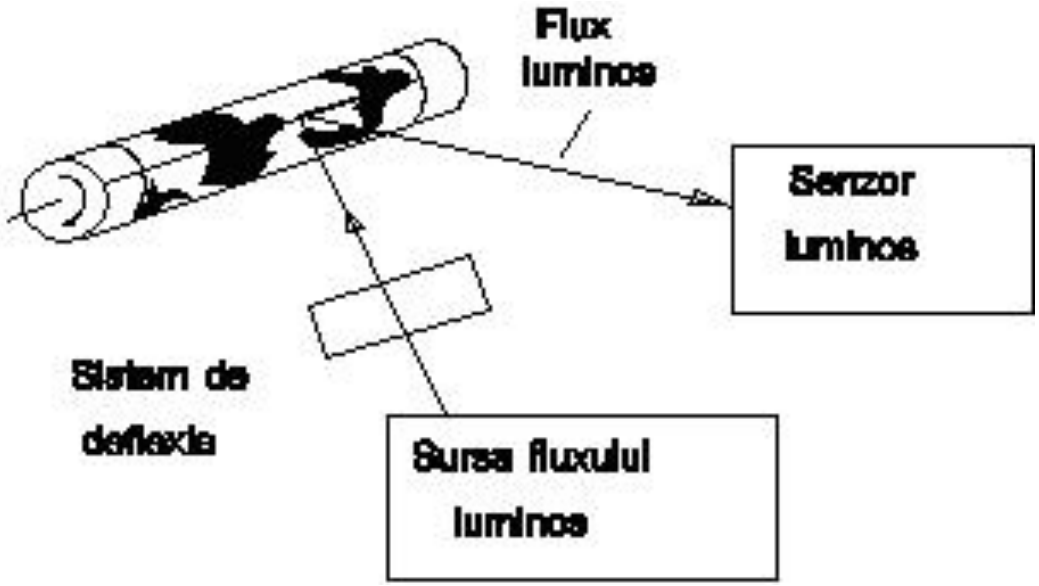


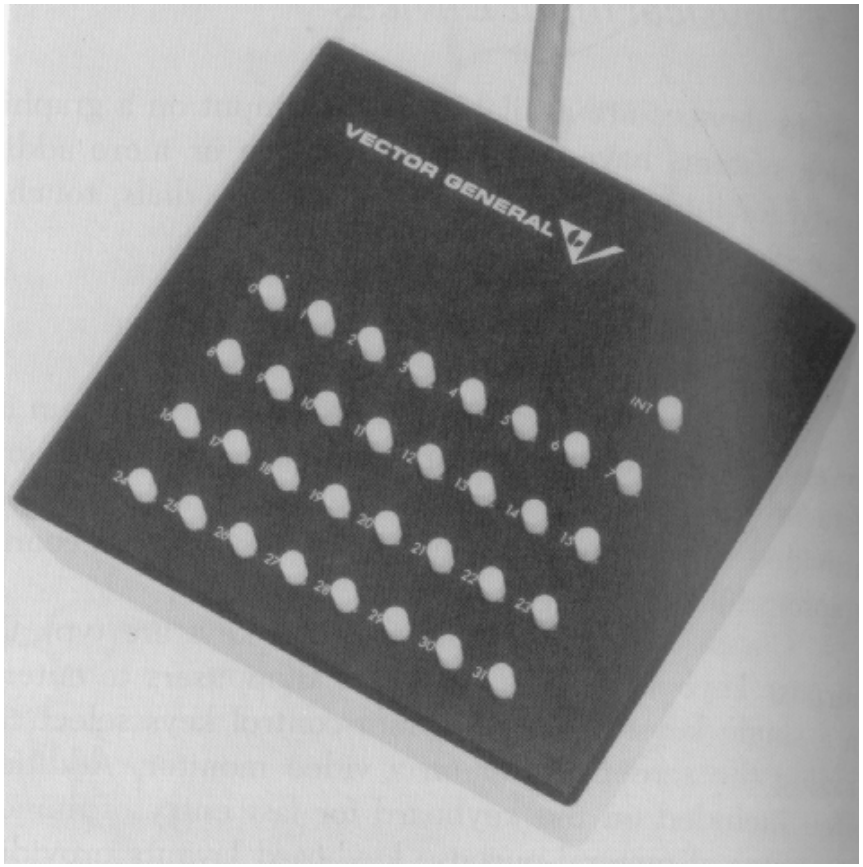
Image scanner

- Bitmap



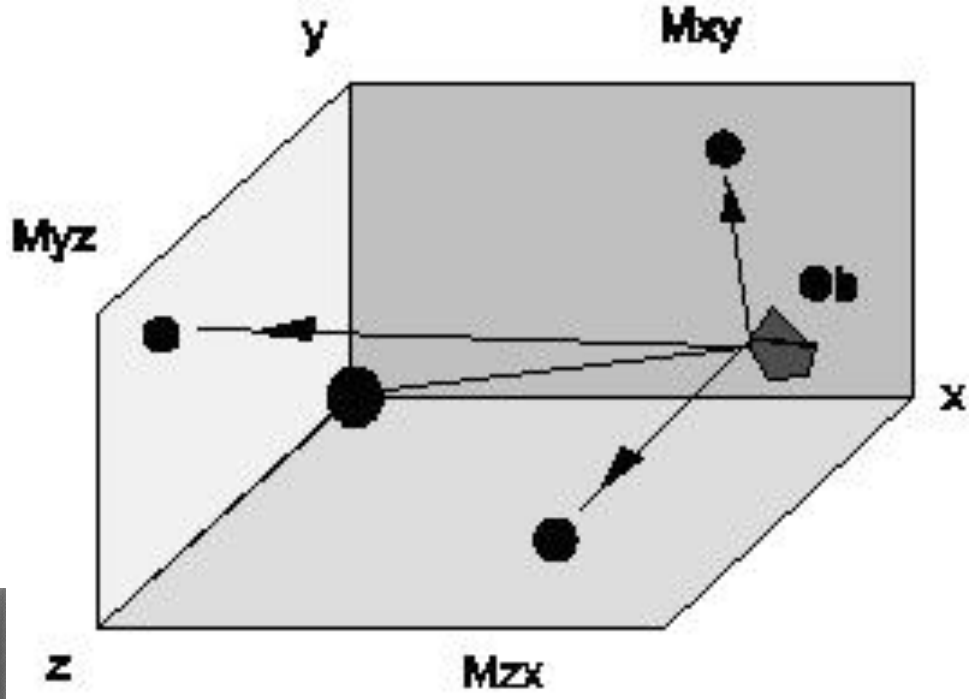
Buttons

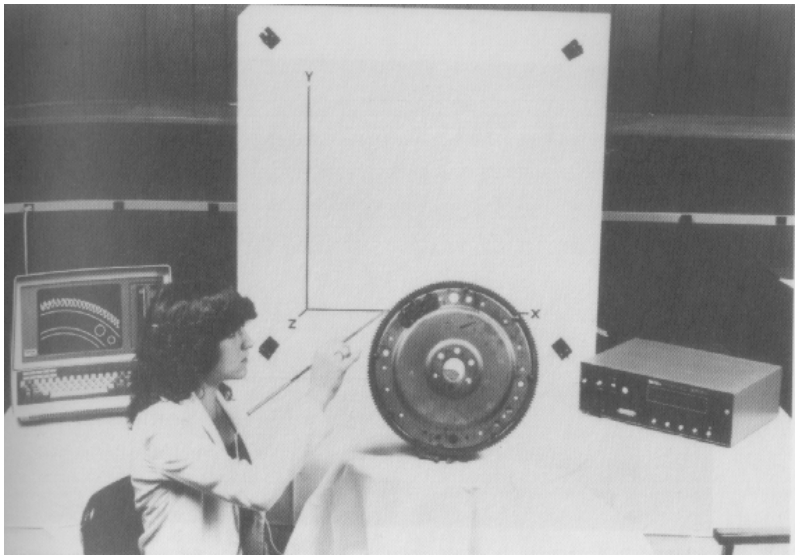
- Choice



3D Input device

- Location





Ring Mouse

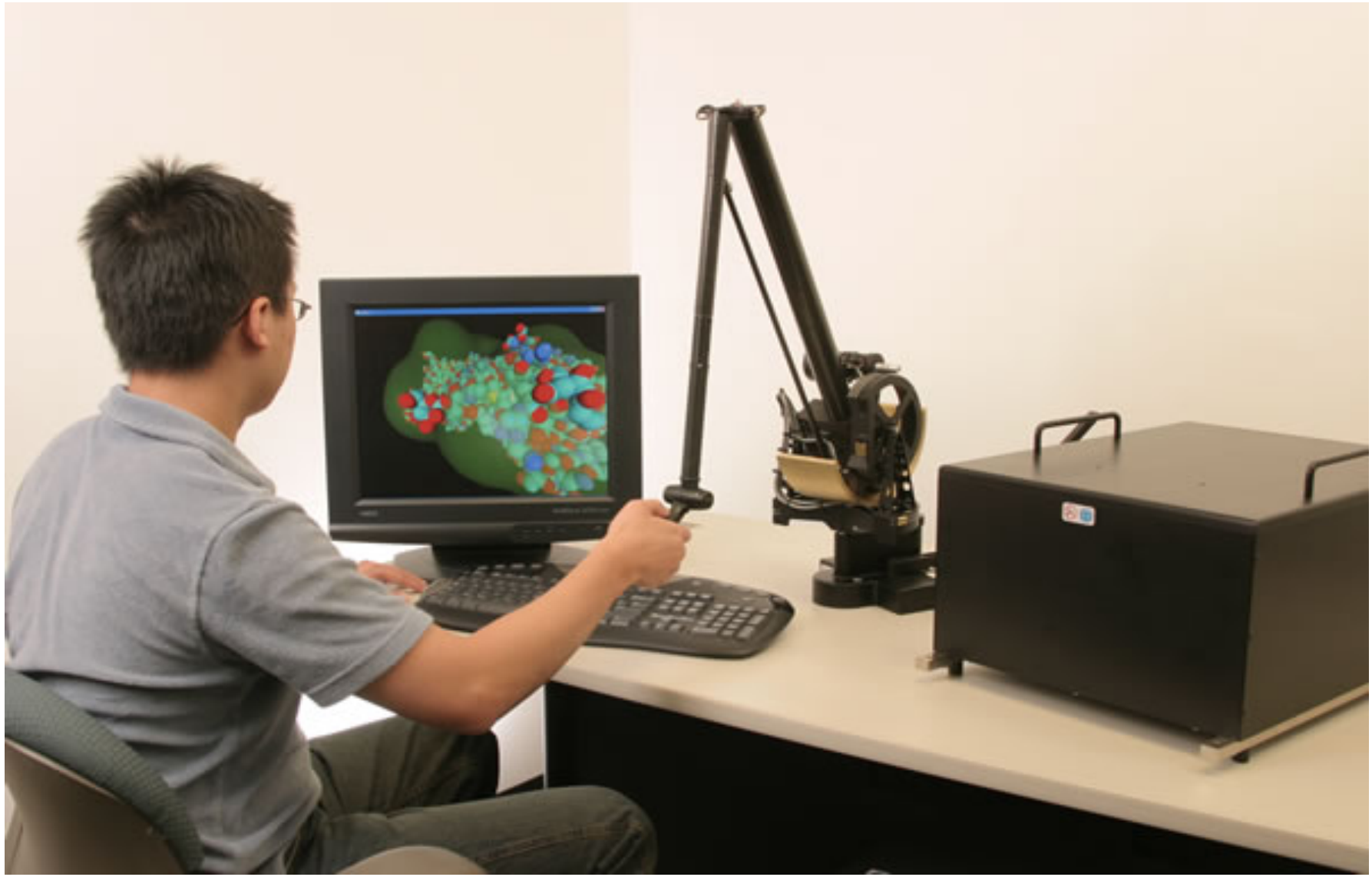
- Optical trackpad ("Opto Touch Wheel")
- Embedded 2.4GHz wireless model for a communication to 10m
- The wearer uses the thumb to navigate the cursor
- Can be charged by electric power by USB
- It has as well left and right click buttons

Haptic device

- 3-dimensional pen-style haptic device that "makes it possible for users to touch and manipulate virtual objects
- 3D Touch-enabled Modeling for Product Design
- The position and orientation of the pen are tracked through encoders in the robotic arm.
- Three degrees of force, in the x, y and z, direction are achieved through motors that apply torques at each joint in the robotic arm

ex. PHANTOM Desktop

Haptic device



Haptic device - glove

- Provides six degrees of freedom positional tracking that accurately measures translation and rotation of the hand in three dimensions.
- Includes a system of internal sensors at joints and in muscles to detect changes in pressure and position.

- Glove with 16 sensors (2 per finger + abduction).

Questions and proposed problems

1. Explain the following operations performed by the Input Output Processor (IOP): scan conversion of the output primitives, refresh screen, raster operations, and character generation. Give an example for each operation.
2. Is the dot matrix printer a vector or raster device? Argument the statement.
3. Is the pen plotter a vector or raster device? Argument the statement.
4. Why do you think the resolution of the electrostatic plotter can be limited?
5. Is the laser printer a vector or raster device? Is the image composed of vectors or pixels? Argument the statement.
6. Is the ink-jet printer a vector or raster device? Is the image composed of vectors or pixels? Who could perform the scan conversion? Argument the statement.
7. Is the Cathode Ray Tube (CRT) a vector or raster device? Is the image composed of vectors or pixels? Who could perform the scan conversion? Argument the statement.

Questions and proposed problems

8. What is the relationship between a phosphor dot, phosphor dot pattern and a pixel, for a BW and color CRT device? What element decides the maximum resolution of a CRT display device?
9. What are the differences between vector and raster graphics? Highlight the differences in graphics models, images, output graphics devices, file formats, image memory buffer, file formats, information description, and object related semantics.
10. What is the differences between vector graphics model and raster graphics model?
11. What is the differences between vector graphics image and raster graphics image?
12. What is the differences between vector graphics device and raster graphics device?
13. What could limit the resolution and dynamics of the LCD (Liquid Crystal Displays) and TFT (Thin Film Transistor) LCD screens?
14. What limits the resolution and dynamics of the PDP (Plasma Display Panel)?

Questions and proposed problems

15. Compare the following architectures: simple raster display system, peripheral display processor, and integrated display processor. Highlight the differences and advantages of each architecture?
16. What are the main differences between logical and physical input devices? Give some examples.
17. How the mouse with ball detects the moving directions? Why the optical mouse does not work on a glossy and shiny surface?
18. What are the similarity and difference between mouse and track-ball?
19. How the graphic tablet transforms the signal into position?
20. How the light pen transforms the signal into position?
21. What is the main difference between an input graphics device and a haptic device?