Grafica pe calculator

Câteva noțiuni fundamentale

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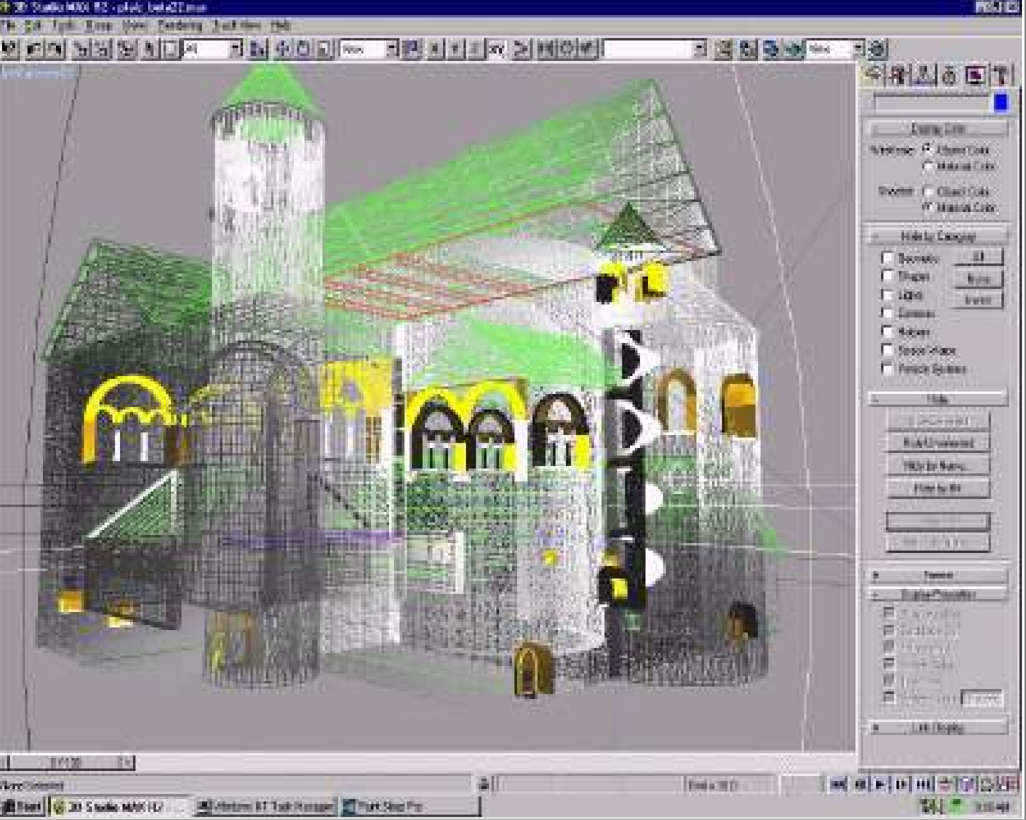
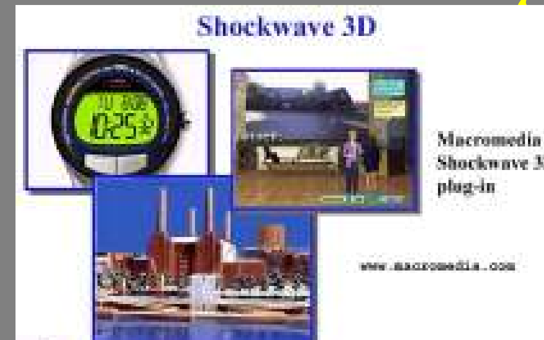
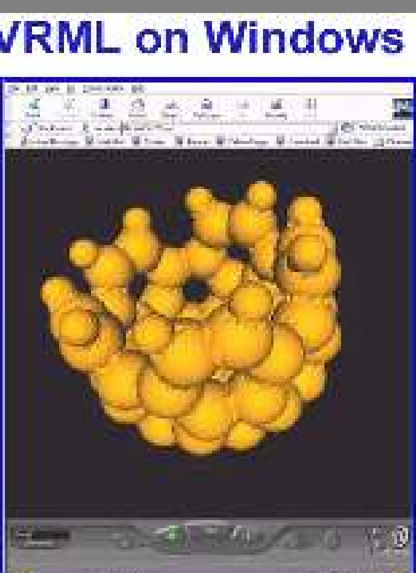
Clasificarea aplicațiilor pentru sinteză grafică

- Editoare grafice (Gimp, Inkscape, Adobe Photoshop, etc.)
- Biblioteci grafice (grafics, OpenGL, etc.)
- Aplicații cu facilități grafice (birotică, matematică, proiectare asistata de calculator, etc.)

Editoare grafice

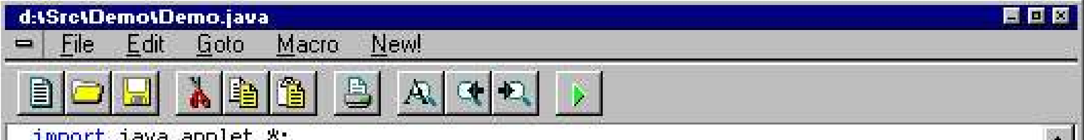






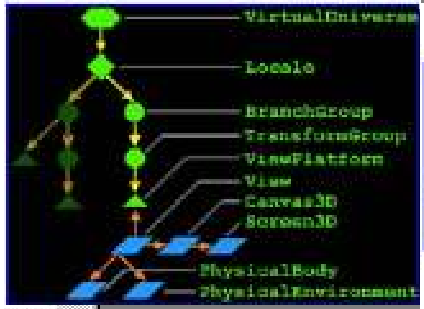
Sid (left) and Wendy (right)
Created using Java version of Improv running within a VRML browser

Biblioteci grafice




```java
import java.applet.*;
import java.awt.*;

public class Demo extends Applet {
    Image image;
    int count;

    public void init()
    {
        image = getImage(getDocumentBase(), "World.jpg");
        count = 1;
    }

    public void paint(Graphics g)
    {
        g.drawImage(image, 0, 0, this);
        g.setColor(Color.red);
        for (int y = 15; y < size().height; y += 15) {
            int x = (int) (size().width/2 + 30*Math.cos(Math.PI*y/75));
            g.drawString("Hello", x, y);
        }
        showStatus("Paint called " + count + " time" + ((count > 1) ? "s" : ""));
        count += 1;
    }
}
```

Java 3D Scene Graph

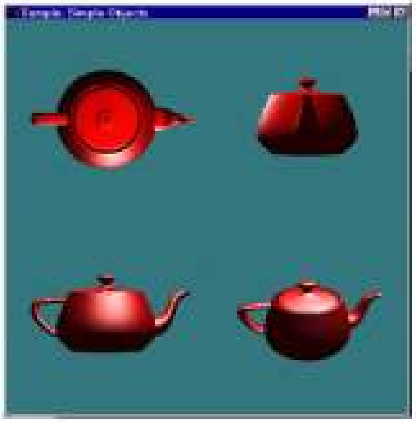


Java 3D Examples

VRML Example

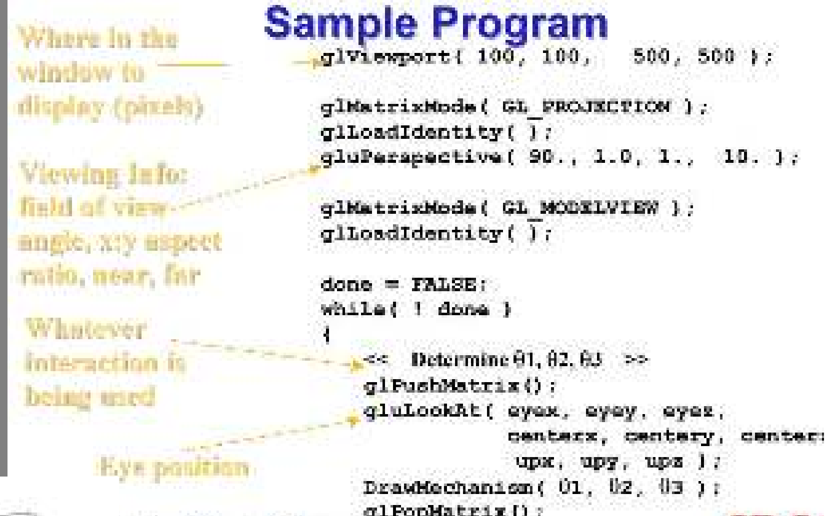
```
#VRML 2.0 utf8
Shape
{
  appearance
    Appearance
    {
      material
        Material { }
    }
  geometry
    Cylinder
    {
      radius  2.0
      height  4.0
    }
}
```

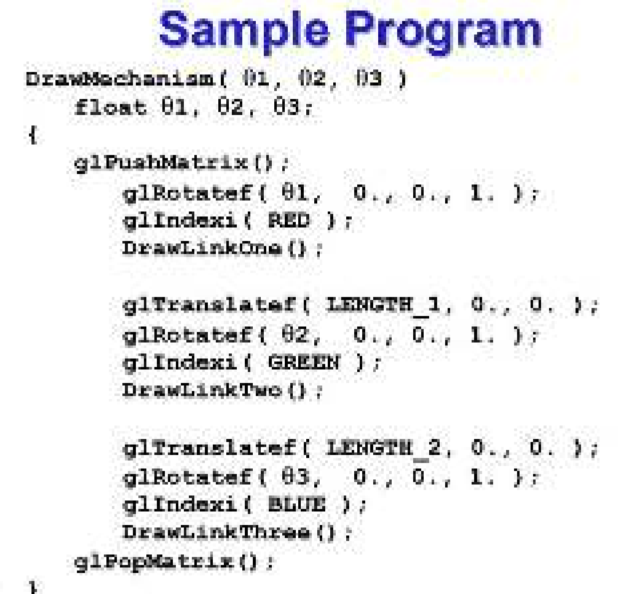
Sample Viewport Application

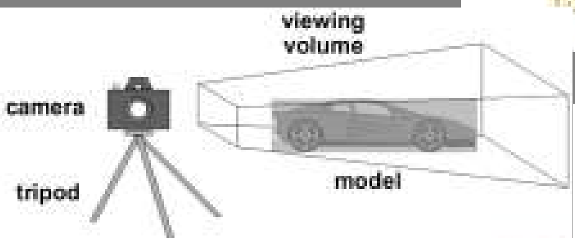


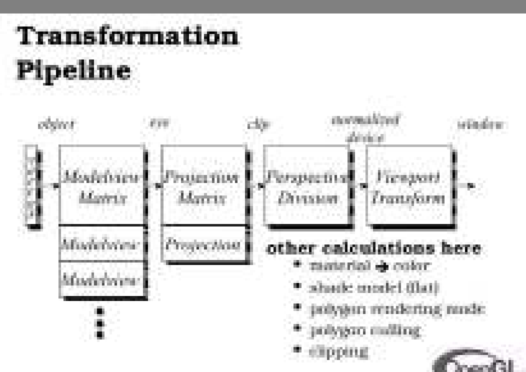
```c
// top left: top view
glViewport(0, win_height/2, win_width/2, win_height/2);
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
glOrtho(-3.0, 3.0, -3.0, 3.0, 1.0, 50.0);
gluLookAt(0.0, 5.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -1.0);
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
glCallList(object);

// top right: right view
glViewport(win_width/2, win_height/2, win_width/2, win_height/2);
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
glOrtho(-3.0, 3.0, -3.0, 3.0, 1.0, 50.0);
gluLookAt(5.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0);
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
glCallList(object);

// bottom left: front view
glViewport(0, 0, win_width/2, win_height/2);
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
glOrtho(-3.0, 3.0, -3.0, 3.0, 1.0, 50.0);
gluLookAt(0.0, 0.0, 5.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0);
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
glCallList(object);

// bottom right: rotating perspective view
glViewport(win_width/2, 0, win_width/2, win_height/2);
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
gluPerspective(70.0, 1.0, 1, 50);
gluLookAt(0.0, 0.0, 5.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0);
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
glRotatef(30.0, 1.0, 0.0, 0.0);
glRotatef(Angle, 0.0, 1.0, 0.0);
glCallList(object);
```

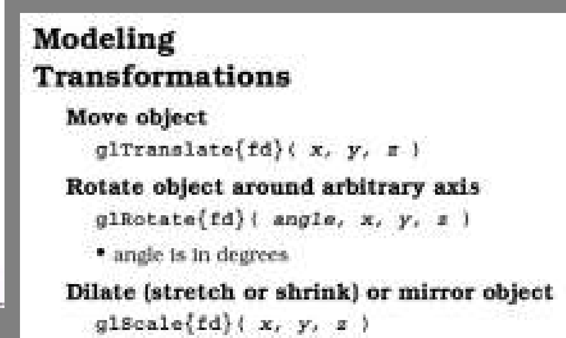
Ex. de programe

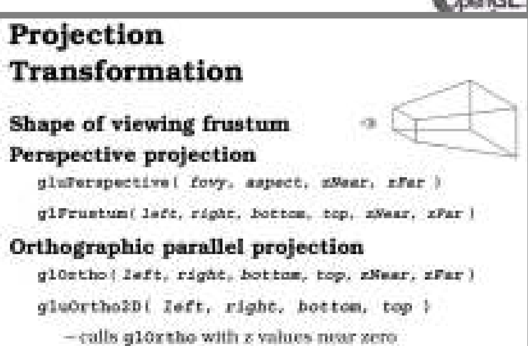


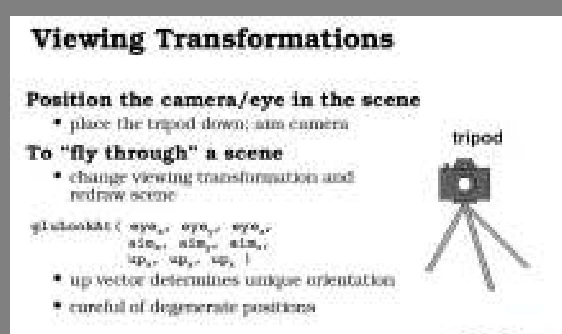




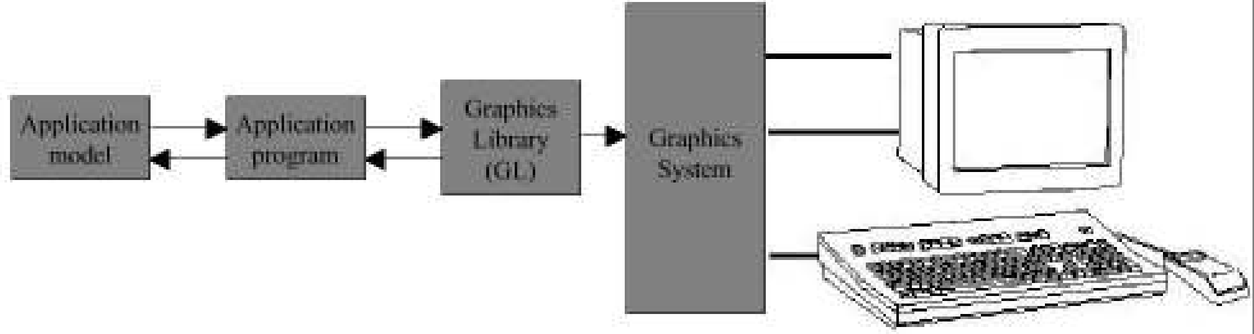


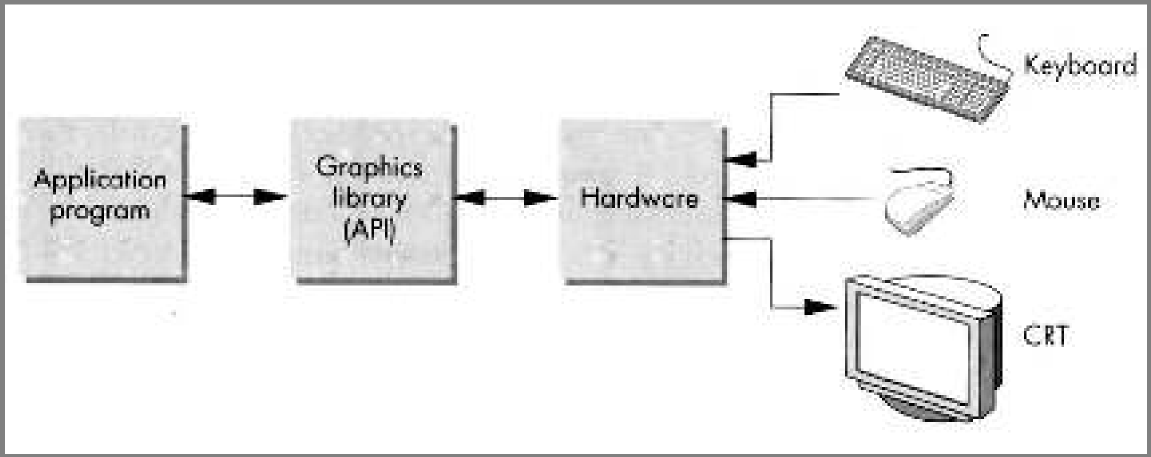


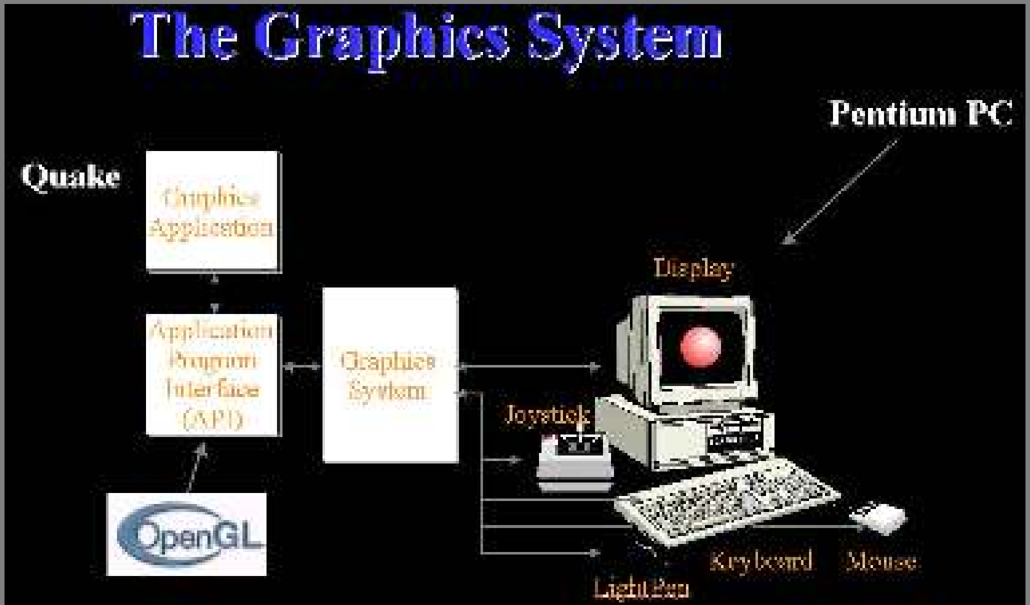




Sistem grafic



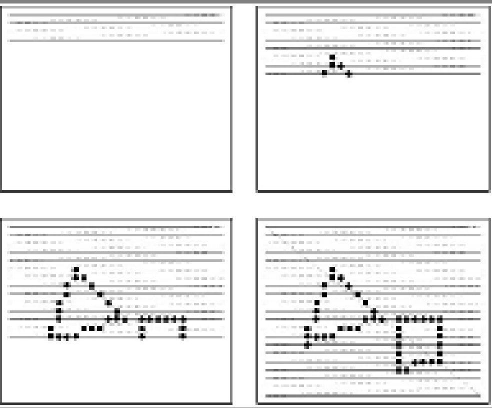


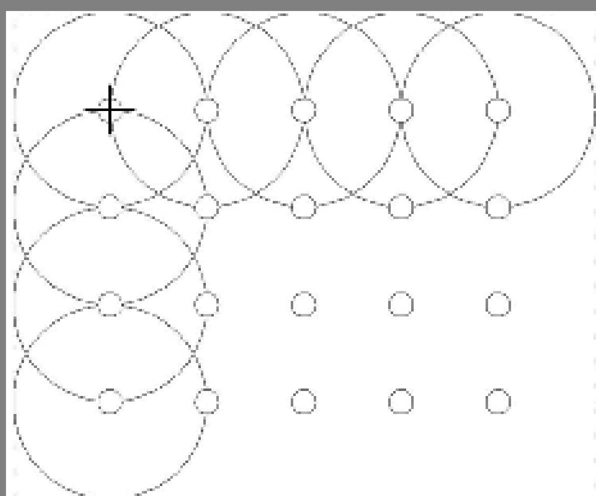


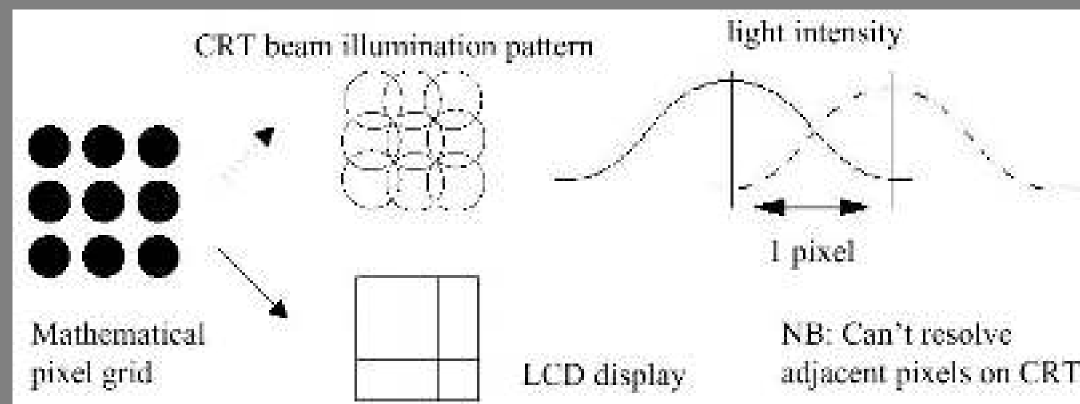
Grafica de tip rastru

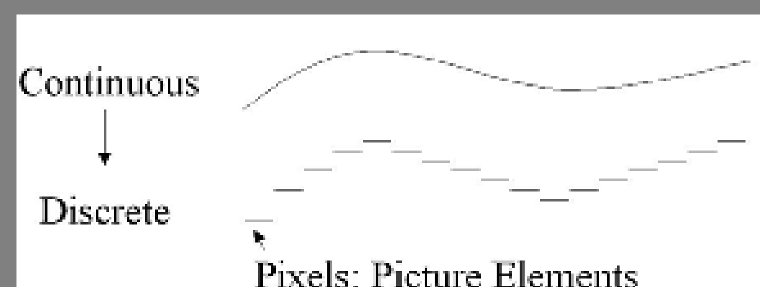
- Display de tip rastru: spațiu de afișare alcătuit dintr-o matrice rectangulara de elemente grafice elementare (pixeli)
- Pixel (picture element): elementul cel mai fin vizibil pe ecran
- Rezoluție ecran: nr. de pixeli pe verticala x nr. de pixeli pe orizontala

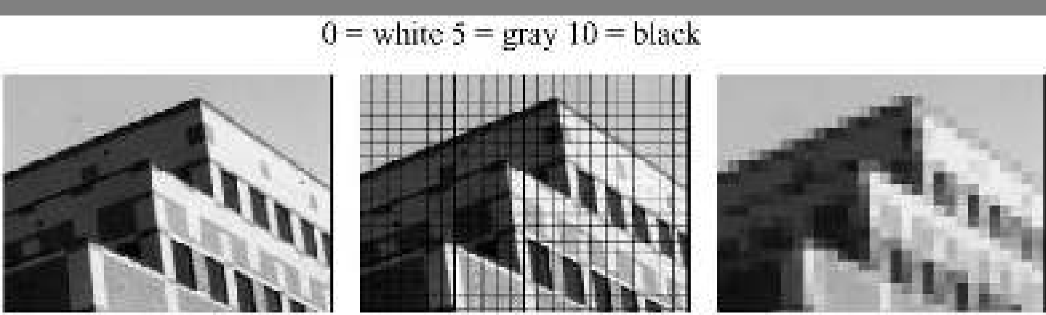
Discretizare



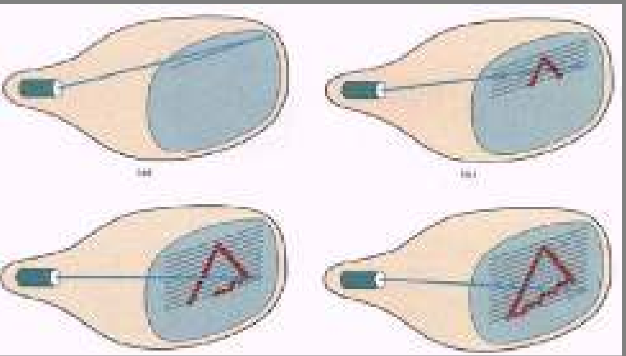


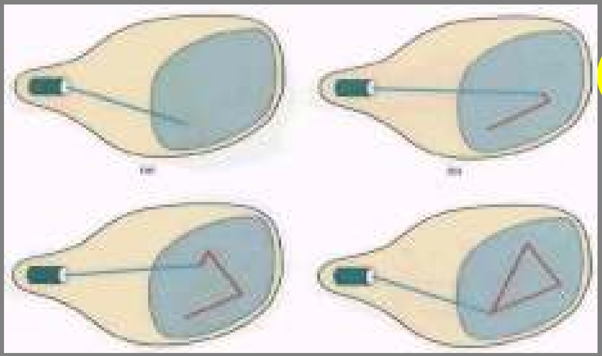






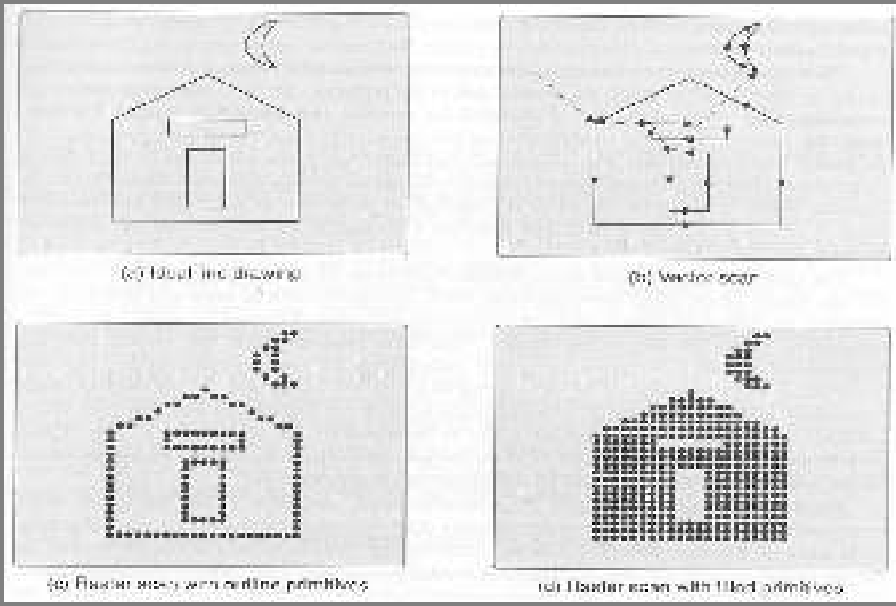
Grafica rastru/ vectoriala

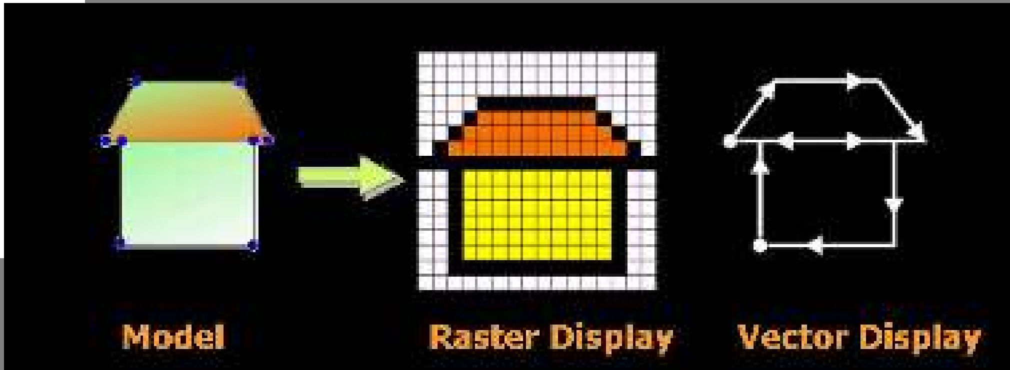




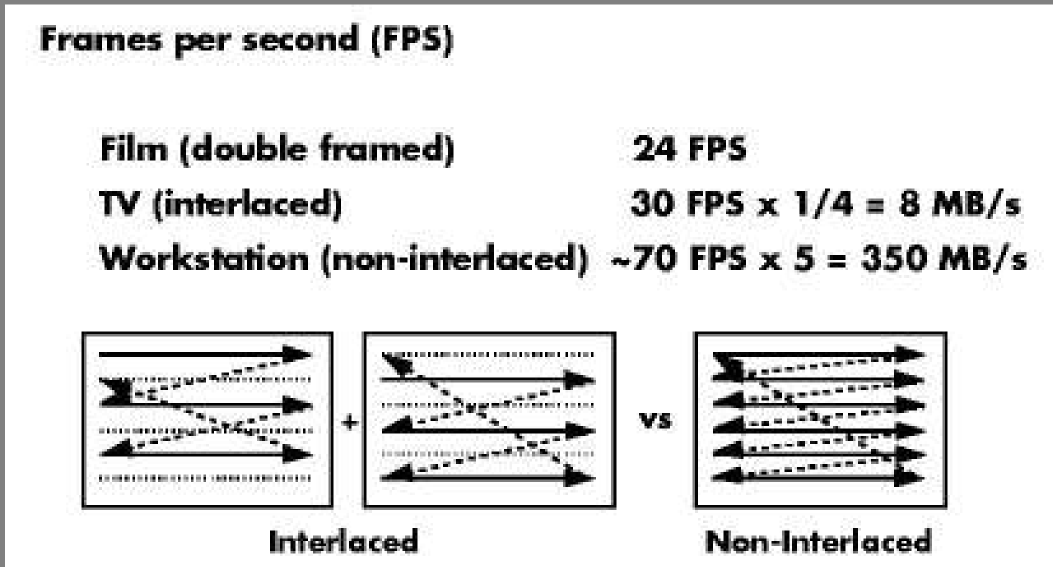
Vector Displays

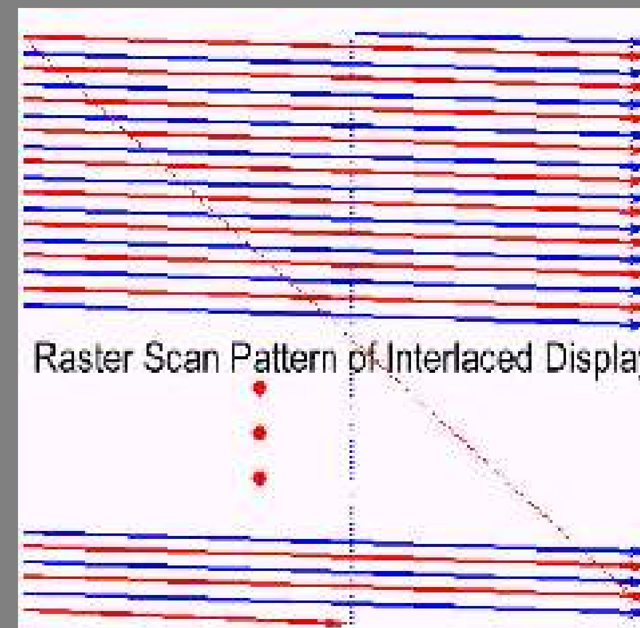
- Oscilloscopes were some of the 1st computer displays
- Used by both analog and digital computers
- Computation results used to drive the vertical and horizontal axis (X-Y)
- Intensity could also be controlled (Z-axis)
- Used mostly for line drawings
- Called *vector*, *calligraphic* or affectionately *stroker* displays
- Display list had to be constantly updated (except for storage tubes)

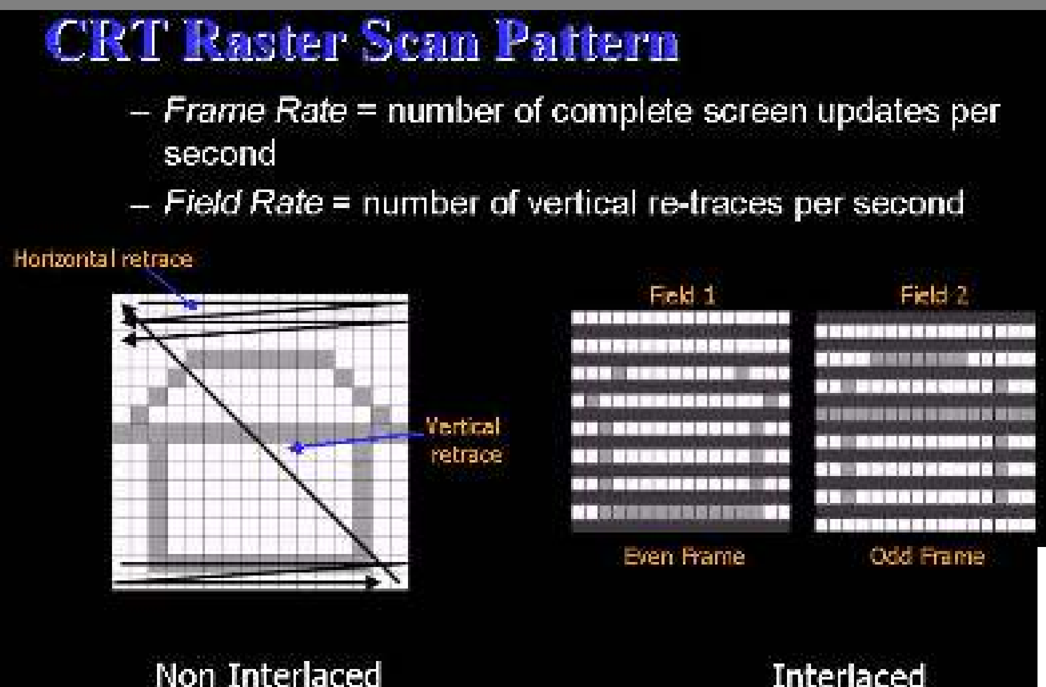


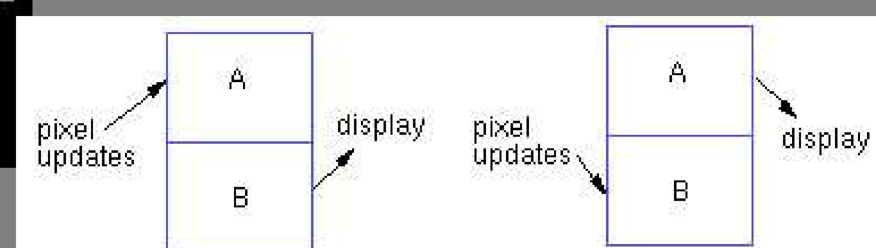


Refresh


Frames per second (FPS)
Film (double framed) 24 FPS
TV (interlaced) 30 FPS x 1/4 = 8 MB/s
Workstation (non-interlaced) ~70 FPS x 5 = 350 MB/s
+
vs
Interlaced
Non-Interlaced


Raster Scan Pattern of Interlaced Display

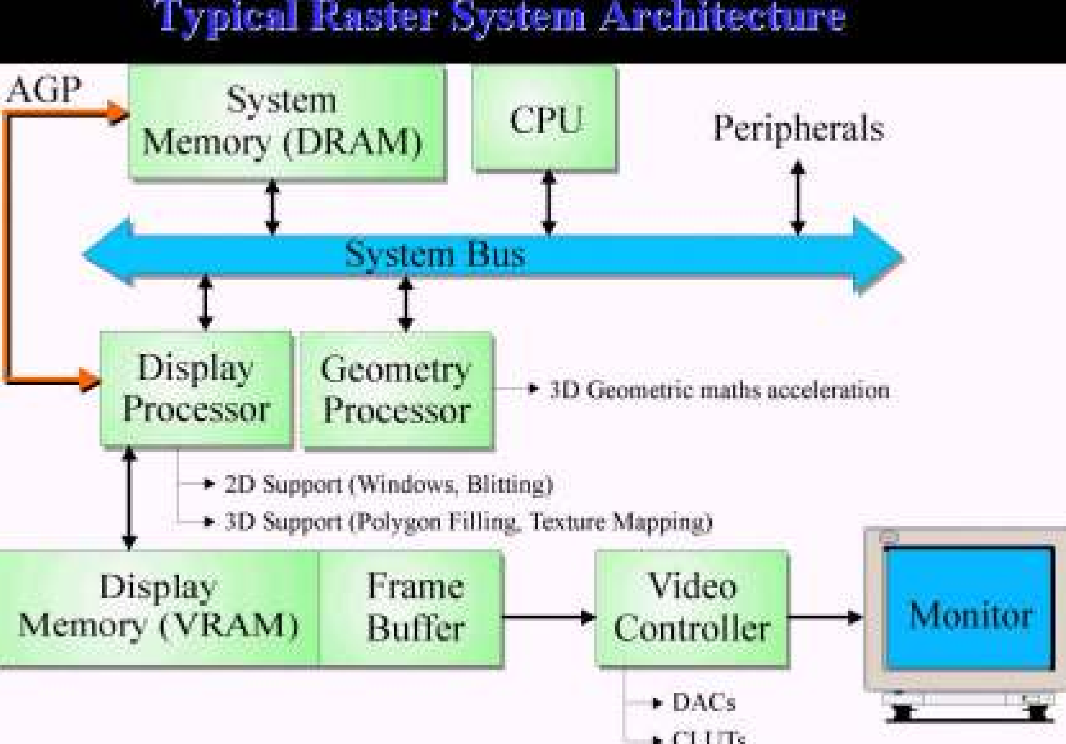

CRT Raster Scan Pattern
– Frame Rate = number of complete screen updates per second
– Field Rate = number of vertical re-traces per second
Horizontal retrace
Vertical retrace
Field 1
Field 2
Even Frame
Odd Frame
Non Interlaced
Interlaced

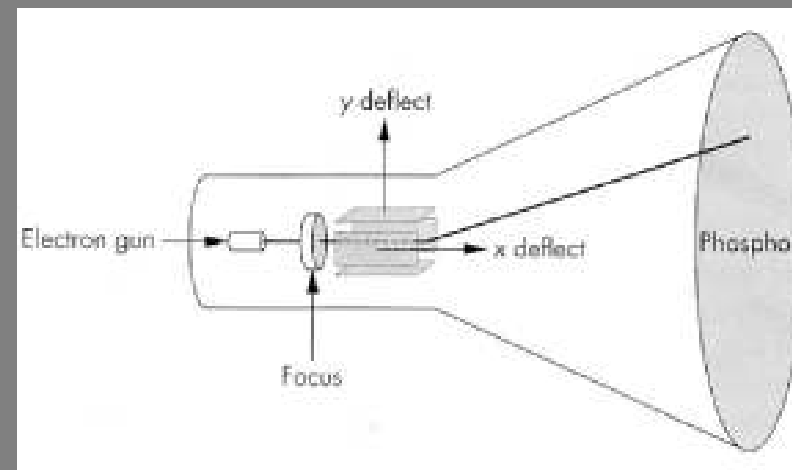

pixel updates
A
B
display
pixel updates
A
B
display

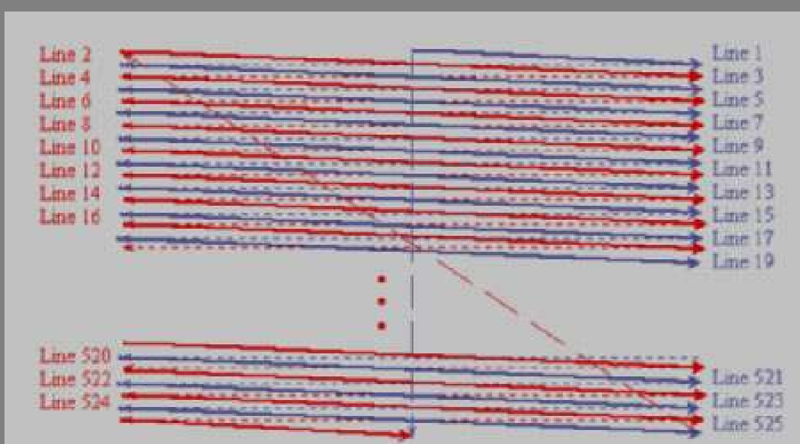
Grafica de tip rastru: termeni

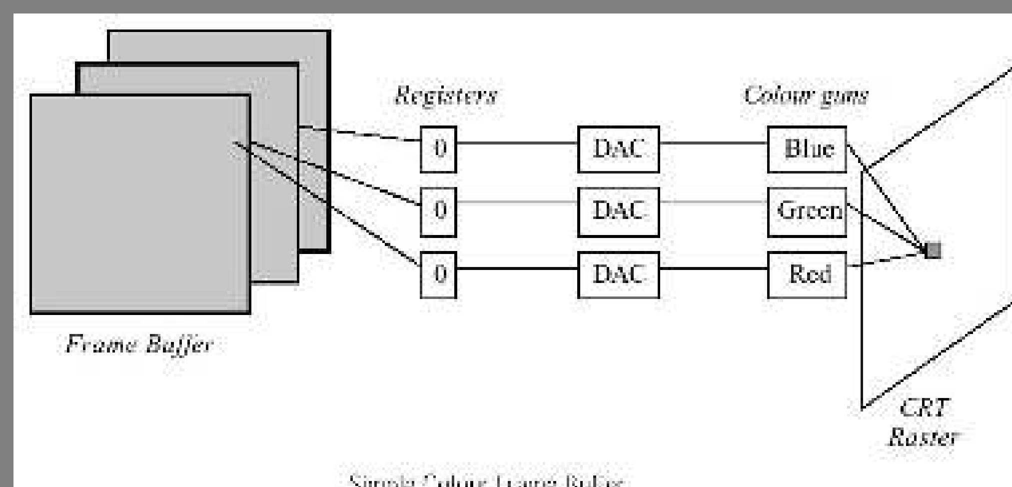
- Imagine digitalizata: A = (a_{ij}) unde a_{ij}= 0,1 sau 0...n (n – numărul de culori)
- Linie de scanare – linie de pixeli
- Zona tampon-cadru (frame buffer): pentru prelucrarea ulterioara a imaginii
- Zona de memorie: memoria video

Sistem rastru

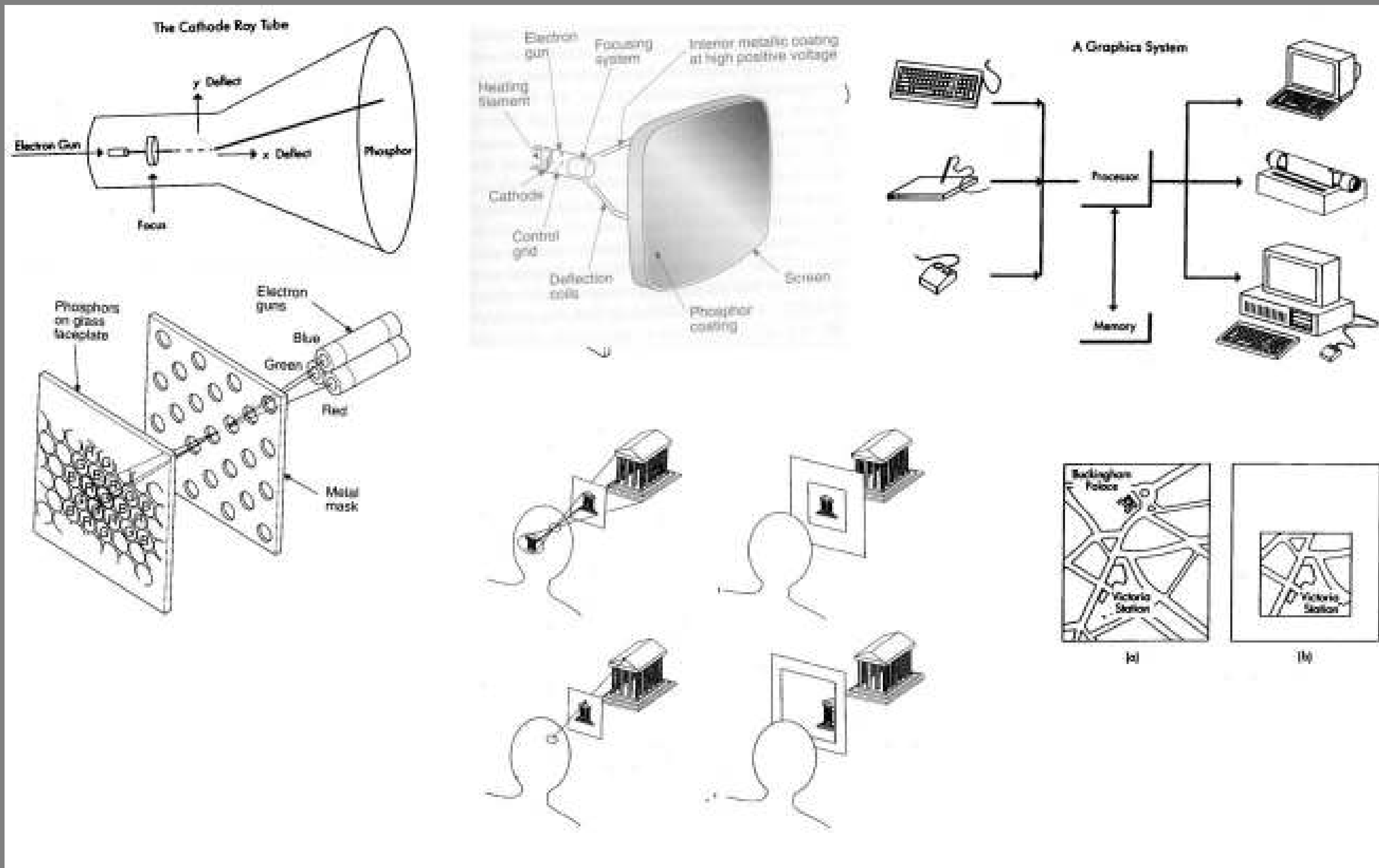




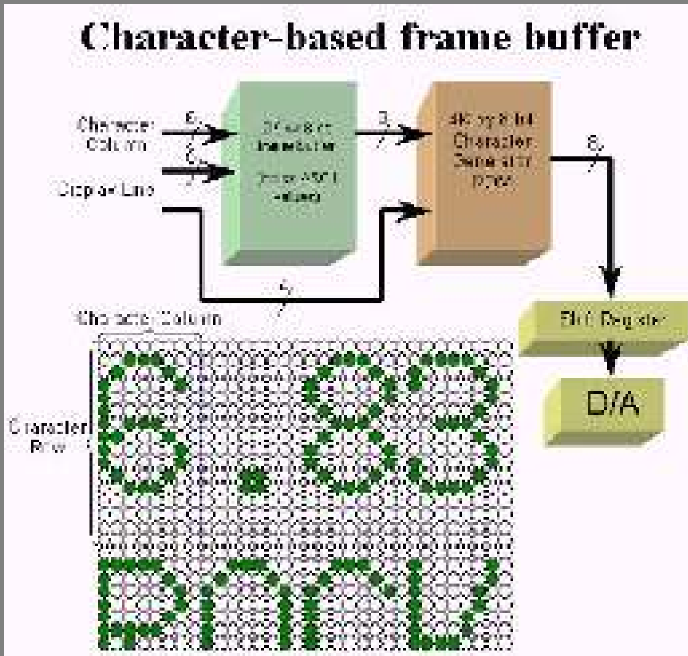


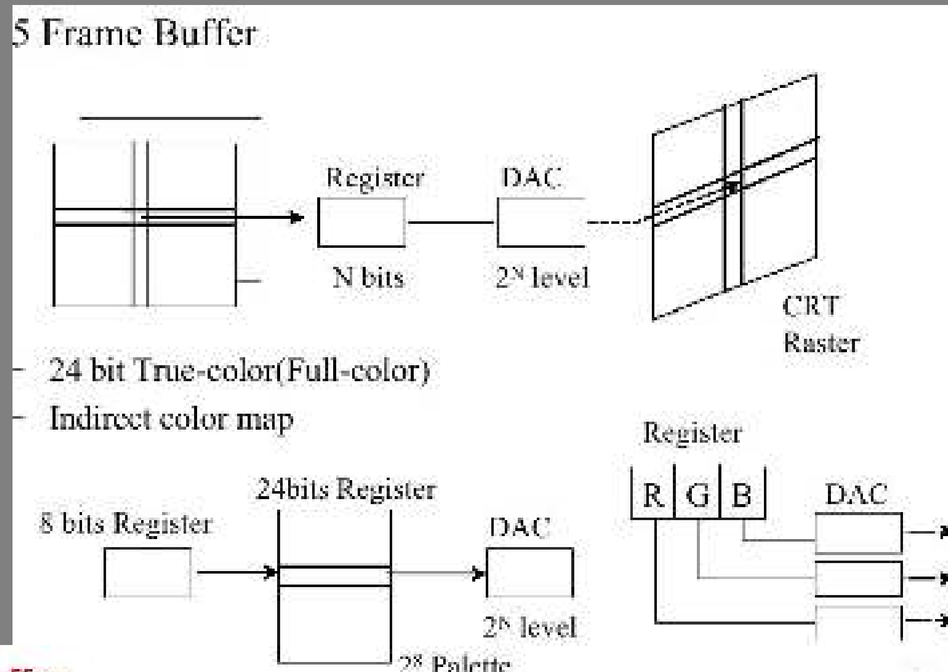


Principiul rastrului



Frame buffer (tampon cadru)



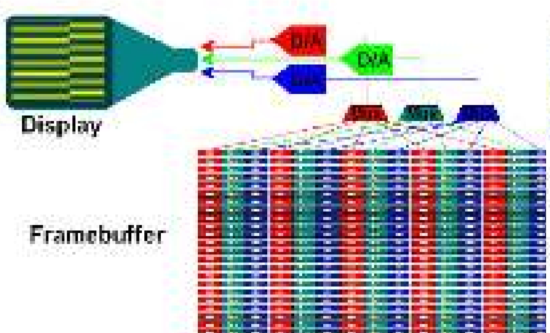


A *true-color* (aka *24-bit* or *32-bit*) *framebuffer* stores one byte each for red, green, and blue

Each pixel can thus be one of 2^{24} colors

Pay attention to Endian-ness

How can 24-bit and 32-bit mean the same thing here?

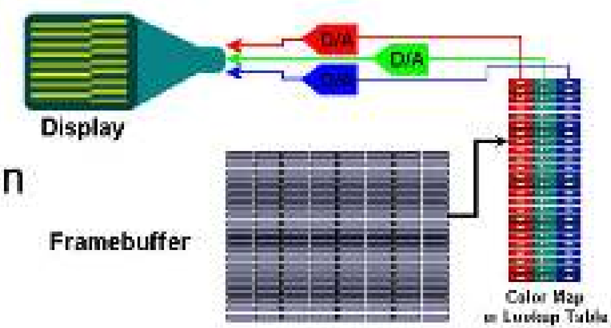


An *indexed-color* (*8-bit* or *PseudoColor*) framebuffer stores one byte per pixel

This byte indexes into a *color map*:

How many colors can a pixel be?

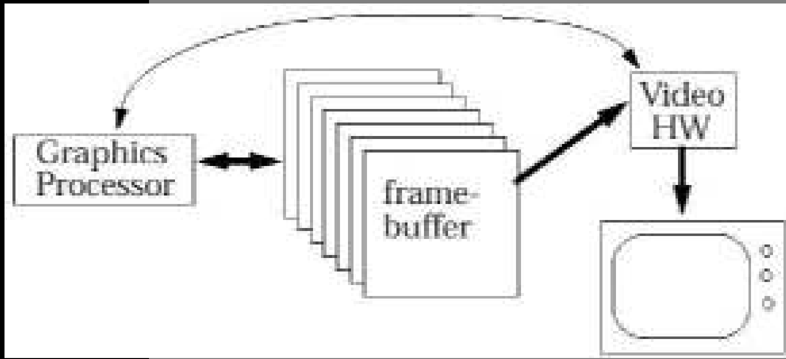
Cute trick: color-map animation



Video

- CRT electron guns receive an analogue voltage signal from DACs, 1 per colour channel.
- Most current DACs are 8-bit per channel.

⇒ 24 bits per pixel required
  - 2^{24} possible colours = 16777216
  - (humans can see many more than this!)



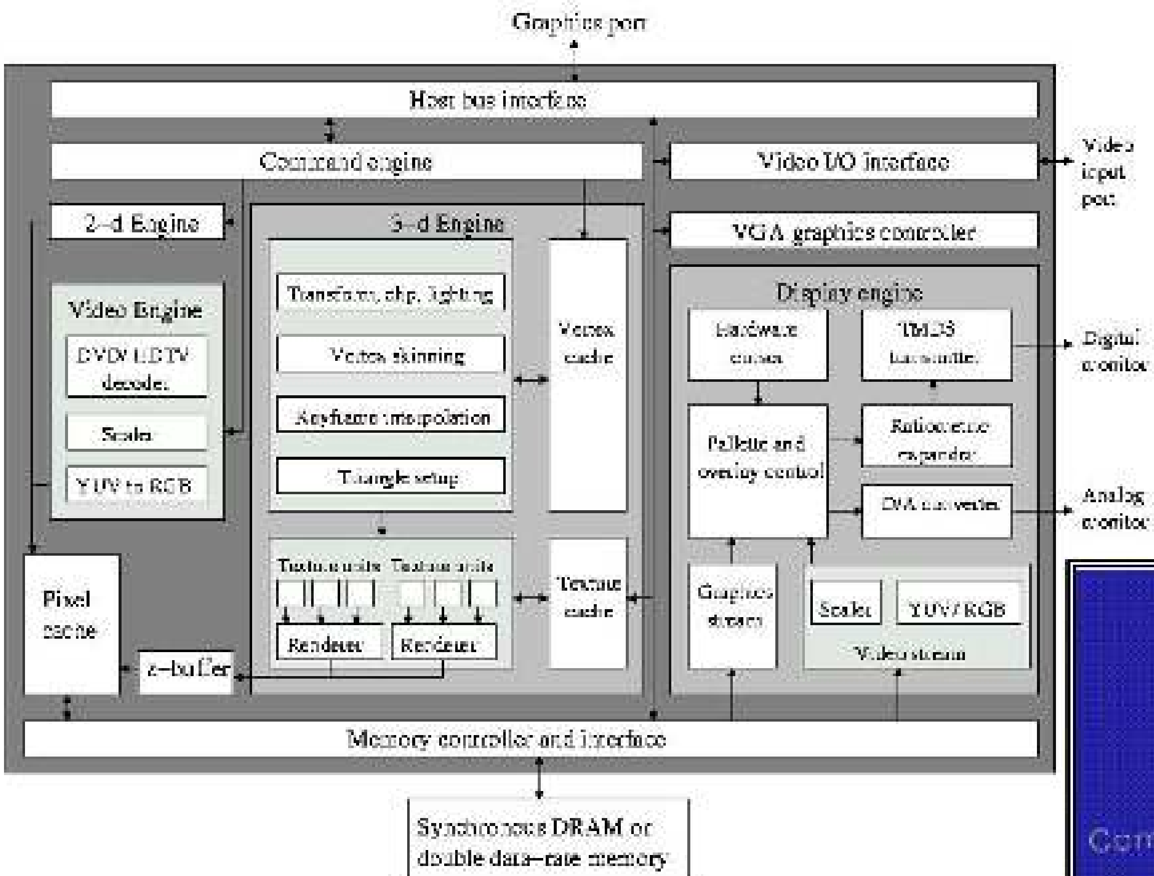
- Bandwidth requirements for a typical graphics system:
  - Resolution = 1024 × 768
  - Refresh rate = 75 Hz. non-interlaced
  - 24 bits per pixel

⇒ 176,847,200 bytes/sec. transfer required
∴ RAM access time ≤ 5.65 ns.

❶ Use faster RAM = VRAM
- Video RAM (dual ported)
  - CPU and DACs can access RAM simultaneously
  - no need for DMA or CPU latency
- more expensive than standard DRAM

❷ Reduce bandwidth:
- use Colour LookUp Tables (CLUT):
  - this is becoming very popular in systems using texture mapping: it reduces the total memory requirements for textures ⇒ CLUT per texture
- reduces memory per pixel
  - total storage costs are now down, but slight increase in latency due to CLUt lookup, but this is usually negligible.
- requires a fixed palette of colours

Video



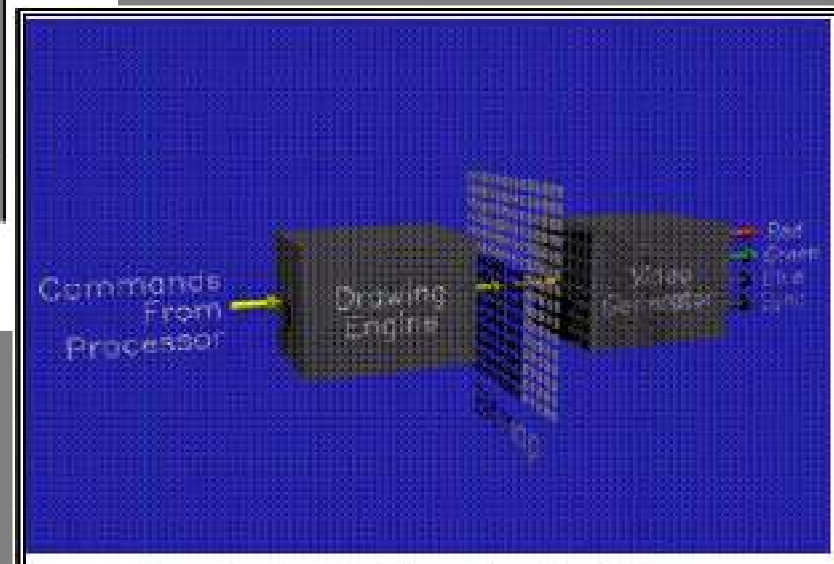
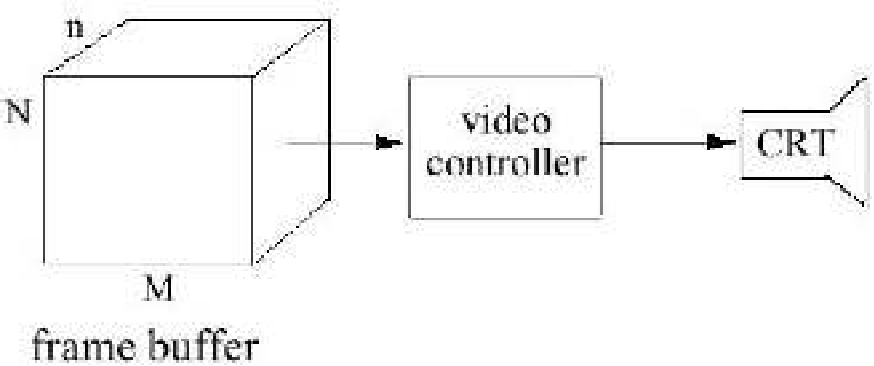
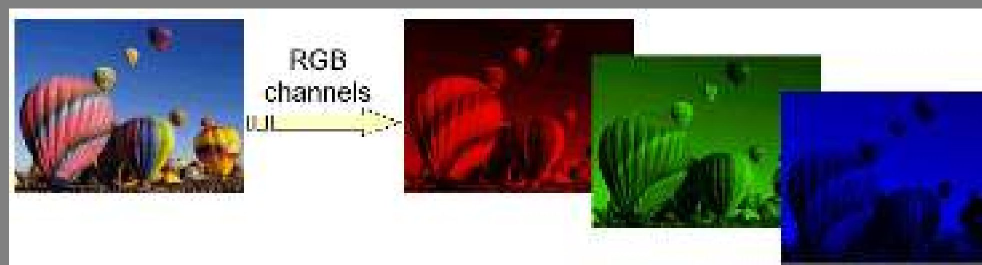


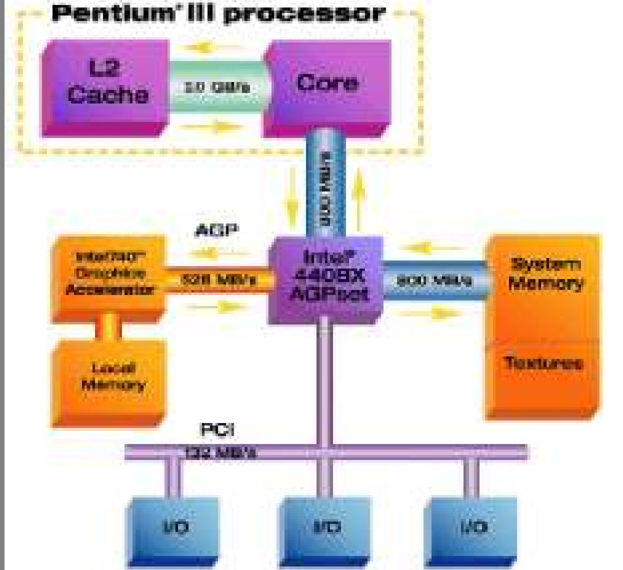
Figure 9 - Display Controller Block Diagram

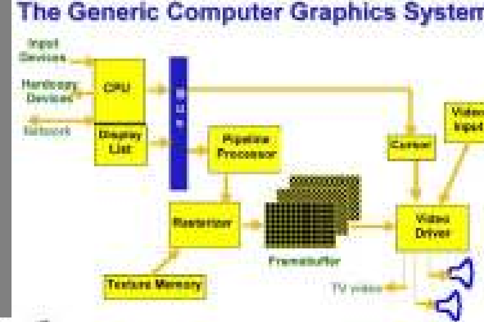




Grafica de tip rastru: termeni

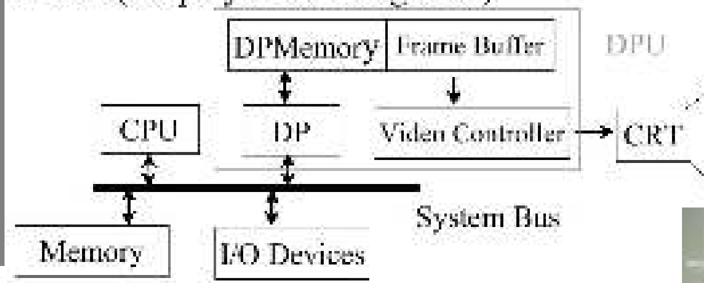
- Rasterizare: primitive afisate prin excluderea sau includerea unor pixeli în zona-tampon cadru
- Cuplor grafic (în funcție de viteza de execuție, rezoluția și numărul de culori simultane: HGC, CGA, EGA, VGA, SVGA, AGA.





Hardware, rasterizare

4 DPU (Display Processing Unit)



- Scan conversion (run-length encoding)
- Drawing Line Segments
- Character generation
- Refreshing Screen
- Interfacing with interactive input devices (ex. mouse)
- Additional functions
- Z-buffer
- VGA Card (Graphic Chip, VideoRAM, RAM DAC)
  - S3 911, ATI Mach 64, Tseng Labs ET4000/W32

controller. Since the intensity of the electron beam can be controlled by analog voltage signals, the color values represented digitally in the lookup tables or in the frame buffer must be converted to three analog signals, one for each color coordinate. This conversion is done by three digital-to-analog (D/A) converters. In addition to periodically refreshing the screen with the data from the frame buffer, video refresh controllers must also generate special synchronization signals for the monitors, which control the movement of the electron beam, specifying when it has to return to the left side of the screen to start scanning the next consecutive row (horizontal retrace) and when it has to return to the upper left corner to start the next image (vertical retrace). In order to sustain the image on the screen, the video refresh controller must generate periodically scanning electron beams which excite the phosphors again before they start fading. The flicker-free display requires the screen to be refreshed at about 60 times a second.

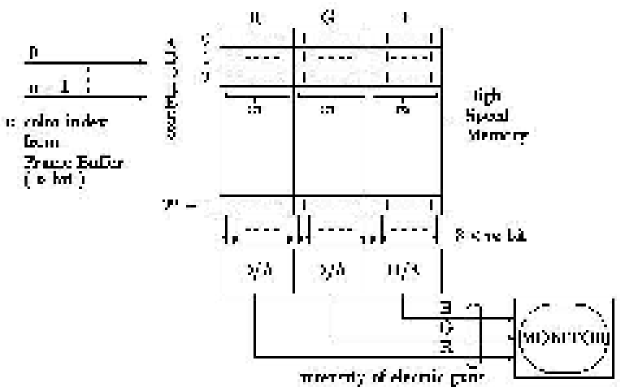
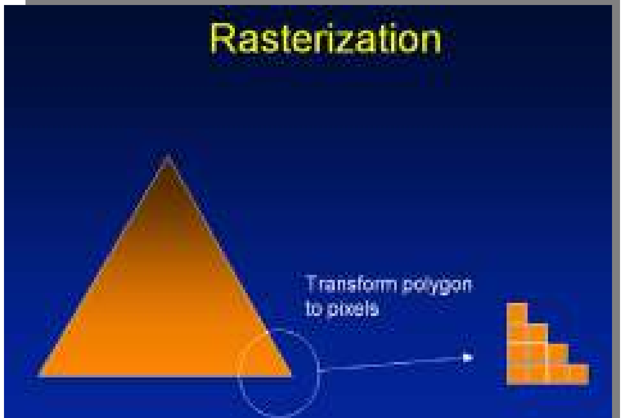


Figure 1.5: Organization of a video lookup table



Screen Resolution

- Number of pixels per square cm
  - Measured in dots per inch (*dpi*)
- Number of adressable colors per pixel
  - measured in bits
- Depends on the medium:

  TV Screen: 30 dpi, 8 bits color
  Computer Screen: 70-100 dpi, up to 24 bits color
  Laser Printer: 300-2400 dpi, 3 bits color (8 colors)
  Photo: ~ 800 dpi, 36 bits color

Hardware

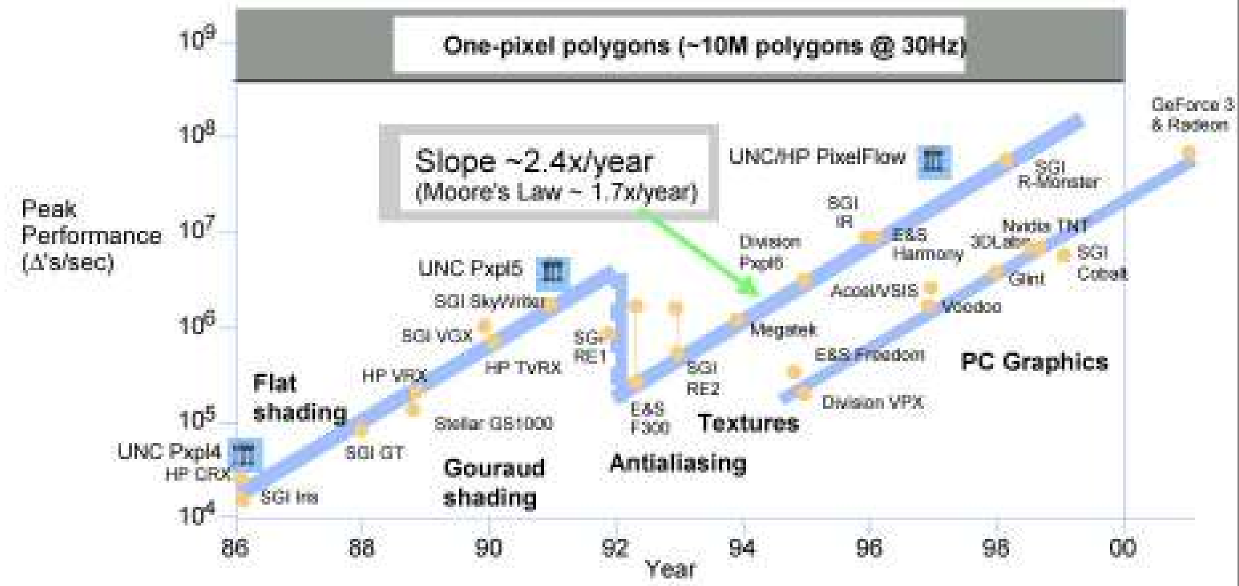
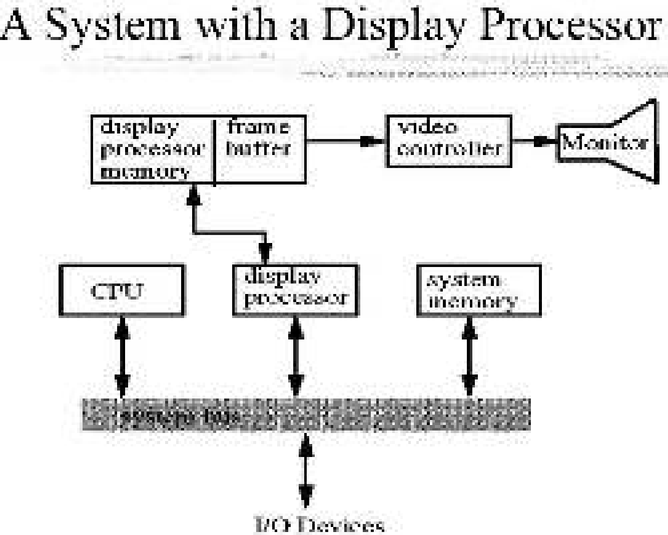
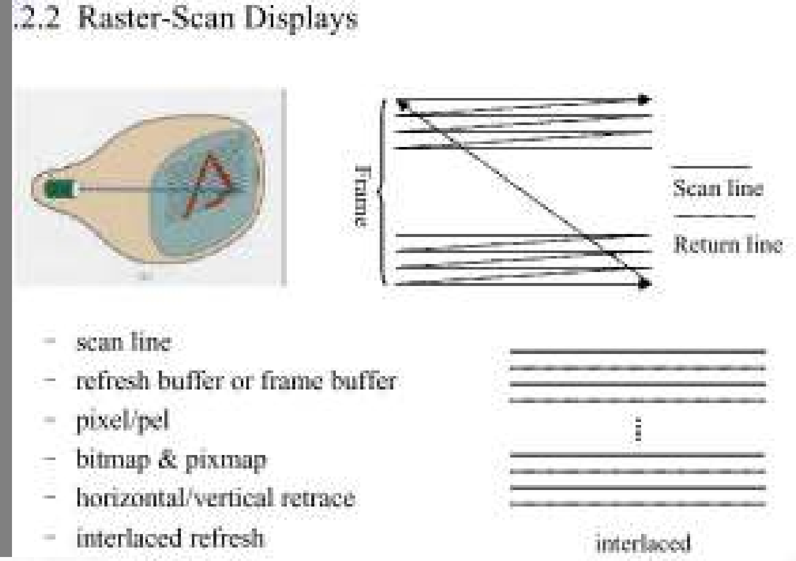
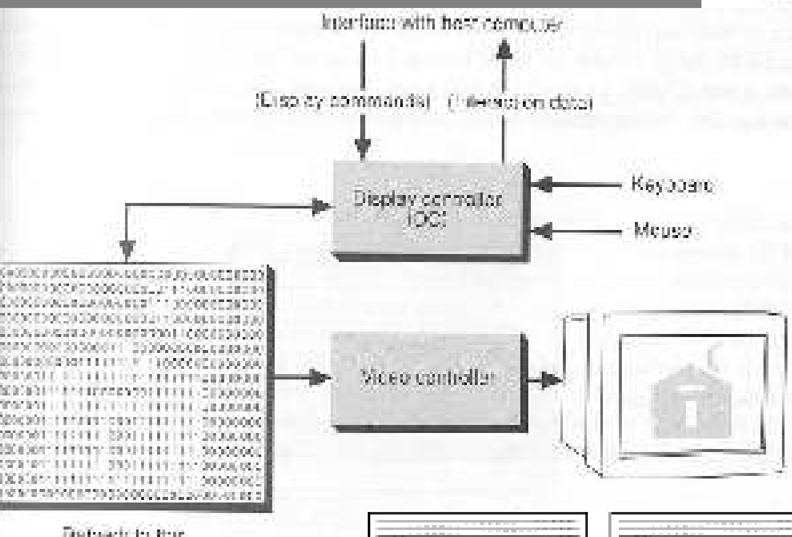


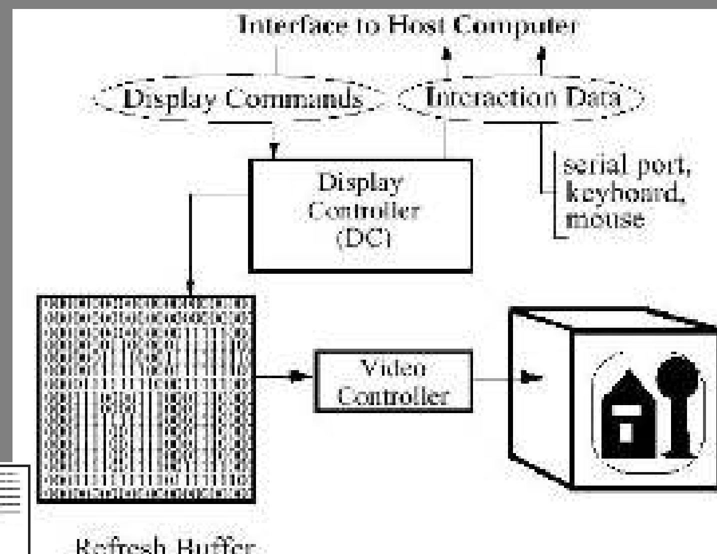
Figure 1: *Performance of Graphics GPUs. They have been progressing at a rate faster than Moore's law. Courtesy of John Poulton, UNC Chapel Hill.*

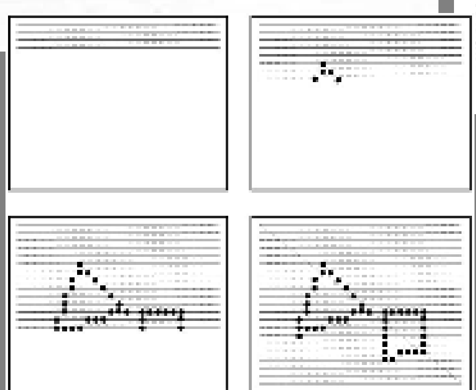
Display

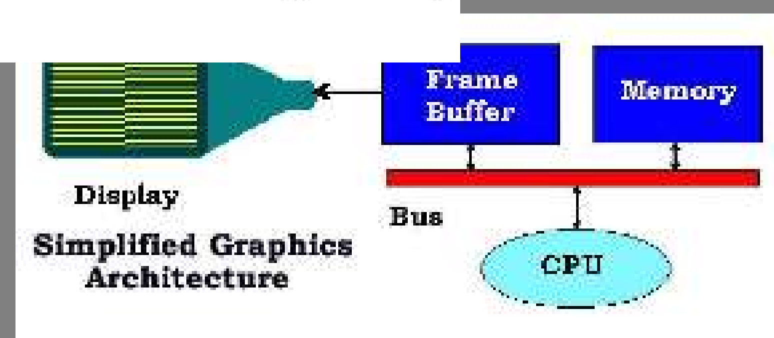

A System with a Display Processor
display processor memory
frame buffer
video controller
Monitor
CPU
display processor
system memory
system bus
I/O Devices


2.2 Raster-Scan Displays
Frame
Scan line
Return line
– scan line
– refresh buffer or frame buffer
– pixel/pel
– bitmap & pixmap
– horizontal/vertical retrace
– interlaced refresh
interlaced


Interface with host computer
(Display commands)
(Interaction data)
Display controller (DC)
Keyboard
Mouse
Video controller
Refresh buffer

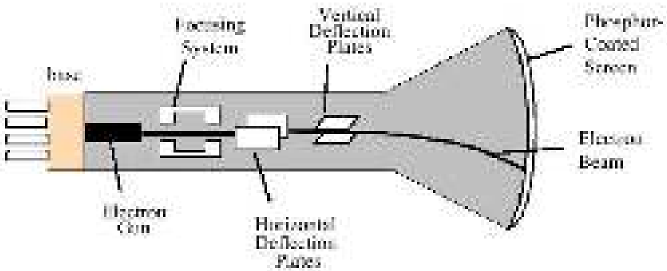

Interface to Host Computer
Display Commands
Interaction Data
Display Controller (DC)
serial port, keyboard, mouse
Video Controller
Refresh Buffer



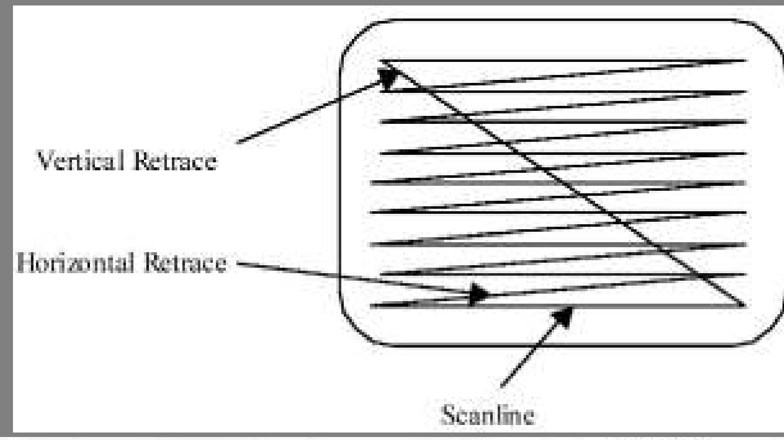

Frame Buffer
Memory
Display
Bus
CPU
Simplified Graphics Architecture

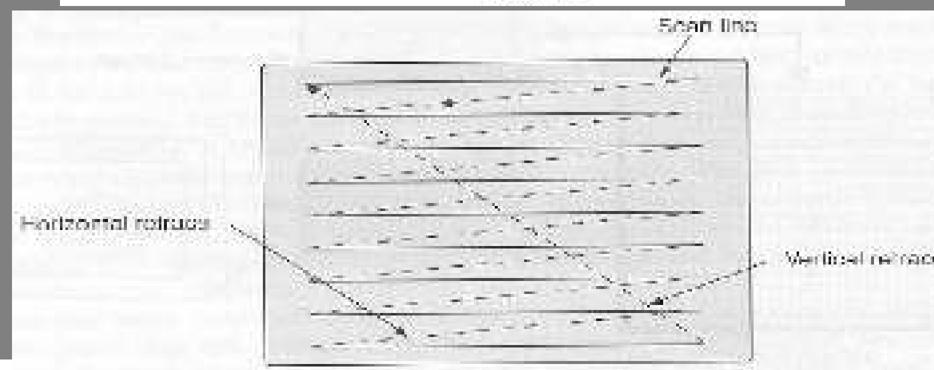
Display

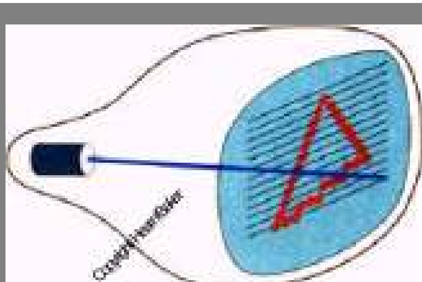
1 CRT (Cathode-Ray Tubes)

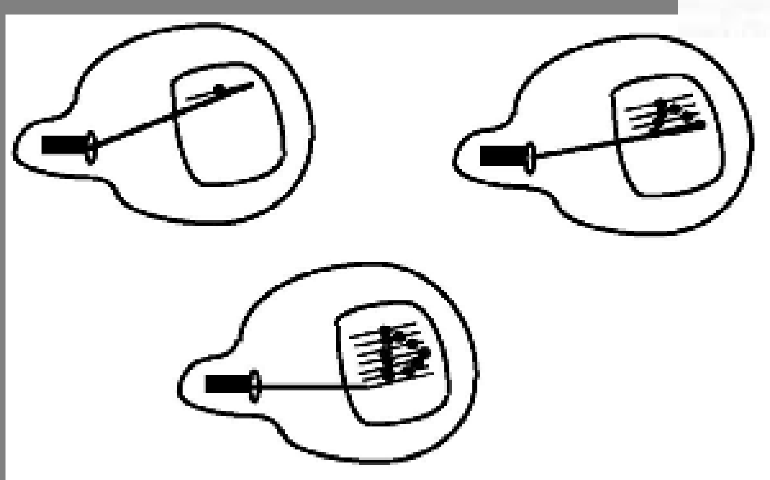


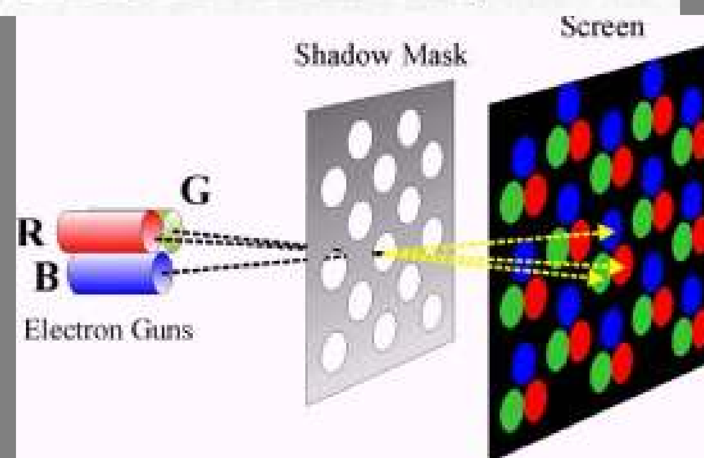
- intensity
- focusing
- persistence - the time it takes emitted light to decay to 1/10 of its original intensity
- refresh rate (persistence <-> refresh rate)





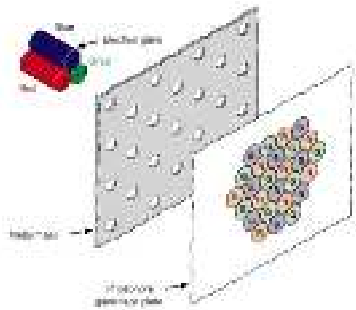


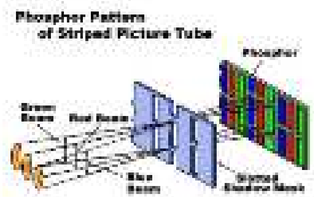


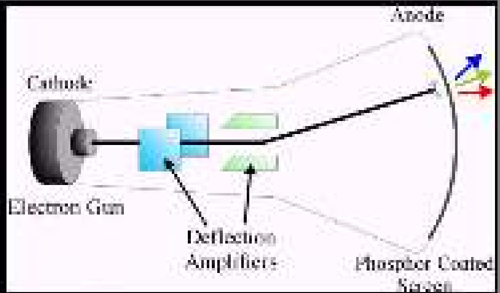


Color CRT

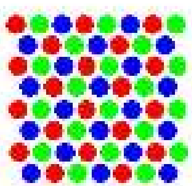
Color CRTs have
- Three electron guns
- A metal *shadow mask* to differentiate the beams



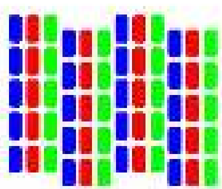




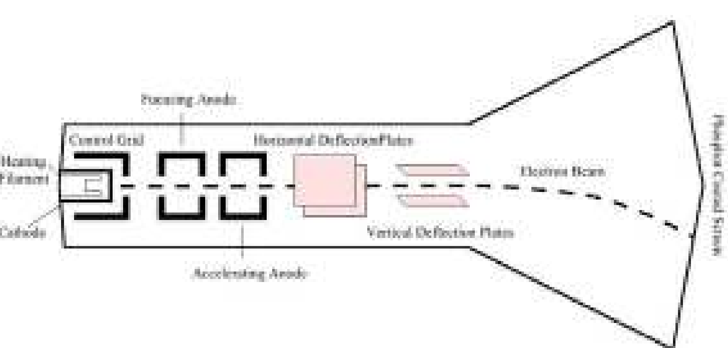
- Color CRTs are *much* more complicated
  - Requires manufacturing very precise geometry
  - Uses a pattern of color phosphors on the screen:

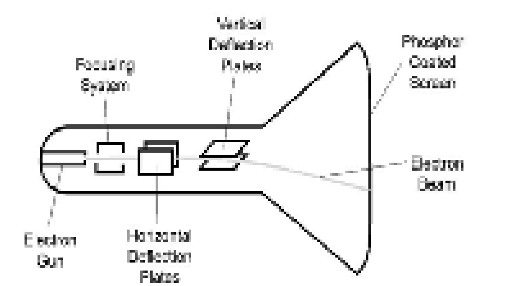


Delta electron gun arrangement



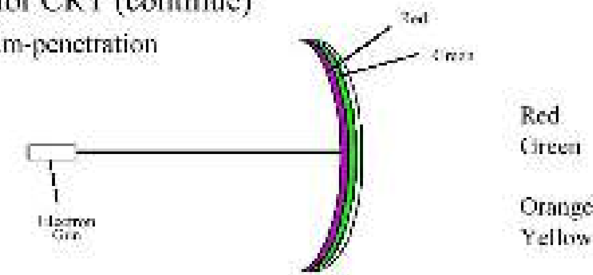
In-line electron gun arrangement



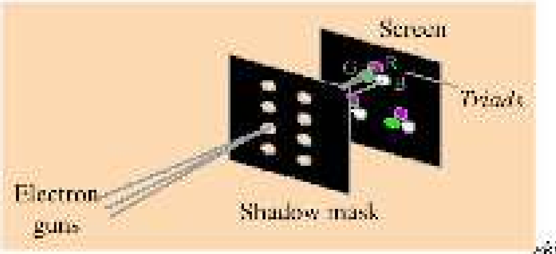


.4 Color CRT (continue)

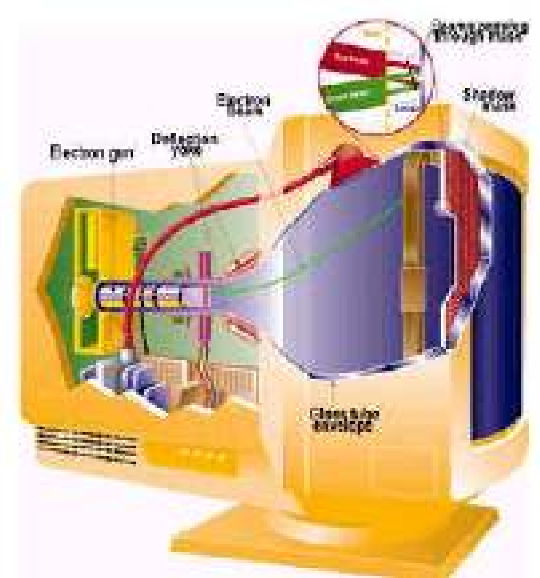
- beam-penetration



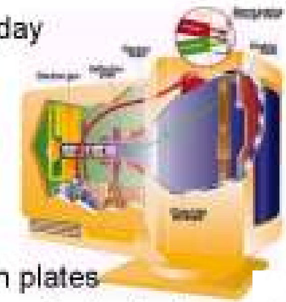
- shadow-mask



Color CRT



- Cathode Ray Tubes (CRTs)
  - Most common display device today
  - Evacuated glass bottle (last of the vacuum tubes)
  - Heating element (filament)
  - Electrons pulled towards anode focusing cylinder
  - Vertical and horizontal deflection plates
  - Beam strikes phosphor coating on front of tube



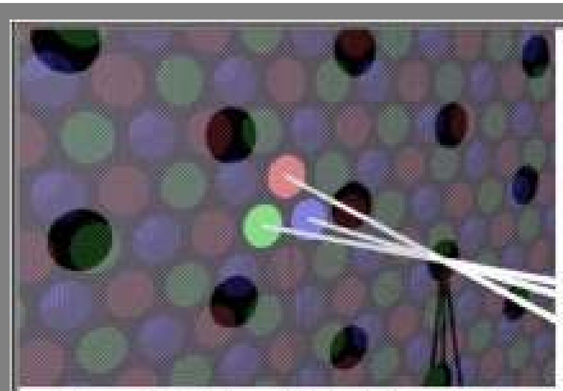
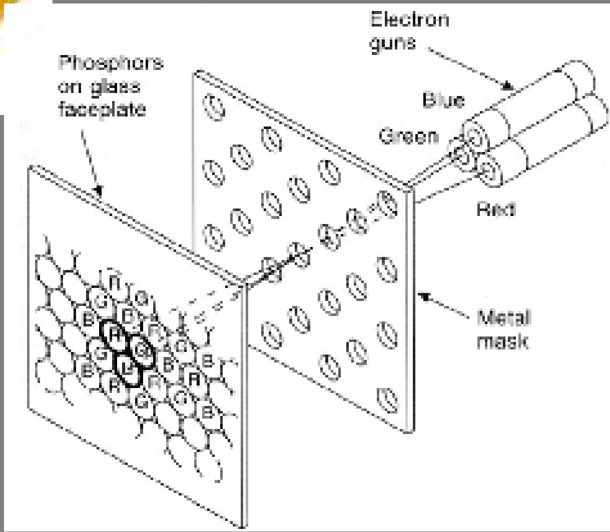
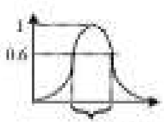


Figure 5 - CRT Shadow Mask and Phosphor Dots

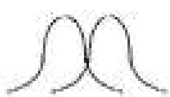


2.2.1 CRT (continue)

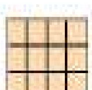
- intensity distribution



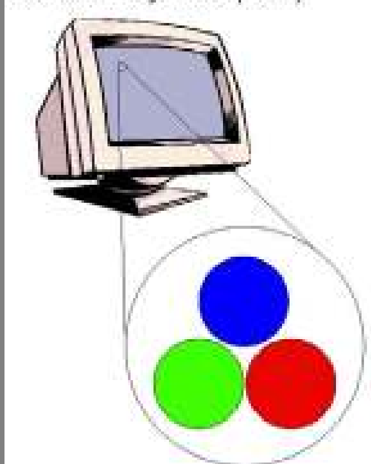
- separation->sharpness



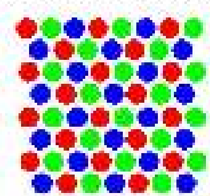
- resolution = 1/spot_size, informally (w * h)
  - *high-definition* system
- aspect ratio = # of vertical / # of horizontal = 3/4

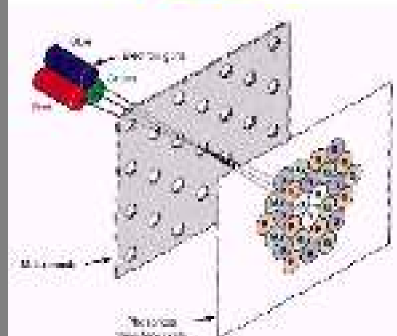


Cathode Ray Tube (CRT)

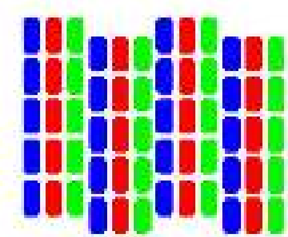


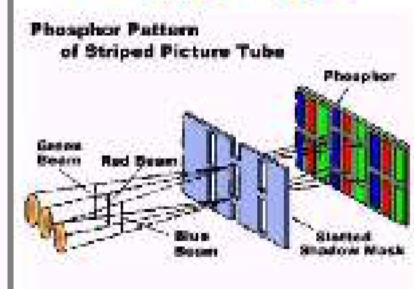
Delta Electron Gun Arrangement



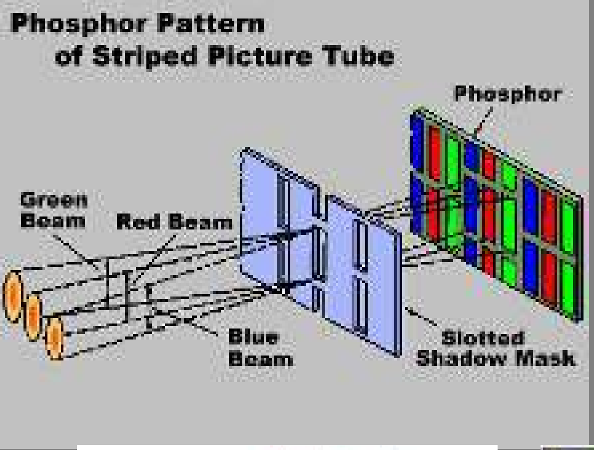


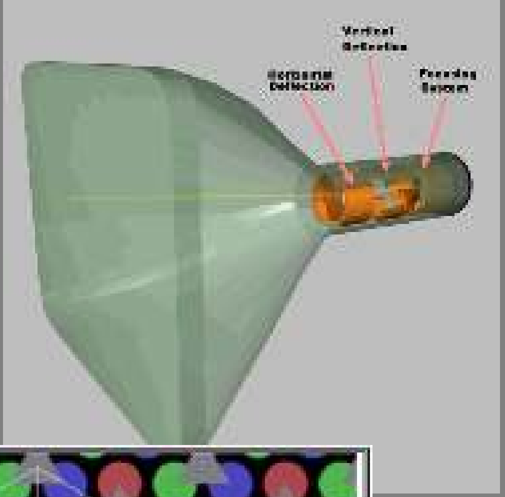
In-line Electron Gun Arrangement

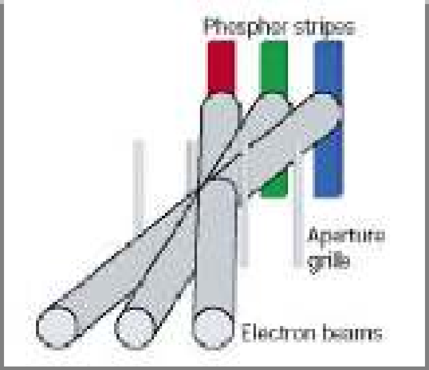




Color CRT







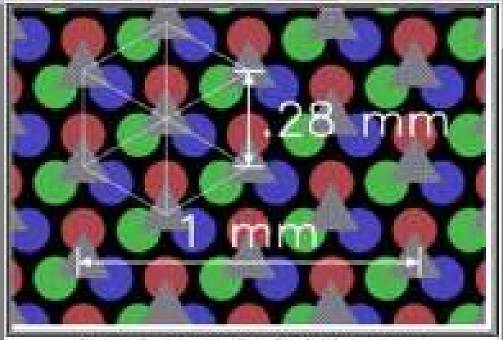
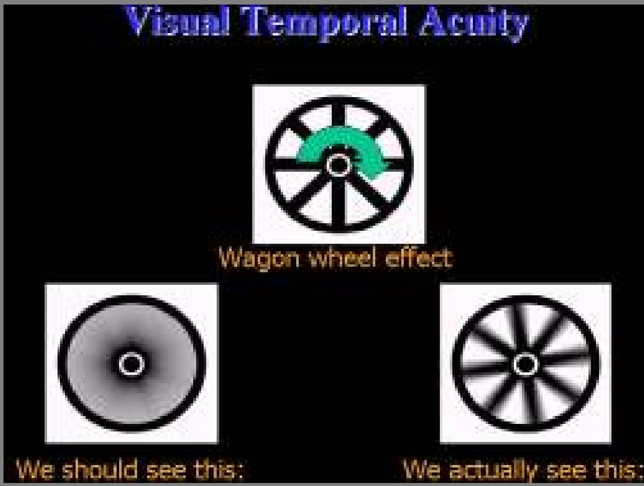


Figure 7 - Monitor Dot Pitch Measurement



Display Characteristics

2D Graphics displays are characterised by

- resolution = number of independent pixels (e.g. 1024 × 768)
- colours/bits per pixel (e.g. 24bit → 2^{24} colours = 16,777,216)
- dot pitch = no. of phosphors per inch. (dpi)
- refresh rate (Hz.)
- interlaced / non-interlaced
- phosphor wavelengths (nm.)
  - these are usually specified using *chromaticity* values
- whitepoint (K)
  - Color temperature, in degrees Kelvin
  - some monitors allow you to change the whitepoint

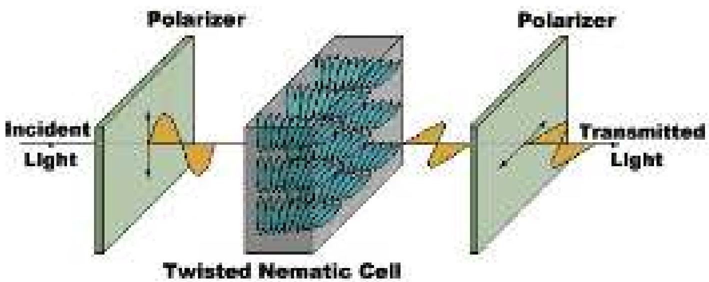
Refresh Rates & Broadcast Standards

- Human eye can perceive updates of 60 - 80 Hertz.
  - *critical fusion frequency*
- Current displays typically 70 Hz.
- European (except France) TV (PAL), introduced in 1960:
  - Phase Alternating Line
  - frame rate = 25 Hz. and field rate = 50 Hz.
  - 625 scan lines
- US + Japanese TV (NTSC), introduced in 1953:
  - National Television System Committee (or "Never The Same Colour")
  - frame rate = 29.97 Hz. and field rate = 59.94 Hz.
  - 525 scan lines
- Both TV systems use *interlacing*.

LCD

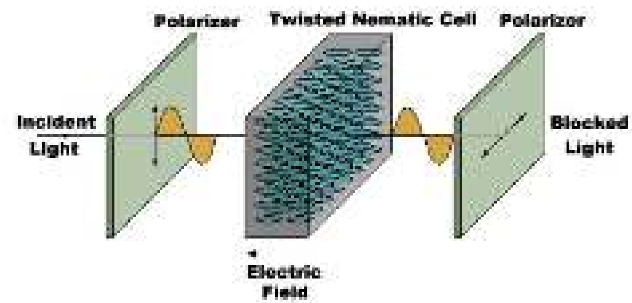
Liquid Crystal Displays (LCDs)

- LCDs: organic molecules, naturally in crystalline state, that liquefy when excited by heat or E field
- Crystalline state twists polarized light 90°.



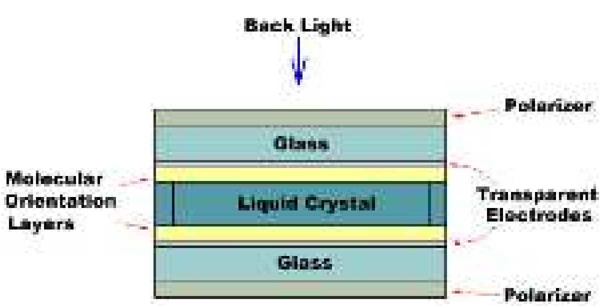
Liquid Crystal Displays (LCDs)

- LCDs: organic molecules, naturally in crystalline state, that liquefy when excited by heat or E field
- Crystalline state twists polarized light 90°



Transmissive & reflective LCDs:

- LCDs act as light valves, not light emitters, and thus rely on an external light source.
- Laptop screen: backlit, *transmissive display*
- Palm Pilot/Game Boy: *reflective display*



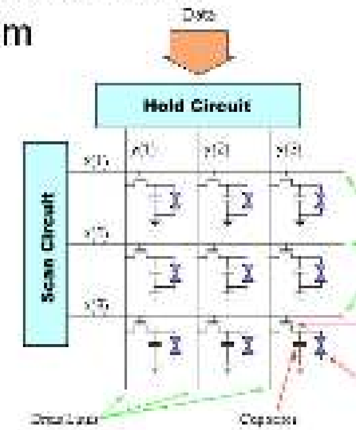
Active-Matrix LCDs

- LCDs must be constantly refreshed, or they fade back to their crystalline state
  - Refresh applied in a raster-like scanning pattern
  - *Passive LCDs*: short-burst refresh, followed by long slow fade in which LCD is between On & Off
  - Not very crisp, prone to *ghosting*
- *Active matrix LCDs* have a transistor and capacitor at every cell
  - FET transfers charge into capacitor during scan
  - Capacitor easily holds charge till next refresh

Active Matrix LCDs

- Active-matrix pros: crisper with less ghosting
- Active-matrix cons: more expensive
- Today, most things seem to be active-matrix

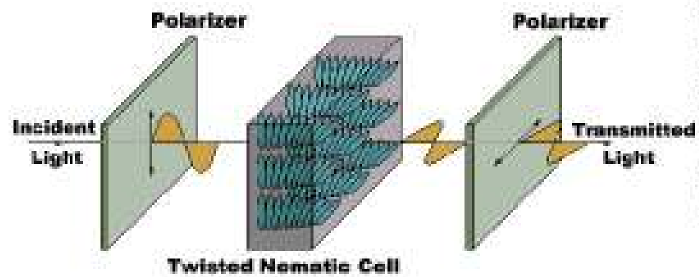
More on LCDs:
http://144.125.176.215/Displays/e3_s1.htm



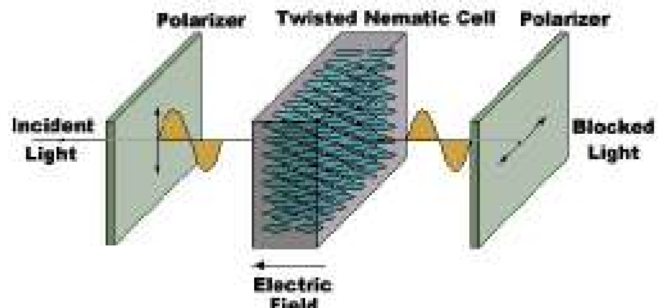
LCD

Liquid Crystal Displays (LCDs)

Currently, the most popular alternative to the CRT is the Liquid Crystal Display (LCD). LCDs are organic molecules that, in the absence of external forces, tend to align themselves in crystalline structures. But, when an external force is applied they will rearrange themselves as if they were a liquid. Some liquid crystals respond to heat (i.e. *mood rings*), others respond to electromagnetic forces.

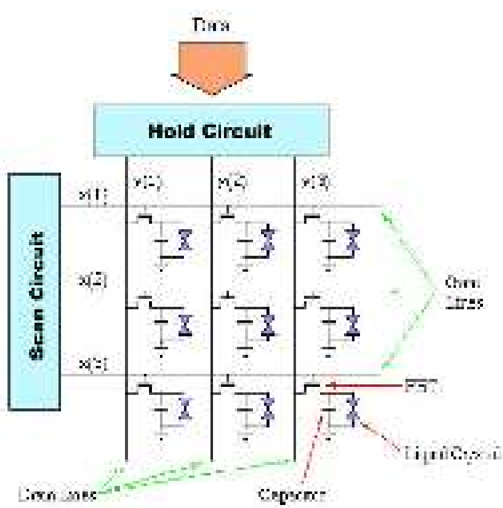


When used as optical (light) modulators LCDs change polarization rather than transparency (at least this is true for the most popular type of LCD called *Super-twisted Nematic Liquid crystals*). In their unexcited or crystalline state the LCDs rotate the polarization of light by 90 degrees. In the presence of an electric field, LCDs the small electrostatic charges of the molecules align with the impinging E field.



The LCD's transition between crystalline and liquid states is a slow process. This has both good and bad side effects. LCDs, like phosphors, remain "on" for some time after the E field is applied. Thus the image is *persistent* like a CRT's, but this lasts just until the crystals can realign themselves, thus they must be constantly refreshed, again, like a CRT.

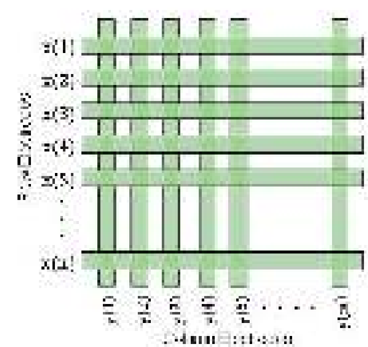
Active Matrix LCDs

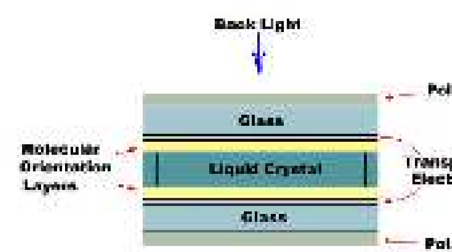


The LCD's themselves have extremely low power requirements. A very small electric field is required to excite the crystals into their liquid state. Most of the energy used by an LCD display system is due to the back lighting.

I mentioned earlier that LCD's slowly transition back to their crystalline state when the E field is removed. In scanned displays, with a large number of pixels, the percentage of the time that LCDs are excited is very small. Thus the crystals spend most of their time in intermediate states, being neither "On" or "Off". This behavior is indicative of *passive displays*. You might notice that these displays are not very sharp and are prone to ghosting. Another way to building LCD displays uses an *active matrix*. The individual cells are very similar to those described above. The main difference is that the electric field is retained by a capacitor so that the crystal remains in a constant state. Transistor switches are used to transfer charge into the capacitors during the scanning process. The capacitors can hold the charge for significantly longer than the refresh period yielding a crisp display with no shadows. Active displays, require a working capacitor and transistor for each LCD or pixel element, and thus, they are more expensive to produce.

Reflective and Backlit LCDs



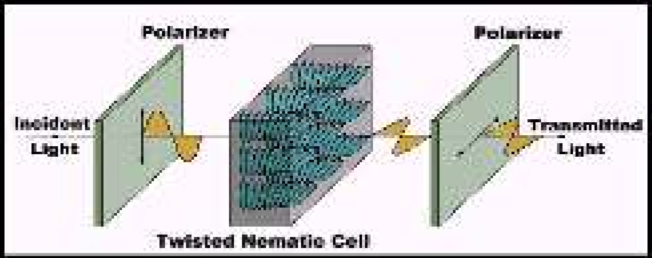


Rather than generating light like a CRTs, LCDs act as light valves. Therefore, they are dependent on some external light source. In the case of a transmissive display, usually some sort of *back light* is used. Reflective displays take advantage of the am[bient] light. Thus, transmissive displays are difficult to see when they are overwhelmed by external light sources, whereas refle[ctive] displays can't be seen in the dark. You should also note that at least half of the light is lost in most LCD configurations. C[an you] see why?

LCD

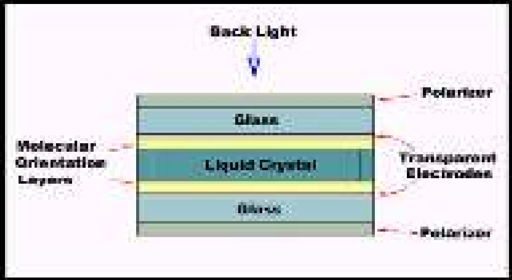
Liquid Crystal Displays (LCDs)

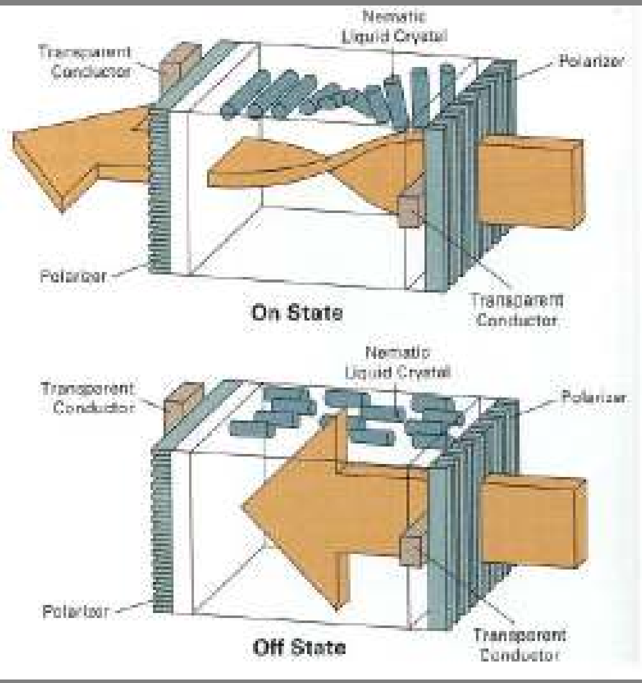
- LCDs: organic molecules, naturally in crystalline state, that liquify when excited by heat or E field
- Crystalline state twists polarized light 90°.



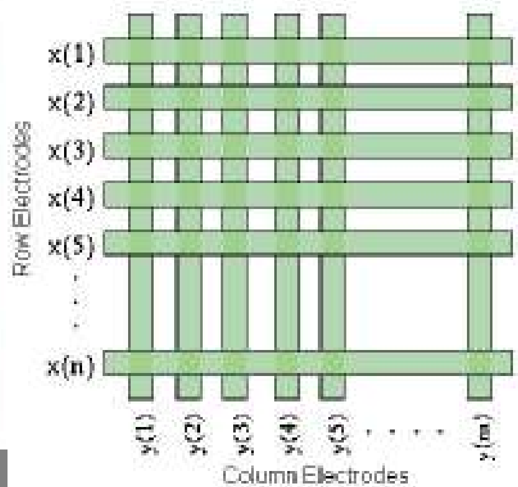
Transmissive & reflective LCDs:

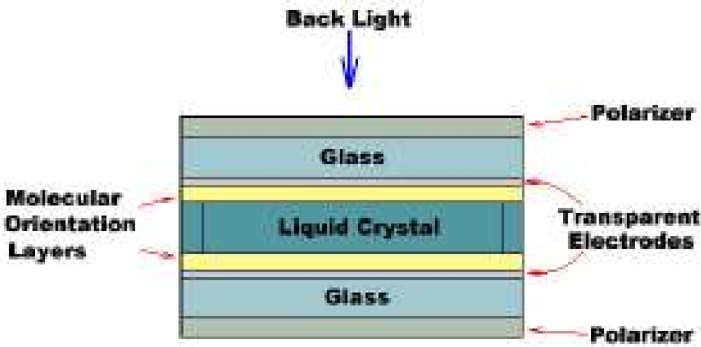
- LCDs act as light valves, not light emitters, and thus rely on an external light source.
- Such devices are called spatial light modulators, or SLMs, which reflect light produced externally.
- Laptop screen: backlit, *transmissive display*
- Palm Pilot/Game Boy: *reflective display*



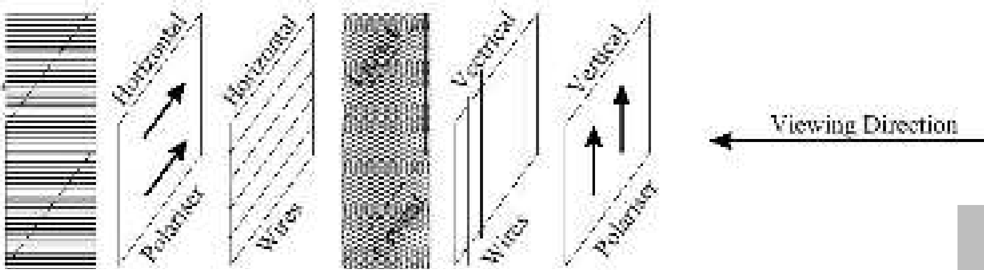


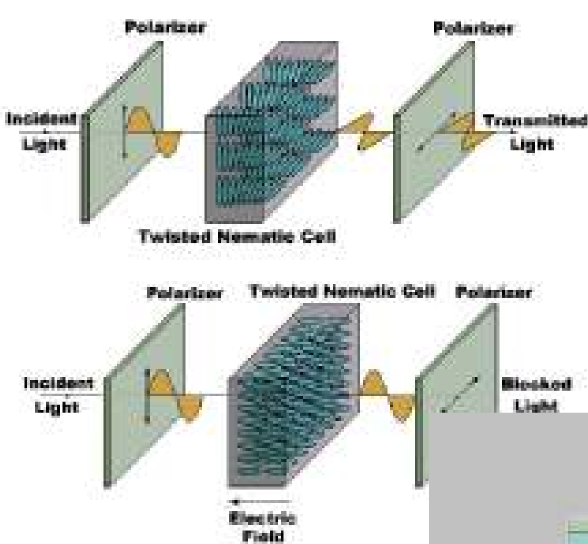
Reflective and Backlit LCDs

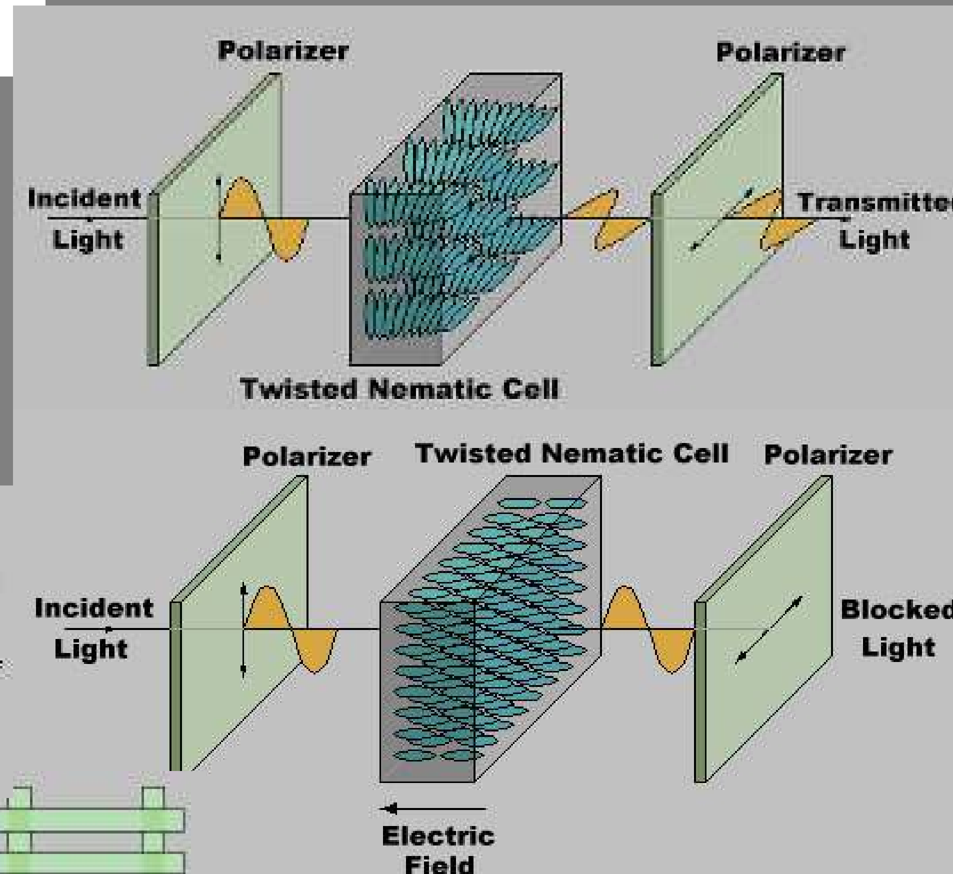




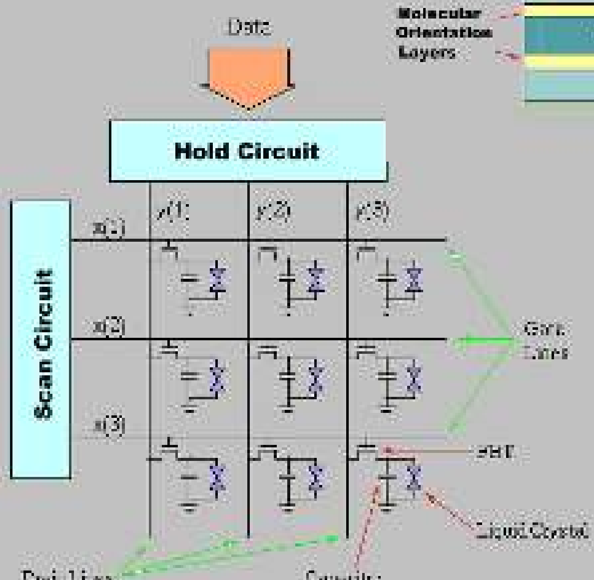
LCD

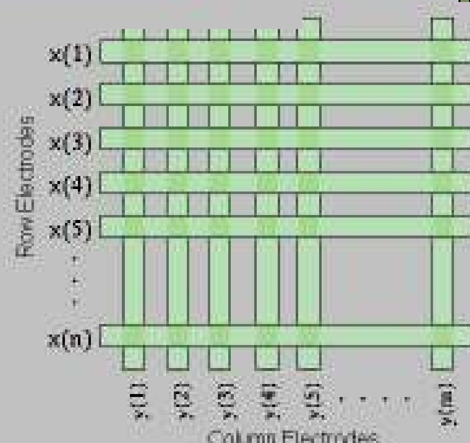

Horizontal
Polarizer
Horizontal
Wires
Vertical
Wires
Vertical
Polarizer
Viewing Direction

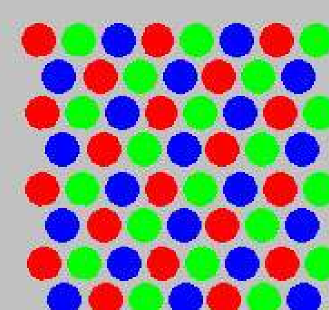

Polarizer
Polarizer
Incident
Light
Transmitted
Light
Twisted Nematic Cell
Polarizer
Twisted Nematic Cell
Polarizer
Incident
Light
Blocked
Light
Electric
Field

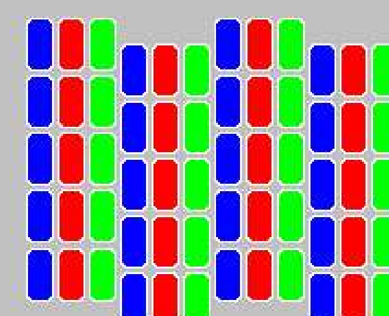

Polarizer
Polarizer
Incident
Light
Transmitted
Light
Twisted Nematic Cell
Polarizer
Twisted Nematic Cell
Polarizer
Incident
Light
Blocked
Light
Electric
Field


Back Light
Polarizer
Glass
Molecular
Orientation
Layers
Liquid Crystal
Transparent
Electrodes
Glass
Polarizer


Data
Hold Circuit
Scan Circuit

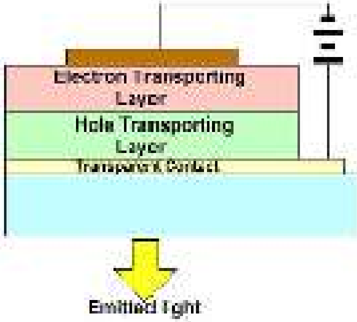

x(1)
x(2)
x(3)
x(4)
x(5)
x(n)
Row Electrodes
Column Electrodes



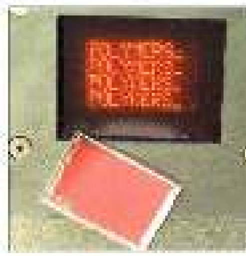


Light Emitting Diode (LED) Arrays

OLED Structure



- Organic Light Emitting Diodes (OLEDSs)
- 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 microsec)
  - Can be made large or small
  - Tend to breakdown



LED

- Organic Light-Emitting Diode (OLED) Arrays
  - The display of the future? Many think so.
  - OLEDs function like regular semiconductor LEDs
  - But with thin-film polymer construction:
    - Thin-film deposition or vacuum deposition process...not grown like a crystal, no high-temperature doping
    - Thus, easier to create large-area OL

OLED pros:

- Transparent
- Flexible
- Light-emitting, and quite bright (daylight visible)
- Large viewing angle
- Fast (< 1 microsecond off-on-off)
- Can be made large or small

OLED cons:

- Not quite there yet (96x64 displays...)
- Not very robust, display lifetime a key issue

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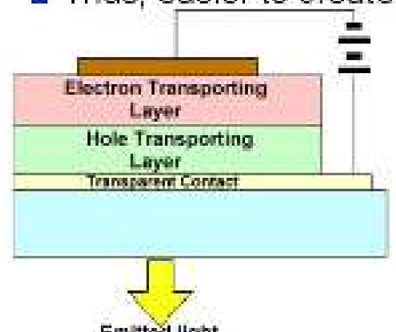
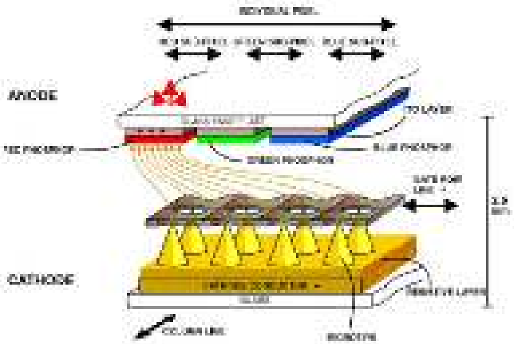


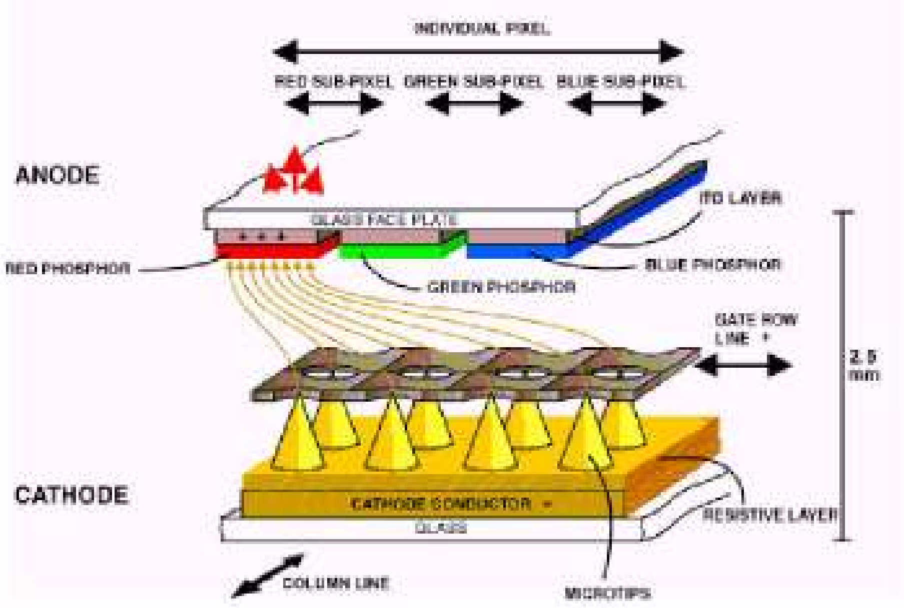
FED

Field Emission Devices (FEDs)

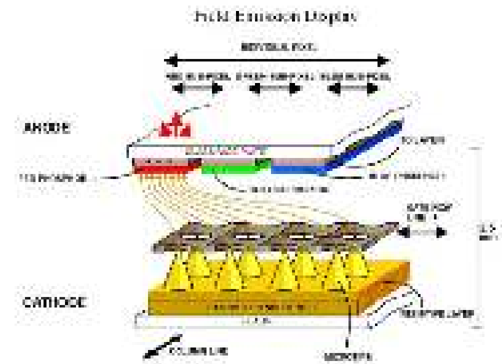
- Like a CRT, with many small electron guns at each pixel
- Unreliable electrodes, needs vacuum
- Thin, but limited in size



Field Emission Display



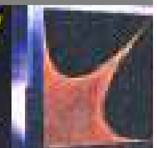
Field Emission Devices (FEDs)



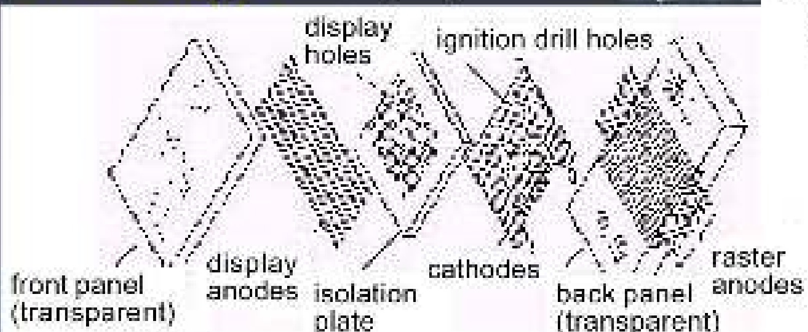
- Works like a CRT with multiple electron guns at each pixel
- Uses modest voltages applied to sharp points to produce strong E fields
- Reliable electrodes proven difficult to produce
- Limited in size
- Thin, and requires a vacuum

Plasma

Plasma-Panel Display

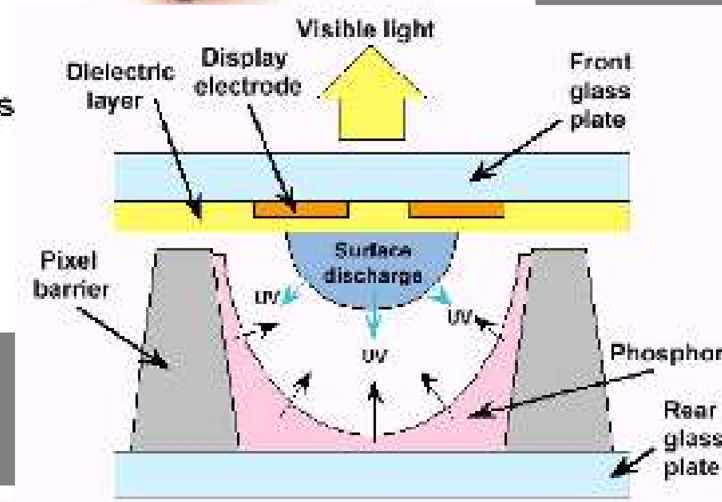


- glowing gas between 2 glass panels
- ***advantages:*** flat, high brightness, good image
- ***disadvantages:*** heavy, expensive, instable



Plasma display panels

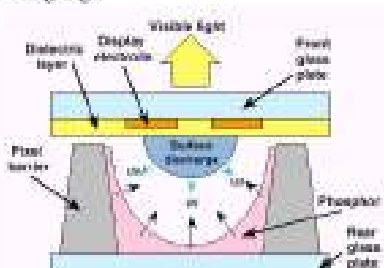
- Similar in principle to fluorescent light tubes
- Small gas-filled capsules are excited by electric field, emits UV light
- UV excites phosphor
- Phosphor relaxes, emits some other color



Plasma Display Panels

- Promising for large format displays
- Basically fluorescent tubes
- High-voltage discharge excites gas mixture (He, Xe)
- Upon relaxation UV light is emitted
- UV light excites phosphors
- Large viewing angle

- Less efficient than CRTs
  - Not as bright
  - More power
- Large pixels (~1mm compared to 0.2mm for CRT)
- Ion bombardment depletes phosphors



Plasma Display Panel Pros

- Large viewing angle
- Good for large-format displays
- Fairly bright

Cons

- Still very expensive
- Large pixels (~1 mm versus ~0.2 mm)
- Phosphors gradually deplete
- Less bright than CRTs, using more power

Intrebări ?