
Daniel Rozin, Wooden Mirror (1999)

Introduction to Computer Graphics

Lecture 2

General Graphics Systems

University of Virginia

Vector Graphics

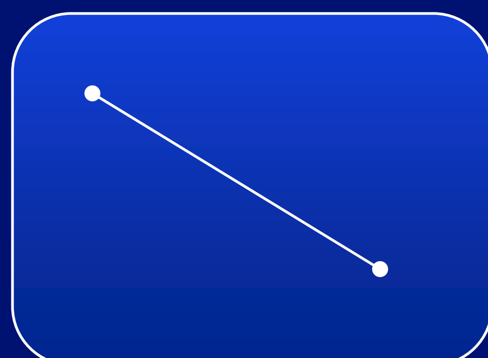
How to generate an image using vectors

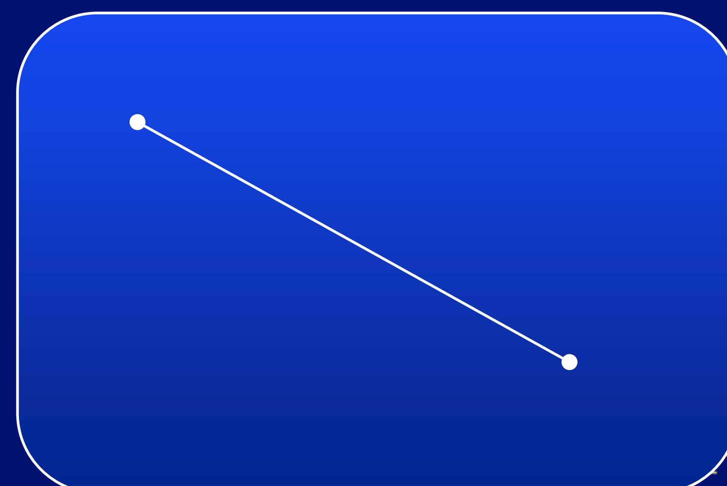
Cheap transmission

- A line is represented by endpoints (10,10) to (90,90)
- The points along the line are computed using a line equation
  - $y = mx + b$

Computation required

- If you want the image larger, no problem…





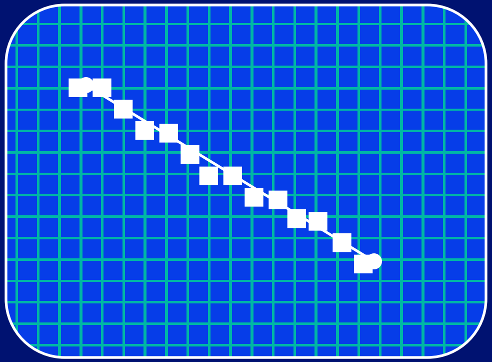
Raster Graphics

How to generate a line using rasters

- A line is represented by assigning some pixels a value of 1

Lot's of extra info to communicate

- The entire line is specified by the pixel values No computation
  – *What do we do to make image larger?*



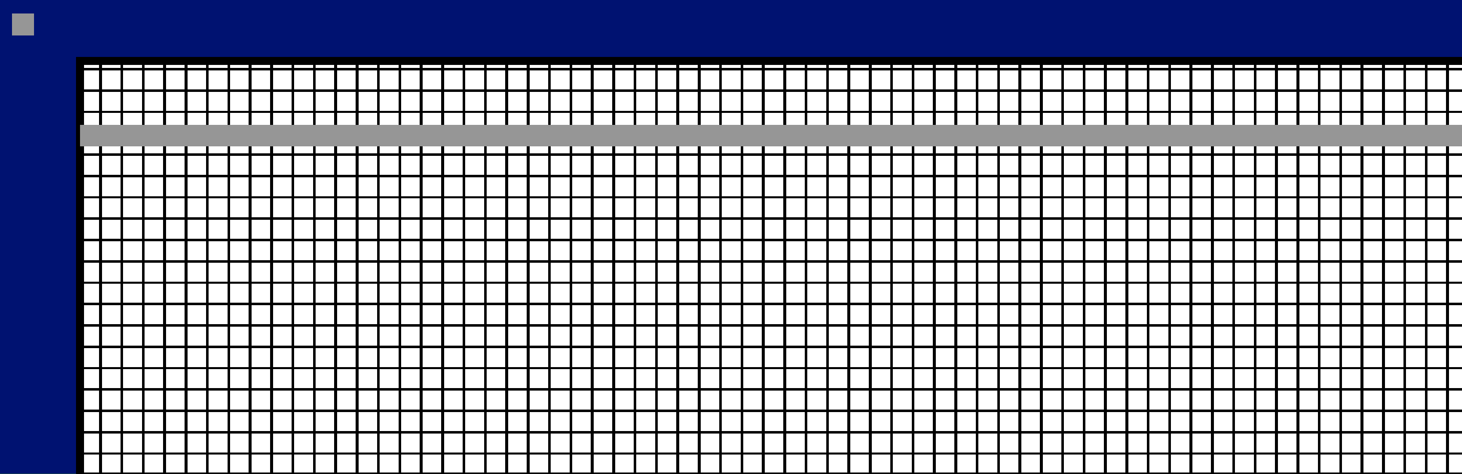
Display Technologies

- ***Vector Displays***

Display Technologies

Raster Displays

- Raster: A rectangular array of points or dots
- Pixel: One dot or picture element of the raster
- Scan line: A row of pixels



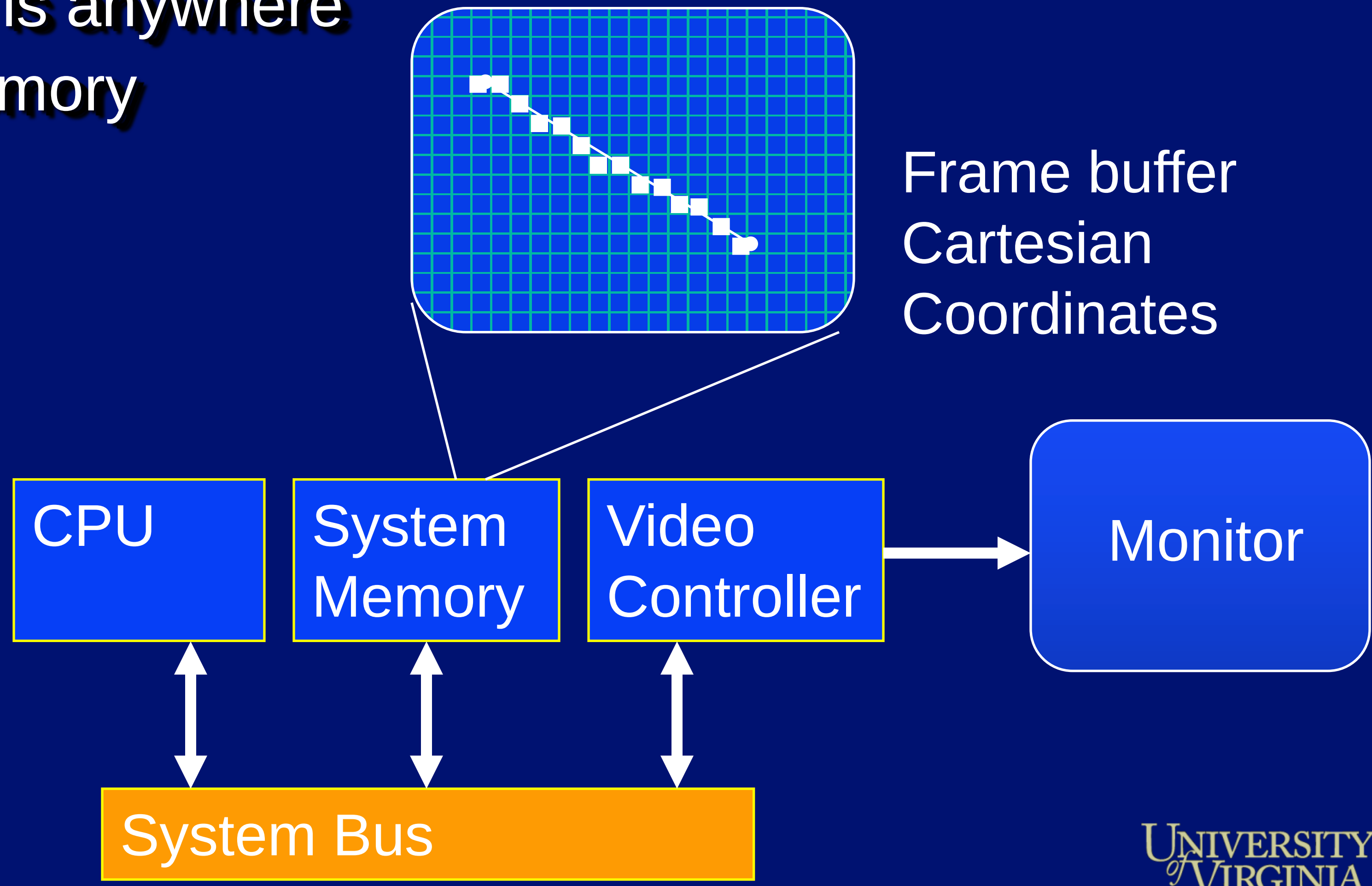
Graphics Software

- ***Special-purpose programs***
  - Photoshop, Powerpoint, AutoCAD, StudioMax, Maya, Blender, PovRay, ...

- ***General graphics libraries and standards***
  - Windows API, OpenGL, Direct3D,…

Raster-Scan Graphic System

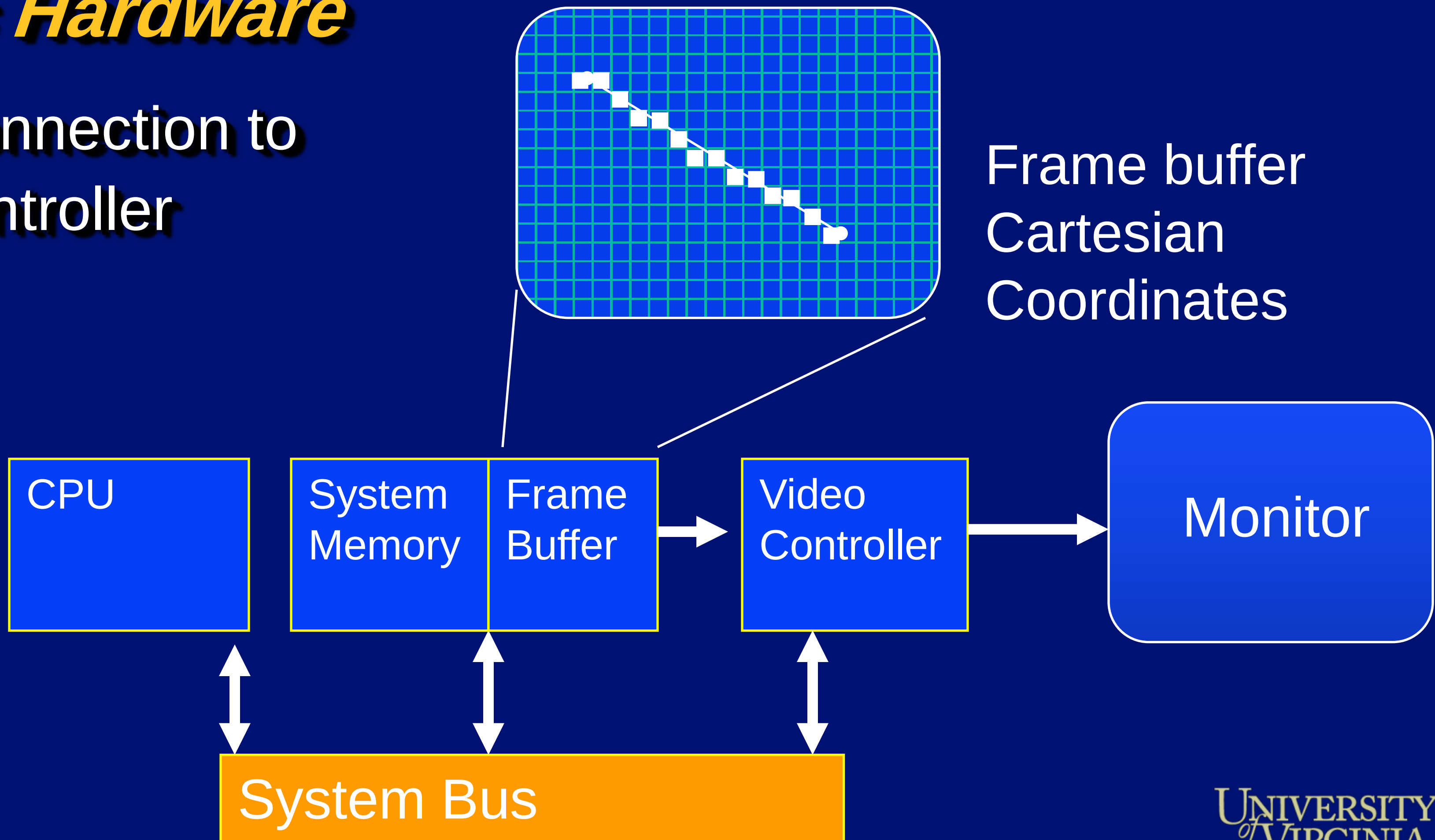
- Frame buffer is anywhere in system memory



Permanent place for frame buffer

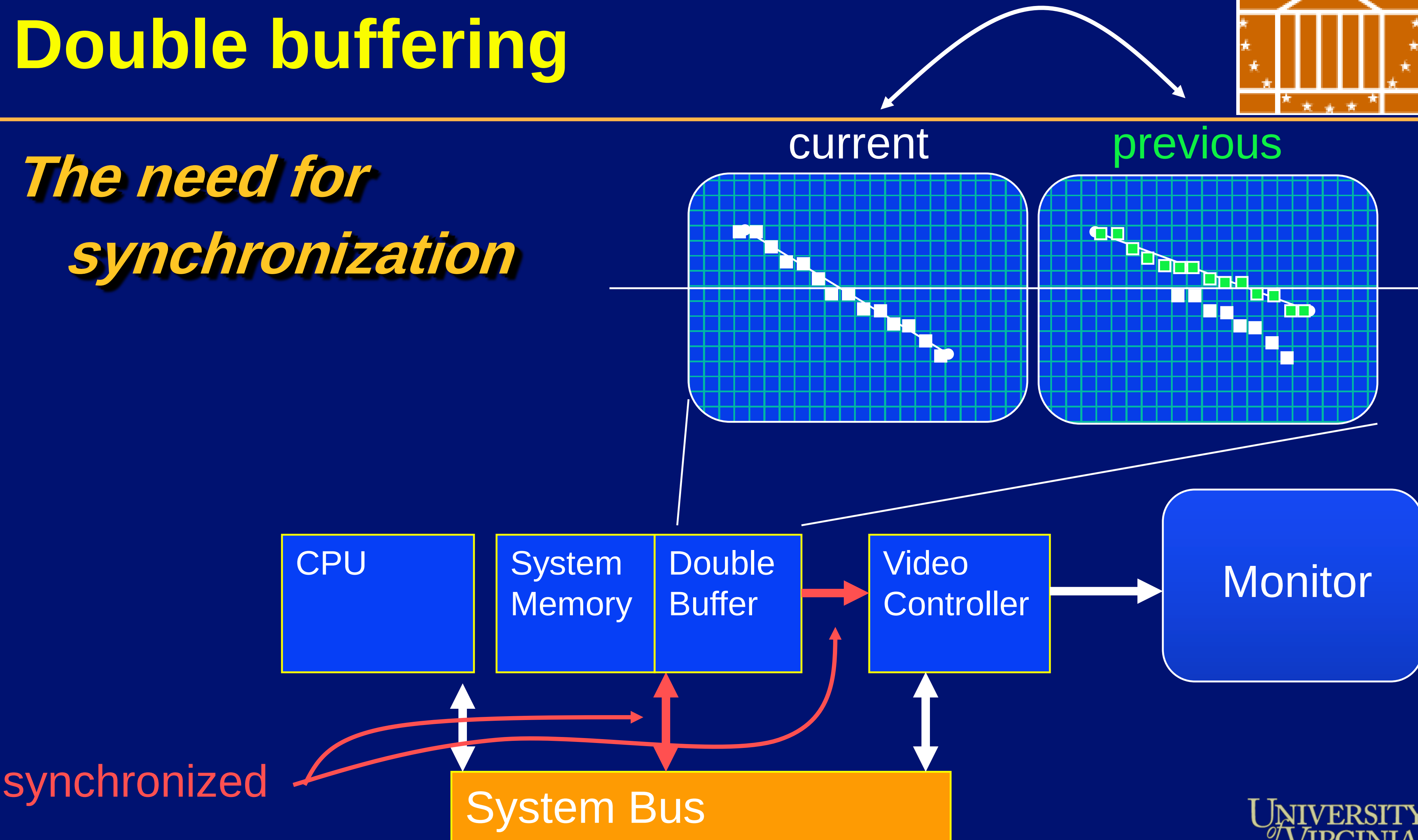
Graphics Hardware

- Direct connection to video controller



Double buffering

The need for synchronization



Display Processor

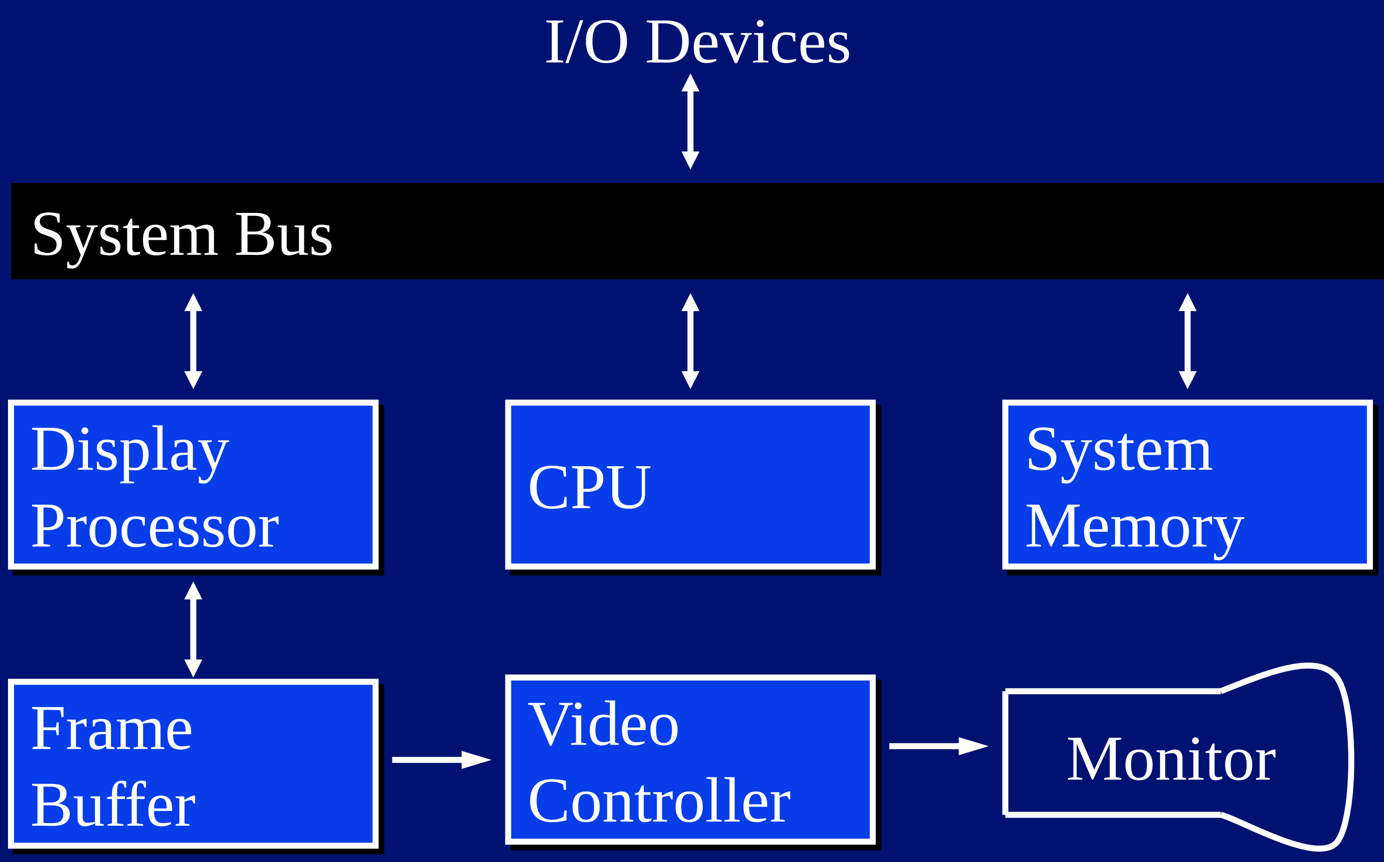


Figure 2.29 from Hearn and Baker

Frame Buffer

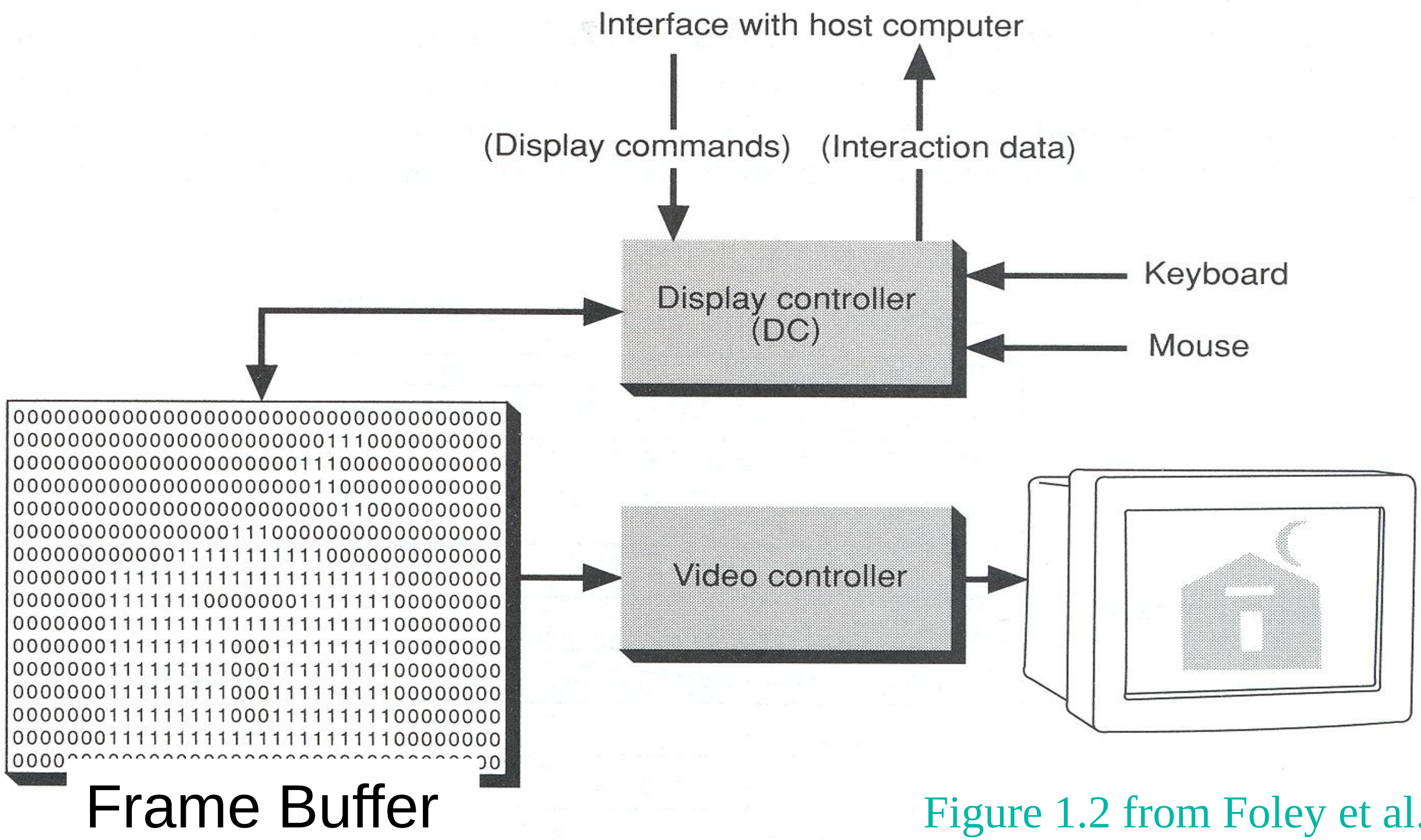
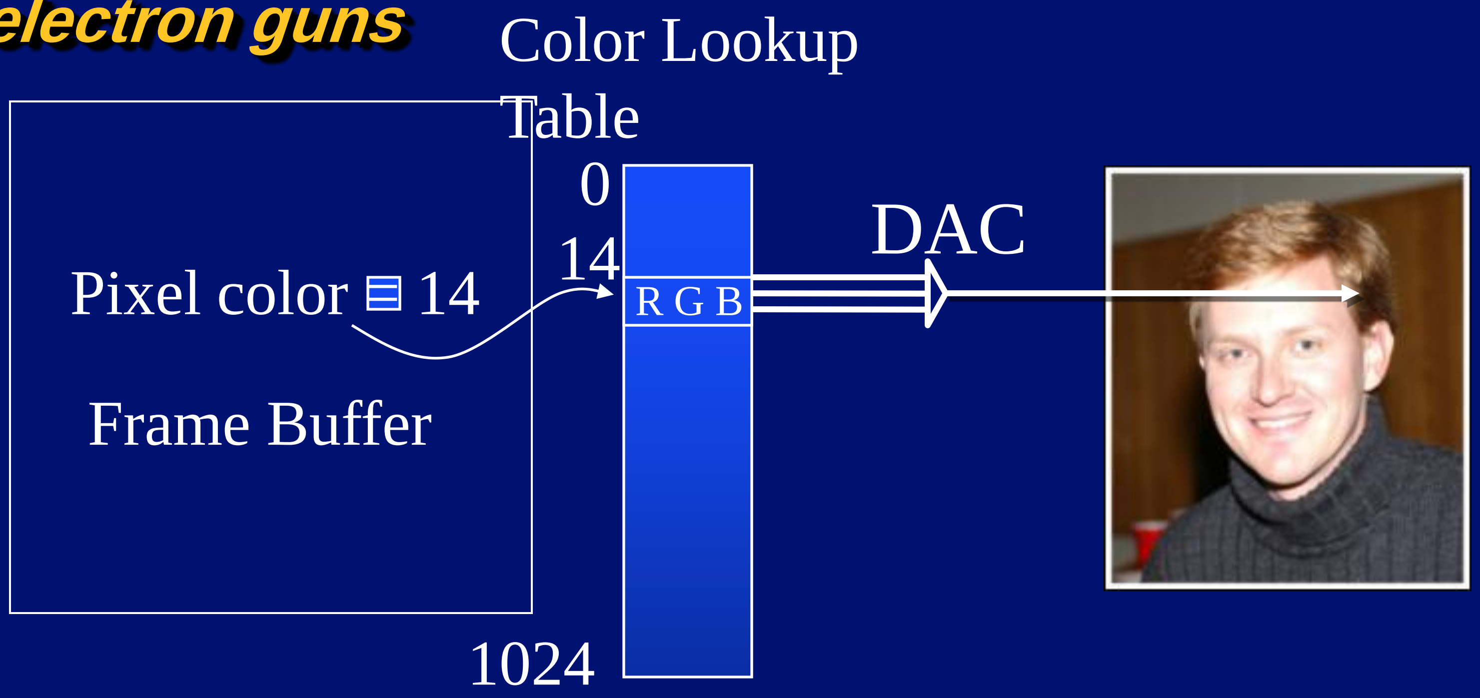


Figure 1.2 from Foley et al.

Color Lookup Framebuffer

- ***Store indices (usually 8 bits) in framebuffer***
- ***Display controller looks up the R,G,B values before triggering the electron guns***



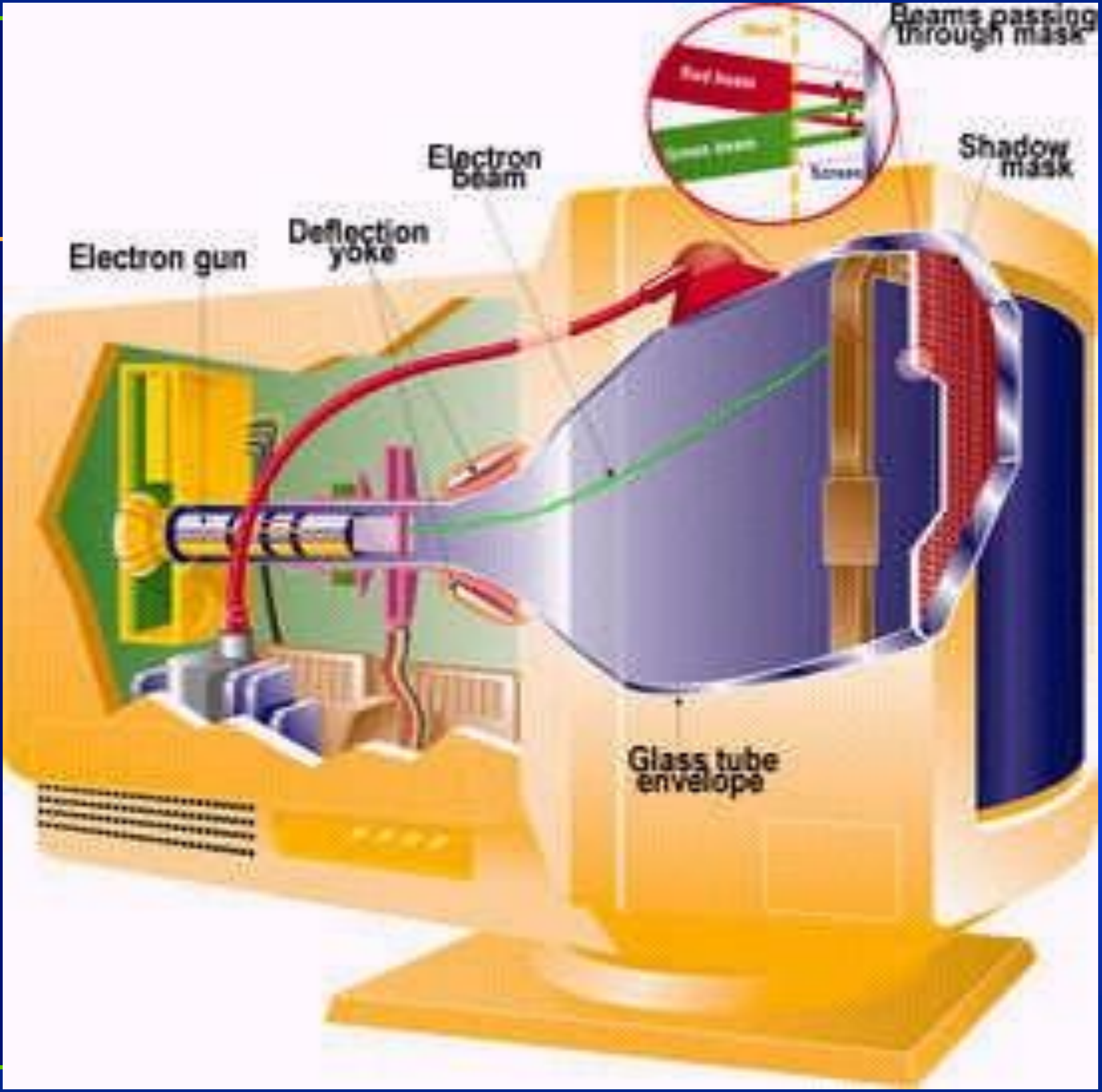
Graphics Card or Display Adaptors

A number of display Adaptors are available with varying capabilities specially Intel systems support following Adaptors:

- Monochrome Adaptor (MA)
- Hercules Adaptor (HA)
- Color Graphics Adaptor (CGA)
- Enhanced Graphics Adaptor (EGA)
- Multicolor Graphics Adaptor (MCGA)
- Video Graphics Adaptor (VGA)
- Super Video Graphics Adaptor (SVGA)
- Extended Graphics Adaptor (XGA)

CRT details

- filament
- Electrons pulled towards anode focusing cylinder
- Vertical and horizontal deflection plates
- Beam strikes phosphor coating on front of tube



Display Technology: Raster

Raster CRT pros:

- Leverages low-cost CRT technology (i.e., TVs)
- Bright! Display *emits* light

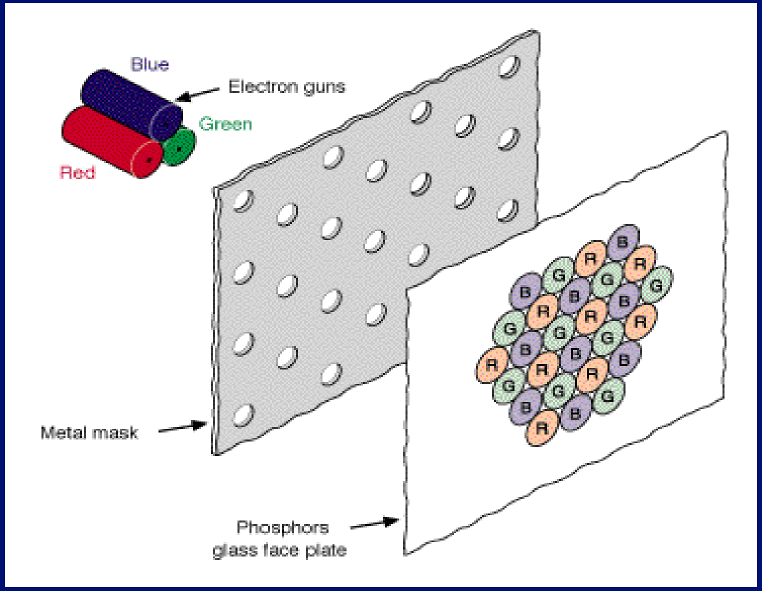
Cons:

- Requires screen-size memory array
- Discret sampling (pixels)
- Practical limit on size (call it 40 inches)

Display Technology: Color CRTs

Color CRTs have

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



Display Technologies: CRTs

Phosphers

- Flourescence: Light emitted while the phospher is being struck by electrons
- Phospherescence: Light emitted once the electron beam is removed
- Persistence: The time from the removal of the excitation to the moment when phospherescence has decayed to 10% of the initial light output

Display Technologies: CRTs

Refresh

- Frame must be “refreshed” to draw new images
- As new pixels are struck by electron beam, others are decaying
- Electron beam must hit all pixels frequently to eliminate flicker
- Critical fusion frequency
  - *Typically 60 times/sec*
  - *Varies with intensity, individuals, phospher persistence, lighting...*

Display Technologies: CRTs

Interlaced Scanning

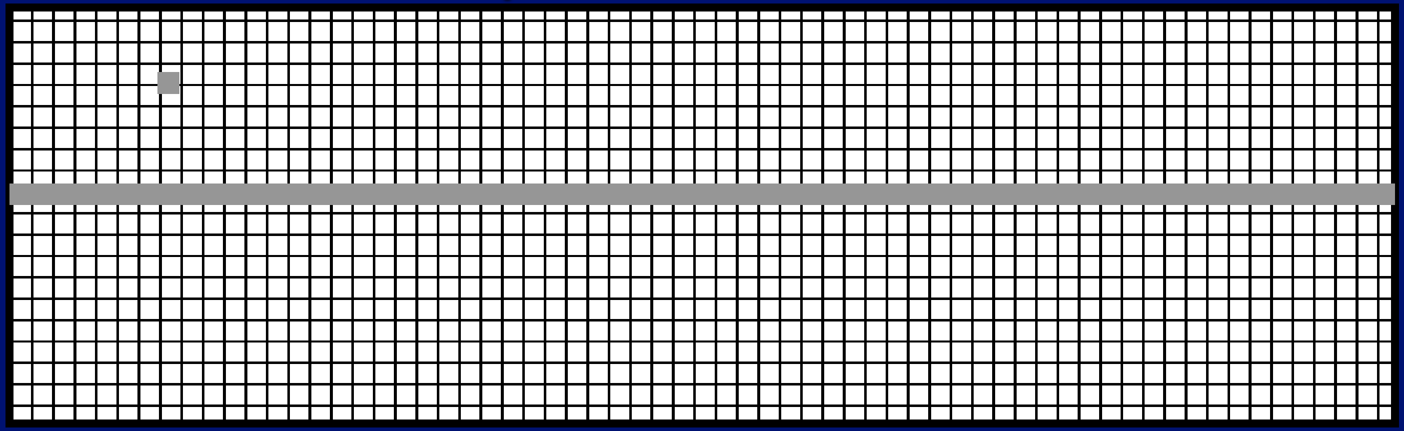
- Assume we can only scan all pixels of entire screen 30 times / second
- To reduce flicker, divide frame into two “fields” of odd and even lines

1/30 Sec		1/30 Sec	
1/60 Sec	1/60 Sec	1/60 Sec	1/60 Sec
Field 1	Field 2	Field 1	Field 2
Frame		Frame	

Display technologies: CRTs

Raster Displays

- Raster: A rectangular array of points or dots
- Pixel: One dot or picture element of the raster
- Scan line: A row of pixels

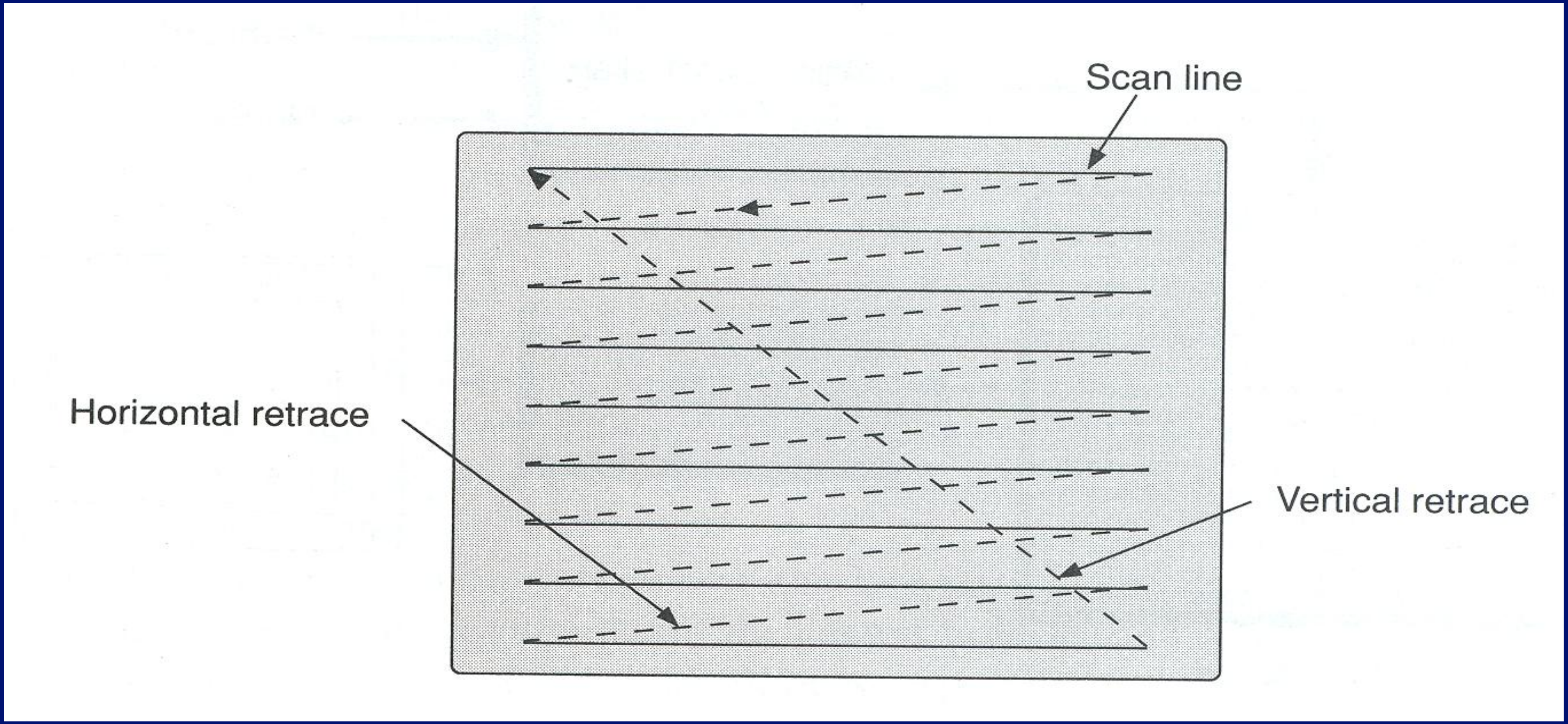


Display Technologies: CRTs

CRT timing

- Scanning (left to right, top to bottom)
  - *Vertical Sync Pulse: Signals the start of the next field*
  - *Vertical Retrace: Time needed to get from the bottom of the current field to the top of the next field*
  - *Horizontal Sync Pulse: Signals the start of the new scan line*
  - *Horizontal Retrace: The time needed to get from the end of the current scan line to the start of the next scan line*

Frame Buffer Refresh



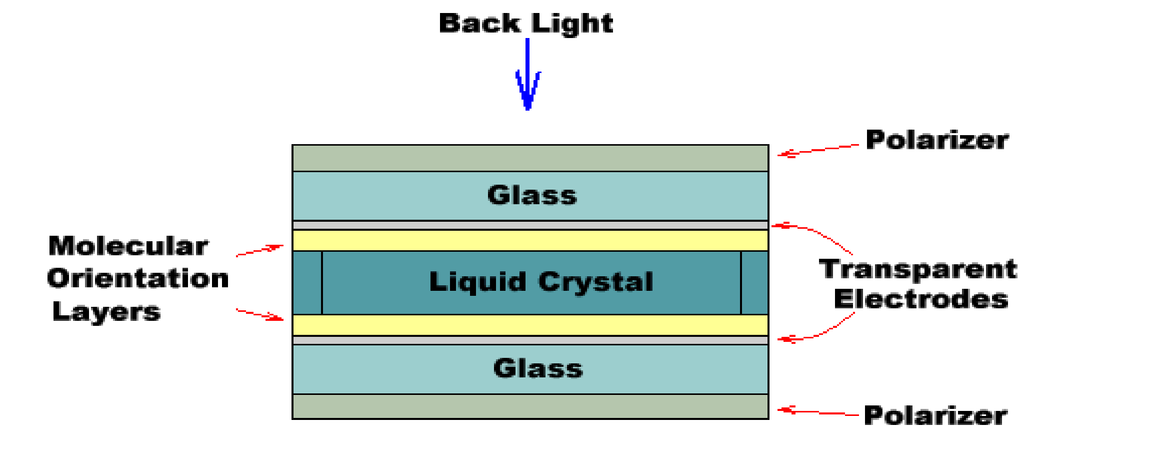
Refresh rate is usually 30-75Hz

Figure 1.3 from FvDFH

Display Technology: LCDs

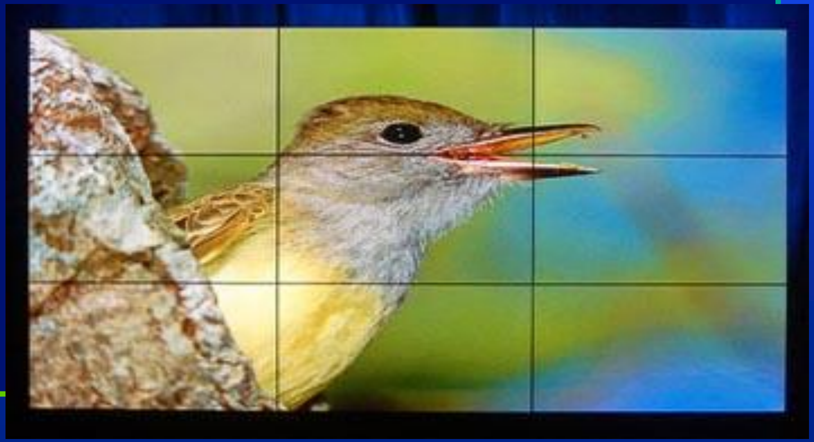
Transmissive & reflective LCDs:

- LCDs act as light valves, not light emitters, and thus rely on an external light source.



Active matrix LCD

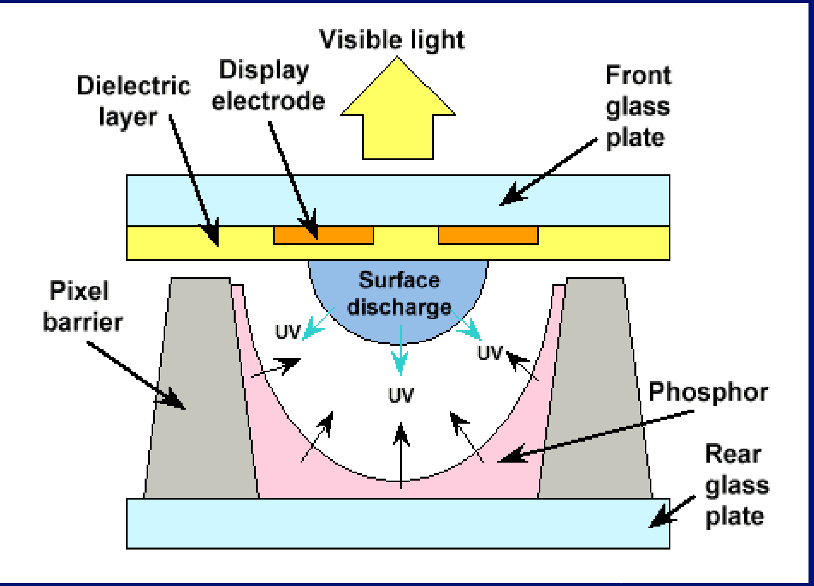
- Each pixel is activated directly
- Pixels have 4 transistors
  - *One each for red, green, blue*
  - *One for opaqueness*
- Transistors arranged in a thin film
- Animation is crisp and clean



Display Technology: Plasma

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



Display Technology

Plasma Display Panel Pros

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

Cons

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

OpenGL

- *3D (and 2D)*
- *Fast*
- *Hardware, language, OS, company independent*
- *Broad support*
- *Low-level (right level!)*
- *Standard graphics terminology*

OpenGL

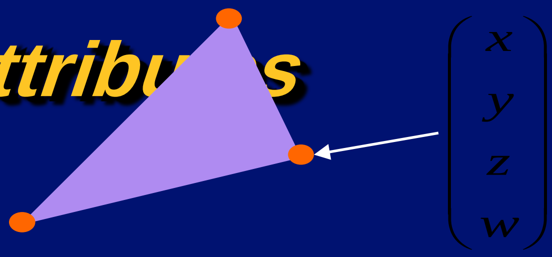
Hide the details

- User should not need to worry about how graphics are displayed on monitor
- User doesn't need to know about how a line is converted into pixels and drawn on screen (hardware dependent)
- User doesn't need to rebuild the basic tools of a 3D scene
  - *Virtual camera, light sources, polygon drawing*

OpenGL does this for you…

Representing Geometric Objects

- ***Geometric objects are represented using vertices***
- ***A vertex is a collection of generic attributes***
  - positional coordinates
  - colors
  - texture coordinates
  - any other data associated with that point in space
- ***Position stored in 4 dimensional homogeneous coordinates***



Preliminaries

- *Header Files*
  - #include <GL gl.h>
  - #include <GL glu.h>
  - #include <GL glut.h>
- *Libraries*
- *Enumerated types*
- *OpenGL defines numerous types for compatibility*
  – GLfloat, GLint, GLenum, etc.

UNIVERSITY of VIRGINIA

OpenGL Libraries

- ***GL (Graphics Library): Library of 2-D, 3-D drawing primitives and operations***
  - API for 3-D hardware acceleration
- ***GLU (GL Utilities): Miscellaneous functions dealing with camera set-up and higher-level shape descriptions***
- ***GLUT (GL Utility Toolkit): Window-system independent toolkit with numerous utility functions, mostly dealing with user interface***

How to install GLUT?

- ***Download GLUT***
- http://www.opengl.org/resources/libraries/glut.html
- ***Copy the files to following folders:***
- glut.h → VC/include/gl/
- glut32.lib → VC/lib/
- glut32.dll → windows/system32/

OpenGL function format

function name

dimensions

`glVertex3f(x,y,z)`

belongs to GL library

x,y,z are floats

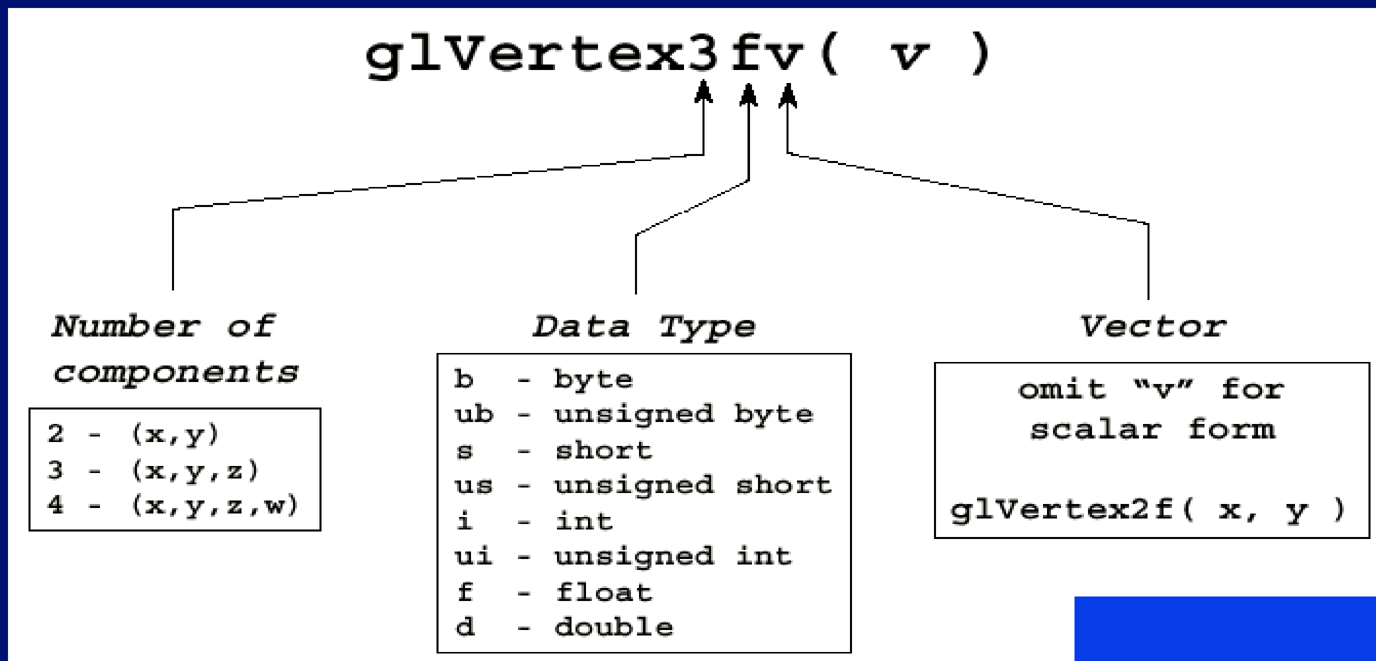
`glVertex3fv(p)`

`p` is a pointer to an array

OpenGL: Conventions

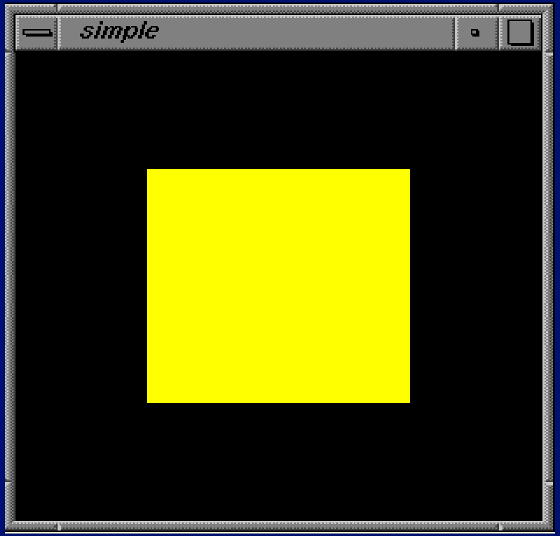
- ***Function names indicate argument type and number***
  - Functions ending with **`f`** take floats
  - Functions ending with **`i`** take ints
  - Functions ending with **`b`** take bytes
  - Functions ending with **`ub`** take unsigned bytes
  - Functions that end with **`v`** take an array.
- ***Examples***
  - **`glColor3f()`** takes 3 floats
  - **`glColor4fv()`** takes an array of 4 floats

OpenGL Command Formats



Code Example

```
void Display()
{
  glClear(GL_COLOR_BUFFER_BIT);
  glColor4f(1,1,0,1);
  glBegin(GL_POLYGON);
    glVertex2f(-0.5, -0.5);
    glVertex2f(-0.5,  0.5);
    glVertex2f(0.5, 0.5);
    glVertex2f(0.5, -0.5);
  glEnd();
  glFlush();
}
….
```



Quiz (1)

Consider three different raster systems with resolutions of 640 by 480 ,1280 by 1024, and 2560 by 2048. what size frame buffer (in bytes) is needed for each of these systems to store 12 bits per pixel? How much storage is required for each system if 24 bits per pixel are to be stored?

Answer

*a) (640*480*12) / 8 b)(1280*1024*12) / 8*

*c)(2560*2048*12) / 8 we can replace 12 with 24.*

Quiz(2)

Consider two raster systems with resolution of 640 by 480 and 1280 by 1024.how many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 60 frames per second? What is the access time per pixel in each system?

University of Virginia

Answer

- ***Pixels Number = 60*640*480=18432000 pixels.***
- ***Access time per pixel = 54.3 nano-Second/Pixel.***
- ***Pixels Number = 60*1024*1280=78643200 pixels.***
- ***Access time per pixel = 12.7 nano-Second/Pixel.***

Quiz(3)

suppose we have a computer with 32 bits per word and a transfer rate of 1 mip (one million instructions per second). How long would it take to fill the frame buffer of a 300 dpi(dot per inch) laser printer with a page size of 8 ½ inches by 11 inches?

Answer

- *let Total bits in the printer frame buffer X*
- *X=8.5 × 11 × 300^2*
- *X= 8415000 bits*
- *loading time = 8415000 / (32 × 10^6 bps) = 0.263 sec.*

UNIVERSITY of VIRGINIA

Quiz(4)

How much time is spent scanning across each row of pixels during screen refresh on a raster system with a resolution of 1280 by 1024 and a refresh rate of 60k frames per second?

Answer

- *The scan rate for each pixel row = 60 × 1024 = 61440 lines/sec*
- *scan time =16.3 microseconds per scan line*