Graphics Hardware

- Display (CRT, LCD,...)
- Graphics accelerator
  - Scan controller
  - Video Memory (frame buffer)
  - Display/Graphics Processor
- CPU/Memory/Disk ...

Display Technologies

- Front projection
- Back projection
- Direct view
- Backlit

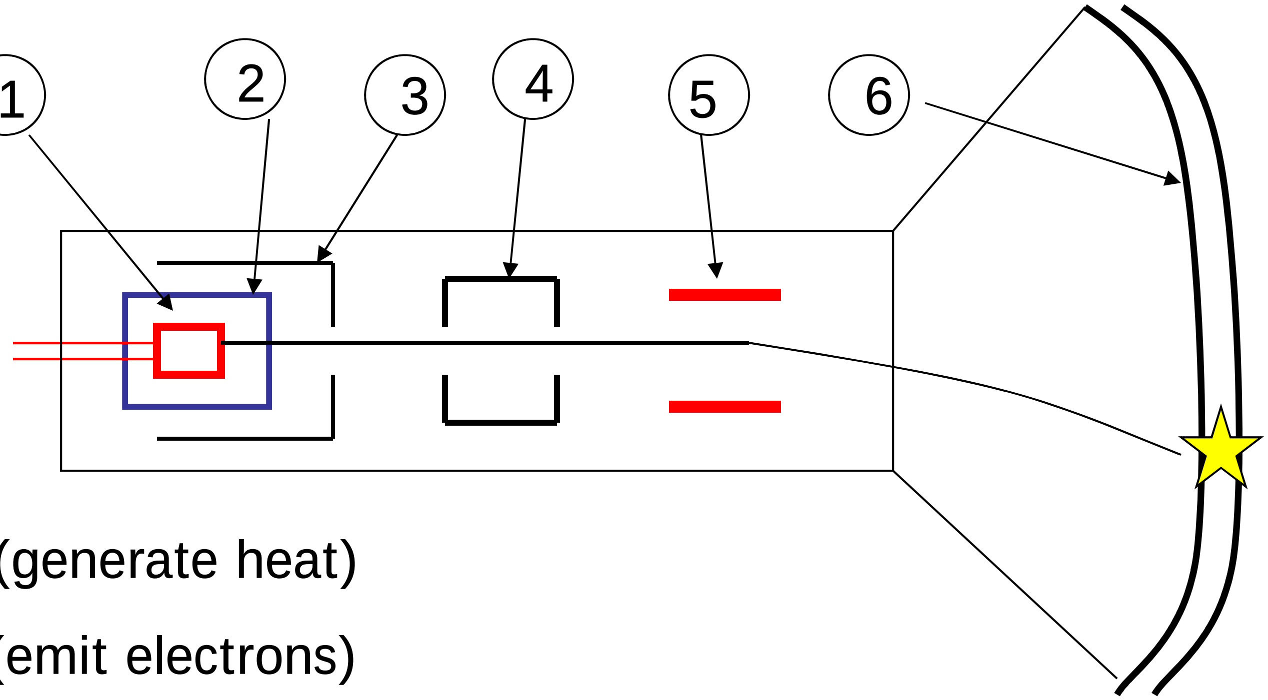
Display Technologies

- CRT
- LED
- LCD
- Plasma Panels
- DLP
- OLED
- Etc.

Trade-offs

- Cost, Weight, Size
- Power consumption
- Spatial & Color resolution
- Peak brightness, Black, contrast
- Etc.

Cathode Ray Tube (CRT)



1. Filament (generate heat)
2. Cathode (emit electrons)
3. Control grid (control intensity)
4. Focus
5. Deflector
6. Phosphor coating

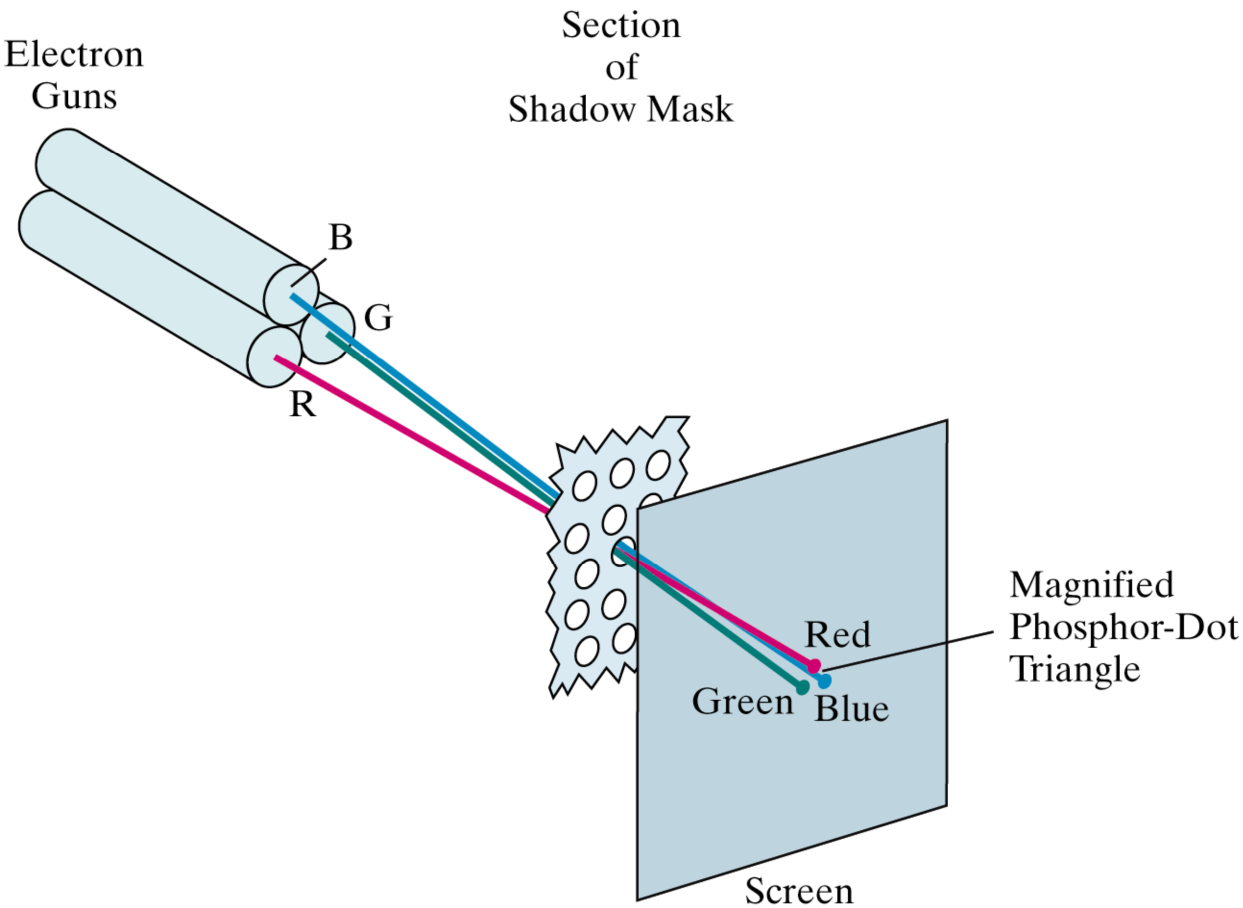


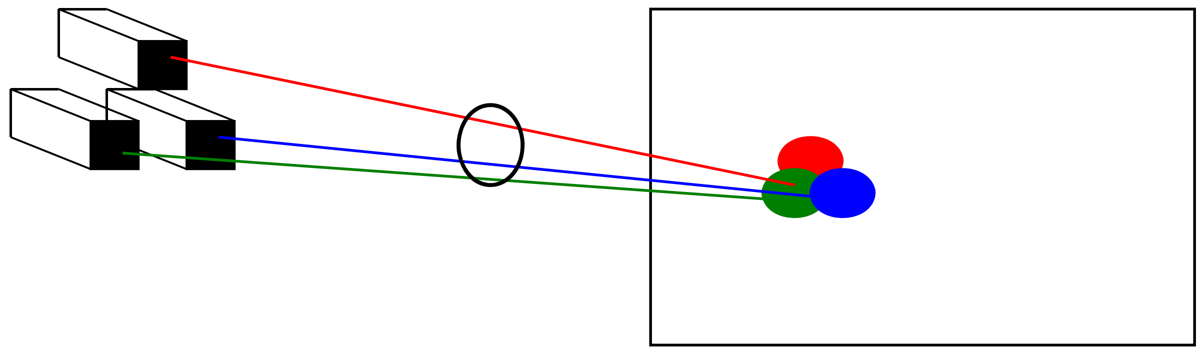
Figure 2-10

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

Computer Graphics with Open GL, Third Edition, by Donald Hearn and M.Pauline Baker.

Color CRT

3 electron guns, 3 color phosphor dots at each pixel



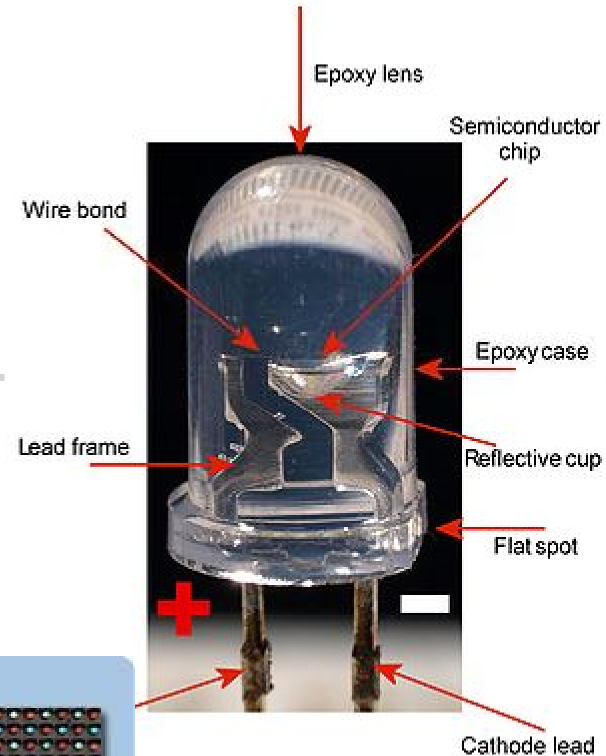
Color = (red, green, blue)

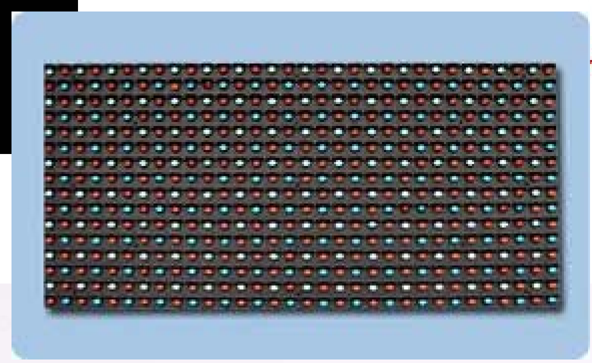
Red = 0 to 100%
Green = 0 to 100%
Blue = 0 to 100%

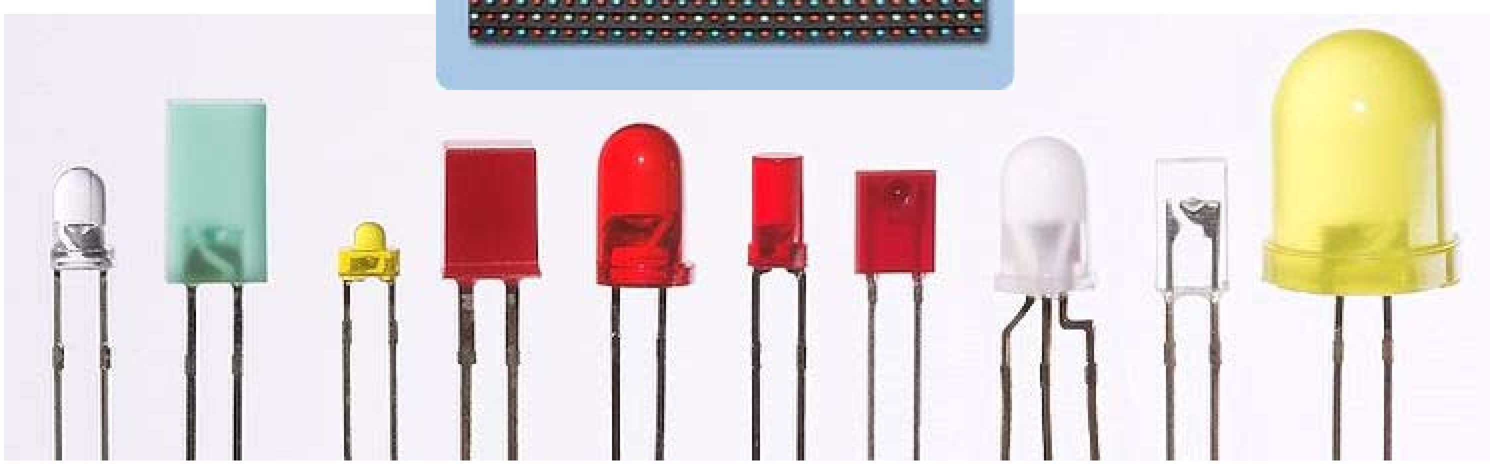
Black = (0,0,0)
White = (1,1,1)
Red = (1,0,0)
Green = (0,1,0)
Blue = (0,0,1)
...

LED

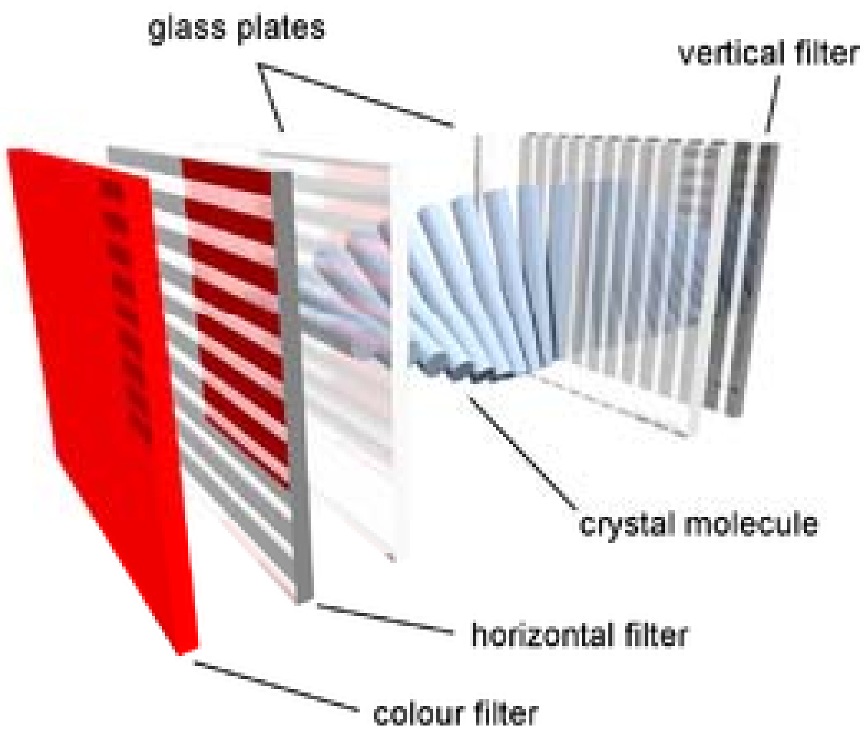
- Direct view
- backlight source



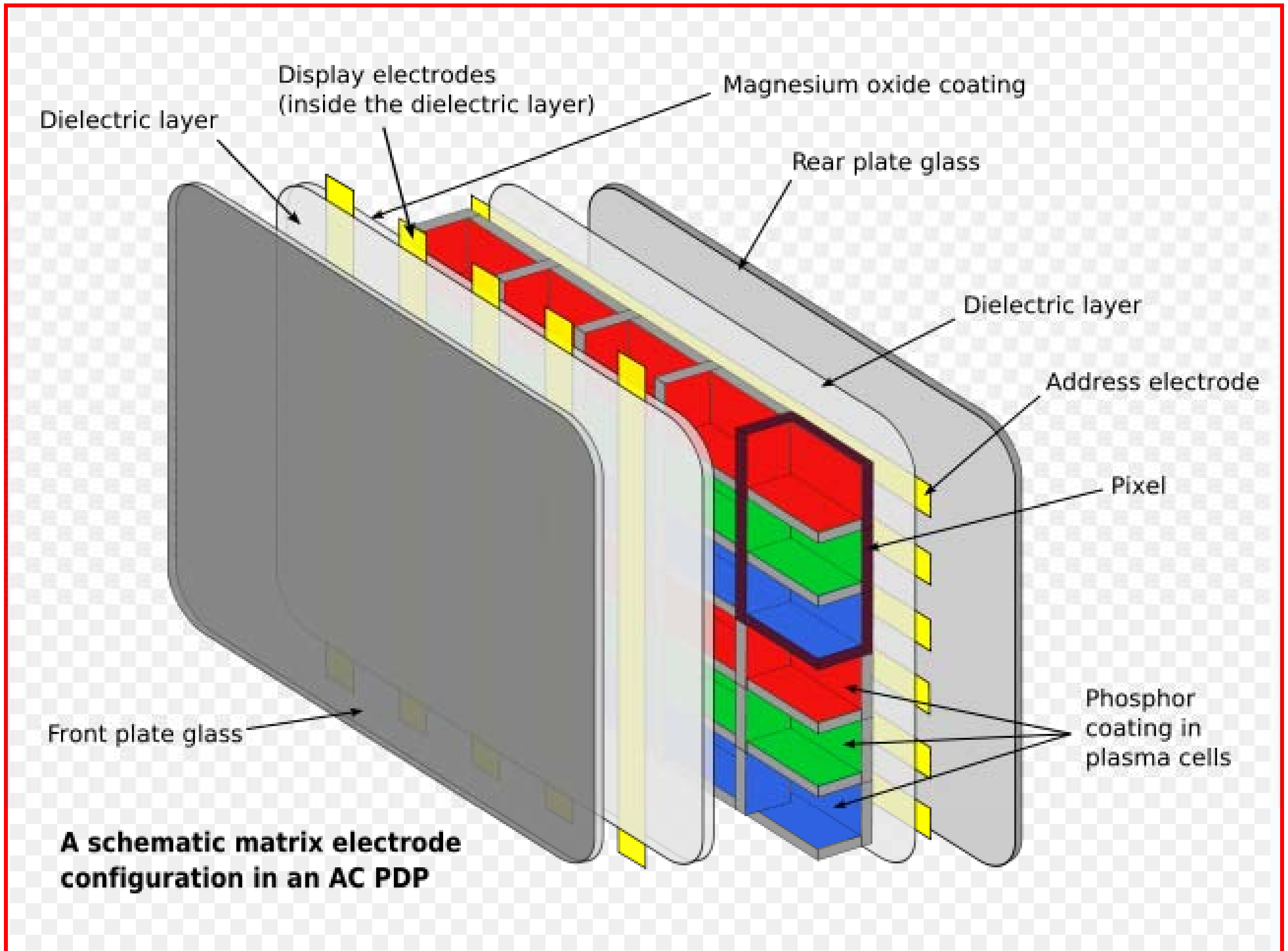




LCD: backlit


glass plates
vertical filter
crystal molecule
horizontal filter
colour filter

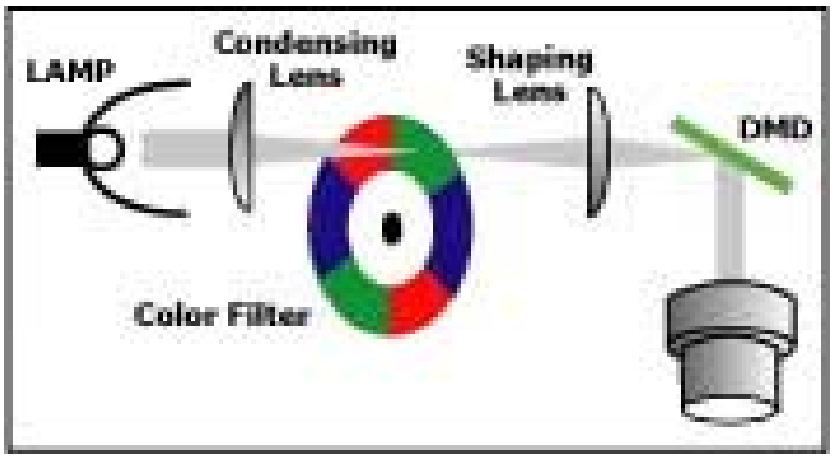
Plasma Panels: emit light; soon extinct?



DLP: http://www.dlp.com/includes/video_demo.aspx

For digital projection

Digital Micromirror Device



Trade-offs

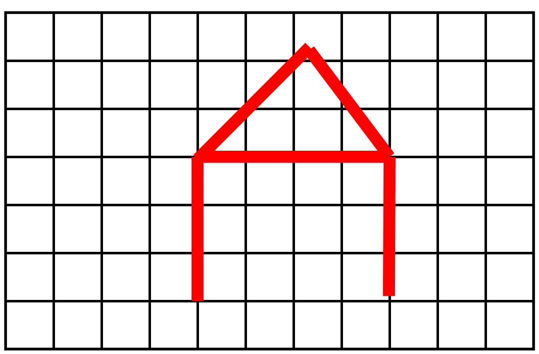
Rear projection
Front projection
Direct view
Backlit

Peak brightness
Black level
Contrast
Screen brightness
Motion artifaces
Aging
Maximum resolution
Thickness
Weight
Power consumption

http://www.displaymate.com/ShootOut_Comparison.htm

Random Scan Order

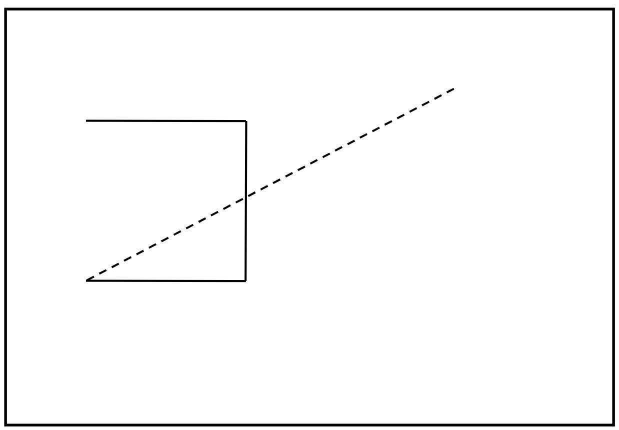
- Old way: No pixels - The electron gun draws straight lines from location to location on the screen (vector graphics)



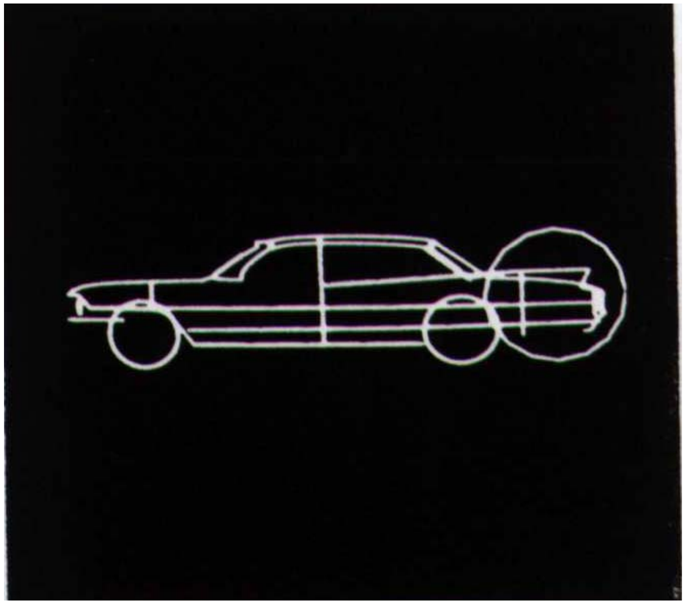
a.k.a. calligraphic display, Random scan device, vector drawing display

Use either **display list** or **storage tube** technology

Vector graphics



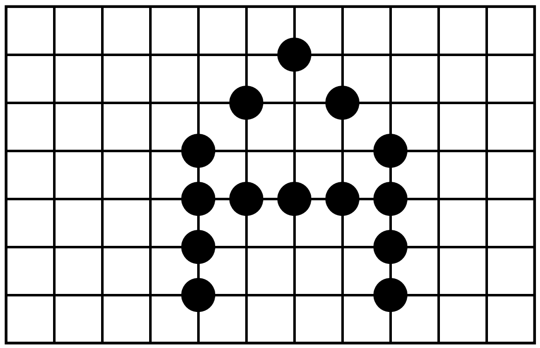
Display list
Move (100,200)
Draw(200,200)
Draw(200,100)
Draw(100,100)



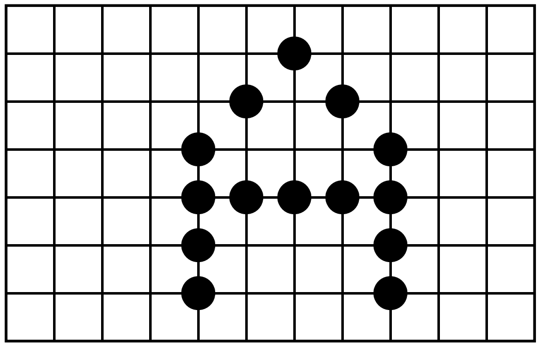
Raster Display graphics

Digital Display

- Based on (analog) raster-scan TV technology
- The screen (and a picture) consists of discrete pixels



How CRT draws a picture



- We have only one electron gun but many pixels in a picture need to be lit simultaneously...

Refresh of CRT

- **Refresh** – the electron gun needs to come back to hit the pixel again before it fades out

- An appropriate fresh rate depends on the property of phosphor coating

  Phosphor persistence: the time it takes for the emitted light to decay to 1/10 of the original intensity

- Typical **refresh rate**: 60 – 80 times per second (Hz)

  (What will happen if refreshing is too slow or too fast?)

Frame Buffer

- Frame buffer: the memory to hold the pixel intensity values
- Properties of a frame buffer that affect the graphics performance:
  - Size: screen resolution
  - Depth: color level

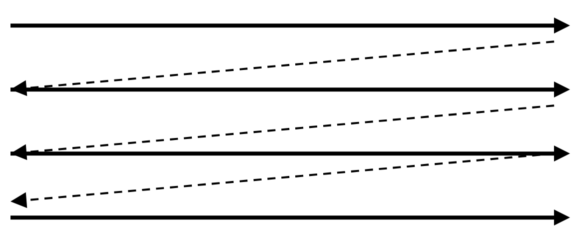
    1 bit/pixel: black and white

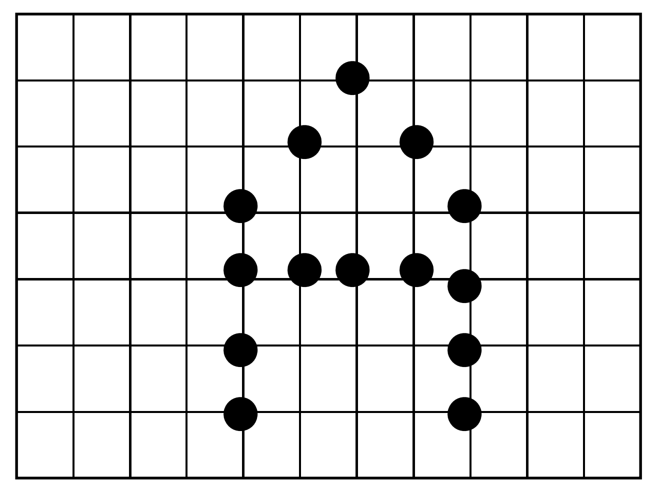
    8 bits/pixel: 256 levels of gray

    24 bits/pixel: 16 million colors
  - Speed: refresh speed

Raster Scan Order

- What we do now: the electron gun will scan through the pixels from left to right, top to bottom (scanline by scanline)





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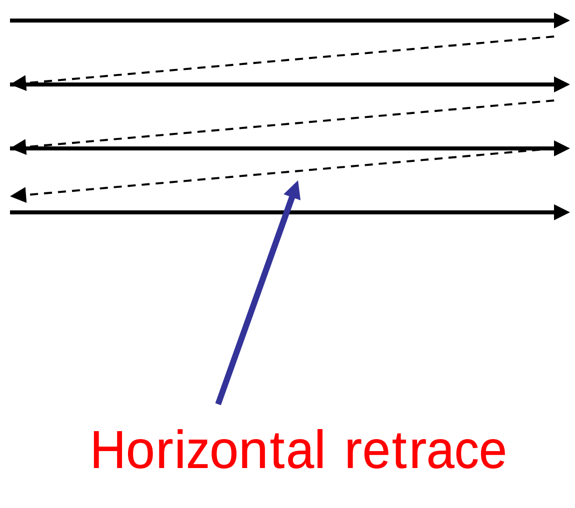

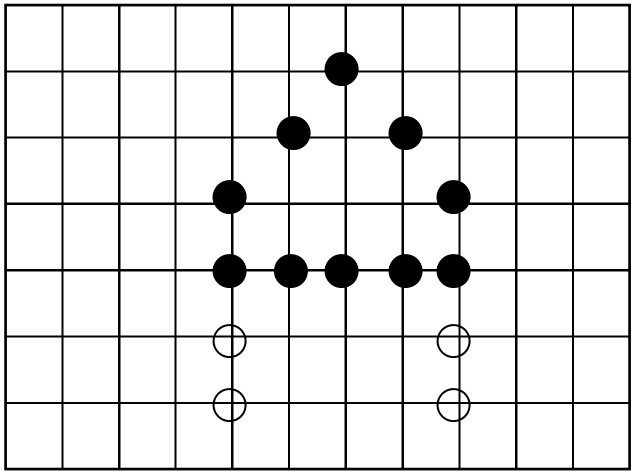

Raster Scan Order

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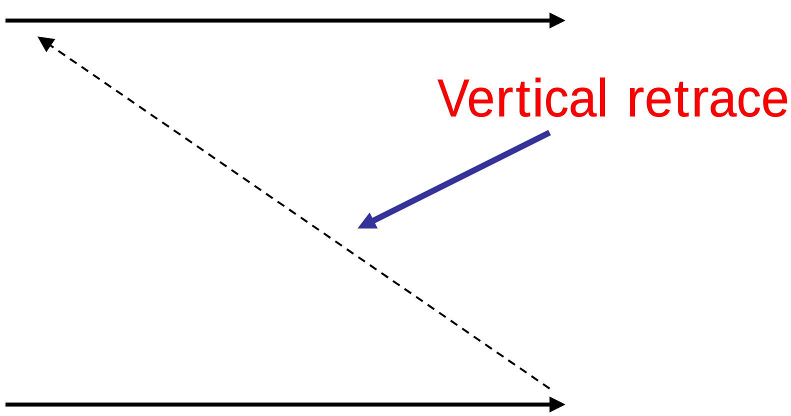
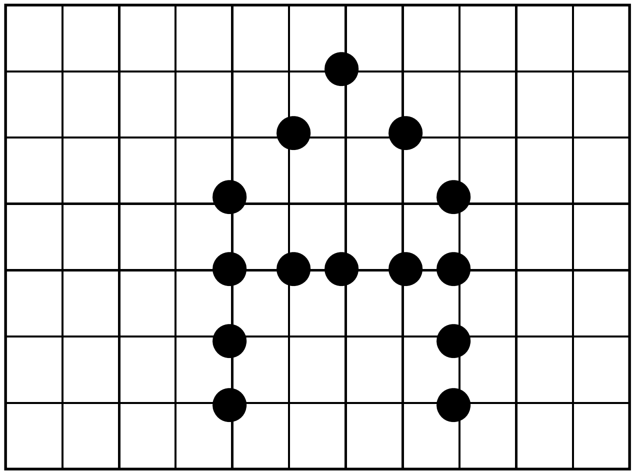
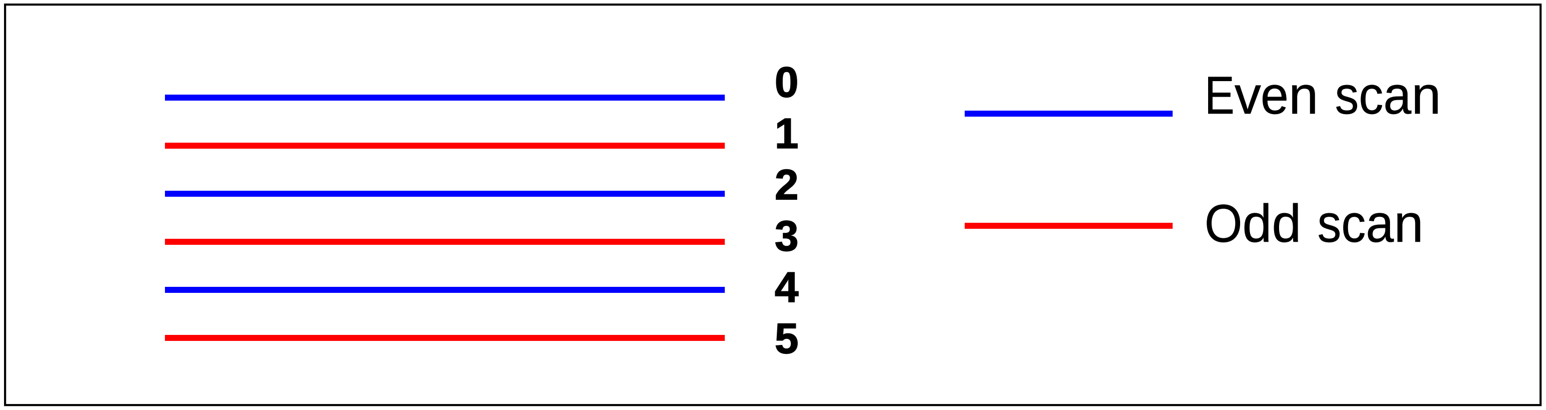




Progressive vs. Interlace

- Progressive: Scan every scan line
- Interlace: Scan only every other scan line (even -> odd -> even -> odd ...)

  \- so the refresh rate becomes twice as fast

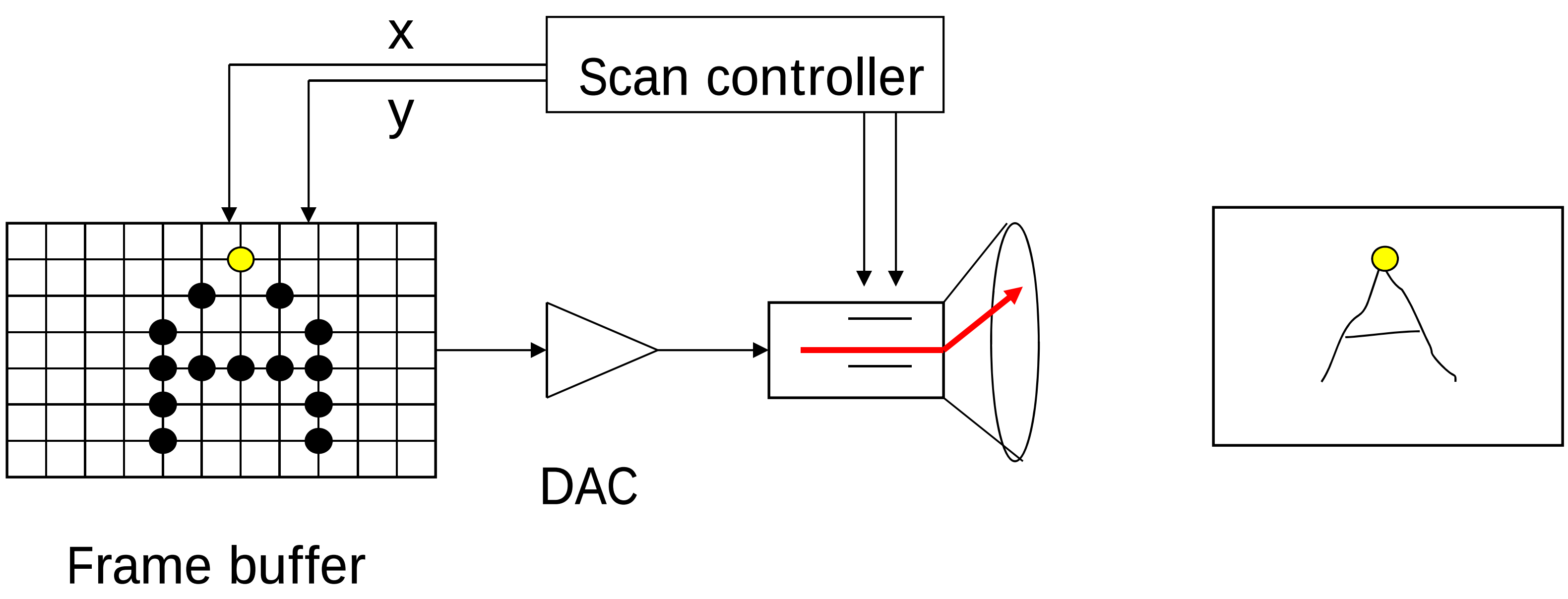


Standards

- NTSC: Interlaced, 525 line, 59.94Hz, 4:3
- DTV: Digital version of NTSC, 480i, 4:3
- HDTV: e.g. 720p, 60Hz, 16:9
- Blu-ray: 1080p
- Other standards?

Raster Scan Control

- Scan Controller (video adaptor) and frame buffer



Color is expensive ...

- At least used to be
- The more color you want, the more bits you will need for each pixel
- Exercise: 1024 x 1280 screen with

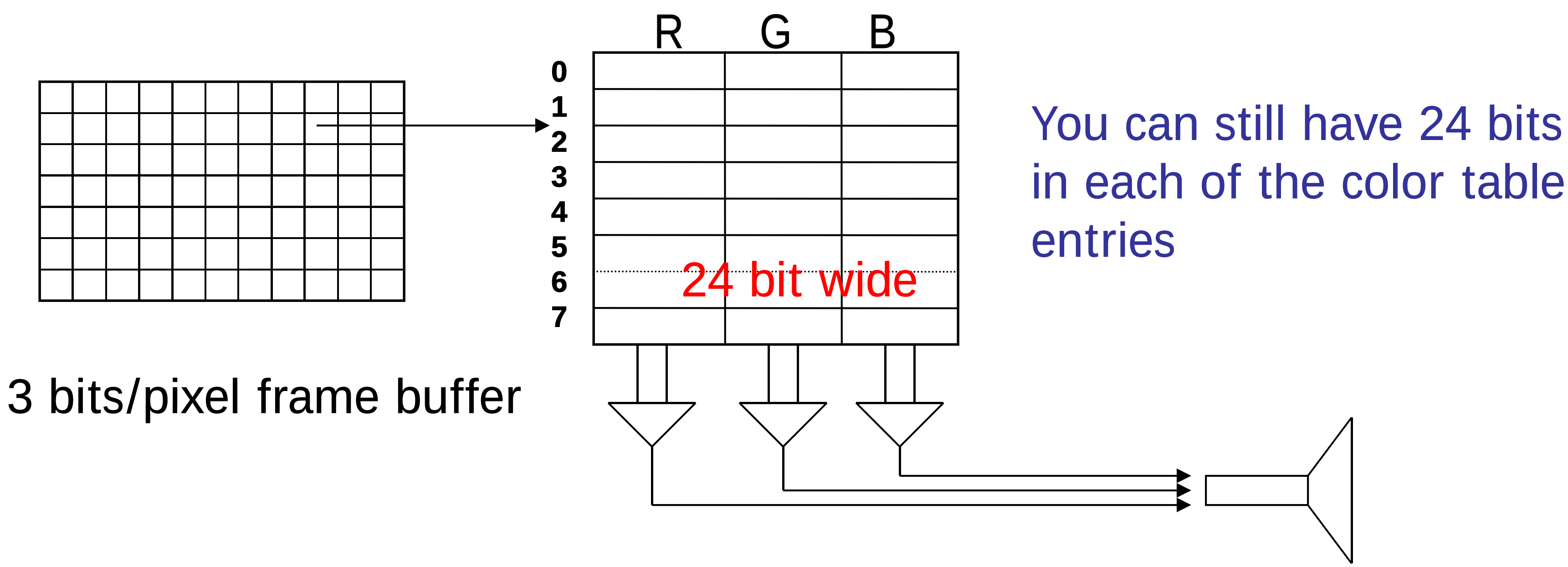
  24 bits per pixel, how many bytes in the frame buffer?

1024 x 1280 x 24 / 8 = 4M Byte

@30fps = 120MB/sec

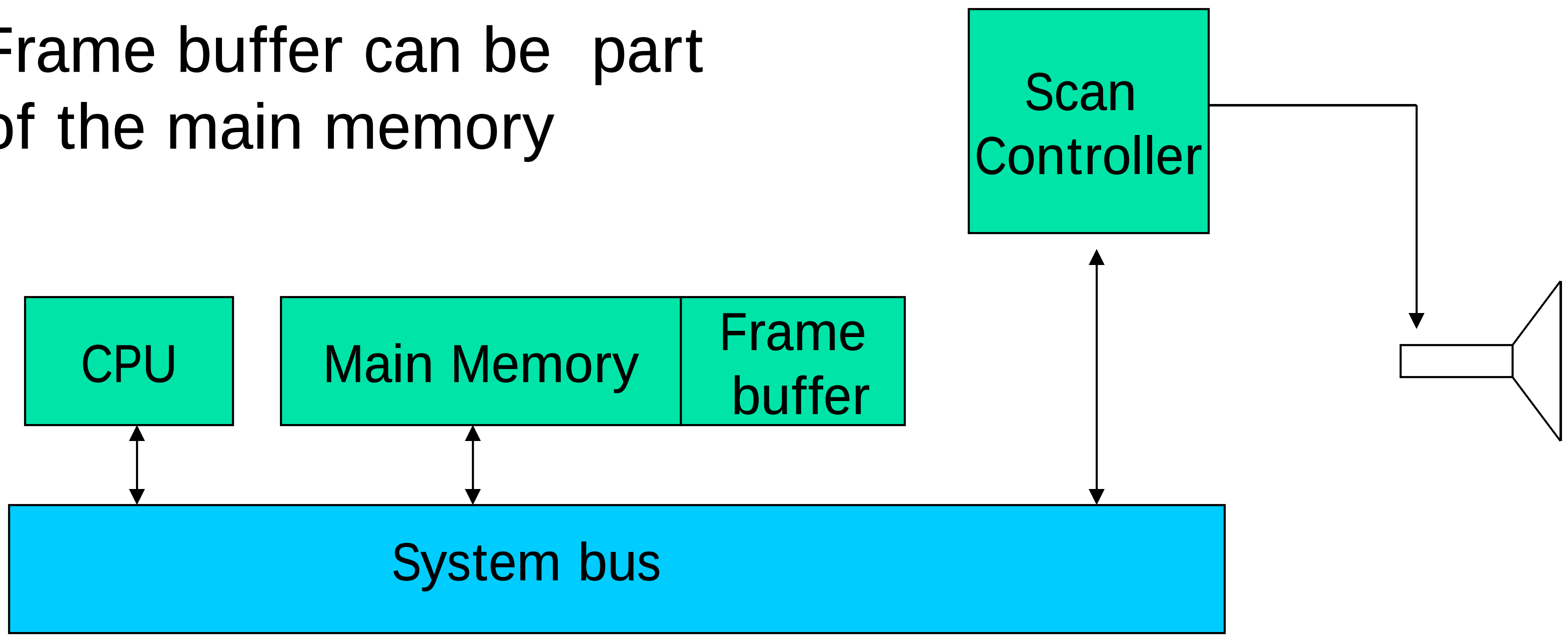
Color Lookup Table

- Say I am a poor man ... I only have 3 bits per pixel
- But I insist on having high quality pictures ...
- Use Color Look Up Table (LUT)



A simple graphics system

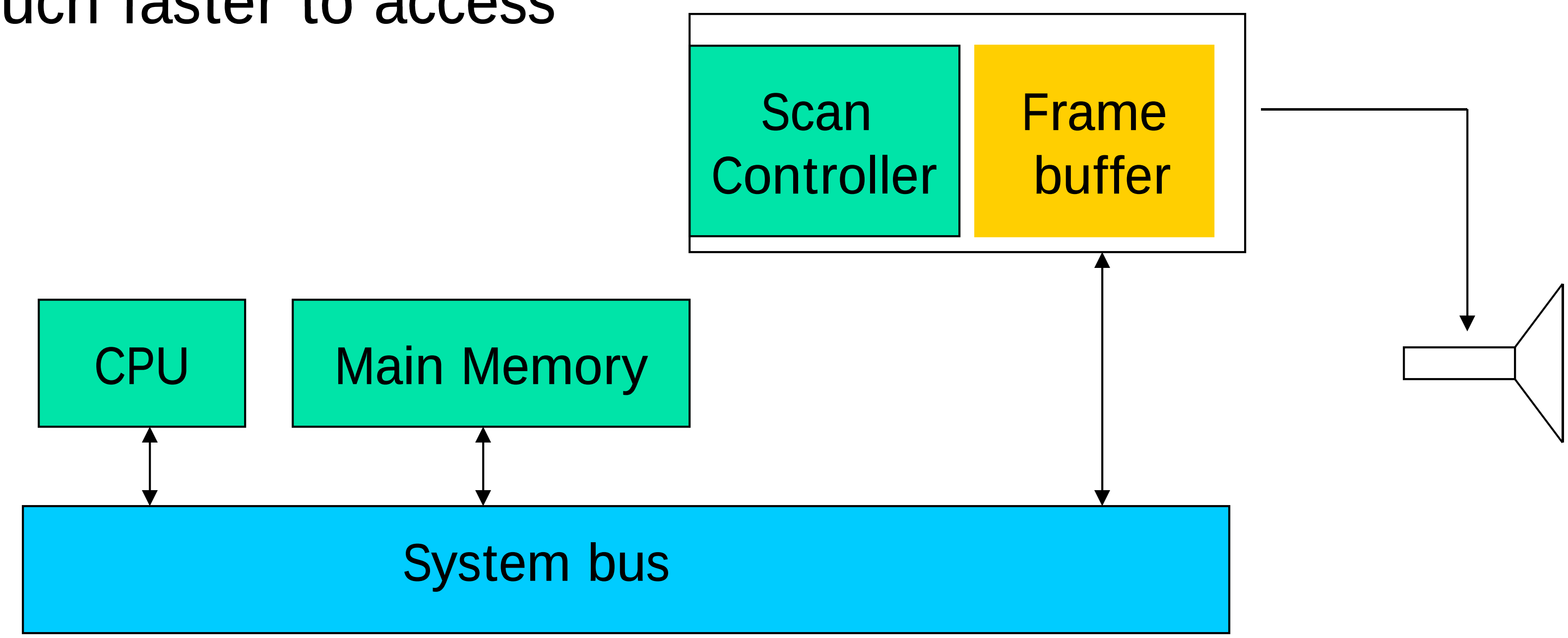
Frame buffer can be part of the main memory



Problem?

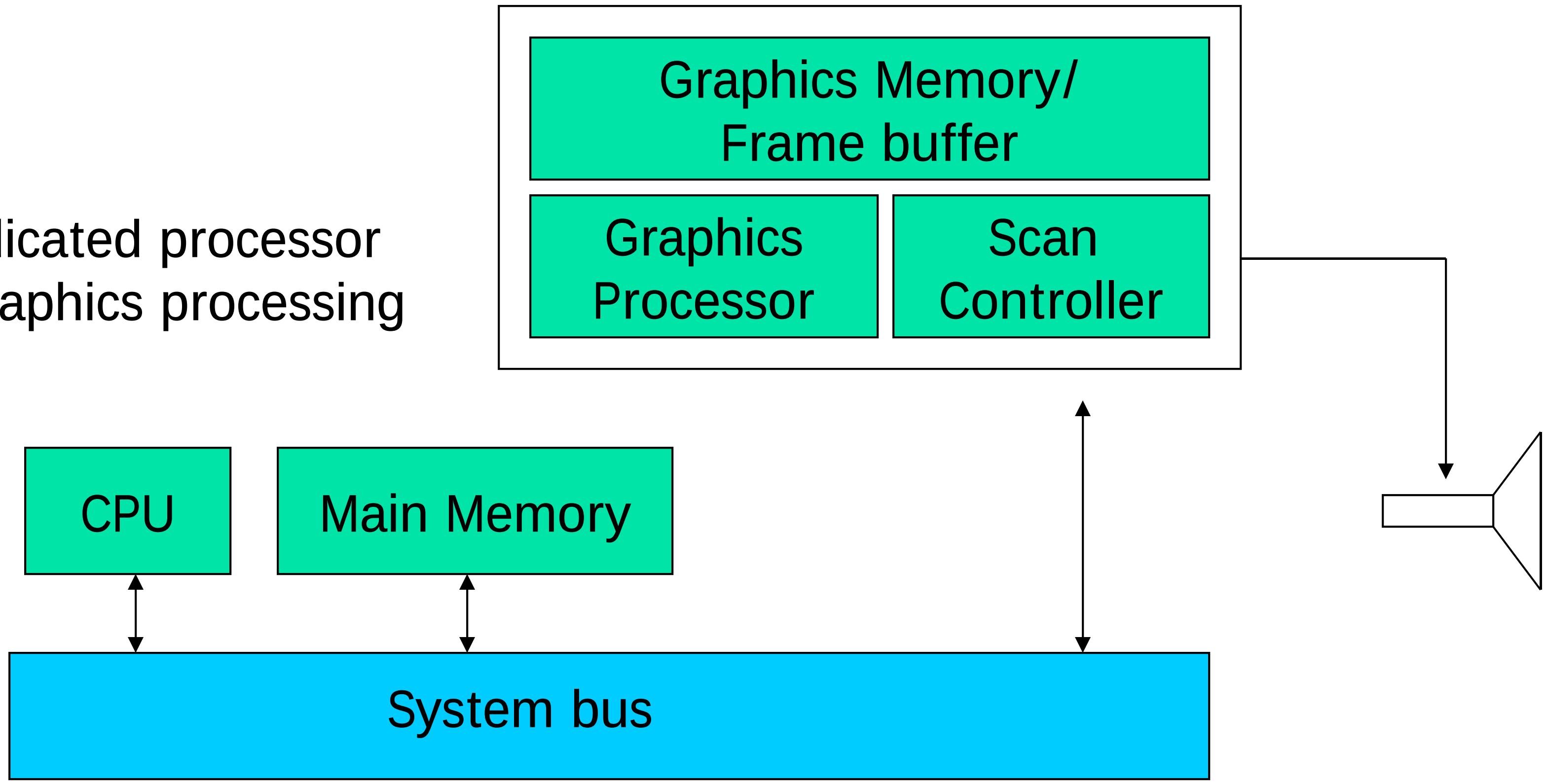
Dedicated memory

Video memory: On-board frame buffer: much faster to access



Graphics Accelerator

A dedicated processor
for graphics processing



Graphics Accelerator

Graphics Accelerator

NVIDIA GPUs

[redacted]

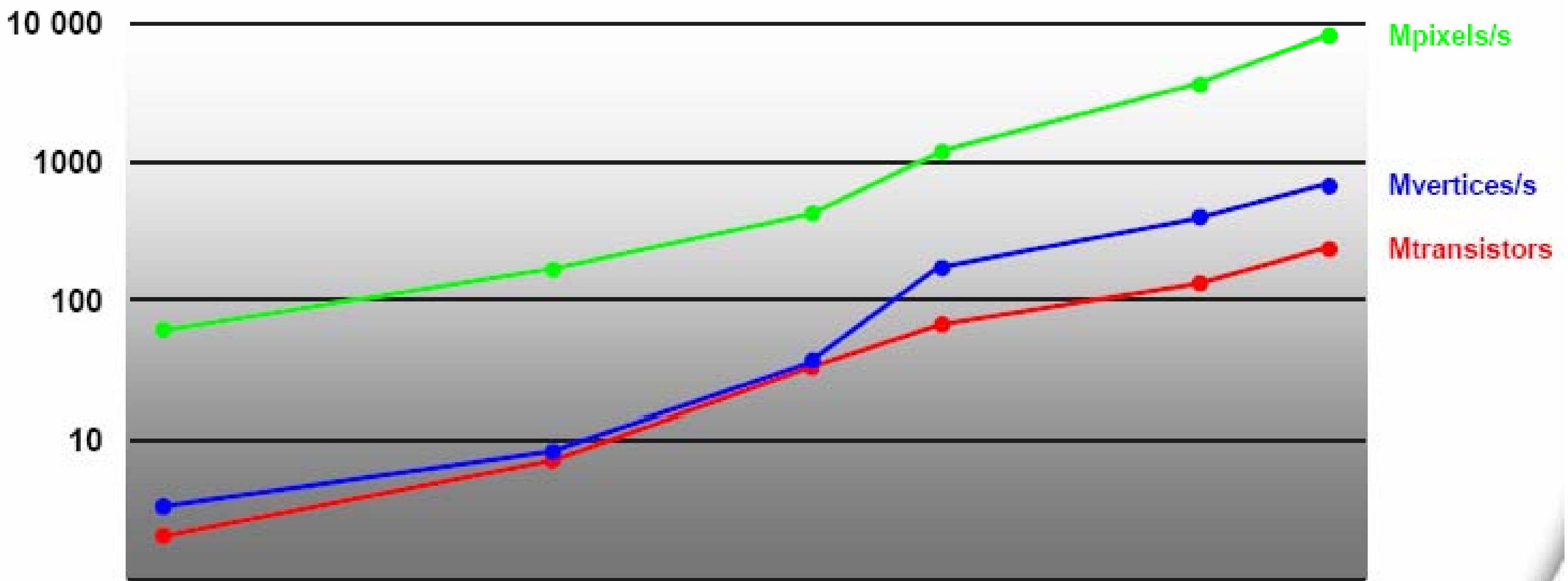
	Quadro FX 5600	Quadro FX 4600
Memory Size	1.5GB GDDR3	768MB GDDR3
Memory Interface	384-bit	384-bit
Memory Bandwidth	76.8 GB/sec.	67.2 GB/sec.
Max Power Consumption	171W	134W
Number of Slots	2	2
Display Connectors	DVI-I DVI-I Stereo	DVI-I DVI-I Stereo
Dual-Link DVI	2	2
Price	$2,999.00	$1,999.00

AMD GPUs

Desktop vs Mobility Radeon Graphics

	Desktop Radeon HD 6990	**Desktop Radeon HD 6870**	**Radeon HD 6990M**
Transistors	5.28 billion	1.7 billion	1.7 billion
Engine Clock	830 MHz	900 MHz	715 MHz
Shader (ALUs)	3072	1120	1120
Texture Units	192	56	56
ROP Units	64	32	32
Compute Performance	5.1 TFLOPS	2.01 TFLOPS	1.60 TFLOPS
DRAM Type	GDDR5-5000	GDDR5-4200	GDDR5-3600
DRAM Interface	256-bits per GPU	256-bits	256-bits
Memory Bandwidth	160 GB/s per GPU	134 GB/s	115.2 GB/s
TDP	375 W	151 W	100 W

Evolution of Performance



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Bus	PCI (133 MB/s)		AGP (266 MB/s)	AGP2x (533 MB/s)	AGP4x (1.06 GB/s)			AGP8x (2.1 GB/s)		PCIe (4 GB/s)
Video memory	4 MB			32 MB	64 MB	128 MB			256 MB	512 MB
API	DirectX 1 OpenGL 1.1	DirectX 2	DirectX 3	DirectX 5 OpenGL 1.2	DirectX 6	DirectX 7	DirectX 8 OpenGL 1.3	OpenGL 1.4	DirectX 9 OpenGL 1.5	

GPUs

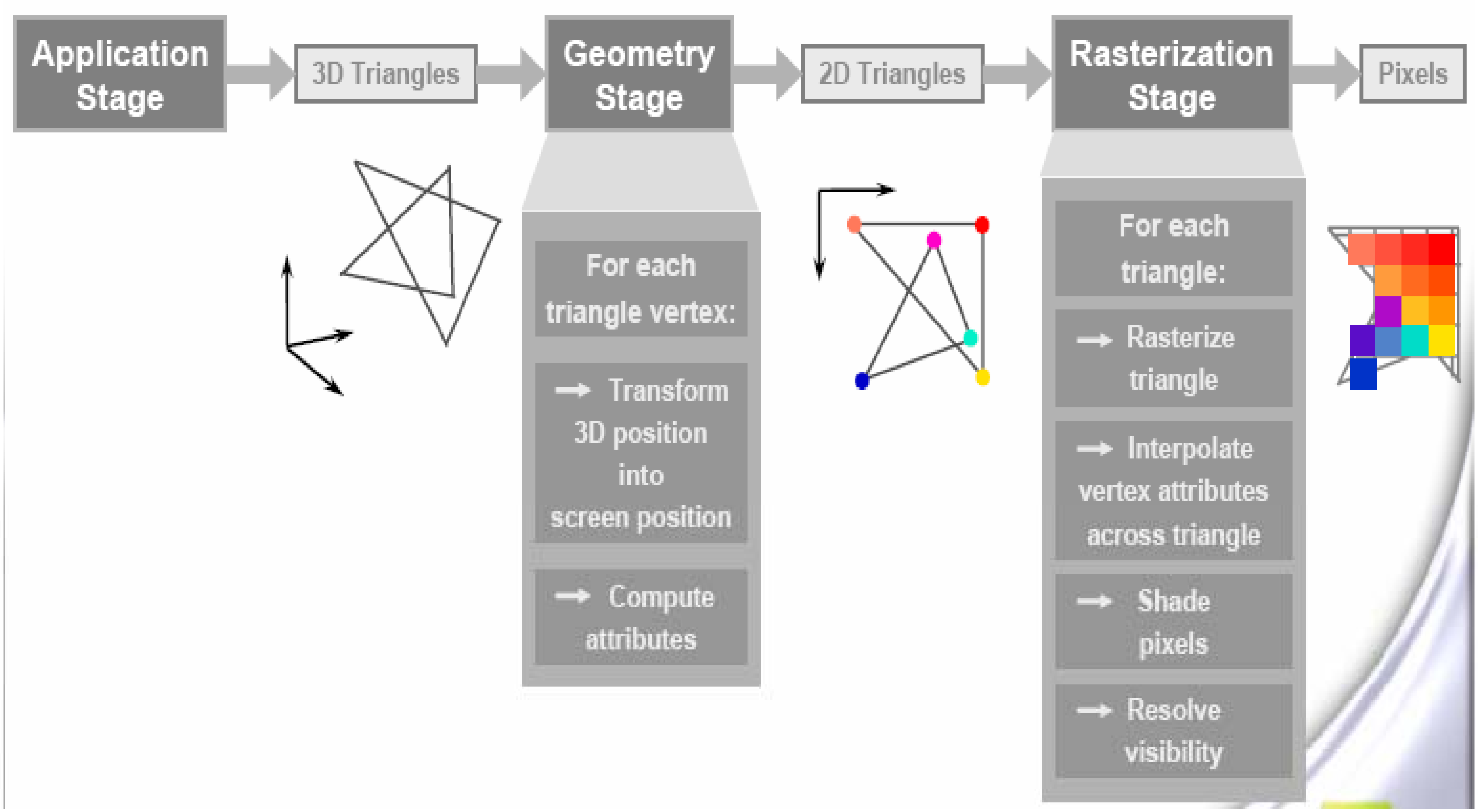
The Evolution of GPUs

ftp://download.nvidia.com/developer/presentations/2004/Perfect_Kitchen_Art/English_Evolution_of_GPUs.pdf

THE GPU COMPUTING ERA

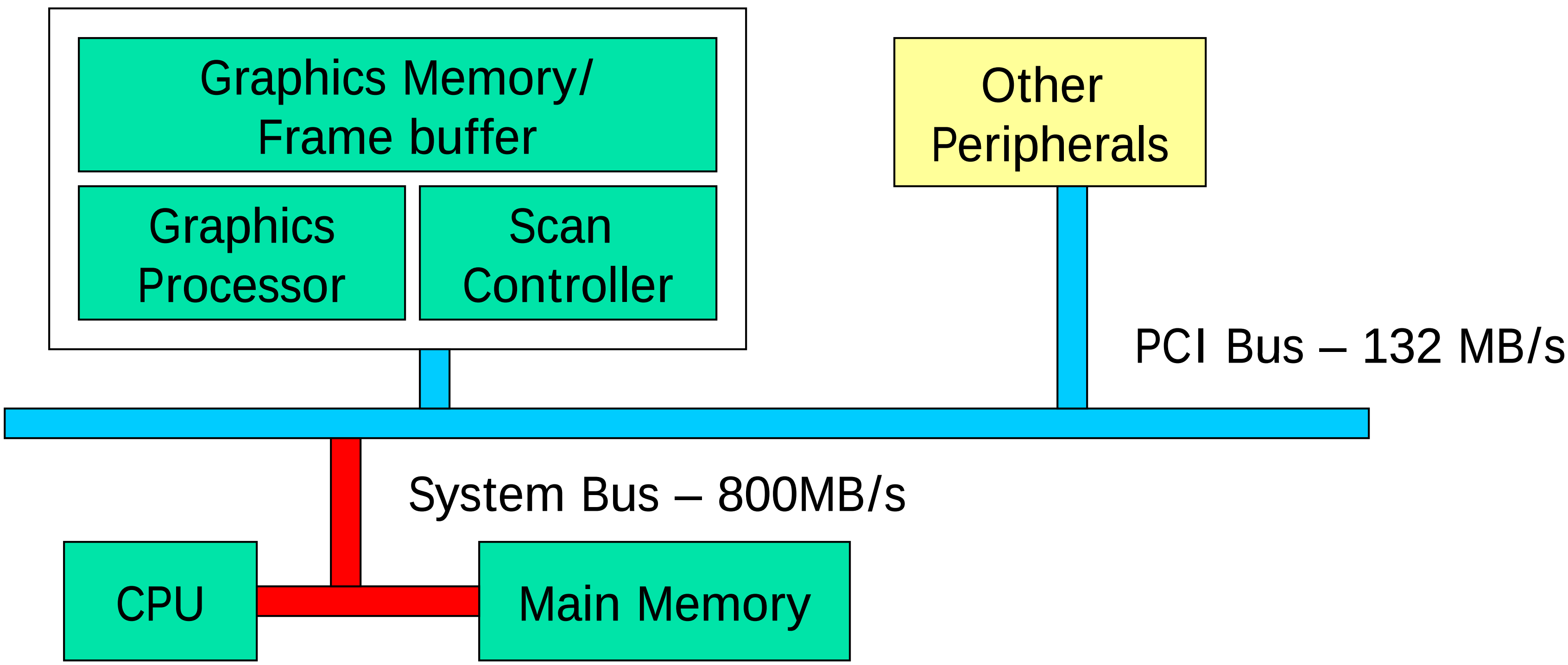
http://sbel.wisc.edu/Courses/ME964/2011/Literature/onGPUcomputingDally2010.pdf

The Graphics Pipeline



Graphics Bus Interface

PCI based technology

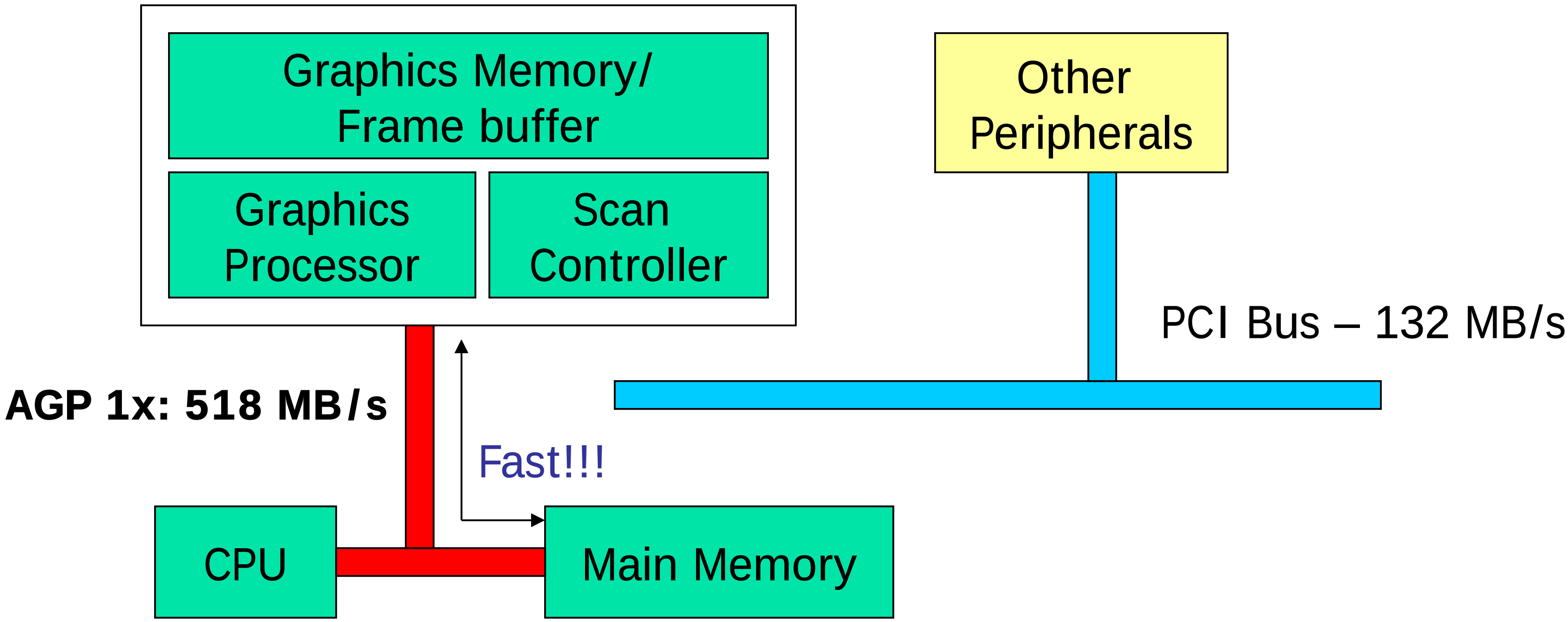


Graphics Bus Interface (2)

- PCI Bus becomes the bottleneck!
  - Many devices are using it
  - There is a lot of stuff needs to be transmitted from main memory to graphics memory (geometry, textures, etc)
  - Example: 2M triangle, 90 Bytes each – 180MB > 132 MB (PCI bandwidth)

Accelerated Graphics Port (AGP)

A dedicated bus that allows direct access of main memory

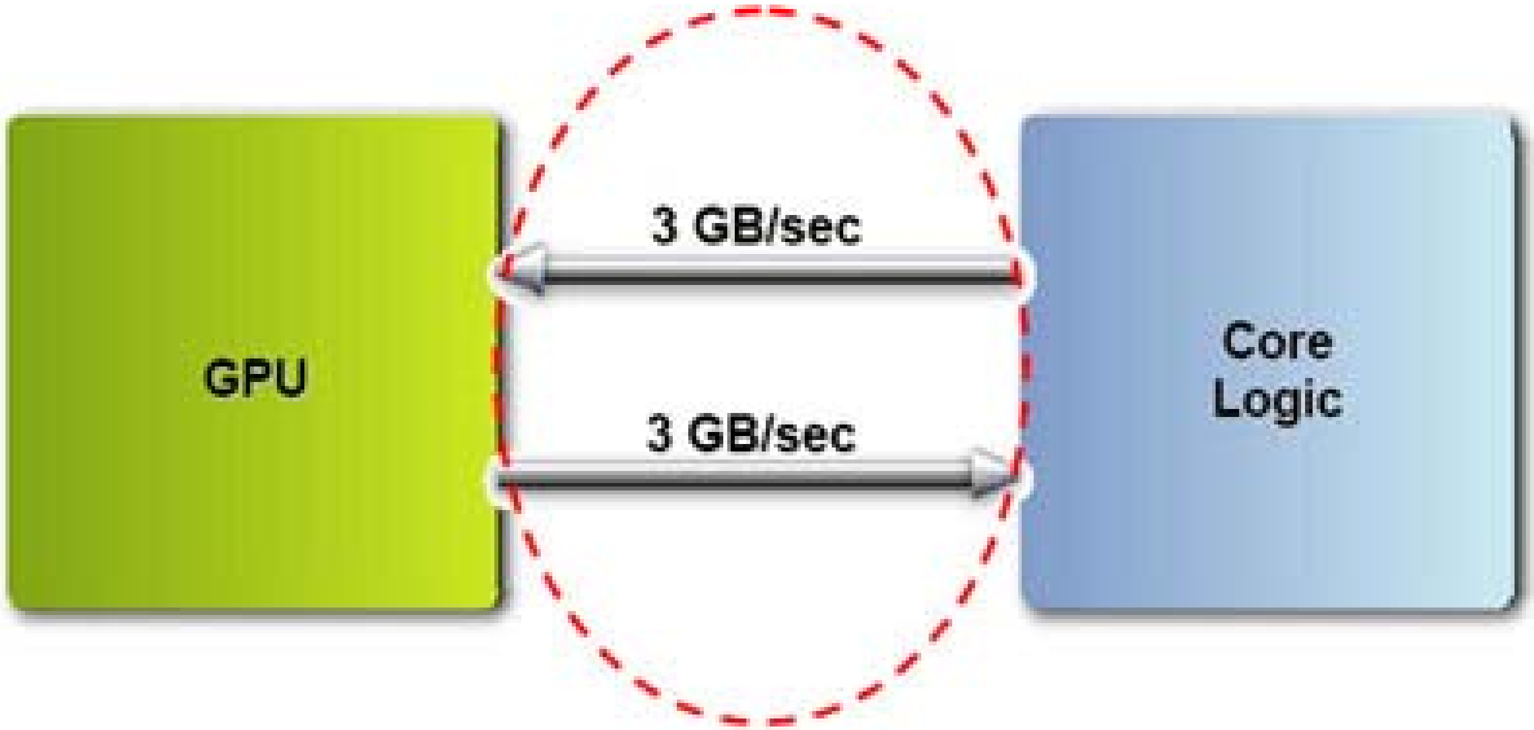


AGP

- AGP 1x is four times as fast compared to PCI! (now we have AGP 8x)
- No more local bus congestion!
- More geometry can be processed!
- Direct execution of many graphics operations from main memory

PCI Express

- Bandwidth?



Reading and Lab1

- Textbook Chapter 1, 2

Lab 1: Compile and run the sample OpenGL program posted on the class web site