Graphics Hardware

CSC 292:
Computer Graphics

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Hardcopy Technologies

Basically printing on paper, film etc. Some general issues are:

- The *resolution* of a device is the closest spacing at which adjacent black and white lines can be distinguished.
- Many devices work by producing (colored) dots, and image quality vs. *dot size* or *spot size* is an issue.
- Generally want some overlap - but not too much or potential detail is lost.
- Resolution can be no greater than *addressability* (lines per inch) and depends on spot size also on intensity distribution across spot.
- Many devices can create only a few solid colors. Other colors must be produced by *dither* patterns.

Dot matrix printers

- Head of pins (7-24) fired against ribbon.
- Can use several (offset) rows to get closer spacing.
- Color produced with colored ribbons.
- Typically bilevel, no gradation possible with dots.
- use of *subtractive primaries*, (cyan, magenta, and yellow) permit up to 8 solid colors via overprinting.
- Often true black is added, since mix of three primaries generally produces a muddy black.
- Advantages: Cheap, low resolution.
- Disadvantages: Slow, limited colors.

Pen Plotters

- Analog of vector display.
- Draws lines with actual pens.
- Flatbed plotters - up to 6x10 feet.
- Also drum plotters.
- Include microprocessor with "line" "circle" etc. commands.
- Also tries to optimize pen movements (e.g. minimize "up" time).
- Addressability to 1/1000 inch.
- Advantages: Can do big drawings, high contrast.
- Disadvantages: Slow, limited colors, can't do shaded or colored regions.

Electrostatic Plotters

- Uses comb of electric contacts to place charge on paper.
- Powdered *toner* sticks to charged areas and is fused to paper.
- Up to 72" wide, 3 inches/second, 100-400 contacts/inch.
- Device is bilevel - gray must be dithered.
- May include scan conversion.
- Can be done with color, either multiple passes or multiple heads.
- Faster than pen plotters, but lower contrast.
- Becoming obsolete.

Laser printers

- Use photocopy technology (Xerox).
- Laser beam deflected in desired pattern.
- Positively charged selenium drum loses charge where light (laser beam) hits.
- Toner sticks to charged areas and is transferred to paper.
- Colored powders can be used.
- Still bilevel (8-color) device. Dithering needed to get shades.
- Generally do scan conversion; often accept high level language (e.g. Adobe Postscript - de-facto industry standard)
- Common as desktop printers taking 8.5 x 11 or 8.5 x 14 inch paper.
- Larger sizes (30+ inches) are available.
- High resolution. Some can do up to 1500 dpi

Ink-jet printers

- A bit like dot-matrix printers only they spray ink from a row of holes on a head, 200dpi.
- Black and white or color.
- Usually on/off (bilevel) control. Some can do variable dot size (effective halftoning).
- Higher maintenance than some other devices - ink jets clog.
- May accept video.

Thermal Transfer Printers

- A bit like electrostatic (comb-type) printers.
- Line of heating nibs (200/inch) melt pigment from transfer sheets (wax paper) onto plain paper.
- For color, alternating strips of color on roll, or separate rolls.
- Still bilevel in general.
- More expensive than ink-jet printers.

Dye Sublimation Printers

- Similar in operation, except dye vaporized across a small space when heated instead of melting in contact.
- Allows good multi-level control (e.g. 256 levels each of cyan, magenta, and yellow).
- Near photographic quality.
- Slow.
- Expensive.

Cameras (film recorders)

- Photograph an image displayed on a CRT.
- Simplest way, photograph color CRT.
- Colors can also be done in separate scans, using filters, on monochrome CRT giving higher quality.
- Very good color, very high resolution possible.
- High resolution systems can be very expensive ($100,000).

Cycolor Technique

- Micro-capsules of dye, embedded in paper, harden when exposed to light of correct color. e.g. green light causes magenta capsules to harden.
- Pressure rollers break unhardened capsules against plain paper.
- True shading is possible.
- New technology.

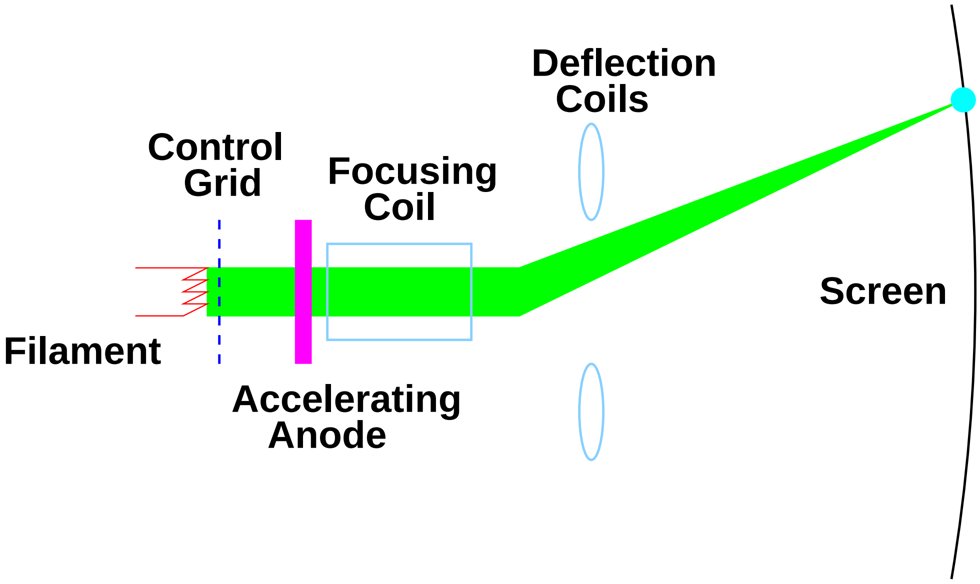
Only film recorders, dye-sublimation, cycolor, and some ink-jet printers can record a wide range of colors directly.

Display Technologies

Want to display transient, rapidly changing imagery. for interactive applications, Movies/video etc.

- CRT (most common).
- LCD (next most common).
- Plasma panels.
- Electroluminescent displays.
- Electrophoretic displays.
- Projection devices.

Monochrome CRT



- Pretty much like a TV.
- Filament emits electrons, accelerated by gun (15-20KV), focused onto a point on the screen.
- Beam is deflected horizontally and vertically by magnetic fields, and hits *phosphors* on screen which emit light.
- Stream of electrons is modulated by *grid* to produce pattern.

- Whole screen (e.g. 1000 rows) is *refreshed* many times per second (at least 60) to give illusion of continuous illumination.
- Beam is Gaussian, so spot size is defined to be diameter at which 50% of central intensity is reached. Typical size is .005 inches in hi-res monitor.
- Beam must focused dynamically to get sharp images on flat screen.

Light Emission Process

- Beam exites electrons in phosphor.
- Immediate *fluorescence* due to fast return to lower state.
- Persistent *phosphorescence* due to slower return.
- For CRTs, want most of the light emitted by fluorescent processes.
- The *persistence* is time until light is 10% of initial value, typically 10-60 microseconds (so there is really a lot of variation)
- Decay is complex mix of exponentials.

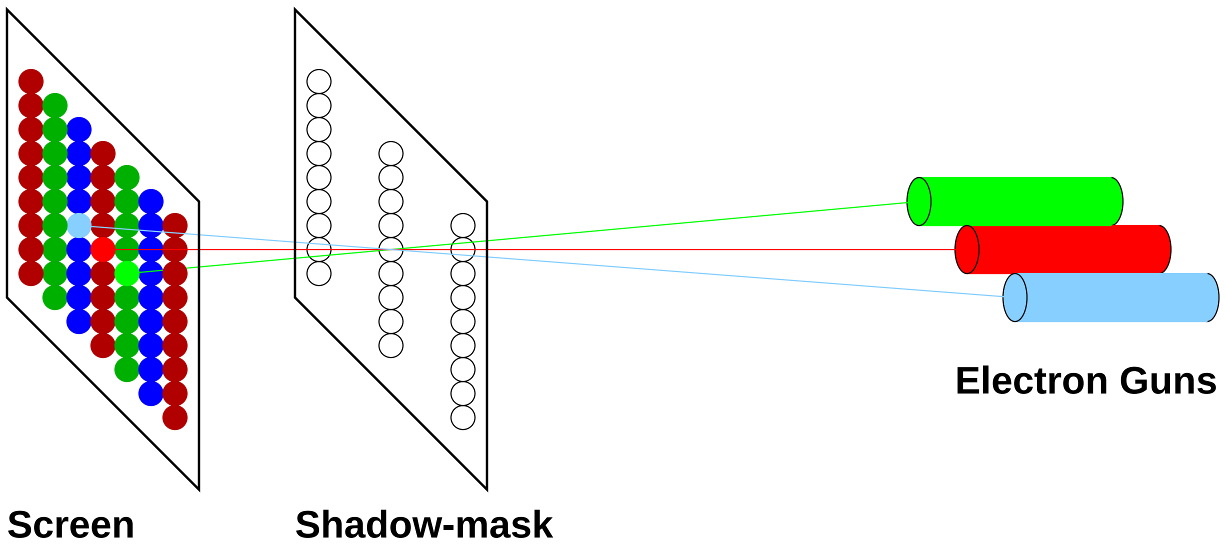
Visual Fusion

- As refresh rate slows below 60Hz, *flicker* develops.
- The *critical fusion frequency* (CFF) is rate at which picture appears to stop flickering.
- Depends (nonlinearly) on persistence, also on ambient lighting, wavelength, and individual.
- To eliminate flicker for 99% of viewers in high-intensity images needs 80-90 Hz.

Other Issues

- Horizontal scan rate = scan lines per second.
- Resolution (lines per inch). Resolution limit occurs when interline spacing is about equal to the 60% intensity diameter of the spot.
- Resolution is not constant - *bloom* with increasing intensity can increase spot size.
- Generally, vertical resolution is determined by spot size.
- Horizontal resolution is also effected by maximum modulation frequency - *bandwidth*.
- 1000 x 1000 at 60 Hz needs 45 Mhz according to book (30 MHz plus some for retrace I guess).
- Need more if spot-size is non-zero.
- 100 MHz is common in high-res monitors.

Color CRT



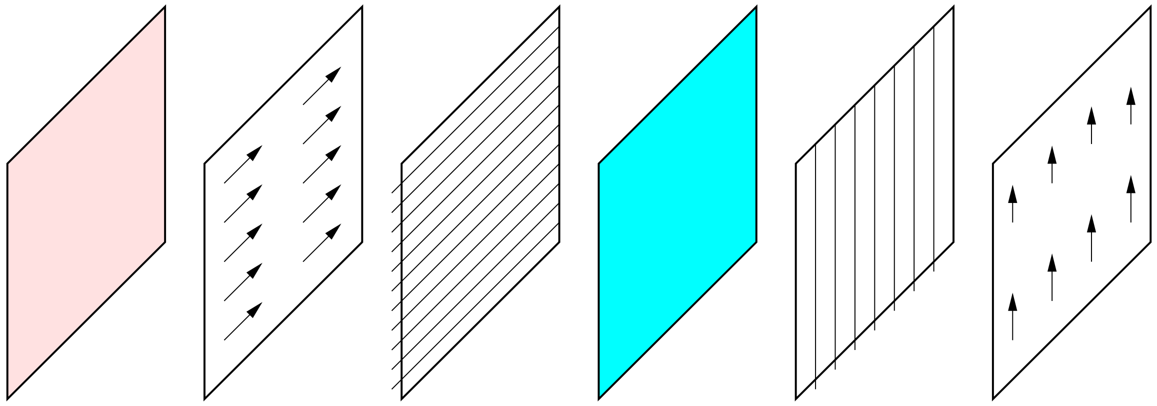
- Obtained by adding a *shadowmask* and using 3 (independently modulated) guns.
- Phosphors in triads of different colors, either triangular or linear.
- One hole in shadowmask per triad pinhole-images the gun cluster onto the correct phosphor dots.

- Clearly alignment is critical.
- Resolution limit is determined by triads and shadowmask not just spot size and bandwidth.
- The *pitch* is the distance between triads. Varies from .60 mm on Home TV to .20 mm on hi-res monitors.
- Beam diameter is typically 7/4 the pitch to ensure a hit and avoid severe aliasing problems.
- Only about 20% of the electrons hit the screen.

Direct-view storage tube

- Like a standard CRT except it does not have to be refreshed.
- Image is stored as distribution of charge on inside surface of screen.
- Big advantage: no refresh needed.
- Slow redraw however.
- Tektronix 4010 was of this type - "Model T" of graphics terminals.
- Obsolete now, but many display systems have a tektronix compatible mode so old software can still be run.

Liquid Crystal Displays (LCD)



- Use *liquid crystals* composed of long *chiral* molecules, spirally arranged, that twist the polarization of light.
- An applied electric field destroys this polarizing effect.
- Without field, LC twists light so it passes both polarizers. With field, light is not twisted, so dark spot appears.
- Matrix addressing is used to switch dots on and off, one row at a time; persistence allows scanning.

Active Matrix Panels

- A variation of the LCD has a transistor at each cell that can hold a variable voltage.
- Allows brighter displays, and variable tone and color.
- Does not have to be refreshed frequently.

Overall LCD advantages: low cost, low weight, flat, small size, low power consumption.

Disadvantages: small size, low contrast, slow response (last two fixed with active matrix).

Plasma panels

- Array of tiny neon bulbs (glass sheet with holes) between two addressing grids of wires.
- The *hysteresis* in discharge tube physics allows matrix addressing to be used to turn bulbs on and off - high voltage initiates, lower voltage maintains.
- Can be changed one row at a time.
- Does not need to be refreshed.
- Flat, transparent, and rugged.
- Expensive.
- Military use.
- Color has been demonstrated in labs, but not commercially available.

Electroluminescent displays

- Use material (zinc sulphide doped with manganese) that glows when placed in electric field.
- Grid of wires provides matrix addressing.
- Active matrix can be used.
- Bright, flat, color available.

Others

Electrophoretic displays

- Colored particles in solution of contrasting color.
- Voltage applied via matrix addressing is used to move particles to either front or back of screen, where they stay until moved.

Projection systems

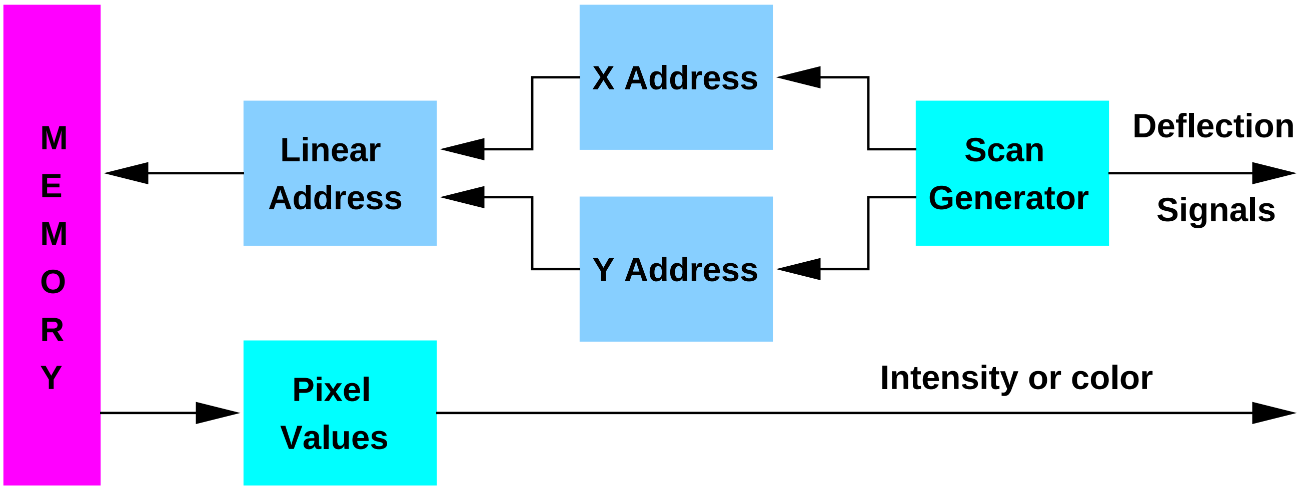
- Projection CRTs.
- Light valves for higher intensity: oil-film devices, or LCD based.

Raster Scan Display Systems

The various hardware architectures for providing graphics functionality differ on two axes

1. Processing performed by specialized graphics hardware.
   - Simplest has only *video controller*.
   - More complex systems use a *graphics display processor* with varying functionality.
2. Relationship of frame buffer to CPU memory architecture.
   - Dual ported
   - Accessible only to graphics controller
   - Accessible only over main bus

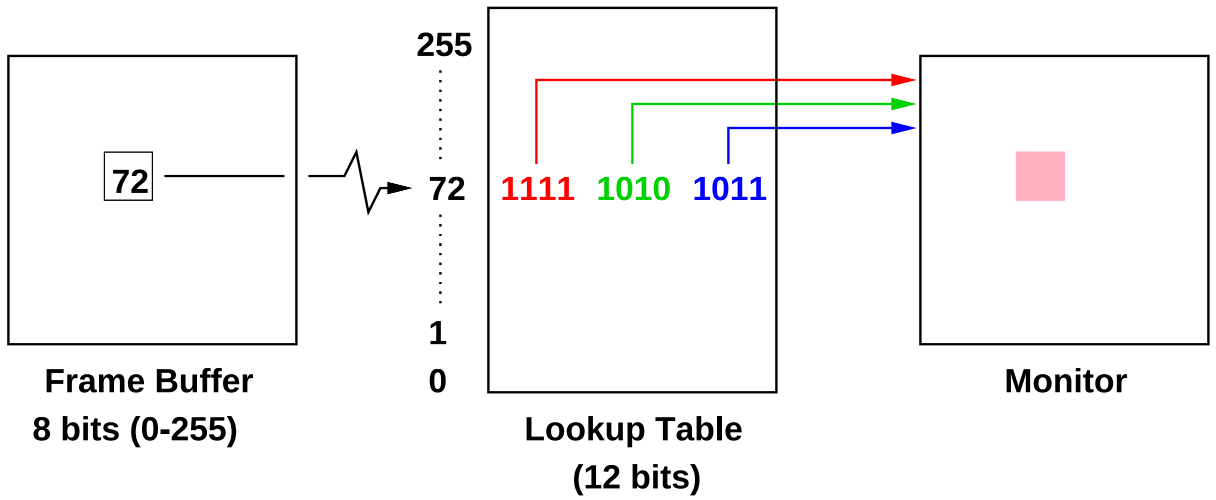
Video Controller



- Does coordination between memory accesses and sweeping the CRT beam (or otherwise setting physical display pixels.
- Problems with memory access – 50 ns pixel time (480 x 640 x 60 Hz) is shorter than typical 200 ns RAM cycle time.
  - Must fetch multiple pixels per access.
  - Can eat up a lot of memory bandwidth.
  - Can eat up a lot of main bus bandwidth if so organized.

Lookup Tables

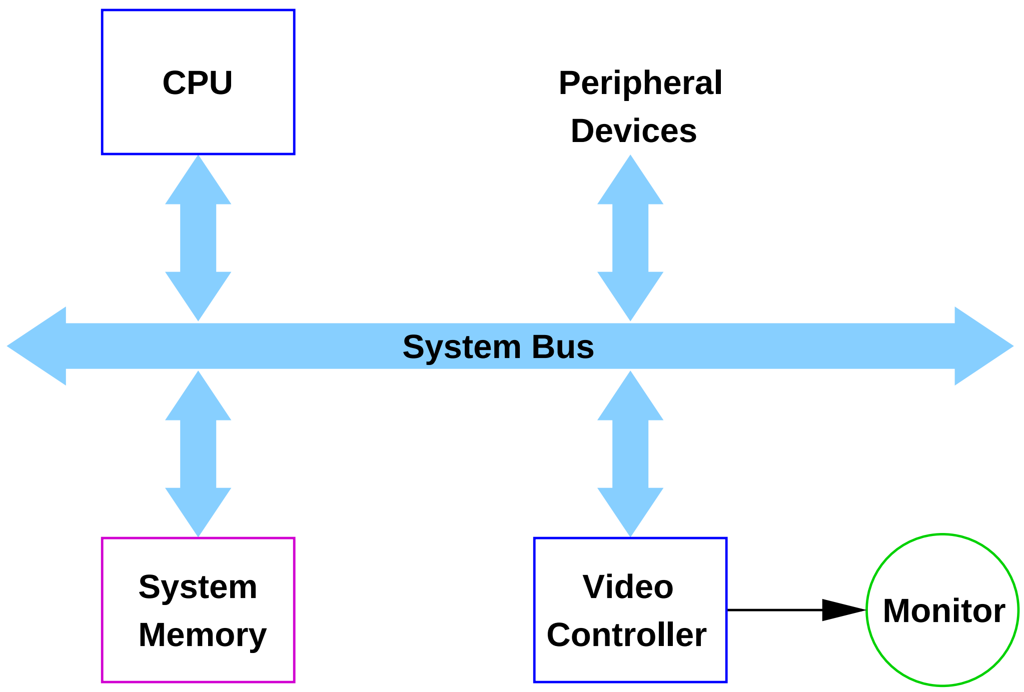
Video controller often uses a *lookup table* to allow indirection of display values in frame buffer.



- Allows flexible use of colors without lots of frame-buffer memory.
- Allows change of display without remapping underlying data *double buffering*.
- Permits simple animation.
- Common sizes: 8 x 12; 8 x 24; 12 x 24.

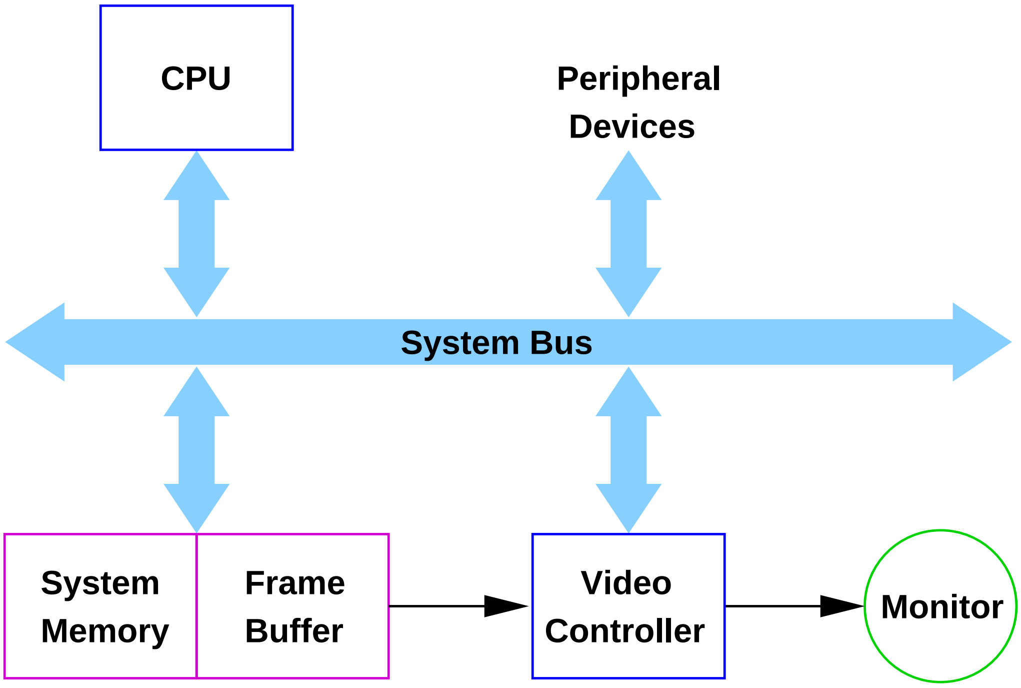
Simple Raster systems

No special graphics processing except *video controller*. Two basic frame-buffer mappings.



Single ported frame buffer:

- Passes video information over system bus.
- Simple and flexible.
- Problems with bus congestion.

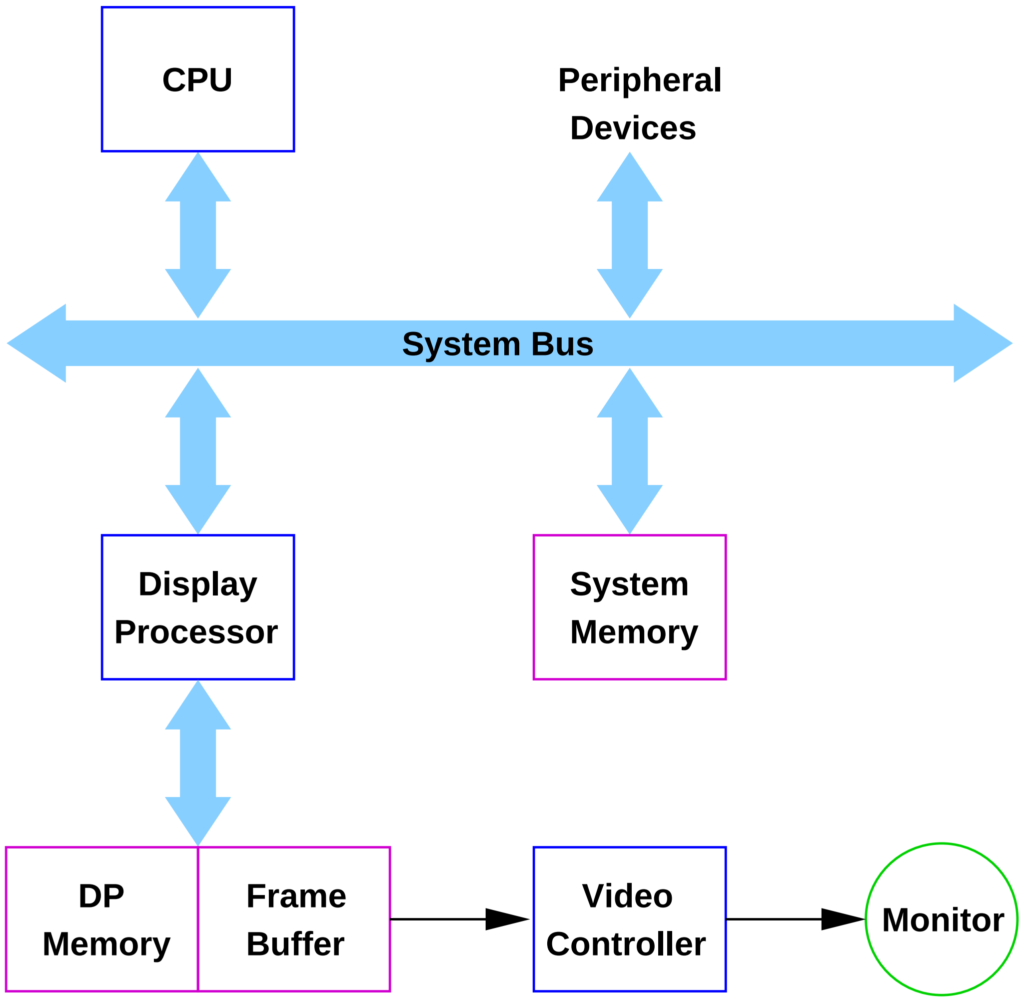


Dual ported frame buffer:

- Frame buffer in special, dual ported *Video RAM*.
- Unloads bus.
- More expensive.
- Less flexible.

Systems with video processors

- Makes sense to put special-purpose hardware close to video (speed, expense)
- May do various scan conversion algorithms, pix moves, windowing, sometimes rotation of existing primitives
- Commands such as Text, Move, Line, Polygon...
- 3D stuff as well - hidden surface removal, shading, texture mapping.
- "Wheel of reincarnation" - move too much functionality down, and you have another general purpose processor that could also use some special-purpose help...
- Various architectures.

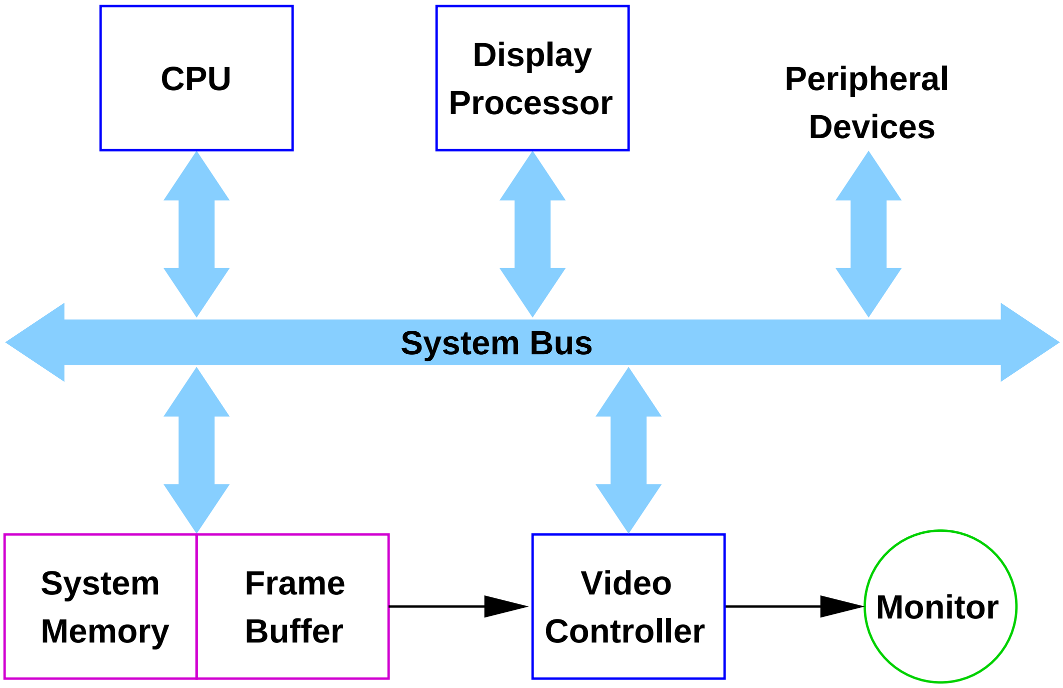


Mostly independent peripheral processor.

- Graphics processor has its local memory and manages the frame buffer and specialized graphics programs.
- Typical architecture for “plug in” graphics cards.

- Graphics processor is controlled via an *instruction queue*.
- All data transferred between host memory and coprocessor memory must go through both CPU
- Unimplemented algorithms may be slow, since host machine has no direct access to the frame buffer.
- May be considerable communication overhead if coprocessor instruction registers are not *memory mapped*.

Some of the problems with peripheral processors can be overcome by using a *single address space*(SAS) architecture.



- Graphics processor and the host processor share a common memory space.

- Problems with data transfer are reduced.
- Graphics processor may still have some private memory for algorithms and working storage.
- Main bottleneck is bus congestion.
- Becoming a popular architecture (e.g. SGI) despite drawbacks.

More Stuff about Video

- Two types of refresh: *interlaced* and *noninterlaced*.
- Three types of analog video output: monochrome, RGB, and NTSC.
- RGB has three color channels and a synch channel. Sometimes synch is on green channel (composite).
- RS-170 is standard for 480 scan-line monochrome, RS-170A for RGB color. Other standards for higher resolution.

- NTSC encodes both intensity and color information into one analog signal, with about 5 MHz bandwidth.
- NTSC has 525 scan lines, of which only 480 have image data in them. The rest is vertical blanking period. Effective resolution is about 350 x 350
- All sorts of other standards are out there, or coming along, especially new ones for digital video and high definition TV.

Input Devices

- Tablets (wire grids, sonic, resistive).
- Mouse (mechanical, optical).
- Trackball.
- Joystick.
- Touch panels (IR, capacitive, sonic, resistive).
- Light pen (obsolete).
- Keyboard devices.
- Valuator devices (rotary, slide).
- Choice devices (function keys).

- Image scanners.
- Digital Cameras.
- Video cameras.
- Eye trackers.
- “6D mouse” (Polhemus, Flock)
- Datagloves.
- Force-feedback articulated devices (Phantom).
- Exoskeleton devices.
- Microphones.