Display Devices

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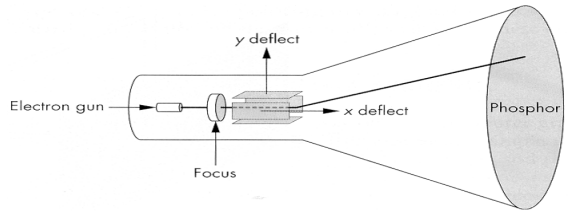
Reading

Hearn & Baker, *Computer Graphics (2nd edition)*,
Chapter 2: Video Display Devices, p. 36-48, Prentice Hall

Optional

- I.E. Sutherland. Sketchpad: a man-machine graphics communication system. *Proceedings of the Spring Join Computer Conference*, p. 329-346, 1963.
- T.H. Myer & I.E. Sutherland. On the design of display processors. *Communications of the ACM* 11(6): 410-414, 1968.
- http://www.howstuffworks.com/lcd.htm
- http://graphics.lcs.mit.edu/classes/6.837/F01/Lecture01/Slide11.html
- http://graphics.lcs.mit.edu/classes/6.837/F01/Lecture01/Slide13.html

Cathode Ray Tubes (CRTs)

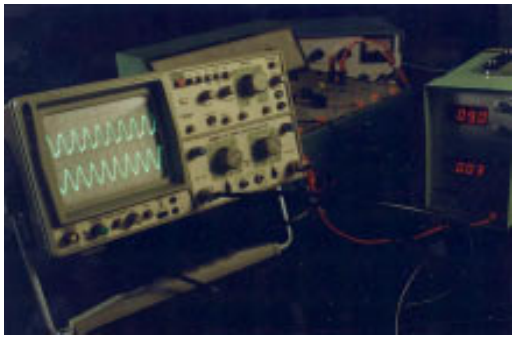


- Consists of:
  - electron gun
  - electron focusing lens
  - deflection plates/coils
  - electron beam
  - anode with phosphor coating

CRTs, cont.

- Electrons "boil off" the heated cathode and shoot towards the anode. Electrons striking the phosphors create light through:
  - fluorescence (fraction of usec)
  - phosphorescence (10 to 60 usec)
- Different phosphors have different:
  - color
  - persistence (as long as a few seconds)
- The image must be **refreshed** to avoid **flicker**:
  - typically need at least 60 Hz (why 60 Hz?)
  - exact frequency depends on:
    - persistence
    - image intensity
    - ambient lighting
    - wavelength
    - observer

Moving the Beam



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Calligraphic Displays

- Electron beam traces out lines that make up an image
  - Line segments to draw are stored in a **display list**
  - Display hardware continuously executes contents of list

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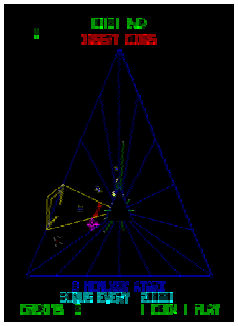
Calligraphic Displays



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Calligraphic Displays

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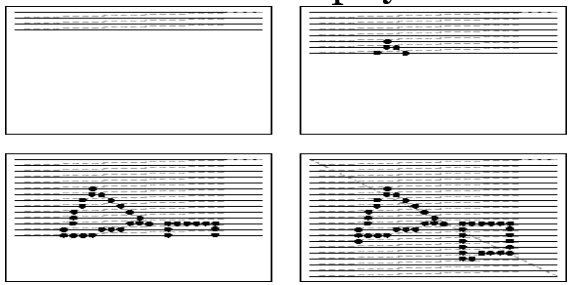
Raster Displays



Electron beam traces over screen in **raster scan order.**

- Each left-to-right trace is called a **scan line.**
- Each spot on the screen is a **pixel.**
- When the beam is turned off to sweep back, that is a **retrace**, or a **blanking interval.**

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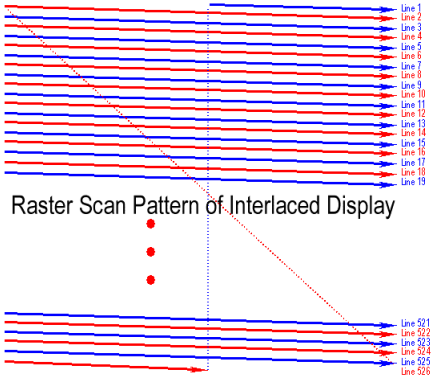
Interlaced Displays



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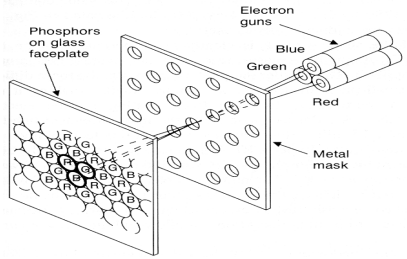
Color CRT Monitors



Most color monitors employ **shadow mask** technology:

- uses **triads** of red, green, and blue phosphors at each pixel
- uses three electron guns, one per color
- **shadow mask** used to make each kind of phosphor only "visible" from one gun

These are also known as **RGB monitors.**

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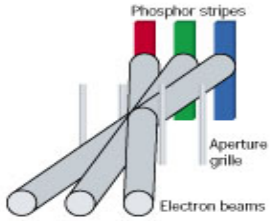
Color CRT Monitors, cont'd



A competing technology is called Trinitron (by Sony):

- uses vertical stripes of red, green, and blue phosphors at each pixel
- uses three electron guns, one per color
- uses an **aperture grille** to make each kind of phosphor only "visible" from one gun

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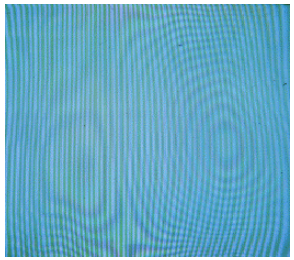
CRT Drawbacks

- Moire patterns result when shadow-mask and dot-pitch frequencies are mismatched
- Convergence (varying angles of approach distance of e-beam across CRT face)
- Limit on practical size (< 1 meter)
- Distortions from magnetic fields
- Spurious X-ray radiation
- Occupies a large volume



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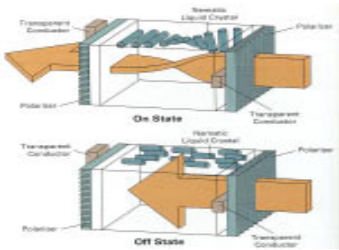
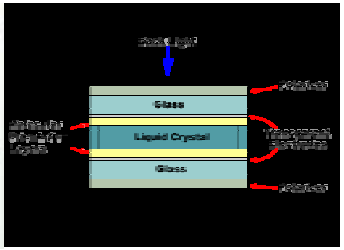
Liquid Crystal Displays





Laptops typically use **liquid crystal displays (LCD's).**

- Light enters a **vertical polarizer**
- **Nematic crystal** twists light based on applied voltage (more voltage, less twisting)
- Light passes through **horizontal polarizer**

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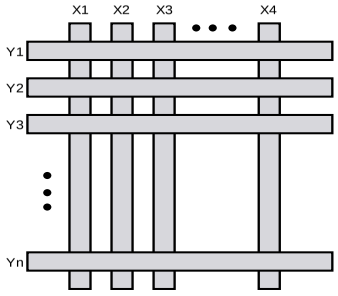
Liquid Crystal Displays



Passive matrix displays use a matrix of electrodes to control the voltages. Problem: slow to switch, overflows.

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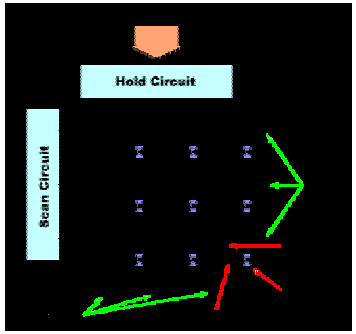
Active Matrix Displays



•Active matrix displays have a transistor at each cell. They use a faster switching crystal and transistors that hold charge and prevent overflow.

•Color filters are used to get color display.

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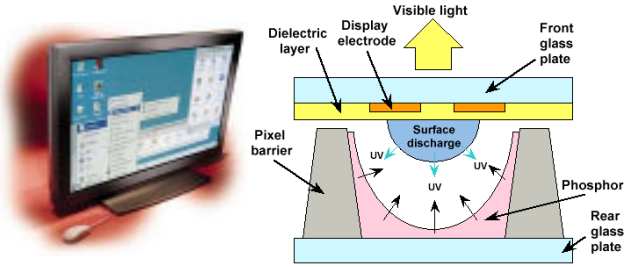
Plasma Displays



- Large format displays (pixels ~1mm compared to 0.2mm for CRT)
- Large viewing angle
- Basically fluorescent tubes

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Resolution

- The display's **resolution** is determined by:
  - number of scan lines
  - number of pixels per scan line
  - number of bits per pixel

Examples:			
	Bitmapped display	960 x 1152 x 1b	1/8 MB
	NTSC TV	640 x 480 x 16b	1/2 MB
	Color workstation	1280 x 1024 x 24b	4 MB
	Laser-printed page		
	300 dpi	8.5 x 11 x 300^2 x 1b	1 MB
	1200 dpi	8.5 x 11 x 1200^2 x 1b	17 MB
	Film	4500 x 3000 x 30b	50 MB

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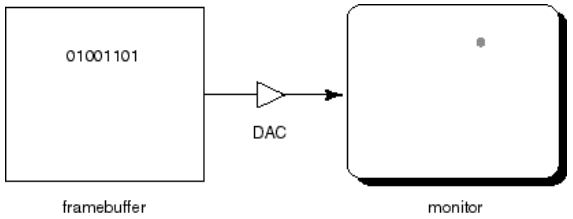
Framebuffers



Intensity of the raster scan beam is modulated according to the contents of a **framebuffer.**

Each element of the framebuffer is associated with a single **pixel** on the screen.

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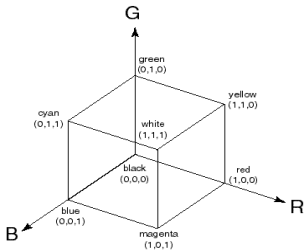
Additive color mixing



All colors on a monitor are produced using combinations of red, green, and blue.
A monitor that allows 256 voltage settings for each of R, G, and B is known as a **full-color system.**
The description of each color in framebuffer memory is known as a **channel.**

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Specifying colors

- The number of color choices depends on the amount of framebuffer storage allocated per pixel.
- 16 bpp systems often allocate 5 bits to red, 6 to green, and 5 to blue. Why does green get the extra bit?

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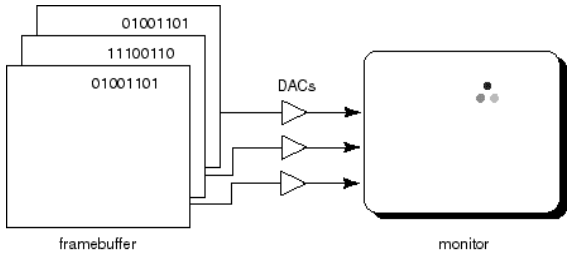
RGB framebuffer



The term **true-color** is sometimes used to refer to systems which the framebuffer directly stores the values of each channel.

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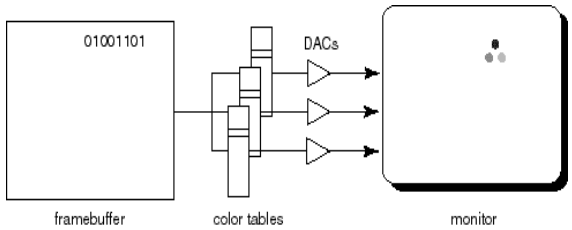
Color tables



• **Color tables** allow more color versatility when you only have a few bits per pixel. You get to select a small **palette** of from a large number of available colors.

• Each framebuffer element is now an index into the color table, where the actual values of each channel are stored.

– Color table entries can be changed in software.

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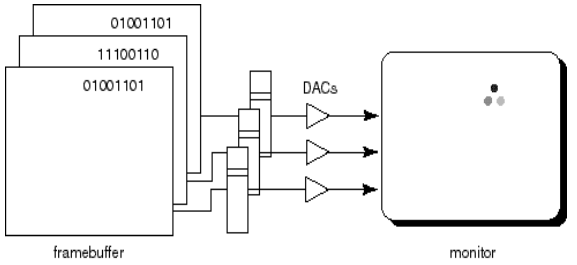
Color tables on 24-bit systems

Even full-color systems often use color tables. In this case, there is a separate color table for each 8 bit channel.



•Most SGI workstations are like this.

•**Q:** Why would you want this capability?

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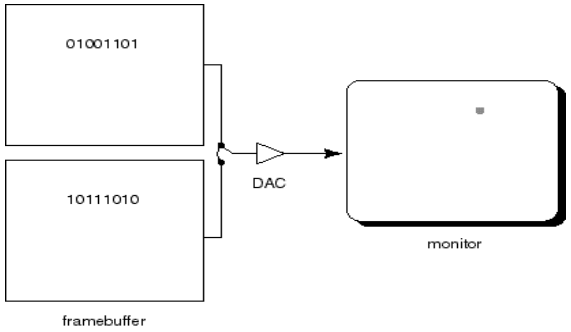
Double-buffering

- **Q:** What happens when you write to the framebuffer while it is being displayed on the monitor?
- **Double-buffering** provides a solution.



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Summary

- Here's what you should take home from this lecture:
  - The basic components of black-and-white and color CRTs
  - Computing screen resolution & framebuffer size
  - How different display technologies work
  - The correspondence between elements of framebuffer memory and pixels on-screen
  - How color tables work
  - How double-buffering works

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