# Display Devices

# Reading

Hear & 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.

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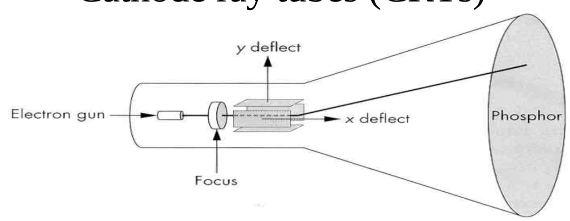
# Cathode ray tubes (CRTs)




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

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# 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

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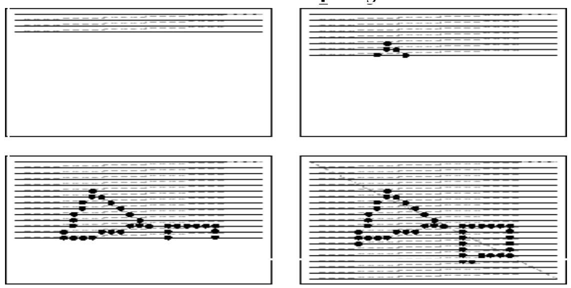
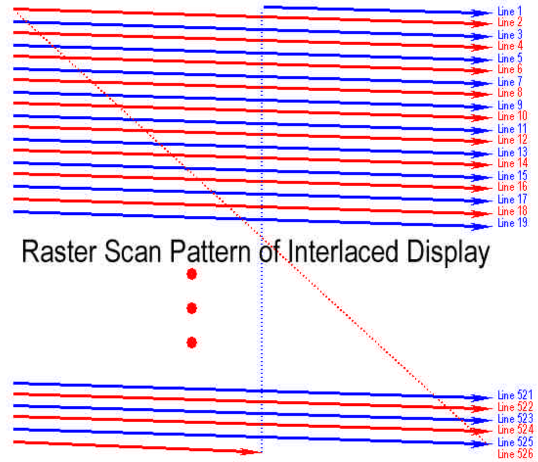
# Raster displays



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

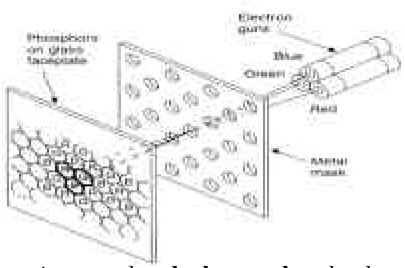
- Each left-to-right trace is called a **scan line**.
- Each spot on the screen is a **pixel**.
- When the beam is turned off to sweep back, that is a **retrace**, or a **blanking interval.**








# Color CRT monitors



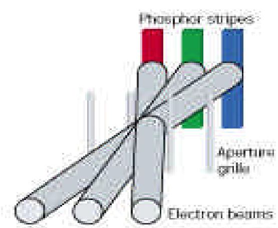

Most color monitors employ **shadow mask** technology:

- 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**.



# Color CRT monitors, cont’d

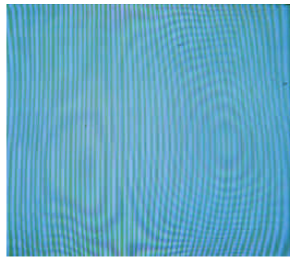



A competing technology is called Trinitron (by Sony):

- 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

# 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)
- Spurious X-ray radiation
- Occupies a large volume



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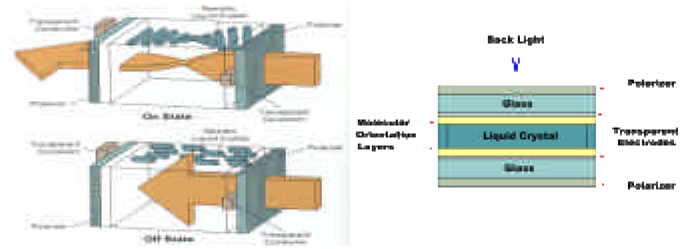
# Liquid Crystal Displays




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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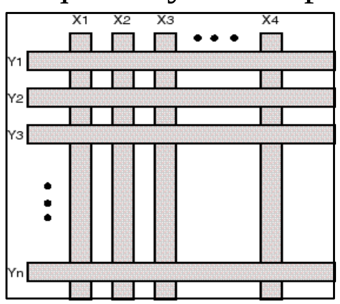
# Liquid Crystal Displays




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

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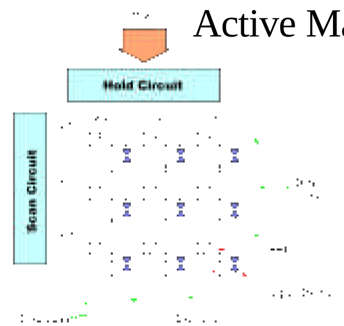
# Active Matrix Displays




•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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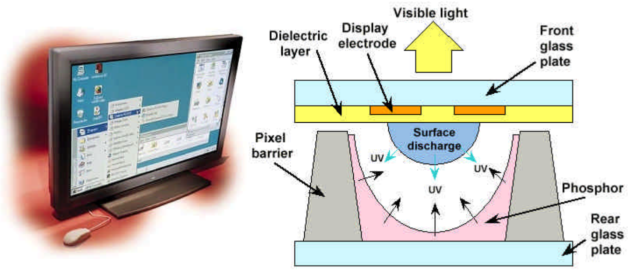
# Plasma Displays




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



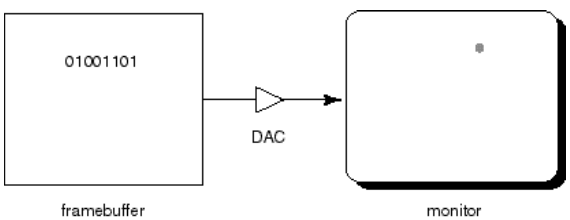
# Resolution

- 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 |



# Framebuffers

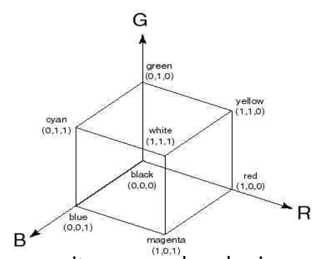



Intensity of the raster scan beam is modulated according to the contents of a **framebuffer**.

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



# 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**.

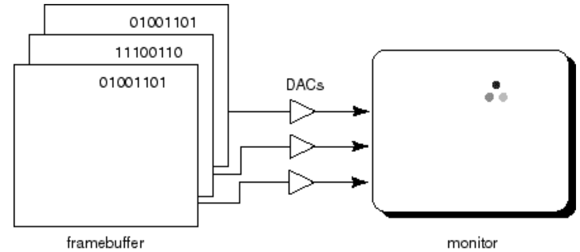
## Specifying colors

•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?



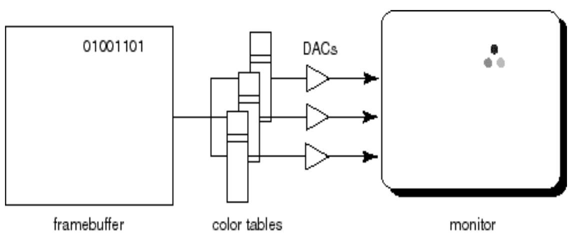
## RGB framebuffer




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



## 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.

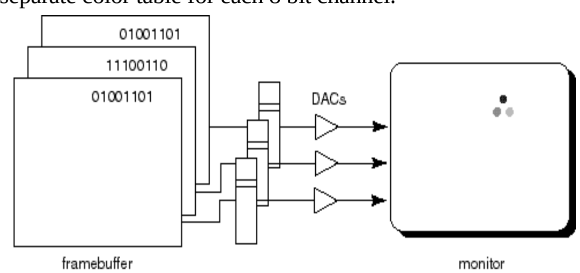
•Each framebuffer element is now an index into the color table, where the actual values of each channel are stored.

– Color table entries can be changed in software.



## 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.

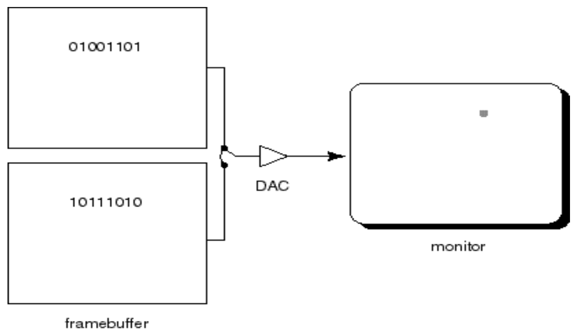



•Most SGI workstations are like this.

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

# 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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