Display Devices

Reading

Optional

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
Raster displays

- 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.

Electron beam traces over screen in raster scan order.

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

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

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.
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:

- IT mapped display \(60 \times 1152 \times 1b\) /8 MB
- TSC TV \(40 \times 480 \times 16b\) /2 MB
- Color workstation \(280 \times 1024 \times 24b\) MB
- Laser-printed page
  - 00 dpi \(.5 \times 11 \times 300^2 \times 1b\) MB
  - 200 dpi \(.5 \times 11 \times 1200^2 \times 1b\) 7 MB
- Film \(500 \times 3000 \times 30b\) 0 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.

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