Computer Graphics Hardware

Output Devices
   Display
   Vector
   Raster
   Hardcopy
   Plotters
   Printers

Input Devices
Graphics Processors

Video Display Devices

Video Monitor

CRT (cathode ray tube) was most common
   Storage CRT versus Refresh CRT
      Draw once and image remains on screen
      Constant refreshing of screen
         Refresh rates - 30 Hz, interlaced

Basic CRT design
    (see figure)
    Vacuum in a glass tube
    Electron gun
    Cathode with coiled wire filament
       heat and it emits electrons
       very high voltages
    Deflection system
    Phosphor coated screen

    Focusing system

    Acceleration system
Focusing system
    electrons repel each other - diverge
    a) Magnetic
        coil around outside of tube
        very small spot size
        flying spot scanners
    b) Electrostatic
        most common in graphics monitors
        positively charged metal cylinder
        (electrostatic lens)
            focuses beam in middle of screen
        curved screen
            distance from "lens" to screen is constant
        flat screen
            distances increase from center
            additional electronic deflection dependent focusing
            (see figure)

Acceleration system
    Speed electron towards the screen
    a) Positively charged metal near screen
    b) Accelerating anode
       (see figure)

Deflection system
    Control where beam hits screen
    a) Magnetic deflection
        2 pairs of coils mounted outside envelope
        top and bottom
        right and left
        vary currents in coils to get correct deflection
        most common
        (see figure)
    b) Electrostatic deflection
        2 pairs of plates inside envelope
        vary charge
        (see figure)
Screen
coated with phosphors
electrons hit screen and loose energy
heat
most goes to electrons of phosphor
jumps them to higher energy states
when fall back to lower states - give off energy as light

Phosphor characteristics
color of light - wavelength of energy
persistence
time taken to go from initial light level to 1/10th
long persistence
refresh less frequently
what happens to image of moving objects?
short persistence
refresh more frequently
less motion blur
typical 10 - 60 microseconds

Intensity
Control grid of electron gun
the more negatively charged, more electrons get repelled
the fewer make it through the control grid

Intensity distribution of spot on screen

Gaussian fall off of intensity with distance
Function of the electron density in the beam
Resolution

Maximum number of dots that can be displayed without overlap on CRT
(1K by 1K)
independent of screen size

OR

Maximum number of dots that can be displayed per inch or cm
(300 dpi)

How define overlap?
okay to overlap portions falling below 60% of maximum

What happens to overlap as increase intensity?

Aspect ratio
ratio of number of vertical points to horizontal points to produce equal length lines
3/4

Raster Scan versus Random Scan
(see figures)
Random scan
refresh is a function of the image complexity
Raster scan
horizontal retrace and vertical retrace
interlaced versus noninterlaced
Refresh rate

60 hz is typical
how often refresh each "dot" on screen?
    once every 16667 microseconds
compare to persistence (10-60 microseconds)
"dot" is mostly dark!

flicker
when image appears to go on and off
refresh rate not high enough

CFF - critical fusion frequency
freq at which flickering display just fuses into nonflickering
what determines CFF?
    for given phosphor?

Horizontal scan rate
scan lines displayed per second
approximately refresh rate times number of lines

Color CRTs

Beam penetration
Random scan
two layers of phosphor
    slow beam - outer layer (say red)
    faster beam - inner layer (say green)

Shadow mask
more colors
better quality
small patches of red, green and blue phosphors
    perceive as one colored patch

3 electron guns
a) delta-delta
    triad of patches
    (see figure)
    shadow mask
difficult to keep aligned
    high resolution
b) precision in-line
easier to align, lower resolution
Flat-Panel Displays
   Thinner, lighter, require less power
   Examples?

Emissive versus nonemissive
   Can you see it in the dark?
   Could be lighted nonemissive

Emissive
   Plasma panels
      mixture of gases between two glass plates
      vertical and horizontal conducting ribbons
      apply voltage to two ribbons to make plasma glow
      (see figure)
   Thin-film electroluminescent displays
      similar, but phosphor instead of gas
      (see figure)
   LED's
      matrix of diodes, one per pixel
      apply voltage and they produce light

Nonemissive
   LCD
      LC substance flow like a liquid, but have crystalline
      molecular structure
      Usually use nematic LC's (threadlike)
      Two polarizers, two conductors, reflector
      LC in normal state twists the light,
      so is reflected back to viewer
      apply voltage to conductors to turn off
      (see figure)
   Active Matrix LCD - transistor at each pixel (stores)
Projection CRT
   project light from small diameter, very bright CRT onto screen
   (example?)

LCD Projection
   flat panel display used with overhead projector
   (see figure)

3D Viewing

Stereoscopic viewing
   Stereo images (not full 3-d)

   a) Red and green glasses
      red and green images

   b) Scan alternate images in alternate frames
      View with goggles that shutter each lens in synch with scanning
      (see figures)

   c) Multiple stereo images versus just two
      Time Multiplexing
         As rotate head, see different views
         Compare to 2 view perception as move head
Hard Copy Output Devices
  Plotters
  Printers

Impact Devices
  Inked ribbon
  examples?

Nonimpact Devices
  Lasers, ink-jets, xerographic, electrostatic, electrothermal
  examples?

Pen plotters
  Stationary paper and 2-D moving pen
  (see example)
  Paper moves in 1-D and pen in 1-D
  (see example)
Resolution issues
  Random Scan or Raster Scan?
  How draw line?
    What determines resolution along length of line?
    What determines resolution across width of line?

Dot Matrix Printers
  Print head with matrix of wire pins
  Retract some pins before printing to print specified pattern

Laser Printers
  Drum coated with photoelectric material (e.g., selenium)
  Laser beam creates charge distribution on drum
  Toner applied to drum and sticks according to charge
  Toner transferred to paper
Ink-Jet Printers
   Paper rolled on drum
   Boiled ink squirted onto paper through little nozzles (jets)
   Charged ink stream deflected by electric field
   (see figures)

Electrostatic Printers
   Negatively charge a row at a time on paper
   Apply toner
   (see figure)

Electrothermal Printer
   Heat sensitive paper
   Dot matrix print head applies heat
   (example?)

Dye Sublimation

How get color output?

Impact device?

Non impact device?
   3 pigments: cyan, magenta, yellow (sometimes black)

Will you get the same colors on a laser printer, as on a CRT?

Non Hard Copy, Non Display Output Devices

Print 3-D solid objects
   Ink jet like head
   Squirts fast drying thermopolymer material
   Builds up 3-D models in layers
Input Devices

Keyboards

- Standard Keyboard
- Button Boxes
  (see example)

Mouse

- Mechanical mouse
  - Rotating ball
    - Two perpendicular padded shafts rotated by ball motion
      - Shaft encoders output proportional to rotation
- Optical mouse
  - Laser
  - Reflective Grid
  - Added buttons, trackball, thumbwheels

Trackball

- Like upside down mouse with big ball
- Fingers or hand move ball

Joystick

- Movable
  - Measure motion
- Stationary
  - Measure strain

Data Glove

- Measures hand position and uses as input
- Many degrees of freedom

(aside - data glove as output device
  - Haptic computer interface
    - Texture and pressure sensation via forces applied
      to finger tip
  (see example))
Motion Capturing Systems

Selspots
  Attached to body in motion
  Capture 3-D paths of points
  (see example)
  Occlusion of visual "spots"

Full Body Scanners
  How does it work?
  (see example)
  Captures shape and color in 12 seconds

Uses?

Digitizers

Graphics Tablets
  (see example)
  High resolution input
  Trace contours
    Hand held cursor
    Stylus
    (see example)
Electromagnetic
  Grid of wires
  Electromagnetic pulses generated in sequence
  Induces electrical signal in stylus or cursor
Acoustic
  Strip microphones
  Detect sound of spark on stylus tip
  Time arrival at different microphones
Can be 3-D
  (see example)
Image Scanners

Hand Held
(see example)
Flat Bed
(see example)
Drum
(see example)

Touch Panels

Optical
Line LED's along top and side
Line of light detectors along bottom and other side

Electrical
One plate of conducting material
One plate of resistive material
Touch pushes plates together
Measure voltage drop across resistive plate

Acoustical

Built into plasma panels

Transparent overlay on other displays