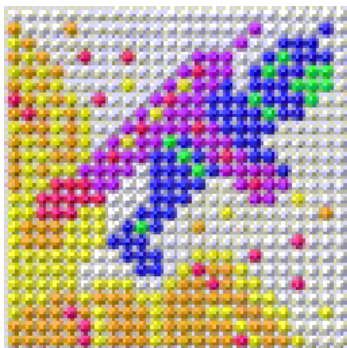# Graphic Images

George Seurat - "pointilist"
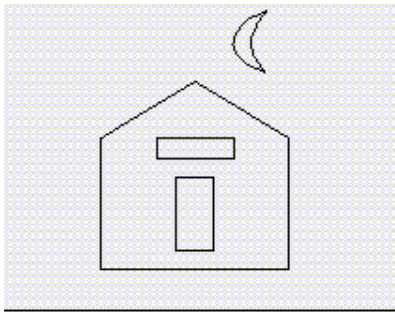*Un dimanche apres-midi a l'Ile de la Grande Jatte*

Tile mosaic

Output from a computer version of *Lite Brite* (a toy for children)
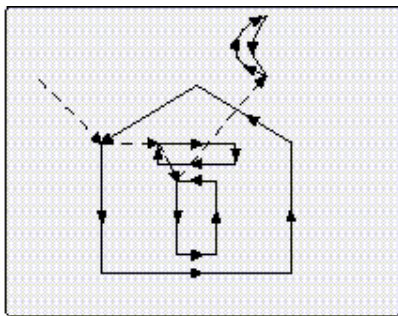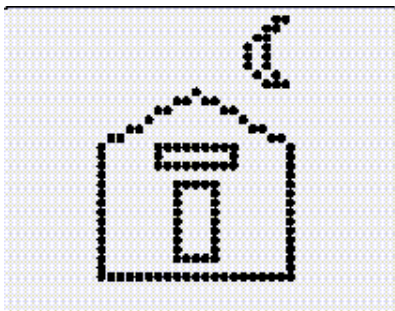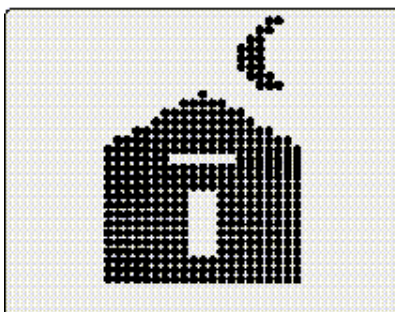
Needlepoint

Vector vs. Raster Display

(a) Ideal line drawing

(b) Random scan

(c) Raster scan with outline primitives

(d) Raster scan with filled primitives

Vector (1960's, 70's, 80's)
- vector, stroke, line drawing, …
- single phosphor (monochrome)
- display list
- wireframe

Raster (1980's, 90's, 00's)
- set of horizontal scan lines (raster)
- 1 or 3 (colour) beams
- refresh/frame buffer
- aliasing
- filled polygons
- Advantages:
    - lower cost
    - filled primitives
    - refresh independent of complexity
- Disadvantages:
    - scan conversion
      (more computationally demanding)
    - aliasing

Architecture of a Raster Display
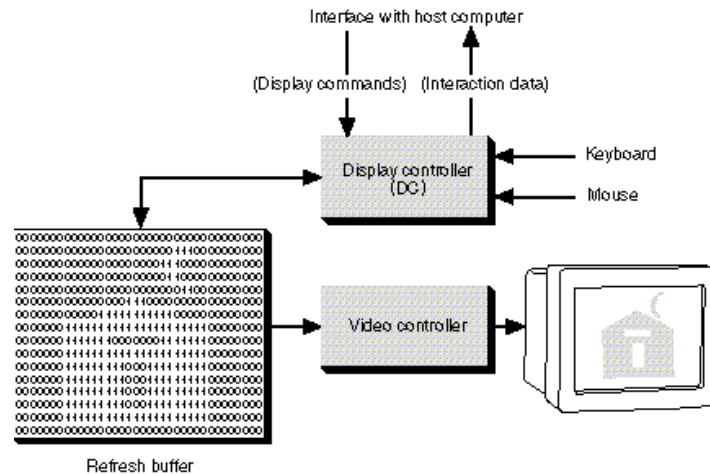
- Display controller
  - receives and interprets sequences of output commands
- Refresh buffer
  - stores the entire image in an array of pixel values (bitmap)
- Video controller
  - entire image is scanned out sequentially by video controller (inexpensive, scan-out logic)

Raster Display Scan Pattern
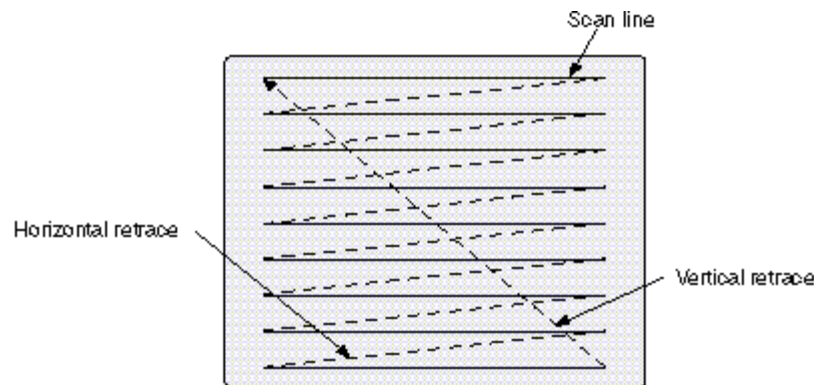
ras.ter \'ras-t<e>r\ n (ca. 1934)

: a scan pattern (as of the electron beam in a cathode-ray tube) in which an area is scanned from side to side in lines from top to bottom;

: a pattern of closely spaced rows of dots that form the image on a cathode-ray tube (as of a television or computer display)

From Websters

- Number of lines (vertical): 320, 525, 640, 768, 1024
- Resolution along the line (horizontal): 420, …
- Frames/second: 25, 30, 60
- Interlaced or not

Pixel Based Graphics

- Resolution:
  - number of distinguishable lines per inch that a device can create
  - Horizontal x Vertical
    - 320x420 (Mac Classic)
    - 640x480 (VGA)
    - 1024x768 (SVGA)
    - 1280x1024 (graphics workstations)
- Depth (intensities & colours):
  - Bits/Pixel
    - 1 (bit mapped)
    - 2 (4 levels)
    - 8 (256 levels)
    - 24 (16 million)
  - Colour displays need separate red, green and blue, 8 bits for each yields 24 bits/pixel
- 320x240 display, with 1 bit/pixel requires 16.4K/frame
- 1024x1024 display, with 24 bits/pixel requires 3MB/frame

Output Devices

- Cathode Ray Tube (CRT)
  - black and white or colour
- Liquid Crystal Display (LCD)
  - passive or active matrix
- Printer
  - dot matrix, ink jet, laser
- Plotter
  - single or multiple pens

Hardcopy Technologies
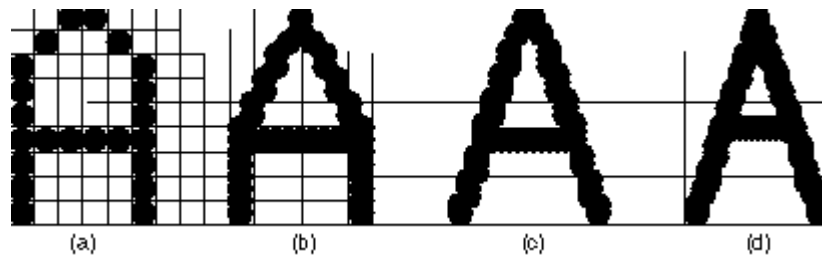
Dot size: diameter of a single dot on the device's output

Addressability: # of dots per inch that can be created 1/(inter dot distance), dots/inch
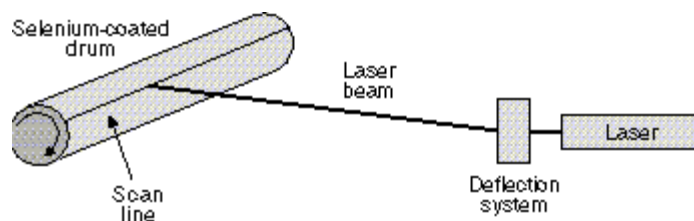
Resolution: distinguishable lines/inch

Hardcopy Technologies

Dot-matrix printer: 7-24 pins which can be individually fired to strike a ribbon against a paper. Colour with 2 passes CMYK

Plotter: vector (pen) or raster (electrostatic) pen (flatbed or drum): higher contrast electrostatic: faster

Laser Printer:

Ink-jet Printer: sprays CMY(K) onto paper simultaneously
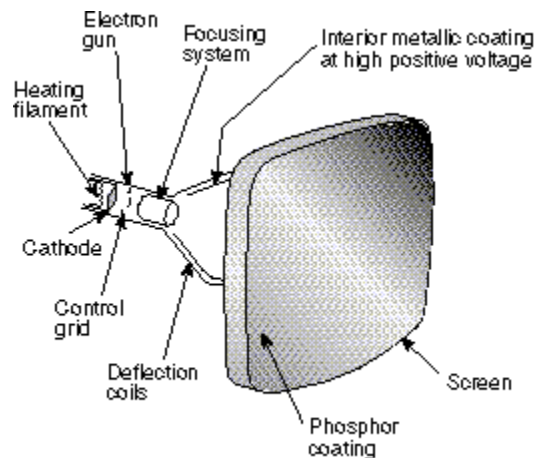
Thermal Transfer: finely spaced heating ribs heat coloured wax paper onto plain (fast)

Thermal Sublimation Dye Transfer: similar to above but allows for 256 intensities of each of CMY, excellent colour (slow)

Camera-Film Recorder a camera that photographs an image displayed on a CRT

Display Technologies

Cathode Ray Tube (CRT)

must REFRESH because of phosphor decay
- independent of image (raster)
- dependent on image (vector)

- fluorescence:
  - light emitted while phosphor struck by electrons
- phosphorescence:
  - light emitted once electron beam is remove
- persistence:
  - time from electron beam removed to phosphorescence decayed to 10% of initial light output
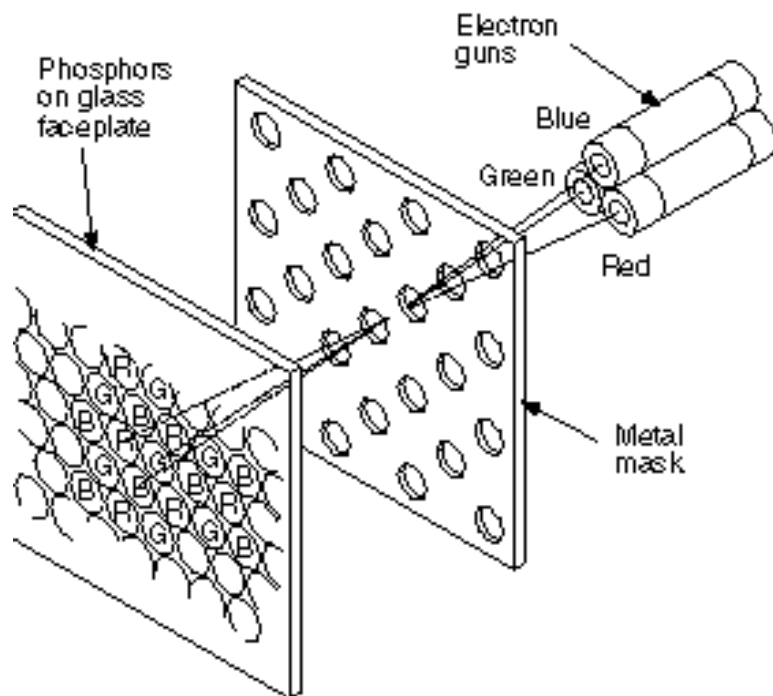
Display Technologies

Cathode Ray Tube (CRT) (continued)

- refresh rate
  - \# times per second the image is redrawn
  - typically 60 times/sec for raster displays
    (60 Hz)
- Flicker
  - when the eye can no longer integrate individual
    light pulses (due to low refresh rate, etc...)
- Critical Fusion Frequency (CFF):
  - refresh rate above which there is no perceptible
    flicker
- Horizontal Scan Rate:
  - \# of lines per second
  - refresh rate x \# scan lines
- Bandwidth
  - speed at which the electron gun can be turned on
    and off
- Resolution
  - same as for hardcopy (distinguishable lines/inch)
  - vertical resolution (raster) determined by dot size
  - horizontal resolution (raster) determined by dot
    size and bandwidth

# Display Technologies

Cathode Ray Tube (CRT) (continued)
- Shadow Mask
  - a thin metal plat perforated with many small holes, mounted close to the viewing surface, and carefully aligned so the three electron beams hit only one type of phosphor

- delta-delta shadow mask

Display Technologies
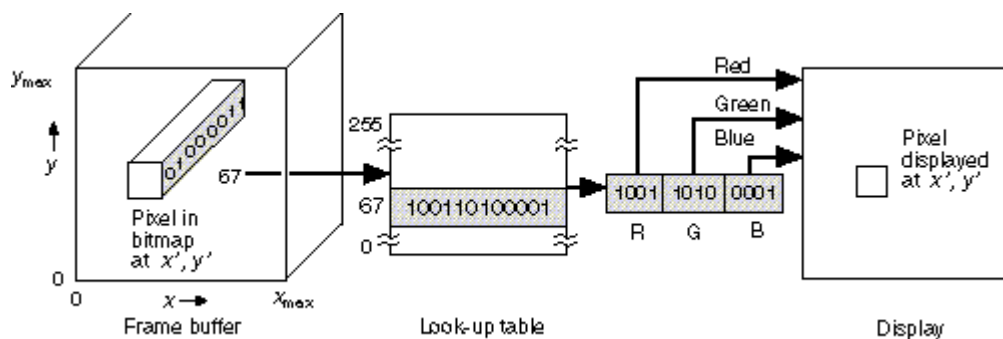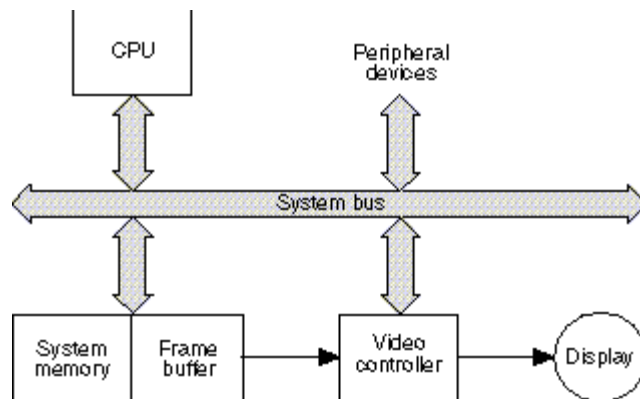
Cathode Ray Tube (CRT) (continued)

- Precision in-line delta CRT
  - 3 in-line phosphor dots

  $$\boxed{R}\ \boxed{G}\ \boxed{B}$$
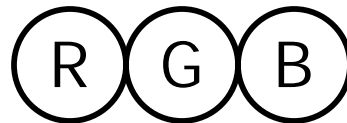
- Flat panel CRT
  - electron beams move parallel to the viewing surface and are then turned 90° to strike the surface

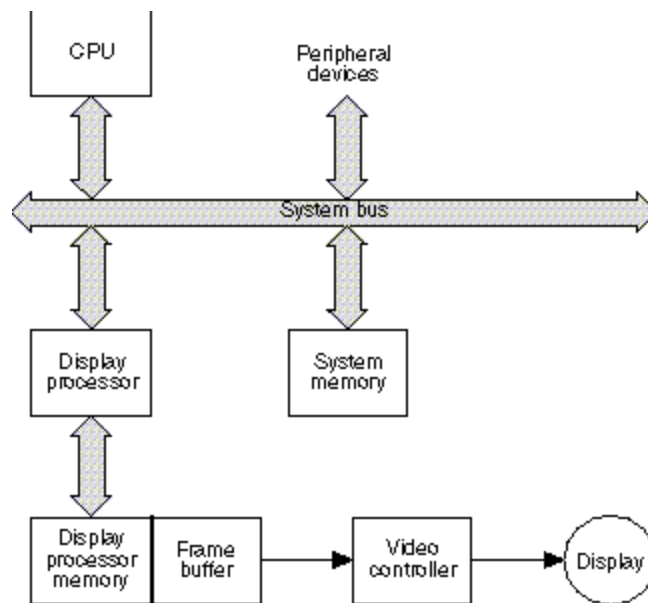- Shadow masks limit the brightness and resolution of colour CRT's

Raster-Scan Display Systems

- ## Simple system
  - frame buffer
  - video controller
 - look up table (LUT)

Raster-Scan Display Systems

- ## Peripheral Display Processor
  - introduces a separate graphics processor
    - (scan conversion and raster operations)
  - separate frame buffer for image refresh

  - Wheel of Reincarnation
    - (Myer & Sutherland 1968)

Raster-Scan Display Systems

- **Integrated Display Processor**
  - single-address-space (SAS)
  - display processor, CPU, and video controller are all on the same bus
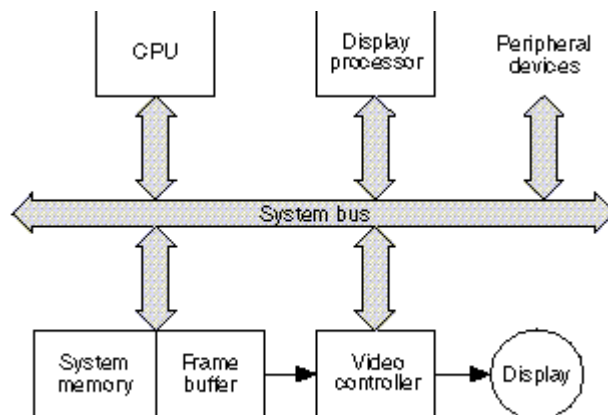
Video Controller

Constant refresh of the display

- Interlaced vs. Non-interlaced
  - refresh broken into two fields (odd/even) each lasting 1/60th of a second (full refresh 1/30th sec)
  - perceived as something closer to 60Hz since changes in images are presented at that rate
- Sprites
  - small, fixed size pixmaps on top of the frame buffer
- Video mixing
  - two images (frame buffer & video signal) are merged to form a composite image
    - graphics image is set into a video image
    - video image is places on top of the frame-buffer

Video Controller

Output from the Video Controller

- RGB
  - separate cables carry red, green and blue signals to control the three electron guns of a shadow mask CRT
  - a fourth cable carries the sync to signal the start of a vertical and horizontal refresh
- Monochrome
  - same standards but only intensity & sync
- NTSC (National Television System Committee)
  - North American TV standard
  - colour, intensity & sync combined into a signal
  - 525 scan lines, 30 frames/sec interlaced
  - 600 pixel horizontal resolution
  - 480 visible lines
  - typical resolution 300x300
- PAL/SECAM
  - European standard
  - 625 lines, 25 frames/sec interlaced