Basic Graphics System

Input devices → Processor → Frame buffer → Output device

Image formed in FB
A Graphics System

- Output Devices
- Modern Video Connections
- Screen Properties
- Input Devices
- Imaging Systems

Output Devices

- CRT Displays
- LCD Displays
- Plasma Displays
- Projectors
- Rear-Projectors
- Inkjet Printers
- Laser Printers
Magnetic-Deflection CRT

Figure 2-2
Basic design of a magnetic-deflection CRT.

Operation of a CRT Electron Gun

Figure 2-3
Operation of an electron gun with an accelerating anode.
Electrostatic Deflection within a CRT

Figure 2-4
Electrostatic deflection of the electron beam in a CRT.


SAGE Vector Graphics

Maury Markowitz 2003 SAGE (Semi Automatic Ground Environment) control room 1950s – 1980s
CRT Shadow-Masks

Section of a Shadow Mask

Electron Guns

Magnified Phosphor-Dot Triangle

Red, Green, Blue

Screen

Figure 2-10
Operation of a delta-delta, shadow-mask CRT. Three electron guns, aligned with the triangular color-dot patterns on the screen, are directed to each dot triangle by a shadow mask.


CRT - Cathode Ray Tube

Shadow-Mask vs. Aperture Grille

Dot Trio  Aperture Grille

How Stuff Works 2005 How Computer Monitors Work

Shadow-Mask vs. Aperture Grille

Wikipedia 2004 Samsung SyncMaster 755DFX & ViewSonic GraphicSeries GT775 V
Drawing on a Raster-Scan System

Figure 2-7
A raster-scan system displays an object as a set of discrete points across each scan line.


Progressive Raster-Scan Lines

How Stuff Works 2000 How Television Works
Interlaced Raster-Scan Lines

Raster Scan Pattern of Interlaced Display

Monochrome Monitor 1984

Apple Computer, Inc. 1984 Apple II 12" Monochrome Monitor
Color Monitor 1986

Apple Computer, Inc. 1986 Apple IIe 12" AppleColor RGB Monitor

24" Widescreen Display

Sony Electronics, Inc. 2000 GDMFW900 24" CRT Monitor
Flat Panel Displays

- Plasma Displays
- Organic Light-Emitting Diode Displays (OLEDs)
- Liquid Crystal Displays (LCDs)
- Digital Light Processing (DLPs)
- Liquid Crystal on Silicon (LCoSs)
- Surface-Conduction Electron-Emitter Displays (SEDs)
- Field Emission Displays (FEDs)
- Nano-Emissive Display (NEDs)

Plasma Display Illustration

Plasma Display


Plasma Display Simplified

Figure 2-11

Basic design of a plasma-panel display device.

Thin-Film Electroluminescent Display

Figure 2-13
Basic design of a thin-film electroluminescent display device.

Monochrome EL Display

Planar Systems, Inc. 2003 EL Displays
OLED - Organic Light-Emitting Diode

Samsung 2005 40" OLED Screen

LCD - Liquid Crystal Display

How Stuff Works 2005 How Computer Monitors Work
LCD Illustration of On / Off States

The light-twisting, shutter effect used in the design of most liquid-crystal display devices.


LCD Pixels

How Stuff Works 2005 How Computer Monitors Work
LCD – Liquid-Crystal Display

Apple Computer, Inc. 2004 30" Cinema HD Display

LCD Projector

The Projector Pros 2004 LCD Flat Panel Displays Projector Technologies
DLP – Digital Light Processing

1-Chip DLP Projector

DLP Texas Instrument 2005 1-Chip DLP Processor
3-Chip DLP Projector

LCOS – Liquid Crystal on Silicone
Rear-Projection Screens

The Projector Pros 2004 Learn About Rear Projection Televisions

Multi-Projector Graphics Wall

Visbox, Inc, 2005 VisWall
Multi-Panel Graphics Wall


Head Mounted Display Systems

5DT HMD 800 & Cybermind Nederland hi-Res900 & H3D Video Eyewear
CAVE VR Environment

NCSA 2000 Cave VR Environment
VR Media Lab, Aalborg University 2004 Cave

Electronic Paper

Bistable flat panel displays
- e-ink Displays
- Gyricon Displays
- Iridigm Displays
- Magink Displays
Modern Video Connections

DVI-I
Digital or Analog

VGA
Analog Only

DVI-D
Digital Only

Standard Video Adapter

1: Red out
2: Green out
3: Blue out
4: Unused
5: Ground
6: Red return (ground)
7: Green return (ground)
8: Blue return (ground)
9: Unused
10: Sync return (ground)
11: Monitor ID 0 in
12: Monitor ID 1 in or data from display
13: Horizontal Sync out
14: Vertical Sync
15: Monitor ID 3 in or data clock
Single Link DVI

Single Link DVI-I

Single Link DVI-D

Dual Link DVI

Dual Link DVI-I

Dual Link DVI-D
Screen Properties

- Raster → Pixels → Frame Buffers
- Screen Size
- Screen Resolution
- Aspect Ratio
- Screen Depth
- Human Vision

The Screen

- Size
- Resolution
- Aspect Ratio
# Measuring a Display Screen

![Display Screen Diagram](image)

Common Screen Resolutions

<table>
<thead>
<tr>
<th>Computer Standard</th>
<th>Resolution</th>
<th>Ratio</th>
<th>Pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGA</td>
<td>320×200</td>
<td>16:10</td>
<td>64K</td>
</tr>
<tr>
<td>QVGA</td>
<td>320×240</td>
<td>4:3</td>
<td>77K</td>
</tr>
<tr>
<td>EGA</td>
<td>640×350</td>
<td>approx. 5:3</td>
<td>224K</td>
</tr>
<tr>
<td>VGA</td>
<td>640×480</td>
<td>4:3</td>
<td>307K</td>
</tr>
<tr>
<td>SVGA</td>
<td>800×600</td>
<td>4:3</td>
<td>480K</td>
</tr>
<tr>
<td>XGA</td>
<td>1024×768</td>
<td>4:3</td>
<td>786K</td>
</tr>
<tr>
<td>WXGA</td>
<td>1280×768</td>
<td>15:9</td>
<td>983K</td>
</tr>
<tr>
<td>SXGA</td>
<td>1280×1024</td>
<td>5:4</td>
<td>1.3M</td>
</tr>
<tr>
<td>UXGA</td>
<td>1600×1200</td>
<td>4:3</td>
<td>1.9M</td>
</tr>
<tr>
<td>WUXGA</td>
<td>1920×1200</td>
<td>16:10</td>
<td>2.3M</td>
</tr>
<tr>
<td>WQXGA</td>
<td>2560×1600</td>
<td>16:10</td>
<td>4.1M</td>
</tr>
</tbody>
</table>

![Common Screen Resolutions Table](image)

_Wikipedia_
Visually Comparing Resolutions

Patrick G. Durland 2005 Wikipedia: Video Standards

Aspect Ratios

4:3
16:9
2.39:1

Wikimedia Foundation, Inc. 2006 Wikipedia
Multiple Video Walls

Draper, Inc. 2005 VideoWalls

Removing Display Edges

Draper, Inc. 2005 Zero Edge Framing System
Multi-High Resolution Displays

RGB, Inc. 2005 SuperWall

Light & Human Vision
Light

- *Light* is the part of the electromagnetic spectrum that causes a reaction in our visual systems
- Generally these are wavelengths in the range of about 350-750 nm (nanometers)
- Long wavelengths appear as reds and short wavelengths as blues
Electromagnetic Waves

Luminance and Color Images

- **Luminance Image**
  - Monochromatic
  - Values are gray levels
  - Analogous to working with black and white film or television

- **Color Image**
  - Has perceptual attributes of hue, saturation, and lightness
  - Do we have to match every frequency in visible spectrum? No!
Additive and Subtractive Color

- Additive color
  - Form a color by adding amounts of three primaries
    - CRTs, projection systems, positive film
    - Primaries are Red (R), Green (G), Blue (B)

- Subtractive color
  - Form a color by filtering white light with cyan (C), Magenta (M), and Yellow (Y) filters
    - Light-material interactions
    - Printing
    - Negative film

The Human Eye

Levine 1985 Vision of Man and Machine
Human Retina

Levine 1985 Vision of Man and Machine

Human Cones and Rods

Levine 1985 Vision of Man and Machine
The Human Eye

Levine 1985 Vision of Man and Machine

Human Cone Response

Bowmaker & Dartnall 1980 Visual pigments of rods and cones in a human retina J. Physiol. 298 pp 501-61
Frame Buffers

- Raster → Pixels → Frame Buffers
- Resolution & Depth

Vector Graphics

Hearn & Baker 2004 Computer Graphics
Mapping Frame Buffer ➔ Display Surface

Hill 2001 *Computer Graphics using OpenGL*

Color Frame Buffers and the Monitor

Hill 2001 *Computer Graphics using OpenGL*
Screen Depth

Indexed Colors

Wikimedia Foundation, Inc. 2006 Wikipedia
Direct Colors

Display Depths

- Indexed Color
  - 1-bit (2 colors) monochrome
  - 2-bits (4 colors) CGA
  - 4-bits (16 colors) EGA & higher resolution VGA
  - 8-bits (256 colors) lower resolution VGA & SVGA

- Direct Color
  - HiColor
    - 15-bits (5-bits or 32 levels per red/green/blue) → 32,768
    - 16-bits (5-bits for red & blue, but 6-bits or 64 levels for green)
  - Truecolor
    - 24-bits (8-bits per red/green/blue) → 16.7 distinct colors
  - 32-bit Color
    - 34-bits (24-bits for color & 8-bits for alpha)
Input Devices

- Keyboards
  - Qwerty
- Pointers
  - Mice
  - Pens
- Manipulators
  - 3D Plotters
  - Motion Tracking

Keyboards

Kingston Computer 2006 Keyboards / The Human Solution 2003 DataHand & Ergodex
Mice & Trackballs

Doug Englebart’s 1963 Mouse / Kingston Computer 2006 Mice & Trackball

Pens

Wacom Technology 2006 Cintiq 21UX & Intuos3 12x19 & TabletPC Hardware
Gesture Systems

FingerWorks 2002 iGesture

3D Scanners

3D Scanner Ltd., 2005 Freedom Robot CMM / Inition Ltd., 2005 Microscribe G2 / HandyScan 3D 2005 HandyScan
Motion Tracking

Imaging Systems

- Camera Specification
- Image Formation
- Pinhole Camera
- Synthetic Camera Model
- Ray Tracing
Camera Specification

- Six degrees of freedom
  - Position of center of lens
  - Orientation
- Lens
- Film size
- Orientation of film plane

Image Formation

- In computer graphics, we form images which are generally two dimensional using a process analogous to how images are formed by physical imaging systems
  - Cameras
  - Microscopes
  - Telescopes
  - Human visual system
Elements of Image Formation

- Objects
- Viewer
- Light source(s)

- Attributes that govern how light interacts with the materials in the scene
- Note the independence of the objects, the viewer, and the light source(s)

Pinhole Camera

Use trigonometry to find projection of point at \((x, y, z)\)

\[
\begin{align*}
x_p &= -x/z/d \\
y_p &= -y/z/d \\
z_p &= d
\end{align*}
\]

These are equations of simple perspective

Angel 2006 Interactive Computer Graphics
Pinhole Camera Views

![Diagram of pinhole camera views](image)

**Figure 1.13**: Side view of pinhole camera.

**Figure 1.14**: Angle of view.

Synthetic Camera Model

![Diagram of synthetic camera model](image)

- Projector
- Image plane
- Projection of p
- Center of projection

**Angel 2006 Interactive Computer Graphics**
Real vs. Synthetic Camera Models

Ray Tracing and Geometric Optics

One way to form an image is to follow rays of light from a point source finding which rays enter the lens of the camera. However, each ray of light may have multiple interactions with objects before being absorbed or going to infinity.
Geometric Pipeline

Vertices → Vertex Processor → Clipper Assembler → Rasterizer → Framegment Processor → Pixels

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Graphics Programming Library

Application program → Graphics library (API) → Drivers → Keyboard → Mouse → Display

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