CMPE 466 COMPUTER GRAPHICS

Chapter 2
Computer Graphics Hardware

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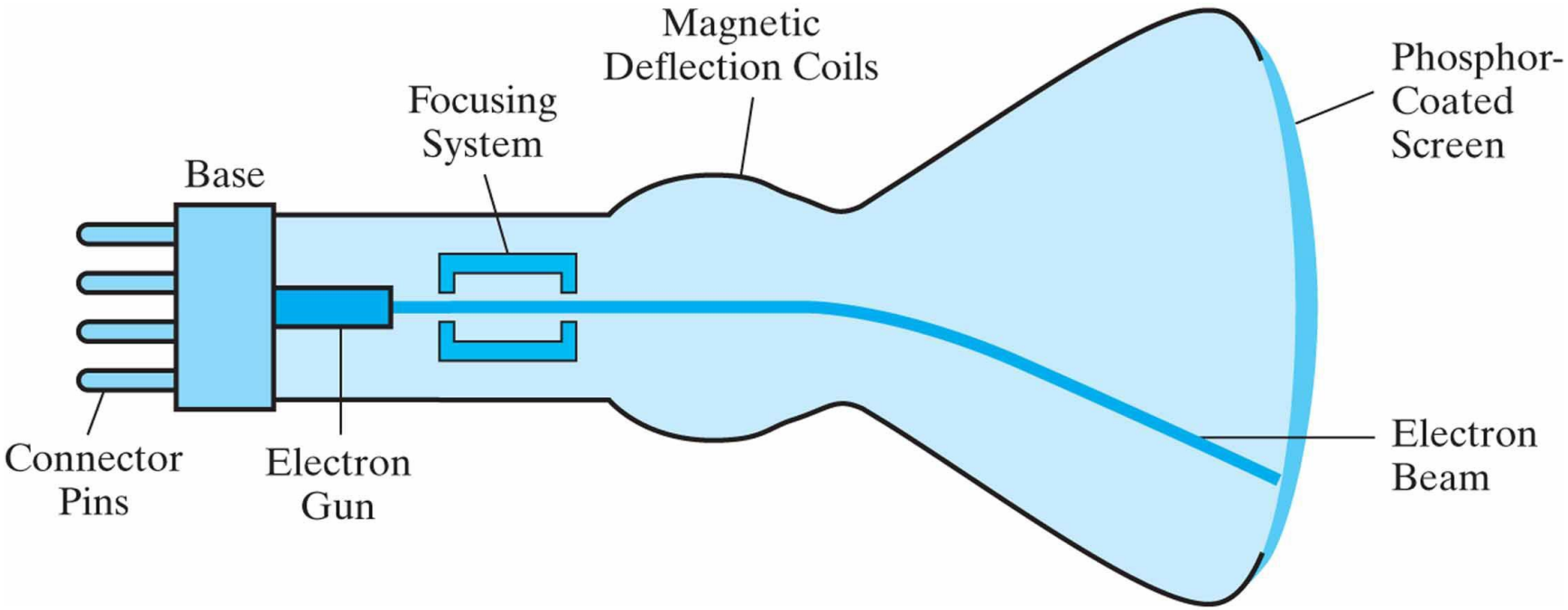
Material based on
- *Computer Graphics with OpenGL®,* Fourth Edition by Donald Hearn, M. Pauline Baker, and Warren R. Carithers
- *Fundamentals of Computer Graphics*, Third Edition by by Peter Shirley and Steve Marschner

Video display devices

Refresh cathode ray tube (CRT)

Figure 2-1 Basic design of a magnetic-deflection CRT.



CRT: acceleration and deflection

Figure 2-2 Operation of an electron gun with an accelerating anode.

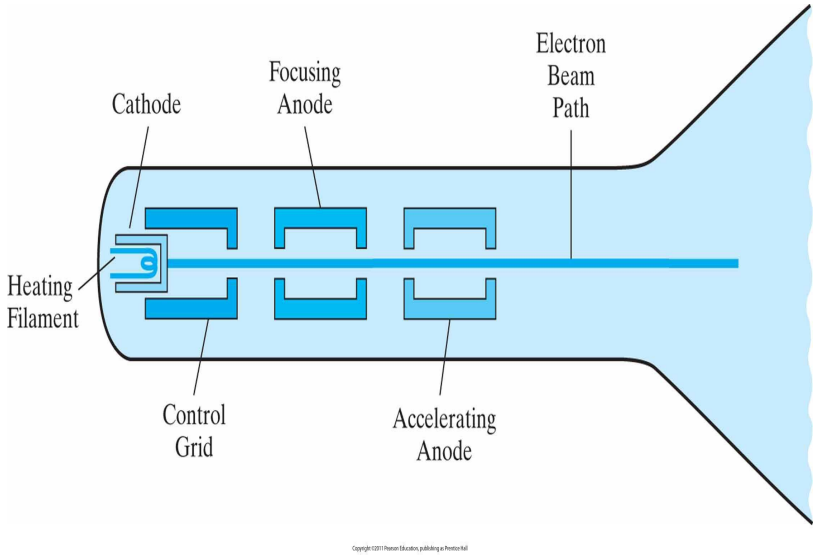
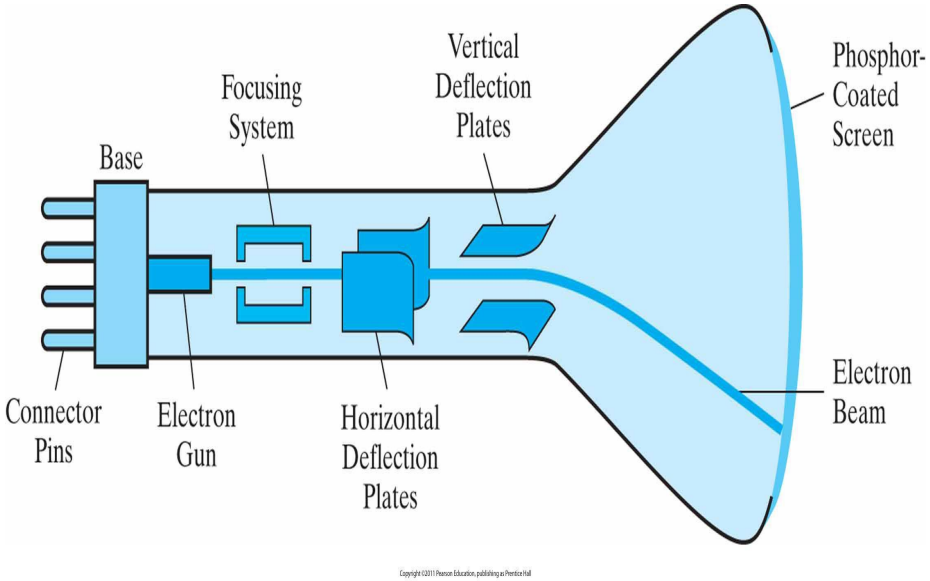


Figure 2-3 Electrostatic deflection of the electron beam in a CRT.



CRT principles

- Kinetic energy is absorbed by the phosphor
  - Part of energy is converted into heat
  - The remainder causes electrons in the phosphor atom to move up to higher quantum energy levels
- After a short time, “excited” phosphor electrons begin dropping back to their stable ground state
  - Electrons give up their extra energy as small quanta of light (photons)
  - Frequency (or color) of light emitted is in proportion to the energy difference between the excited quantum state and the ground state

Phosphor spots

Figure 2-4 Intensity distribution of an illuminated phosphor spot on a CRT screen.

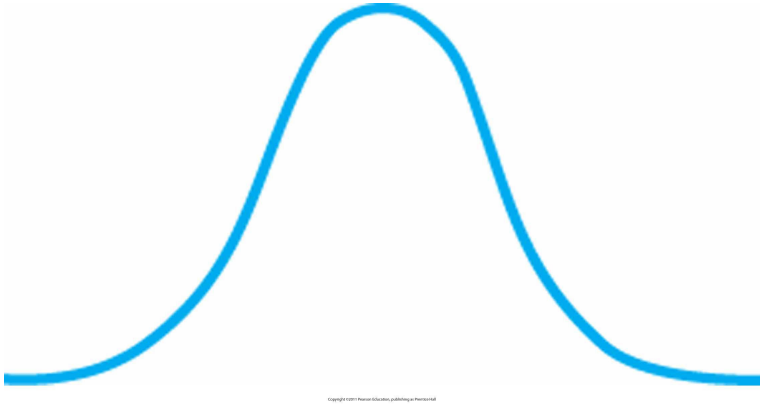
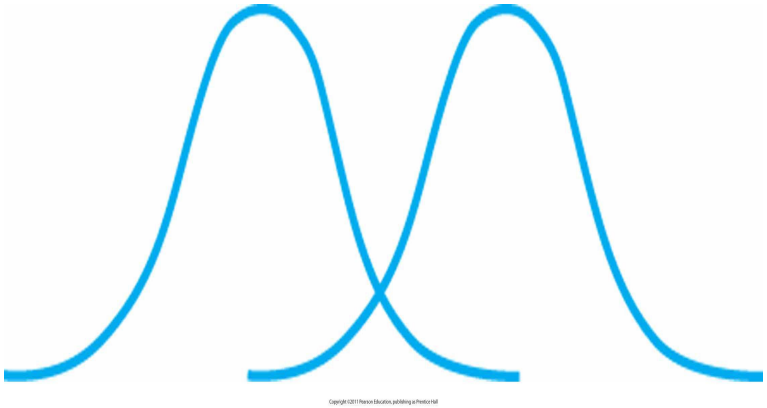


Figure 2-5 Two illuminated phosphor spots are distinguishable when their separation is greater than the diameter at which a spot intensity has fallen to 60 percent of maximum.



Resolution and size

- Maximum number of points that can be displayed without overlap on a CRT is referred to as the resolution
- Alternatively, resolution is the number of points per cm that can be plotted horizontally and vertically
- Or, just simply, total number of points in each direction
  - E.g. 1280 by 1024
- Physical size of a graphics monitor is given as the length of the the screen diagonal
  - E.g. 15 inches

Raster-scan display

- Electron beam is swept across the screen, one row at a time, from top to bottom
- Each row is referred to as a scan line

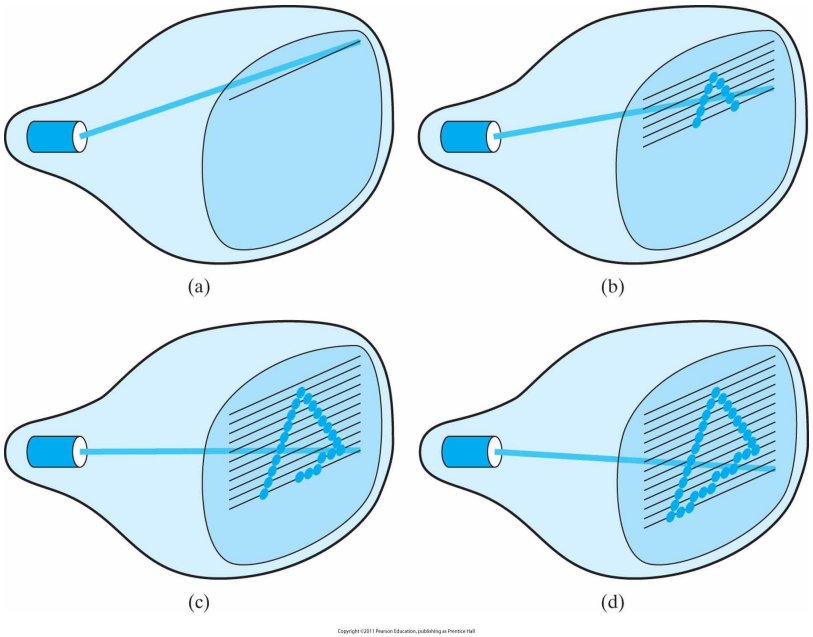


Figure 2-6 A raster-scan system displays an object as a set of discrete points across each scan line.

Frame buffer, pixels, and bit planes

- Picture definition is stored in a memory area called the refresh buffer or the frame buffer
- Each screen spot that can be illuminated by the electron beam is referred to as a pixel or pel (picture element)
- CRT, home TV sets, and printers use raster scan methods
- The number of bits per pixel in a frame buffer is referred to as the depth or number of bit planes
- A frame buffer with one bit/pixel is called a bitmap; a frame buffer with multiple bits/pixel is called a pixmap

Refresh rate

- As each screen refresh takes place, we tend to see each frame as a smooth continuation of patterns in the previous frame as long as the refresh rate is not too low (≥ 24 frames/sec)
  - < 24 frames/sec causes flickering
- Early raster-scan systems had a refresh rate of 30 frames/sec
- Currently, refresh rates are 60, 80, 120 fps (or Hertz)

Color CRT (RGB) monitors

- Color monitors use a combination of phosphors that emit different colored light
  - Our eyes tend to merge the light emitted from three dots into one composite color
- An RGB color system with 24 bits/pixel is referred to as a full-color or a true-color system

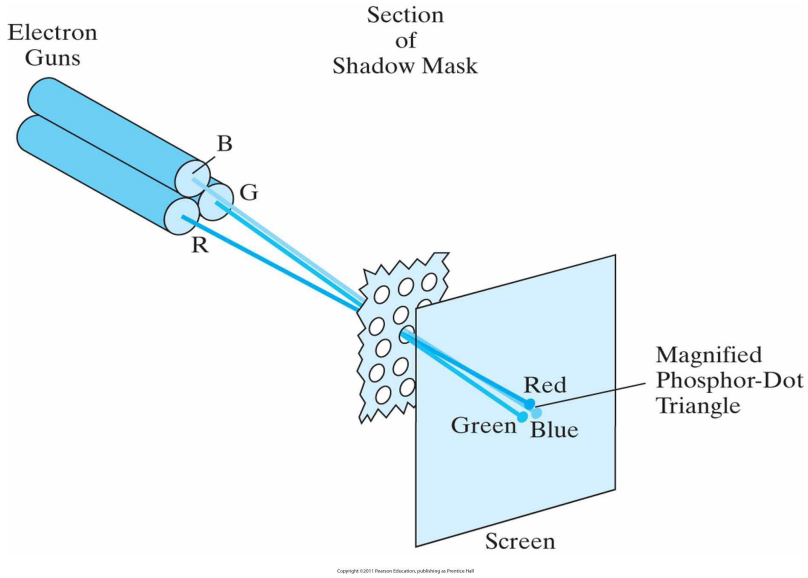
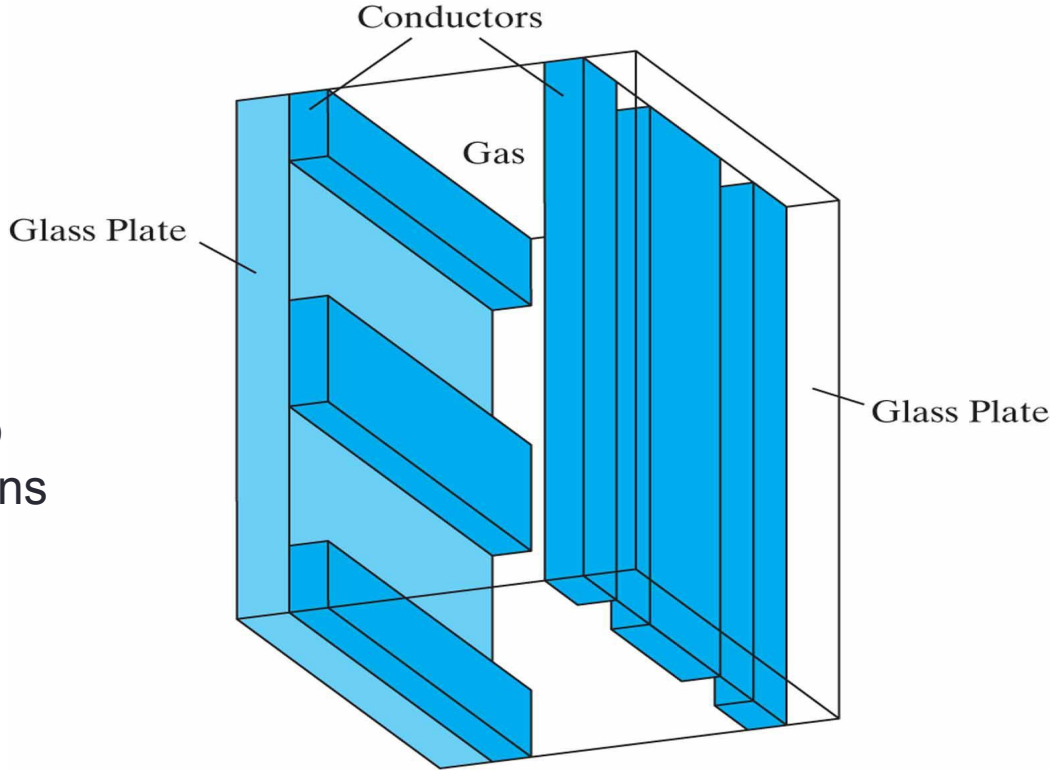


Figure 2-9 Operation of a delta-delta, shadow-mask CRT. Three electron guns, aligned with the triangular color-dot patterns on the screen, are directed to each dot triangle by a shadow mask.

Flat-panel plasma displays

Figure 2-10 Basic design of a plasma-panel display device.

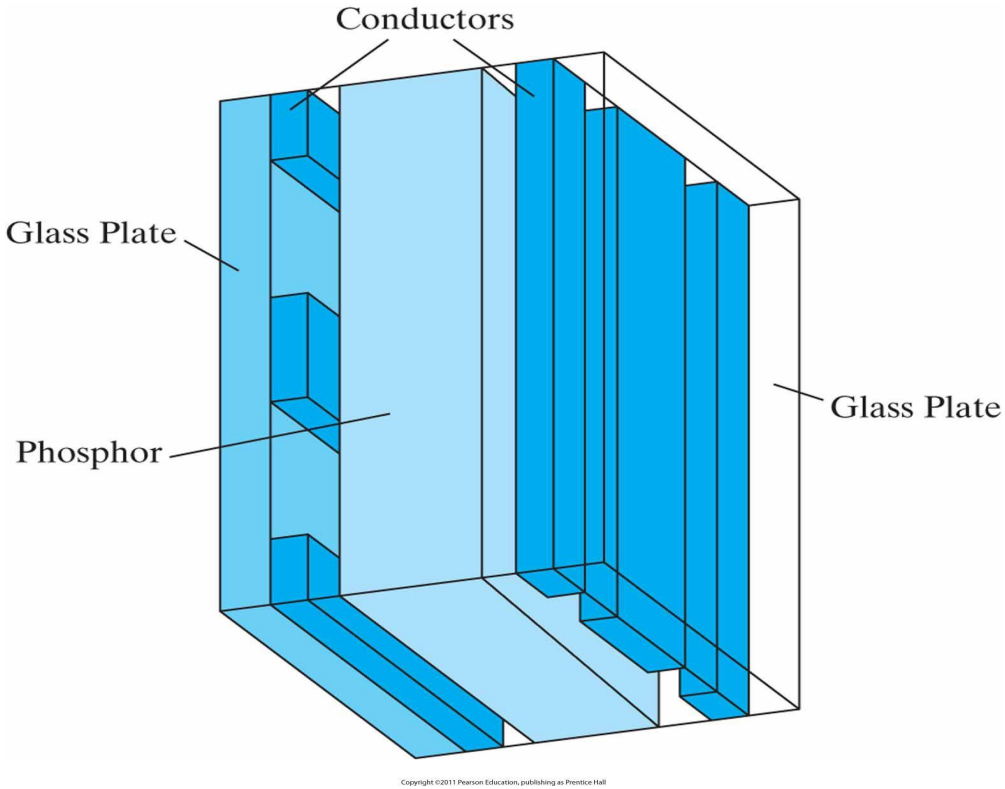
Mixture of gases that usually include neon gas at the intersection of conductors break down into a glowing plasma of electrons and ions



Flat-panel TFEL displays

Figure 2-11 Basic design of a thin-film electroluminescent display device.

The region is filled with phosphor doped with manganese. Electrical energy is absorbed by manganese atoms which then release energy as a spot of light



LED and LCD displays

- Light-emitting diode (LED) displays use a matrix of diodes arranged to form pixel positions
- Liquid-crystal displays (LCD) are non-emissive. They produce a picture by passing polarized light from the surrounding or from an internal light source through a liquid-crystal material that can be aligned to either block or transmit light

Stereoscopic and virtual reality systems

Figure 2-15 Glasses for viewing a stereoscopic scene in 3D. (*Courtesy of XPAND, X6D USA Inc.*)

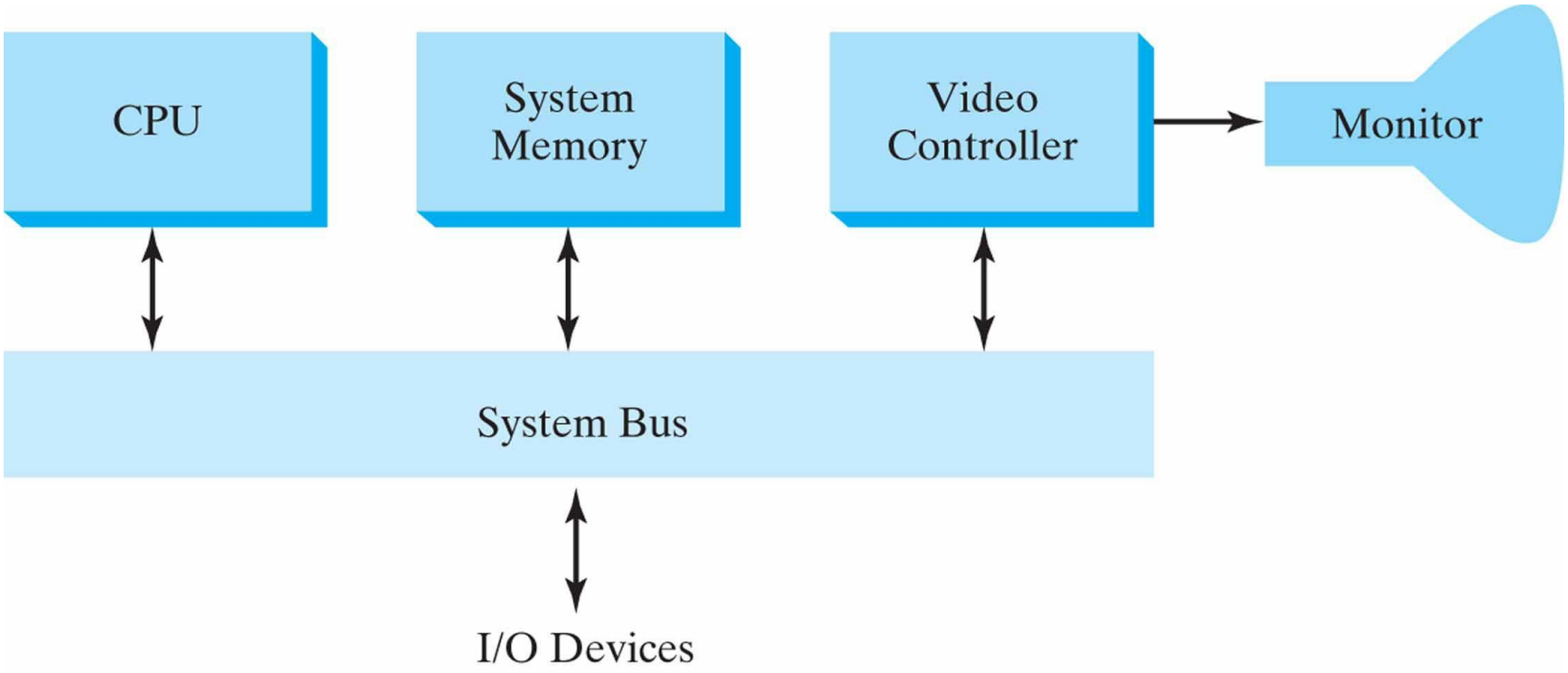
3D effect is created by presenting a different view to each eye so that scenes appear to have depth

Stereoscopic effect on a raster system

- On a raster system, we can display each of the two views on alternate refresh cycles
- The screen is viewed through glasses, with each lens designed to act as a rapidly alternating shutter that is synchronized to block out one of the views

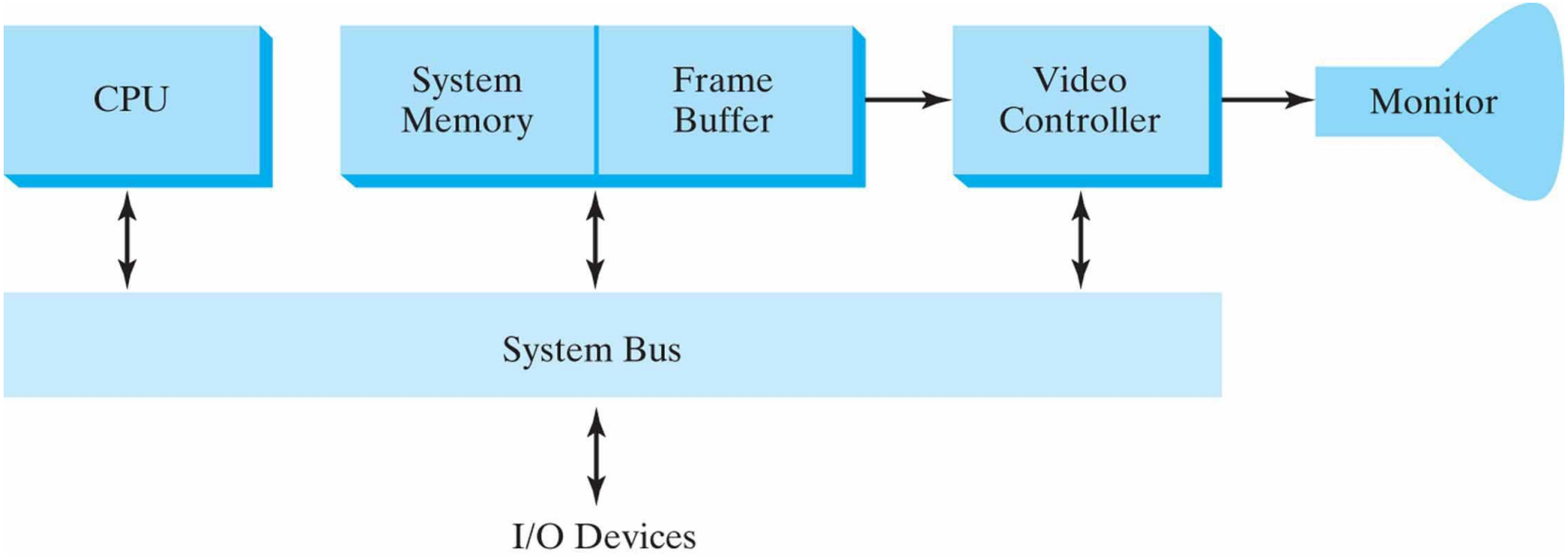
Simple raster-graphics system

Figure 2-16 Architecture of a simple raster-graphics system.



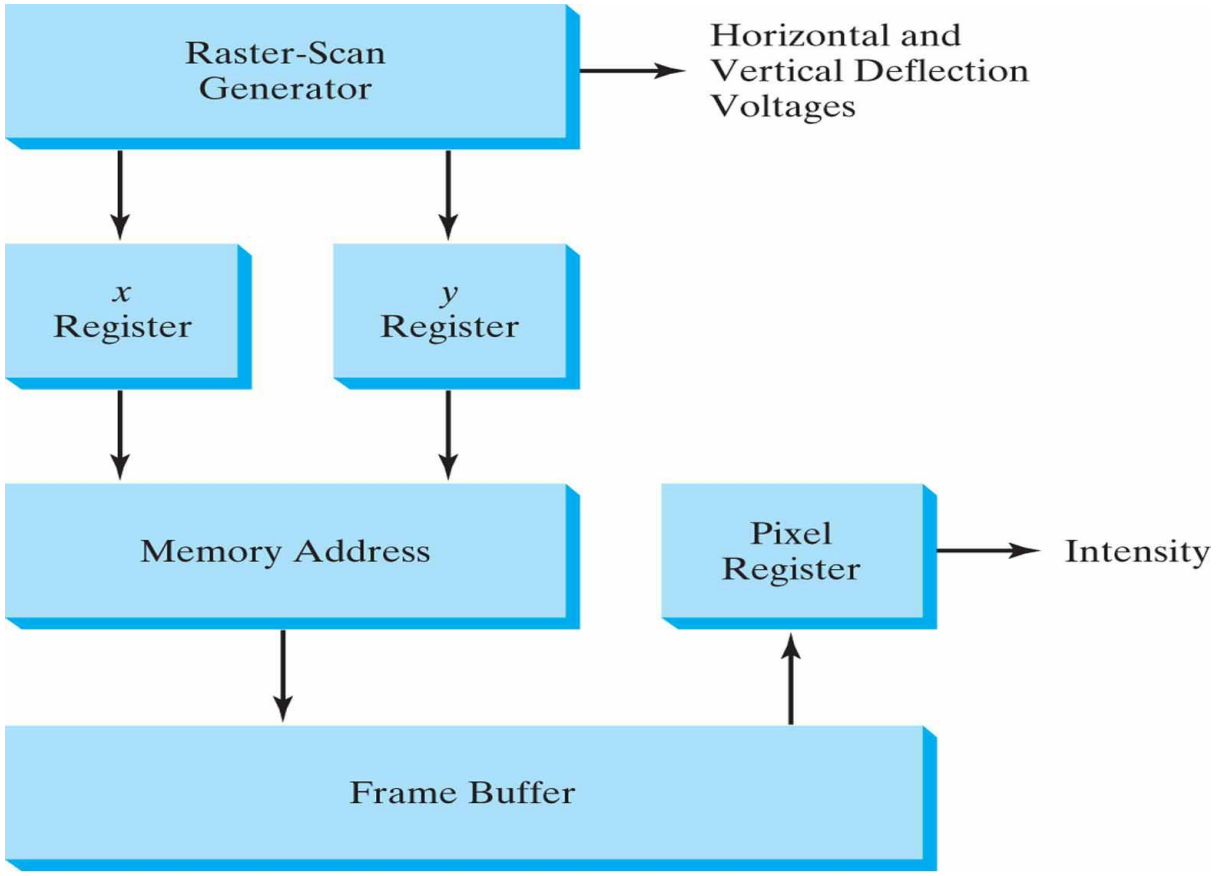
System with a frame buffer

Figure 2-17 Architecture of a raster system with a fixed portion of the system memory reserved for the frame buffer.



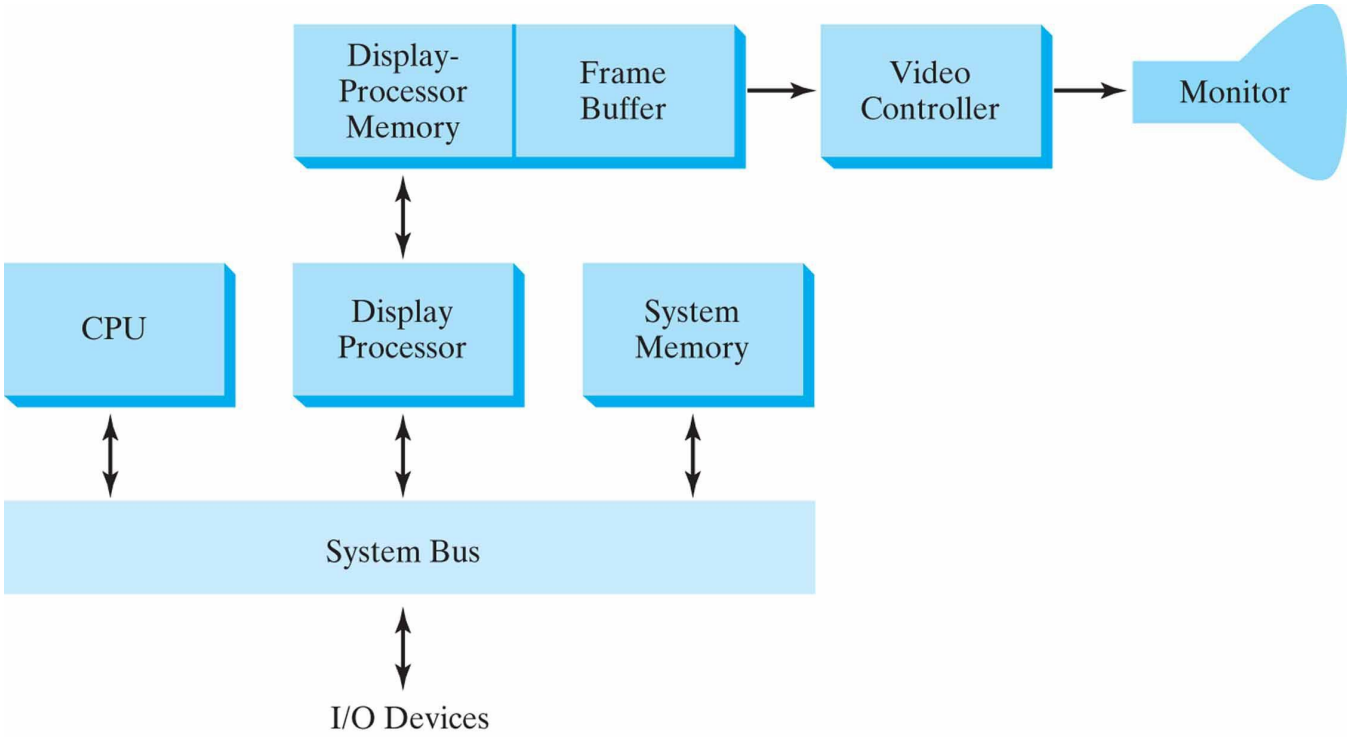
Operation of a video controller

Figure 2-19 Basic video-controller refresh operations.



System with a display processor

Figure 2-20 Architecture of a raster-graphics system with a display processor.



Some notes

- It is possible to retrieve pixel values from different memory areas (multiple frame buffers) on different refresh cycles
  - This is very useful for generating real-time animations
- Display processor is also called a graphics controller or a graphics co-processor
  - State-of-the-art: See e.g., Nvidia and ATI GPUs
- Digitizing a picture definition given in an application program into a set of pixel values for storage in the frame buffer is called scan conversion

Input and hard-copy devices

Input devices

- Keyboards, button boxes, and dials
- Mouse devices
- Trackballs (2D) which can be rotated and spaceballs (3D) that use the amount of pressure applied
- Joysticks
- Data gloves
- Digitizers (e.g. graphics tablets) for drawing, painting, or interactively selecting positions
- Image scanners
- Touch panels
- Light pens
- Voice systems

Hard-copy devices

- Printers
- Plotters