Displays

CSE 457, Autumn 2003
Graphics

http://www.cs.washington.edu/education/courses/457/03au/

History

» **Whirlwind Computer - MIT, 1950**

- CRT display

» **SAGE air-defense system - middle 1950's**

- "Whirlwind II"

- light pens

» **Sketchpad - 1963, Ivan Sutherland**

- first interactive graphics system

- constraint-based

- interaction techniques for choosing, pointing, drawing
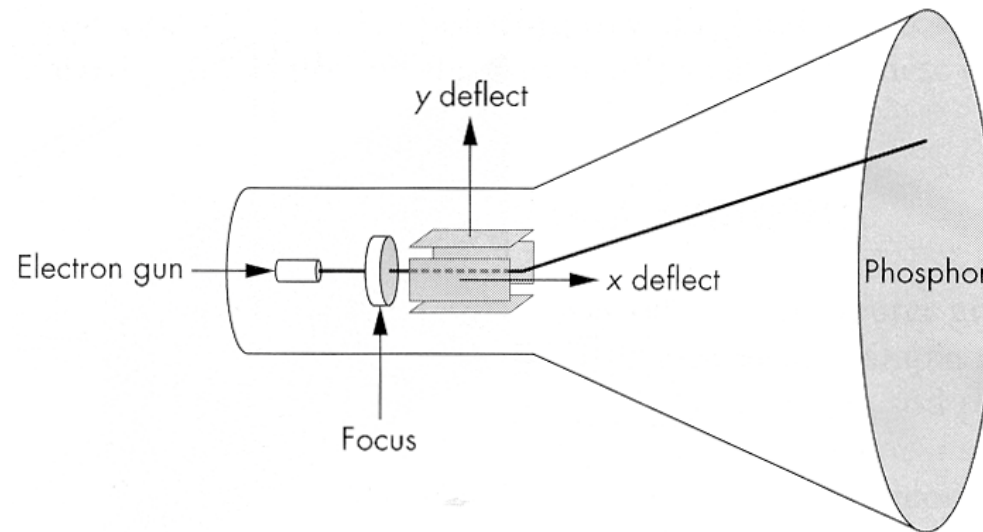
- data structures for replicating components

Modern graphics systems
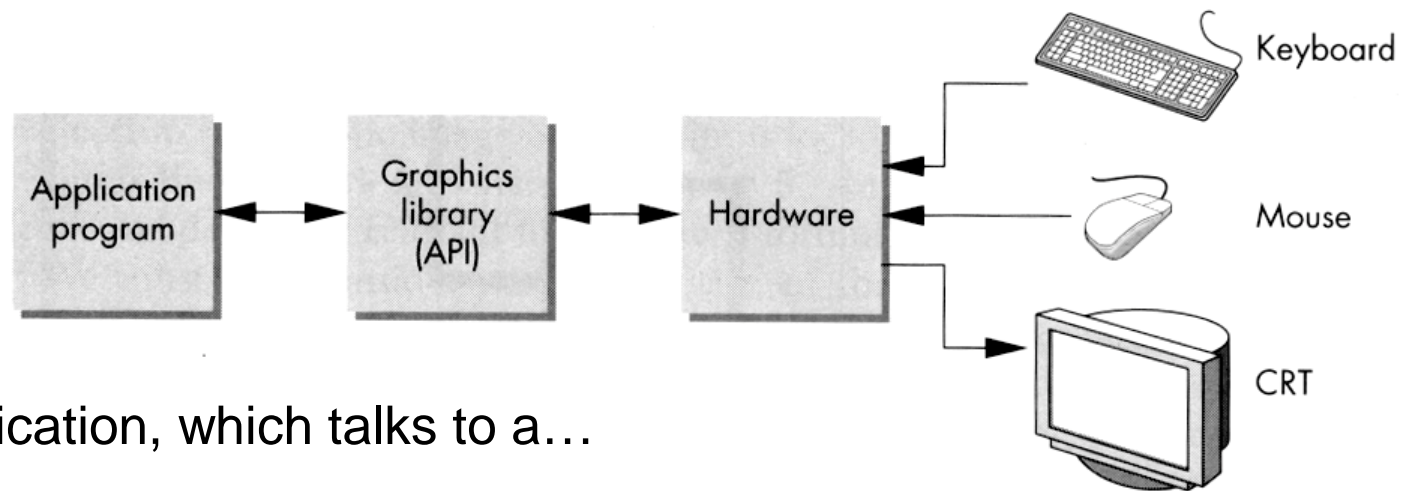
- An application, which talks to a…

- Graphics library (e.g., OpenGL or Direct3D), which talks to the…

- Graphics hardware

The graphics hardware can do a lot of fancy work these days. At a minimum, it contains a framebuffer to drive a display…

Cathode ray tubes (CRTs)

- 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 (usually 10 to 60 usec for monitors)
- Different phosphors have different:
  - » Spectral Power Distribution (and therefore different color)
    - red: europium yttrium vanadate
    - green: zinc cadmium sulfide
    - blue: zinc sulfide
  - » persistence (can be as long as a few seconds)
  - » The image must be **refreshed** to avoid visible **flicker**

Calligraphic displays

- Also called **vector displays**, **stroke displays**, or **random-scan displays**.

- Used by:
  - » Sutherland's Sketchpad
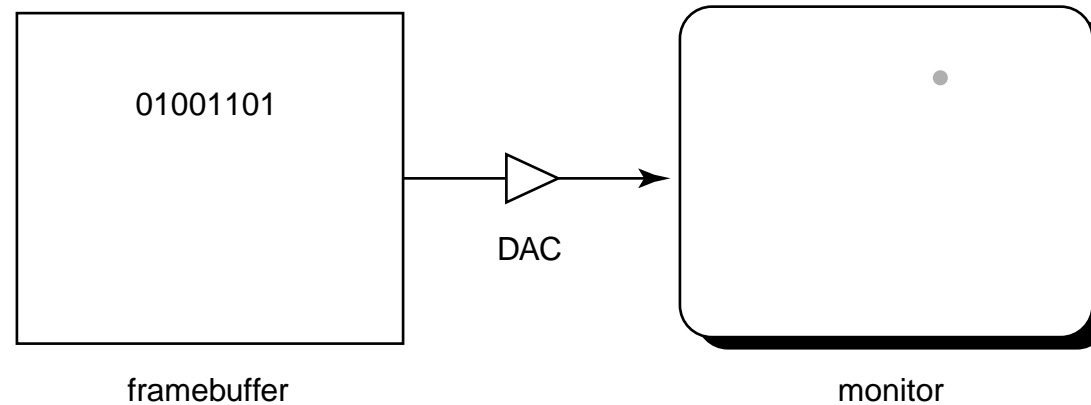 - » Asteroids video game
  - » Oscilloscopes
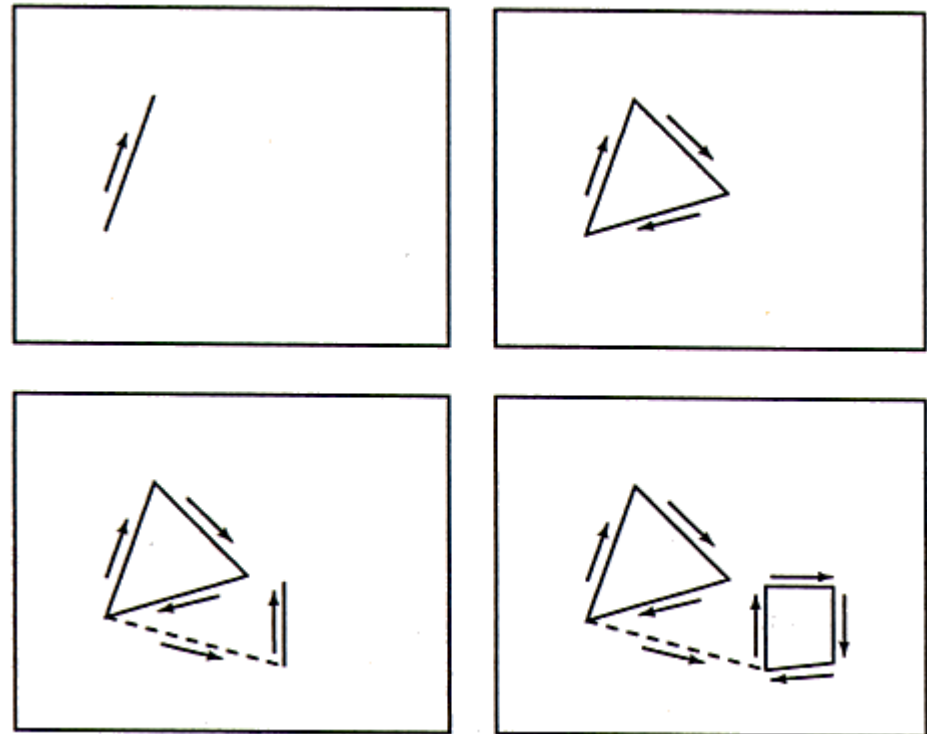
Raster displays

Electron beam traces over screen in **raster scan order**.

- 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** (both horizontal and vertical)

Framebuffers

01001101

framebuffer   monitor

DAC
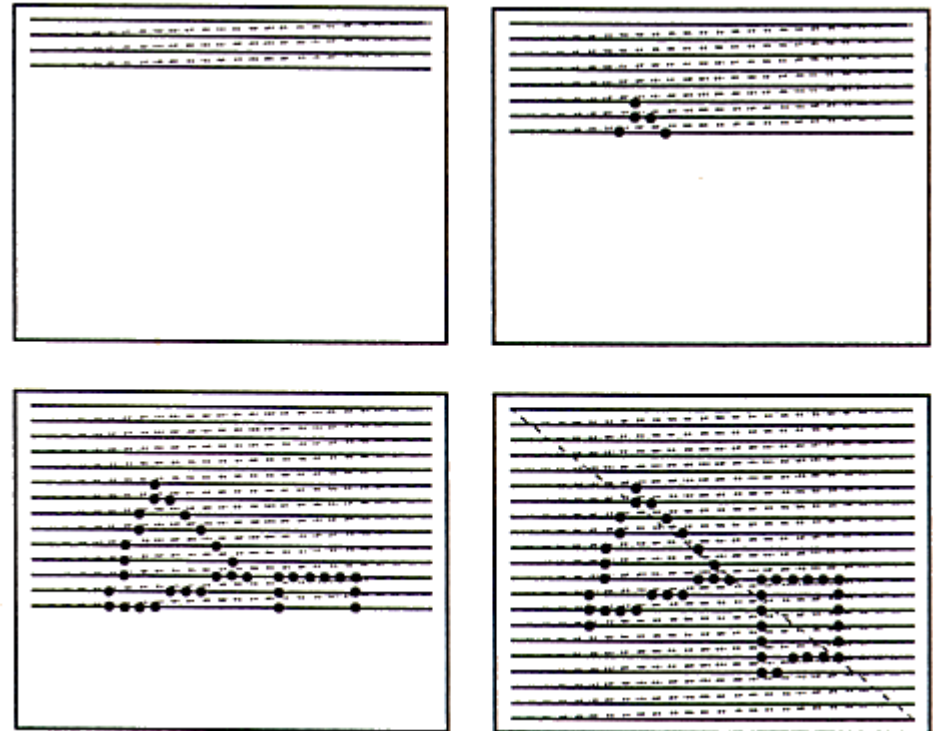
- Intensity of the raster scan beam is modulated according to the contents of a **framebuffer**.

- Each element of the framebuffer is associated with a single **pixel** on the screen.

Resolution

- The display's **"resolution"** is determined by:
    » number of scan lines
    » number of pixels per scan line
    » number of bits per pixel

Bitmapped display	960x1152x1b	1/8 MB
NTSC TV	640x480x16b	1/2 MB
Color Workstation	1280x1024x24b	4MB
Laser printed page		
300 dpi	$8.5x11x300^2x1b$	1MB
1200 dpi	$8.5x11x1200^2x1b$	17MB
Film	4500x3000x30b	50MB

Resolution is used here to mean total number of bits in a display. It should really refer to the resolvable dots per unit length…

Aspect ratio

- **Frame aspect ratio** = horizontal / vertical size

|	
TV	4 : 3
HDTV	16 : 9
Letter-size paper	8.5 : 11 (about 3 : 4)
35mm film	3 : 2
Panavision	2.35 : 1

- **Pixel aspect ratio** = pixel width / pixel height
 - » nowadays, this is <u>almost</u> always 1.

Color CRT monitors

- Many color monitors employ **shadow mask** technology. The variety depicted:

» 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
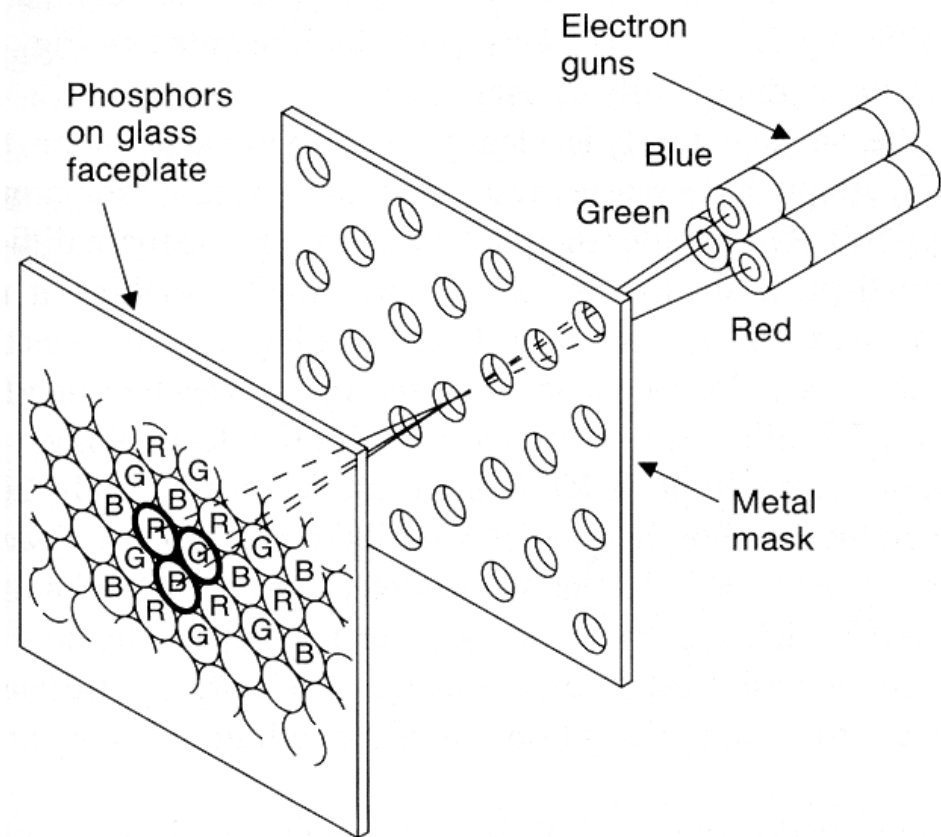
Color Trinitron CRT's

- ## 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
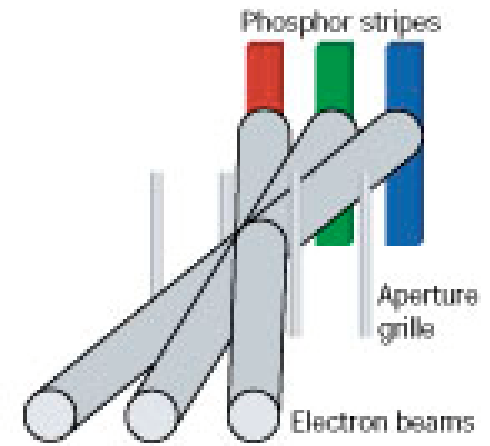
You can see two horizontal lines at about ¼ and ¾ of the way up the screen on Trinitron displays. Why?

Liquid Crystal Displays

- Most common flat panel display today
  - » Light enters a **vertical polarizer**
  - » **Nematic crystal** twists light based on applied voltage (more voltage, less twisting)
  - » Light passes through **horizontal polarizer**

- Passive matrix displays use a matrix of electrodes to control the voltages. Problem: slow to switch, overflows.

- Active matrix displays have a transistor at each cell with a faster switching crystal and transistors that hold charge and prevent overflow.

- Color filters are used to get color display.
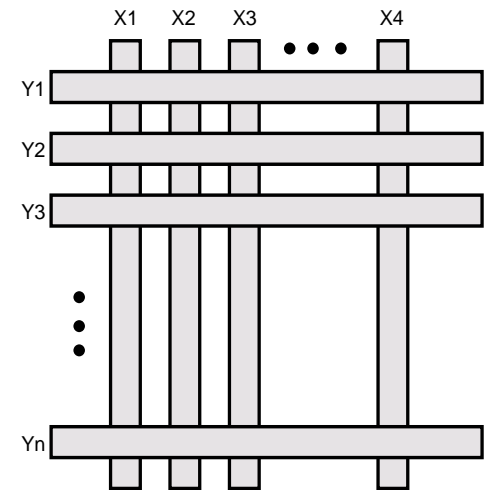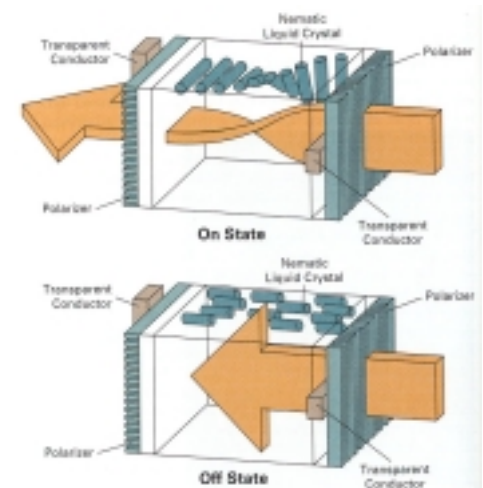
Additive color mixing

- All colors on a monitor or LCD are produced using combinations of red, green, and blue primaries

- A display that allows 256 voltage settings for each of R, G, and B is known as a **full-color system**.

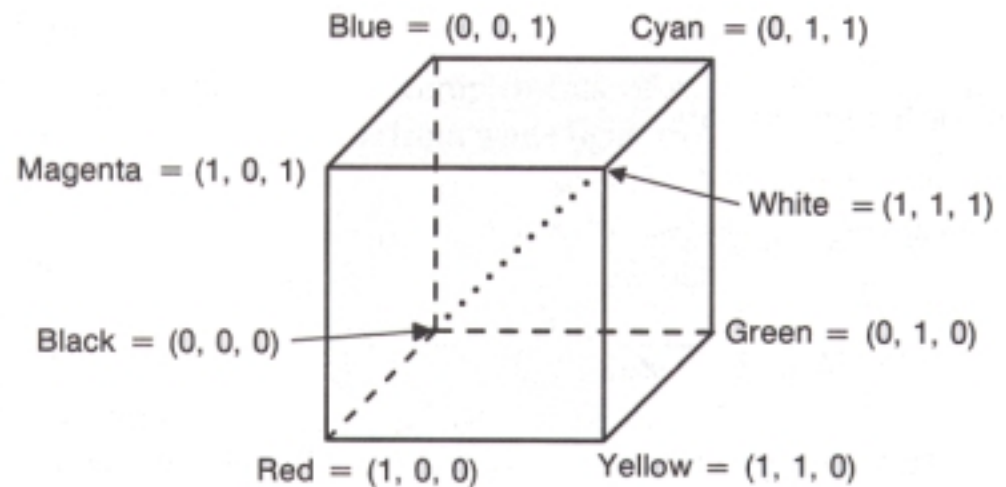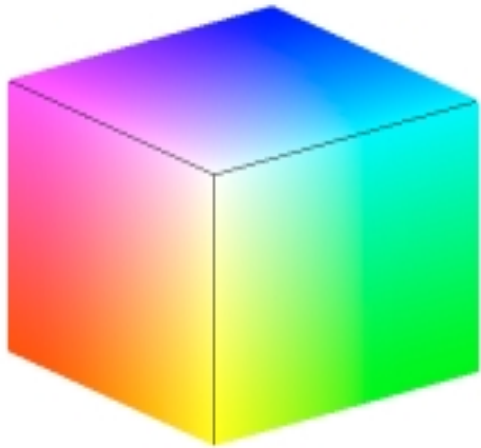- The description of each color in framebuffer memory is known as a **channel**.

Blue = (0, 0, 1)   Cyan = (0, 1, 1)

Magenta = (1, 0, 1)

White = (1, 1, 1)

Black = (0, 0, 0)   Green = (0, 1, 0)

Red = (1, 0, 0)   Yellow = (1, 1, 0)

Fig. 13.28 The RGB cube. Grays are on the dotted main diagonal.

Color tables

Color tables allow more color versatility when you only have a few bits per pixel in memory but your display can handle more than that. You get to select a small **palette** of from a larger number of possible colors.
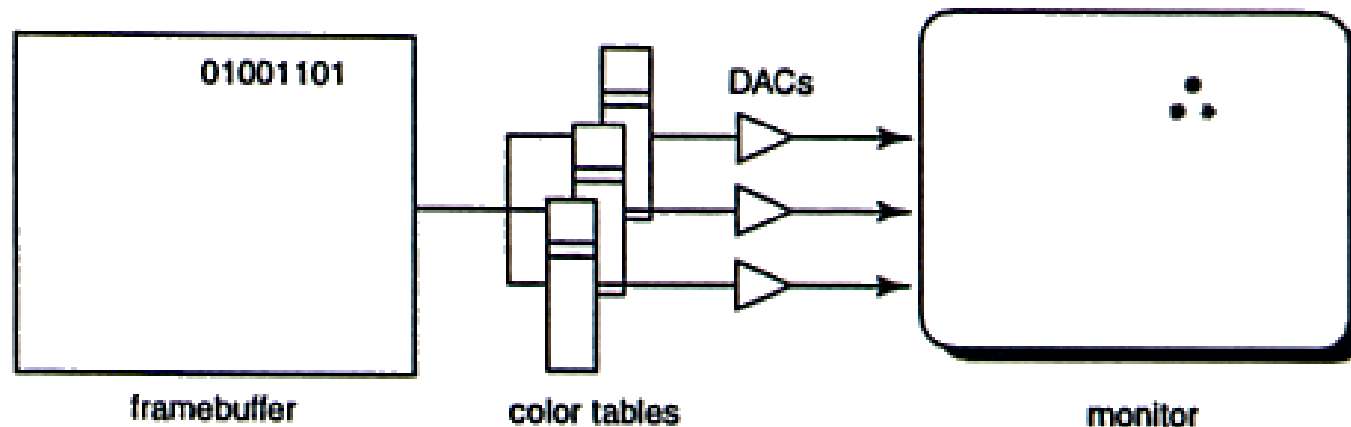
Each framebuffer element is now an index into the color table, where the actual values of each channel are stored.
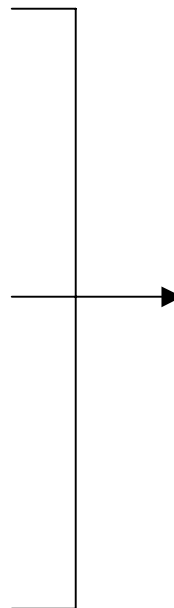Color table entries can be changed in software.
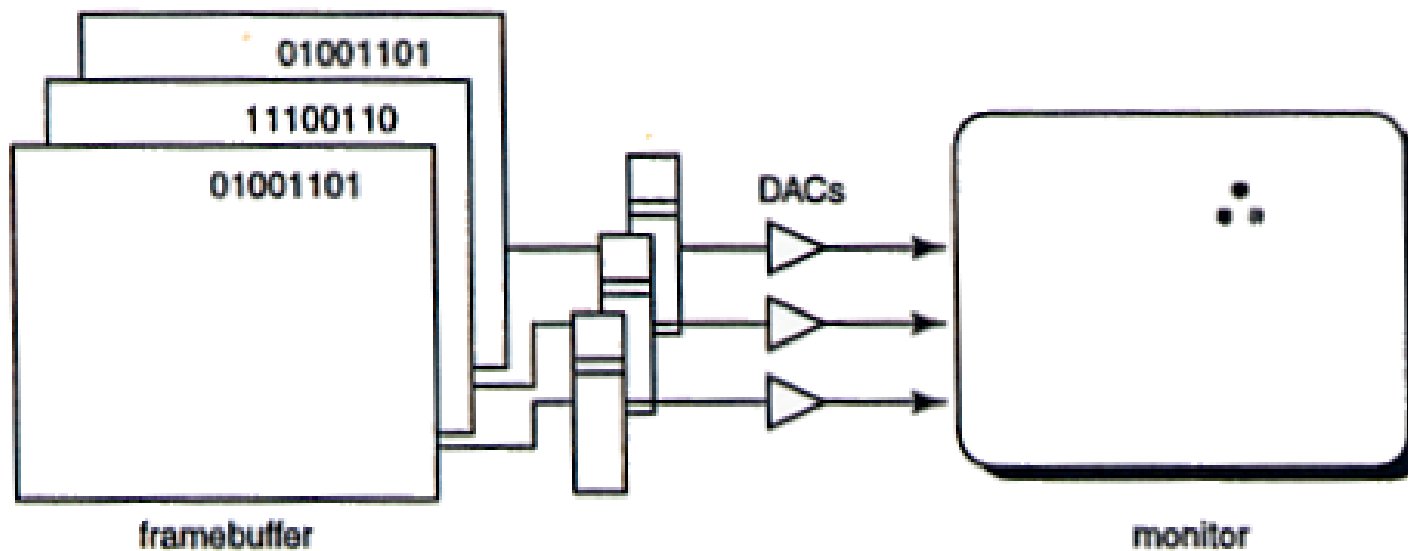
RGB framebuffer
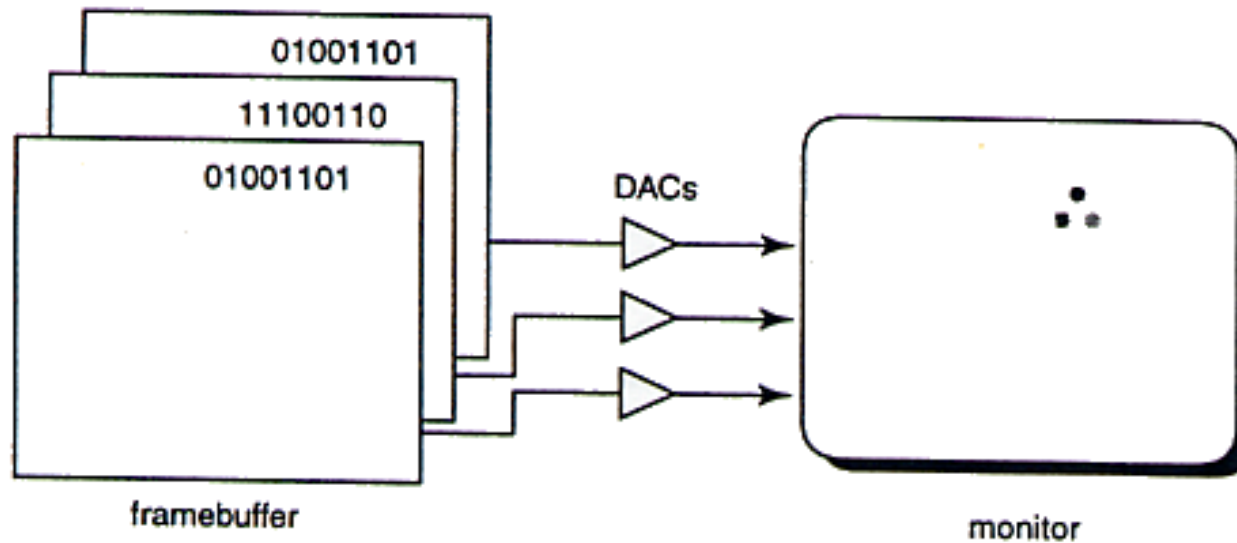
- The term **true-color** is sometimes used to refer to systems which the framebuffer directly stores the values of each channel.

- As memory prices have fallen, true-color has become fairly standard.

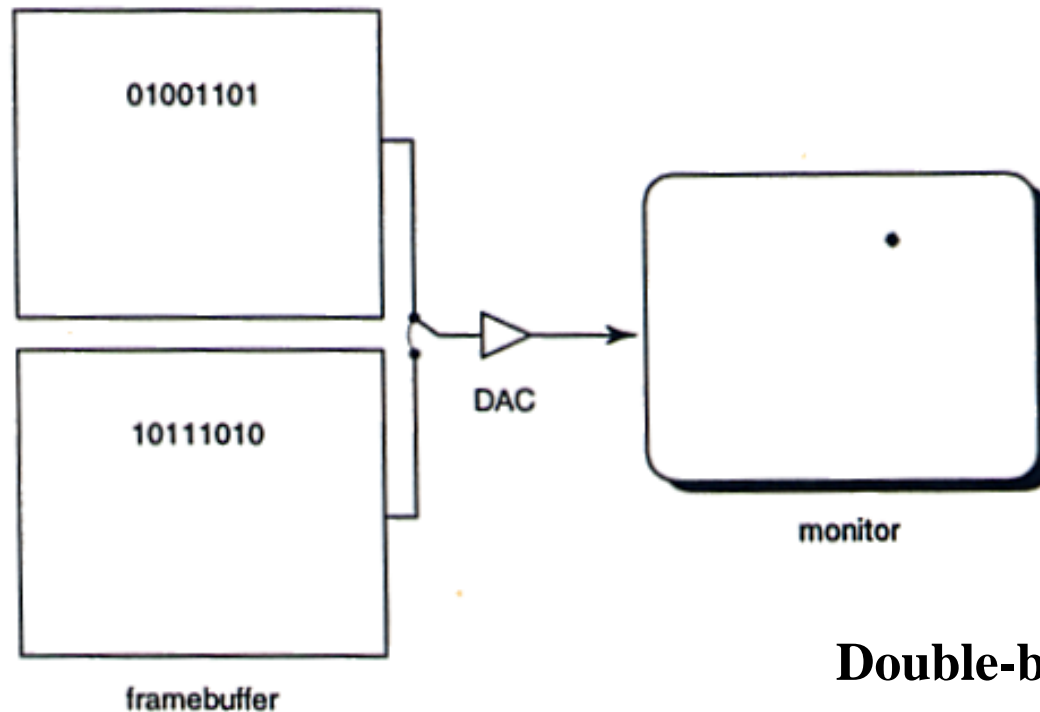# Anatomy of an RGB image

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.

Q: Why would you want this capability?

Double-buffering

- What happens when you write to the framebuffer while it is being displayed on the monitor?

01001101

10111010

framebuffer

DAC

monitor

Double-buffering provides a solution.

Summary

- Here's what you should take home from this lecture:
    - » All of the **boldfaced terms**.
    - » Sketchpad (1963) was the first interactive graphics system.
    - » The basic components of black-and-white and color CRTs.
    - » Raster vs. calligraphic displays.
    - » The principle operation for an LCD display.
    - » Computing screen resolution & framebuffer size.
    - » The correspondence between elements of framebuffer memory and pixels on-screen.
    - » How color tables and double-buffering work.