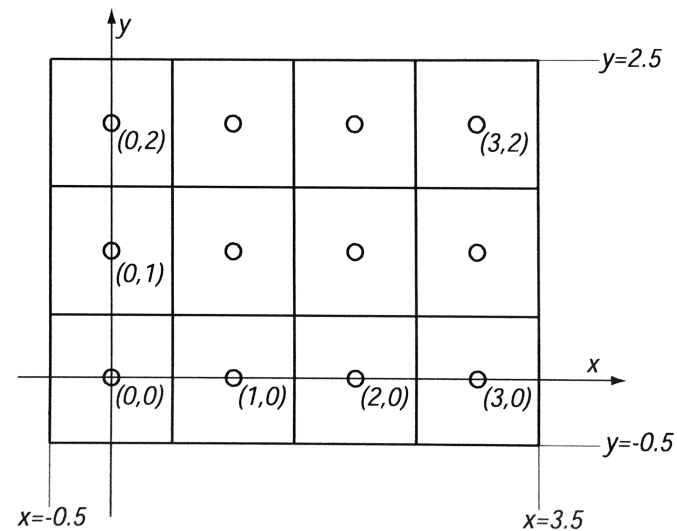# 4 – Hardware, raster displays, color
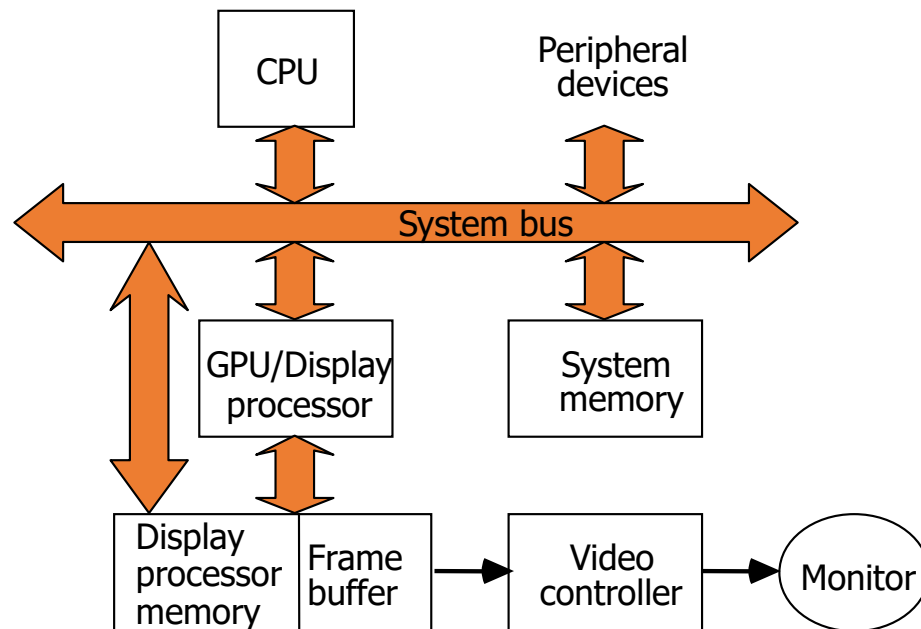
Basic Definitions

- Raster: A rectangular array of points or dots.
- Pixel: One dot or picture element of the raster
- Scan Line: A row of pixels

Example Raster Graphics Architecture

Raster system architecture with a display processor.
(originally from Computer Graphics: Principles and Practice.)
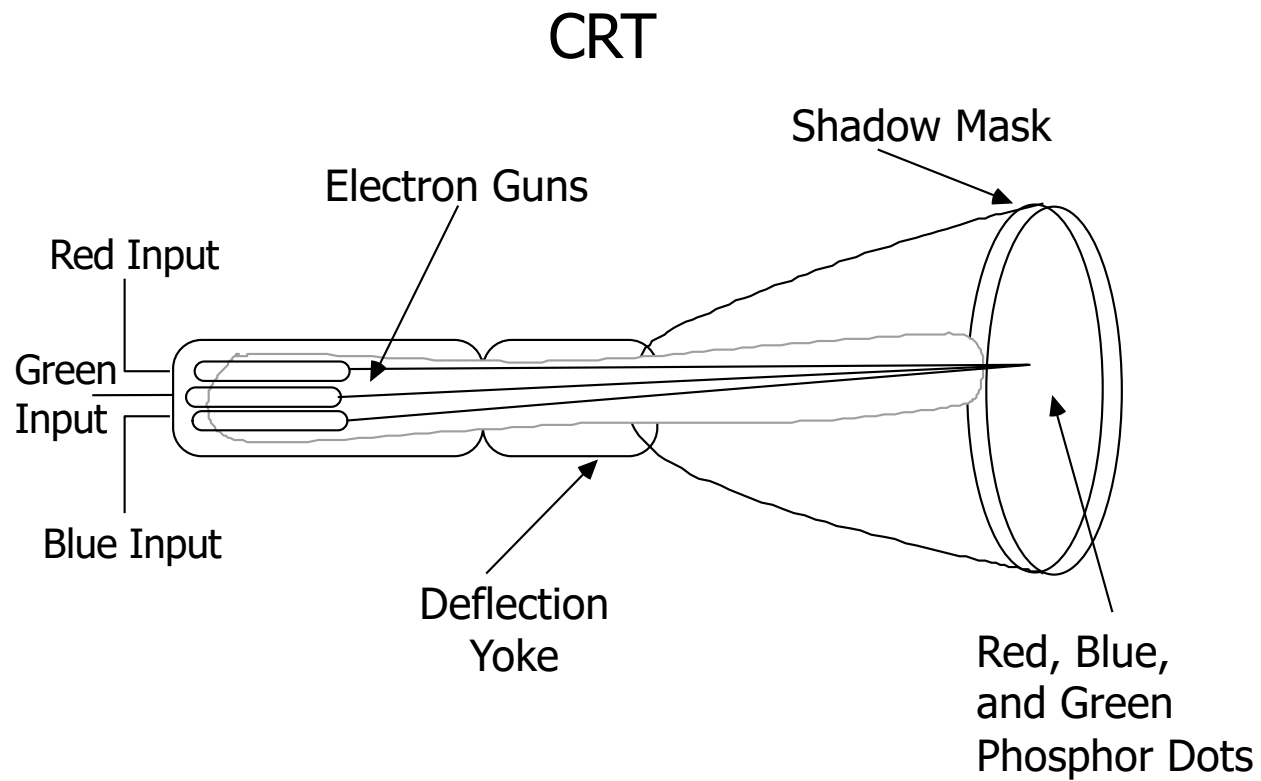
Displays and Cameras

Book covers LED, LCD, ink-jet, dye sub, cameras and scanners

Bayer mosaic

CRT Monitor

CRT

Shadow Mask

Electron Guns

Red Input

Green
Input

Blue Input

Deflection
Yoke

Red, Blue,
and Green
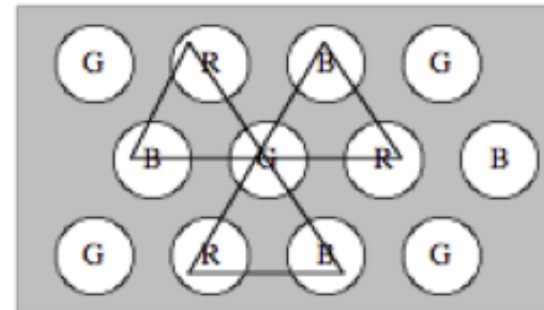Phosphor Dots

Electron Gun

- Stream of electrons directed to front
  - Num electrons controls brightness

- Phosphor, glows briefly

- Gaussian distribution of electrons, light
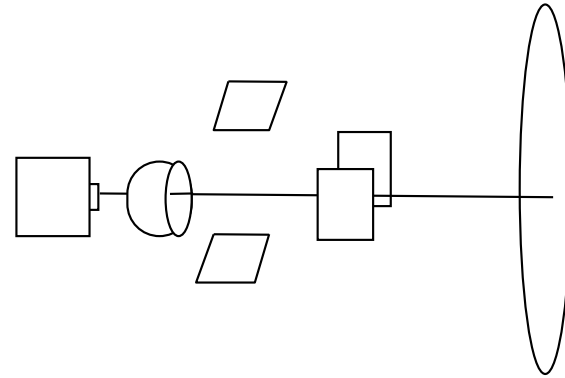
Color CRT

- RGB electron guns
- Screen coated with phosphor pattern


- Fluorescence
- Phosphorescence
- Persistence

Shadow Mask

- Phosphors arranged in triads

- Each triad has one R/G/B phosphor dot

- Typically 2.3 to 2.5 triads per pixel

- Shadow mask has one small hole for each phosphor triad

SHADOW MASK

Phosphor Dot Screen

Red
Green
Blue

Convergence Point
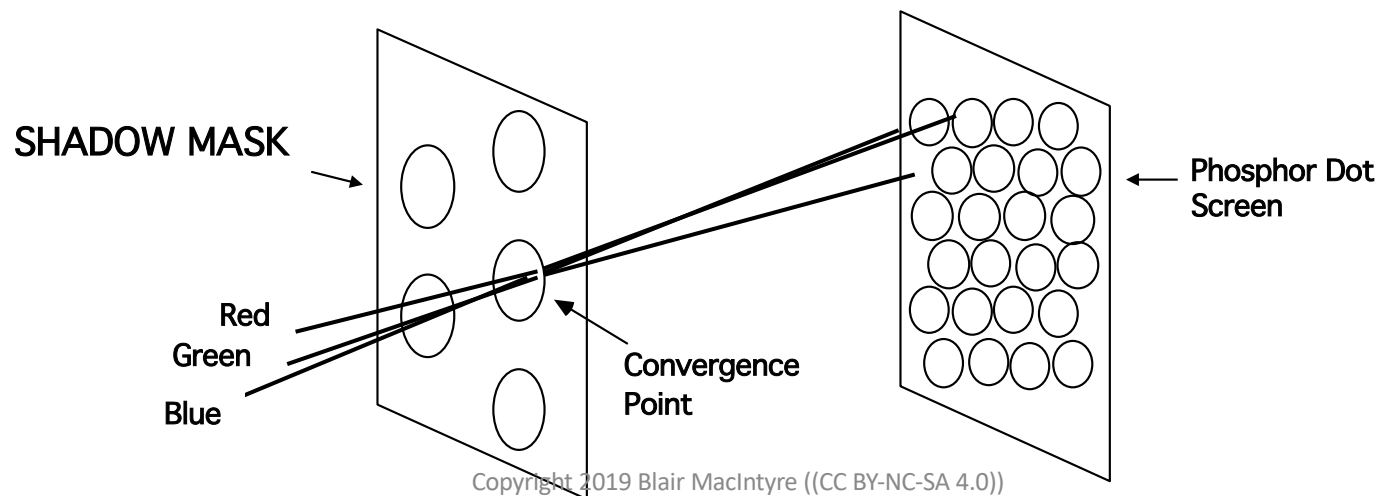
Scanning An Image to a Display

- Frame: image to be scanned on CRT/LCD

- Frame must be "refreshed" to eliminate flicker in the image.

- Critical Fusion Frequency
  - Typically 60 times/sec for raster displays
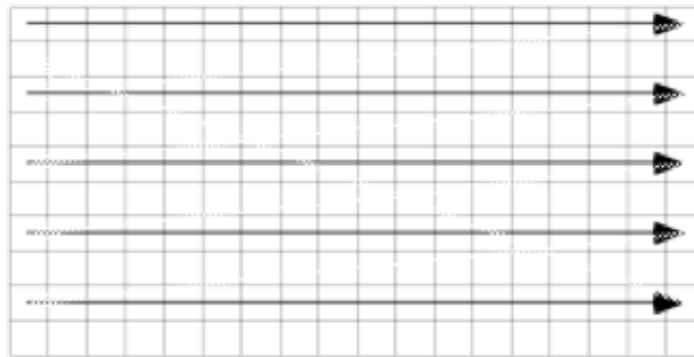 - Varies with intensity, individuals, phosphor persistence, lighting, …
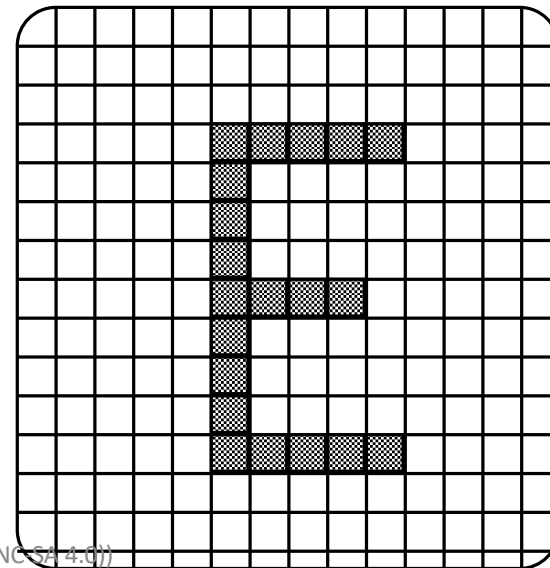
Interlaced Scanning

- Assume can only scan 30 times/sec
- To reduce flicker, divide frame into two "fields" (odd and even lines)

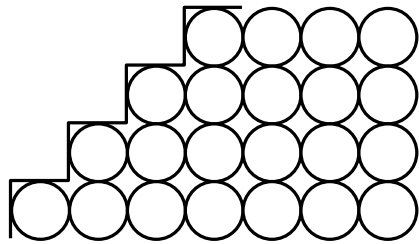| 1/30 SEC		1/30 SEC	
1/60 SEC	1/60 SEC	1/60 SEC	1/60 SEC
FIELD 1	FIELD 2	FIELD 1	FIELD 2
FRAME		FRAME	

Scanning

VERTICAL SYNC PULSE — Signals the start of the next field.

VERTICAL RETRACE — Time needed to get from the bottom of the current field to the top of the next field.

HORIZONTAL SYNC PULSE — Signals the start of the new scan line.

HORIZONTAL RETRACE — Time needed to get from the end of the current scan line to the start of the next scan line.
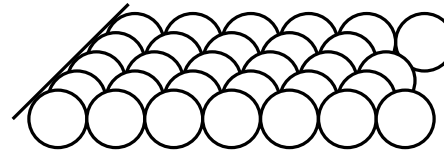
Resolution and Addressability

Resolution is a measure of the width of a single line drawn on the CRT screen (1/spotsize). Usually stated as the number of just merged lines per inch or centimeter.

Resolution = Addressability

Addressability is a measure of the spacing between the centers of those lines.

Resolution < Addressability

(Everybody, incorrectly, uses **resolution** when they mean **addressability**.)

Smooths out the "jaggies" but the overlap will cause filled areas to be brighter than lines, and lines to be brighter than single pixels.
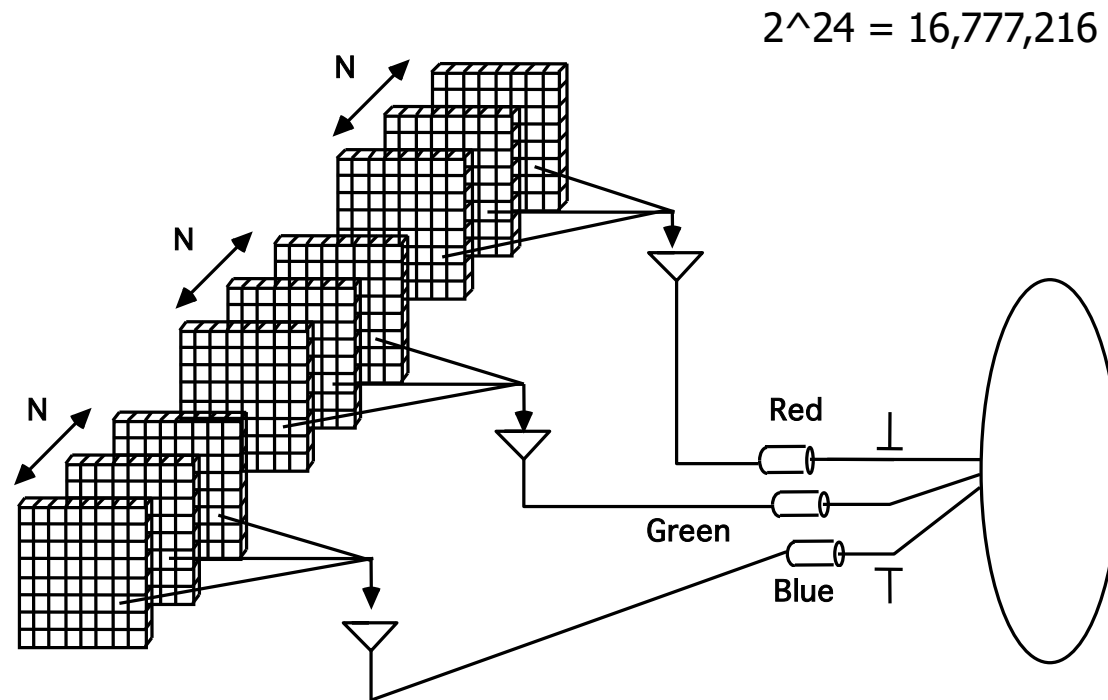
Frame Buffers

- 2D array
  - each (x,y) location = a pixel
- *Bit Planes, Bit Depth*
  - number of bits in a pixel
- Typical frame buffers:
  - 640 x 480 x 8
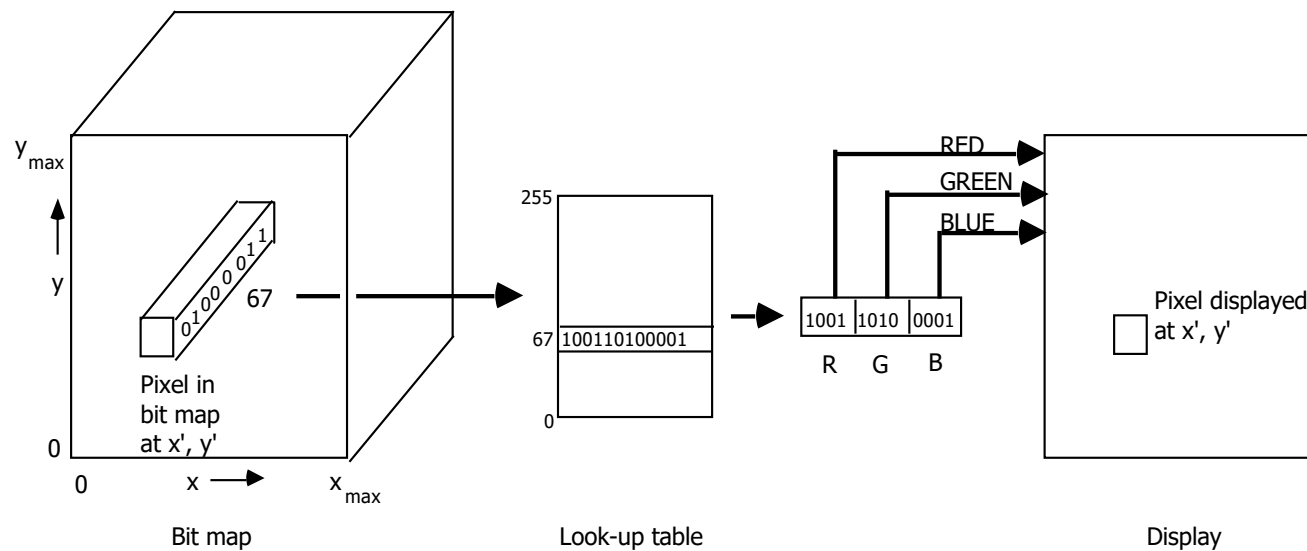 - 1280 x 1024 x 8
  - 1280 x 1024 x 24
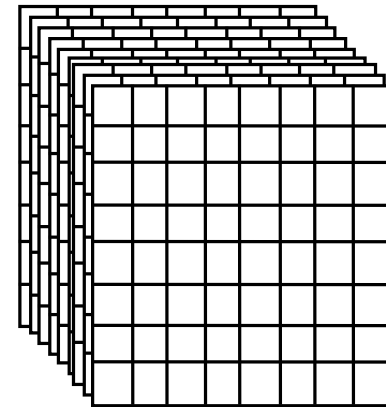
True Color Display
24 bitplanes, 8 bits R/G/B

$2\verb|^|24 = 16{,}777{,}216$

Color Map Look-Up Tables

Bit map   Look-up table   Display

LUT Video look-up table organization. A pixel with value 67 (binary 01000011) is displayed on the screen with the red electron gun at 9/15 of maximum, green at 10/15, and blue at 1/15. This look-up table is shown with 12 bits per entry. Up to 24 bits per entry are common.
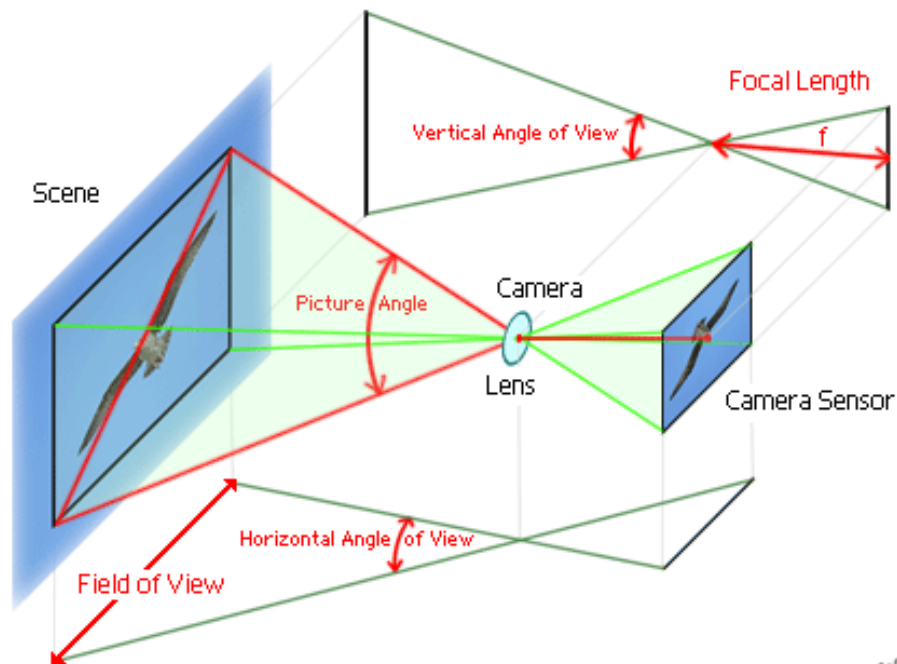
Camera

Aperture
Exposure

f/2.8

f/16

f/1.4   f/2   f/2.8   f/4   f/5.6   f/8

Images from https://en.wikipedia.org/wiki/Aperture
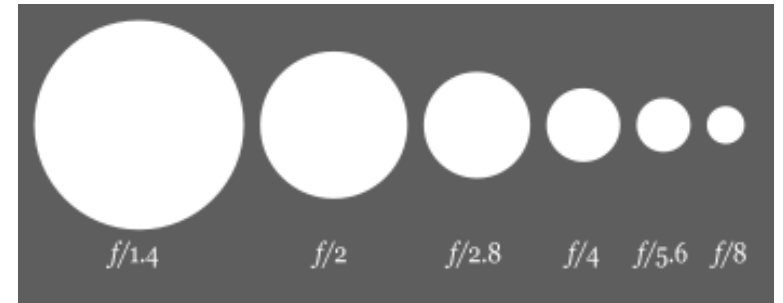
Camera Focal Length

field of view = 2 atan (sensorsize / (2f))

© 2003 Vincent Bockaert   123di.com

http://www.dpreview.com/glossary/optical/focal-length

Aperture, Depth of Field, and Bokeh

"Christmas Tree Lights Bokeh" by Rushilf - Own work

"Josefina with Bokeh" by carlosluis - http://www.flickr.com/photos/paseodelsur/51805888/.