Introduction and Overview *of* Graphics Systems

Suggested Books of Computer Graphics

- **Computer Graphics, C Version**: Donald Hearn and M. Pauline Baker; Pearson Education.
- **Computer Graphics: Principles and Practice in C:** John F. Hughes, James D. Foley, Andries van Dam, Steven K. Feiner; Addison Wesley
- **Computer Graphics:** Zhigang Xiang and Roy A. Plastock; McGraw Hill Education
- **Computer Graphics with Open GL:** Hearn Baker Carithers; Pearson Education Limited
- **Fundamentals of Computer Graphics:** Peter Shirley, Stephen R. Marschner, Michael Ashikhmin, MORE; CRC Press

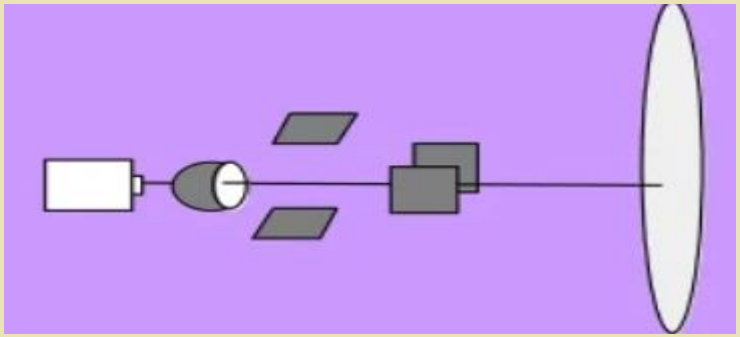
Objective

- Video Display Device
- CRT
- Types of Display System
- Color Generation Technique
- Input/Output Device
- Numerical based on display System
- Application of Computer Graphics

Video Display Devices

- The primary output device in a graphical system is the video monitor.

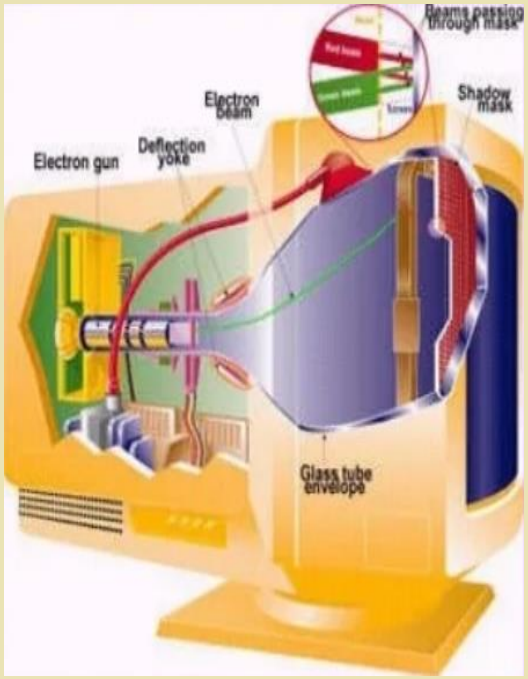
Electronic GUN



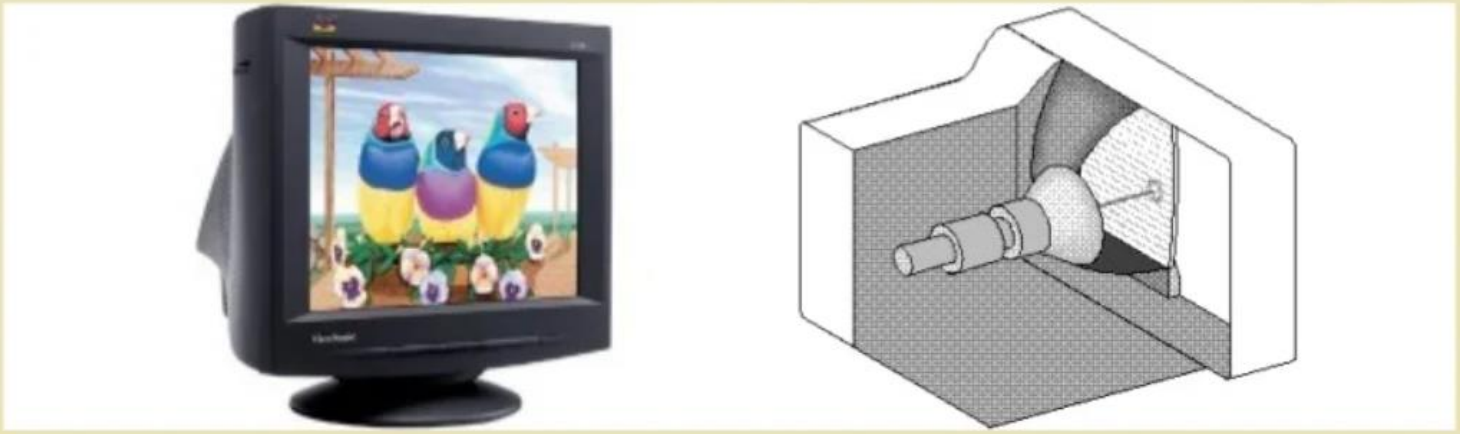
- Contains a filament that, when heated, emits a stream of electrons
- Electrons are focused with an electromagnet into a sharp beam and directed to a specific point of the face of the picture tube
- The surface of the picture tube is coated with small phosphor dots
- When the beam hits a phosphor dot it glows with a brightness proportional to the strength of the beam and how often it is excited by the beam
- The picture is repeatedly repainted (refresh CRT)

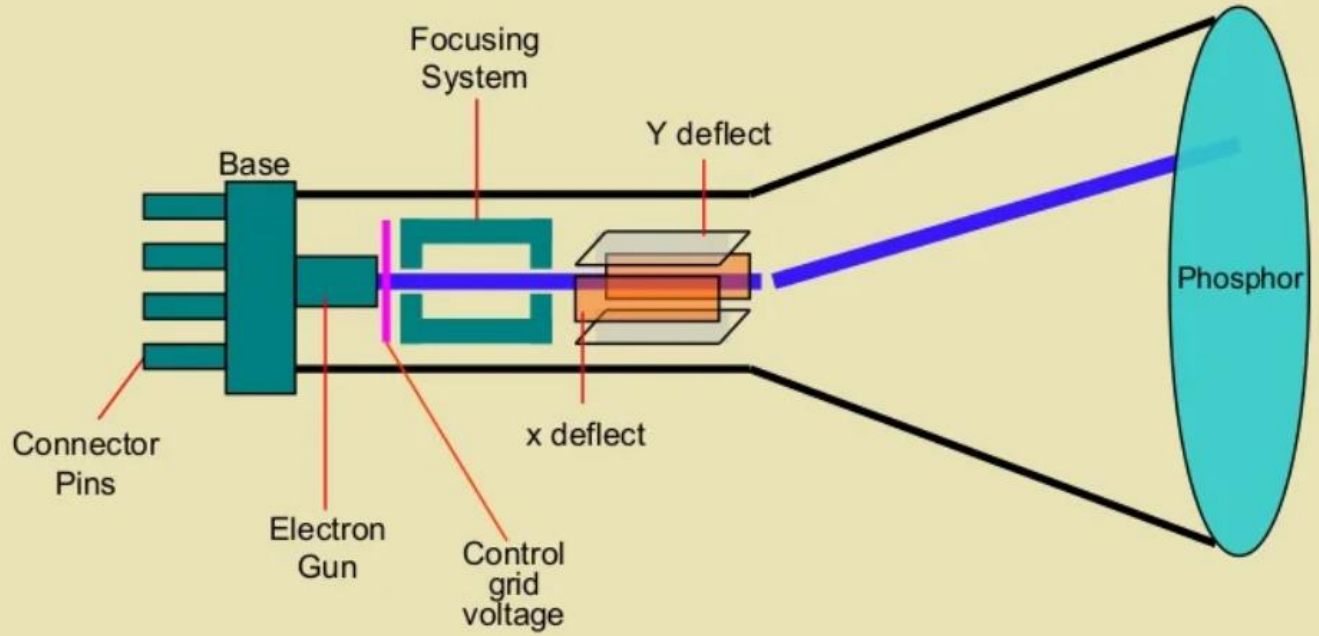
Display Technology

- Cathode Ray Tubes (CRTs)
  - Most common display device today
  - Evacuated glass bottle
  - Extremely high voltage
  - Heating element (filament)
  - Electrons pulled towards anode focusing cylinder
  - Vertical & horizontal deflection plates
  - Beam strike phosphor coating on front of tube

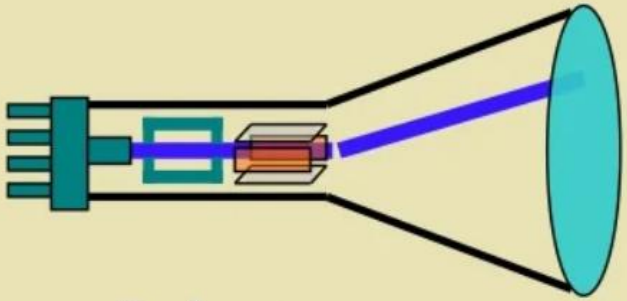


Cathode-ray tubes (CRT)





Basic operations of a CRT



Steps

1. The electron gun emits a beam of electrons (cathode rays).
2. The electron beam passes through **focusing** and **deflection** systems that direct it towards specified positions on the phosphor-coated screen.
3. When the beam hits the screen, the phosphor emits a small spot of light at each position contacted by the electron beam.

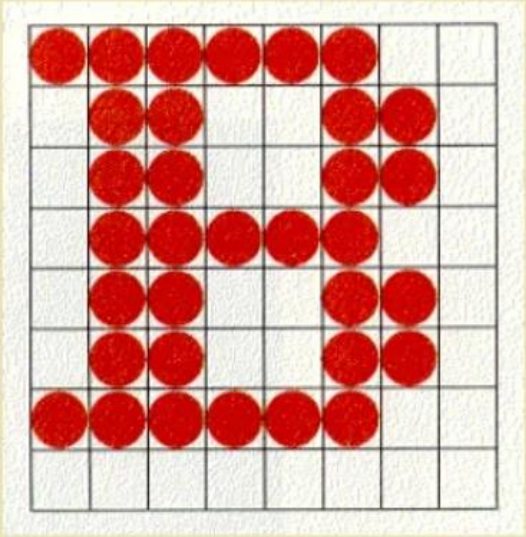
   Because the light emitted by the phosphor fades very quickly some method is needed for maintaining the screen picture.

1. Redraw the picture by quickly directing the electron beam back over the same screen points.

Phosphor Persistence

- **Definition:** The time from the initial light output to the moment when has decayed to its 10%.
- There are different kind of phosphors for use in a CRT. Besides color, a major difference is their persistence – how long they continue to emit light after the CRT beam is removed.
- A phosphor with low-persistence is useful in animation.
- A high-persistence phosphor is useful for displaying highly complex, static pictures.
- Graphics monitors are usually constructed with a persistence in the range from 10 to 60 microseconds.

Raster Scan Displays



B

- Developed in the early seventies.
- It is today's dominant hardware technology. Almost all graphics systems are raster-based.
- A picture is produced as an array – the **raster** – of picture elements.
- This elements are called **Pixels** or Pels (Picture Elements). A pixel corresponds to a location, or small area, in the image.
- Collectively, the pixels are stored in a part of memory called the **refresh buffer** or **frame buffer**.

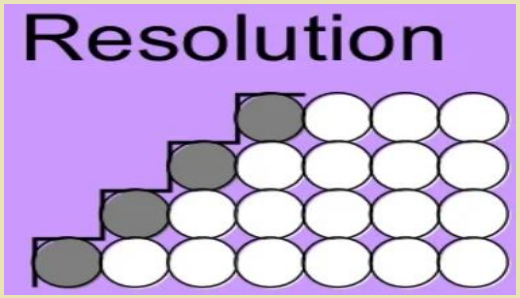
List of properties of CRT

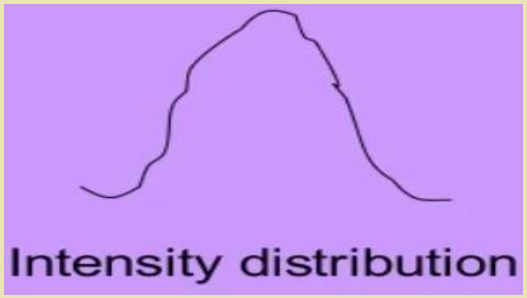
- Persistence
- Resolution
- Addressability
- Aspect ratio

List of properties of CRT: Persistence

- How long small spots continue to emit light after the beam is moved. How long it takes for the emitted light from the screen to decay to one-tenth of its original intensity
  - Lower persistence requires high refresh rates & it is good for animation
  - High persistence is useful for displaying highly complex static picture
  - Graphics monitors are usually constructed with 10 to 60 microsecond

List of properties of CRT: Resolution



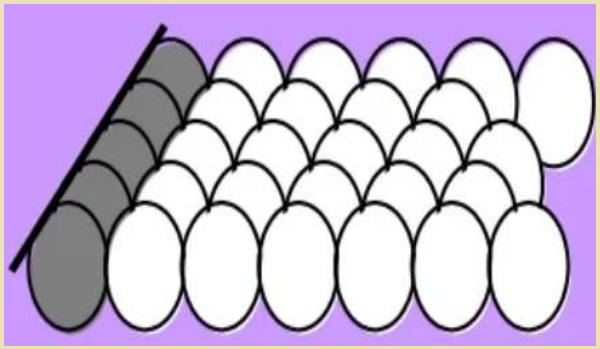


- The maximum number of points that can be displayed without an overlap on a CRT is referred to as resolution
- The smaller the spot size, the higher resolution
- The higher the resolution, the better is the graphics system
- High quality resolution is 1280x1024
- The intensity distribution of spots on the screen have Gaussian shape
- Adjacent points will appear distinct as long as their separation is greater than the diameter at which each spot has intensity of about 60% of that at the center of the spot.

Resolution

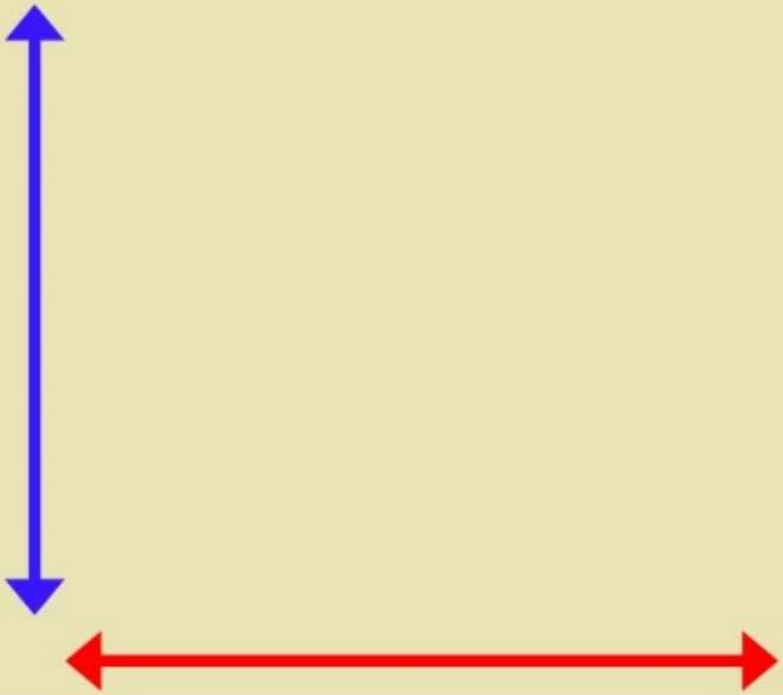
- The maximum number of points (pixels) that can be displayed without overlap on a screen is referred to as the resolution, and determines the detail that can be seen in an image.
- A more precise definition is the number of points per centimeter that can be plotted horizontally and vertically, although it is often simply stated as the total number of points in each direction (i.e. 1280×1024).
- The physical size of a graphics monitor, on the other hand, is given as the length (in inches) of the screen diagonal.

List of properties of CRT: Addressability



- Addressability is the number of individual dots per inch (d.p.i.) that can be created. If the address of the current dot is (x, y) then the next dot will be ((x+y), (x+y+1))
- The picture on a screen consists of intensified points
- The smallest addressable point on the screen is called pixel or picture element.

- The aspect ratio gives the ratio of vertical points to horizontal points necessary to produce equal-length lines in both directions on the screen. So 4:3 (most common) means that a vertical line plotted with 4 points has the same length as a horizontal line plotted with 3 points.

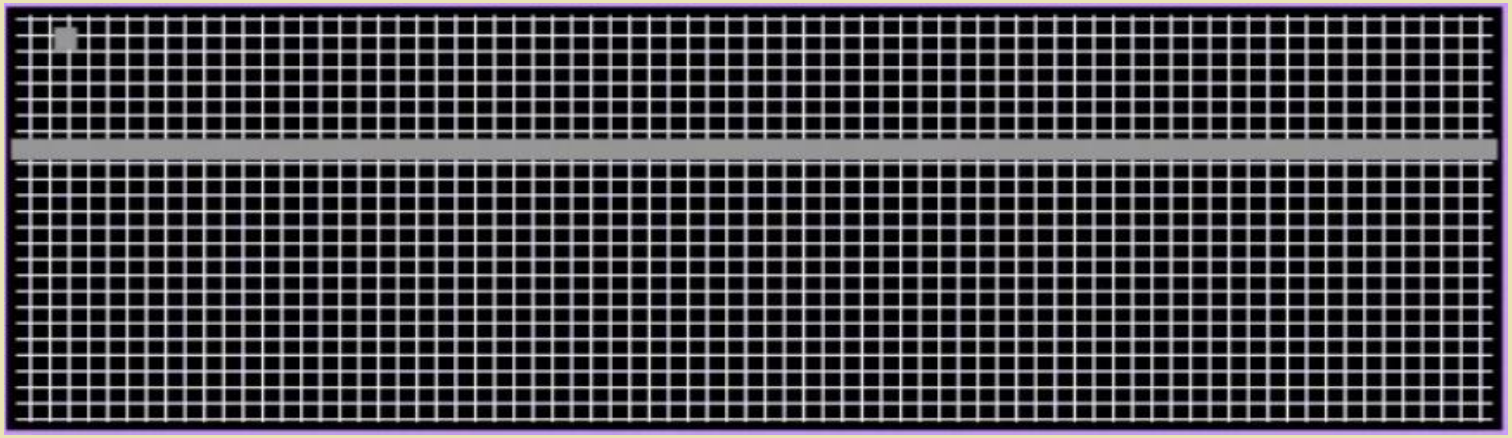


Display Technologies: CRTs

- Raster Scan Display
- Vector Displays
- Liquid Crystal Displays (LCDs)
- Plasma Panel
- Organic LED Arrays

Raster Scan Display

- Raster: A rectangular array of points or dots
- Pixel: One or picture element of the raster. Its intensity range for pixels depends on capability of the system
- Scan line: A row of pixels
- Picture elements are stored in a memory called frame buffer



Raster Scan Display

- Frame must be refreshed to draw new images
- As new pixels are stuck by electron beam, others are decaying
- Electron beam must hit all pixels frequently to eliminate flicker
- Critical fusion frequency: Typically 60times/sec

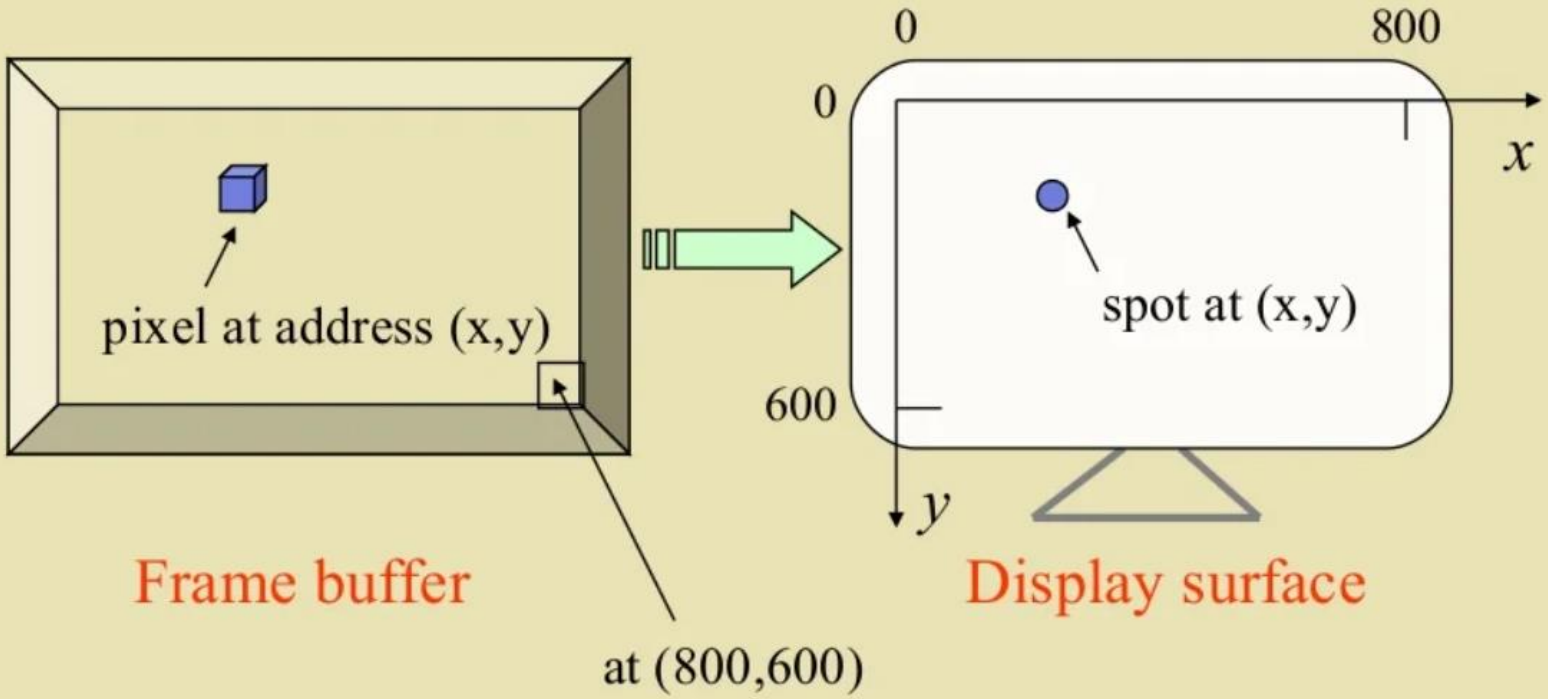
Raster Scan Display

- Intensity of pixels depends on the system for example black and white screens each point can be on or off thus it needs one bit of memory to present each pixel
- To point color screen additional bits are needed. If three bits are used, then number of different colors are 2^2^2
- A special memory is used to store the image with acan-out synchronous to the raster. We call this the frame buffer

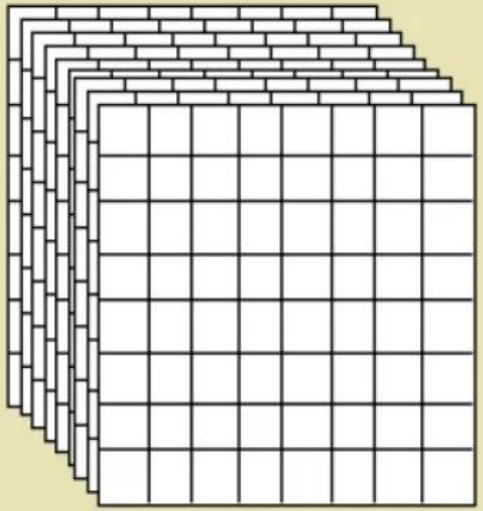
Raster Scan Display

- Raster CRT pros.
  - Allows solids, not just wire frames
  - Leverages low-cost CRT technology (i.e., TVs)
  - Bright! Display emits light
- Raster CRT cons.
  - Requires screen-size memory array
  - Discrete sampling (pixels)
  - Practical limit on size

The Frame Buffer

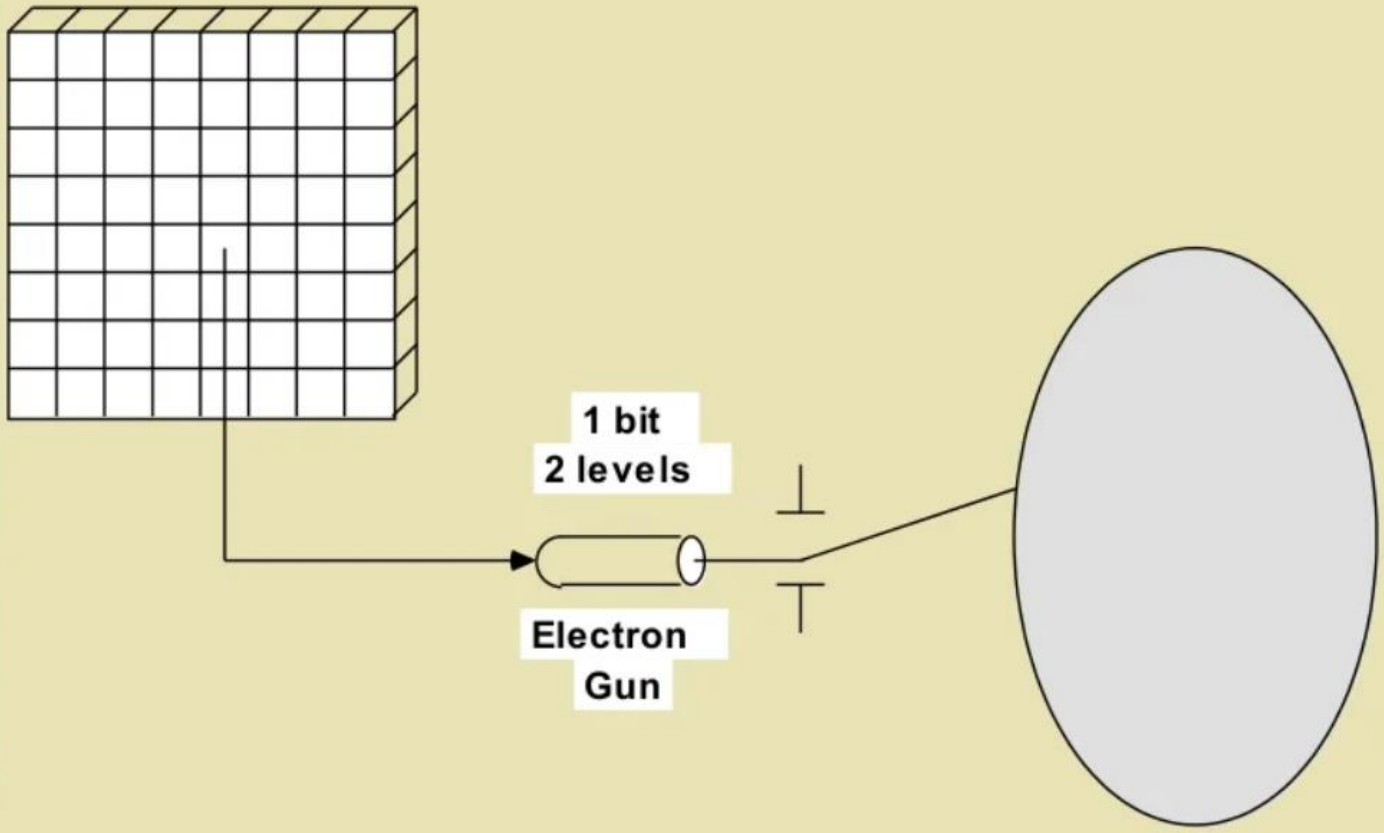


Frame Buffers

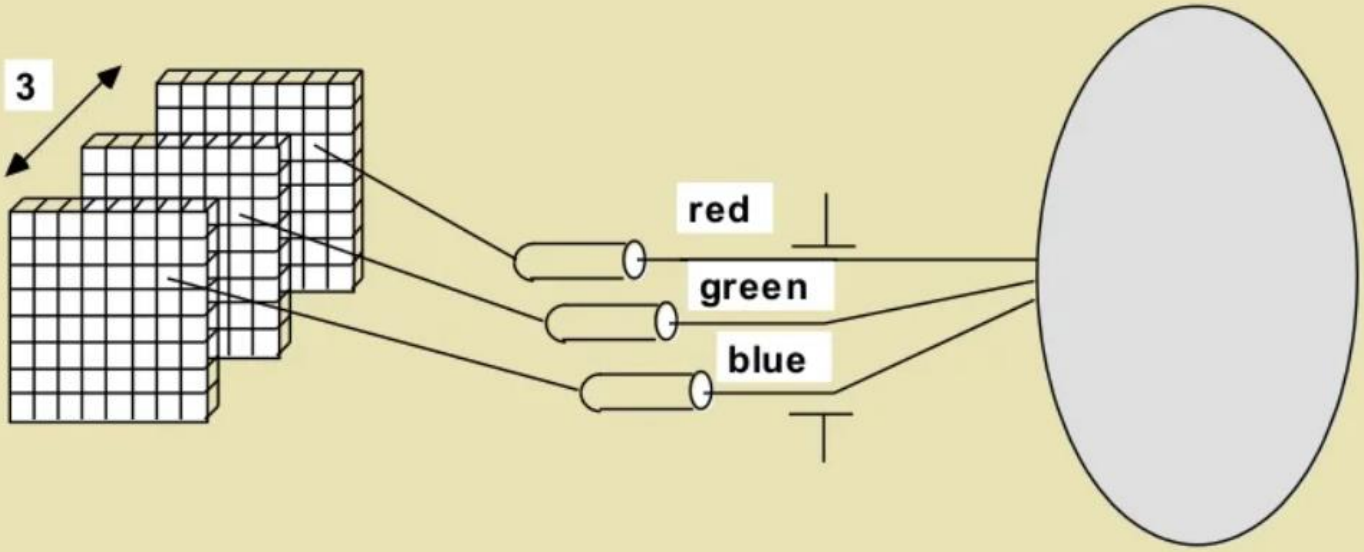


- **A frame buffer may be thought of as computer memory organized as a two-dimensional array with each (x,y) addressable location corresponding to one pixel.**
- ***Bit Plane*s or *Bit Depth* is the number of bits corresponding to each pixel.**
- **A typical frame buffer resolution might be**
  - **640 x 480 x 8**
  - **1280 x 1024 x 8**
  - **1280 x 1024 x 24**

Monochrome Display (Bit-map Display)



3-Bit Color Display

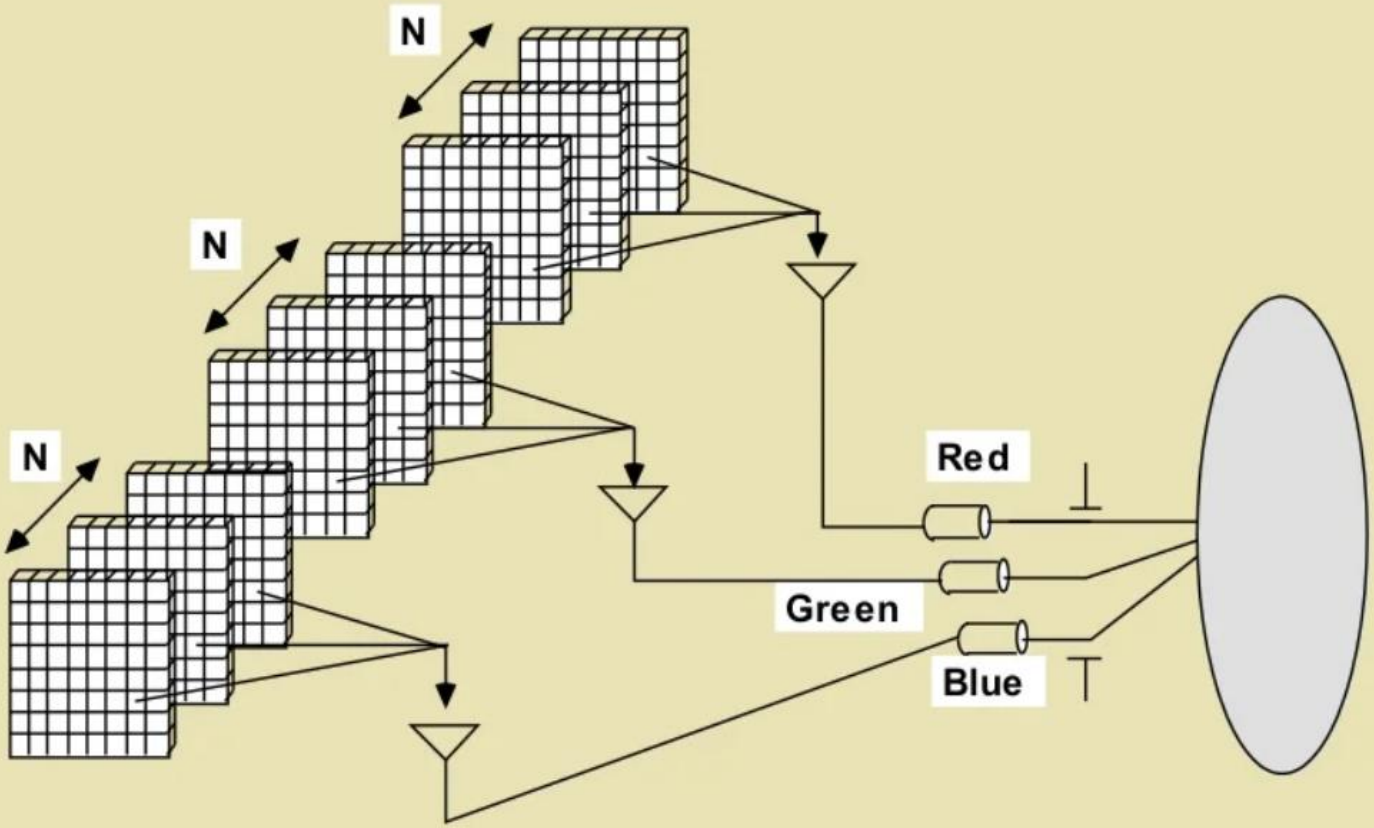


COLOR:	black	red	green	blue	yellow	cyan	magenta	white
R	0	1	0	0	1	0	1	1
G	0	0	1	0	1	1	0	1
B	0	0	0	1	0	1	1	1

True Color Display

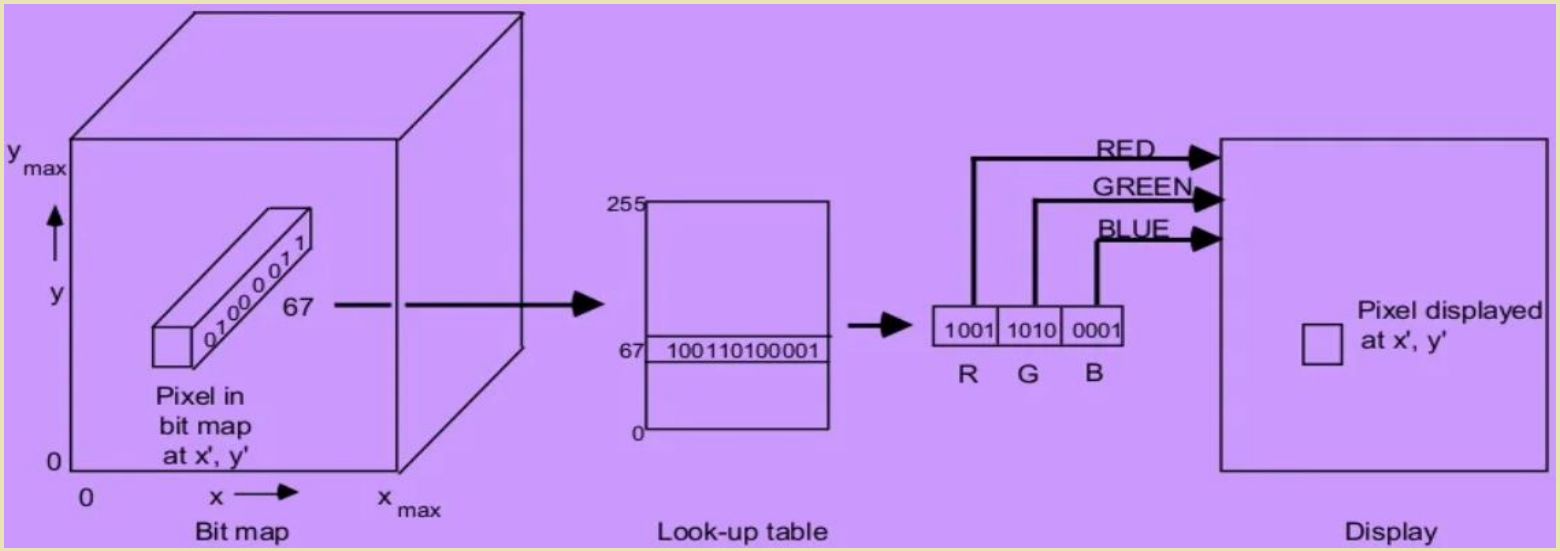
24 bit planes, 8 bits per color gun.

$2^{24} = 16{,}777{,}216$



Color MAP Look- UP Tables

- Extends the number of colors that can be displayed by a given number of bit-planes



- Video look-up table organization: each table entry is a 12 bit per entry
- A pixel with value 67 is displayed on the screen with the red electron gun at 9/15 (binary 1001) of maximum green at 10/15 and blue is 1/15

Refresh-rate

- **Definition:** The number of times per second the image is redrawn.
- The entire contents of the frame buffer are displayed on the CRT at a rate high enough to avoid flicker. This rate is called the refresh rate.
- For a human to see a steady image on most CRT displays, the same path must be retraced, or refreshed, by the beam at least 60 times per second.
- Current raster-scan displays perform refreshing at the rate of 60 to 80 frames per second, although some systems now have refresh rates of up to 120 frames per second.
- Refresh rates are described in units of cycles per second, or Hertz (Hz), where a cycle corresponds to one frame (i.e. a refresh rate of 60 frames per second = 60 Hz).

Refresh-rate for films and TV

- On films, below 24 frames per second, we can perceive a gap between successive screen images.
  - Old silent films show flicker because they where photographed at a rate of 16 frames per second.
  - When sound systems were developed in the 1920s, motion picture film rates increased to 24 frames per second removing flickering.
  - Today TV refresh rate is 25 frames per second in Europe and 30 frames per second in the USA.

Refresh-rate for films and TV

- The depth (or intensity) of the frame buffer, defined as the number of bits that are used for each pixel, determines properties such as how many colors can be represented on a given system.

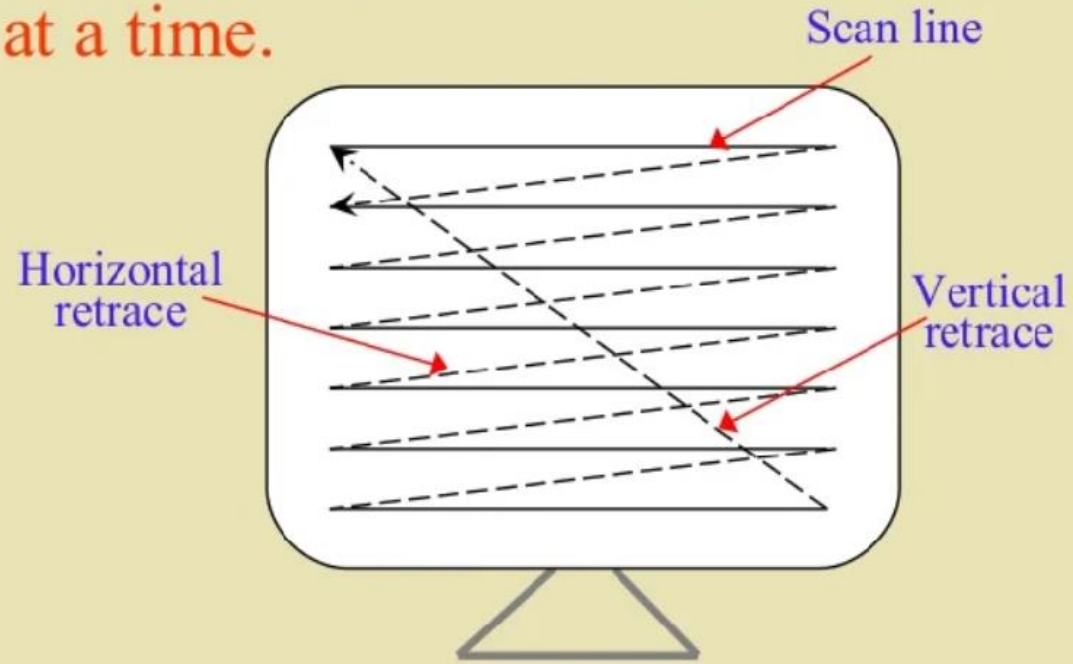
  1-bit-deep frame buffer allows 2^1 colors (black and white)

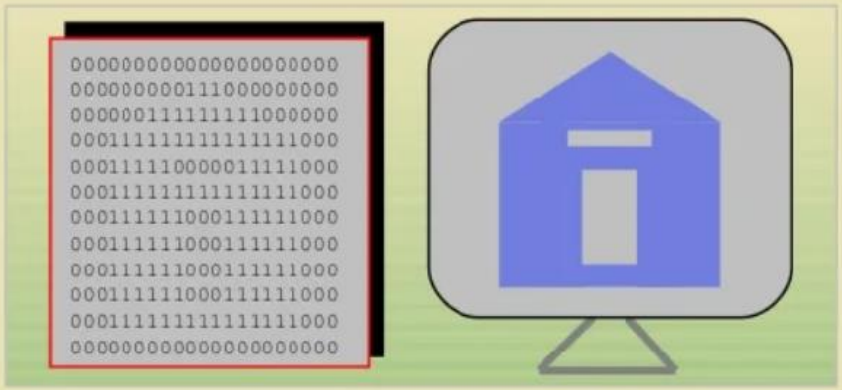
  8-bit-deep frame buffer allows 2^8 (=256) colors

  In full color systems (also called RGB-color systems), there are 24 (or more) bits per pixel in order to display sufficient colors to represent most images realistically.

Raster Scan Displays

- Electron beam "paints" the picture on screen one line at a time.



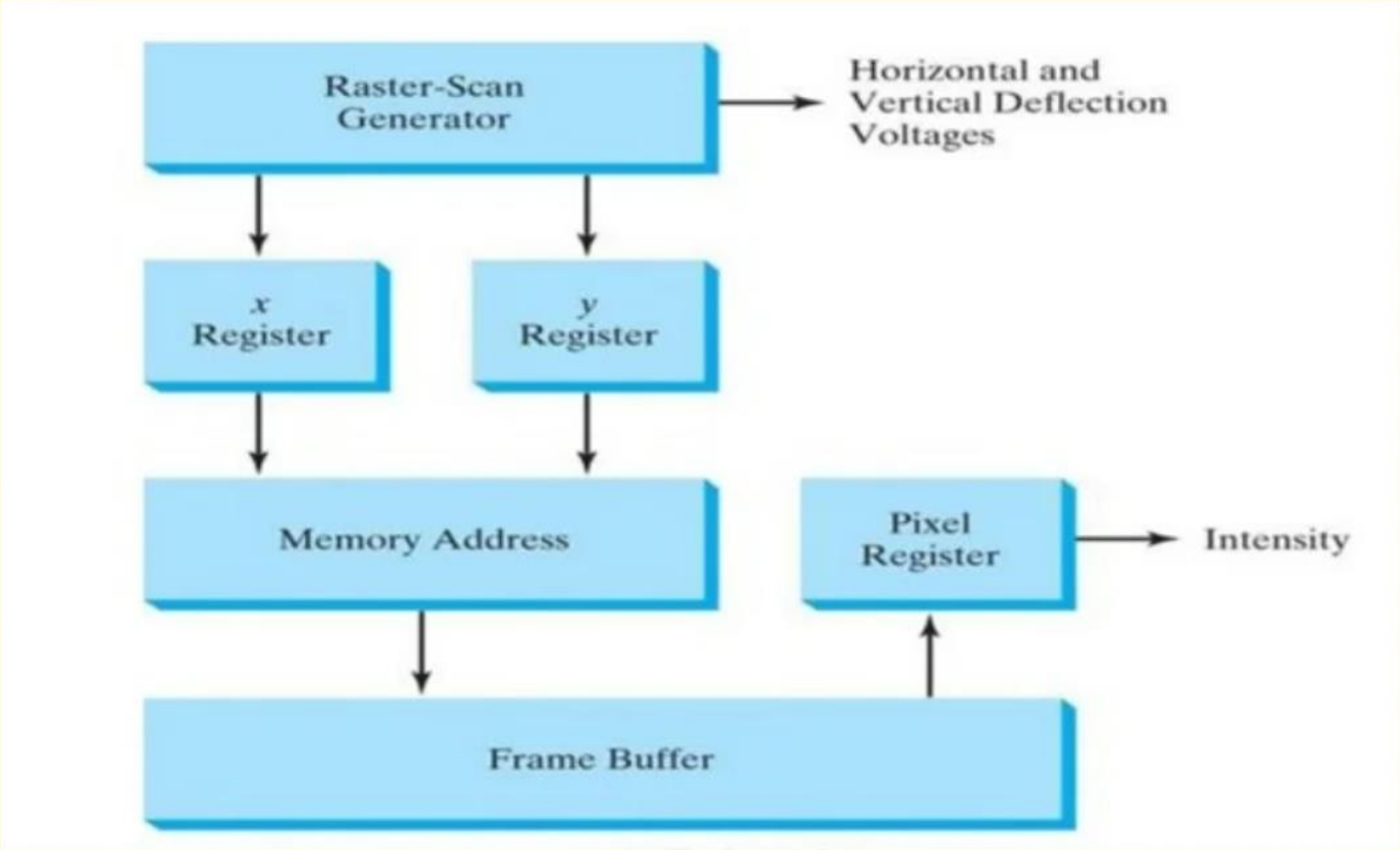


Raster Scan Displays

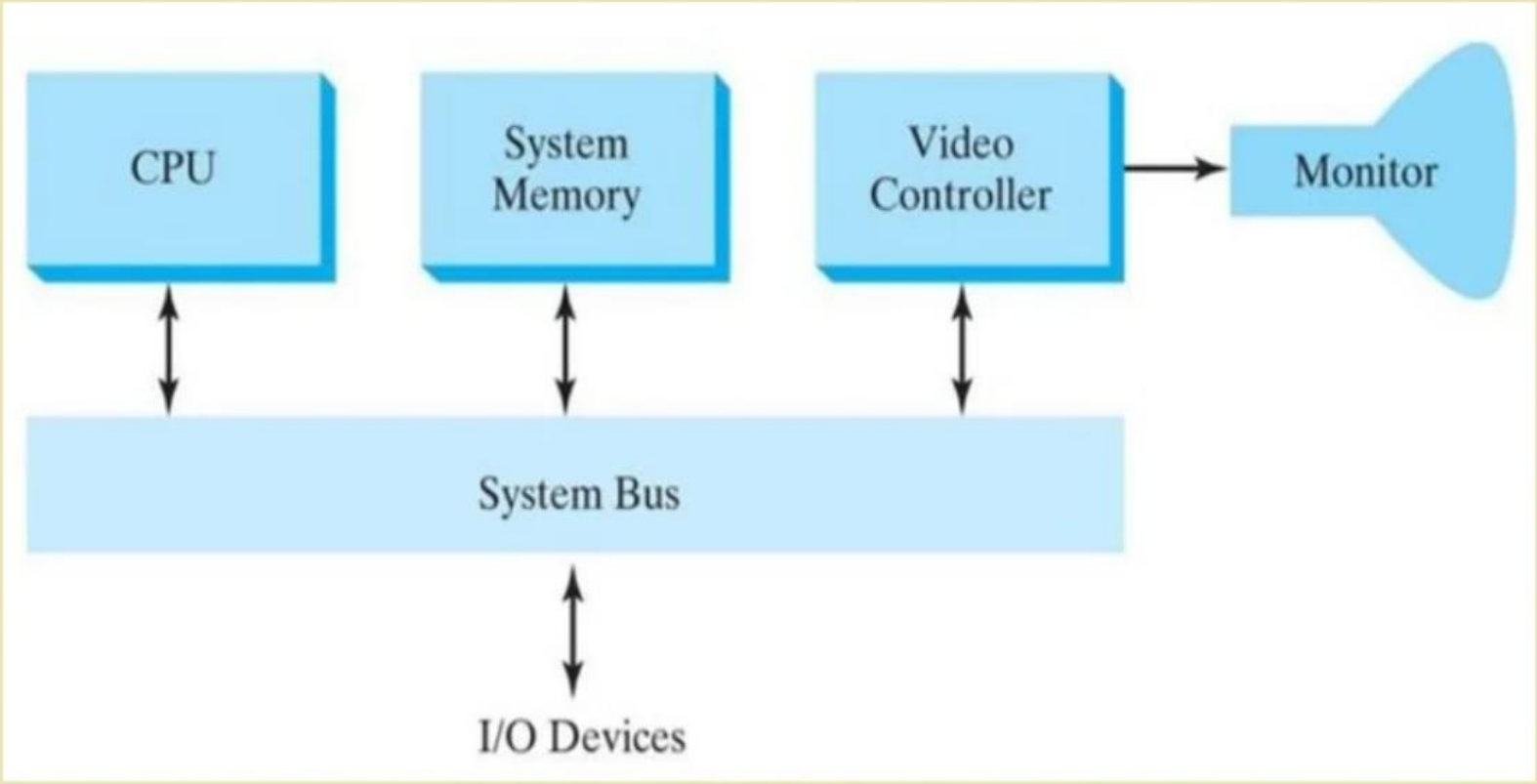
- They are based on TV technology
- Refresh rate = 60 to 80 frames per second.

  Note: Below 24 frames/second, eye detects flicker.
- Each screen point is visited every refresh cycle.
- Their capability to store intensity information for each screen point makes them well suited for the realistic display of scenes containing shading and color patterns.
  - The frame-buffer with 1-bit intensity is called a bitmap.
  - The frame-buffer with multiple-bits intensity is called a pixmap.

Operation of Video Controller

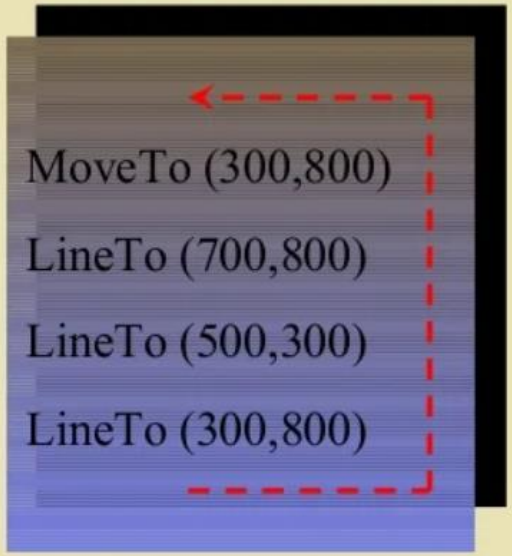


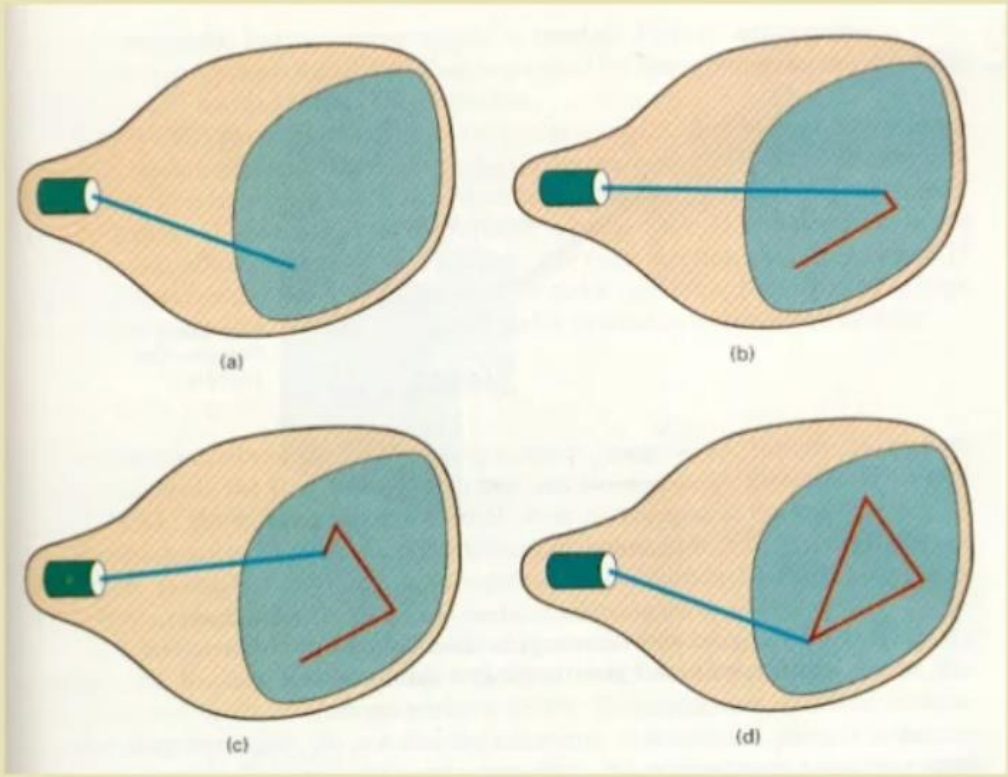
Simple Raster Scan System



Random-Scan (Vector) displays

- Vector stands for line.
- Developed in the mid-sixties and in common use until the mid-eighties.
- The electron beam is directed only to parts of the screen where the picture is to be drawn.



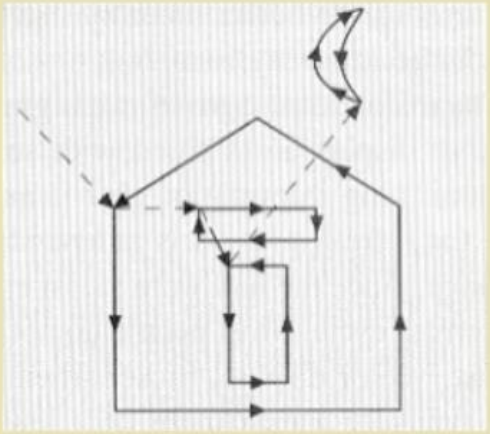


Random Scan Displays

- Picture is stored as a set of point- and line-drawing commands with (x,y) or (x,y,z) endpoint coordinates, as well as character-plotting commands.
- Refresh rate depends on the number of lines to be displayed. *To avoid flicker it must be at least 30 times per second (30 Hz).*
- They are designed to draw all the component lines of a picture 30 to 60 times per second – more than 60 could burn the phosphor.
- High quality vector systems are capable of handling approximately 100,000 lines at this refresh rate.
- They are designed for line drawing applications and cannot display realistic shaded images.

Raster Scan Vs Random Scan

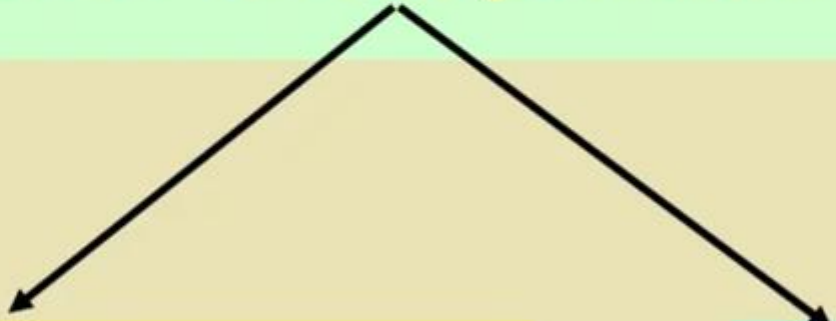
Raster scan



Random scan

Color Display

2 Basic Techniques for Color Display



Beam-Penetration Method

Shadow-Mask Method

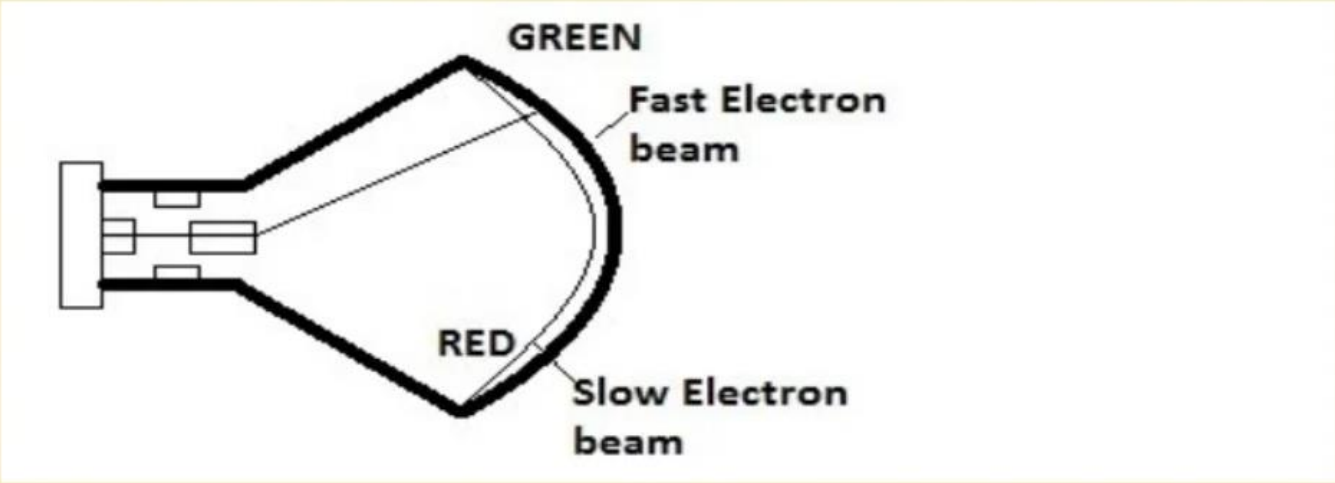
Beam-Penetration Method

Used with *random scan monitors*

The screen has two layers of phosphor: usually ***red and green***

The displayed color depends on how far the electron beam penetrates through the two layers.

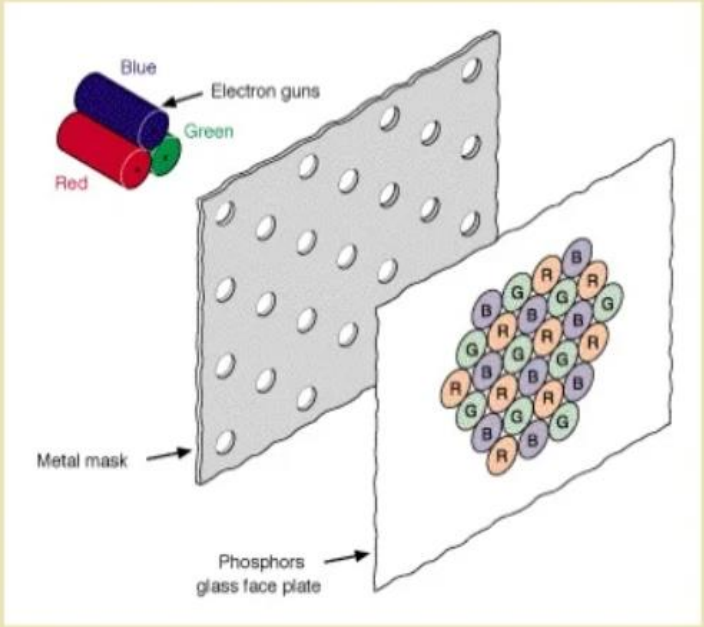
A beam of slow electrons excites only the outer of the red layer, a beam of fast electrons penetrates through the red layer and excites the inner green layer, and at intermediate beam speeds, combinations of the two colors are emitted to show other colors (yellow & orange).

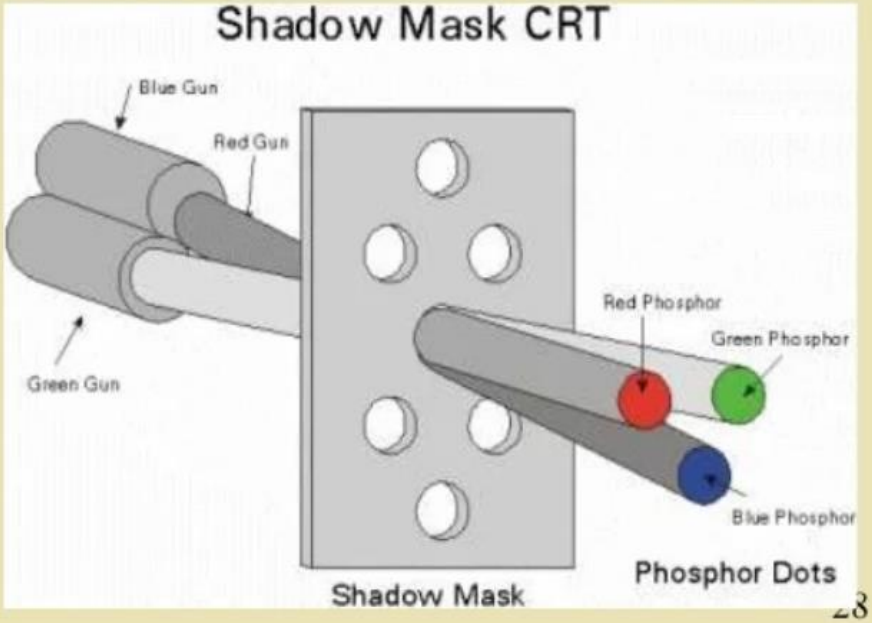


Shadow-Mask Method

Color CRTs have

- Three electron guns
- A metal *shadow mask* to differentiate the beams





Shadow-Mask Method

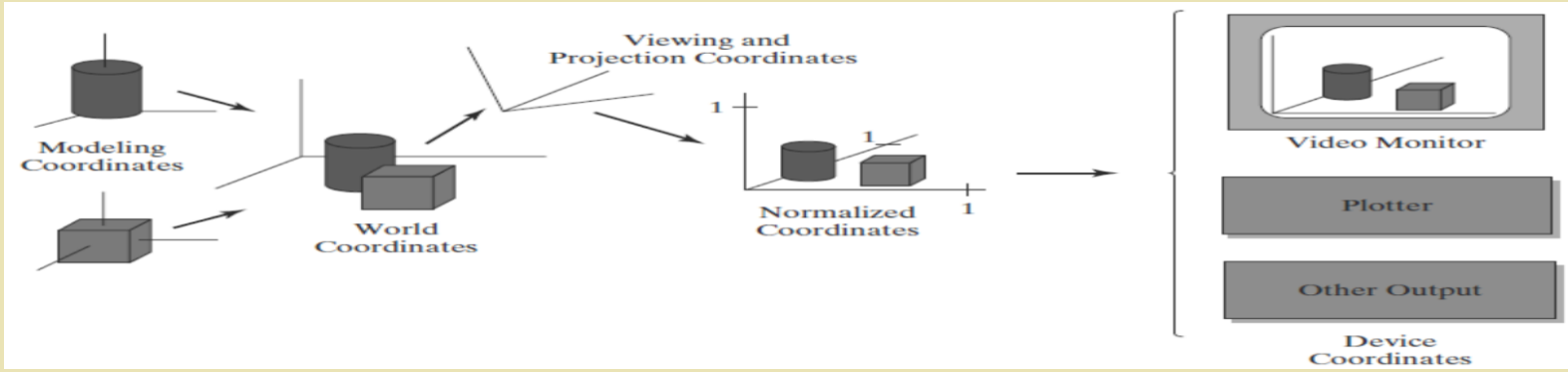
- The Shadow mask in the previous image is known as the *delta-delta* shadow-mask.
- The 3 electron beams are deflected and focused as a group onto the shadow mask, which contains a series of holes aligned with the phosphor-dot patterns.
- The 3 beams pass through a hole in the shadow mask and activate a dot triangle, which appears as a small color spot on the screen.
- A second arrangement of the 2 electron guns is in-line where the corresponding red-green-blue color dots on the screen aligned along one scan- line instead of triangular pattern

Controlling Colors in shadow mask

- Different colors can be obtained by varying the intensity levels of the three electron beams.
- Example: Simply turning off the red and green guns, we get only the color coming from the blue phosphor.
- Yellow = Green + Red
- Magenta = Blue + Red
- Cyan = Blue + Green
- White is produced when all the 3 guns possess equal amount of intensity.

Computer Graphics Software: Coordinate Representations

- Used to generate picture using programming package
- Reference frames used for constructing and displaying scene are called **modeling coordinates**, or sometimes local coordinates or master coordinates
- Constructing ("model") a scene by placing the objects into appropriate locations within a scene reference frame is called **world coordinates.**
- Object locations are transformed to a 2D- projection of the scene, which corresponds to what we see on the output device.
- The scene is then stored in **normalized coordinates**, where each coordinate value is in the range from −1 to 1 or in the range from 0 to 1, depending on the system.



Applications

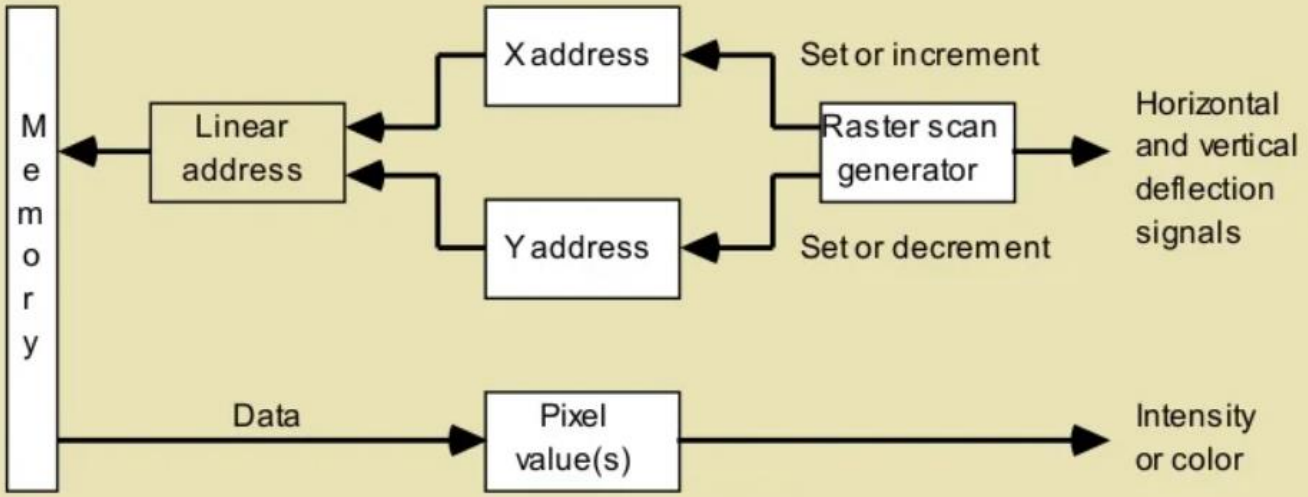
- Color CRTs in graphics systems are designed as RGB monitors, which employ the shadow mask technique
- The color CRT takes the intensity level for each electron gun (red, green, and blue) directly from the computer system without any intermediate processing
- An RGB color system with 24 bits of strage per pixel is generally referred to as full-color system or true-color system. It allows 256 voltage settings for each electron gun nearly 17 million colors

Display Processor

- **Also called either a Graphics Controller or Display Co-Processor.**
- **Specialized hardware to assist in scan converting output primitives into the frame buffer.**
- **The display processor is used to convert digital information from the CPU into analog value needed by the display device.**
- **A major task of display processor is to perform a process called scan conversion. It is the process of separating contiguous graphics objects as a collection of ellipse, rectangles and polygons.**

Video Controller

Cycles through the frame buffer, one scan line at a time. Contents of the memory are used the control the CRT's beam intensity or color.

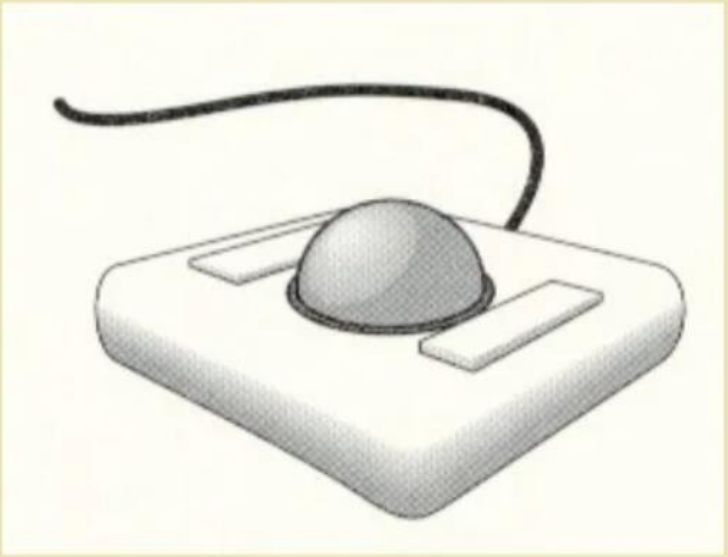


Input Devices

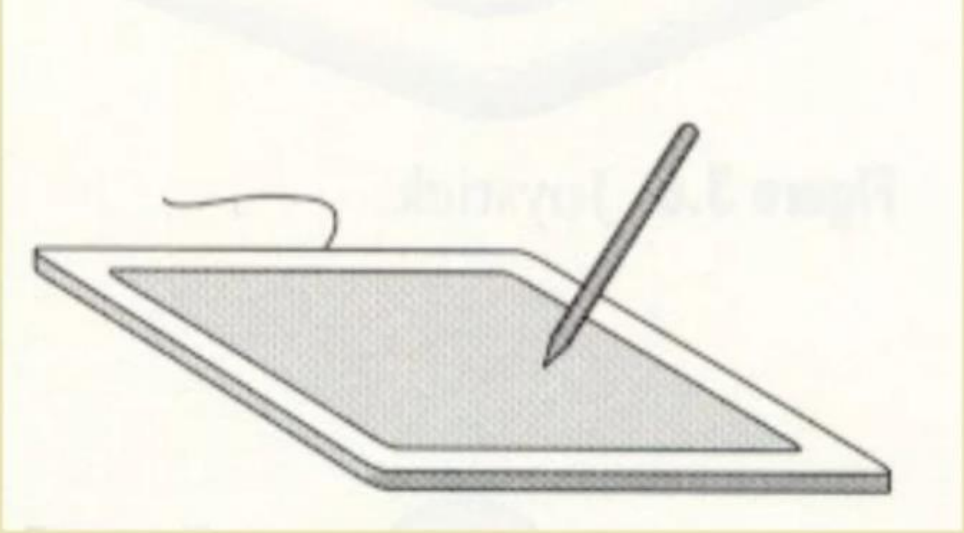
Each device is more suitable for certain tasks than for others

- Keyboard
  - Entering non-graphical data (i.e. text)

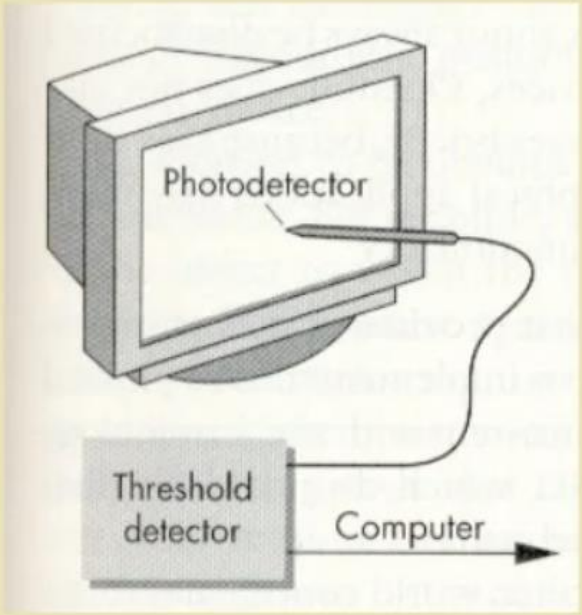
- Mouse
  - Used to select a location to the screen.
  - The motion of the roller at the bottom of the mouse is converted into signals sent back to the computer.
- Optical Detector Mouse
  - Measure distance traveled by counting lines on a special pad.



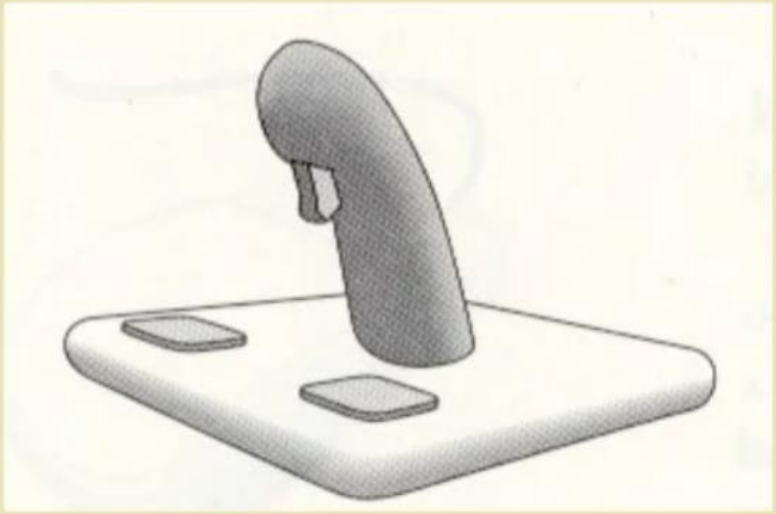
- Trackball
  - Similar in use to the mouse.
  - Popular with portable computers because they can be incorporated directly into the keyboard.
  - There exist various pressure-sensitive devices in keyboards that perform similar functions to the mouse and trackball.



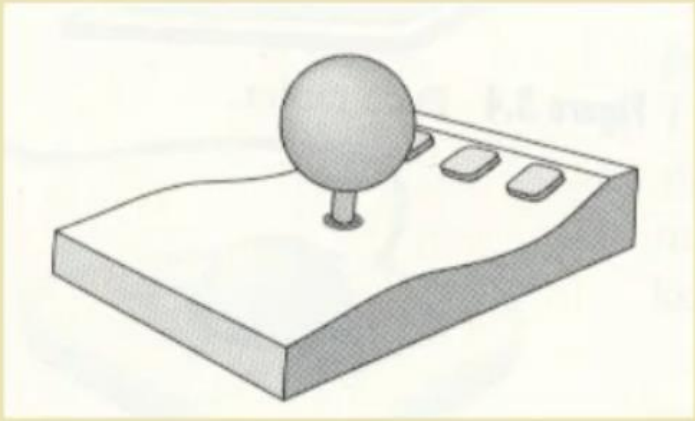
- Data Tablet
  - It has rows and columns of wires embedded under its surface. The position of the stylus is determined through electromagnetic interactions between signals traveling through the wires and sensors in the stylus.
- Touch-Sensitive Screens
  - Have many of the same properties as Data Tablet.



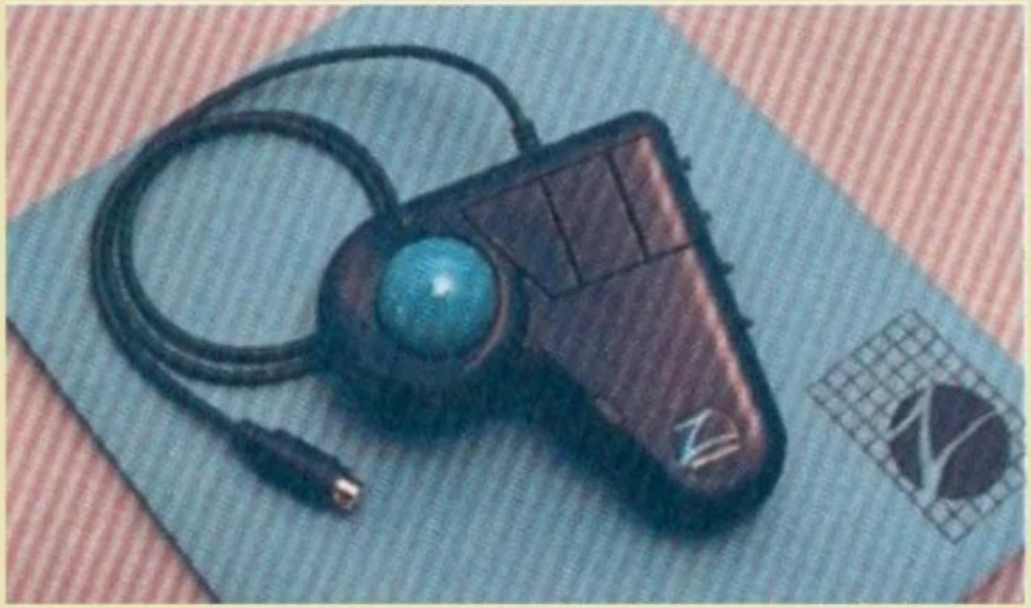
- Light pen
  - If it is positioned on the face of the CRT at a location, a signal is sent to the computer.
  - Not very popular as other devices.



- Joystick
  - The motion of the screen in two orthogonal directions is encoded and integrated to identify a screen location.
  - Variable sensitive device – well suited for flight simulators and games.

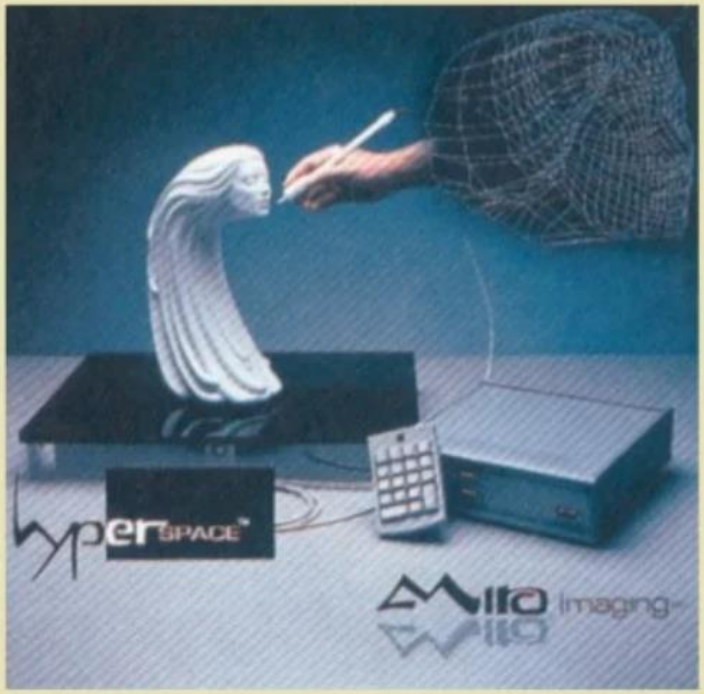


- Spaceball
  - 3D input device
  - Stick does not move but it has pressure sensors (rotations).
  - 3 independent twists (translations).



- Z-mouse
  - 3D input device
  - It has three buttons, a thumbwheel on the sided, a trackball on the top, and a standard mouse ball underneath.

- Data Glove
  - Used to grasp a “virtual” object.
  - Sensors detect hand and finger motions.



- Digitizers
  - 2D or 3D input devices.
  - Interactive selection of coordinate positions on an object.
  - Wireframe models – rectangular grid

Video Display Devices

- Display H/W
  - Video display devices
- Input devices
  - Locator Devices
  - Keyboard devices
- Hard-copy devices
  - Ink-jet printer
  - Laser printer
  - Film recorder
  - Electrostatic printer
  - Pen plotter