Unit 2
Graphics Hardware

Due to the widespread recognition of the power and utility of computer graphics in virtually all fields, a broad range of graphics hardware and software systems are now available for both 2D and 3D applications. Some are described in what follows.

Input Devices

Keyboard

A keyboard creates a code such as ASCII uniquely corresponding to a pressed key. It usually consists of alphanumeric keys, function keys, cursor-control keys, and separate numeric pad. It is used to move the cursor, to select the menu item, pre-defined functions. In computer graphics keyboard is mainly used for entering screen coordinates and text, to invoke certain functions. Now-a-days ergonomically designed keyboard (Ergonomic keyboard) with removable palm rests is available. The slope of each half of the keyboard can be adjusted separately.

Mouse

A mouse is a small hand-held device used to position the cursor on the screen. Mice are relative devices, that is, they can be picked up, moved in space, and then put down gain without any change in the reported position. For this, the computer maintains the current mouse position, which is incremented or decremented by the mouse movements. Following are the mice, which are mostly used in computer graphics.

a. Mechanical mouse

When a roller in the base of this mechanical mouse is moved, a pair of orthogonally arranged toothed wheels, each placed in between a LED and a photo detector, interrupts the light path. the number of interrupts so generated are used to report the mouse movements to the computer.

b. Optical mouse

The optical mouse is used on a special pad having a grid of alternating light and dark lines. A LED on the bottom of the mouse directs a beam of light down onto the pad, from which it is reflected and sensed by the detectors on the bottom of the mouse. As the mouse is moved, the reflected light beam is broken each time a dark line is crossed. The number of pulses so generated, which is equal to the number of lines crossed, are used to report mouse movements to the computer.

Mechanical mice: Uses a single ball with logic circuits to control X and Y axes.

Optical and Laser Mice: Optical mice make use of one or more LEDs and an imaging array of photodiodes to detect movement. A laser mouse is an optical mouse that uses coherent (laser) light.

Mechanical	Optical

Light Pen

A light pen is a computer input device in the form of a light-sensitive wand used in conjunction with a computer's CRT display. Light pen is sensitive to the short burst of light emitted from phosphor coating at the instant electron beam strikes a particular point. It allows the user to point to displayed objects or draw on the screen in a similar way to a touch screen but with greater positional accuracy.

Touch Screen (Touch Panels)

Touch panels allows displayed objects or screen positions to be selected with the touch of a finger. Typically, these are used to select the processing options represented with graphical icons. Touch input can be recorded using optical, electrical, or acoustical methods.

Optical touch panels: Employ a line of infrared light-emitting diodes (LEDs) along one vertical and one horizontal edge of the frame. The opposite vertical and horizontal edges contain light detectors which are used to record the interrupted beams when panel is touched.

Electrical touch panels (Resistive): Constructed by two transparent plates (one coated with conducting and another with resistive material) separated by a small distance. When outer plate is touched, it is forced into contact with the inner plate creating voltage drop across resistive plate which is then converted to the coordinate values of the touched screen position.

Capacitive touch panels: A capacitive touch screen panel consists of an insulator such as glass, coated with a transparent conductor such as indium tin oxide (ITO). As the human body is also an electrical conductor, touching the surface of the screen results in a distortion of the screen's

electrostatic field, measurable as a change in capacitance. Different technologies may be used to determine the location of the touch. The location is then sent to the controller for processing.
Acoustic touch panels: High frequency sound waves are generated in horizontal and vertical directions across a glass plate. Touching the screen causes part of each wave to be reflected from the finger to the emitters. The screen position at the point of contact is calculated by measuring the time interval between the transmission of each wave and its reflection to the emitter.

Tablet (Digitizer)
It is a common device for drawing, painting, or interactively selecting coordinate positions on an object in 2/3 dimensional space by activating a hand cursor or stylus on a flat surface. Common variations are:

Passive tablets: Passive tablets, most notably those by Wacom, make use of electromagnetic induction technology, where the horizontal and vertical wires of the tablet operate as both transmitting and receiving coils.
Active tablets: Active tablets differ in that the stylus used contains self-powered electronics that generate and transmit a signal to the tablet resulting less jitter.
Optical tablets: Optical tablets operate by a very small digital camera in the stylus, and then doing pattern matching on the image of the paper
Acoustic tablets: A small sound generator was mounted in the stylus, and the acoustic signal picked up by two microphones placed near the writing surface. Some modern designs are able to read positions in three dimensions.
Electromagnetic tablets: Wacom is one example of a graphics tablet that works by generating and detecting an electromagnetic signal: in the Wacom design, the signal is generated by the pen, and detected by a grid of wires in the tablet.
Capacitive tablets: These tablets have been designed to use an electrostatic or capacitive signal.

Joystick
A joystick is an input device consisting of a stick that pivots on a base and reports its angle or direction to the device it is controlling. Uses are in cockpit of aircrafts, video games etc.

Output Devices
Typically, primary output device in a graphics system is video monitor whose operation is based mostly on standard **cathode-ray tube (CRT)** design.

Cathode Ray Tube (CRT)
- CRTs are the most common display devices on computer today. A CRT is an evacuated glass tube, with a heating element on one end and a phosphor-coated screen on the other end.

- When a current flows through this heating element (filament) the conductivity of metal is reduced due to high temperature. These cause electrons to pile up on the filament.
- These electrons are attracted to a strong positive charge from the outer surface of the focusing anode cylinder.
- Due to the weaker negative charge inside the cylinder, the electrons head towards the anode forced into a beam and accelerated towards phosphor-coated screen by the high voltage in inner cylinder walls.
- The forwarding fast electron beam is called Cathode Ray. A cathode ray tube is shown in figure below.

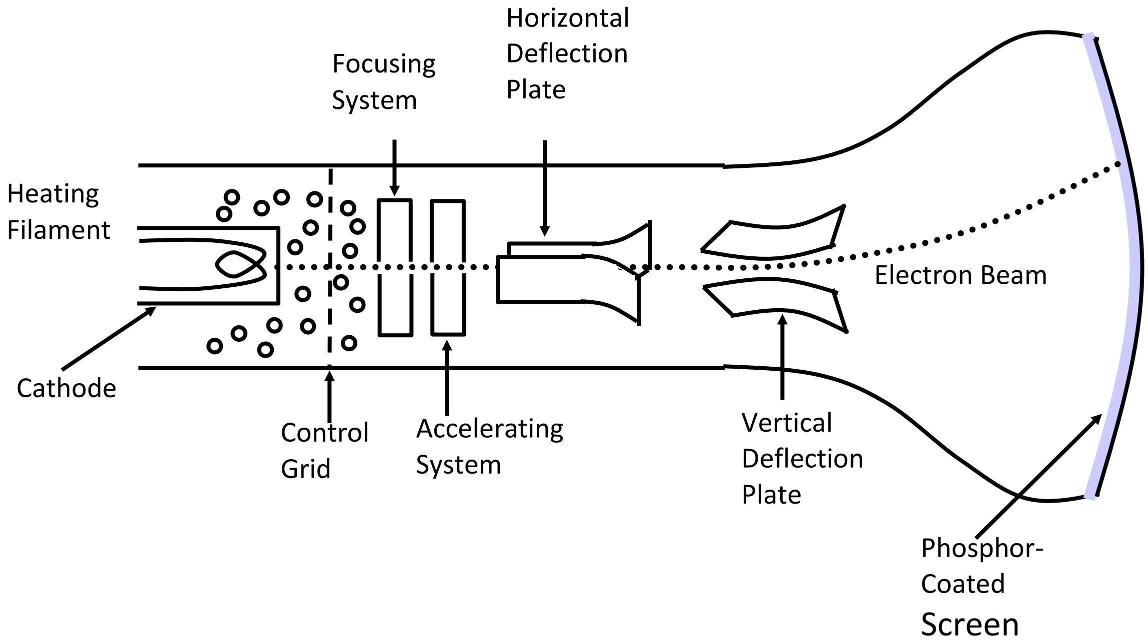


Fig: Cathode-ray tube (CRT)

- There are two sets of weakly charged deflection plates with oppositely charged, one positive and another negative. The first set displaces the beam up and down and the second displaces the beam left and right.
- The electrons are sent flying out of the neck of bottle (tube) until the smash into the phosphor coating on the other end.
- When electrons strike on phosphor coating, the phosphor then emits a small spot of light at each position contacted by electron beam. The glowing positions are used to represent the picture in the screen.
- The amount of light emitted by the phosphor coating depends on the no of electrons striking the screen. The brightness of the display is controlled by varying the voltage on the control grid.

<u>Persistence</u>:

- How long a phosphor continues to emit light after the electron beam is removed?
- Persistence of phosphor is defined as **time** it takes for emitted light to decay to 1/10 (10%) of its original intensity. Range of persistence of different phosphors can react many seconds.

- Phosphors for graphical display have persistence of 10 to 60 microseconds. Phosphors with low persistence are useful for animation whereas high persistence phosphor is useful for highly complex, static pictures.

Refresh Rate:

- Light emitted by phosphor fades very rapidly, so to keep the drawn picture glowing constantly; it is required to redraw the picture repeatedly and quickly directing the electron beam back over the some point. The no of times/sec the image is redrawn to give a feeling of non-flickering pictures is called refresh-rate.
- If Refresh rate decreases, flicker develops.
- Refresh rate above which flickering stops and steady it may be called as critical fusion frequency (CFF).

Resolution:

Maximum number of points displayed horizontally and vertically without overlap on a display screen is called resolution. More precise definition of resolution is no of dots per inch (dpi/pixel per inch) that can be plotted horizontally and vertically.

Display Technologies

A. Raster-Scan Display

- The most common type of graphics monitor employing a CRT is the raster-scan display, based on television technology.
- In raster-scan the electron beam is swept across the screen, one row at a time from top to bottom. No of scan line per second is called horizontal scan rate.
- As electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots.
- **Picture definition** is stored in a memory called **frame buffer or refresh buffer**. Frame buffer holds all the intensity value for screen points.
- Stored intensity values are then retrieved from the frame buffer and "painted" on the screen one row (scan line) at a time.
- Each screen point is referred to as a **pixel** or **pel** (picture element).
- Availability of frame buffer makes raster-scan display well suited for the realistic display.
- Example: Monitors, Home television, printers.

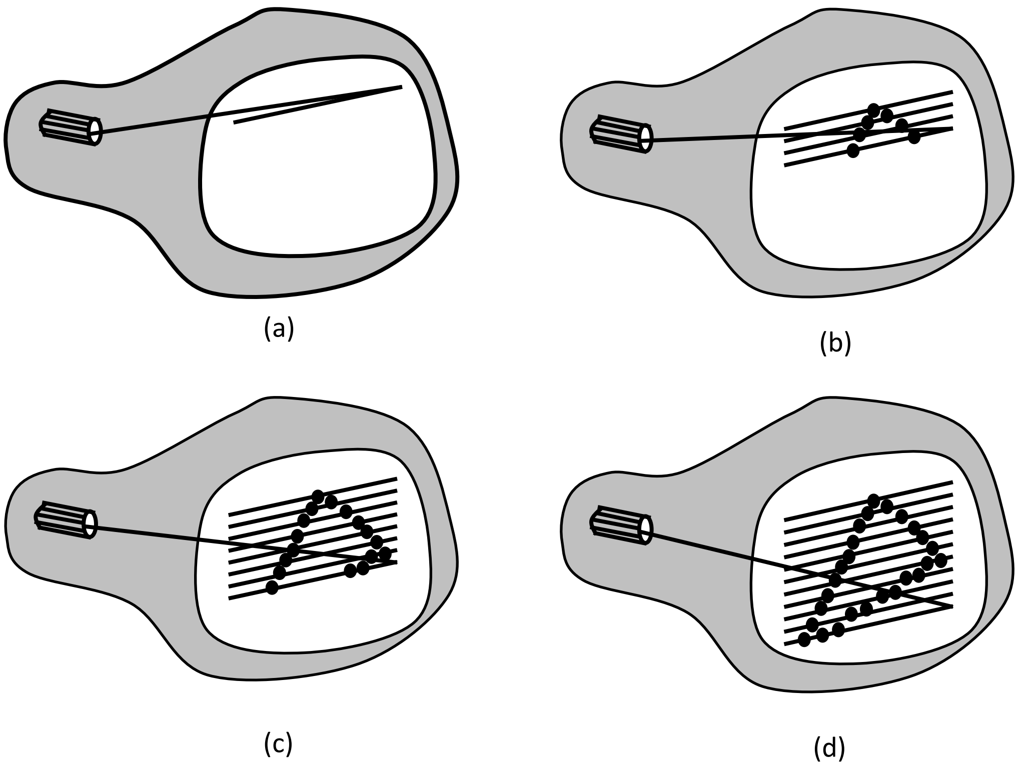


Figure: A raster-scan system displays an object as a set of points across each screen scan line

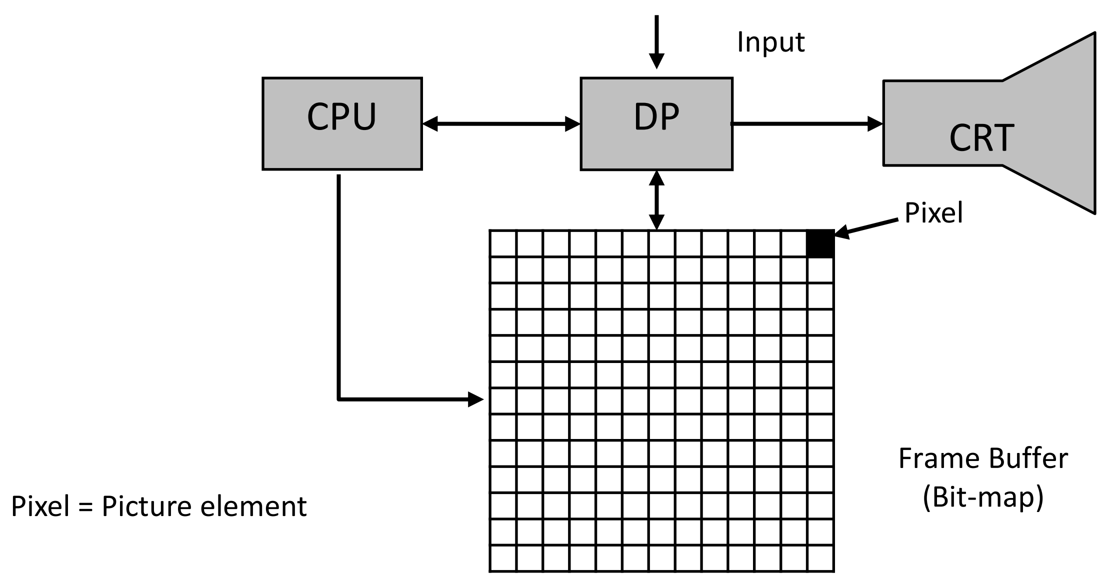


Figure: Raster Scan display system

- Intensity range for pixel position depends on capability of raster system. For **B/W system** each point on screen is either on or off, so only one bit per pixel is needed to control the pixel intensity. **To display color** with varying intensity level, additional bits are needed. Up to 24 to 32 bit per pixel are included in high quality systems, which require more space of storage for the frame buffer, depending upon the resolution of the system.

- A system with 24 bit pixel and screen resolution 1024 × 1024 require 3 megabyte of storage in frame buffer.

  1024*1024 pixels = 1024*1024*24 bits = 3 MB (using 24-bit per pixel)
- The frame butter in B/W system stores a pixel with one bit per pixel so it is termed as **bitmap**. The frame buffer in multi bit per pixel storage is called **pixmap**.
- Refreshing on Raster-Scan display is carried out at the rate of 60 or higher frames per second. Sometimes refresh rates are described in units of cycles per second or hertz (Hz), where cycle corresponds to one frame.
- Returning of electron beam from right end to left end after refreshing each scan line is called **horizontal retrace** of electron beam. At the end of each frame, the electron beam returns to the top left corner to begin next frame called **vertical retrace**.

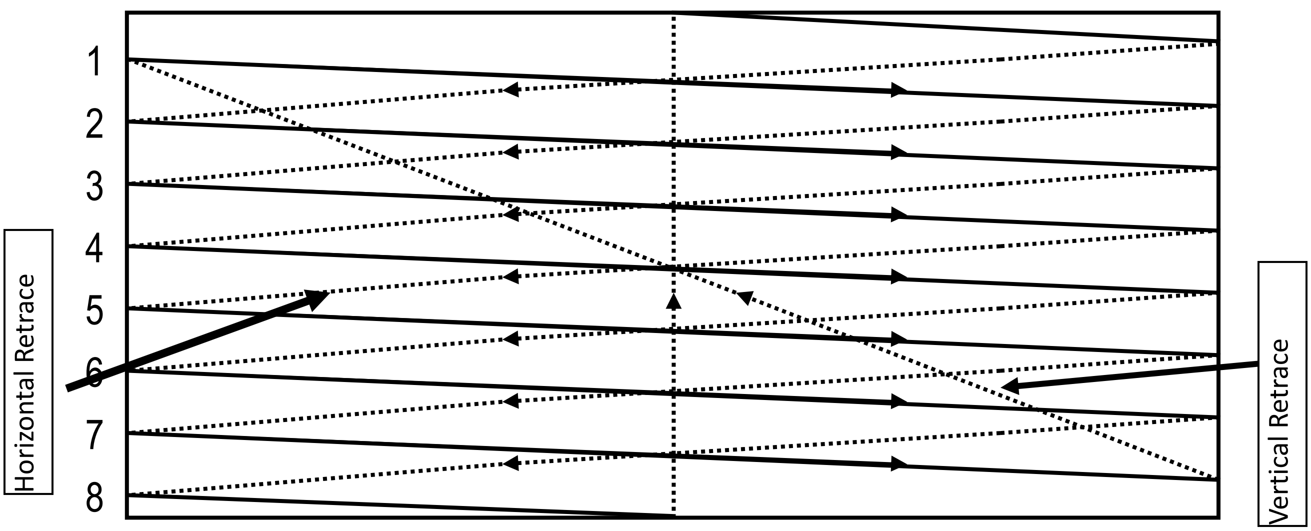


Figure: Horizontal retrace and Vertical retrace

Interlaced vs. **non-interlaced** scan (refresh procedure)
- In interlaced scan, each frame is displayed in two passes. First pass for odd scan lines and another for even ones.
- In non-interlaced refresh procedure, electron beam sweeps over entire scan lines in an frame from top to bottom in one pass.

Question*: Consider a RGB raster system is to be designed using 8 inch by 10 inch screen with a resolution of 100 pixels per inch in each direction. If we want to store 8 bits per pixel in the frame buffer, how much storage (in bytes) do we need for the frame buffer?*

Solution: Size of screen = 8 inch × 10 inch.
Pixel per inch (Resolution) = 100.
Then, Total no of pixels = (8×100) × (10 × 100) pixels = (800 × 1000) pixels
Per pixel storage = 8 bits

Therefore, Total storage required in frame buffer = (800 ×1000×8) bits
= (800 ×1000×8)/8 Bytes
= 800000 Bytes

B. Random scan (Vector) display

- In random scan system, the CRT has the electron beam that is directed only to the parts of the screen where the picture is to be drawn. It draws a picture one line at a time, so it is also called **vector display** (or stroke writing or calligraphic display). The component lines of a picture are drawn and refreshed by random scan system in any specified order.

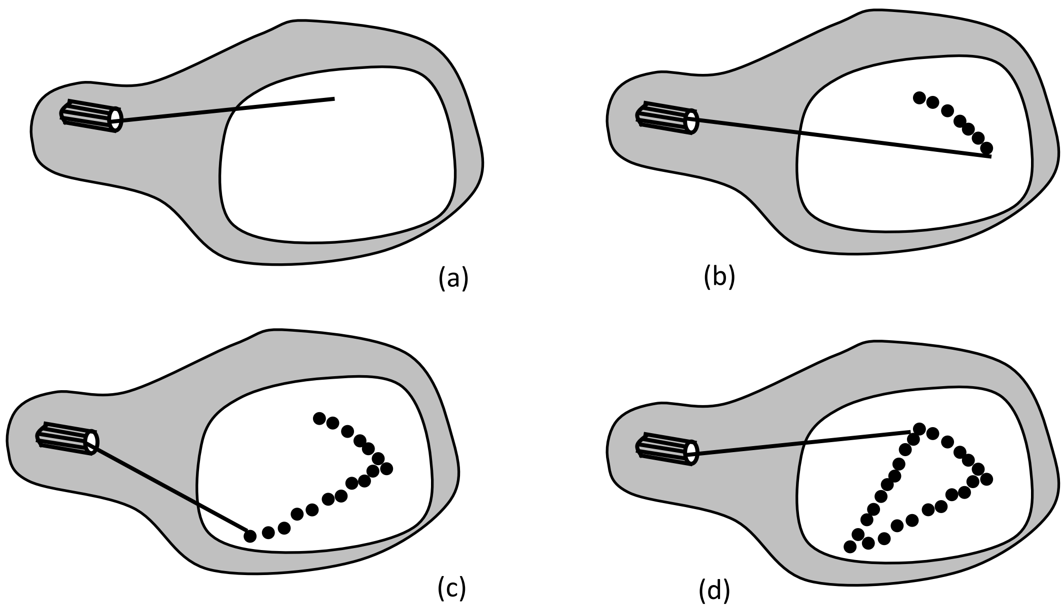


Figure: Random Scan Display

- The refresh rate of vector display depends upon the no of lines to be displayed for any image.
- **Picture definition** is stored as a set of line drawing instructions in an area of memory called the **refresh display file** (Display list or display file).
- To display a picture, the system cycles through the set of commands (line drawing) in the display file. After all commands have been processed, the system cycles back to the first line command in the list.
- Random scan systems are designed for drawing all component lines 30 to 60 times per second. Such systems are designed for line-drawing applications and cannot display realistic shaded scenes. Since CRT beam directly follows the line path, the vector display system produce smooth line.

C. Color CRT

A CRT monitor displays color pictures by using a combination of phosphors that emit different-colored light. By combining the emitted light from the different phosphors, a range of colors can be generated. Two basic techniques for producing color displays with CRT are:

1. Beam-penetration method

2. Shadow-mask method

Beam Penetration method

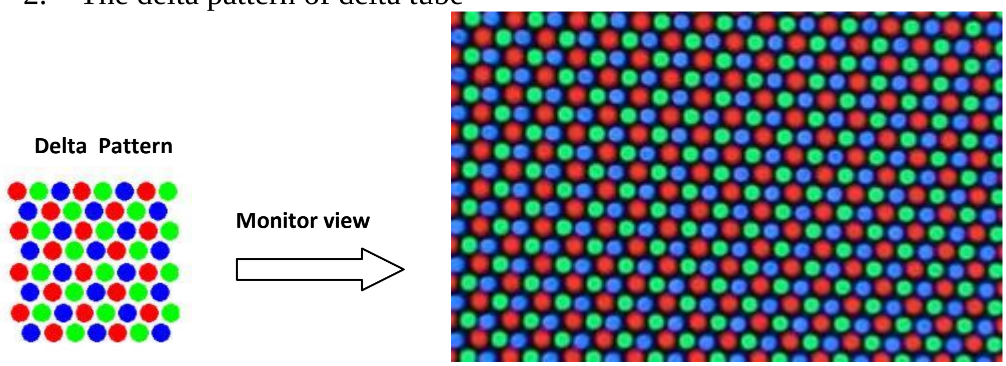
This method is commonly used for random scan display or vector display. In random scan display CRT, the two layers of phosphor usually red and green are coated on CRT screen. Display color depends upon how far electrons beam penetrate the phosphor layers.

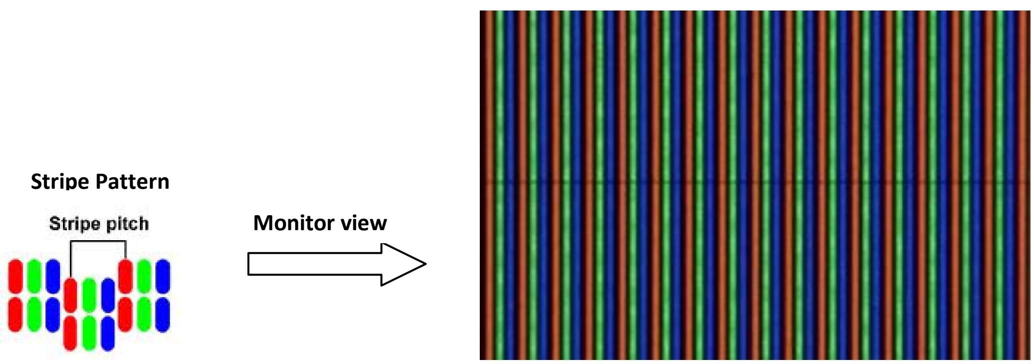
- **Slow electrons** excite only red layer so that we can see red color displayed on the screen pixel where the beam strikes.
- **Fast electrons** beam excite green layer penetrating the red layer and we can see the green color displayed at the corresponding position.
- At **Intermediate** beam speeds, combinations of red and green light are emitted to show two additional colors - orange and yellow.
- The speed of the electrons and hence the screen color at any point, is controlled by the beam-acceleration voltage.
- Beam-penetration has an inexpensive way to produce color in random-scan monitors, but quality of pictures is not as good as other methods since only 4 colors are possible.

Shadow Mask Method

Shadow mask method is used for raster-scan systems because they can produce wide range of colors than beam-penetration method. In shadow mask CRT has three phosphor color dots at each pixel position. The phosphor on the face of the screen is laid out in a precise geometric pattern. There are two primary variations.

1. The stripe pattern of inline tube
2. The delta pattern of delta tube





- In color CRT, there are **three electron guns**, one for each red, green and blue color. In phosphor coating there may be either strips one for each primary color, for a single pixel or there may be three dots one for each pixel in delta fashion.

- Special metal plate called a **shadow mask** is placed just behind the phosphor coating to cover front face.
- The mask is aligned so that it simultaneously allow each electron beam to see only the phosphor of its assigned color and block the phosphor of other two color.

Depending on the pattern of coating of phosphor, two types of raster scan color CRT are commonly used using shadow mask method.

a) **Delta-Delta CRT**
In delta-delta CRT, three electron beams one for each R, G, and B colors are deflected and focused as a group onto shadow mask, which contains a series of holes aligned with the phosphor dots.

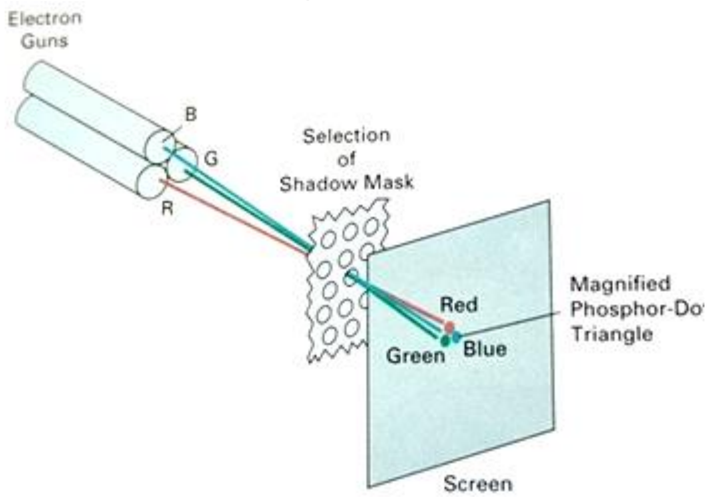


Figure: Shadow mask in Delta-Delta CRT

- Inner side of viewing has several groups of closely spaced red ,green and blue phosphor dot called triad in delta fashion.
- Thin metal plate adjusted with many holes near to inner surface called shadow mask which is mounted in such a way that each hole aligned with respective triad.
- Triads are so small that is perceived as a mixture of colors. When three beams pass through a hole in shadow mask, they activate the dot triangle to illuminate a small spot colored on the screen.
- The color variation in shadow mask CRT can be obtained by varying the intensity level of the three electron guns.

Drawback: Difficulties for the alignment of shadow mask whole and respective triads.

b) **Precision inline CRT**
This CRT uses strips pattern instead of delta pattern. Three strips one for each R, G, and B colors are used for a single pixel along a scan line so called **inline**. This eliminates the drawbacks of delta-delta CRT at the cost of slight reduction of image sharpness at the edge of the tube.
  - Normally 1000 scan lines are displayed in this method. Three beams simultaneously expose three inline phosphor dots along scan line.

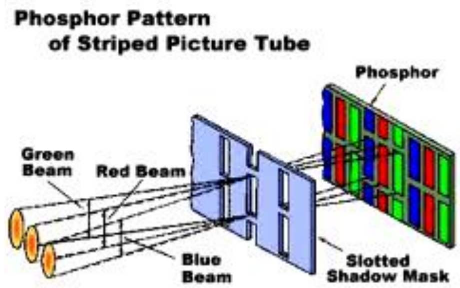


Figure: Inline CRT

D. Direct-view Storage tubes (DVST)

This is alternative method for method maintaining a screen image to store picture information inside the CRT **instead of refreshing** the system.

- DVST stores the picture information as a charge distribution just behind the phosphor-coated screen.
- Two electron guns used: primary gun – to store picture pattern and flood gun – maintains the picture display.
- Pros: Since no refreshing is needed complex pictures can be displayed in high-resolution without flicker.
- Cons: Ordinarily do not display color and that selected parts of picture can not be erased. To eliminate a picture section, entire screen must be erased and modified picture redrawn, which may take several seconds for complex picture.

E. Flat panel Displays

Flat-panel display refers to a class of video devices that have reduced volume (thinner), weight and power consumption compared to CRT. These emerging display technologies tend to replace CRT monitors. Current uses of flat-panel displays include TV monitors, calculators, pocket video games, laptops, displays in airlines and ads etc.

Two categories of flat-panel displays:

a) Emissive displays: convert electrical energy into light. Example: Plasma panels, electroluminescent displays and light-emitting diodes.
b) Non-emissive displays: use optical effects to convert sunlight or light from other sources into graphics patterns. Example: liquid-crystal displays.

Architecture of Raster-Scan System

The raster graphics systems typically consist of several processing units. CPU is the main processing unit of computer systems. Besides CPU, graphics system consists of a special purpose processor called video controller or display processor (DP). The display processor controls the operation of the display device. The organization of raster system is as shown below:

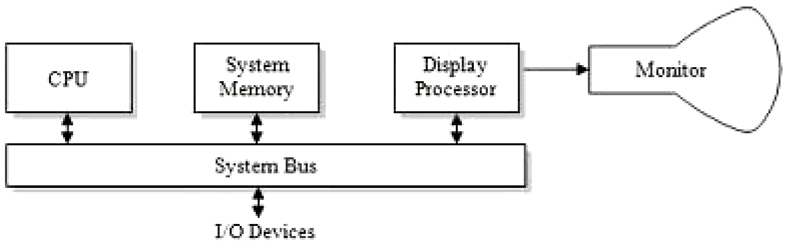


Fig: Architecture of simple raster-graphics system

- A fixed area of system memory is reserved for the frame buffer. The video controller has the direct access to the frame buffer for refreshing the screen.
- The video controller cycles through the frame buffer, one scan line at a time, typically at 60 times per second or higher. The contents of frame buffer are used to control the CRT beam's intensity or color.

The video controller

The video controller is organized as in figure below. The raster-scan generator produces deflection signals that generate the raster scan and also controls the X and Y address registers, which in turn defines memory location to be accessed next. Assume that the frame buffer is addressed in X from 0 to X_{max} and in Y from 0 to Y_{max} then, at the start of each refresh cycle, X address register is set to 0 and Y register is set to 0 (top scan line).

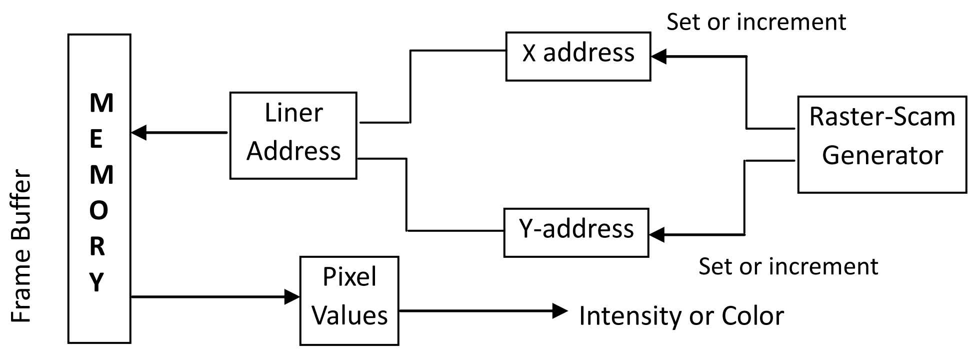


Fig: Basic video-controller refresh-operation

As first scan line is generated, the X address is incremented up to X_{max}. Each pixel value is fetched and used to control the intensity of CRT beam. After first scan line, X address is reset to 0 and Y address is incremented by 1. The process is continued until the last scan line ($Y=Y_{max}$) is generated.

Raster-Scan Display Processor

The raster scan with a peripheral display processor is a common architecture that avoids the disadvantage of simple raster scan system. It includes a separate graphics processor to perform graphics functions such as scan conversion and raster operation and a separate frame buffer for image refresh. The display processor has its own separate memory called display processor memory.

- System memory holds data and those programs that execute on the CPU, and the application program, graphics packages and OS.

- The display processor memory holds data plus the program that perform scan conversion and raster operations.
- The frame buffer stores displayable image created by scan conversion and raster operations.

The organization is given below in figure:

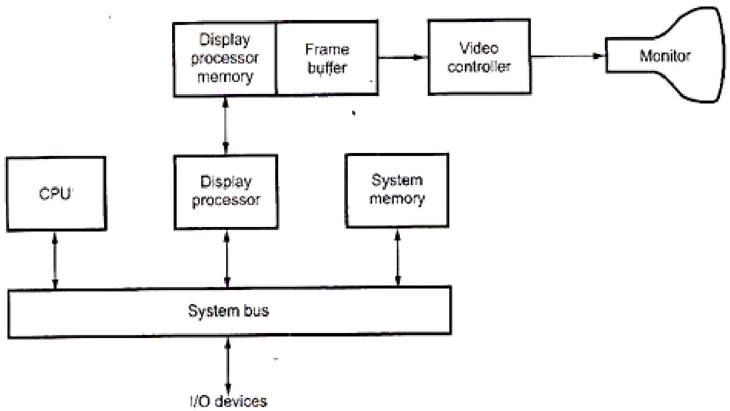


Fig: Architecture of a raster-graphics system with a display processor

Architecture of Random-scan (Vector) Systems

The organization of simple vector system shown in the figure below:

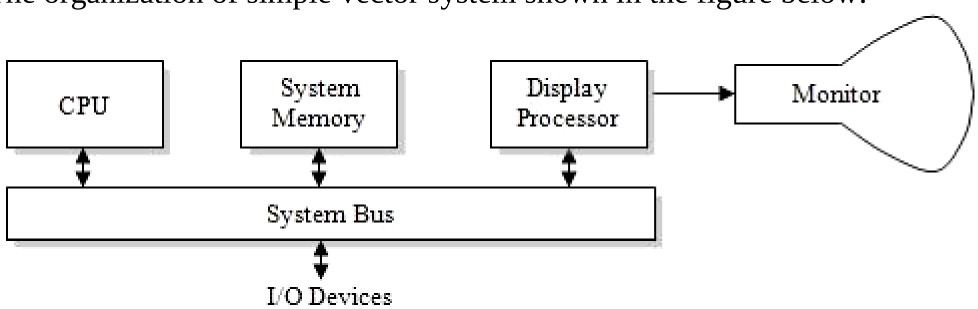


Figure: Architecture of Vector Display System

- Vector display system consists of several units along with peripheral devices. The display processor is also called as graphics controller.
- Graphics package creates a display list and stores in systems memory (consists of points and line drawing commands) called display list or display file.
- Vector display technology is used in monochromatic or beam penetration color CRT.
- Graphics are drawn on a vector display system by directing the electron beam along component line.

<u>Advantages</u>:

- Can produce output with high resolutions.
- Better for animation than raster system since only end point information is needed.

<u>Disadvantages</u>:

- Cannot fill area with pattern and manipulate bits.
- Refreshing image depends upon its complexity.