COMPUTER GRAPHICS

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Chapter -2 Graphics Hardware

Must know CG Terminologies?

1. **Pixel**

- Pix + el = picture element
- Fundamental building block of any image or computer graphics
- Defined as addressable tiny objects or color spot (dots) displayed on screen, which forms an image or
- Image is a collection of pixels.

2. **Resolution**

- ❖ Resolution is defined as total number of pixels in our digital screen
- ❖ I.e. Resolution = no. of pixels in X direction * no. of pixels in Y direction.

3. **Aspect ratio**

- ❖ Screen's aspect ratio refers to the ratio of the no. of X (horizontal) pixel to the no of Y (vertical) pixels i.e. Aspect Ratio = total no of X (horizontal) pixels / total no of Y (vertical) pixel
- ❖ Example : 800*600 Resolution = 480000 No. of pixels = 4:3 Aspect ratio

4. **Persistence**

- ❖ Basically persistence means how much time is taken by the emitted light to reduce to one-tenth ($1/10^{th}$ or 10%) of its original intensity.
- ❖ Different kinds of phosphors are used in a CRT. The difference is based upon the time for how long the phosphor continues to emit light after the CRT beam has been removed. This property is referred to as **Persistence.**
- ❖ Now, phosphors with lower persistence require higher refresh rates to maintain a picture on the screen without any flicker.
- ❖ Graphics monitor are usually constructed with persistence in the range from 10 to 60 micro second.

5. **Refresh Rate**

- ❖ How many times per second a screen is refreshed by electron beam is known as its refresh rate.
- ❖ It's measured in Hertz (Hz), the unit of frequency.
- ❖ For a good quality of display device it is suggested that it should have higher resolution & refresh rate.

- Alternatively referred to as **frame rate**, **horizontal scan rate**, **vertical frequency**, or **frequency**. **Refresh rate** is a CRT monitor measurement in Hz that indicates how many times per second a monitor screen image is renewed. For example, a monitor with a refresh rate to 75 Hz means the screen is going to redraw 75 times per second.
- Usually 50/sec
- Refresh rate above which flickering stops is called Critical Fusion Frequency (CFF)
- The factor affective CFF are persistence, image intensity, ambient room light, Wave length of emitted light, observer.
- An older refresh rate standard, developed by the Video Electronics Standards Association (VESA Local Bus), was only 60 Hz. This refresh rate caused the display's image to flicker, causing eye fatigue and headaches in users. A new standard set the refresh rate to 75 Hz. It is believed that 70 Hz or higher eliminates the flicker. When purchasing a monitor, look for a refresh rate of 75 to 85 Hz.
- Finally, an LCD does not have a refresh rate

6. Aliasing

- Aliasing is distortion that appear in any display system when the sampling the continuous object to discrete integer pixel position.
- This is because, lines, polygon, circle etc. are continuous but a raster device is discrete.

7. Bit Map and Pixel Map

- If a pixel has only two-color values (i.e. black and white), it can be encoded by a 1 bit of information. On a black and white system with one bit per pixel, the frame buffer is called bitmap.
- An image of more than two colors is called pix map.

8. Bit Depth (**Or Color Depth**)

- It is defined as number of bits assigned to each pixel in the image.

9. Phosphorescence

- It is a process in which energy absorbed by a substance is released relatively slowly in the form of light.

10. Persistence

- A phosphor's persistence is the time for the emitted light to decay to 10 % of the initial intensity.
- The persistence may be varied with different phosphors.
- The phosphors used for graphics display usually have persistence of 10 to 60 microseconds

2.1 Interactive input devices

Interactive Graphics

- ❖ Interactive graphic systems provide the potential for natural and efficient man-machine communication.
- ❖ In order to exploit fully this potential and provide a conceptually simple man-computer interface, the graphic input and output devices must be closely integrated.

There are many interactive input devices. Some of them are listed below:

1. Keyboard
2. Mouse
3. Trackball
4. Space ball
5. Joystick
6. Dials button boxes
7. Light pen
8. Data glove
9. Touch panels
10. Graphic tablet

Graphic Tablet

- ❖ Tablet is a digitizer.
- ❖ Also called a **drawing tablet** or a **pen tablet**, a **graphics tablet** is a natural input device that converts information from a handheld stylus.
- ❖ The user uses the stylus like a pen, pencil, or paintbrush, pressing its tip on the tablet surface.
- ❖ The device can also be used in replacement of a computer mouse.
- ❖ The first graphics tablet for home computers was the **KoalaPad.**
- ❖ Developed by Koala Technologies in 1984,
- ❖ KoalaPad Originally designed for use by the Apple II computer, but later was available for the IBM PC compatible computer as well.
- ❖ Similar to an artist drawing with a pencil and paper, a user draws on the graphics tablet with a stylus.

- The computer will convert the drawing strokes into digital form, displaying them on the computer screen.
- The graphics tablet can also be used to capture users' signatures.
- This use is similar to the signature pads found at many retail stores, where you would write your signature after using a credit card to make a purchase.

Below is a list of professions and people who are more likely to use a graphics tablet.

- Architects and Engineers
- Artists
- Cartoonist
- Fashion designers
- Graphic designers
- Illustrators
- Photographers
- Teachers

Touch panel

- Touch Screens are not only display but also input devices.
- Electronic visual devices which are sensitive to pressure and hence detect the presence and location of touch within the display region.
- A user interacts with the computer by touching the pictures or words on screen, as the screens are sensitive to pressure.
- The term "touch" refers to contact or touch to the display of the device by finger or hand. It refers to a situation of "direct manipulation".
- Doctor Samhurst developed the first touch sensor in 1971 and it was patented by the University of Kentucky Research Foundation.
- Now-a-days smart phones, portable game consoles, PDAs etc are driving the demand for touch screens.
- With time, display manufacturers & chip manufacturers acknowledged this trend of acceptance and began integrating touch screen functionality in to the fundamental design of their products.

Touch screen have basically **3 components** and as it is I/O device, so it should be combined with a display and a PC to make a complete touch input system.

1. **Touch Sensor**: -

   - A clear glass panel with a touch responsive surface.
   - The Touch panel is placed over the display screen in such a manner that the responsive area of the panel covers the viewable area.
   - Various touch sensor technologies are available in market which uses a different method to detect the touch.
   - In general sensor has an electric current, going through it and as soon as somebody touches the screen that causes a voltage change which in turn helps to locate the presence of touch on the screen.

2. **Controller**

   - A small PC card that connects between the touch sensor & the PC.
   - Controller takes information from touch sensor and translates it into such a language that a PC can understand.

- ❖ It's usually installed inside the monitor. It determines the type of connection we need on PC.

3. **Software Driver**

- ❖ It's a software update for the PC system that allows the touch screen and computer to work together.
- ❖ Operating system gets instruction on how to interpret the touch event information that is sent from the controller.

Touch screens advantages over normal/conventional devices are as follows:-

- ❖ **Easy** to **use**: - It provides a rich user interface experience as it is just facilitated by touch.
- ❖ **Saves Space**: - Intelligent utilization of space is of great importance. This touch screens facilitates this by saving space of keyboard.
- ❖ **Speed** & **Reliability**: - Navigation with other devices is comparatively is slow as compared to touch screens as just by touch the navigation becomes extremely faster and reliable.

Types of Touch screen Technology:

- ❖ RESISTIVE
- ❖ CAPATITIVE
- ❖ SAW(SURFACE ACOUSTIC WAVE)

Keyboard:

- KEY on BOARD
- Most common input device invented 100 years ago and used to type data into the computer
- It Has special keys for giving the computer commands
- Commands tell the computer to do something, like save the file, copy the file etc.
- These special keys are called command or function keys
- There is no specific standard but we have stuck to the qwerty keyboard
- Different types of keyboards are found and type is depends what we need to input

Types:

1. **Ergonomic keyboard**

   - The artifact of this keyboard is slightly broader and different in shape, when compared with the normal keyboard.

2. **Wireless Keyboard**

   - A wireless keyboard, the name itself doles the meaning that this keyboard can be operated without addressing a wired connection to the processor.
   - Also called Cordless keyboards

Working Mechanism of Keyboard:

Step-1: Key is pressed on keyboard

Step-2: keyboard controller sends the scan code for the key to keyboard controller

Step-3: keyboard controller sends an interrupt request to the system software

Step-4: system software responds to the interrupt by reading the scan code from the keyboard buffer.

Step-5: System software passes the scan code to the CPU.

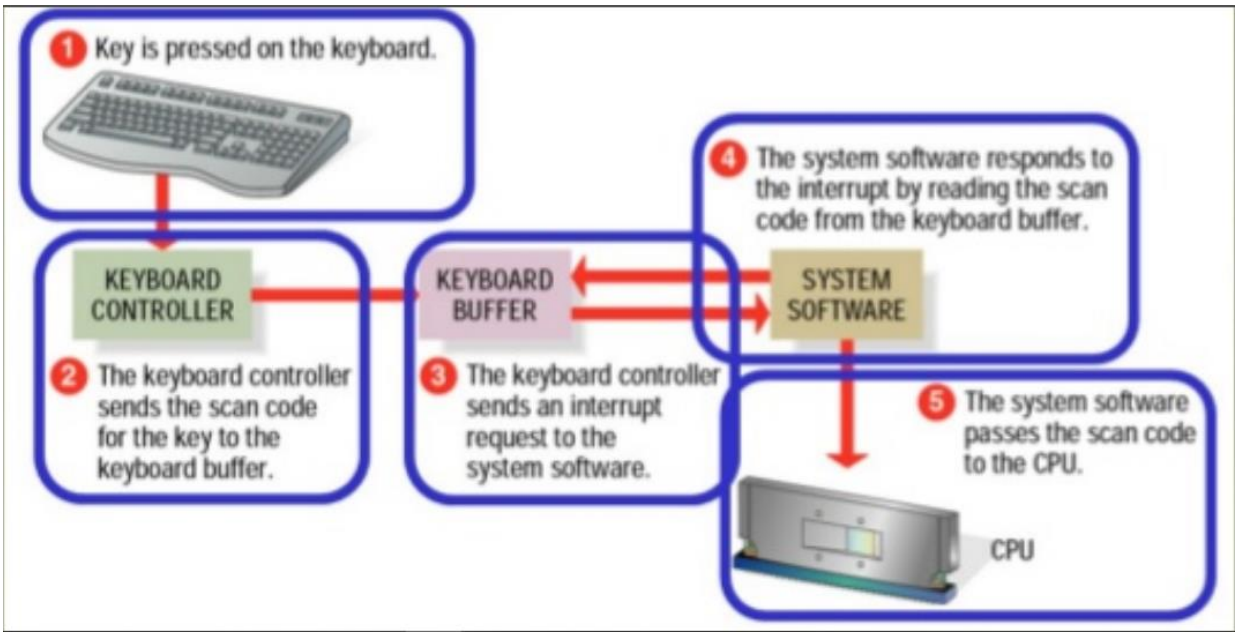


Figure: working mechanism of keyboard

Light Pens

- Ben Gurley → 1959 → basic idea from Mouse.

Figure: Light Pen (image source: internet)

- A light pen is a pen-shaped input device that are used to select screen positions by detecting the light coming from points on the CRT screen.

- Utilizes a light sensitive detector, requiring you to hold a pen and point it at the screen.

- The device contains a light sensor which, when pointed at a cathode ray tube screen, generates a signal each time the electron beam raster passes by the spot the pen is pointing at.

- Light enters the lens of a light pen, where it encounters a photoelectric cell, which converts the energy to a signal that is sent to the computer.

- The light is obtained from the refresh of the CRT, and at the instant the light is generated, the computer knows what location on the screen is being refreshed

- This information is coordinated with the signal from the light pen, and is subsequently used by the graphics software to make a decision

How it Works?

When an activated light pen is made to point at a spot on the screen the electron beam emitted lights up that spot, which in turn, generates an electric pulse that causes the co-ordinate position of the electron beam to be located.

Advantages of Light Pens

- Allows you to select objects on a display screen
- **Accuracy**: drawing directly on the screen so it is more accurate more precise
- **Durability:** The light pen and computer respond instantly when you move it or click on one of the buttons located on the pen's sides. The tip cannot damage the computer screen in any way.
- **Flexibility:** In addition to having the full range of mouse options, including allowing you to drag and drop, you can use the light pen to directly draw or write on the screen. This makes providing your signature relatively simple.
- **Reduced workspace:** when you use a light pen instead of a mouse because you do not need a flat surface to operate a light pen.
- **Maintenance and Value**: Buying a light pen to use on your CRT computer monitor is cheaper than buying a touch-screen monitor. The same is true for repairs or replacements.

Disadvantages of Light Pens

- Light pens have the advantage of 'drawing' directly onto the screen, but this can become uncomfortable, and they are not as accurate as digitizing tablets.
- Light pens normally require a specially designed monitor to work with

Data Gloves:

- Cyber gloves or wired gloves.

- A data glove is an interactive input device that is essentially a glove worn on the hand that contains various electronic sensors that monitor the hand's movements and transform them into a form of input for applications such as virtual reality and robotics.

- Data Gloves facilitates tactile sensing and fine-motion control in robotics and virtual reality. Data gloves are one of several types of electromechanical devices used in haptics applications.

- Tactile sensing involves simulation of the sense of human touch and includes the ability to perceive pressure, linear force, torque, temperature, and surface texture.

- Fine-motion control involves the use of sensors to detect the movements of the user's hand and fingers, and the translation of these motions into signals that can be used by a virtual hand

- for example: in gaming , robotic hand→ in remote-control surgery

- These movements are then interpreted by a driver or software made specifically for the glove so that the gestures can be converted into an input for a separate program such as for virtual reality, games or for controlling animatronics or other kinds of robots.

2.2 Display Devices and Hard Copy Devices (video display devices)

- Computer Graphics has become a common element in today's modern world.
- Be it in user interfaces, or data visualization, motion pictures etc, computer graphics plays an important role.
- The primary output device in a graphics system is a video monitor. Although many technologies exist, but the operation of most video monitors is based on the standard Cathode Ray Tube (CRT) design.

Monitors, commonly called as **Visual Display Unit** (VDU), are the main output device of a computer. It forms images from tiny dots, called pixels that are arranged in a rectangular form. The sharpness of the image depends upon the number of pixels.

There are two kinds of viewing screen used for monitors.

1. Cathode-Ray Tube (CRT)
2. Flat-Panel Display (FPD)

Cathode Ray Tube (CRT)

- A cathode ray tube (CRT) is a specialized vacuum tube in which images are produced when an electron beam strikes a phosphorescent surface.
- It modulates, accelerates, and deflects electron beam(s) onto the screen to create the images.
- Most desktop computer displays make use of CRT for image displaying purposes.

The primary components are

A) **heated metal**
B) **Cathode** and
C) **Control grid**.

Working

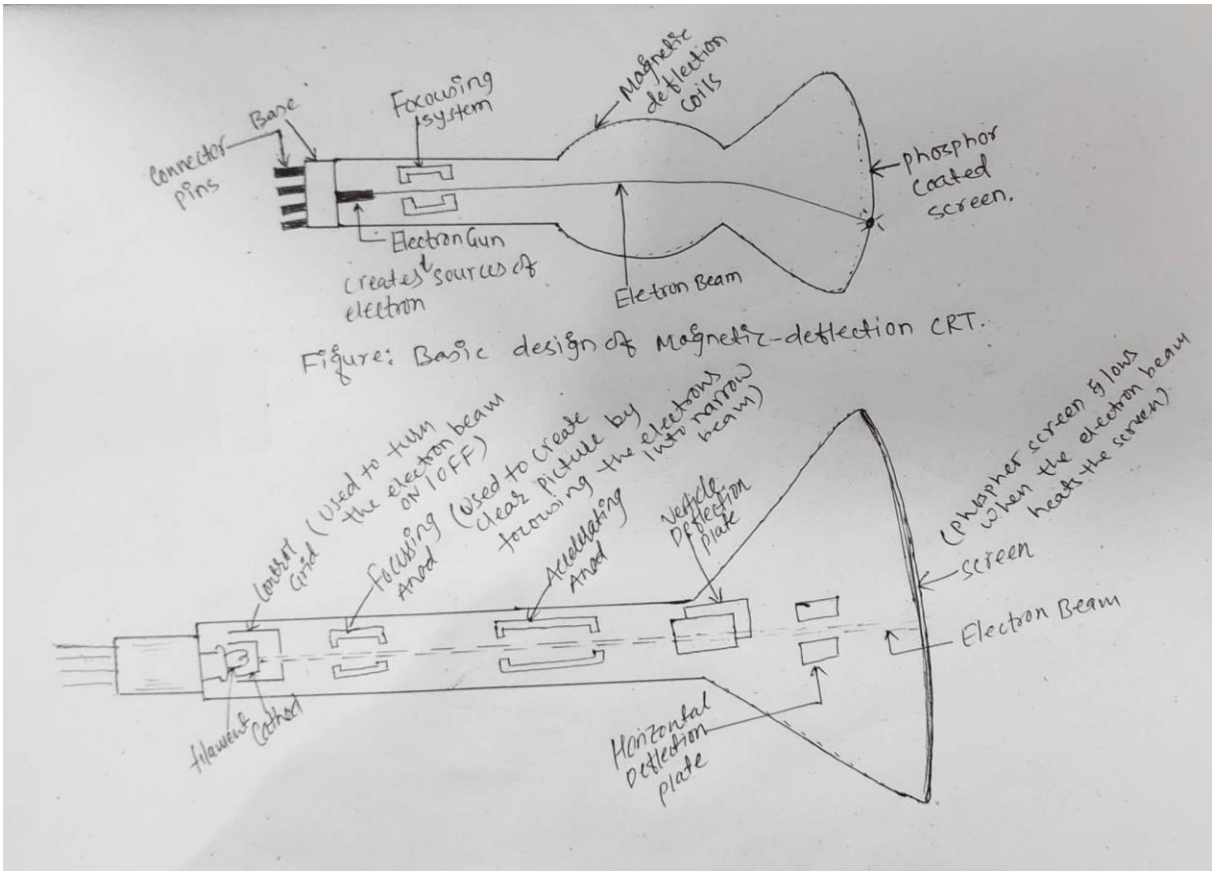


Figure: Basic design of Magnetic-deflection CRT.

1. The heat is supplied to the cathode (by passing current through the filament). This way the electrons get heated up and start getting ejected out of the cathode filament.
2. This stream of negatively charged electrons is accelerated towards the phosphor screen by supplying a high positive voltage.
3. This acceleration is generally produced by means of an accelerating anode.
4. Next component is the **Focusing System**, which is used to force the electron beam to converge to small spot on the screen.
5. If there will not be any focusing system, the electrons will be scattered because of their own repulsions and hence we won't get a sharp image of the object.
6. This focusing can be either by means of electrostatic fields or magnetic fields.

Types of Deflection:

1. **Electrostatic Deflection**

   The electron beam (cathode rays) passes through a highly positively charged metal cylinder that forms an electrostatic lens. This electrostatic lens focuses the cathode rays to the center of the screen in the same way like an optical lens focuses the beam of light. Two pairs of parallel plates are mounted inside the CRT tube.
2. **Magnetic Deflection**

   Here, two pairs of coils are used. One pair is mounted on the top and bottom of the CRT tube, and the other pair on the two opposite sides. The magnetic field produced by both these pairs is such that a force is generated on the electron beam in a direction which is perpendicular to both the direction of magnetic field, and to the direction of flow of the beam. One pair is mounted horizontally and the other vertically.

Flat Panel Display

- **Flat-Panel Devices** are the devices that have less volume, weight, and power consumption compared to Cathode Ray Tube (CRT).
- Due to the advantages of the Flat-Panel Display, use of CRT decreased.
- As Flat Panel Devices are light in weights that's why they can be hang on walls and wear them on our wrist as a watch.
- Flat Panel Display (FPD) allow users to view data, graphics, text and images.
- **Example:** Small T.V. monitor, calculator, pocket video games, laptop computers, an advertisement board in elevator.

Types of Flat panel display:

1. **Emissive Display:**

   The Emissive Display or Emitters are the devices that convert electrical energy into light energy.

   Examples: Plasma Panel, LED (Light Emitting Diode), Flat CRT.

Plasma Panel

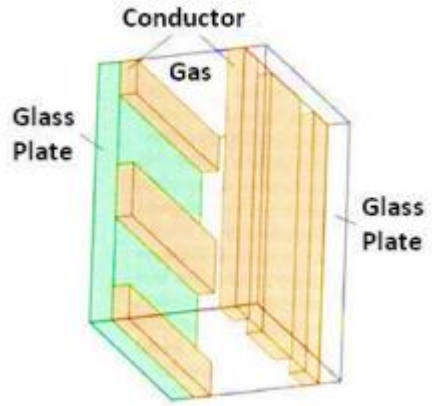


Figure: Basic design of Plasma-panel display device

- Also known as gas-discharge display
- It is constructed by filling the region between two glass plates with a mixture of gases that usually includes neon.
- A series of vertical conducting ribbons is placed on one glass panel and a set of horizontal ribbon is built into the other glass panel.
- Firing voltage is applied to a pair of horizontal and vertical conductors cause the gas at the intersection of the two conductors to break down into glowing plasma of electrons and ions.
- Picture definition is stored in a refresh buffer and the firing voltages are applied to refresh the pixel positions, 60 times per second.
- Alternating current methods are used to provide faster application of firing voltages and thus brighter displays.
- Separation between pixels is provided by the electric field of conductor.
- One **disadvantage** of plasma panels is they were strictly monochromatic device that means shows only one color other than black like black and white.

Light Emitting Diode (LED)

- In this display a matrix of multi-color light emitting diode is arranged to form the pixel position in the display. And the picture definition is stored in refresh buffer.
- Similar to scan line refreshing of CRT information is read from the refresh buffer and converted to voltage levels that are applied to the diodes to produce the light pattern on the display.

2. **Non-Emissive Display:**

   Non-Emissive Display or Non-Emitters are the devices that use optical effects to convert sunlight or some other source into graphic patterns.

   Examples: LCD (Liquid Crystal Display)

Liquid Crystal Display (LCD)

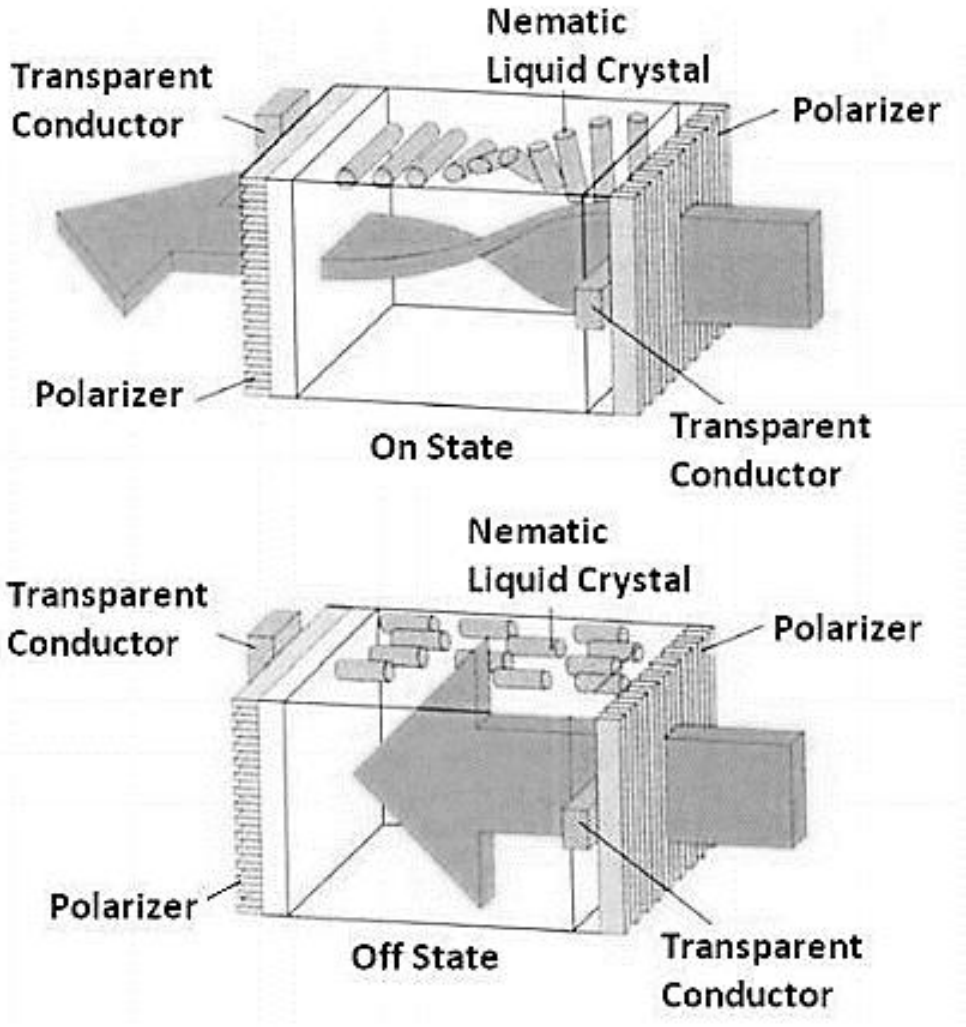


Figure: Design of LCD by using light twisting shutter effect

- It is generally used in small system such as calculator and portable laptop.
- This non emissive device produce picture by passing polarized light from the surrounding or from an internal light source through liquid crystal material that can be aligned to either block or transmit the light.

- The liquid crystal refreshes to fact that these compounds have crystalline arrangement of molecules then also flows like liquid.
- It consists of two glass plates each with light polarizer at right angles to each other sandwich the liquid crystal material between the plates.
- Rows of horizontal transparent conductors are built into one glass plate, and column of vertical conductors are put into the other plates.
- The intersection of two conductors defines a pixel position.
- In the ON state polarized light passing through material is twisted so that it will pass through the opposite polarizer.
- In the OFF state it will reflect back towards source.
- We applied a voltage to the two intersecting conductor to align the molecules so that the light is not twisted.
- This type of flat panel device is referred to as a passive matrix LCD.
- In active matrix LCD transistors are used at each (x, y) grid point. Transistor cause crystal to change their state quickly and also to control degree to which the state has been changed.
- Transistor can also serve as a memory for the state until it is changed.
- So transistor make cell ON for all time giving brighter display then it would be if it had to be refresh periodically

Advantages of Flat Panel Devices:

- Flat Panel Devices like LCD produces high quality digital images.
- Flat Panel monitor are stylish and have very space saving design.
- Flat Panel Devices consumes less power and give maximum image size in minimum space.
- Flat Panel Devices use its full color display capability.
- Full motion video can be viewed on Flat Panel Devices without artifacts or contrast loss.

There are two techniques used for producing images on the CRT screen:

1. Raster Scan Display

2. Random / Vector Scan Display

2.3 Raster and Random Systems and Architectures

- Raster and Vector Graphics A raster image is made of up pixels, each a different color, arranged to display an image
- Vector image is made up of paths, each with a mathematical formula (vector) that tells the path how it is shaped and what color it is bordered with or filled by.

Raster Graphics	Vector Graphics
Raster Graphics are composed of pixels	Vector graphics are composed of paths.
Raster image pixels do not keep on their appearance as size increases - when you blow a photograph up, it becomes blurry for this reason	Vector images keep on appearance regardless of size, since the mathematical formulas dictate how the image is rendered
Normally they have the file extension of .gif, .jpg	They have the extension of .eps

Refresh or Raster Scan Display System

- A raster consists of pixels organized into rows and columns (or a grid) where each cell contains a value of information. In this display system, raster points are used as basic drawing primitives.
- Home television (CRT) and printers are example of systems using raster scan method

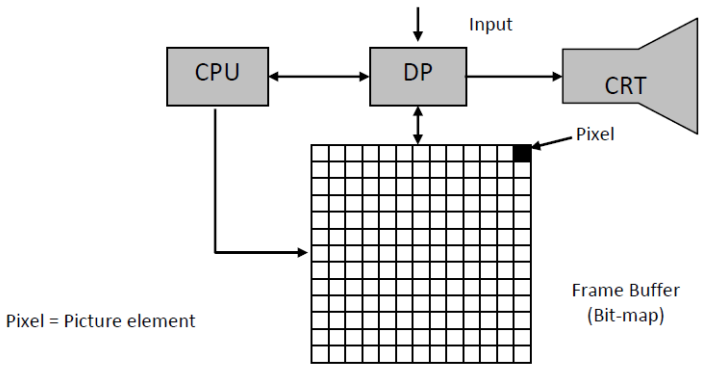


Figure: Raster Scan display system

- In a raster scan system, the electron beam is swept across the screen, one row at a time from top to bottom. As the electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots.

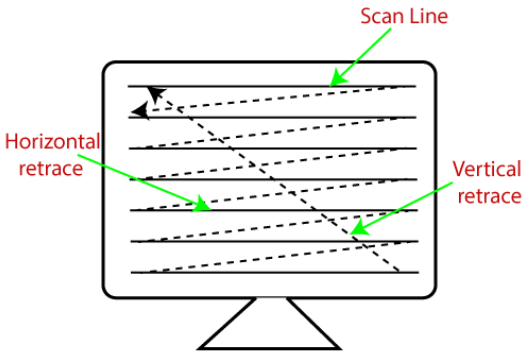
- Picture definition is stored in memory area called the Refresh Buffer or Frame Buffer. This memory area holds the set of intensity values for all the screen points. Stored intensity values are then retrieved from the refresh buffer and "painted" on the screen one row (scan line) at a time as shown in the following illustration.

- Refreshing on raster-scan displays is carried out at the rate of 60 to 80 frames per second. Refreshing must be done because 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 some point.
- The no of times/sec the image is redrawn to give a feeling of non-flickering pictures is called refresh-rate

Each scan line in display device consists of two retrace

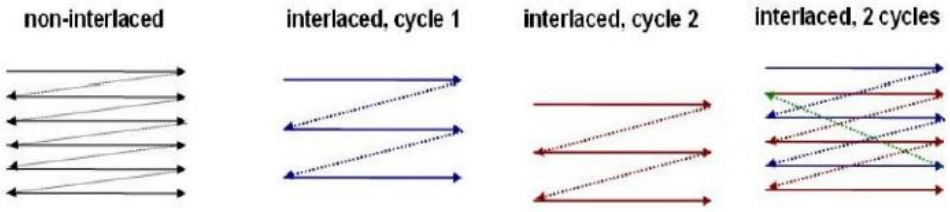
I) Retrace procedure

- At the end of each scan line in raster scan display, the electron beam returns to the left side of the screen to begin displaying the next scan line.
- The return to the left of the screen, after refreshing each scan line is called the **horizontal retrace** of the electron beam. And at the end of each frame the electron beam returns to the top left corner of the screen to begin the next frame which is called **vertical retrace**.



II) Interlaced refresh procedure

- On some raster scan systems each frame is displayed in two passes using an interlaced refresh procedure so that the whole picture should displaced in half time.
- Here, the first scan does the even lines 0, 2, 4...
- Then the second scan does the odd lines 1, 3, 5,



Architecture of Raster graphics System

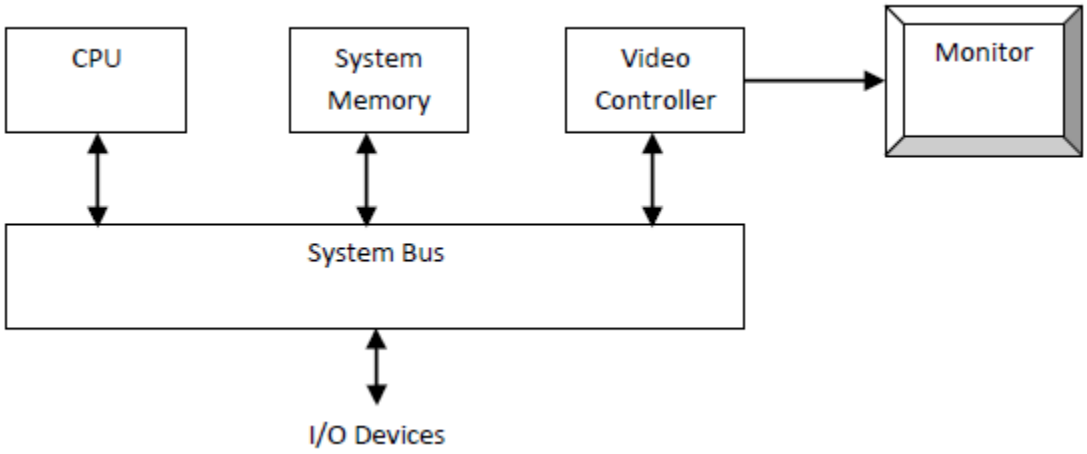


Figure: Architecture of simple raster graphics system.

- Raster graphics systems having additional processing unit like video controller or display controller.

- Here frame buffer can be anywhere in the system memory and video controller access this for refresh the screen.

- In addition to video controller more processors are used as co-processors to accelerate the system in sophisticated raster system.

Raster graphics system with a fixed portion of the system memory reserved for the frame buffer

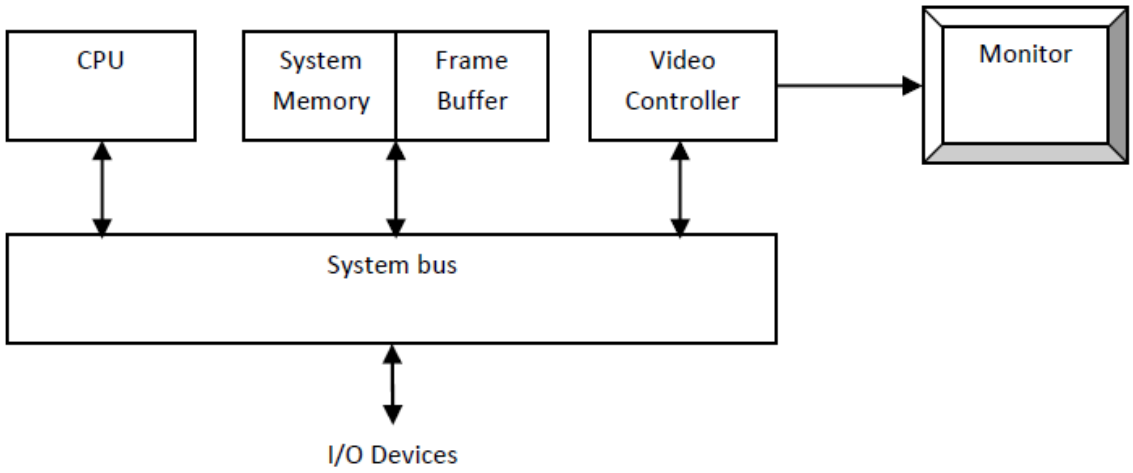


Figure: Architecture of a raster graphics system with a fixed portion of the system memory reserved for the frame buffer

- A fixed area of the system memory is reserved for the frame buffer and the video controller can directly access that frame buffer memory.
- Frame buffer location and the screen position are referred in Cartesian coordinates.
- For many graphics monitors the coordinate origin is defined at the lower left screen corner.
- Screen surface is then represented as the first quadrant of the two dimensional systems with positive X_{value} increases as left to right and positive Y_{value} increases bottom to top.

Random / Vector Scan Display System

- In this technique, the electron beam is directed only to the part of the screen where the picture is to be drawn rather than scanning from left to right and top to bottom as in raster scan.
- It is also called ***vector display, stroke-writing display,*** *or* ***calligraphic display***.

- Picture definition is stored as a set of line-drawing commands in an area of memory referred to as the **refresh display file**. To display a specified picture, the system cycles through the set of commands in the display file, drawing each component line in turn. After all the line-drawing commands are processed, the system cycles back to the first line command in the list.
- Random-scan displays are designed to draw all the component lines of a picture 30 to 60 times each second.

Architecture of Random Scan Display system

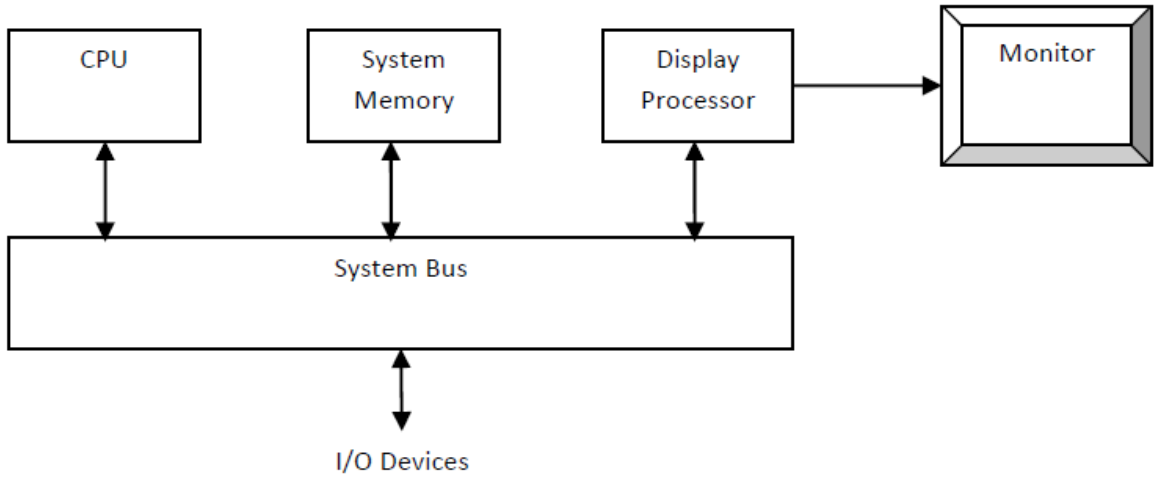


Figure: Architecture of a simple random-scan system

- An application program is input & stored in the system memory along with a graphics package.
- Graphics commands in the application program are translated by the graphics package into a display file stored in the system memory.
- This display file is used by display processor to refresh the screen.
- Display process goes through each command in display file. Once during every refresh cycle.
- Sometimes the display processor in random scan system is also known as display processing unit or a graphics controller.
- In this system graphics platform are drawn on random scan system by directing the electron beam along the component times of the picture.
- Lines are defined by coordinate end points.
- This input coordinate values are converts to X and Y deflection voltages.
- A scene is then drawn one line at a time

2.4 Video Controller

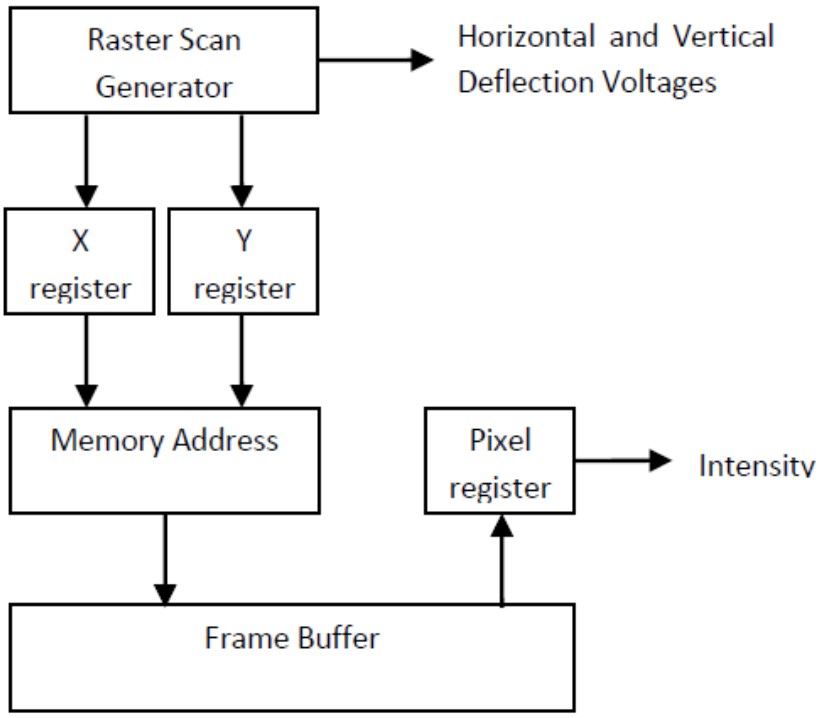


Figure: basic video controller refresh operation.

- Two registers are used to store the coordinates of the screen pixels which are X and Y as shown in above figure.
- 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 Xmax and in Y from 0 to Ymax 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).
- As first scan line is generated, the X address is incremented up to Xmax. 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=Ymax) is generated
- Since screen must be refreshed at the rate of 60 frames per second the simple procedure illustrated in figure cannot be accommodated by typical RAM chips.

- To speed up pixel processing video controller retrieves multiple values at a time using more numbers of registers and simultaneously refresh block of pixel.
- Such a way it can speed up and accommodate refresh rate more than 60 frames per second.

Raster (Refresh) scan vs Vector (Random) Scan display system - v.v Imp

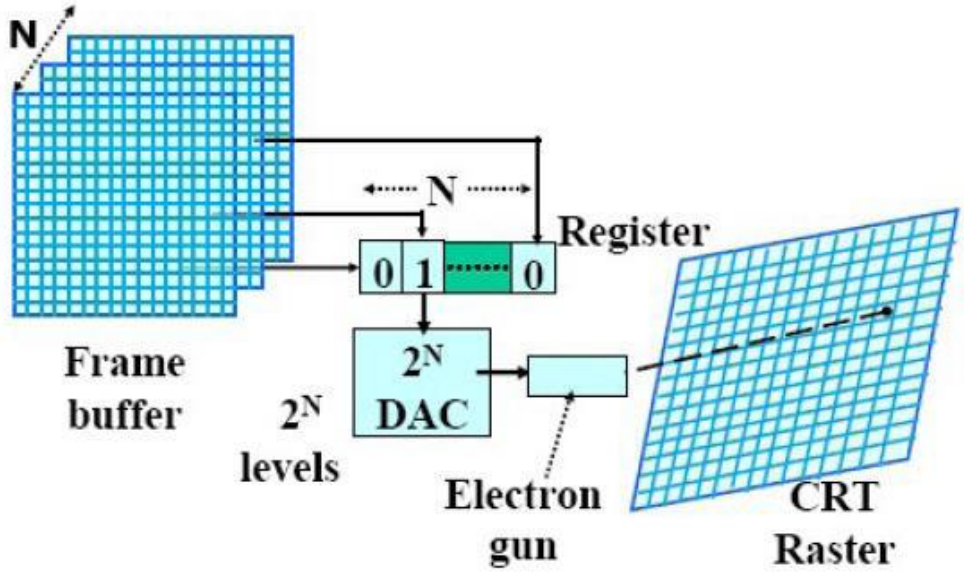
Raster Scan	Random Scan	Remarks
The electron beam is swept across the screen one row at a time from top to bottom	The electron beam is swept to the parts of the screen where a picture is to be drawn.	*Electron Beam*
It has lower or poor resolution because picture definition is stored as an intensity value.	It has high resolution because it stores picture definition as a set of line commands	*Resolution*
Picture definition is stored as a set of intensity values for all screen points (pixels) in a refresh buffer.	Picture definition is stored as a set of line in a display list or file.	*Picture definition*
The capacity of the system to store intensity values for pixels make it well suited for realistic display with shadow and color pattern.	These system are designed for line-drawing and can't display realistic shaded scenes.	*Realistic display*
Screen points or pixels are used to draw an image.	Mathematical functions are used to draw an image	*Image drawing*
They are cheaper than random display.	It is more expensive than raster-scan display.	*cost*
Refresh rate Refresh rate is 60-80 fps.	All components are drawn—30 to 60 times per second.	*Refresh Rate*
Interlacing It uses interlacing.	It doesn't use interlacing	*Interlacing*
Editing Editing is difficult	Editing is easy	*Editing*
Refresh area Refresh area is independent of picture complexity.	Refresh area depends on complexity of picture	*Refresh area*
Smoothness Produce jagged line.	Produce smooth line.	*Smoothness*
CRT, TV, Printer	Pen Plotter	*Example*

2.5 Use of Digital to Analog Converter and Frame Buffer Organization

- A frame buffer is a large, contiguous piece of computer memory into which the intensive values for all pixels are placed.
- At a minimum there is one memory bit for each pixel, this amount of memory is called a bit plane.
- The picture is built up in the frame buffer one bit at a time.
- We know that a memory bit has only two states, therefore a single bit plane yields a black-and white display.
- We know that a frame buffer is a digital device and the CRT is an analog device. Therefore, a conversion from a digital representation to an analog signal must take place when information is read from the frame buffer and displayed on the raster CRT graphics device.
- For this conversion, digital to analog converter (DAC) can be used.
- Each pixel in the frame buffer must be accessed and converted before it is visible on the raster CRT.

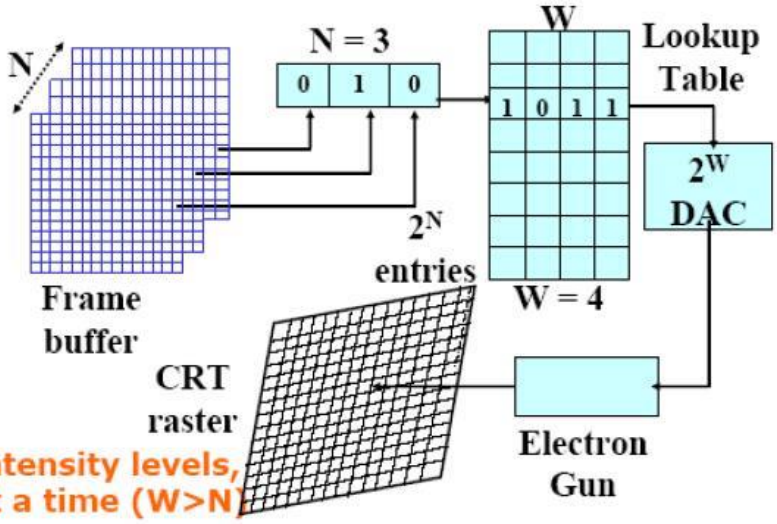
N-bit color Frame buffer

- Color or gray scales are incorporated into a frame buffer raster graphics device by using additional bit planes.
- The intensity of each pixel on the CRT is controlled by a corresponding pixel location in each of the N bit planes.
- The binary value from each of the N bit planes is loaded into corresponding positions in a register.
- The resulting binary number is interpreted as an intensity level between 0 (dark) and 2^n -1 (full intensity).
- This is converted into an analog voltage between 0 and the maximum voltage of the electron gun by the DAC. A total of 2^N intensity levels are possible.
- Figure given below illustrates a system with 3 bit planes for a total of 8 (2^3) intensity levels. Each bit plane requires the full complement of memory for a given raster resolution
- e.g., a 3-bit plane frame buffer for a 1024 X1024 raster requires 3,145,728 (3 X 1024 X1024) memory bits.



An N- bit plane gray level frame buffer

- An increase in the number of available intensity levels is achieved for a modest increase in required memory by using a lookup table. Upon reading the bit planes in the frame buffer, the resulting number is used as an index into the lookup table.
- The look up table must contain 2^N entries.
- Each entry in the lookup table is W bit wise. W may be greater than N. When this occurs, 2^W intensities are available but only 2^N different intensities are available at one time.
- To get additional intensities, the lookup table must be changed.



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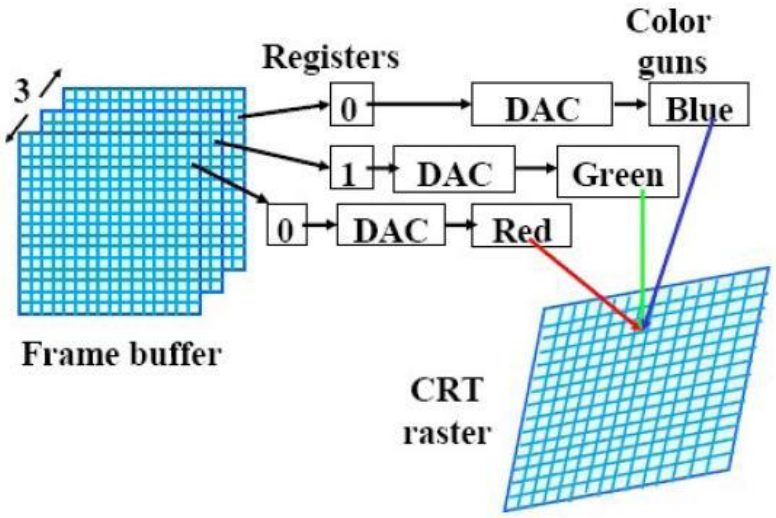
- Because there are three primary colors, a simple color frame buffer is implemented with three bit planes, one for each primary color. Each bit plane drives an individual color gun for each of the three primary colors used in color video.

- These three primaries (red, green, and blue) are combined at the CRT to yield eight colors.



Simple Color buffer

2.6 Color Monitors

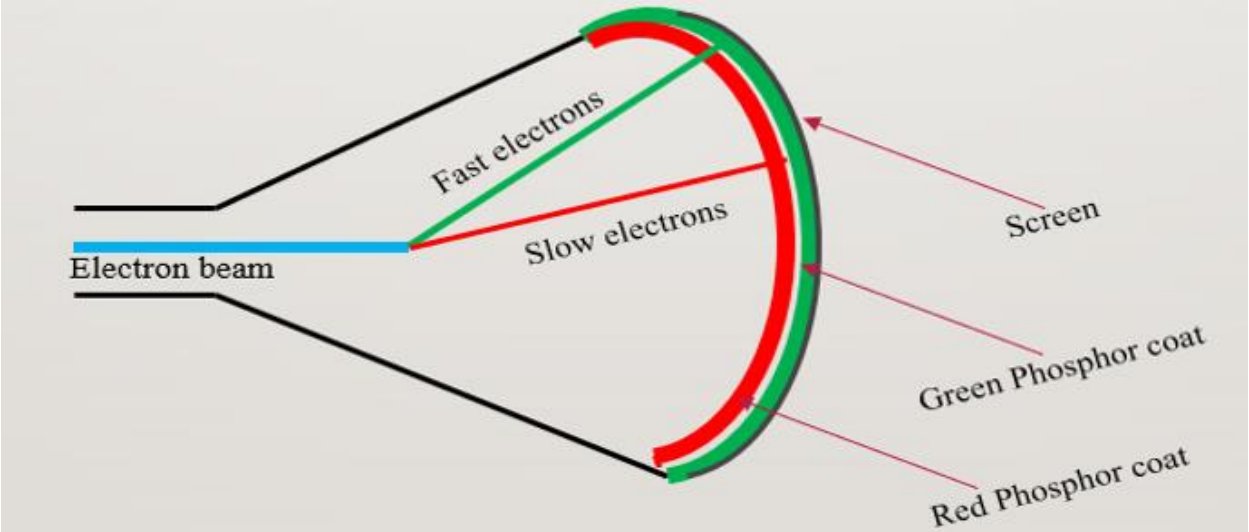
The basic principle behind colored displays is that combining the 3 basic colors – Red, Blue and Green, can produce every color. By choosing different ratios of these three colors we can produce different colors – millions of them in-fact. We also have basic phosphors, which can produce these basic colors. So, one should have a technology to combine them in different combinations.

There are two popular techniques for producing color displays with a CRT are:

1. **Beam Penetration Method:**

   - This method is for random scan monitor display where two different layers of phosphor coating are used

- Red (outer) and Green (Inner) coated on the CRT screen.
- In this method only four colors are possible and hence-the poor picture quality.



Working:

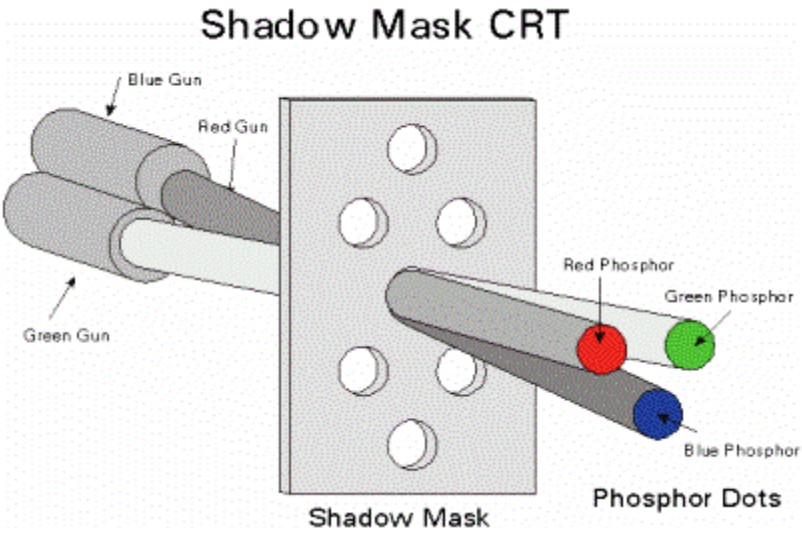
- A beam of slow electrons excites only the outer red layer, then a beam of very fast electrons penetrates through the red phosphor and excites the inner green layer.

- Intermediate is a combination of ted and green so, two additional colors arrange and yellow color

- When quantity of red is more than green then orange color appears

- When quantity of green is more than red color then yellow color appears

2. **Shadow Mask Method:**



- ❖ The Shadow mask CRT, instead of using one electron gun, uses 3 different guns placed one by the side of other to form a triangle or delta structure.
- ❖ Each pixel point on the screen is also made up of 3 type of phosphors to produce red, blue and green colors
- ❖ The phosphor screen is a metal screen called shadow mask. This plate has holes placed strategically (in such a technical way), so that when the beams from the three electron guns are focused on a particular pixel, they get focused on particular color producing pixel only.

Numerical Session:

1. **There is a system with 24 bits per pixel and resolution of 1024 by 1024. Calculate the size of frame buffer (in Megabytes)**

   Solution:
   Resolution = 1024 * 1024
   Total number of pixel = 1024 * 1024 = 1048576 pixels
   Bits per pixels storage = 24 bits

Therefore, total storage required in frame buffer = 1048576 * 24 = 25165824bits

=25165824 / 8 Byte
= 25165824 / (8 * 1024) Kb
= 25165824 / (8 * 1024 * 1024) Mb
= 3 Mb

2. **How Many k bytes does a frame buffer needs in a 600 x 400 pixel?**

Suppose, n bits are required to store 1 pixel.
Then, the size of frame buffer = Resolution * bits per pixel = (600 * 400) * n bits

= 240000 n bits
= 240000 n kb / (8 * 1024)
= 29.30 n k bytes.

3. **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
Pixels Per inch (Resolution) = 100
Then total number of pixels = 8 * 100 * 10 * 100 = 800000 pixels
Bits per pixels' storage =8
Therefore, total storage required in frame buffer = 800000 * 8 bits

= 6400000bits
= 6400000/8 bytes
= 800000Bytes

4. **Find out the aspect ratio of the raster system using 8 x 10 inches' screen and 100 pixels/inch.**

Solution:
We know that,
Aspect ratio = Width / Height
= (8 x 100) / (10 * 100)
= 4 / 5
So, aspect ratio = 4: 5 5.

5. **What is the time required to display a pixel on the monitor of size 1024 * 768 with refresh rate of 60 Hz?**

Solution:
Refresh Rate = 60Hz → 60 frames per second
Total number of pixel in one frame = 1024 * 768 = 786432 pixels.
60 frames need 1 second
1 frame need 1 / 60 second → 786432 pixels need 1/ 60 second
→ 1 pixels need 1 / (60 * 786432) second
→ 10^9 / (60 * 786432) ns
→ 21.19 ns

6. **If the total intensity achievable for a pixel is 256 and the screen resolution is 640 * 480. What will be the size of frame buffer?**

Solution:
1 pixel = 256 different intensity level
Let,
x be the number of bits required to represent 256 different intensity level
Then, $2^X = 256$
Therefore, x= 8 bits
Resolution = 640 * 480
Hence, number of bits required for the screen = 640 * 480 * 8
= 2457600 bits.

7. **If a pixel is accessed from the frame buffer with an average access time of 300ns then will this rate produce an un-flickering effect for the screen size of 640 * 480?**

Solution: Size of screen = 640 * 480
Total Number of pixels = 640 * 480 = 307200
Average access time of one pixel = 300ns
Therefore,
Total time required to access entire pixels of image in the screen = 307200 * 300 = 92160000 ns
= $92160000/10^9$
= 0.09216 seconds

i.e. 1 cycle take 0.09216 second

Now, Number of cycles per second i.e. Refresh Rate =?

0.09216 seconds = 1 cycle

1 second = 1/ 0.09216 = 10.86

Therefore, Refresh Rate= 10.86 cycles per second

Since the minimum refresh rate for unflicker image is 60 frames per second, hence we can say the monitor produces flickering effect.

8. **Consider a raster scan system having 12-inch by 12-inch screen with a resolution of 100 pixels per inch in each direction. If display controller of this system refreshes the screen at the rate of 50 frames per second, how many pixels could be accessed per second and what is the access time per pixel of the system.**

   Solution: Size of Screen = 12 inch * 12 inches
   Resolution = 100 pixels per inch
   Therefore, total number of pixels in one frame = 12 * 100 * 12 * 100
   Refresh Rate = 50 frames per second → 50 frames can be accessed in 1 second
   Therefore,
   Total number of pixels accessed in 1 second = 50 * 12 * 100 * 12 * 100 = 72000000 pixels.
   Again,
   Since, 50 frames can be accessed in 1 second
   1 frame can be accessed in 1/50 second
   (12 * 100 * 12 * 100) pixels can be accessed in 1/50 second
   Then 1 pixel can be accessed in 1 / (50 * 12 * 100 * 12 * 100) second
   $= 10^9$ / (50 * 12 * 100 * 12 * 100) ns
   =13.88 ns

Hence, Access time per pixel = 13.88ns/pixel.

9. **How much time is spent scanning across each row of pixels during screen refresh on a raster system with resolution 1280 * 1024 and refresh rate of 60 frames per second?**

   Solution:
   Resolution = 1280 * 1024
   i.e. One frame contains 1024 scan line and each scan line consists of 1280 pixels.
   Refresh Rate = 60 frames per second
   i.e. 60 frame take 1 second
   1 frame take 1/60 second
   i.e. 1024 scan line take 1/60 second i.e. 0.0166 second
   1 scan line take 0.0166/1024
   = 0.016 Ms