

COMPUTER GRAPHICS

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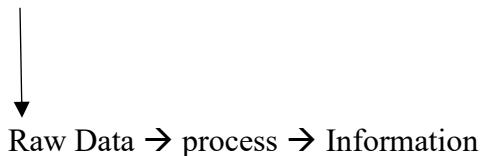
Unit 1: Overview of Computer Graphics and Graphics Systems

1.1 Introduction, Application and Recent Trends of Computer Graphics

Geometric Shapes

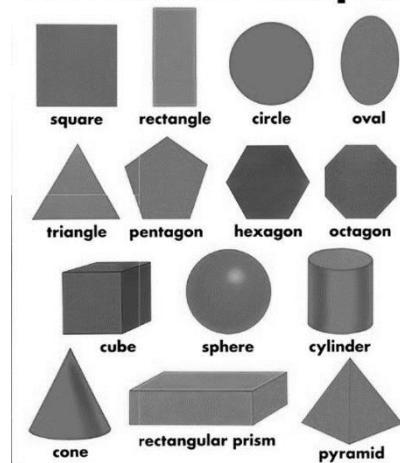
Computer Graphics

Computer



Graphics → Graph + pics

Graph → Geometrical shapes / mathematical figures



Pics → image → how image behaves in different co-ordinates? OR how the image fits in screen of different display device?

- Firstly, provide raw data to the computer to make geometrical / mathematical figures.
- by processing that raw data with the help of algorithms or programs we will get a beautiful / meaningful information i.e. Graph, bar, image etc. that is call computer graphics

Definition:

- CG is an art of drawing pictures, lines, charts or diagrams using computer with the help of programs (algorithms) and software.

OR

- computer graphics is the technology that deals with designs and pictures on computers with the help of algorithms / set of instructions / tools or system.
- computer graphics are visual representations of data displayed on a monitor made on a computer.
- Computer Graphics is a field related to the generation of graphics using computers.

In short, Computer graphics refer different things in different contexts:

- ✓ **Pictures**, scenes that are generated by a computer.
- ✓ **Tools** used to make such pictures, software and hardware, input/output devices.
- ✓ The **whole field of study** that involves these tools and the pictures they produce

Types of Computer Graphics:

Basically 2-Types

1. Interactive Computer Graphics:

- ❖ Involves two way communication between computer and user.
- ❖ User has full control over the content
- ❖ In the Interactive Graphics, data / information shown in the display unit can be interact by one or more input device.
- ❖ I/O Device → request to system/ computer → O/P as a Graphical content.
- ❖ Example: Simulators, User Interface etc.
- ❖ Interactive computer graphics affects our lives in a number of indirect ways.

2. Non-interactive Computer Graphics

- ❖ Involves one-way communication between user and computer /system.
- ❖ User has control over some parts of the contents and totally controlled by program.
- ❖ Also called **passive computer graphics**
- ❖ Example: Videos, Images etc.

Computer Graphics vs Image Processing.

CG	IP
1. It is Field related to generation of pictures using computers (various algorithms for the generation of images)	1. It applies the techniques to modify or interpret existing pictures. (various techniques are used to manipulate pictures)
2. It includes creation storage and manipulation of images of objects	3. It is part of CG that handles image manipulation or interpretation
4. Synthesize pictures from mathematical or geometrical models.	5. Analyze pictures to derive descriptions (often in mathematical or geometrical forms) of objects appeared in the pictures
6. Eg. Drawing pictures	7. Making blurred image visible

Application of Computer Graphics

Widely used in numerous field in various way

1. User Interface (UI)

- CG is used to design: Menus, icons, cursors, dialog boxes, scrollbars, grids, 3D
- The interaction of users interacts with electronic devices such as computers mobiles and other devices. This interface uses icons, menus and other visuals, graphics by which user easily interacts.
- For example, Word processing, spreadsheet, and desktop-publishing programs are the typical examples where user-interface techniques are implemented.

2. Plotting and presentation

- Plotting bar charts histograms pie charts task scheduling charts are most commonly used plotting.
- Plotting is used to present data meaningfully and concisely
- Computer graphics are used for creating charts, bar diagrams and other visuals for the presentation purpose, with this user, can easily understand the points.
- Extensively used to plot and present 2D and 3D graphs of physical data, mathematical reports, scientific reports, economic and financial data/ functions and behavior.

3. Office Automation and electronics publishing.

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- Provides a full set of word-processing features as well as fine control over placement of text and graphics, so that you can create newsletters, advertisements, books, and other types of documents.
- It means by using a personal computer or workstation high-quality printed documents can be produced.
- Electronic publishing / desktop publishing system allows you more power to print the meaningful materials in-house.
- The most powerful desktop publishing systems enable you to create illustrations. While less powerful systems let you insert illustrations created by other programs.

- Office automation and electronic publishing can produce both traditional printed (Hardcopy) documents and electronic (softcopy) documents that contain text, tables, graphs, and other forms of drawn or scanned-in graphics
- A particularly important feature of desktop publishing systems is that they enable you to see on the display screen exactly how the document will appear when printed.
- Systems that support this feature are called WYSIWYGs (what you see is what you get). Until recently, hardware costs made desktop publishing systems impractical for most uses. But as the prices of personal computers and printers have fallen, desktop publishing systems have become increasingly popular for producing newsletters, brochures, books, and other documents that formerly required a typesetter.
- Once you have produced a document with a desktop publishing system, you can output it directly to a printer or you can produce a PostScript file which you can then take to a service bureau. The service bureau has special machines that convert the PostScript file to film, which can then be used to make plates for offset printing. Offset printing produces higher-quality documents, especially if color is used, but is generally more expensive than laser printing.

4. Computer aided Design

- Computer-aided design (CAD) is the use of computer technology for the design of objects, real or virtual.
- One of the major uses of computer graphics is to design components and systems of mechanical, electrical, electrochemical, and electronic devices, including structures such as buildings, automobile bodies, airplane and ship hulls, very large scale integrated (VLSI) chips, optical systems and telephone and computer networks.
- These designs are more frequently used to test the structural, electrical, and thermal properties of the systems.
- The design of geometric models for object shapes, in particular, is often called computer-aided geometric design (CAGD).
- CAD may be used to design curves and figures in two-dimensional ("2D") space; or curves, surfaces, or solids in three-dimensional ("3D") objects.

- CAD is also widely used to produce computer animation for special effects in movies, advertising, technical manuals.

5. **Digital Art:**

- Digital art most commonly refers to art created on a computer in digital form.
- Computer Graphics provide a new way of creating designs. Now Artists and designers use illustrator, coral draw, Photoshop, adobe muse and other different types of applications for creating new designs.
- The impact of digital technology has transformed traditional activities such as painting, drawing and sculpture, while new forms, such as net art, digital installation art, and virtual reality, have been recognized artistic practices.

6. **Web Design:**

- Web design is the skill of designing presentations of content usually hypertext or hypermedia that is delivered to an end-user through the World Wide Web, by way of a Web browser.
- The process of designing Web pages, Web sites, Web applications or multimedia for the Web may utilize multiple disciplines, such as animation, authoring, communication design, corporate identity, graphic design, human-computer interaction, information architecture, interaction design, marketing, photography, search engine optimization and typography.

7. **Education and Training**

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- For the educational or training purpose – A computer simulation, a computer model or a computational model can be used. Which is a computer program, or network of computers, that attempts to simulate an abstract model of a particular system.
- Computer simulations have become a useful part of mathematical modeling of many
 - a) natural systems in physics (computational physics), chemistry and biology,
 - b) Human systems in economics, psychology, and
 - c) Social science and in the process of engineering new technology, to gain insight into the operation of those systems, or to observe their behavior.

i. **Computational Biology:**

- Computational biology is an interdisciplinary field that applies the techniques of computer science, applied mathematics and statistics to address biological problems.

- The main focus lies on developing mathematical modeling and computational simulation techniques in biological sector.

ii. Computational Physics:

- Computational physics is the study and implementation of numerical algorithm to solve problems in physics for which a quantitative theory already exists.
- It is often regarded as a sub discipline of theoretical physics but some consider it an intermediate branch between theoretical and experimental physics.

iii. Information of Graphics:

- Information graphics or information graphics are visual representations of information, data or knowledge.
- These graphics are used where complex information needs to be explained quickly and clearly, such as in signs, maps, journalism, technical writing, and education.
- They are also used extensively as tools by computer scientists, mathematicians, and statisticians to ease the process of developing and communicating conceptual information.

iv. Scientific and business Visualization:

- Scientific visualization is a branch of science, concerned with the visualization of three-dimensional phenomena, such as architectural, meteorological, medical, biological systems.
- Generating computer graphics for scientific, engineering, and medical data sets is termed as scientific visualization whereas business visualization is related with the non-scientific data sets such as those obtained in economics. Visualization makes easier to understand the trends and patterns inherent in the huge amount of data sets. It would, otherwise, be almost impossible to analyze those data numerically

- Scientific visualization focuses on the use of computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results.

8. Simulation and modeling

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- Simulation is the imitation of the conditions like those, which is encountered in real life. Simulation thus helps to learn or to feel the conditions one might have to face in near future without being in danger at the beginning of the course.
- For example, astronauts can exercise the feeling of weightlessness in a simulator; similarly, a pilot training can be conducted in flight simulator.
- The military tank simulator, the naval simulator, driving simulator, air traffic control simulator, heavy-duty vehicle simulator, and so on are some of the mostly used simulators in practice.
- Simulators are also used to optimize the system, for example the vehicle, observing the reactions of the driver during the operation of the simulator

9. Entertainment

- Disney movies such as Lion Kings and The Beauty of Beast, and other scientific movies like Jurassic Park, Avatar, The lost world etc. are the best example of the application of computer graphics in the field of entertainment.
- Instead of drawing all necessary frames with slightly changing scenes for the production of cartoon-film, only the key frames are sufficient for such cartoon-film where the in between frames are interpolated by the graphics system dramatically decreasing the cost of production while maintaining the quality.
- Computer and video games such FIFA, PUBG, Doom, Pools are few to name where graphics is used extensively.

10. Cartography

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- Cartography is a subject, which deals with the making of maps and charts.
- Computer graphics is used to produce both accurate and schematic representations of geographical and other natural phenomena from measurement data.
- Examples include geographic maps, oceanographic charts, weather maps, contour maps and population-density maps. Surfer is one of such graphics packages, which is extensively used for cartography.

COMPONENTS OF COMPUTER GRAPHICS

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- ❖ Interactive computer Graphics consist of three components
 - ✓ Digital buffer,
 - ✓ TV monitor and
 - ✓ Display controller.
- ❖ Using these components, we are able to see the output on the screen in form of pixels (picture elements).
- ❖ Following is the explanation of these components

1. Digital Memory Buffer

- ❖ This is a place where images and pictures are stored as an array (matrix of 0 & 1, 0 represents darkness and 1 represents image or picture).
- ❖ Digital memory buffer also called **frame buffer**.
- ❖ In today's term frame buffer is called V-RAM (video RAM) and it helps to store the image in bit form. It helps to increase the speed of graphics (sometimes we watch movies on our computer system and movie run slowly. System engineer is then called for. He/ She comes and fits in V-RAM (in Megabytes) into our system and movie runs perfectly.

2. TV Monitor

- ❖ Monitor helps us to view the display and they make use of CRT technology (Cathode ray Tube).

3. Display Controller

- ❖ It is an interface between Memory Buffer and TV Monitor.
- ❖ Its job is to pass the contents of frame buffer to the monitor. This passing has to be fast for steady display on the monitor (depending upon the material of the system). The image must be passed repeatedly to the monitor to maintain a steady picture on the screen.

- ❖ The display controller reads each successive byte of data from FB Memory and converts 0's and 1's into corresponding video signals. This signal is then feed to the TV monitor to produce a black and white picture on screen.
- ❖ In today's term, display controller is recognized as a display card and one of our choices can be VGA card with a resolution of 640x480. (Display Controller is also capable of displaying image in colors).

Recent Trends of Computer Graphics

There are lots of exciting trends in computer graphics driven by advances in research, hardware, and increasing demand from games, film, AR/VR, and industry. Here are some of the major recent trends in computer graphics:

1. Real-time ray tracing

- Ray tracing is a technique that simulates the realistic behavior of light, shadows, reflections, and refractions in 3D scenes.
- It creates stunning and immersive visuals, but it is also computationally intensive and requires powerful hardware.
- However, recent advances in GPU technology and software optimization have enabled real-time ray tracing for interactive applications, such as games, VR, and AR.
- To prepare for this trend, familiarization with the principles and tools of ray tracing, such as the NVIDIA RTX platform, DirectX Raytracing, and Vulkan Ray Tracing are required.

2. Generative adversarial networks

- Generative adversarial networks (GANs) are a type of neural network that can generate realistic and diverse images, videos, sounds, and texts from scratch or based on some input.
- GANs consist of two components: a generator that tries to create convincing outputs, and a discriminator that tries to distinguish between real and fake outputs. The two components compete and learn from each other, improving their performance over time.
- GANs have many applications in computer graphics, such as content creation, style transfer, image synthesis, face manipulation, and animation.

- To prepare for this trend, understanding of the basic concepts and architectures of GANs, as well as the ethical and social implications of their use are required.

3. Procedural content generation

- Procedural content generation (PCG) is a method that uses algorithms and rules to create large amounts of varied and complex content automatically or semi-automatically.
- It can reduce the cost and time of manual content creation, as well as enhance the replay ability and diversity of games and simulations. PCG can generate different types of content, such as landscapes, buildings, characters, items, quests, stories, and music.
- To prepare for this trend, techniques and frameworks of PCG, such as noise functions, grammars, cellular automata, L-systems, and evolutionary algorithms are required.

4. Virtual production

- Virtual production is a process that integrates real-time computer graphics with live-action filmmaking.
- It allows directors, actors, and crew members to visualize and manipulate digital environments and assets on set, using tools such as motion capture, green screens, LED walls, and VR headsets.
- Virtual production can enhance the creative and collaborative possibilities of filmmaking, as well as reduce the post-production workload and costs.
- To prepare for this trend, skills and software of virtual production, such as Unreal Engine, Unity, Blender, Maya, and MotionBuilder should be known.

5. Machine learning for computer graphics

- Machine learning is a branch of artificial intelligence that enables computers to learn from data and perform tasks that are difficult or impossible to program explicitly.
- Machine learning has many applications in computer graphics, such as image processing, computer vision, natural language processing, audio synthesis, and data analysis.
- Machine learning can improve the quality, efficiency, and innovation of computer graphics, as well as open new horizons for research and development.

- To prepare for this trend, knowledge and skills of machine learning, such as statistics, linear algebra, calculus, programming, Python, TensorFlow, PyTorch, and Keras should be acquired.

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1.2. Interactive Input Devices

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 number 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 ($1/10^{\text{th}}$ 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

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 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 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.

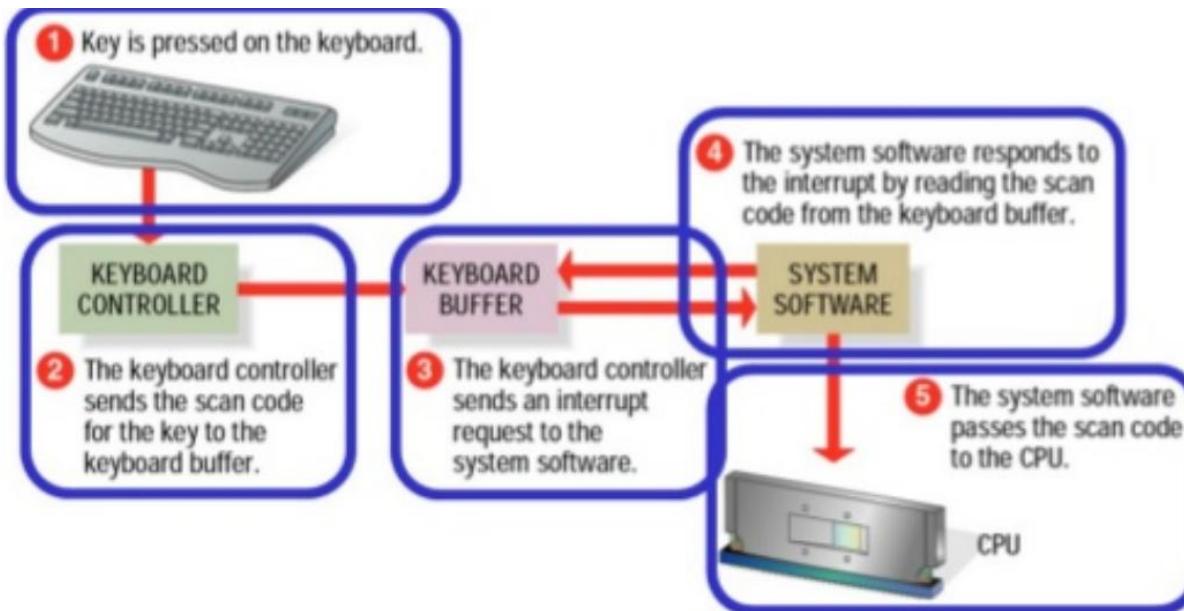


Figure: working mechanism of keyboard

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.

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)

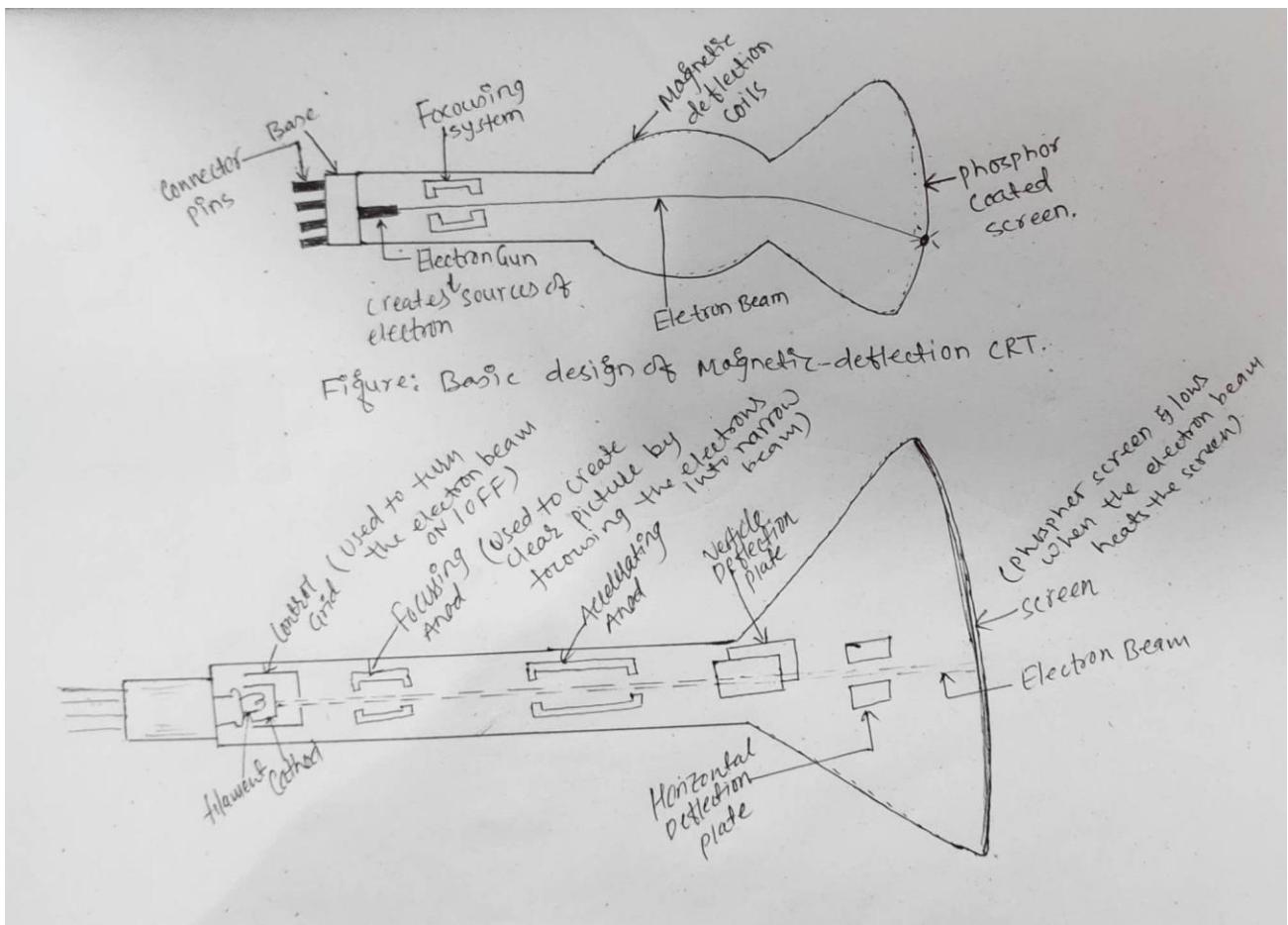
Cathode Ray Tube (CRT)

- ❖ 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



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.

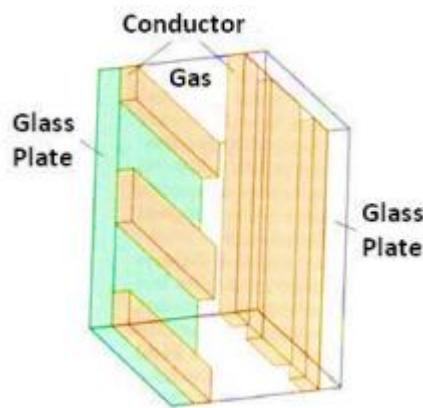
Flat Panel Display

- ❖ **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)

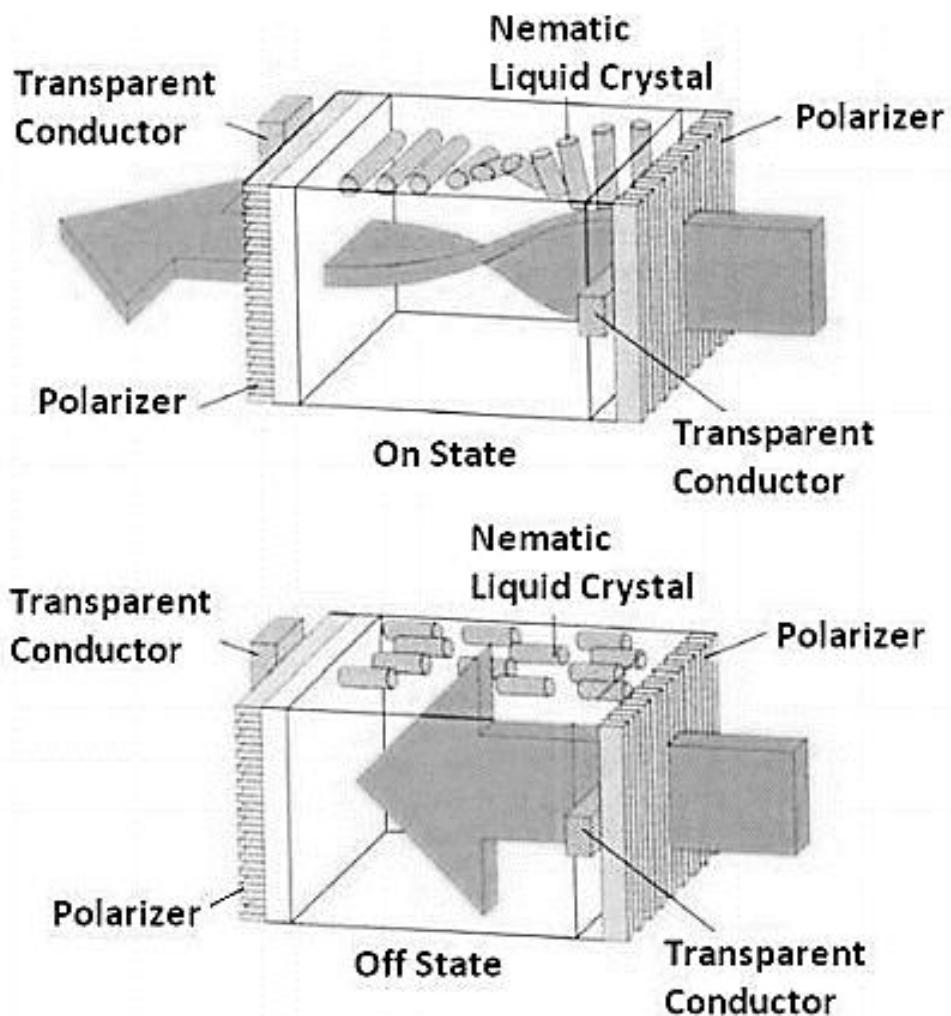


Figure: Design of LCD by using light twisting shutter effect

- ❖ 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 conductors 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

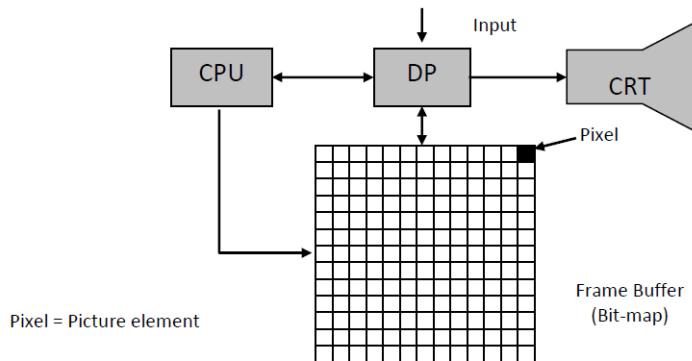


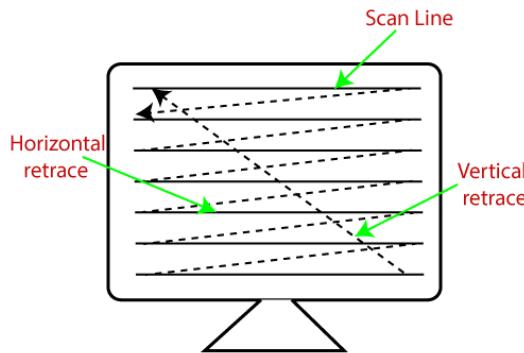
Figure: Raster Scan display system

- ❖ 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

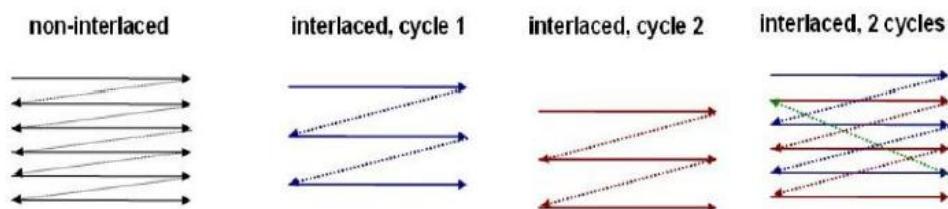
I) Retrace procedure

- ❖ 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 be displayed 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

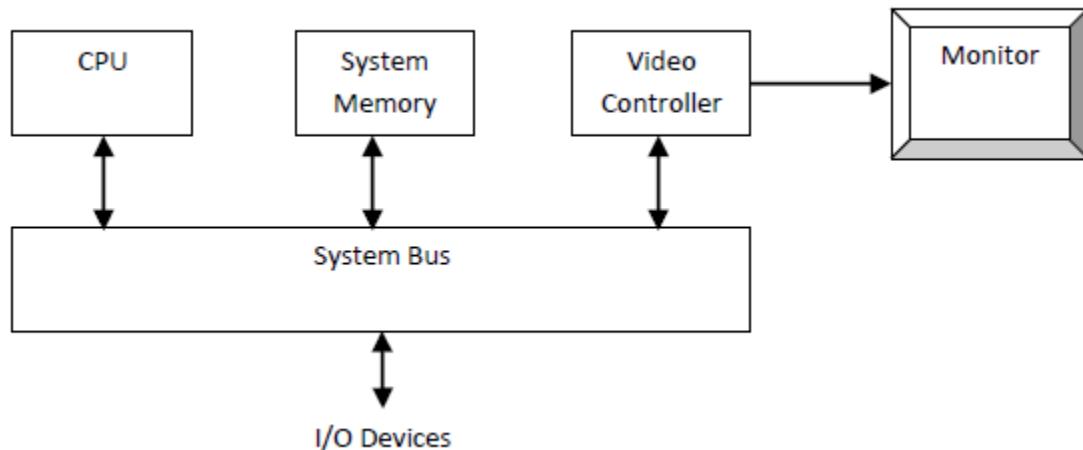


Figure: Architecture of simple raster graphics system.

- ❖ 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

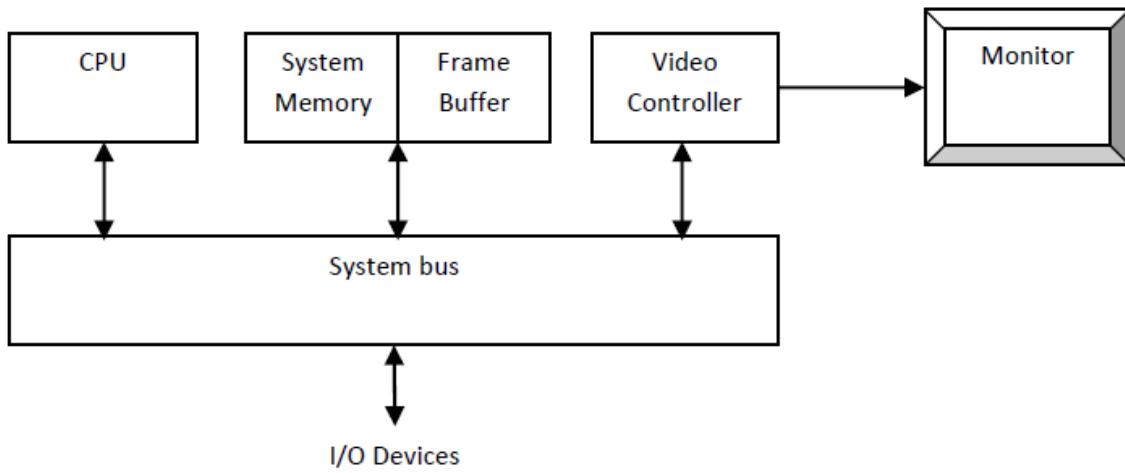
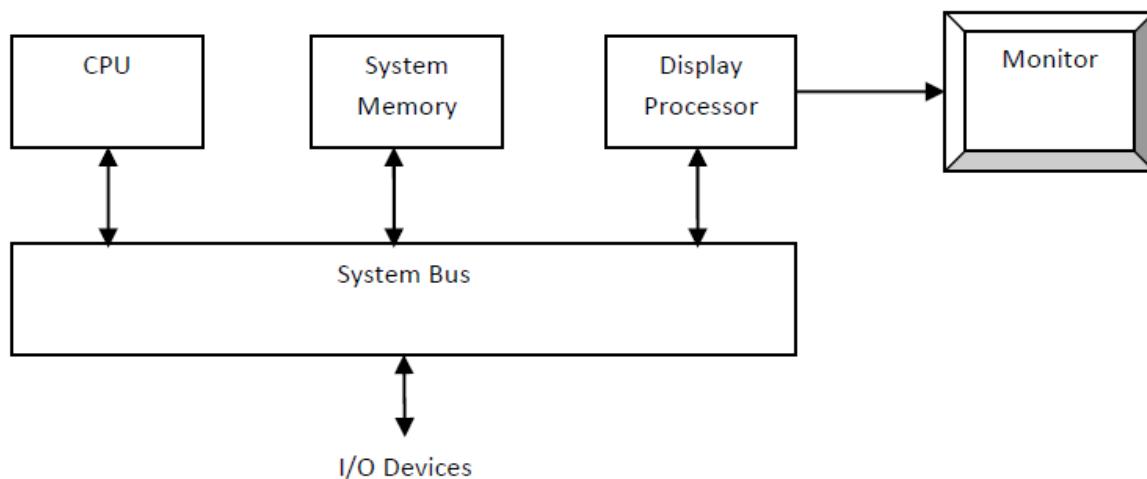


Figure: Architecture of a raster graphics system with a fixed portion of the system memory reserved for the frame buffer

- ❖ 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

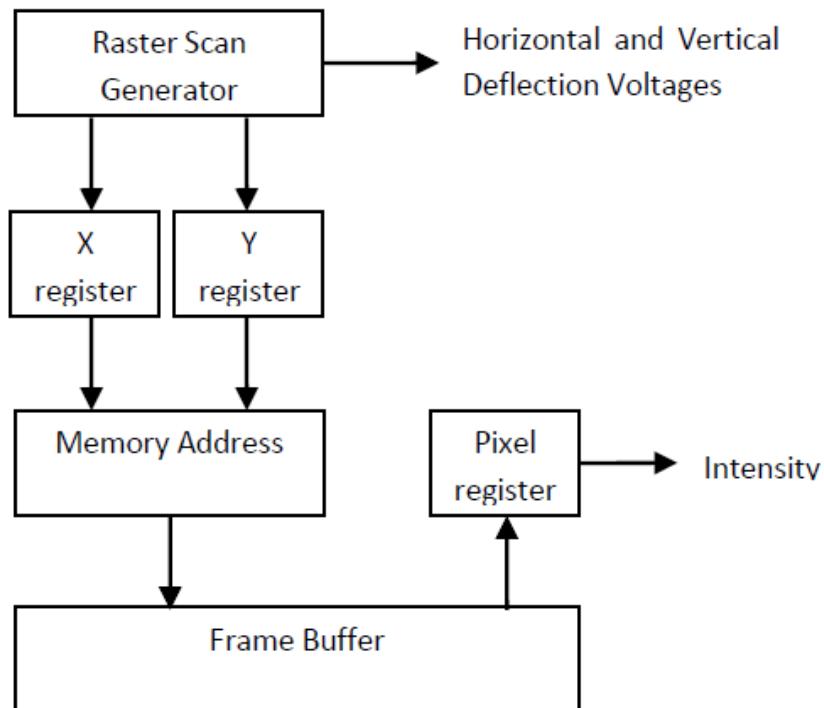


Figure: basic video controller refresh operation.

- ❖ 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 ($Y=Y_{\text{max}}$) 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.	<i>Electron Beam</i>
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	<i>Resolution</i>
Picture definition is stored as a set of intensity values for all screen	Picture definition is stored as a set of line in a display list or file.	<i>Picture definition</i>

points (pixels) in a refresh buffer.		
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.	<i>Realistic display</i>
Screen points or pixels are used to draw an image.	Mathematical functions are used to draw an image	<i>Image drawing</i>
They are cheaper than random display.	It is more expensive than raster-scan display.	<i>cost</i>
Refresh rate Refresh rate is 60-80 fps.	All components are drawn—30 to 60 times per second.	<i>Refresh Rate</i>
Interlacing It uses interlacing.	It doesn't use interlacing	<i>Interlacing</i>
Editing Editing is difficult	Editing is easy	<i>Editing</i>
Refresh area Refresh area is independent of picture complexity.	Refresh area depends on complexity of picture	<i>Refresh area</i>
Smoothness Produce jagged line.	Produce smooth line.	<i>Smoothness</i>
CRT, TV, Printer	Pen Plotter	<i>Example</i>

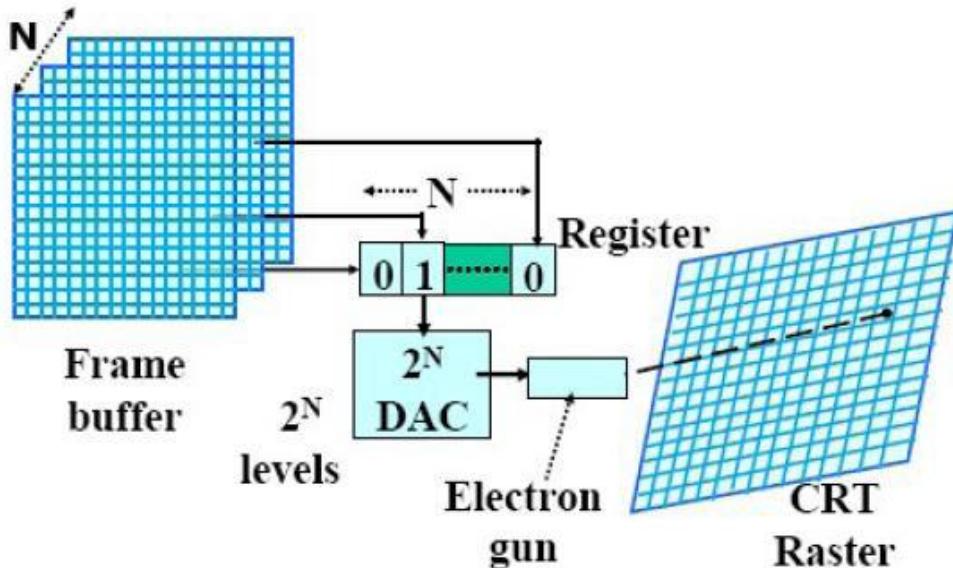
2.5 Use of Digital to Analog Converter and Frame Buffer Organization

- ❖ 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.

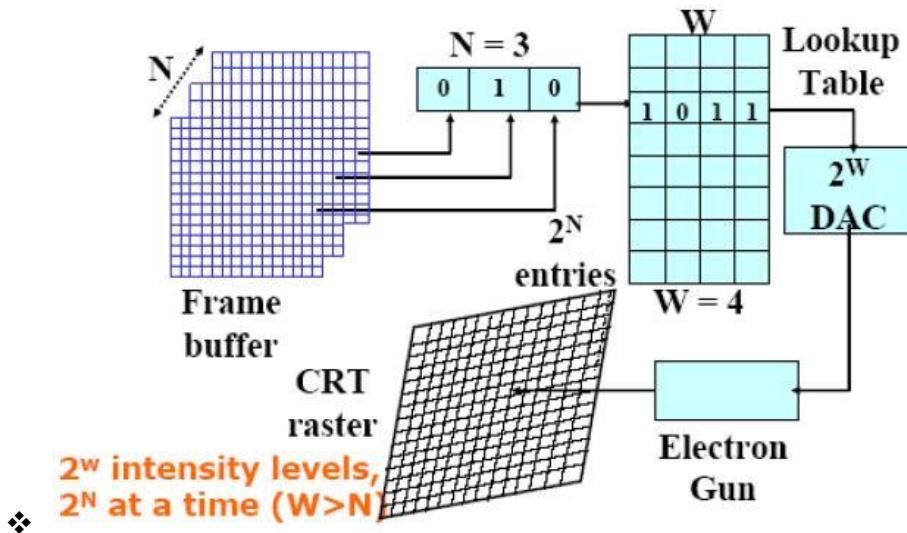
- ❖ We know that a memory bit has only two states, therefore a single bit plane yields a black-and white display.
- ❖ We know that a frame buffer is a digital device and the CRT is an analog device. Therefore, a conversion from a digital representation to an analog signal must take place when information 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

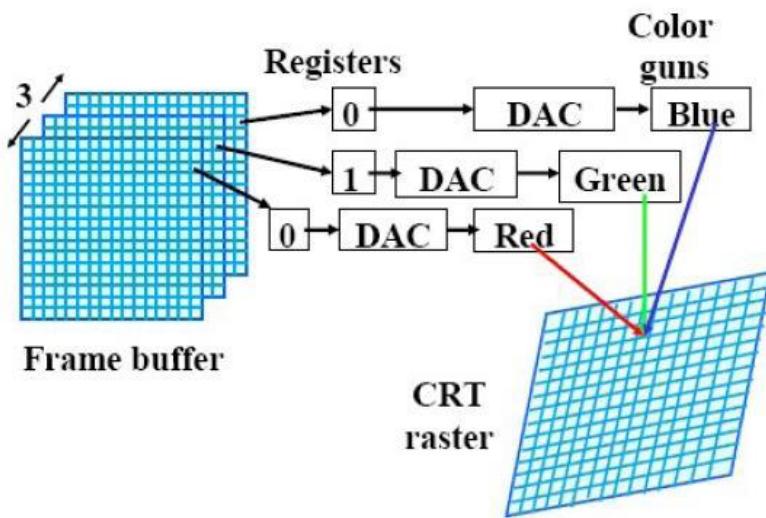
- ❖ Color or gray scales are incorporated into a frame buffer raster graphics device by using additional bit planes.
- ❖ The intensity of each pixel on the CRT is controlled by a corresponding pixel location in each of the N bit planes.
- ❖ The binary value from each of the N bit planes is loaded into 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.



- ❖ 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

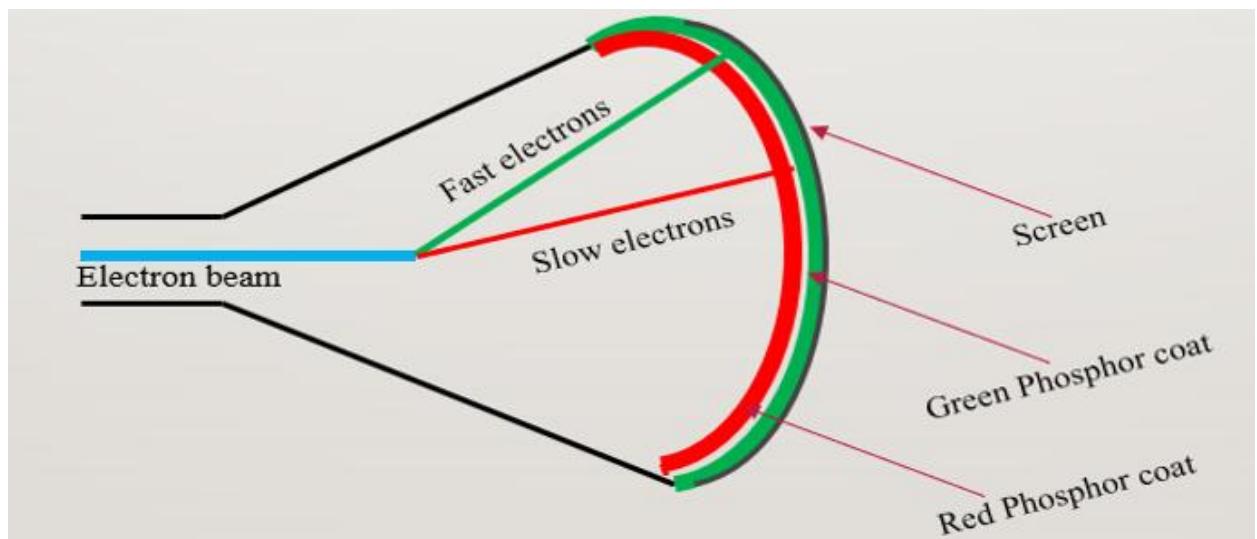
2.6 Color Monitors

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.

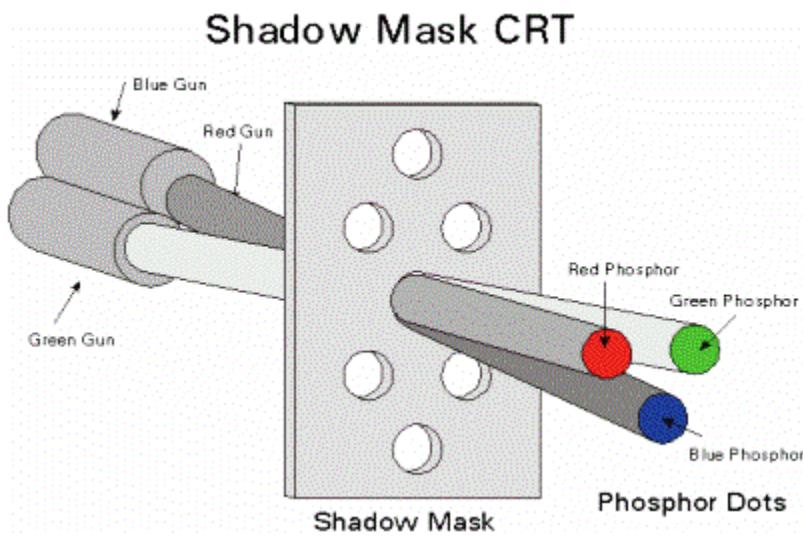


Working:

- ❖ 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 red 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:

$$\text{Resolution} = 1024 * 1024$$

$$\text{Total number of pixel} = 1024 * 1024 = 1048576 \text{ pixels}$$

$$\text{Bits per pixels storage} = 24 \text{ bits}$$

$$\text{Therefore, total storage required in frame buffer} = 1048576 * 24 = 25165824 \text{ bits}$$

$$\begin{aligned} &= 25165824 / 8 \text{ Byte} \\ &= 25165824 / (8 * 1024) \text{ Kb} \\ &= 25165824 / (8 * 1024 * 1024) \text{ Mb} \\ &= 3 \text{ Mb} \end{aligned}$$

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.

$$\begin{aligned} \text{Then, the size of frame buffer} &= \text{Resolution} * \text{bits per pixel} = (600 * 400) * n \text{ bits} \\ &= 240000 n \text{ bits} \end{aligned}$$

$$\begin{aligned}
 &= 240000 \text{ n kb} / (8 * 1024) \\
 &= 29.30 \text{ n k bytes.}
 \end{aligned}$$

- 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

$$\begin{aligned}
 &= 6400000 \text{ bits} \\
 &= 6400000 / 8 \text{ bytes} \\
 &= 800000 \text{ Bytes}
 \end{aligned}$$

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

Solution:

We know that,

$$\begin{aligned}
 \text{Aspect ratio} &= \text{Width} / \text{Height} \\
 &= (8 \times 100) / (10 \times 100) \\
 &= 4 / 5
 \end{aligned}$$

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

$$\begin{aligned}
 \text{1 frame need } 1 / 60 \text{ second} &\rightarrow 786432 \text{ pixels need } 1 / 60 \text{ second} \\
 &\rightarrow 1 \text{ pixels need } 1 / (60 * 786432) \text{ second} \\
 &\rightarrow 10^9 / (60 * 786432) \text{ ns} \\
 &\rightarrow 21.19 \text{ ns}
 \end{aligned}$$

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 = $640 * 480 * 8$

$$= 2457600 \text{ bits.}$$

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

$$\begin{aligned}
 &= 92160000 / 10^9 \\
 &= 0.09216 \text{ seconds}
 \end{aligned}$$

i.e. 1 cycle take 0.09216 second

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

$$0.09216 \text{ seconds} = 1 \text{ cycle}$$

$$1 \text{ second} = 1 / 0.09216 = 10.86$$

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

$$= 10^9 / (50 * 12 * 100 * 12 * 100) \text{ ns}$$

$$= 13.88 \text{ ns}$$

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