Class code:

msqi5sz

Chapter 1
Overview of Computer Graphics and Graphics Systems

Credit hours: 7 hrs

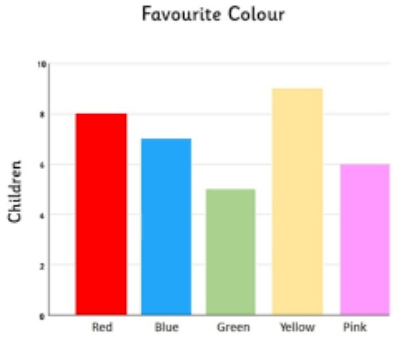
Content:

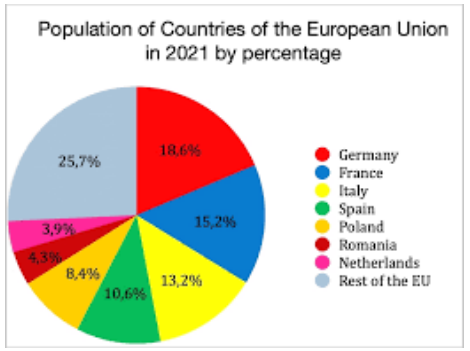
1. Introduction, Applications and Recent trends of Computer Graphics
2. Interactive Input Devices
3. Display Devices, Color Monitors, Hard Copy Devices
4. Raster and Random Scan Systems and Architectures
5. Video Controller
6. Use of Digital to Analog Converter and Frame Buffer Organization
7. Graphics Software, Modern Graphics Hardware (GPU)*

**Newly introduced*

1.1 Introduction to Computer Graphics

- Till recently the output obtained from a computer has been alphanumeric.
- It is well known that anything presented in graphical and pictorial form tremendously aids human comprehension.
- Examples:
  - bar charts, pie charts sales graphs are commonly used by managers.
  - Building plans, perspective views are used by architects.
  - Engineers use mechanical drawings, circuit diagrams in their work.





Chinese proverb

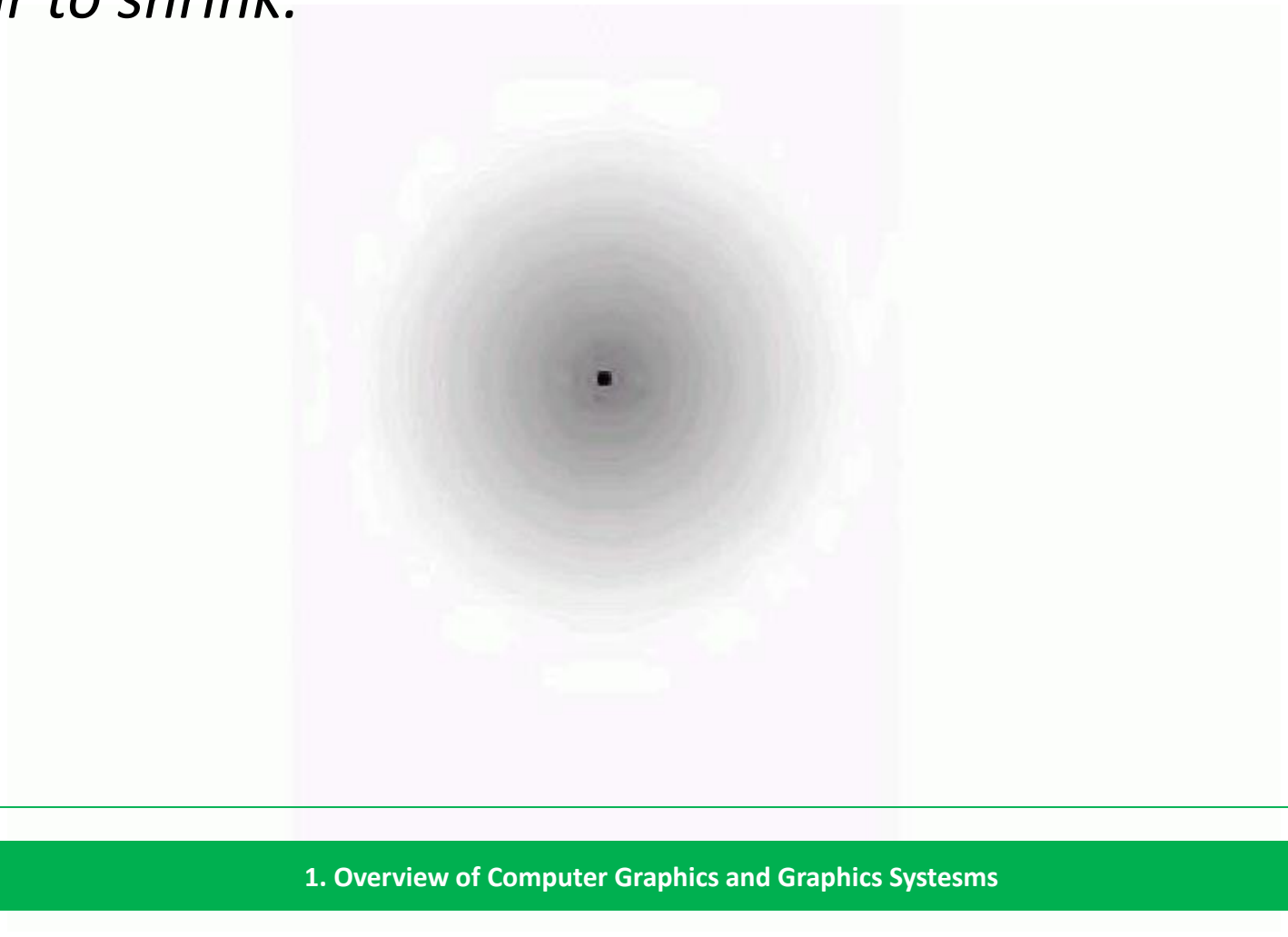
“a picture is worth ten thousand words”

- **Graphics** are defined as any sketch or a drawing or a special network that pictorially represents some meaningful information.
- **Computer graphics** is an art of drawing pictures on computer screens with the help of programming.
- It involves computations, creation, and manipulation of data.
- In other words, we can say that computer graphics is a rendering tool for the generation and manipulation of images.

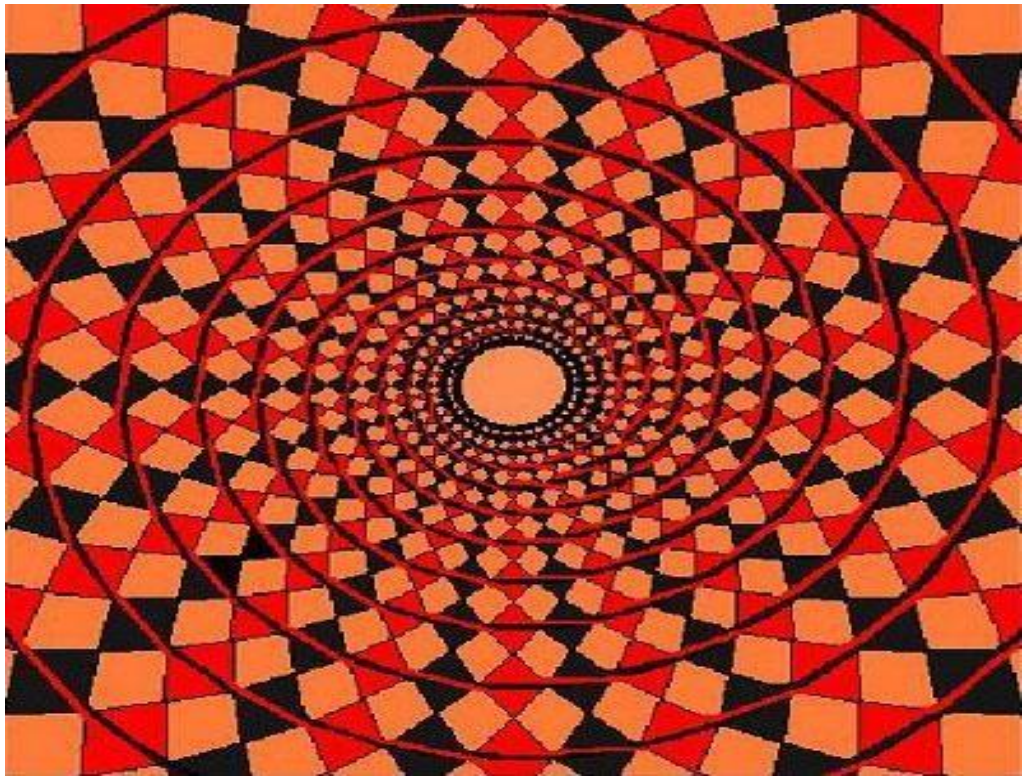
- Computer Graphics is a field related to the generation of graphics using computers.
- It includes the creation, storage, and manipulation of images of objects.
- These objects come from diverse fields such as physical, mathematical, engineering, architectural, abstract structures and natural phenomenon.
- Computer graphics today is largely interactive, i.e. user controls the contents, structure, and appearance of images of the objects by using input devices, such as keyboard, mouse, or touch-sensitive panel on the screen.


REAL COFFEE
ICE
BREAK
REGULAR
STRENGTH

- *Keep staring at the black dot. After a while, the gray haze around it will appear to shrink.*




Created with Stereographic Suite
http://www.indasoftware.com/stereo/



Recap:

- Computer graphics is concerned with the generation, representation, manipulation and display of pictures with the aid of a computer.
- The Process transforms and presents information in a visual form.
- Image created by computer is called computer graphics.

1.2 History of Computer Graphics

- Crude plotting of hardcopy devices such as **teletypes** and **line printers** dates from the early days of computing.
- Data was displayed on printers or hardcopy plotters

- 1950s
  - Early projects like the Whirlwind and SAGE Projects introduced the CRT as a viable display and interaction interface and introduced the light pen as an input device.
  - The **whirlwind computer** developed in 1950 at the Massachusetts Institute of Technology (MIT) had **computer driven CRT displays** for output.

- SAGE (Semi-Automated Ground Environment) air-defense system used **command and control CRT** display consoles
- The operator identified targets with light pens using CRT display consoles.

- One of the first **interactive video games** to feature recognizable, interactive graphics – *Tennis for Two*– was created for an oscilloscope by William Higinbotham to entertain visitors in 1958 at Brookhaven National Laboratory and simulated a tennis match.

- **Ivan Sutherland (1963) – SKETCHPAD**
  - Considered founder of Computer graphics field
  - Beginnings of modern interactive graphics attributed to Ivan Sutherland's doctoral work
  - presented work at Spring Joint Computer Conference in 1963 in the form of a movie.
  - He developed the Sketchpad drawing system
  - He formulated the ideas of display primitives (lines, polygons, arcs, characters)
  - Because of his work, CAD and CAM became attractive.

- Hardware expensive
- Large scale, extensive computing resources needed
- About 1965, IBM brought out the first widely available interactive computer graphics terminal : Vector Graphics Display
- A Special type of CRT produced by Tektronix- the Direct-view Storage tube (DVST) was introduced in 1968.
- It had keyboard, mouse and simple computer interface.

- Raster Graphics
  - By late 60’s, may researchers were concerned with dynamic graphics.
  - TV raster displays were used to create images for realistic flight simulation application and so on.

Xerox Alto

- Hardware and software development continued.

Summary:

- **1950s-1960s: Early Foundations**
  - **1950s:** The earliest computer graphics were simple line drawings created by computers like the Whirlwind I at MIT.
  - **1960s:** Ivan Sutherland's Sketchpad (1963) is a significant milestone, allowing users to interact with graphics using a light pen.
- **1970s: Birth of 3D Graphics**
  - **1972:** The first video game, "Pong," introduces basic computer graphics to the public.
- **1980s: Advancements in Hardware and Software**
  - **1983:** Apple releases the Apple Lisa with a graphical user interface (GUI).

- **1990s: Rise of 3D Graphics and Video Games**
  - **1992:** The first widely-used version of OpenGL is released.
  - **1995:** The release of Windows 95 includes a GUI and DirectX, a collection of APIs for multimedia tasks.
- **2000s: Graphics Processing Units (GPUs) and Realism**
  - **2000:** NVIDIA introduces the GeForce 256, the first GPU.
  - **2001:** The film "Shrek" showcases the capabilities of computer-generated imagery (CGI).
  - **2007:** Apple releases the first iPhone, revolutionizing mobile graphics.

- **2010s: Virtual Reality (VR) and Augmented Reality (AR)**
  - **2010:** The launch of the Kinect sensor for Xbox, showcasing motion-controlled gaming.
  - **2012:** Oculus Rift Kickstarter campaign marks the beginning of the modern VR era. Launch of the Oculus Rift, a virtual reality headset.
  - **2016:** Pokémon Go brings augmented reality to the mainstream.
- **2020s: Continued Advancements**
  - **2020s:** Ongoing developments in ray tracing, AI-powered graphics, and real-time rendering.
  - **2022:** Continued growth in virtual and augmented reality applications.
  - **2023 (Projected):** Anticipated advancements in graphics technology driven by AI and machine learning.

- More detailed Study:
  - https://ohiostate.pressbooks.pub/graphicshistory/back-matter/cg-historical-timeline/
  - https://www.thecrazyprogrammer.com/2021/07/history-of-computer-graphics.html
  - https://www.tutorialandexample.com/history-of-computer-graphics

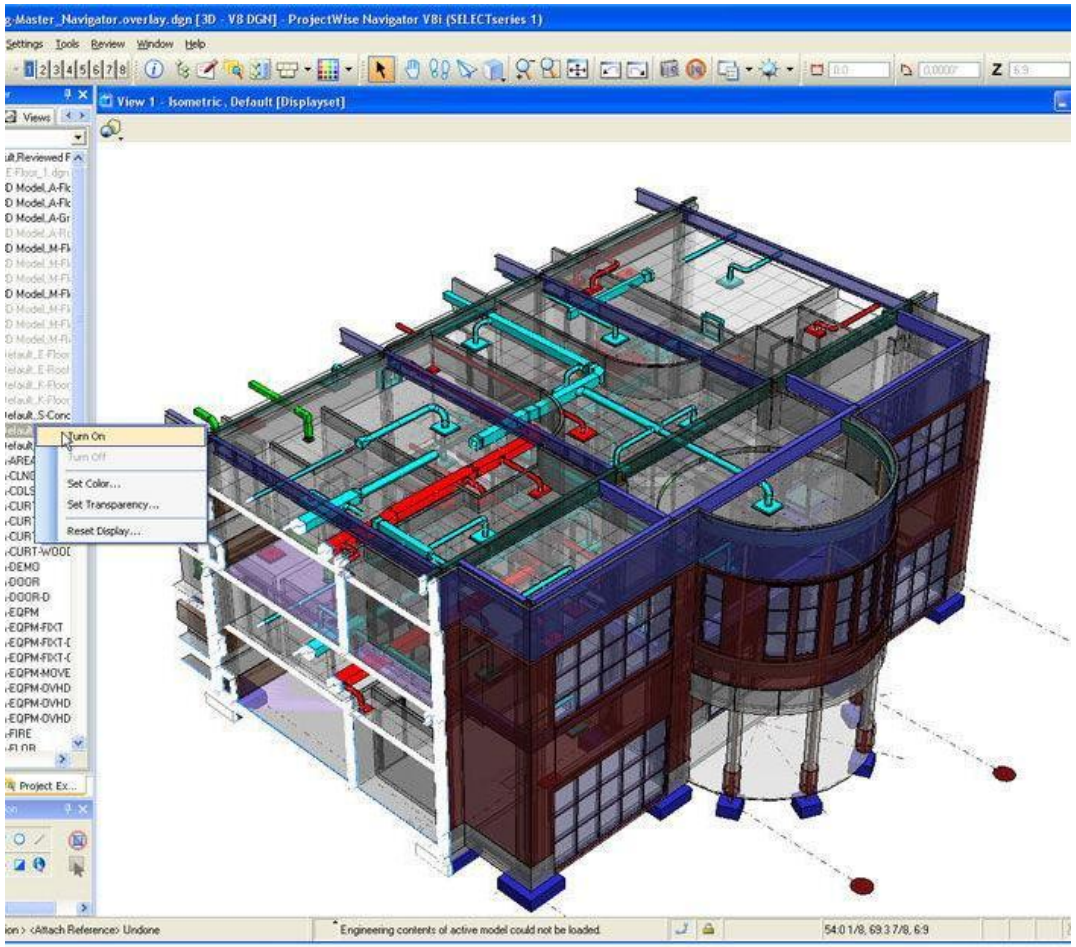
1.3 Application of Computer Graphics

- Computer Aided Design (CAD)
- Presentation Graphics
- Computer Art
- Entertainment
- Education and Training
- Visualization
- Image Processing
- Graphical User Interfaces (GUIs)
- Simulation
- Cartography

i) Computer Aided Design (CAD)

- In CAD, graphics is used to design components and systems of mechanical, electrical, electro-mechanical and electronic devices including structures such as buildings, automobile bodies, airplane, VLSI chips, optical systems and telephone and computer networks.
- Objects are displayed in wireframe outline that shows the overall shape and internal features of objects.

- Architects use computer graphics to layout floor plans that shows positioning of rooms, doors, windows, stairs, shelves and other building features.
- Electrical designers then try out arrangements for wiring, electrical outlets and other system to determine space utilization on a building.

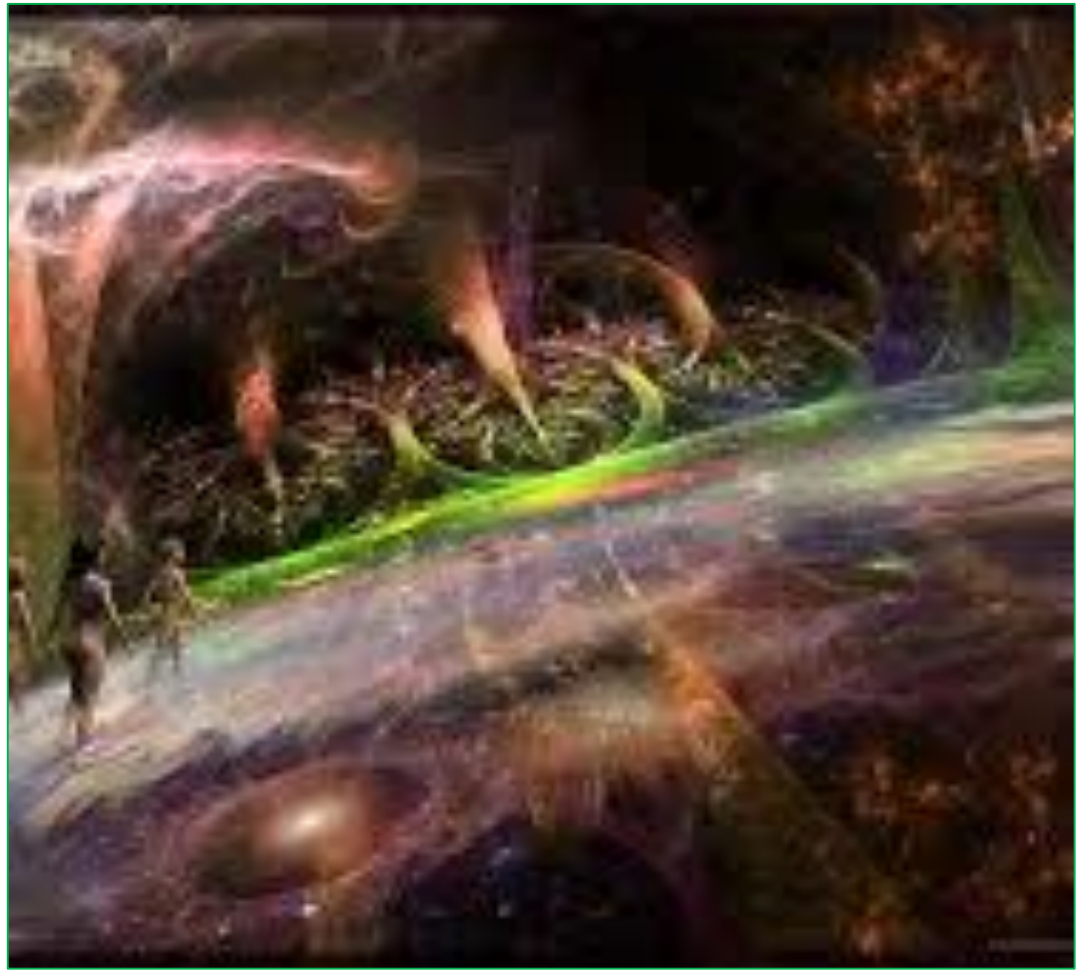


ii) Presentation Graphics

- Presentation Graphics is commonly used to summarize financial, statistical, mathematical, scientific and economic data for research reports, managerial reports and other types of reports.
- Typical examples are bar charts, line graphs, surface graphs, pie charts and other displays showing relationship between multiple variables

iii) Computer Art

- Computer graphics is used to generate arts.
- Mathematics packages, CAD packages, desktop publishing software and animation packages providing facilities



iv) Entertainment and Gaming

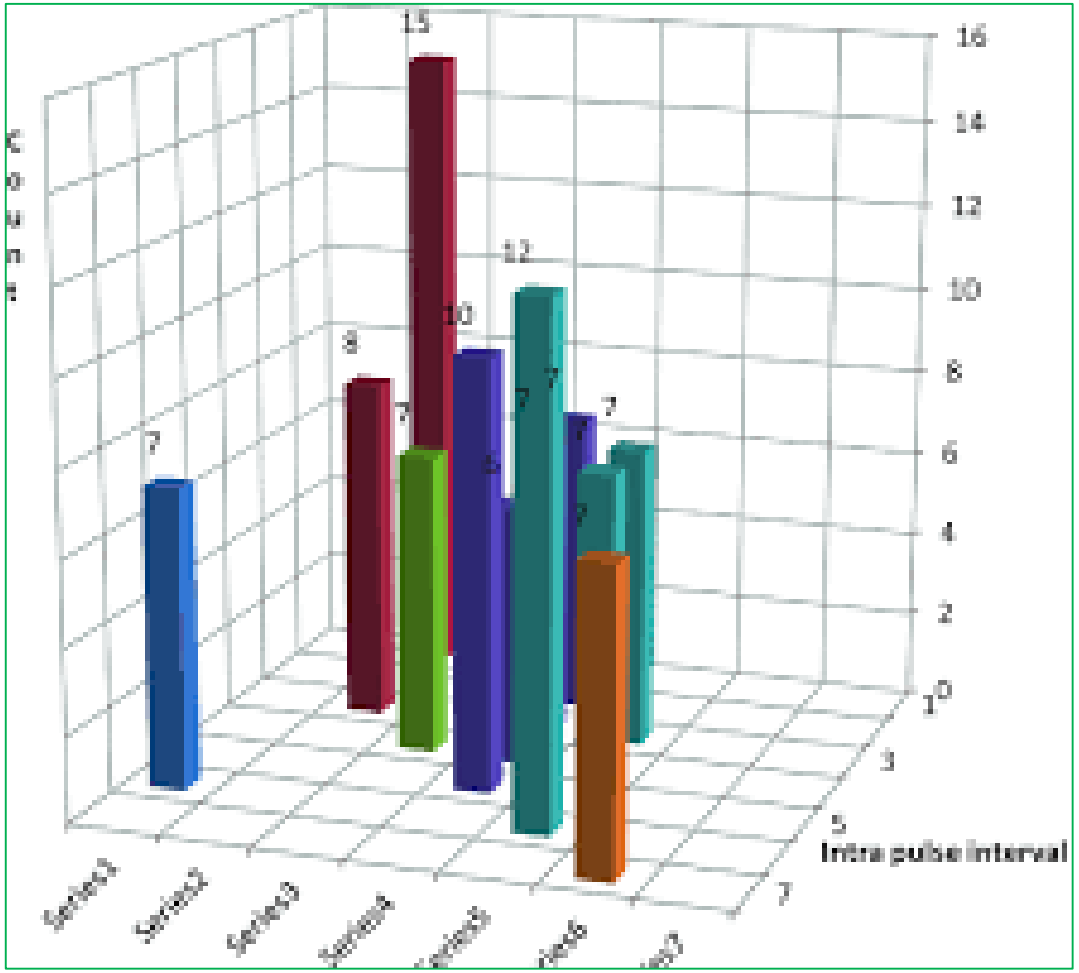
- Computer graphic is extensively used in the production of motion pictures, music, videos and TV shows.
- Sometimes graphic scenes are displayed by themselves and sometimes graphic objects are combined with actors and live scenes
- Image processing techniques such as morphing can be used to produce transformation of one person or object in another
- A graphics scenes generated for the movie AVTAAR.

v) Education and Training

- Computer graphics is used in education and training for making it more effective and more illustrative.
- Computer generated models of physical, financial, and economic systems are often used as educational aids.
- A student can learn surgery using data gloves and realistic computer graphics.

vi) Visualization

- 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.



vii) Image Processing

- Image can be created using simple point program or can be fed into computer by scanning the image.
- These picture/ images need to be changed to improve the quality.
- For image/pattern recognition systems, images need to be changed in specified format so that the system can recognize the meaning of the picture.
- Currently computer graphics is widely used for image processing.

VIII) Graphical User Interface (GUI)

- GUIs have become key factors for the success of the software or operating system.
- GUI provides point-and-click facilities to allow users to select menu items, icons, and objects on the screen.
- Word processing, spreadsheet, and desktop-publishing programs are typical applications that take advantage of user-interface technique.

ix) Simulation

- A representation of a problem, situation, etc. in mathematical terms, using a computer is called simulation.
- Computer Simulation is the process of mapping the real-world scenarios into mathematical model using computer graphics.
- Recently computer graphics is widely used to create simulated environment.
- E.g.; Robot Operation Simulation, Pilot Training, Military Training etc.

X) Cartography

- Cartography is the study and practice of designing maps using computer graphics.
- Computer graphics is used to produce both accurate and schematic representations of geographical and other natural phenomena from measurement data.
- Examples include geographic maps, exploration maps, for drilling and mining, oceanographic charts, weather maps etc.

Assignment:

- Computer Aided Design (CAD)
- Computer Aided Manufacturing (CAM)
- Computer Graphics Vs Image Processing

1.4 Advantages of Computer Graphics

1. **Visualization:** Simplifies complex data representation and aids in architectural design.
2. **Entertainment and Media:** Drives animation, gaming, and special effects in films and games.
3. **Education:** Enhances learning through interactive visuals and realistic simulations.
4. **Medical Imaging:** Crucial for diagnostic imaging, surgery planning, and medical training.
5. **Design and Creativity:** Used in graphic design, product design, and prototyping.
6. **Communication:** Improves communication through visual elements like infographics and UI design.
7. **Research and Simulation:** Facilitates scientific visualization and real-world simulation for various industries.
8. **Efficiency and Cost Savings:** Reduces the need for physical prototypes, enables remote collaboration, and optimizes processes.

1.5 Disadvantages of Computer Graphics

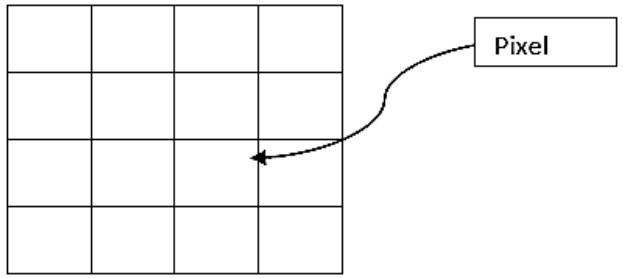
1. **Costly Equipment:**
   - *High Initial Investment:* Expensive hardware and software can be a barrier.
2. **Complexity:**
   - *Learning Curve:* Mastering graphics software can be challenging.
3. **Health Issues:**
   - *Eye Strain:* Prolonged use may cause discomfort and eye strain.
4. **Dependency on Technology:**
   - *Reliance on Electricity:* Susceptible to power outages and technical issues.
5. **Skill Dependence:**
   - *Skill Disparities:* Quality varies based on user skills.
6. **Intellectual Property Concerns:**
   - *Piracy:* Digital art is vulnerable to unauthorized use and piracy.
7. **Isolation of Traditional Art Forms:**
   - *Loss of Handcraftsmanship:* Traditional skills may decline.
8. **Ethical and Social Concerns:**
   - *Misuse in Media:* Graphics can be manipulated, raising authenticity concerns.
   - *Impact on Employment:* Automation may lead to job displacement.
9. **Environmental Impact:**
   - *Energy Consumption:* Intensive tasks contribute to energy consumption.
10. **Standardization Challenges:**
    - *Compatibility Issues:* Different formats may lead to collaboration challenges.

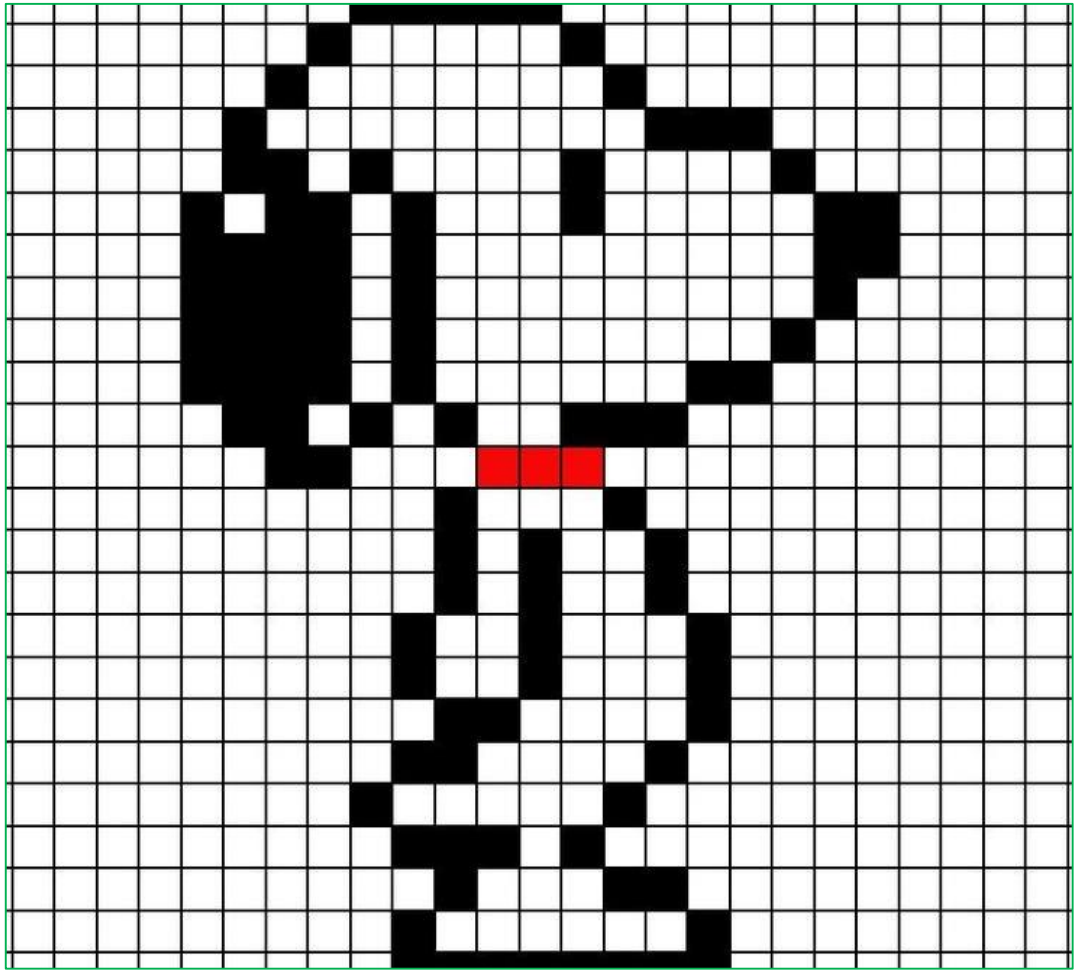
1.6. Basic Terminologies in Computer Graphics

- Pixel
- Resolution
- Aspect ratio
- Refresh rate
- Bit depth
- Frame buffer

Pixel

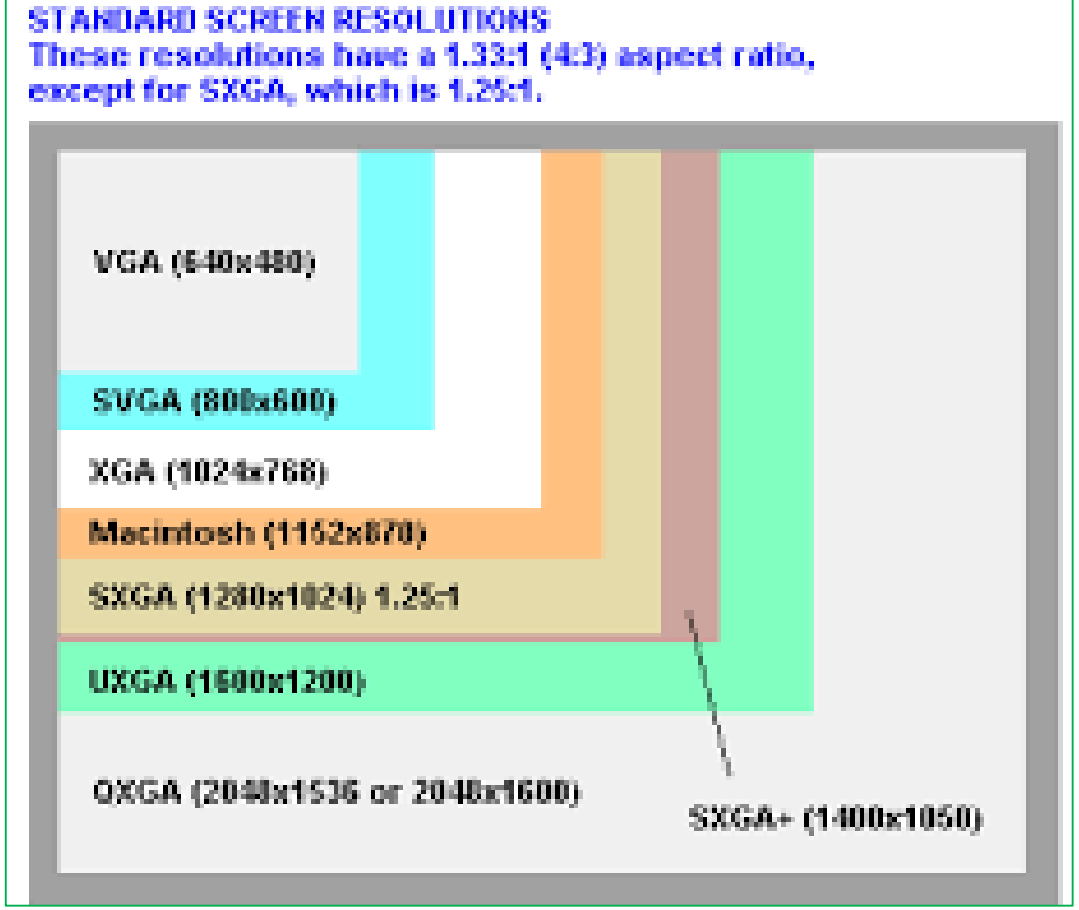
- Graphic images are made up of tiny dots called pixels.
- Each pixel has a particular address on the screen
- The smallest indivisible unit of a digital image.
- An image is a two dimensional array of pixels.





Resolution

- Resolution is defined as the maximum number of points that can be displayed horizontally and vertically without overlap on the display device.
- It is defined as the maximum number of pixels or dots can be displayed on the screen.
- Examples:800 by 600 pixels,1024 by 768 pixels,1152 by 864 pixels etc.

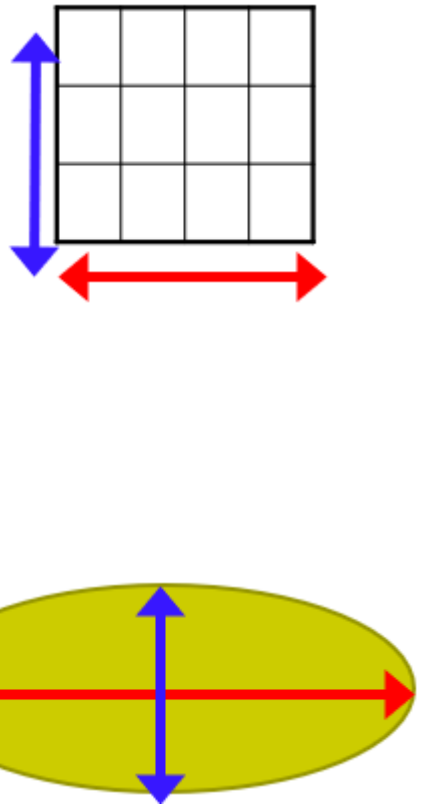


Code	Name	Aspect ratio	Width	Height
XGA	eXtended Graphics Array	4:3	1024	768
XGA+	eXtended Graphics Array Plus	4:3	1152	864
WXGA	Widescreen eXtended Graphics Array	16:9	1280	720
WXGA	Widescreen eXtended Graphics Array	16:10	1280	800
SXGA (UVGA)	Super eXtended Graphics Array	4:3	1280	960
SXGA	Super eXtended Graphics Array	5:4	1280	1024
HD	High Definition	16:9	1360	768
HD	High Definition	16:9	1366	768
WXGA+	Widescreen eXtended Graphics Array Plus	16:10	1440	900
HD+	High Definition Plus	16:9	1600	900
UXGA	Ultra eXtended Graphics Array	4:3	1600	1200
WSXGA+	Widescreen Super eXtended Graphics Array Plus	16:10	1680	1050
FHD (Full HD)	Full High Definition	16:9	1920	1080
WUXGA	Widescreen Ultra eXtended Graphics Array	16:10	1920	1200
QFHD	Quad Full High Definition	16:9	2560	1440

Other

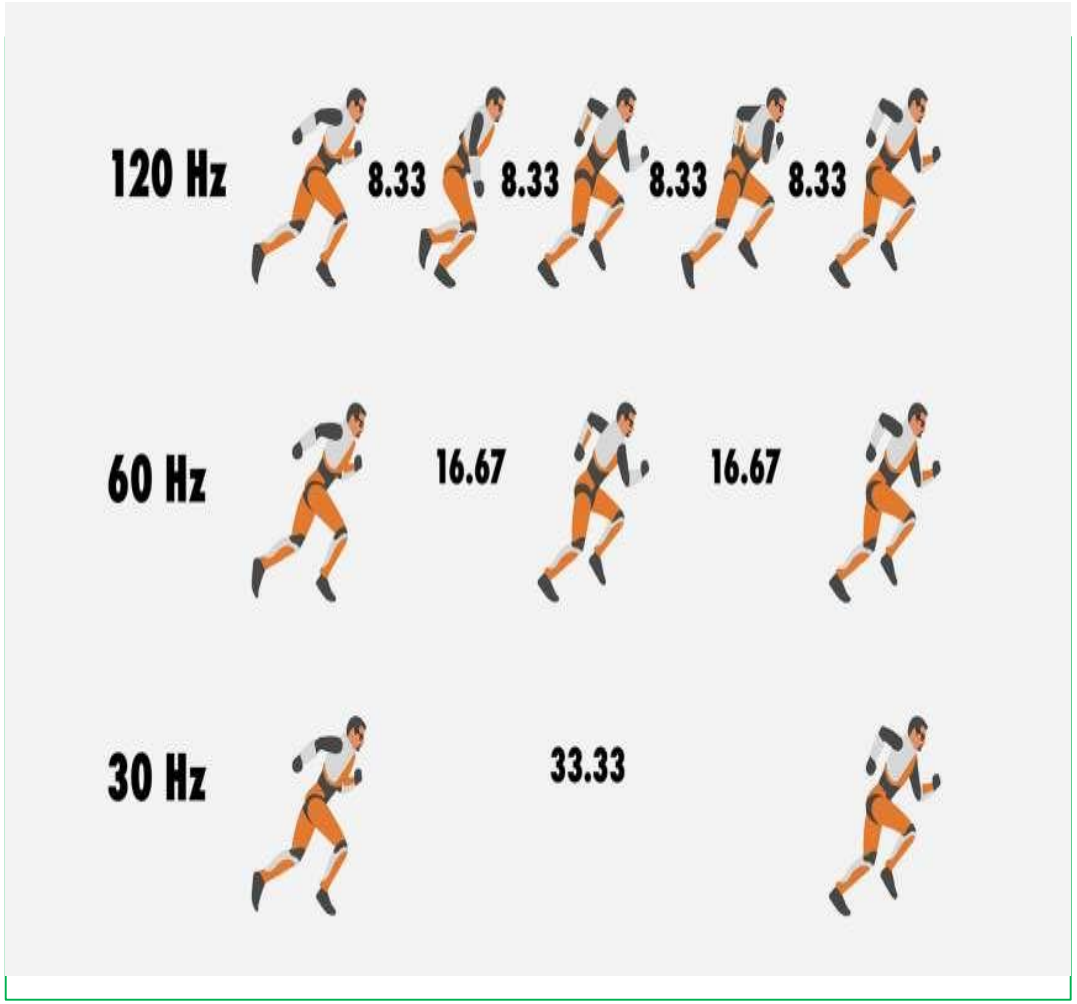
Aspect ratio

- The aspect ratio of an image describes the proportional relationship between its width and its height.
- It is represented as two numbers separated by a colon as 4(Width):3(Height), 16:9 etc.
- A square has the smallest possible aspect ratio 1:1.
- For an ellipse, the aspect ratio denotes the ratio of the major axis to the minor axis.
- An ellipse with an aspect ratio 1:1 is a circle



Refresh rate

- The refresh rate is the number of times per second the image is redrawn to give a feeling of un-flickering pictures and is usually 50 per second.
- As the refresh rate decreases flicker develops because the eye can no longer integrate the individual light impulses coming from a pixel.
- Reducing the refresh rate increases flicker
- The refresh rate above which a picture stops flickering and fuses into a steady image is called Critical Fusion Frequency (CFF).



Bit depth

- The number of **bits** used to indicate the color of a single pixel.
- 1-bit color ($2^1 = 2$ colors): monochrome
- 2-bit color ($2^2 = 4$ colors): CGA,
- 3-bit color ($2^3 = 8$ colors): many early home computers with TV displays
- 4-bit color ($2^4 = 16$ colors): as used by EGA and by the least common denominator VGA standard at higher resolution
- 8-bit color ($2^8 = 256$ colors)

BIT DEPTH	COLOR RESOLUTION	CALCULATION
1-bit	2 colors	2^1 (2)
2-bit	4 colors	2^2 (2x2)
3-bit	8 colors	2^3 (2x2x2)
4-bit	16 colors	2^4 (2x2x2x2)
5-bit	32 colors	2^5 (2x2x2x2x2)
6-bit	64 colors	2^6 (2x2x2x2x2x2)
7-bit	128 colors	2^7 (2x2x2x2x2x2x2)
8-bit	256 colors	2^8 (2x2x2x2x2x2x2x2)
16-bit	65,536 colors	2^{16}
24-bit	16,777,215 colors	2^{24}

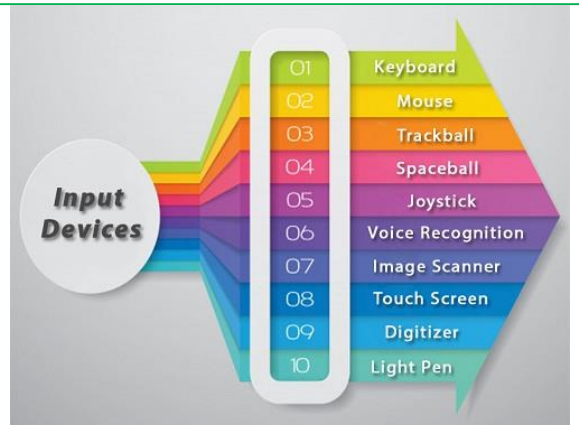
Frame buffer

- The portion of memory reserved for holding the complete bit-mapped image that is sent to the monitor.
- Typically the **frame buffer** is stored in the memory chips on the video adapter.
- In some instances, however, the video chipset is integrated into the motherboard design, and the **frame buffer** is stored in general main memory.

Exam Questions:

1. What do you understand by computer graphics? Mention some of the advantages of computer graphics. [2017 Fall]
2. Explain Frame buffer? How is computer graphics applicable in the field of GUI, entertainment and Medical Science? Explain. [2018 Spring]
3. Explain the use of computer graphics emphasizing the application of graphics in the field of entertainment. [2019 Fall]
4. How the entertainment and gaming industry has revolutionized by the advancement in computer graphics? Explain your answer with some real life examples. [2020 Fall]
5. Define computer graphics. List the application of computer graphics in different fields. [2021 Fall]

1.7 Interactive Input Devices



1.7 Interactive Input Devices

- Interactive input devices are hardware devices that allow users to interact with a computer or other digital systems by providing input.
- These devices enable users to control and manipulate digital content.
- These interactive input devices provide users with diverse ways to communicate with digital systems, catering to different preferences and applications.
- Various devices are available for data input on graphics workstations.
- Most systems have a keyboard and one or more additional devices specially designed for interactive input.
- These include a mouse, trackball, spaceball, joystick, digitizers, dials, and button boxes.
- Some other input devices used in particular applications are data gloves, touch panels, image scanners, and voice systems

Keyboards

- A keyboard creates a code such as ASCII uniquely corresponding to a pressed key.
- It usually consists of alphanumeric keys, function keys, cursor-control keys, and separate numeric pad.
- It is used to move the cursor, to select he menu item, pre-defined functions.
- In computer graphics keyboard is mainly used for entering screen coordinates and text, to invoke certain functions.

Mouse

- A mouse is a small hand-held device used to position the cursor on the screen.
- Mouse are relative devices, that is, they can be picked up, moved in space, and then put down gain without any change in the reported position.
- For this, the computer maintains the current mouse position, which is incremented or decremented by the mouse movements.
- It is used as a popular pointing device. It is used to create images, graphics as well as to click on any button or menu.
- Mechanical Mouse
- Optical mouse

Joystick

- It consists of a small, vertical lever (called the stick) mounted on a base.
- We use the joystick to steer the screen cursor around. Most joysticks select screen positions with actual stick movement; others respond to pressure on the stick.
- Some joysticks are mounted on a keyboard, and some are designed as stand-alone units.
- The distance that the stick is moved in any direction from its center position corresponds to the relative screen-cursor movement in that direction.
- Potentiometers mounted at the base of the joystick measure the amount of movement, and springs return the stick to the center position when it is released.
- Used in video games, CAD, etc.

Touch screen

- It is an Electronic Visual Display, which is used to detect the touch of finger and hand in its display area.
- It is most widely used with those computer machines that can interact with the user.
- **For Example:** Smartphones, Tablet, Etc

Touch Pad

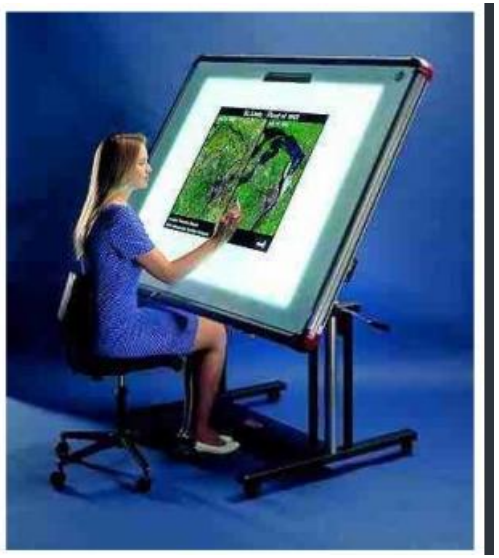
- It is a flat pad used in laptops on which we slide the finger to move the cursor.
- It is a touch-sensitive area. Touchpad is a stationary pointing device that many people find less tiring to use than a mouse.
- It is also called “Trackpad.”
- It is used to translate the motion and position of the user’s finger.
- The movement of a finger across a small touch sensitive surface is translated into pointer movement on screen.
- It also includes two buttons:
  - **Left Click:** It is used to select the option.
  - **Right Click:** It is used to display the options on the screen.

Light Pen

- It is a tool that is light sensitive.
- Light pens are pencil-shaped devices are used to select screen positions by detecting the light coming from points on the CRT screen
- It is used to draw pictures and graphics on the computer screen. It is also used to select the objects.
- The pictures made by the light pen can be stored in the computer and can be improved as needed.

Digitizer

- A digitizer is a locator device use for drawing, painting or interactively selecting coordinate positions of an object.
- These devices can be used to input coordinate values in either a two-dimensional or a three-dimensional space.
- Typically, a digitizer is used to scan over a drawing or object and to input a set of discrete coordinate positions, which can be joined with straight Line segments to approximate the curve or surface shapes.
- One type of digitizer is the graphics tablet (also referred to as a data tablet), which is used to input two-dimensional coordinates by activating a hand cursor or stylus at selected positions on a flat surface.



Data Glove

- A data glove is a device that fits over the user's hand and can be used to grasp a "virtual object."
- The glove is constructed with a series of sensors that detect hand and finger motions.
- Electromagnetic coupling between transmitting antennas and receiving antennas are used to provide information about the position and orientation of the hand.

Trackball

- A trackball is a ball device that can be rotated with the fingers or palm of the hand to produce screen-cursor movement.
- Potentiometers, connected to the ball, measure the amount and direction of rotation.
- Laptop keyboards are often equipped with a trackball to eliminate the extra space required by a mouse.
- A trackball also can be mounted on other devices, or it can be obtained as a separate add-on unit that contains two or three control buttons

Barcode Reader

- The purpose of a **barcode scanner** is to **scan** or read a **barcode** symbol and then provide an electrical output to a computer via a decoder and cable.
- The decoder recognizes the type of **barcode** symbology it is seeing, translates the **bar** and space content and transmits data to a computer in a human readable format.

1.8 Display Devices and Hard copy Devices

1.8 Display Devices and Hard copy Devices

- **Display devices** are used for the visual presentation of information. A display device is a device for visual presentation of images (including text)/video acquired, stored, or transformed in various forms. Eg: Computer monitor, TV screen, etc
- **Hard copy output** devices are devices that provide output on printed paper or Other permanent media that is human readable. Printers and plotters are Hard copy output devices.

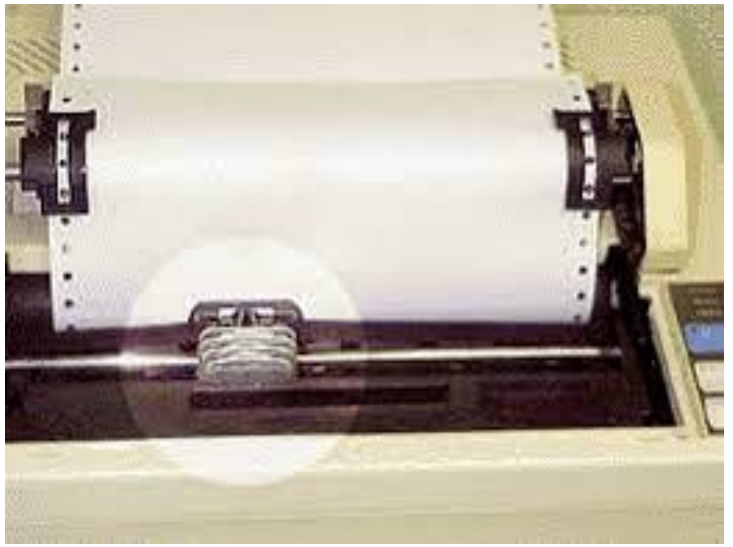
Hardcopy output devices

Hardcopy output devices

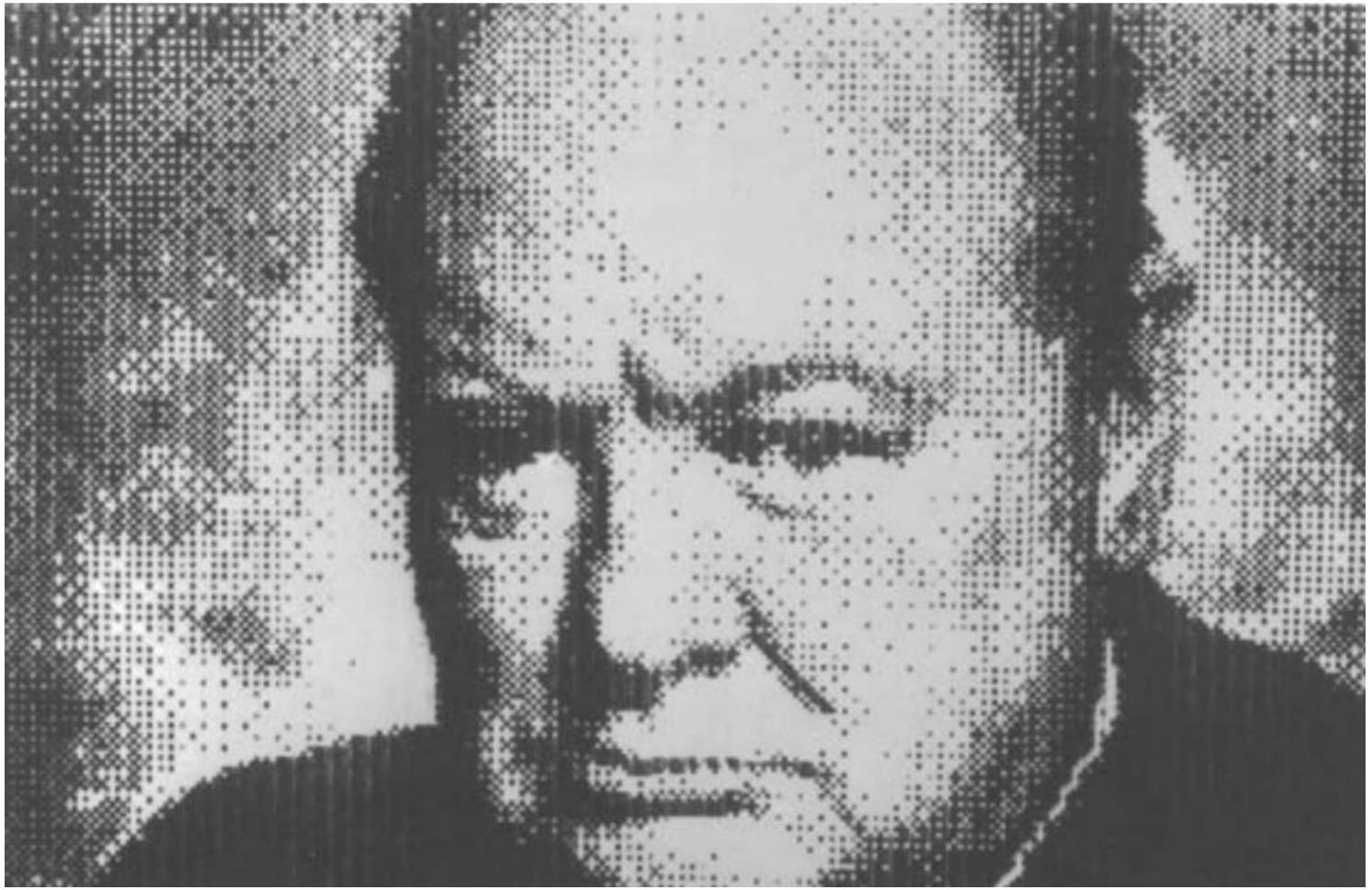
- Printers and plotters are popular examples of hard-copy output devices.
- The quality of the pictures obtained from an output device depends on dot size and the number of dots per inch, or lines per inch, that can be displayed.
- To produce smooth patterns, higher-quality printers shift dot positions so that adjacent dots overlap.
- Mainly two types of printers: Impact printers, non-impact printers.

i) Impact printers

- It is a type of printer that works by direct contact with an ink ribbon with paper.
- These printers are typically loud but remain in use today because of their unique ability to function with multiple forms.
- An impact printer has mechanisms resembling those of a typewriter.
- These printers have a mechanism whereby formed character faces are pressured against an inked ribbon onto the paper in order to create an image.
- Physical contact is established between print head, ribbon cartridge and paper.
- Example: Dot matrix and line matrix



- Individual characters or graphics patterns are obtained by retracting certain pins so that the remaining pins form the pattern to be printed.
- Figure aside shows a picture printed on a dot-matrix printer.
- It illustrates how the density of dot patterns can be varied to produce light and dark areas.



ii) Non-impact Printers

- These are quite operation printers since they do not have physical contact between head, cartridge and paper.
- Different types of non-impact printers are:
  - Inkjet printers
  - Laser printers

Inkjet Printers

- Inkjet Printers Place extremely minute amount of electrically charged ink on paper to create images or text
- Drops of ink are sprayed through a series of nozzles
- Uses monochrome as well as color cartridges
- Can be connected to LPT or USB port
- Provides high quality print

- Ink-jet methods produce output by squirting ink in horizontal rows across a roll of paper wrapped on a drum.
- The electrically charged ink stream is deflected by an electric field to produce dot-matrix patterns.
- An electrostatic device places a negative charge on the paper, one complete row at a time across the sheet.
- Then the paper is exposed to a positively charged toner.
- This causes the toner to be attracted to the negatively charged areas, where it adheres to produce the specified output.

Laser printers

- Laser Printers Use a beam of laser for printing
- a laser beam creates a charge distribution on a rotating drum coated with a photoelectric material, such as selenium.
- Consists of a revolving drum/cylinder that is made up of photoconductive material. Toner is applied to the drum and then transferred to paper.
- Uses static electricity to combine ink powder and paper
- Drum is charged with the help of a charging wire called the charge corona wire Laser Printer

Display Devices

Display Devices

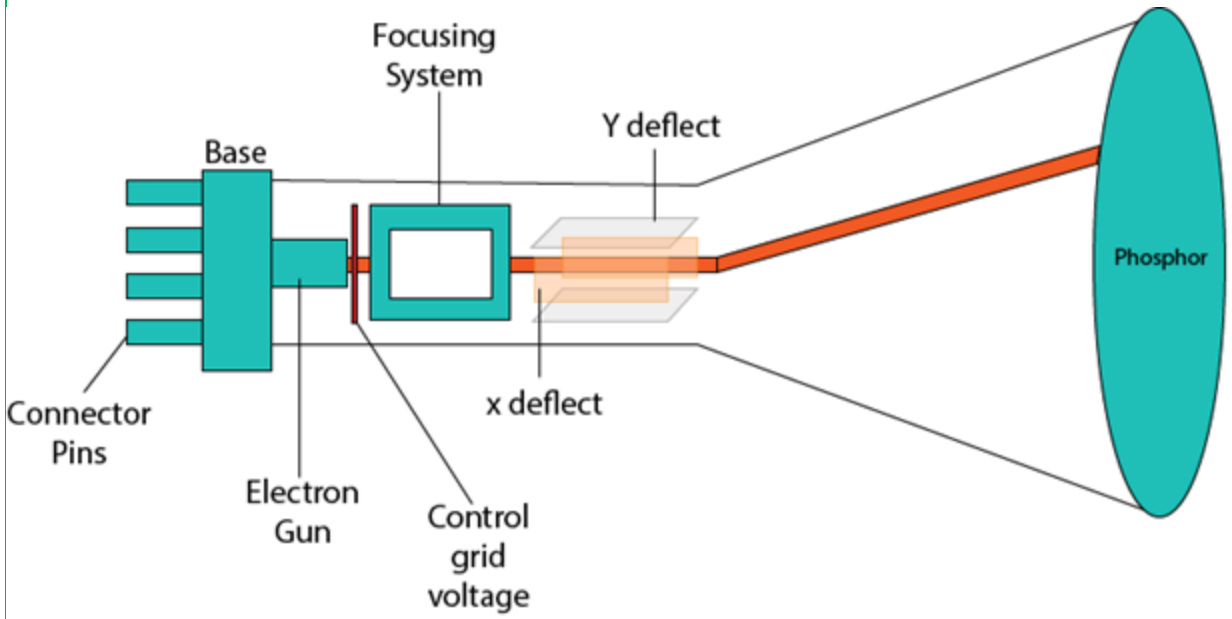
- Typically, the primary output device in a graphics system is a video monitor.
- Historically, the operation of most video monitors was based on the standard cathode-ray tube (CRT) design,
- but several other technologies exist. In recent years, flat-panel displays have become significantly more popular due to their reduced power consumption and thinner designs.

- Fluorescence/ Phosphorescence
  - A phosphors fluorescence is the light emitted as the very unstable electrons lose their excess energy whole the phosphor is being struck by electrons.
  - Phosphorescence is the light given off by the return of the relatively more stable excited electrons to their unexcited state once the electron beam excitation is removed.
- Persistence:
  - A phosphor's persistence is defined as the time from the removal of excitation to the moment when phosphorescence has decay to 10 percent of the initial light output
  - The range of persistence of different phosphors can reach many seconds
  - The phosphors used for graphics display devices usually have persistence of 10 to 60 micro seconds
  - A phosphor with low persistence is useful for animation and a high persistence phosphor is useful to highly complex static pictures

Refresh Cathode-Ray Tubes (CRT)

- It consists of a CRT along with control circuits.
- CRT is a vacuum glass tube with the display screen at one end and connectors to the control circuits at the other.
- Inside of display screen is a special material called phosphor which emits light for a period of time when hit by a beam of electrons.
- The color of light and the time period vary from one type of phosphor to another.
- The major parts of Refresh-CRT are:
  - Electron gun
  - Accelerated anode
  - Focusing system/Focusing Anode
  - Deflection System

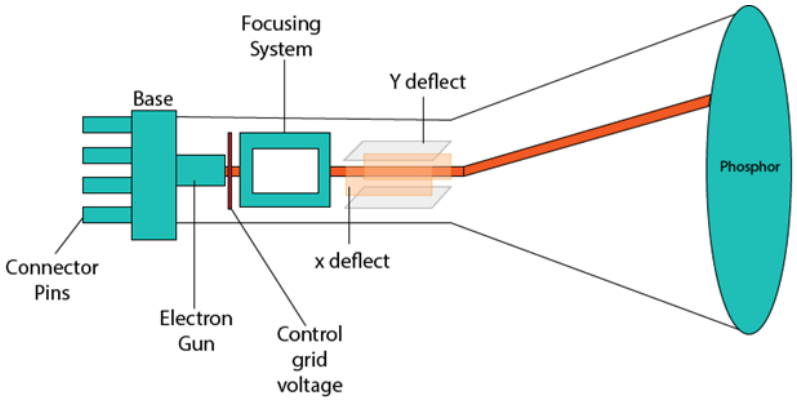
- CRT stands for Cathode Ray Tube. CRT is a technology used in traditional computer monitors and televisions.
- The image on CRT display is created by firing electrons from the back of the tube of phosphorus located towards the front of the screen.
- Once the electron heats the phosphorus, they light up, and they are projected on a screen.
- The most common method now employed for maintaining phosphor glow is to redraw the picture repeatedly by quickly directing the electron beam back over the same screen points.
- This type of display is called a refresh CRT, and the frequency at which a picture is redrawn on the screen is referred to as the refresh rate.



Cathode Ray Tube

Components of CRT

1. **Electron Gun:** Electron gun consisting of a series of elements, primarily a heating filament (heater) and a cathode. The electron gun creates a source of electrons which are focused into a narrow beam directed at the face of the CRT.
2. **Control Electrode:** It is used to turn the electron beam on and off.
3. **Focusing system:** It is used to create a clear picture by focusing the electrons into a narrow beam.
4. **Deflection Yoke:** It is used to control the direction of the electron beam. It creates an electric or magnetic field which will bend the electron beam as it passes through the area. In a conventional CRT, the yoke is linked to a sweep or scan generator. The deflection yoke which is connected to the sweep generator creates a fluctuating electric or magnetic potential.
5. **Phosphorus-coated screen:** The inside front surface of every CRT is coated with phosphors. Phosphors glow when a high-energy electron beam hits them. Phosphorescence is the term used to characterize the light given off by a phosphor after it has been exposed to an electron beam.



Cathode Ray Tube

Properties of CRT

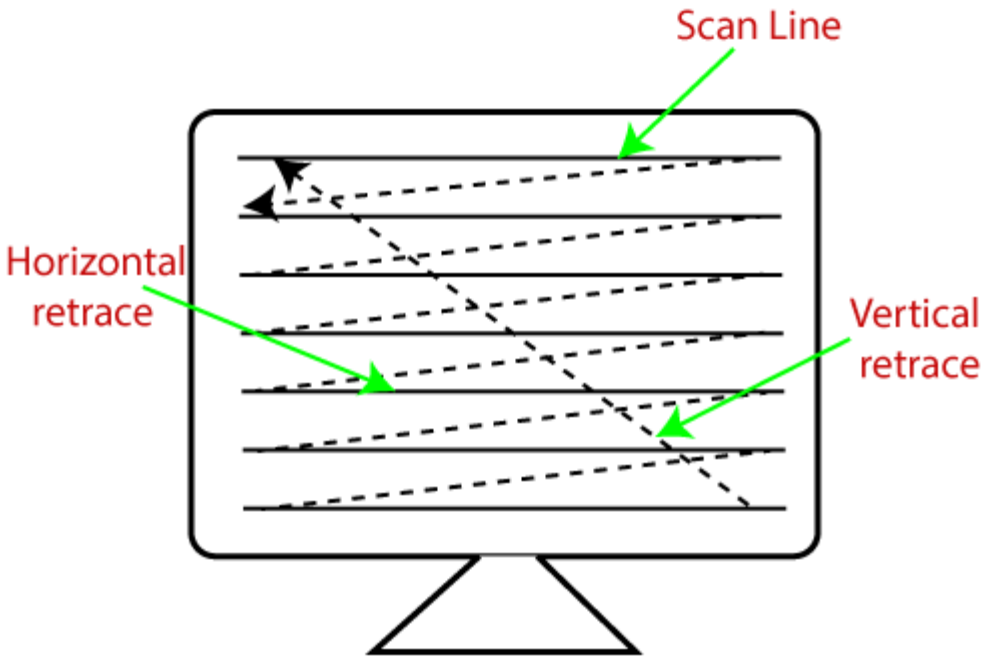
- **Persistence**
  - How long the phosphor continue to emit light after CRT beam is removed.
- **Resolution**
  - Maximum number of points that can be displayed without overlapped is known as resolution. In other words, it is the number of points per centimeter that can be plotted horizontally and vertically.
- **Aspect Ratio**
  - Ratio of vertical points to horizontal points necessary to produce equal length of lines in both directions is known as aspect ratio.

Ways to present an object on the CRT screen

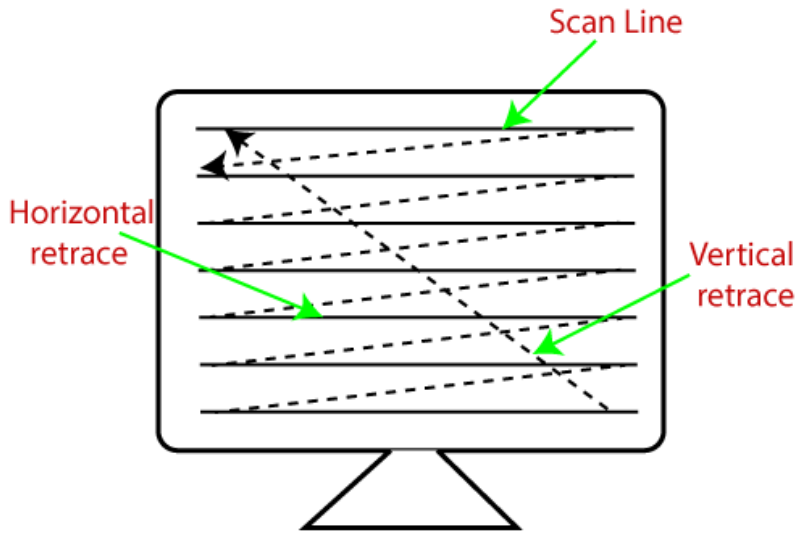
- There are two ways to represent an object on the screen:
  - Raster Scan
  - Random Scan

Raster Scan

- It is a scanning technique in which the electron beam moves along the screen. It moves from top to bottom, covering one line at a time.
- A raster scan is based on pixel intensity control display as a rectangular box on the screen called a **raster**.
- Picture description is stored in the memory area called as **Refresh buffer, or Frame Buffer.**
- Frame buffer is also known as **Raster or Bitmap.** Raster scan provides the refresh rate of 60 to 80 frames per second.
- **For Example: Television**



- The beam refreshing has two types:
  - Horizontal Retracing
  - Vertical Retracing
- When the beam starts from the top left corner and reaches bottom right, and again return to the top left, it is called the **vertical retrace**. It will call back from top to bottom more horizontally as a horizontal reversal.
- **Advantages:**
  - Real image
  - Many colors to be produced
  - Dark scenes can be pictured
- **Disadvantages:**
  - Less resolution
  - Display picture line by line
  - More costly



Random Scan (Vector scan):

- It is also known as stroke-writing display or calligraphic display. In this, the electron beam points only to the area in which the picture is to be drawn.
- It uses an electron beam like a pencil to make a line image on the screen.
- The image is constructed from a sequence of straight-line segments.
- On the screen, each line segment is drawn by the beam to pass from one point on the screen to the other, where its x & y coordinates define each point.
- After compilation of picture drawing, the system cycle back to the first line and create all the lines of picture 30 to 60 times per second.

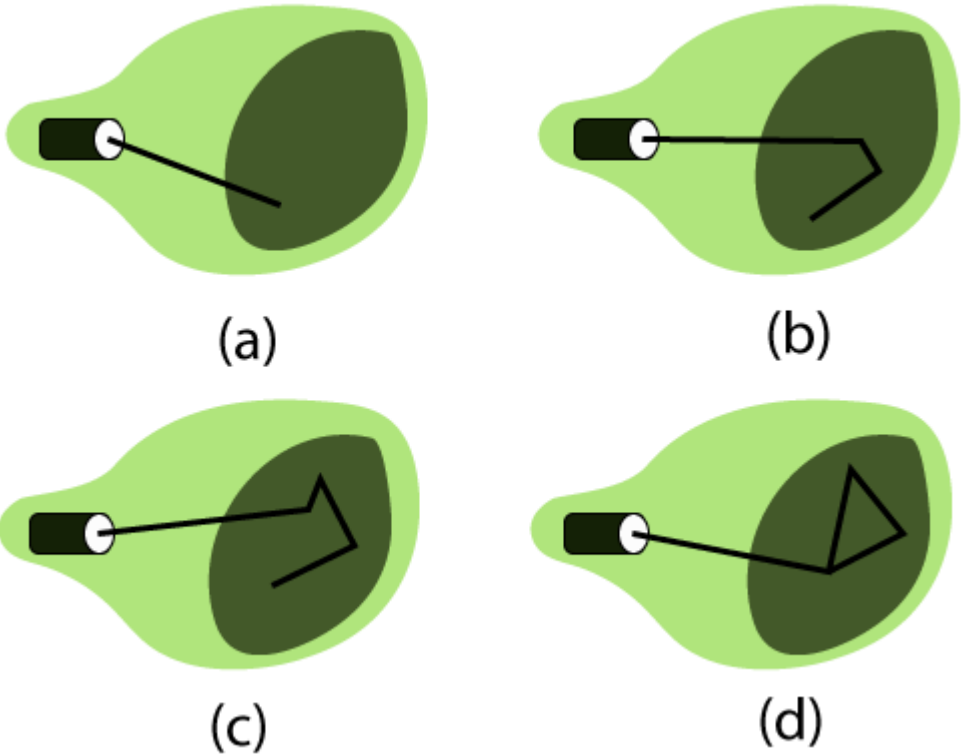


Fig: A Random Scan display draws the lines of an object in a specific order

- **Advantages:**
  - High Resolution
  - Draw smooth line Drawing
- **Disadvantages:**
  - It does only the wireframe.
  - It creates complex scenes due to flicker.

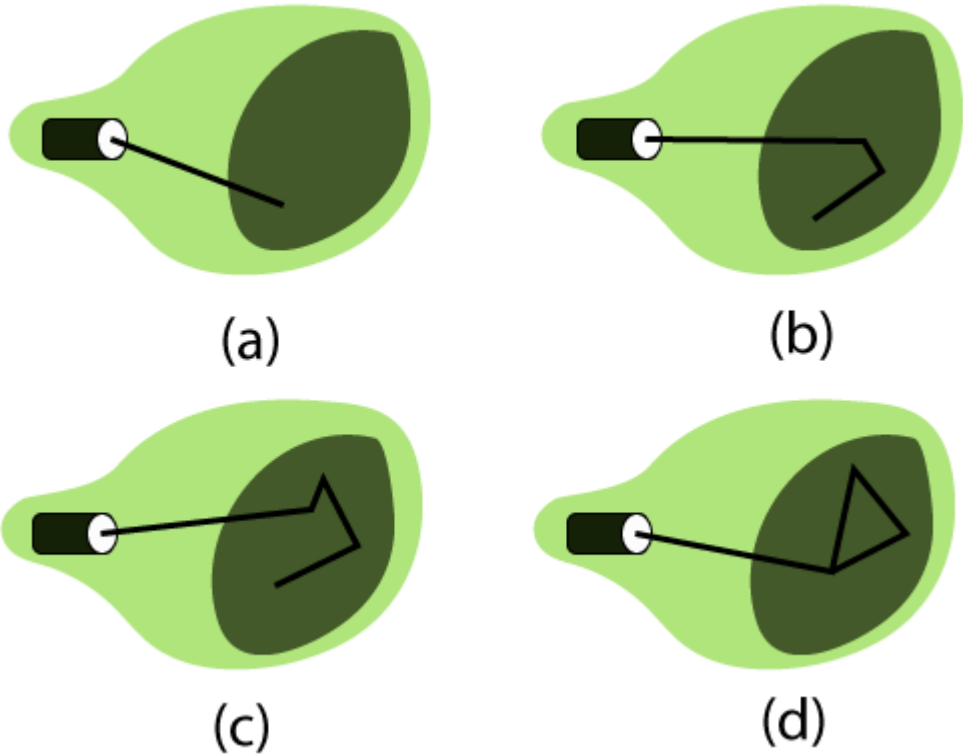


Fig: A Random Scan display draws the lines of an object in a specific order

1.9 Raster and Random Systems Architectures

Raster-Scan System Architecture

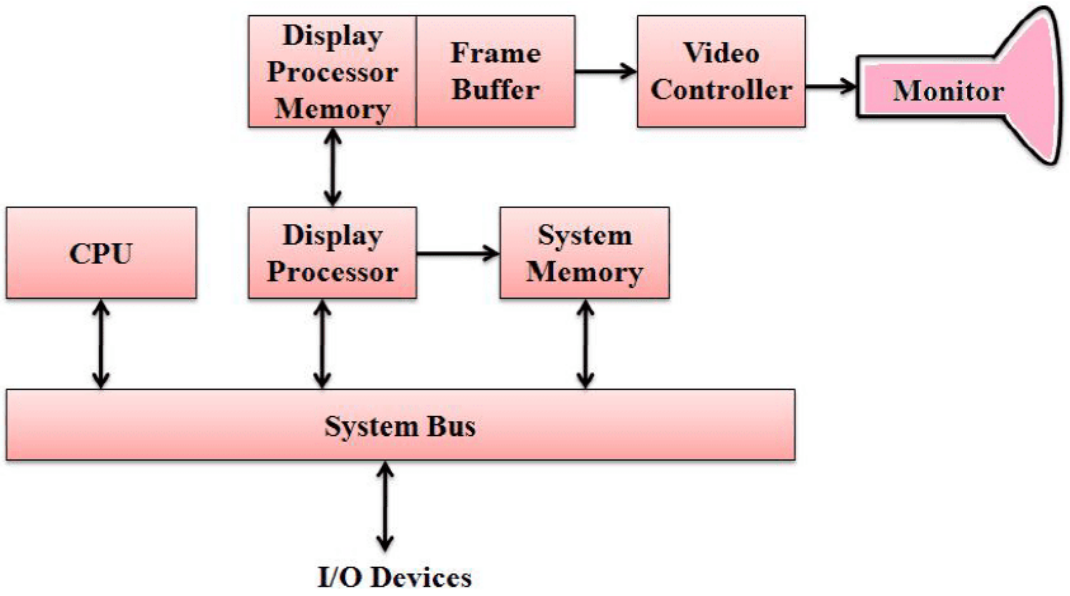
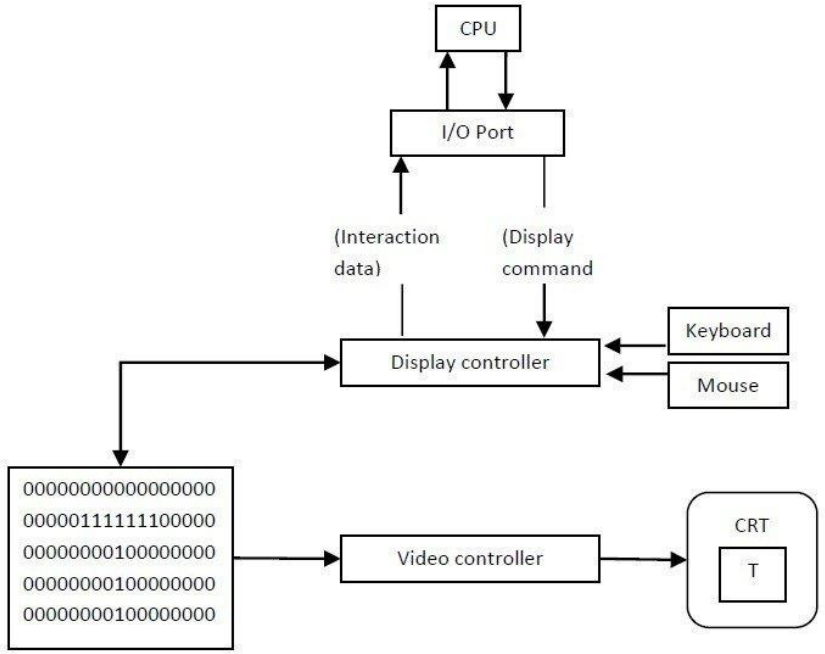


Fig: Architecture of Raster Display



The raster graphics systems typically consists of several processing units.

1. **CPU:**
   - CPU is the main processing unit of computer systems.
2. **System Memory:**
   - Application program and graphics sub-routine package both reside in system memory and execute in the CPU.
3. **Frame Buffer:**
   - When particular command (eg: line(x1,y1,x2,y2)) is called by application program, the graphics subroutine package sets the appropriate pixels in the frame buffer.
   - The frame buffer is a dedicated area of memory that holds the pixel values for each point on the screen.
   - Each pixel's value represents its color and intensity.
4. **Display Processor:**
   - The purpose of the display processor is to free the CPU from the graphics chores (manipulation).
   - The major task is digitizing a picture definition given in an application program into a set of pixel intensity values for storage in frame buffer. This digitization process is called scan conversion.
5. **Video Controller**
   - The video-controller cycles through the frame buffer, one scan at the time (50 fps). It brings a value of each pixel contained in the buffer.
   - The video controller is given direct access to the frame buffer memory to refresh the screen.

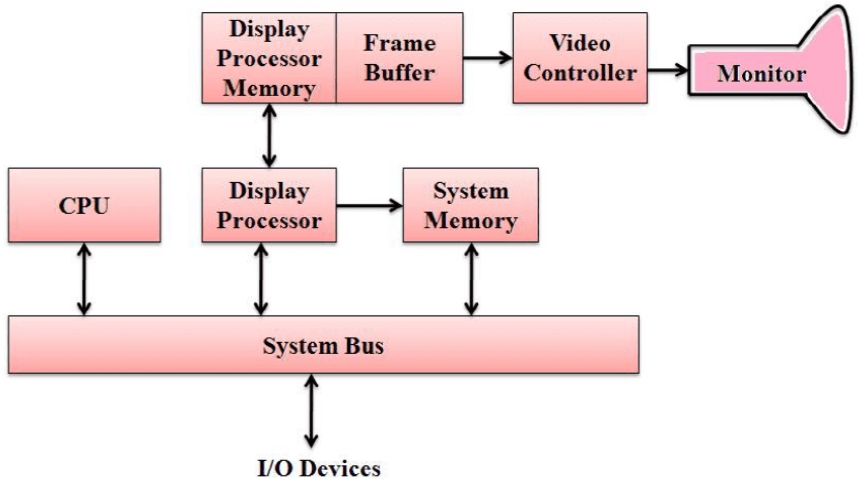


Fig: Architecture of Raster Display

The Video Controller

- https://www.thiyagaraaj.com/tutorials/computer-graphics/overview-of-graphics-system/3-architecture-and-components-of-raster-scan-systems-random-scan-systems

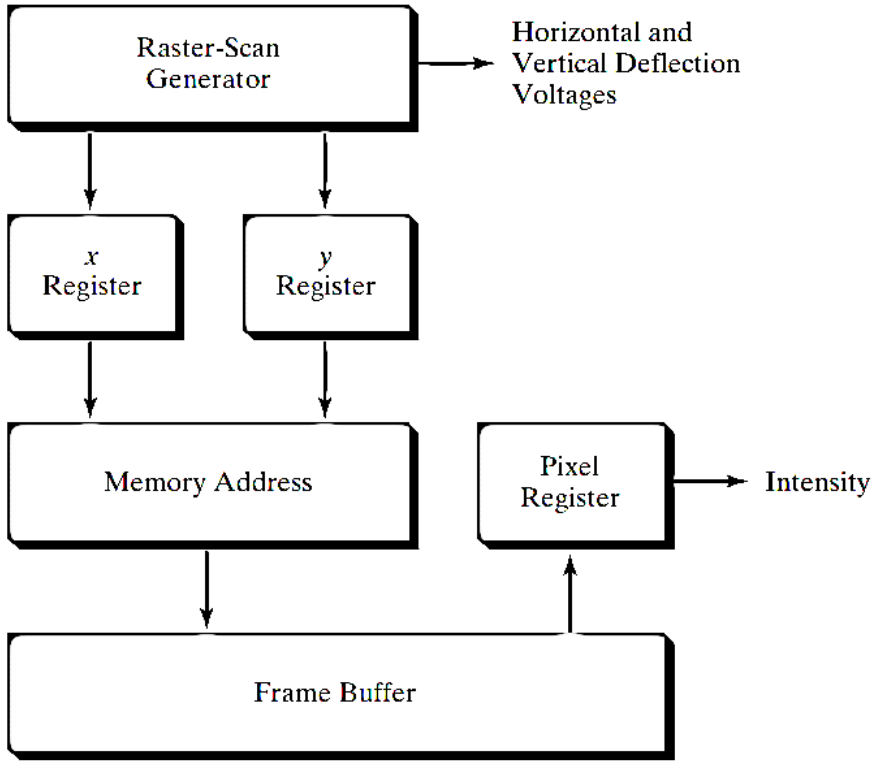


FIGURE 19
Basic video-controller refresh operations.

- A fixed area of the system memory is reserved for the frame buffer, and the video controller is given direct access to the frame-buffer memory.
- The figure aside shows the screen positions referenced with Cartesian coordinate. The left-bottom pixel is the origin.
- The refresh operation of a basic Video controller can be explained with the help of a block diagram.

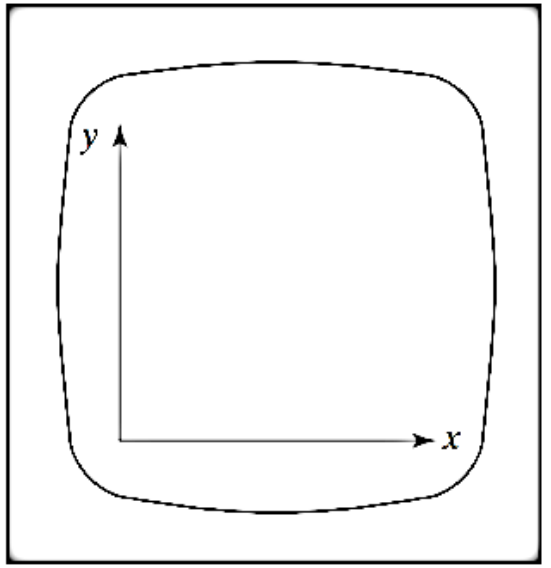


FIGURE 18
A Cartesian reference frame with origin at the lower-left corner of a video monitor.

- Since, the refreshing per pixel is slow process, the video controller retrieves the intensity values for a group of adjacent pixels from the frame buffer.
- This block of pixel intensity is stored in separate registers and used to control the CRT beam for a group of adjacent pixels on the screen.
- Video controller can retrieve pixels from different memory areas on different refresh cycles.

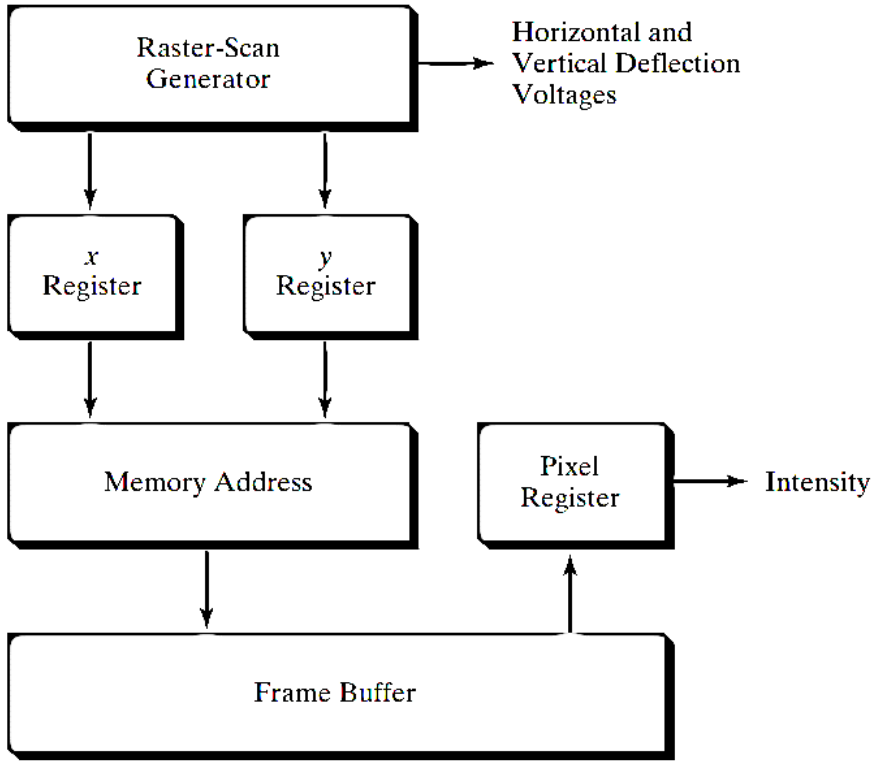


FIGURE 19
Basic video-controller refresh operations.

- Two registers X and Y are used to store coordinates of screen pixel.
- Initially, Y-register is set to Y_{max} and X-register is set to 0.
- The value stored in frame buffer for this pixel is retrieved and thus intensity of CRT beam is set.
- Then X-register is gradually incremented by 1 and same process is repeated for each pixel along all scan lines as before.
- After the last pixel is met, the video controller resets register to first position on the top scan line and refresh process starts again.

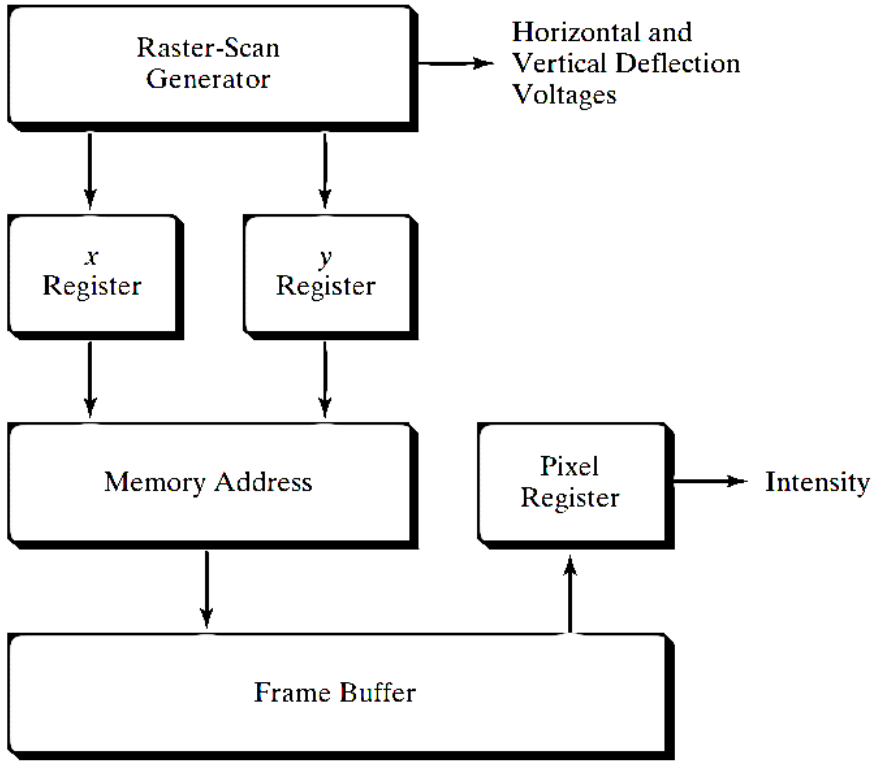
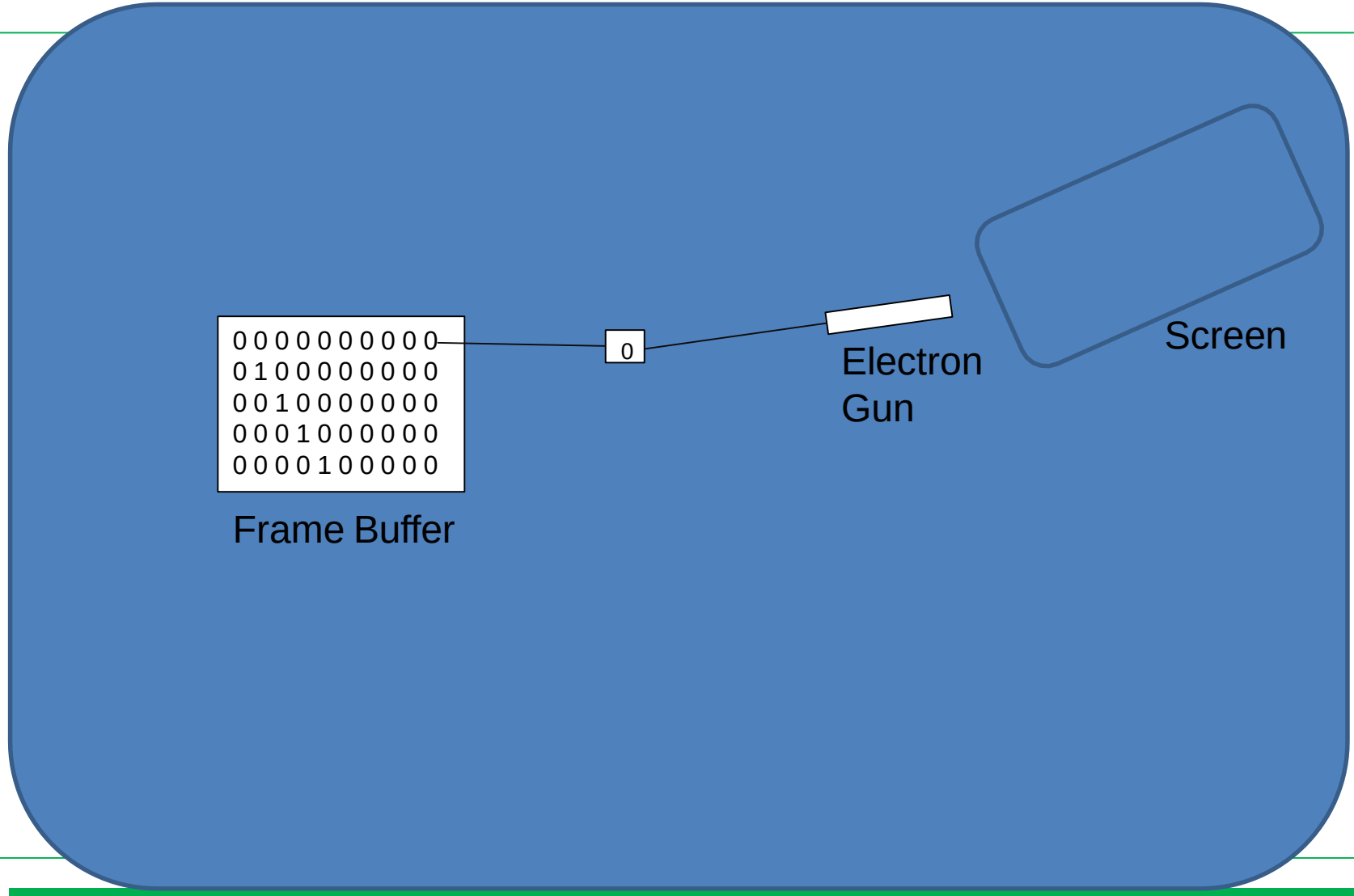
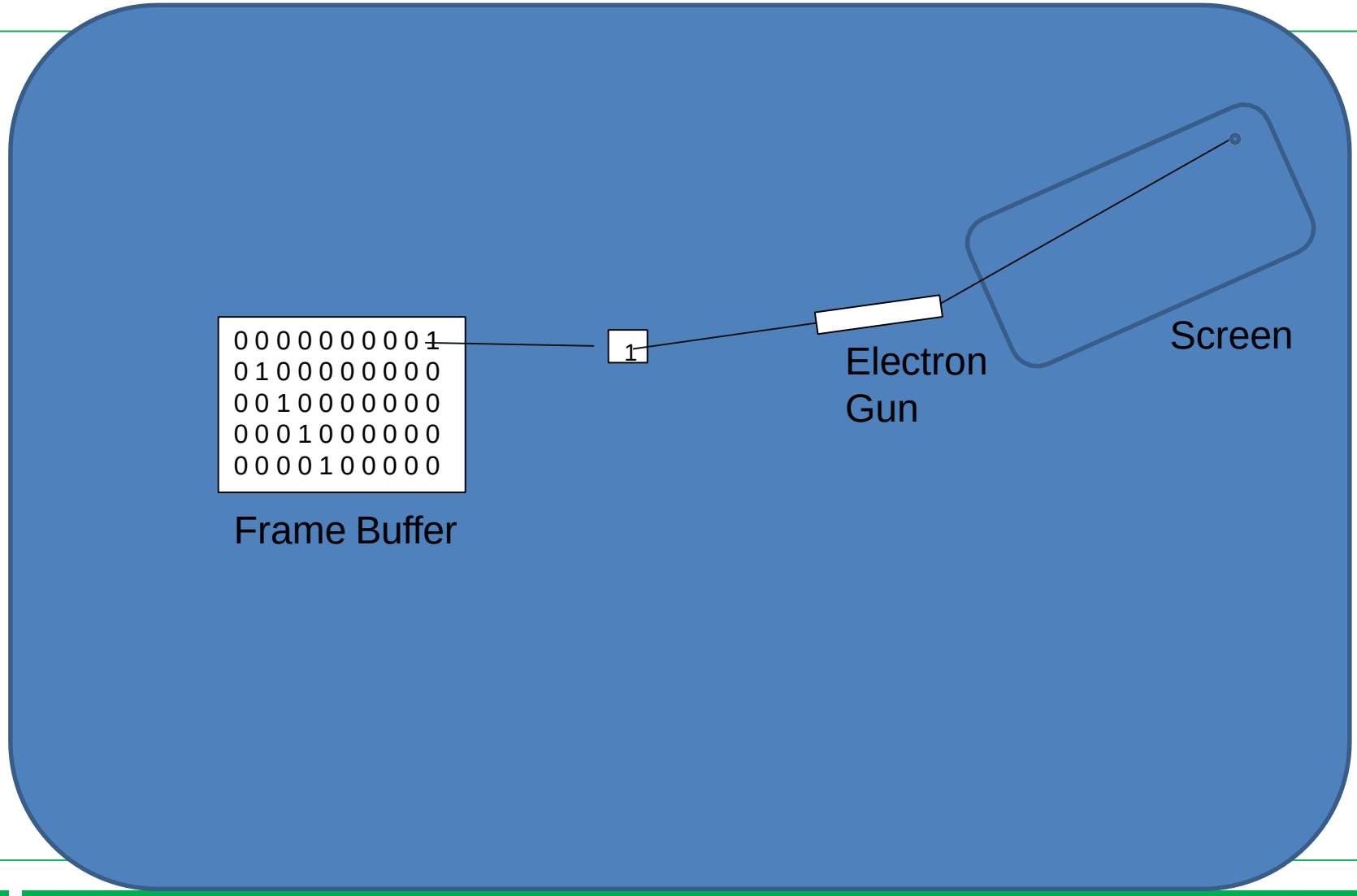


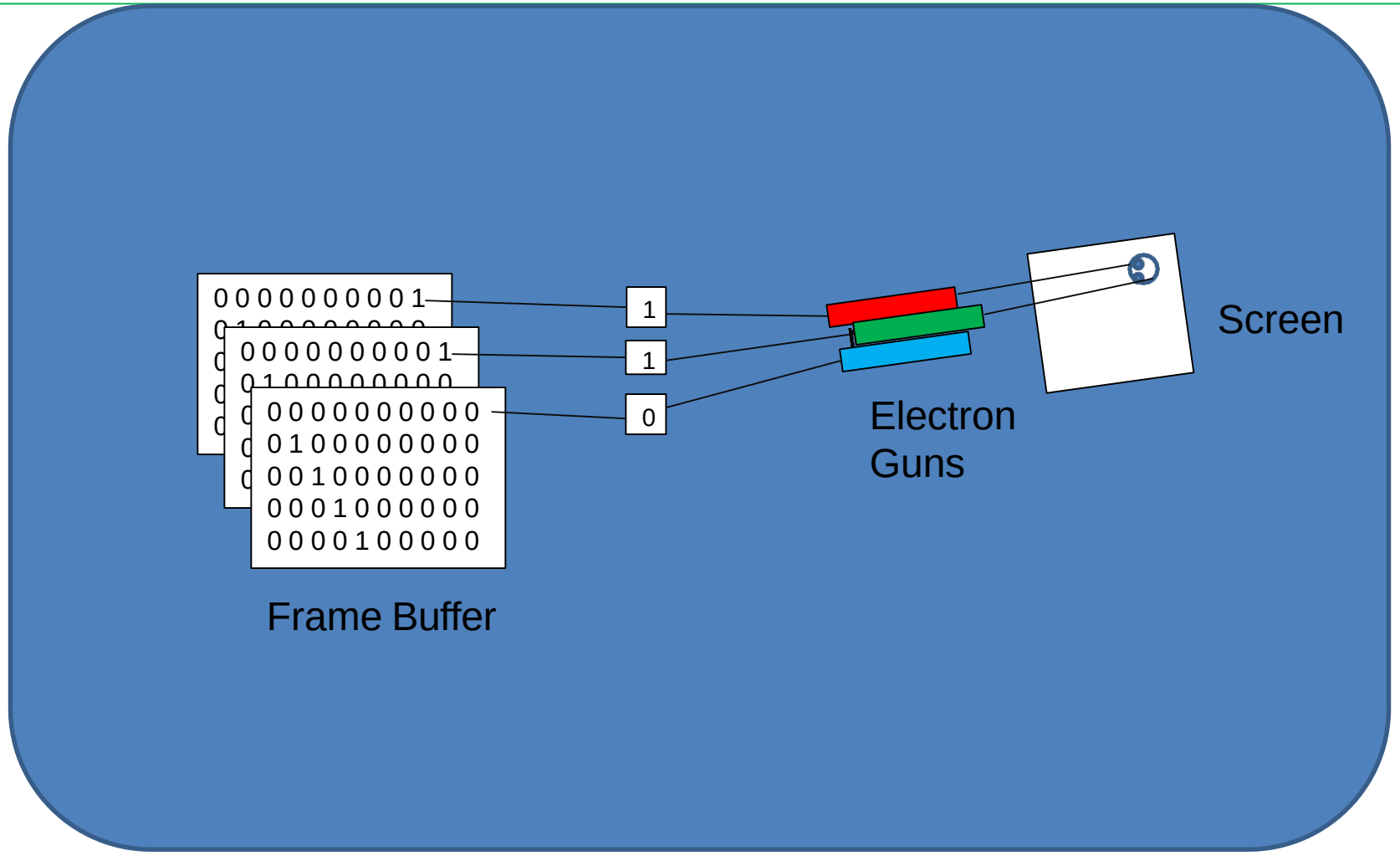
FIGURE 19
Basic video-controller refresh operations.

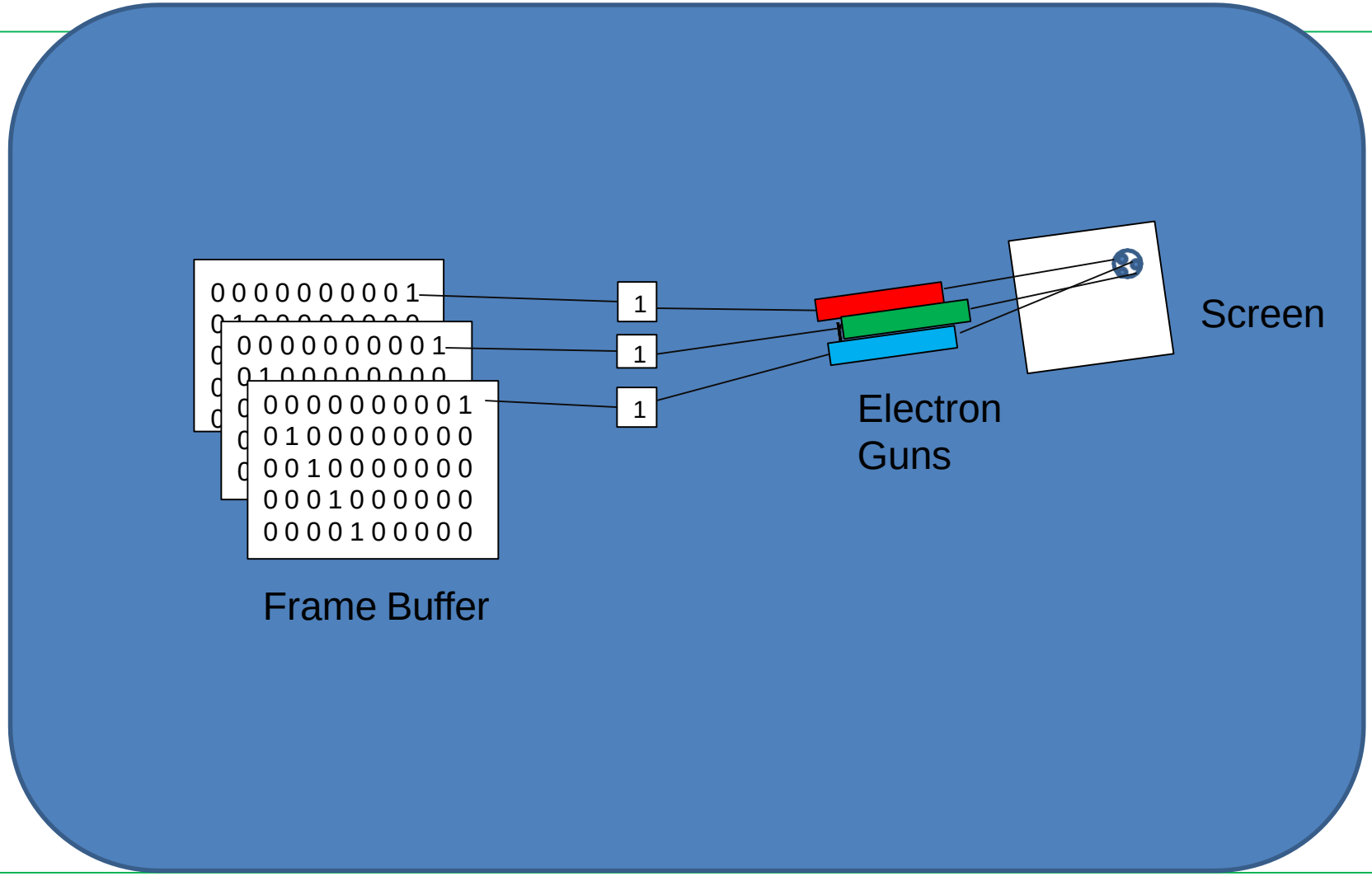
Frame Buffer Organization and D2A Converter

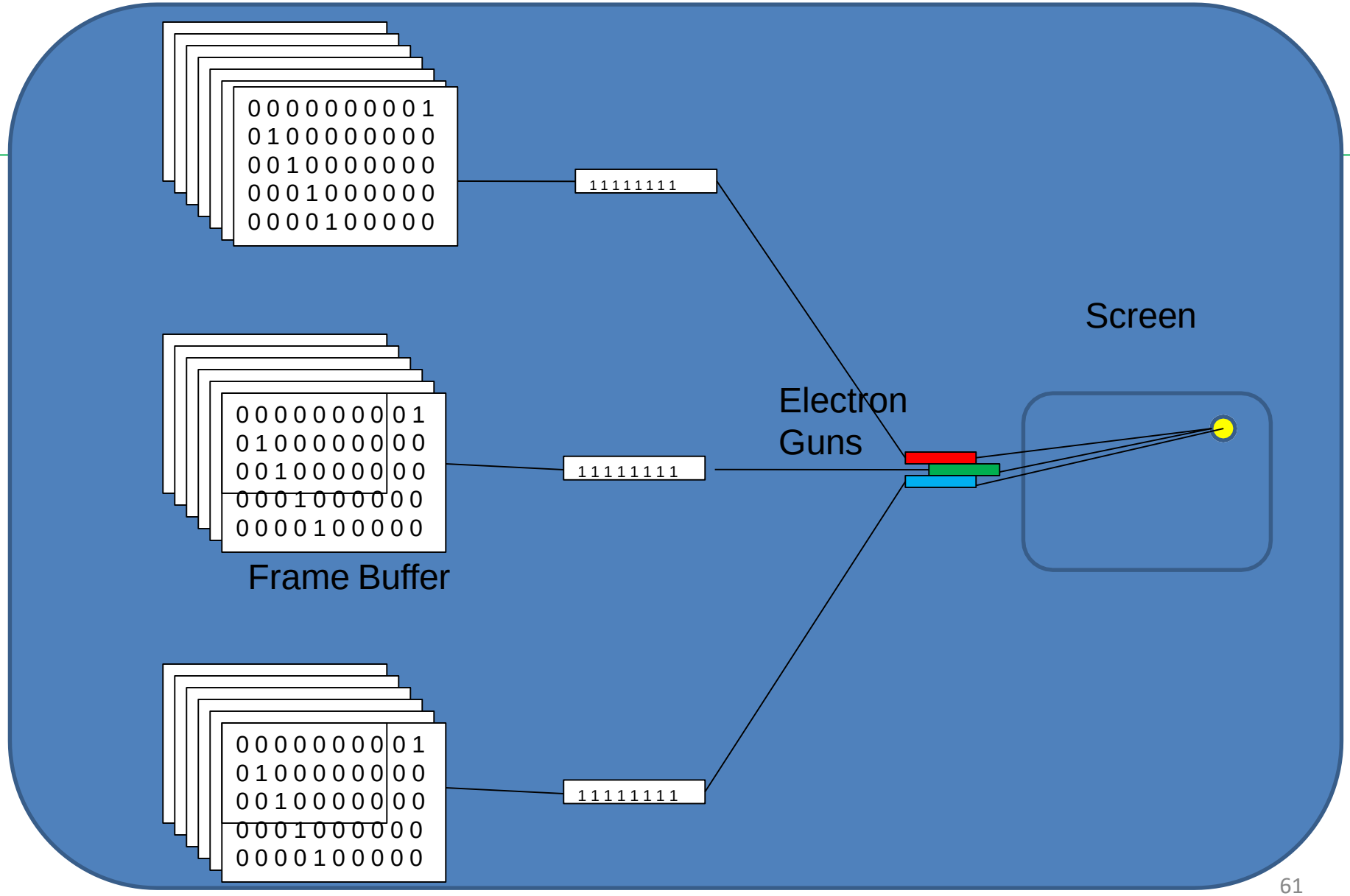
- A frame buffer is a large, contiguous piece of computer memory.
- At a minimum there is one memory bit for each pixel in the rater; this amount of memory is called a bit plane.
- The picture is built up in the frame buffer one bit at a time.
- We know that a memory bit has only two states, therefore 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 we can use a **digital to analog converter (DAC).**
- Each pixel in the frame buffer must be accessed and converted before it is visible on the raster CRT.


0 0 0 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0
Frame Buffer
0
Electron
Gun
Screen


0 0 0 0 0 0 0 0 0 1
0 1 0 0 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0
Frame Buffer
1
Electron
Gun
Screen


0 0 0 0 0 0 0 0 0 1
0 0 0 0 0 0 0 0 0 1
0 0 0 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0
1
1
0
Electron Guns
Screen
Frame Buffer


0 0 0 0 0 0 0 0 0 1
0 0 0 0 0 0 0 0 0 1
0 0 0 0 0 0 0 0 0 1
0 1 0 0 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0
1
1
1
Frame Buffer
Electron Guns
Screen


0 0 0 0 0 0 0 0 1
0 1 0 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0
0 0 0 0 1 0 0 0 0
11111111
0 0 0 0 0 0 0 0 1
0 1 0 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0
0 0 0 0 1 0 0 0 0
11111111
Frame Buffer
0 0 0 0 0 0 0 0 1
0 1 0 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0
0 0 0 0 1 0 0 0 0
11111111
Electron
Guns
Screen

61

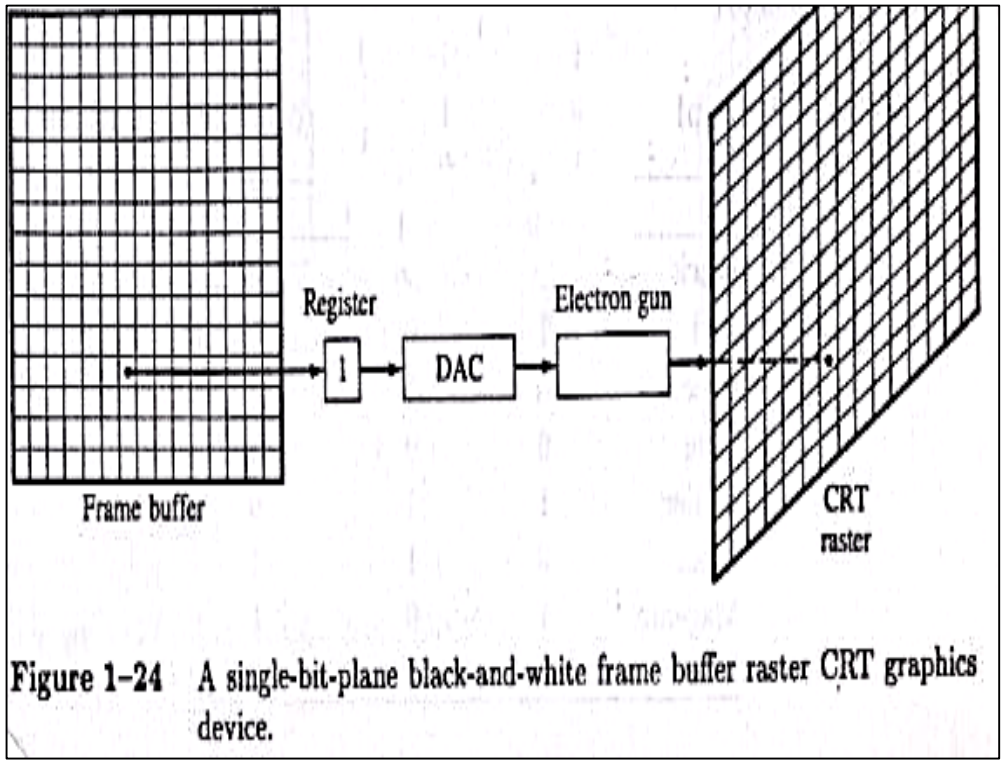


Figure 1–24 A single-bit-plane black-and-white frame buffer raster CRT graphics device.

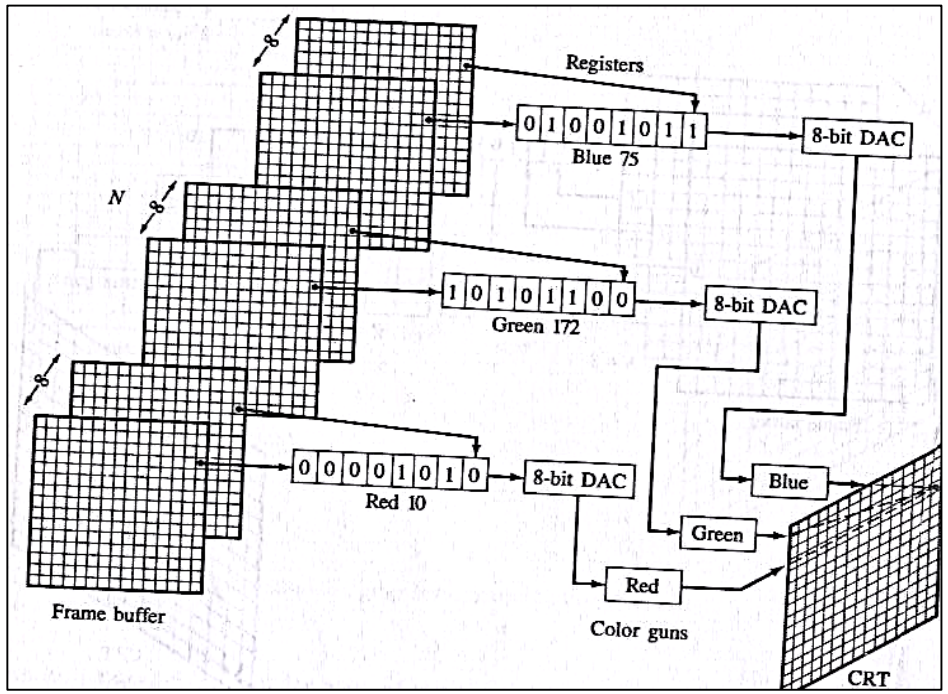
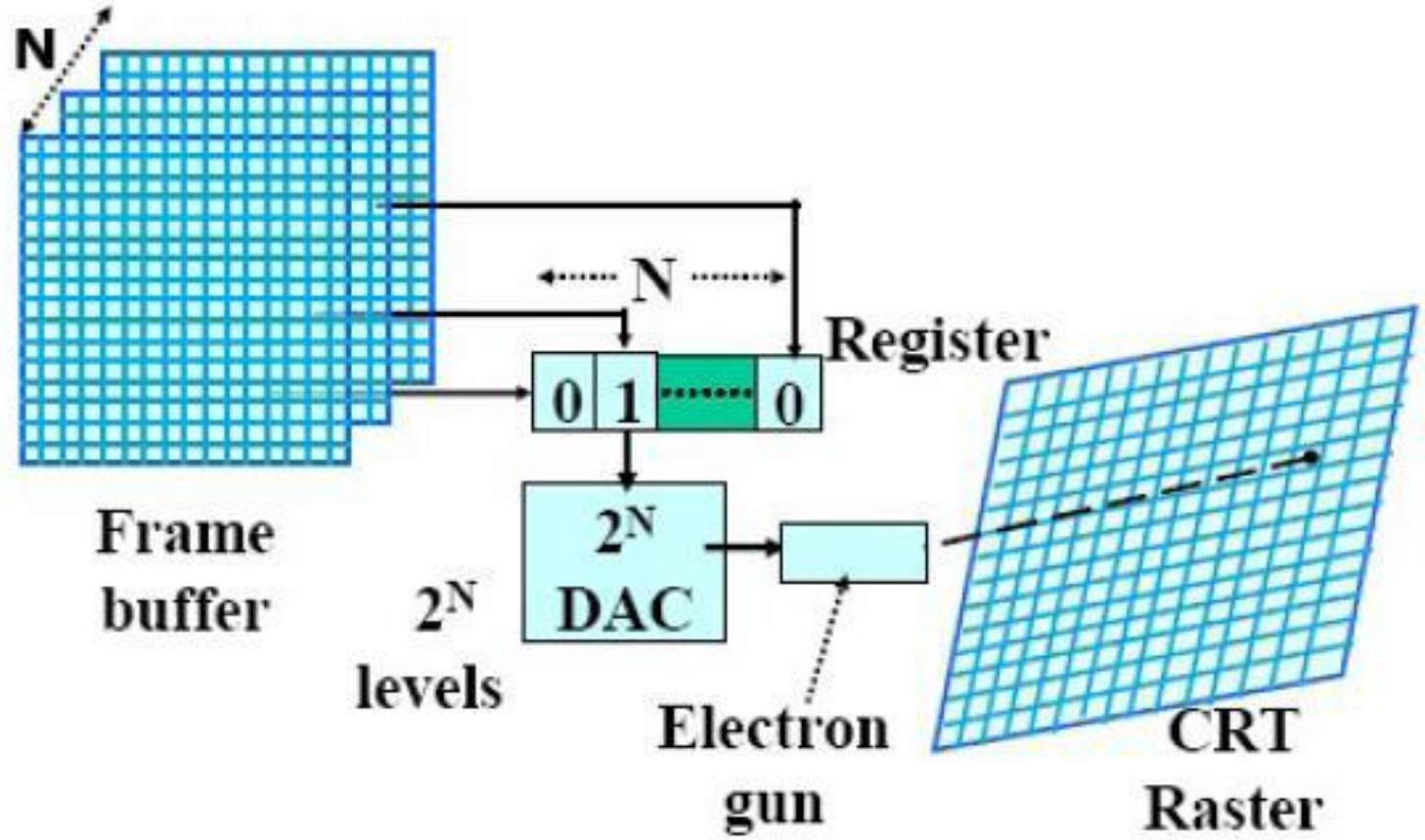
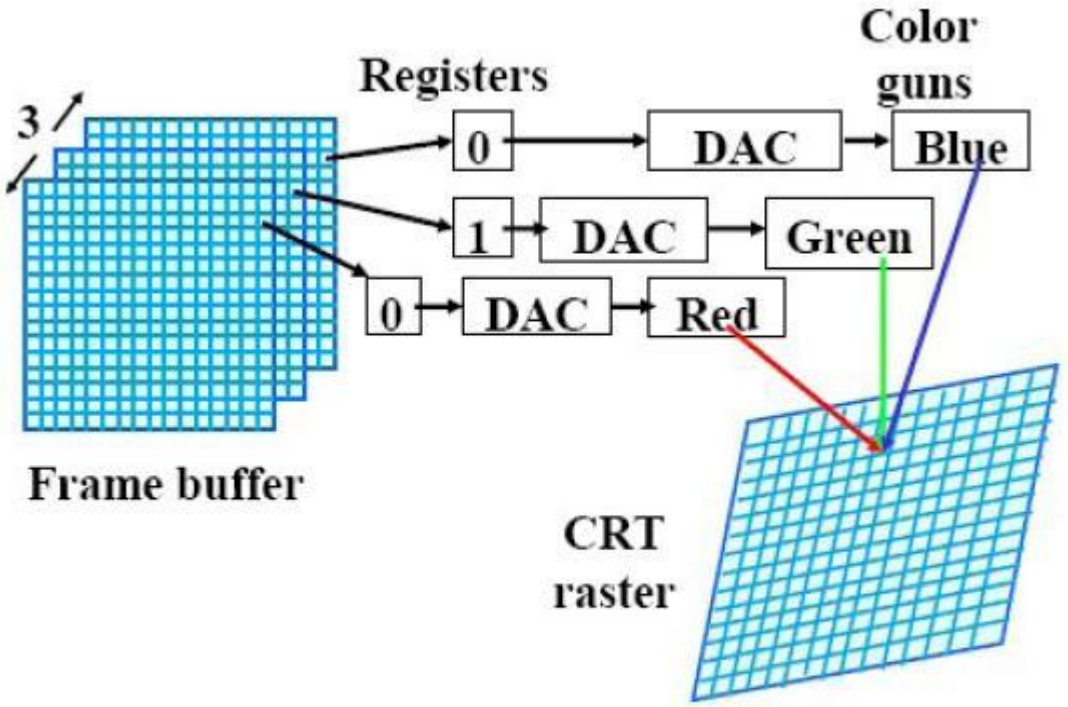


Figure: A 8-bitplane RGB frame buffer raster CRT graphics device



An N- bit plane gray level frame buffer



Simple Color buffer

Random Scan Architecture

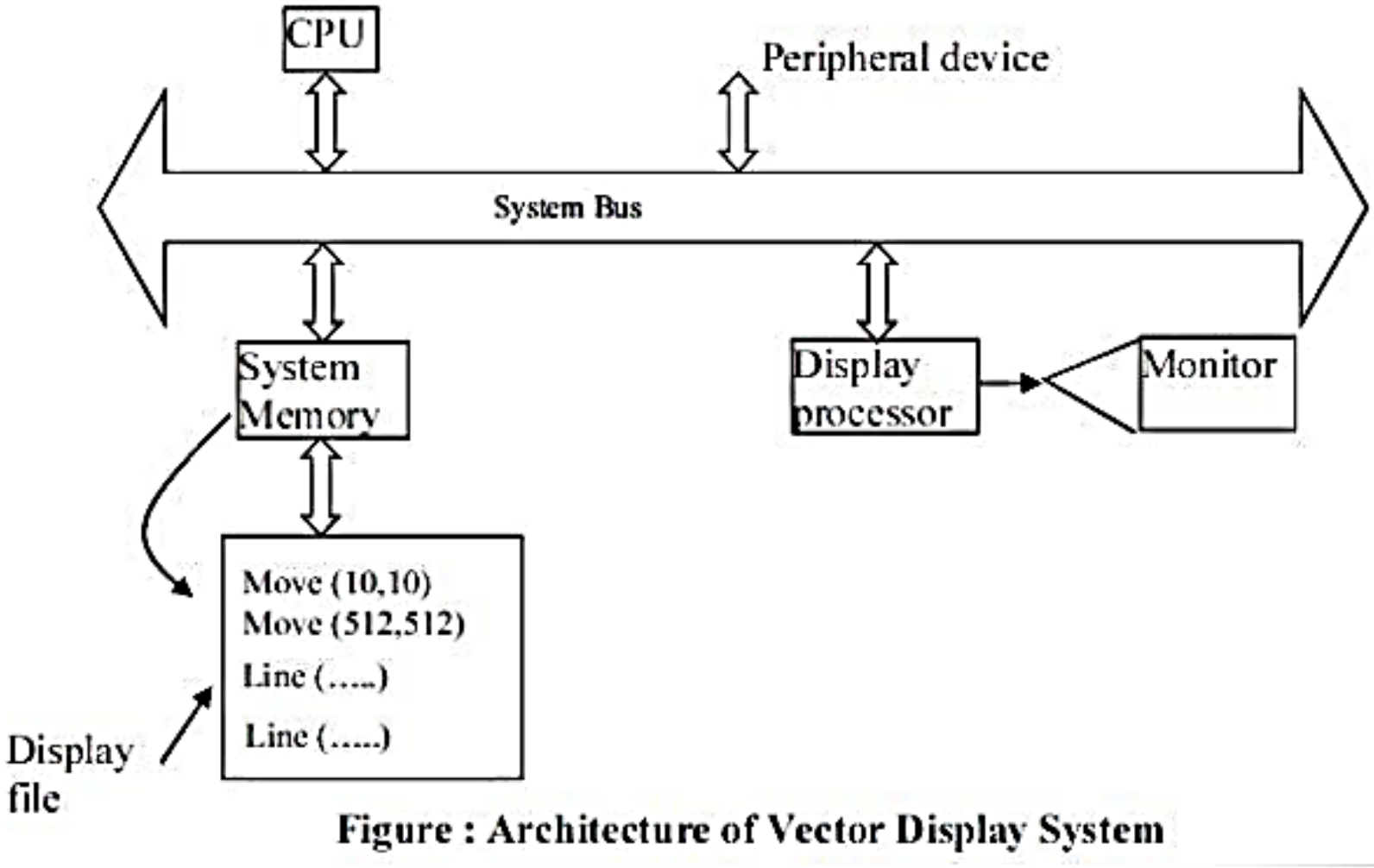


Figure : Architecture of Vector Display System

- The system consists of CPU, a Display processor (DPU or graphics controller), System memory, a CRT monitor and peripherals.
- An application program is input and stored in the system memory along with a graphics package.
- Graphics commands in the application program are translated by graphics package into a display file stored in the system memory.
- The display list/file is then accessed by the display processor to refresh the screen.
- The display processor cycle through each command in the display file program once during every refresh cycle.
- Here, electron beam is directed only to the parts of the screen where a picture is to be drawn.
- If we want a line connecting point A with point B on the random graphic display, we simply drive the beam deflection circuit which will cause beam to go from points A to B.
- If we want to move the beam from point A to point B without showing a line between points, we can blank the beam as we move it.

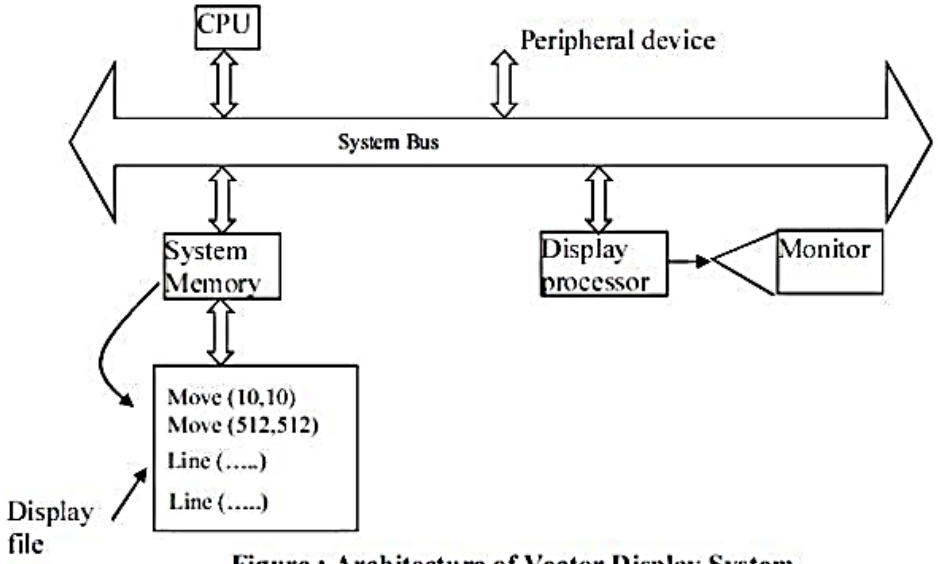


Figure : Architecture of Vector Display System

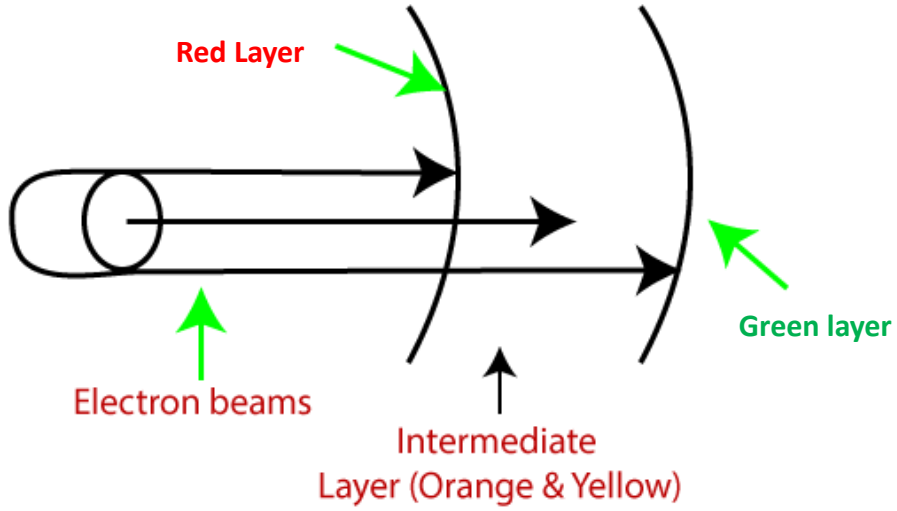
1.10. Color CRT Monitors

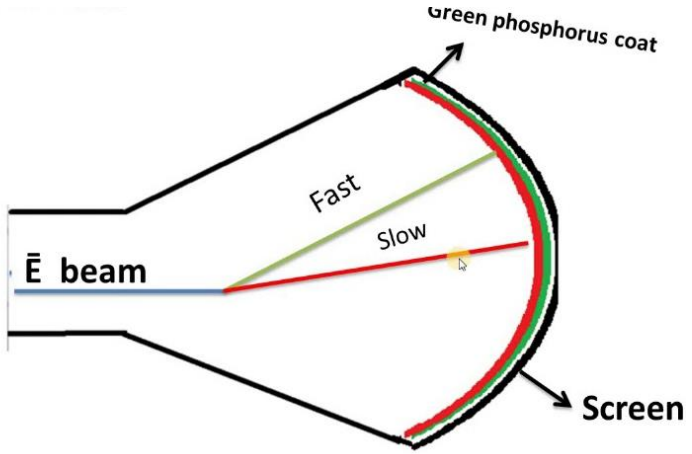
1.10. Color CRT Monitors

- It is similar to a CRT monitor.
- The basic idea behind the color CRT monitor is to combine three basic colors- Red, Green, and Blue.
- By using these three colors, we can produce millions of different colors.
- The two basic color display producing techniques are:
  - Beam-Penetration Method
  - Shadow Mask Method

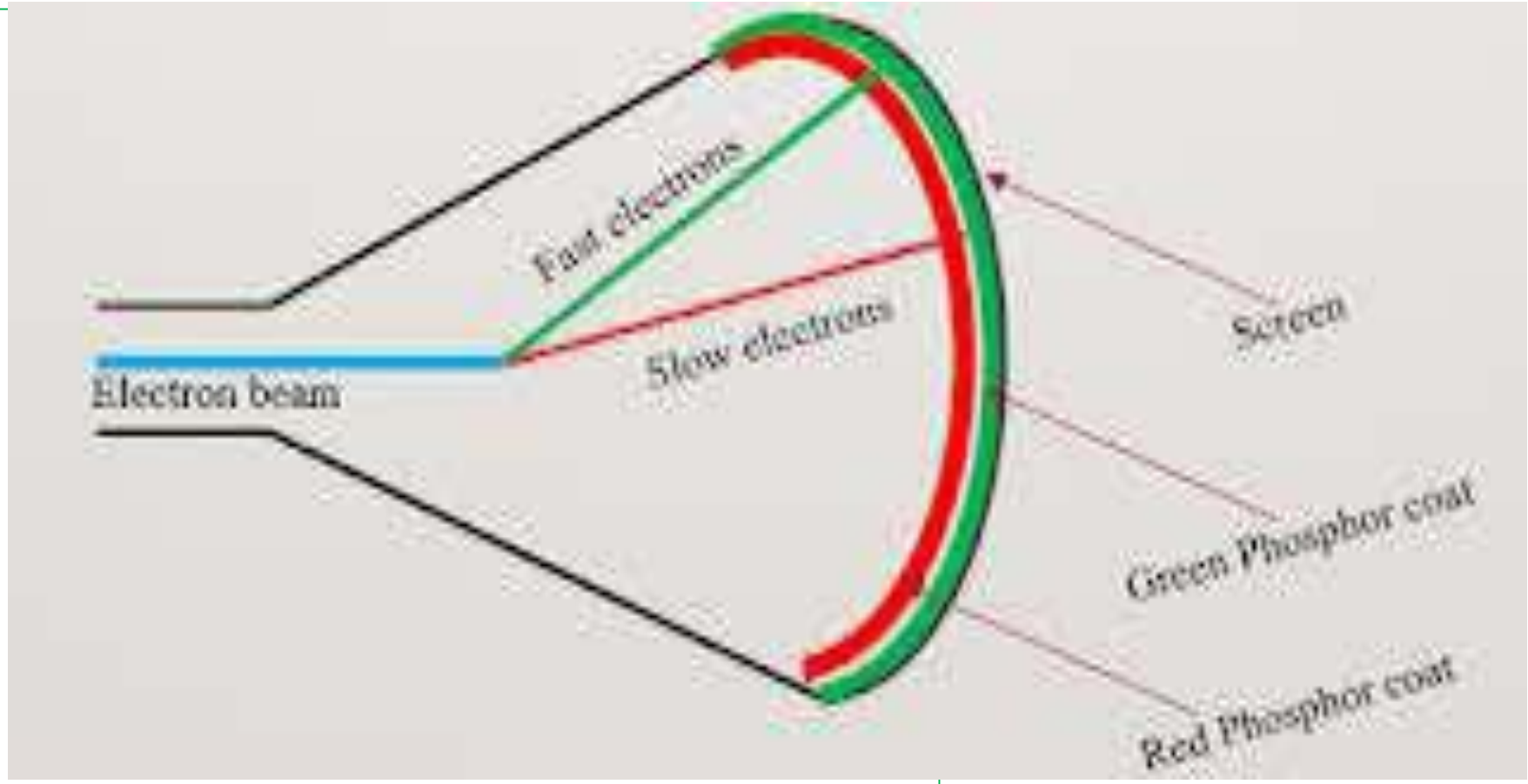
a) Beam-Penetration Method:

- It is used with a **random scan** monitor for displaying pictures.
- There are two phosphorus layers- Red and Green are coated inside the screen.
- The color shown depends on how far the electron beam penetrates the phosphorus surface.
  - A powerful electron beam penetrates the CRT, it passes through the red layer and excites the green layer within.
  - A beam with slow electrons excites only the red layer.
  - A beam with the medium speed of electrons, a mixture of red and green light is emitted to display two more colors- orange and yellow.

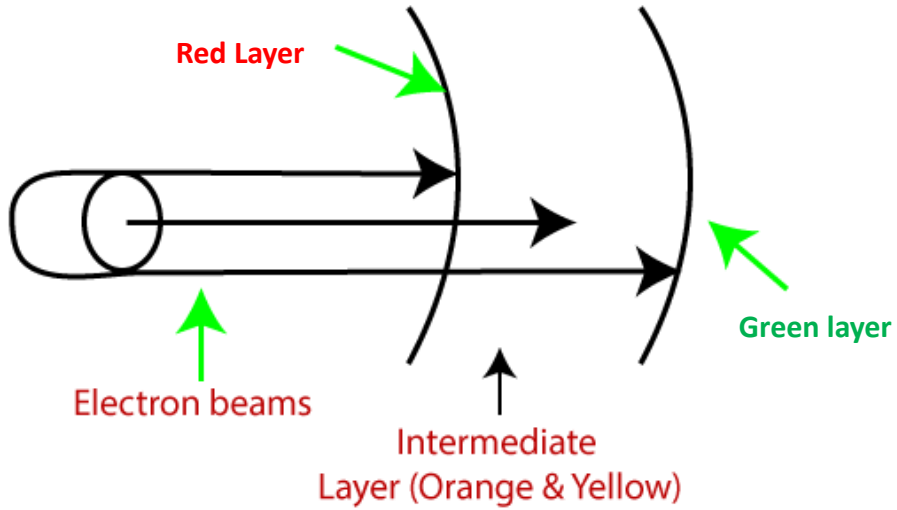




a) Beam-Penetration Method:

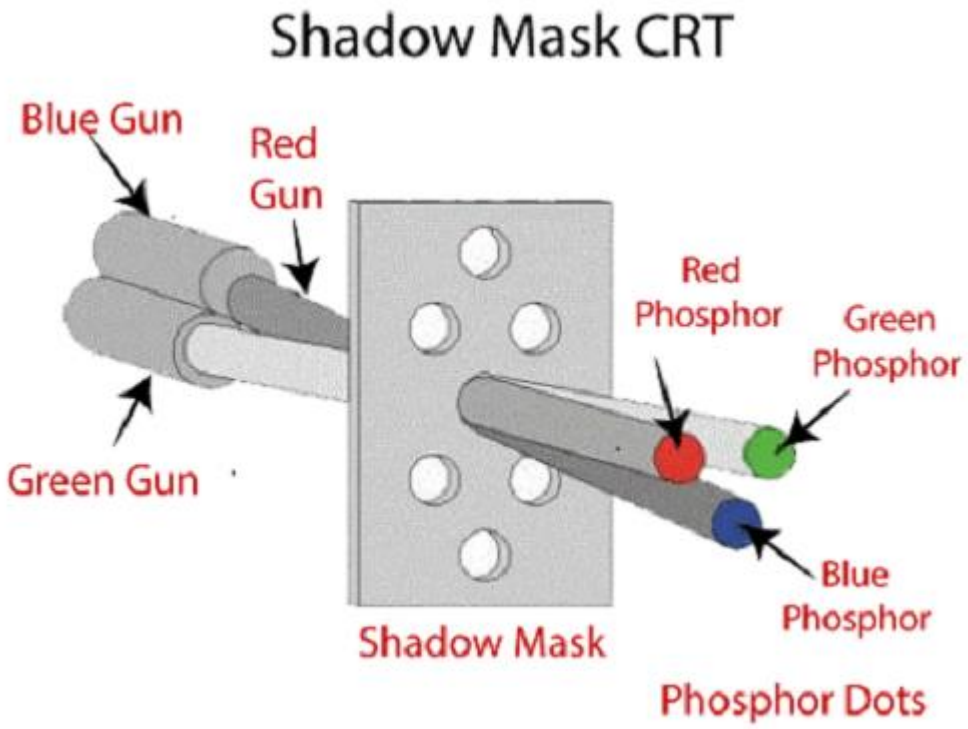


- **Advantages:**
  - Better Resolution
  - Inexpensive
- **Disadvantages:**
  - Only four possible colors
  - Time Consuming

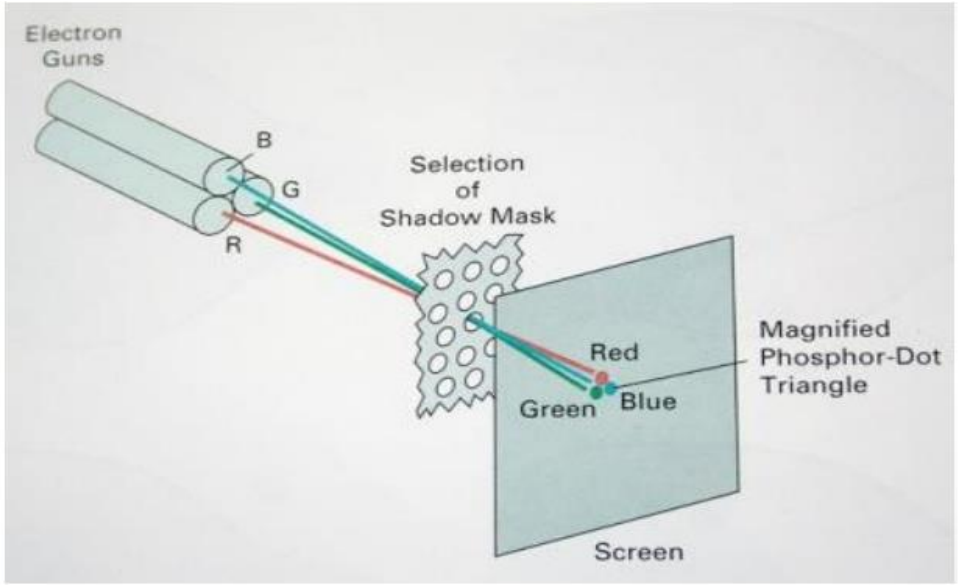


b) Shadow-Mask Method:

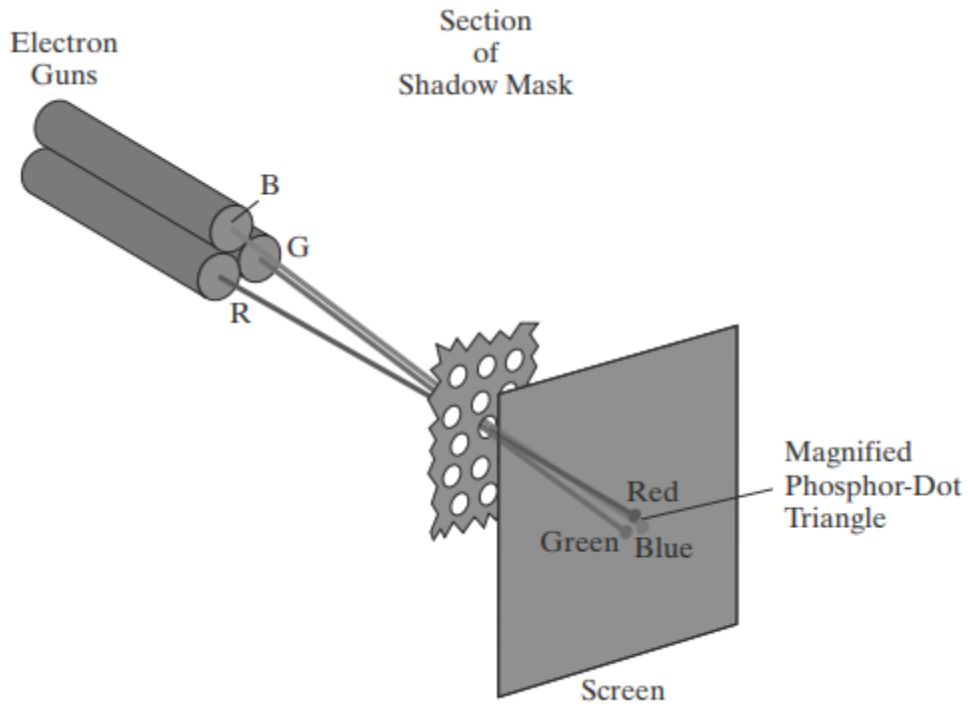
- It is used with a **raster scan** monitor for displaying pictures.
- It has more range of color than the beam penetration method. It is used in television sets and monitors.
- **Structure:**
  - It has three phosphorus color dots at each position of the pixel.
  - First Dot: **Red** color
  - Second Dot: **Green** color
  - Third Dot: **Blue** color
- It has three different guns. Each for one color.
- It has a metal screen or plate just before the phosphorus screen, named **"Shadow-Mask."**
- It also has a shadow grid just behind the phosphorus coated screen with tiny holes in a triangular shape.



- **Working:** A Shadow Mask is a **metal plate with tiny holes** present inside a color monitor.
- A Shadow Mask **directs the beam** by consuming the electrons so that the beam hits only the desired point and displays a resulting picture.
- When the three beams pass through a hole in the shadow mask, they activate a dot triangle, which appears as a small color spot on the screen. The phosphor dots in the triangles are arranged so that each electron beam can activate only its corresponding color dot when it passes through the shadow mask.
- We obtain color variations in a shadow-mask CRT by varying the intensity levels of the three electron beams.



- **Advantages:**
  - Display a wider range picture.
  - Display realistic images.
  - In-line arrangement of RGB color.
- **Disadvantages:**
  - Difficult to cover all three beams on the same hole.
  - Poor Resolution.



1.11. Flat Panel Display

Flat Panel Display (FPD)

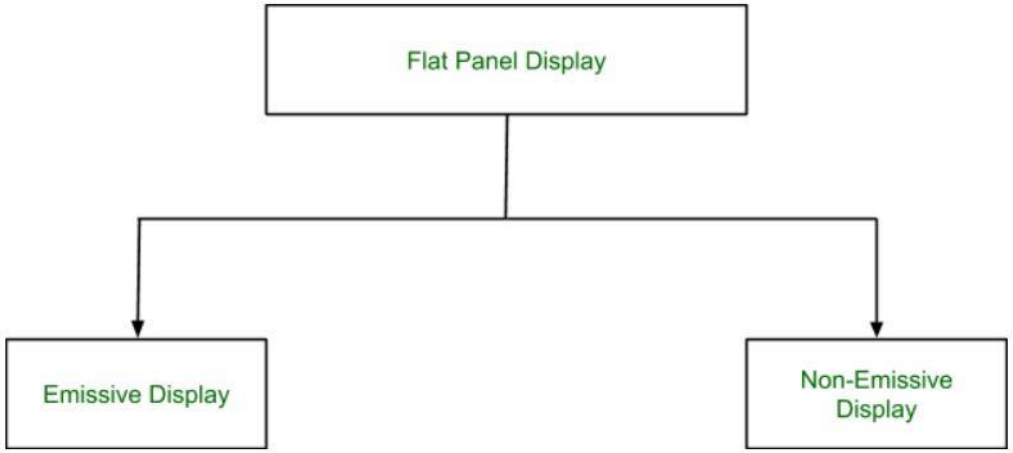
- The Flat-Panel display refers to a class of video devices that have reduced volume, weight and power requirement compare to CRT.
- **Example:** Small T.V. monitor, calculator, pocket video games, laptop computers, an advertisement board in elevator.

1. Emissive Display:

- The emissive displays are devices that convert electrical energy into light.
- Examples are Plasma Panel, thin film electroluminescent display and LED (Light Emitting Diodes).

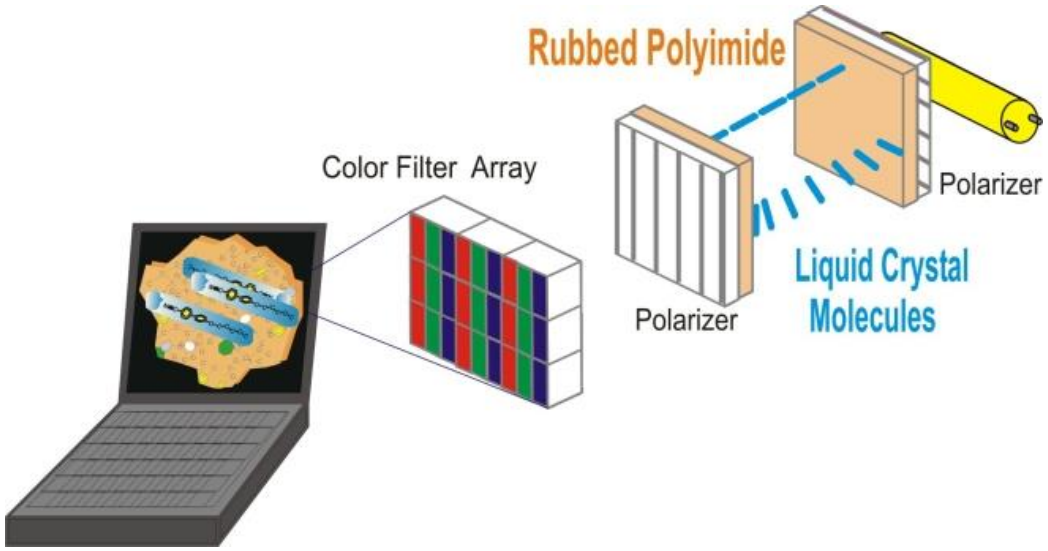
2. Non-Emissive Display:

- The Non-Emissive displays use optical effects to convert sunlight or light from some other source into graphics patterns.
- Examples are LCD (Liquid Crystal Device).



Liquid Crystal Display (LCD)

- LCD is composed of liquid crystal particles. Liquid crystals generally do not emit light on their own rather they are illuminated by a fluorescent backlight.
- Since liquid crystals do not produce light of their own, they need an external light source to work.
- An LCD panel has sets of polarized glass consisting of liquid crystal materials in between them.
- When the external light passes through one of the polarized glasses and electric current is applied on the liquid crystal molecules, they align themselves in such a way that polarized light travels from the first layer to the second polarized glass, causing an image to appear on the screen.



Advantages:

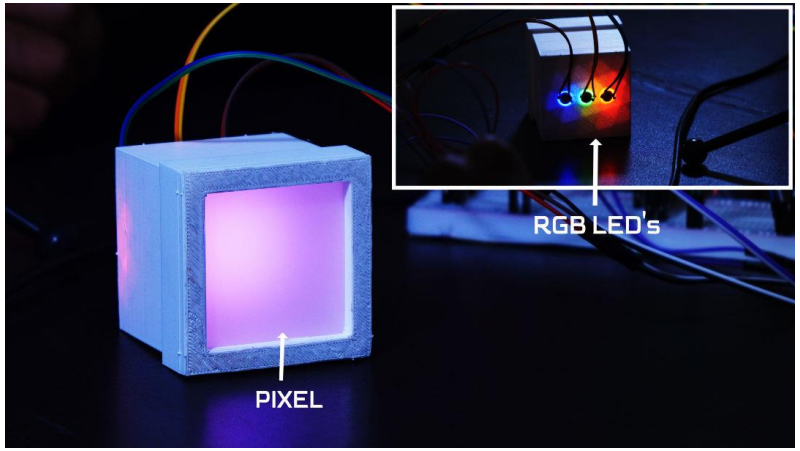
- Good color reproduction
- Very thin
- Light weight
- Excellent longevity (life span)

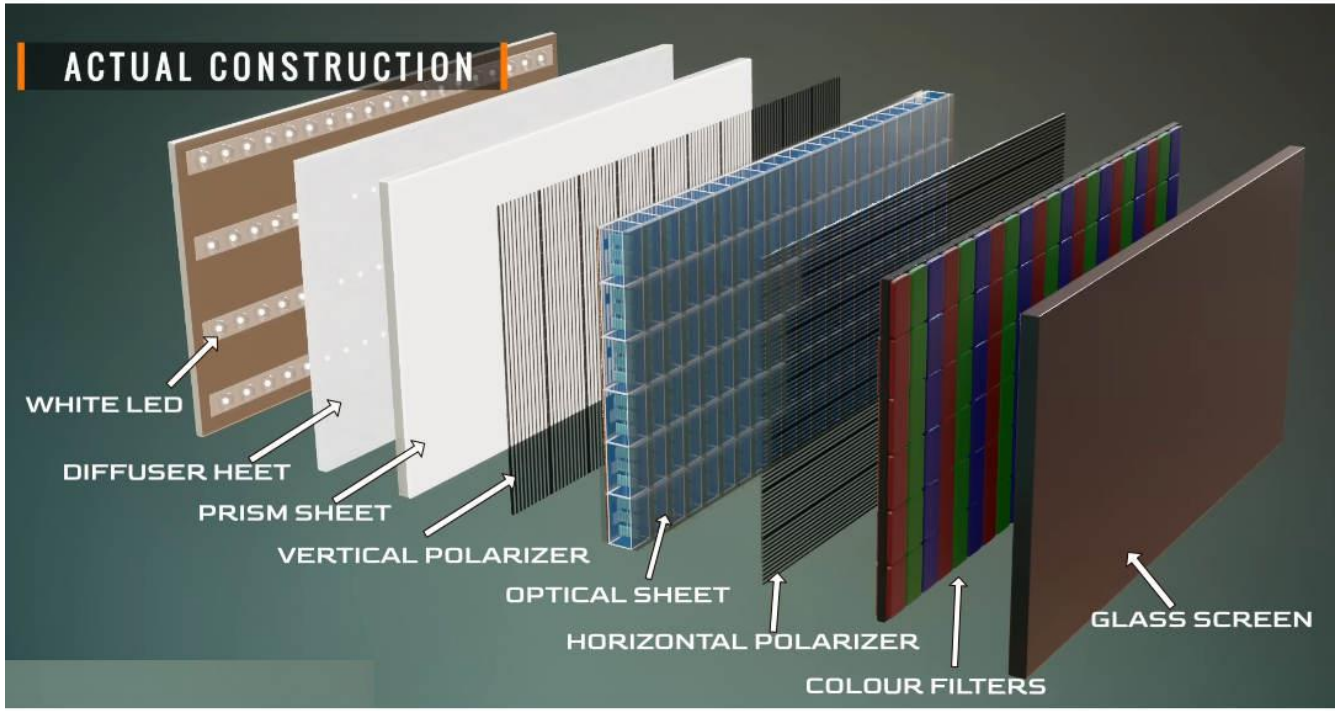
Disadvantages:

- Fixed resolution
- Poor constraint ratios
- viewing angle on older models may be narrow(160 degree)

Light Emitting Diode (LED) Display

- In an LED, a matrix of diodes is organized to form the pixel positions in the display and picture definition is stored in a refresh buffer.
- Data is read from the refresh buffer and converted to voltage levels that are applied to the diodes to produce the light pattern in the display.
- LED emits light, when electrons from n-region and holes from p-region are moved to a p-n junction.
- **Advantages:**
  - Great efficiency
  - Lamp life is 100000 hours
  - Became cost effective when the price of semi-conductors fell
- **Disadvantages:**
  - Need a lot of LED's to produce light.
  - Consistency of led is an issue
  - New technology still relatively expensive





Source: https://www.lesics.com/led-display.html

Numerical:

Numerical:

1. Consider a raster system with resolution of 640x 480, What is the size of frame buffer (in bytes) needed for the system to store 12 bits/pixel ?
2. If the pixel values are accessed from the frame buffer with an average access time (for one single pixel) of 20 ns and the total resolution of the screen is 1024 X 800 , will there be a flickering effect seen on the screen ?
3. In case of raster system with resolution 1024 X 1280, how many pixel could be accessed per second in the system by a display controller at a rate of 60 frames per second? What is accessed time per pixel in this system ?
4. How much time is spent scanning across each row of pixels during screen refresh on a raster system with a resolution of 1280 by 1024 b and a refresh rate of 60 frames per second ?

Numerical:

5. *Calculate the frame buffer size (in KB) for a raster system recording a video for 1 min with resolution of 1280 × 1024, and storing 24 bits per pixel with a refresh rate of 25 fps.*

6. *If pixels are accessed from the frame buffer with an average access the 300ns. Then will this rate produce the flickering effects? (screen resolution = 640×480)*

7. *If pixels are accessed from the frame buffer with an average access the 300ns. Then will this rate produce the flickering effects? (screen resolution = 640×480)*

8. *Consider 256 pixel × 256 scan lines image with 24-bit true color. If 10 minutes video is required to capture, calculate the total memory required?*

Numerical:

9. *If we want to resize at 1024×768 image to one that is 640 pixels wide with the same aspect ratio, what would be the height of the resized image?* [2070 Ashadh]

10. *How much time is spent scanning across each row of pixels during screen refresh on a raster system with resolution 1024×768 and refresh rate 60 frames per second?* [2070 Chaitra]

Numerical:

1. **Consider a raster system with resolution of 640x 480, What is the size of frame buffer (in bytes) needed for the system to store 12 bits/pixel ?**

Ans:

Total no. of pixel required: (640 x 480) pixels

Size of the frame buffer required = (640x480) pixels.

Also 1 pixel can store 12 bits (given)

Therefore, size of frame buffer (in bits) is,

= 640x 480x 12 bits

= (640 x 480 x12)/8 bytes

= 460800 bytes

= 450 KB

2. If the pixel values are accessed from the frame buffer with an average access time (for one single pixel) of 20 ns and the total resolution of the screen is 1024 X 800 , will there be a flickering effect seen on the screen ?

Ans:

To glow one single pixel takes = 20 ns

To glow all pixel on screen it takes = 1024 X 800 X 20 ns
= 16,384,000 ns
= 16,384,000 x 10^{-9} second
= 0.01638 second

Now

frequency(F) = 1/T
= 1/0.01638
= 61.05 HZ

since it is above 50times/sec there will be no flickering effect seen on screen

2. If the pixel values are accessed from the frame buffer with an average access time (for one single pixel) of 20 ns and the total resolution of the screen is 1024 X 800 , will there be a flickering effect seen on the screen ?

Ans:

To glow one single pixel takes = 20 ns

To glow all pixel on screen it takes = 1024 X 800 X 20 ns
= 16,384,000 ns
= 16,384,000 x 10^{-9} second
= 0.01638 second

Now

frequency(F) = 1/T
= 1/0.01638
= 61.05 HZ

since it is above 50times/sec there will be no flickering effect seen on screen

3. **In case of raster system with resolution 1024 X 1280, how many pixel could be accessed per second in the system by a display controller at a rate of 60 frames per second? What is accessed time per pixel in this system ?**

Ans :

1) Pixel accessed :

= 1024 X 1280 X 60 pixel can be accessed in this system

2) Access time per pixel:

= 1/(1024 X 1280 X 60)

= 12.71ns

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

Ans: Resolution=1280*1024

Refresh Rate= 60 frames per second

Since 1 frame consist 1024 scan line

Also 60 frames takes 1 sec for refreshing

1 frame takes 1/60 sec.

1024 scan lines = (1/60) /1024 sec

$= 1.6276 * 10^{-5}$ sec

$= 1.6276*10^{-5} * 10^{6}$ microsecond

= 16.27 microsecond

5. ***Calculate the frame buffer size (in KB) for a raster system recording a video for 1 min with resolution of 1280 × 1024, and storing 24 bits per pixel with a refresh rate of 25 fps.***

[2076 Ashwin Back]

Solution:

Screen resolution = 1280 × 1024

Refresh rate = 25 fps

Bit required to represent a pixel = 24 bits

Memory required just for a frame = 1280 × 1024 × 24 bits

Memory required for 1 second = 1280 × 1024 × 24 × 25 bits

Memory required for recording a video for 1 min is

= 1280 × 1024 × 25 × 24 × 60 bits = 5760,0000 KB

6. ***If pixels are accessed from the frame buffer with an average access the 300ns. Then will this rate produce the flickering effects? (screen resolution = 640×480)***

Solution:

Access time for 1 pixel = 300ns

Access time for 640×480 pixels = $640 \times 480 \times 300\text{ns}$

$$\text{Frequency} = \frac{1}{t} = \frac{1}{640 \times 480 \times 300 \times 10^{-9}}$$

$$= 10.85 \text{ frame per second (fps)}$$

This value is lesser than 50fps, so flicker occurs.

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

Solution:

Size in frame buffer for 1 pixel = 8 bit

For 640×480 pixels, size in frame buffer = 640 × 480 ×8 bits

= 300 KBytes

8. ***Consider 256 pixel × 256 scan lines image with 24-bit true color. If 10 minutes video is required to capture, calculate the total memory required?***

Solution:

Memory required for 1 sec = 256×256×3×50 Bytes

For 10 minutes, total memory required

$$= \frac{(256\times256\times3\times50\times10\times60)}{(1024\times1024\times1024)} = 5.49 \text{ GB}$$

9. ***If we want to resize at 1024×768 image to one that is 640 pixels wide with the same aspect ratio, what would be the height of the resized image?*** *[2070 Ashadh]*

Solution:

$$\text{Aspect ratio} = \frac{H}{W} = \frac{768}{1024}$$

Even after the image is resized, the aspect ratio remains same. So,

$$\frac{H}{640} = \frac{768}{1024}$$

$$\therefore H = 480$$

10. ***How much time is spent scanning across each row of pixels during screen refresh on a raster system with resolution 1024×768 and refresh rate 60 frames per second?*** *[2070 Chaitra]*

Solution:

Resolution = 1024×768

Refresh rate = 60fps

For 60 frames, it takes 1 second to scan

For 1 frame, it takes $\frac{1}{60}$ second

1 frame means total 1024×768 pixels

For 1024×768 pixels, it takes $\frac{1}{60} = 0.016667$ second

For scanning 1 pixel, it takes $\frac{0.016667}{1024\times768}$ second

For scanning 1 row of pixels i.e., 1024 pixels, it takes $\frac{0.016667}{1024\times768}\times1024 = 0.0000217013$ second.

11. ***Consider a raster scan system having 12 inch by 10 inch screen with a resolution of 100 pixels per inch in each direction. If the 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?*** *[2071 Shrawan]*

Solution:

Total pixels = $12 \times 100 \times 10 \times 100$

Refresh rate= 50 frames per second.

Pixels accessed per second(f) = $12 \times 100 \times 10 \times 100 \times 50$

$= 60000000$

Access time per pixel $= \frac{1}{f} = 1.667 \times 10^{-8}$ second

Assignments & Exam Questions

Assignment:

1. Differentiate between:
   a) Raster and Random Scan System
   b) Beam penetration and Shadow Mask Method
2. Explain the construction and working of:
   a) CRT monitor
   b) LCD monitor
   c) LED monitor
   d) Plasma monitor

Exam Questions (Part 1):

1. What is computer graphics? Describe its significance I modern world with reference to its various application areas. [2011 fall]
2. What so you mean by computer graphics? How it is used in education and training? [2011 spring]
3. Why do you think that computer graphics has found its usage in practically all fields? Explain. [2012 fall]
4. Explain the need and use od graphics in the field of IT. [2012 spring]
5. Define computer graphics. Discuss the major application areas of computer graphics. [2013 Fall]
6. What are components that computer graphics consist of? Explain them with diagram. [2013 spring]
7. Discuss the concept of computer graphics in IT field. [2014 fall]
8. Computer graphics makes easier in working computer fields. Why? [2014 spring]
9. Explain different Graphics File formats. [2014 Spring]
10. Give your opinion on why interactive graphics has been able to gain such an immense amount of popularity in diversified fields like business, engineering, medicine, etc. [2015 fall]

11. Why do you think that the use of computer graphics is growing? Explain with suitable examples from various fields. [2015 spring]
12. “A picture speaks thousands of words”. Explain with reasons as to why this statement is true emphasizing the popularity that the field computer graphics has gained in diversified fields. [2016 fall]
13. Computer graphics has enhanced the quality of work in many areas. Support this statement through a brief discussion on areas of application of computer graphics. Specify at least one specific application. [2016 spring]
14. What do you understand by computer graphics? Mention some of the advantages of computer graphics. [2017 Fall]
15. Explain Frame buffer? How is computer graphics applicable in the field of GUI, entertainment and Medical Science? Explain. [2018 Spring]
16. Explain the use of computer graphics emphasizing the application of graphics in the field of entertainment. [2019 Fall]
17. How the entertainment and gaming industry has revolutionized by the advancement in computer graphics? Explain your answer with some real life examples. [2020 Fall]
18. Define computer graphics. List the application of computer graphics in different fields. [2021 Fall]

Exam Questions (Part 2):

1. Explain the working principles of various types of tablets. [2011 fall]
2. Define resolution. What are the factors affecting resolution? Differentiate between vector and raster scan systems. [2011 fall]
3. Define resolution. What are the factors affecting resolution? Differentiate between vector and raster scan systems. Mention their advantages and disadvantages. [2011 spring]
4. What are techniques used by color CRT monitors. Explain shadow mask method using figure. [2011 spring]
5. Explain different types of touch panels with its working mechanisms. [2012 fall]
6. What are the techniques used by color CRT monitors. Explain shadow mask method using figure. [2012 fall]
7. Consider a noninterlaced raster monitor with a resolution of n by m (m scan lines and n pixels per scan line), a refresh rate of r frames per second, a horizontal retrace time of t_{horiz}, and a vertical retrace time of t_{vert}. What is the fraction of the total refresh time per frame spent in retrace of the electron beam? [2012 fall]
8. What is video controller? Explain the basic video-controller refresh operations with proper block diagram. [2012 spring]
9. Enlist different types of input devices. Describe touch panel as an input device. [2012 spring]
10. Define resolution and persistence. What is the difference between raster scan display and vector scan display? [2013 fall]

11. Consider two raster systems with resolutions of 640x840 and 1280x1024. How many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 60 frames per second? What is the access time per pixel in each system? [2013 fall]
12. Describe how color pixel is displayed in a computer system? [2013 fall]
13. On an average it takes 200 ns to access a pixel value from the frame buffer and glow a phosphor dot on the screen for a raster system. If total resolution of the screen is 1024x1024, will this access rate create a flickering effect on the screen? Illustrate. [2013 spring]
14. Explain the architecture of raster display with a neat block diagram. [2013 spring]
15. Compare raster scan display system with vector scan display system along with their architectures. [2014 fall]
16. What is flat panel display? Explain the working principles of LCD monitor with figure. [2014 fall]
17. Differentiate raster scan display system with random scan display. [2015 fall]
18. In case of two raster systems with resolution of 640x480 and 1024x600, how many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 75 frames per second? What is the access time per pixel in each system? [2015 fall]
19. Explain the working principle of shadow mask method with a diagram. [2015 spring]
20. How colors are displayed in monitor? Explain. [2015 spring]

21. Consider two raster systems with resolution of 640x480 and 1280x1024, how many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 60 frames per second? What is the access time per pixel in each system? [2016 fall]
22. What is an input device? Explain. Describe the working principle of a touch panel.[2016 fall]
23. Define resolution and image aspect ratio. A laser printer is capable of printing two pages (size 9x11 inch) per second at resolution of 600 pixels per inch. How many bits per second does such device require? Assume 1 pixel=n bits. [2016 spring]
24. What is emissive display and explain any one with example? What are the advantages and disadvantages of LCD display? [2016 spring]
25. Explain the working of LCD and LED. [2017 Fall]
26. Define Display Controller. Compare and contrast Raster Scan Display and Vector Scan Display architectures. [2017 Spring]
27. Define resolution. Suppose RGB raster system to be designed using 8 inch x 10 inch screen with a resolution of 100 pixels per inch in each direction. If we want to store 6 bits per pixel in the frame buffer, how much storage (in bytes) do we need for frame buffer? [2017 Spring]
28. Explain Frame buffer. Calculate the access time for a pixel and a row for a graphics system having resolution of 1024 x 640 and frequency of 60 Hz. [2018 Spring]
29. Explain the Raster scan system with video controller. [2018 Spring]
30. How colors are displayed in monitor? [2018 Spring]

31. Consider a non-interlaced Raster monitor with a resolution of 1280 x 1024. if horizontal and vertical retrace times are 20 microsecond each, then calculate the fraction of the total refresh time per frame spent in retrace of the electron beam? Assume refresh rate of 60 frames per second. [2019 Fall]
32. Define Video controller? Differentiate between Beam penetration and Shadow mask method. [2019 Fall]
33. Discuss the differences between raster and random scan display systems with its architectural diagram. [2020 Fall, 2021 Fall]
34. Why graphical system contains D2A converter (DAC) and what is the role of Frame buffer organization? [2020 Spring]
35. In a true color system having resolution of 1024 x 768 having the refresh rate of 60 fps, calculate the following: (Note convert your memory into Mega byte).
    a) Size of frame buffer
    b) Access time of one frame
    c) Access time for one pixel
    d) Access time for one row
36. Write short notes on:
    a) Frame Buffer Organization [2017 Fall]
    b) Pros and Cons of Vector Graphics [2019 Fall]
    c) Light pen [2020 Fall]

End of Chapter