# UNIT 1: INTRODUCTION

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# Introduction of Computer Graphics

- The process of transforming and presenting object or information in visual form is called computer graphics.
- It is the creation of pictures with the help of a computer.
- Computer graphics maybe a business graph, drawing like line, circle or any other shape, animations etc.
- Computer Graphics 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, that is, the 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.

# Introduction of Computer Graphics

- Until the early 1980's computer graphics was a small, specialized field, largely because the hardware was expensive and graphics-based application programs that were easy to use and cost-effective were few. Then personal computers with built-in raster graphics displays-such as the Xerox Star, Apple Macintosh and the IBM PC- popularized the use of bitmap graphics for user-computer interaction. A bitmap is a ones and zeros representation of the rectangular array points on the screen. Each point is called a pixel, short for "Picture Elements". Once bitmap graphics became affordable, and explosion of easy-to-use and inexpensive graphics-based applications soon followed. Graphics-based user interfaces allowed millions of new users to control simple, low-cost application programs, such as word-processors, spreadsheets, and drawing programs. The concepts of a "desktop" now became a popular for organizing screen space. By means of a window manager, the user could create position and resize rectangular screen areas called windows. This allowed user to switch among multiple activities just by pointing and clicking at the desired window, typically with a mouse. Besides windows, icons which represent data files, application program, file cabinets, mailboxes, printers, recycle bin, and so on, made the user-computer interaction more effective. By pointing and clicking the icons, users could activate the corresponding programs or objects, which replaced much of the typing of the commands used in earlier operating systems and computer applications. Today, almost all interactive application programs, even those for manipulating text (e.g. word processor) or numerical data (e.g. spreadsheet programs), use graphics extensively in the user interface and for visualizing and manipulating the application specific objects. Even people who do not use computers encounter computer graphics in TV commercials and as cinematic special effects. Thus computer graphics is and integral part of all computer user interfaces, and is indispensable for visualizing 2D, 3D objects in all most all areas such as education, science, engineering, medicine, commerce, the military, advertising, and entertainment. The theme is that learning how to program and use computers now includes learning how to use simple 2D graphics.

## Early History

We need to take a brief look at the historical development of computer graphics to place today's system in context.

| | |
|---|---|
| In 1950 | Ben Laposky created the first graphics image. The Whirlwind Computer developed at the Massachusetts Institute of Technology (MIT) had computer-driven CRT displays for output |
| In 1961 | Ssteve Russel introduced first computer game (SPACE WARS) |
| In 1963 | Iran Sutherland created sketchped for drawing simple shapes |
| In 1965 | Jack Bresentham invented line drawing algorithm |
| In 1969 | John Warnock introduced Hidden Surface algorithm |
| In 1971 | Graphic Processor developed for advanced graphics |
| In 1987 | VGA (Video Graphic Array) introduced by IBM |
| In 1993 | First Graphics web Browser protocol |
| In 1995 | First full length 3D animated motion picture was developed |

# Advantage of Computer Graphic

1) High Quality Graphic Picture
2) Provide tools to produce picture
3) Produce Animation
4) Using Motion Dynamics
5) Using Update Dynamics

# Types of computer graphics

**Interactive and Non Interactive graphics in Computer Graphics**

- **Interactive computer graphics(active),** refers to the dynamic and responsive generation of visual images on a display device, coupled with real-time user interaction.
- The primary characteristic of interactive graphics is the ability to engage with and manipulate the displayed content in real-time.
- This interaction is typically facilitated through input devices such as keyboards and touchscreens.
- **Non-interactive computer graphics (Passive)**, on the other hand, involve the generation and display of visual content without direct, real-time user interaction.
- Users have limited or no control over the displayed content during runtime.

# Application Area of Computer Graphics

- Computer graphics is used today in many different areas of science, engineering, industry, business, education, entertainment, medicine, art and training. All of these are included in the following categories.

**1) Computer Art**

Using computer graphic we can create fine and commercial art which includes animation packages, paint packages. These packages provide facilities for designing, painting and logo designing can also be done.

2**) Scientific and business 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.

**3) Simulation and modeling**

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 simulator 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.

# Application Area of Computer Graphics

**4) Entertainment**

Disney movies such as Lion Kings and The Beauty of Beast, and other scientific movies like Jurassic Park, 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, Doom, Pools are few to name where graphics is used extensively.

**5) Computer Aided Drafting and Design(CAD)**

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.

**6) Cartography**

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 populationdensity maps. Surfer is one of such graphics packages, which is extensively used for cartography

**Input Device (Read Yourself)**

- Mouse
- Keyboard
- Joystick
- Track Ball
- Scanner
- Microphone
- Bar code reader etc

# Graphic Hardware

- Graphics hardware is computer hardware that generates computer graphics and allows them to be shown on a display, usually using a graphics card (video card) in combination with a device driver to create the images on the screen.

1. **Graphics Processing Unit (GPU):** The GPU is the most crucial hardware component for computer graphics. It is responsible for rendering images, videos, and 3D models. Modern GPUs are designed with numerous cores and high-speed memory to handle complex calculations and rendering tasks efficiently.
2. **Central Processing Unit (CPU):** While the GPU handles most of the rendering tasks, the CPU is still essential for overall system performance. It handles tasks such as data processing, scene setup, and managing the overall operation of the computer.
3. **Random Access Memory (RAM):** Adequate RAM is crucial for handling large graphic files and complex rendering tasks. More RAM allows for smoother multitasking and faster data access, which is essential for graphic design and rendering.
4. **Storage Drives:** Solid State Drives (SSDs) are preferred for graphic design work due to their faster read and write speeds, which can significantly improve the performance of graphic design software and reduce loading times.
5. **Display Monitor:** High-resolution monitors with accurate color representation are essential for graphic design work. Professionals often use monitors with wide color gamuts and high refresh rates to ensure accurate and smooth visual representation.
6. **Input Devices:** Graphic designers often use specialized input devices such as graphics tablets and styluses to create digital artwork with precision and control.
7. In summary, a powerful GPU, sufficient RAM, fast storage, and high-quality display monitors are essential for handling the demanding requirements of computer graphics.

# Graphic Hardware

**Display Technology**

Display technology are following of two types:

**1) Raster graphics:**

It is also known as bitmap images, are created using pixels. Each pixel represents a single point in an image and contains information about its color. When these pixels are arranged together, they form a complete image. Raster graphics are commonly used in digital photography and video games due to their ability to represent detailed and realistic images.

**2) Vector graphics:**

Vector graphics are created using mathematical formulae that define shapes, lines, and objects. Instead of pixels, vector graphics use points, lines, and curves to represent elements. This allows for scalable graphics that can be resized without loss of quality. Vector graphics are widely used in graphic design, architectural design, and illustration industries.

Raster graphics excel in creating highly detailed images, while vector graphics shine in tasks that require scalability and precision.

# Raster Graphics vs. Vector Graphics

**1. Raster Graphics (Bitmap Graphics)**

- **Definition**: Composed of a grid of individual pixels, where each pixel has a specific color.
- **Common File Formats**: JPEG, PNG, GIF, BMP, TIFF.
- **Best For**: Photos, digital paintings, and complex images with gradients and shading.
- **Scalability**: Loses quality when enlarged (appears pixelated).
- **Editing**: Pixel-based, so editing specific details can be complex.
- **Examples**: Digital photos, web images, scanned images.
- **Usage:** Digital art, photography, web design, detailed illustrations.

# Raster Graphics vs. Vector Graphics

- **2. Vector Graphics**
- **Definition**: Composed of mathematical equations defining lines, shapes, and colors.
- **Common File Formats**: SVG, AI, EPS, PDF.
- **Best For**: Logos, icons, illustrations, and designs that require scalability.
- **Scalability**: Can be resized infinitely without loss of quality.
- **Editing**: Object-based, making it easier to modify individual elements.
- **Examples**: Company logos, fonts, technical drawings.
- **Usage:** Graphic design, branding, CAD drawings, and animations.

# Output Devices

- An output device accepts data from a computer and translates them into a human acceptable form.
- Output generated by output device classified into two types:

1) **Soft-copy output** – Output which is stored in computer memory and displayed on screen in digital and electronic form of material and modified easily. Example, Cathode ray tube(CRT) and Flat panel.
2) **Hard-copy output** – Output is a physical form of material which is produced on a paper. They cannot be modified easily

# Cathode Ray Tube (CRT)

- It is a technology used in early monitors.
- It uses a beam of electrons to create an image on the screen.
- It comprises the guns(3-RGB) that fire a beam of electrons inside the screen.
- The electron beams repeatedly hit the surface of the screen.
- These guns are responsible for generating RGB (Red, Green, Blue) colors, and more other colors can be generated with the help of combining these three colors.
- Typically, primary output device in a graphics system is video monitor whose operation is based mostly on standard **cathode-ray tube (CRT)** design.
- 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.
- **Electron Gun** − The electron gun is the heart of the CRT. It generates and focuses a stream of electrons into a fine beam.
- **Control Grids** − These grids control the intensity of the electron beam. By adjusting the voltage applied to these grids, the brightness of the display can be modified.
- **Deflection System** − The electron beam needs to be directed precisely to the correct location on the screen. This is achieved through either **electrostatic** or **electromagnetic deflection** Electrostatic deflection is more commonly found in oscilloscopes, while electromagnetic deflection is used in televisions and computer monitors.

# Cathode Ray Tube (CRT)

- **Phosphor-coated Screen** − The screen inside a CRT is coated with a phosphorescent material, usually in the form of tiny dots or stripes. When the electron beam strikes the screen, the phosphor glows, producing light and thus creating an image.
- **Vacuum Tube** − The entire assembly is enclosed in a vacuum tube. This vacuum is necessary to prevent the electrons from being scattered by air molecules as they travel from the electron gun to the screen.

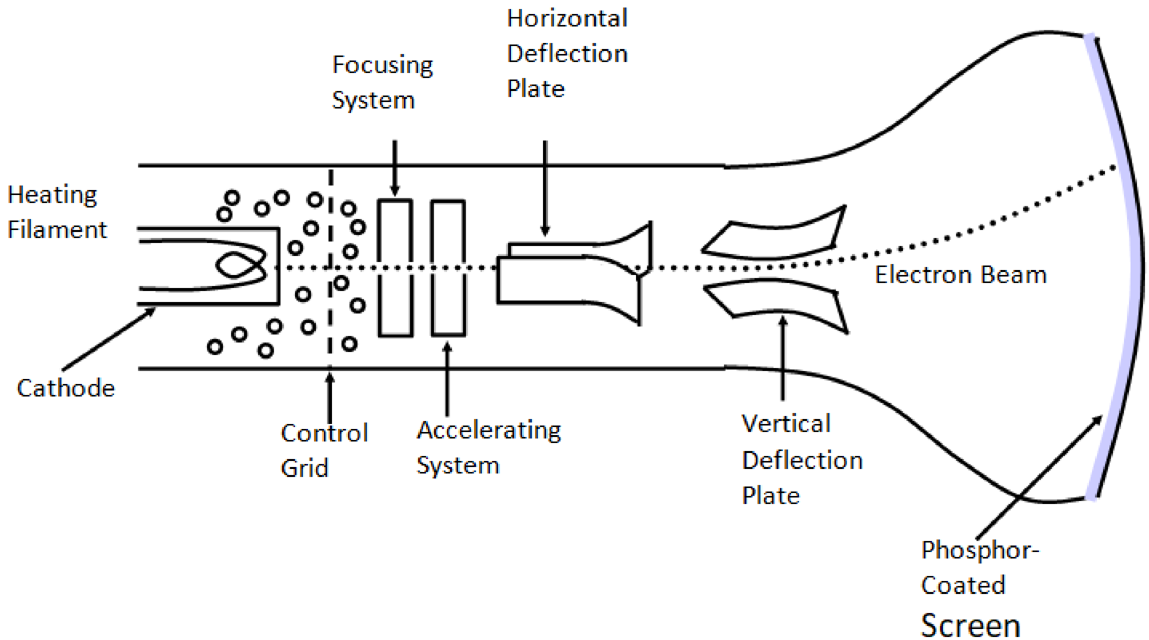



Fig: Cathode-ray tube (CRT)

# How Does a CRT Work?

- The working of CRT is quite interesting. CRT operates by shooting a focused beam of electrons, or "cathode rays," onto a phosphor-coated screen. We can follow the following steps to get a better insight.
- **Electron Emission** − The electron gun generates a stream of electrons by heating a cathode (a metal filament). This process is known as thermionic emission.
- **Focusing the Beam** − The control grids shape the electron beam and focus it into a narrow stream. This step is important to ensure that the image displayed is sharp and not blurry.
- **Deflection of the Beam** − The deflection system moves the electron beam across the screen. In older CRTs, this was achieved using electromagnetic coils placed around the neck of the tube. By varying the current through these coils, the beam could be swept horizontally and vertically across the screen.
- **Image Display** − When the electrons hit the phosphor coating, the phosphor glows, emitting visible light. The pattern in which the electrons hit the screen determines the shape, brightness, and color of the image.
- In color CRTs, there are three electron guns, each emitting electrons toward a red, green, or blue phosphor. These three colors combine in different intensities to form all the colors seen on the screen.

# Graphic Hardware

**1) Raster-Scan Display**

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

# Graphic Hardware

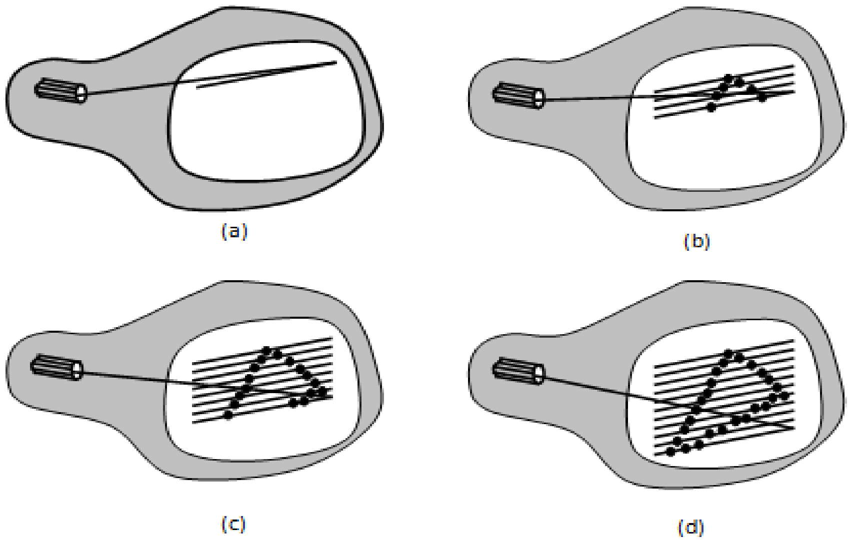



Figure: A raster-scan system displays an object as a set of points across each screen scan line

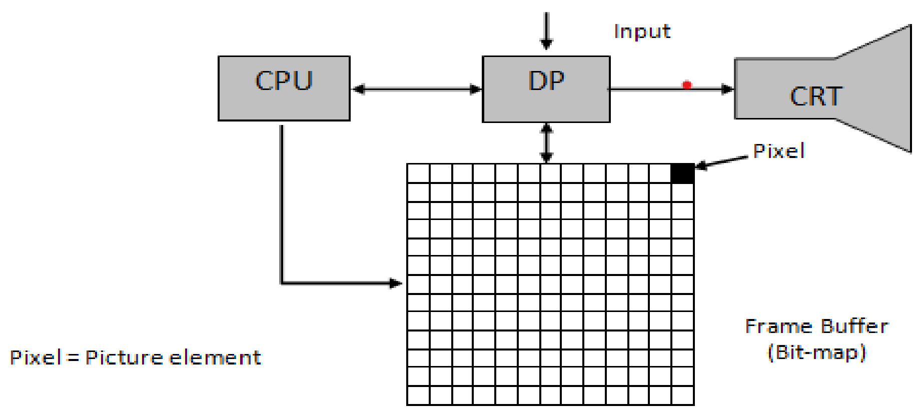
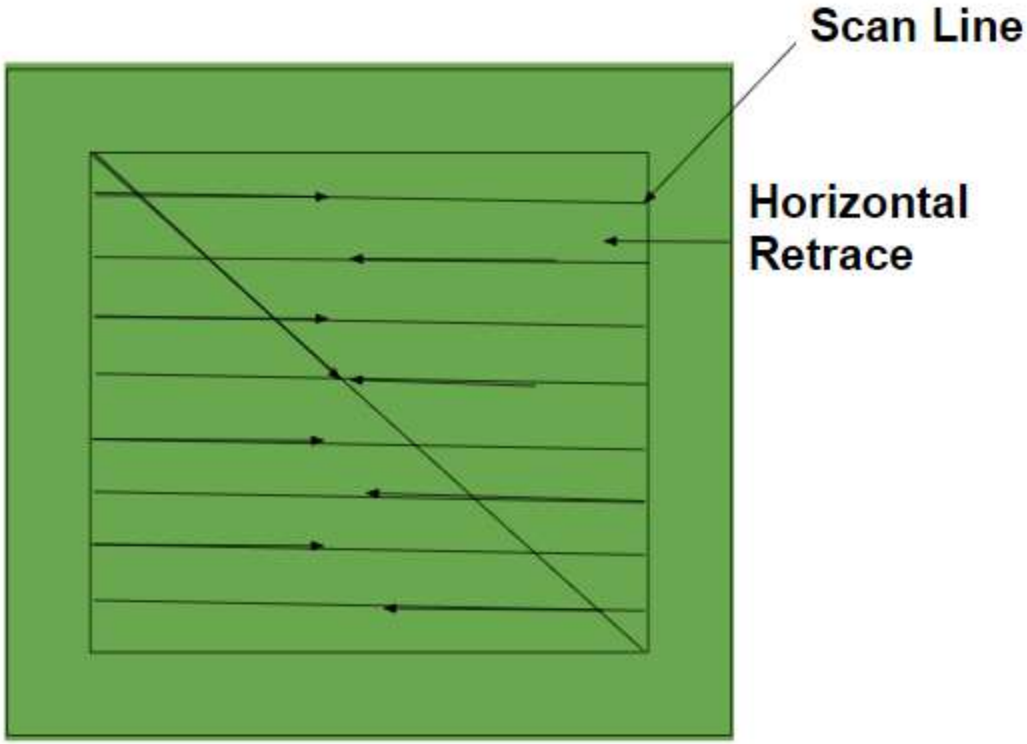



Figure: Raster Scan display system

**Working of Raster Scan Display**

- In the Raster scan system, the electron beam is used as a fixed path on the screen. The electron bean starts from the top left corner of the screen and follows the horizontal path until it reaches the end of the line. This defines a scan line. During the scan, the intensity of the beam is modulated according to the pattern of the desired image along the line.
- After reaching the right corner of the screen, the beam is switched off and it is moved back to the left edge/point of the new row as the new starting point. This defines horizontal retrace.
- Picture definition is positioned in a memory area which is technically known as Frame Buffer. This memory area holds up the set of intense values for all the screen points. Stored intensity values are then retrieved from the frame buffer and used to display images on the screen.
- Now the scanning is continued until it reaches the bottom right corner of the screen. After it reaches the bottom right corner of the screen it defines one scan is completed. Each screen point is known as a pixel.
- After one scan is completed the electron beam is re-positioned at the top left corner of the screen for the next scan. The repositioning process of the electron beam bottom right corner to top left corner is referred to as vertical retrace.
- The way we humans conceptualize graphics is purely visual. A computer, however, must numerically represent images. For a computer to understand what the image is supposed to look like, we must format information in a way that a computer can understand.

- The diagram 3D images are broken into triangles. These triangles are described using vertices. These vertices are written to a vertex buffer and fed to a vertex shader. Then, the computer determines whether the triangle appears on the screen. It culls any objects that don't appear. These objects are then refined by the fragment shade, where effects can be applied. Last, the data describing each pixel is sent to a frame buffer, where the image is drawn before it is presented to the screen as follows:



In raster scan systems refreshing is done at a rate of 60-80 frames per second. Refresh rates are also sometimes described in units of cycles per second / Hertz (Hz). At the end of each scan line, electron beam begins to display next scan line after returning to left side of screen. The return to the left of screen after refresh of each scan line is known as *horizontal retrace* of electron beam. At the end of each frame electron beam returns to top left corner and begins the next frame.

**Advantages**

- Cost for raster scan devices is cheaper/low.
- Doesn't require an intelligent electron beam.
- Used for animation purposes.

**Disadvantages**

- Low resolution.
- Requires more memory.
- Electron beam coordinated to the whole screen not exclusively to those parts of the screen where the picture is to be drawn.

NOTE:

A pixel is a tiny dot or square that represents a single color in a digital image. Pixels are the building blocks of digital images, and are used in computer monitors, smartphones, and televisions.

The maximum number of point that can be displayed without overlap referred to as resolution. Resolution is a measurement of the number of pixels -- picture elements or individual points of color -- that can be contained on a display screen or in a camera sensor. The number of point per centimeter that can be plotted horizontally and vertically is called resolution. For eg: 1024 * 640

# Raster-Scan Displays

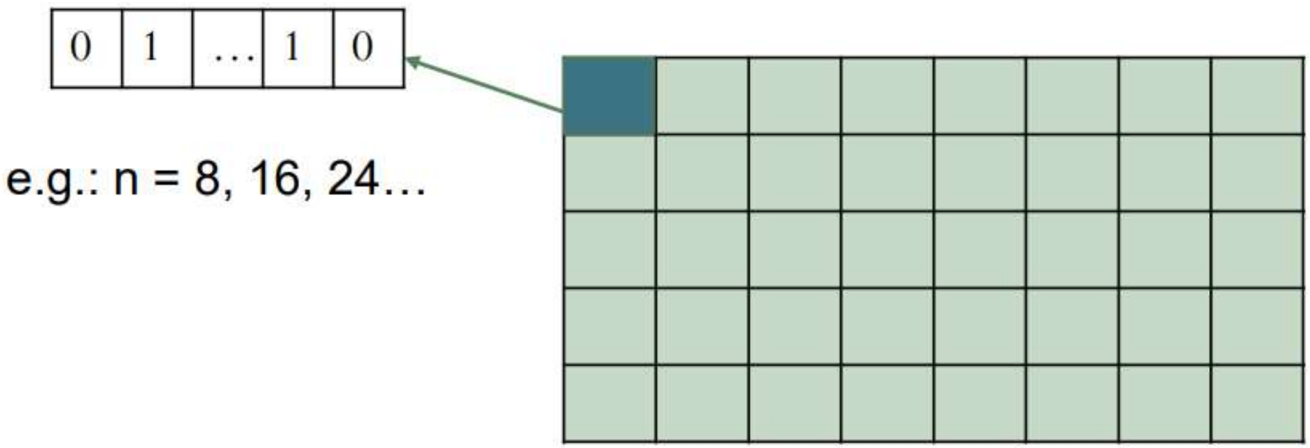
- Terms
  - **Pixel**: each screen spot.
  - **Scan line**: each row of the screen.
  - **Frame**: the total screen.
  - **Resolution**: the maximum number of pixels that can be displayed on a screen without overlapping.
  - **Frame buffer** (refresh/color buffer): the memory area which stores the color value of one frame.

  **Frame buffer** holds the contents of what will be displayed.

What goes on inside the computer to generate something (e.g.: rectangle) on the screen?

# Frame Buffer

- Black-and-white system: one bit for each pixel
- More colors: n bits per pixel




**Terms**

**Bit depth**: the number of bits per pixel in frame buffer.

**Bitmap**: the frame buffer with <u>one</u> bit per pixel.

**Pixmap**: the frame buffer with <u>multiple</u> bits per pixel.

# Frame Buffer

- If we want a frame buffer of 640 by 480 pixels, we should allocate:

  Pixels in Frame buffer = 640 * 480

- How many bits should we allocate?

  n * 640 * 480, n is the number of bits per pixel

# Frame Buffer Bit Depth

- 1 bit per pixel (bitmap)

1-bit

- 16 bits per pixel (high color)
  - 5 bits for red, 5/6 bits for green, 5 bits for blue
  - potential of 32 reds, 32/64 greens, 32 blues
  - total colors: 65536 ($2^{16}$)

8-bit

- 32 bits per pixel (true color)
  - 8 bits for red, green, blue, and alpha
  - potential for 256 reds, greens, and blues
  - total colors: 16777216 ($2^{24}$: more than the eye can distinguish)

24+ bits

# Graphic Card Memory

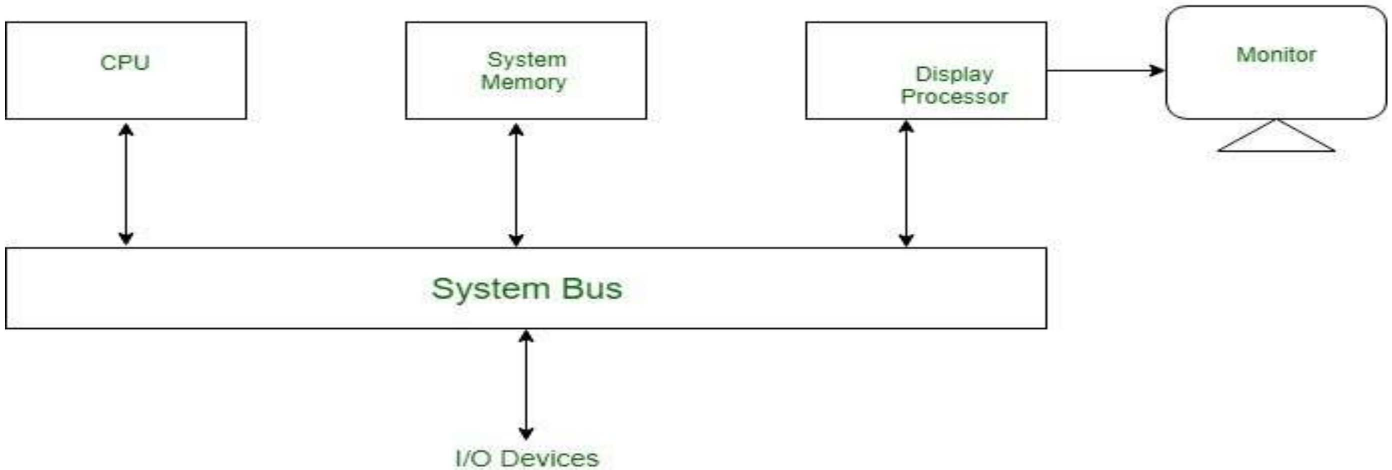
- How much memory is on our graphic card?
  - 640 * 480 * 32 bits = 1,228,800 bytes
  - 1024 * 768 * 32 bits = 3,145,728 bytes
  - 1600 * 1200 * 32 bits = 7,680,000 bytes

# Random Scan(Vector)display system

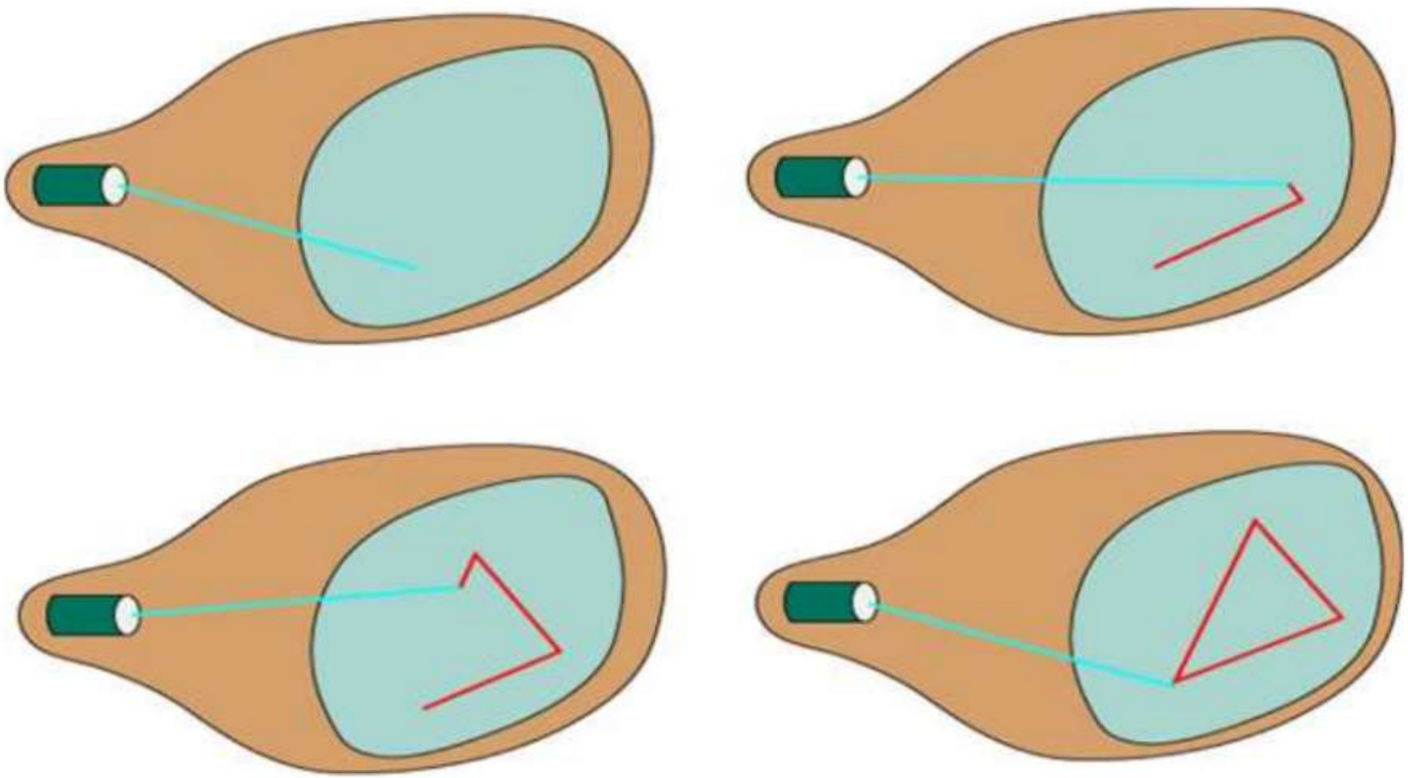
- In Random-Scan Display electron beam is directed only to the areas of screen where a picture has to be drawn. It is also called vector display, as it draws picture one line at time. It can draw and refresh component lines of a picture in any specified sequence. A Pen plotter is an example of random-scan device. he number of lines regulates refresh rate on random-scan displays. An area of memory called **refresh display files** stores picture definition as a set of line drawing commands. The system returns back to first-line command in the list, after all the drawing commands have been processed. High-quality vector systems can handle around 100, 00 short lines at this refresh rate. Faster refreshing can burn phosphor. To avoid this every refresh cycle is delayed to prevent refresh rate greater than 60 frames per second. Suppose we want to display a square ABCD on the screen. The commands will be:
- Draw a line from A to B
- Draw a line from B to C
- Draw a line from C to D
- Draw a line from D to A

# Random Scan(Vector)display system

- vector graphics use mathematical paths, making them perfect for designs that need to be scaled without losing quality, like logos and illustrations. Both have their own strengths and weaknesses, and knowing when to use each can make a big difference in your design work. Input in the form of an application program is stored in the system memory along with graphics package. Graphics package translates the graphic commands in application program into a display file stored in system memory. This display file is then accessed by the display processor to refresh the screen. The display processor cycles through each command in the display file program. Sometimes the display processor in a random-scan is referred as *Display Processing Unit / Graphics Controller*.



# Random Scan(Vector)display system



Random-scan monitors are also known as vector displays or stroke-writing displays or calligraphic displays.

## Advantages:

1. A CRT has the electron beam directed only to the parts of the screen where an image is to be drawn.
2. Produce smooth line drawings.
3. High Resolution

## Disadvantages:

1. Random-Scan monitors cannot display realistic shades scenes.

**Vector-based random scan displays** (used in early oscilloscopes and arcade machines) are best suited for line-drawn graphics rather than rasterized images. They wouldn't be ideal for displaying full-color cartoon images.