COMPUTER GRAPHICS
I UNIT

Computers have become a powerful tool for the rapid and economical production of pictures. There is virtually no area in which graphical displays cannot be used to some advantage, and so it is not surprising to find the use of computer graphics so widespread.

Today, we find computer graphics used routinely in such diverse areas as ***science, engineering, medicine, business, industry, government, art, entertainment, advertising, education, and training, simulations, education, and graph presentations***

1. APPLICATION OF COMPUTER GRAPHICS

1. **Computer-Aided Design**
2. **Presentation Graphics**
3. **Computer Art**
4. **Entertainment**
5. **Education and Training**
6. **Visualization**
7. **Image Processing**
8. **Graphical User Interfaces**

1.1 COMPUTER-AIDED DESIGN

- A major **use** of computer graphics is in design processes, particularly for engineering and architectural systems, but almost all products are now computer designed. Generally referred to as CAD as **Computer-Aided Design**.
- Its methods are routinely used design of **Buildings, Automobiles, Aircraft, Watercraft Spacecraft, Computers, Textiles** and many, many other products.
- Design applications object are first displayed in a **wireframe** outline form that shows the overall sham and internal features of objects. Wireframe displays also allow designers to quickly see the effects of interact the adjustments to design shapes

- Circuits and networks for communication, water supply, or other utilities are constructed with repeated placement of a few graphical shapes. The shapes used in a design represent the different network or circuit components.
- **Standard shapes** for electrical, electronic, and logic circuits are often supplied by the design package. A designer can create personalized symbols that are to be used to construct the network or circuit.
- It is often used in CAD applications. Real-time animations using wise frame displays on a video monitor are useful for testing performance of a vehicle or system. Animations in **virtual reality** environments are used to determine how vehicle operators are affected by certain motions.

- **Realistic displays** are also generated for advertising of automobiles and other vehicles using special lighting effects and background scenes use interactive graphics methods to lay out floor plans, that show the positioning of rooms, doon, windows, stairs, shelves, counters, and other building features. Working from the display of a building layout on a video monitor, an electrical designer can try out arrangements for wiring, electrical outlets, and fire warning systems.
- **Virtual-reality systems**, designers can even go for a simulated "walk" through the rooms or around the out sides of buildings to better appreciate the overall effect of a particular design

1.2 PRESENTATION GRAPHICS

- It is used to produce illustrations for **reports** or to generate **35-mm** slides or transparencies for use with projectors.
- It is commonly **used** to summarize financial, statistical, mathematical, scientific, and economic data for research reports, managerial reports, consumer information bulletins, and other types of reports.
- Workstation devices and **service bureaus** exist for converting screen displays into **35-mm** slides or overhead **transparencies** for **use** in presentations.
- Examples:
  - **Bar charts**
  - **Line graphs**
  - **Surface graphs**
  - **Pie charts**
  - **Time charts**
- Two-dimensional & three dimensions graphics combined with geographical information.
- Time charts and task network layouts are used in project management to schedule and monitor the progress of reports.

1.3 COMPUTER ART

- Computer graphics methods are widely used in both fine art and commercial art applications. Artists use a variety of computer methods, including
  - special-purpose hardware
  - artist's paintbrush (such as Lumens)
  - other paint packages (such **as** Pixel paint and Super paint)
  - specially developed software
  - symbolic mathematics packages (such **as** Mathematics)
  - CAD packages
  - desktop publishing software
  - animation packages
- **Paintbrush** program that allows artists to "paint" pictures on the screen of a video monitor. Actually, the picture is usually painted electronically on a graphics tablet (digitizer) using a stylus, which can simulate different brush strokes, brush widths, and colors. A paintbrush system, with a Wacom cordless, pressure-sensitive stylus, was **used** to produce the electronic **painting** that simulates the brush strokes of Van Gogh.
- The **stylus** translates changing hand pressure into variable line widths, brush sizes, and color gradations. A watercolor painting produced with this stylus and with software that allows the artist to create watercolor, pastel, or oil brush effects that simulate different drying out times, wetness , and footprint.
- **u** use a variety of other computer technologies to produce images. The artist uses a combination of three-dimensional modeling packages, texture mapping, drawing programs, and CAD software. A pen plotter with specially designed software that can mate "automatic art" without intervention from the artist.
- **Mathematical art** the artist uses a combination of mathematical functions, fractal procedures, Mathematics software, **ink-jet printers,** and other systems to create a variety of three-dimensional and two-dimensional shapes and stereoscopic image pairs.
- **Electronic art** techniques for generating electronic images in the fine arts, these methods are **also** applied in commercial art for logos and other designs, page layouts combining text and graphics, **TV** advertising spots and other areas.
- **Commercial art** used for photorealistic techniques are used to render images, logo design, & advertising.

- **Animations** are also using frequently in ***advertising, and television commercials*** are produced frame by frame, where each frame of the motion is rendered and saved as an image file. In each successive frame, the motion is simulated by moving on positions slightly from their positions in the previous frame. When all frames in the animation sequence have been made, the frames are transfer to film or stored in a video buffer for playback. ***Film animations require 24 frames for each second in the animation sequence.***
- If the animation is to be played back on a video monitor, 30 frames per second are required.
- **Morphing,** where one object is transformed (metamorphosed) into another.
  - An oil can into an automobile engine,
  - An automobile into a tiger,
  - A puddle of water into attire
  - One person's face into another face.

1.4 ENTERTAINMENT

- Computer graphics methods are now commonly used in making motion pictures**,** music videos, and television shows.
- Sometimes the graphics **s**cenes are displayed by themselves, and sometimes graphics objects are combined with the actors and live scenes**.**
- A graphics scene generated for the movie Star Trek-Wrath of Khan**.** The planet and spaceship are drawn in wireframe form and will be shaded with rendering methods to produce solid surfaces.
- **Scenes** generated with advanced modeling and surface rendering methods for two award winning short. Many TV series of Deep Space Nine. Person combined with actors in a live scene for the series Stay Tuned**.**
- Music videos use graphic in several ways. Graphics objects can be combined with the live action, graphics and image processing techniques can be used to produce a transformation of one person or object into another (morphing).

1.5 EDUCATION AND TRAINING

- Computer-generated models of physical, financial, and economic systems are often used as educational aids. Models of physical systems, physiological systems, population trends, or equipment, such as the color coded diagram .Help trainees to understand the operation of the system.
- For some training applications, special systems **are** designed.
- **Examples**:
  The specialized systems are the simulators for practice sessions or training of
  - **Ship captains**
  - **Aircraft pilots**
  - **Heavy-equipment operators**
  - **Air traffic control personnel**.
- Some simulators have no video **s**creens**;** for example, a flight simulator with only a control panel for instrument flying.
- But most simulators provide graphics screens for visual operation.
- A viewing screen with multiple panels is mounted in front of the simulator and color projectors display the flight m e on the screen panels. Similar viewing systems are used in simulators for training aircraft control-tower personnel.

1.6 VISUALIZATION

- Scientists, engineers, medical personnel, business analysts, and others often need to analyze large amounts of information or to study the behavior of certain processes.

- Numerical simulations carried out on supercomputers frequently produce data files containing thousands and even millions of data values. Similarly, satellite cameras and other sources are amassing large data files faster than they can be interpreted.

- **Scanning** these large **sets** of numbers to determine trends and relationships is a tedious and ineffective process. But if the data are converted to a visual form, the trends and patterns **are** often immediately apparent.

- **Example** of a large data set that **has** been converted to a color-coded display of relative heights above a ground plane.
- Once we have plotted the density values in this way, we can **see** easily the overall pattern of the data.

- **Scientific visualization** is used in producing graphical representations for scientific, engineering, and medical data **sets** and processes.

- **Business visualization** is used in connection with data **sets** related to commerce, indus**try,** and other nonscientific **areas.**

- **A** collection of data **can** contain scalar values, vectors, higher-order tensors, or any combination of these data types. And data sets can be two-dimensional or three dimensional.

- **Color coding** is just one way to visualize a data set. Additional techniques include contour plots, graphs and charts, surface renderings, and visualizations of volume interiors.

- Mathematicians, physical scientists, and others use visual techniques to analyze mathematical functions and processes or simply to produce interesting graphical representations.
    - Color plot of mathematical curve functions
    - A surface plot of a function airflow over the surface of a space shuttle,
    - Numerical modeling of thunderstorms
    - Study of crack propagation in metals
    - A color coded plot of fluid density over an airfoil
    - A cross-sectional slicer for data sets
    - Protein modeling, stereoscopic viewing of molecular structure
    - A model of the ocean floor
    - A Kuwaiti oil-fire simulation
    - An air-pollution study
    - A com-grow**ing** study
    - Reconstruction of Arizona's Cham Canyon ruins
    - A graph of automobile accident statistics.

1.7 IMAGE PROCESSING:

- Although methods used in computer graphics and Image processing overlap, the two areas are concerned with fundamentally different operations.
    1. In computer graphics, a computer is used to create a picture.
    2. Image processing, applies techniques to modify or interpret existing pictures, such as photographs and TV scans.
- Two principal applications of image processing are:
    1. ***Improving picture quality***
    2. ***Machine perception of visual information, as used in robotics.***
- To apply its methods:
    1. ***Digitize a photograph or other picture into an image file.***
    2. ***Then digital methods can be applied to rearrange picture parts, to enhance color separations, or to improve the quality of shading***.

- These techniques are used extensively in commercial art applications that involve the retouching and rearranging of sections of photographs and other artwork.
- Similar methods are used to analyze satellite photos of the earth and photos of galaxies.
- Medical applications also make extensive use of it techniques for picture enhancements, in tomography and in simulations of operations.

- **Tomography** is a technique of X-ray photography that allows cross-sectional views of physiological systems to be displayed.

- **X-rav tomography** (CT) and **position emission tomography (PET)** uses projection methods to reconstruct cross sections from digital data. These techniques are also **used** to monitor internal functions and show cross sections during surgery.

- **Ultrasonic scanner** is a high-frequency sound waves, instead of X-rays, are used to generate digital data.

- **Nuclear medicine scanner** collects digital data from radiation emitted from ingested radio nuclides and plot color coded images.

- **Computer-aided surgery** is consists of Two-dimensional cross sections of the body are obtained using imaging techniques. Then the slices are viewed and manipulated using graphics methods to simulate actual surgical procedures and to **try** out different surgical cuts.

- Image processing and computer graphics are typically combined in many applications. Medicine, for example, uses these techniques:
    - To model and study physical functions,
    - To design artificial limbs, and to plan and practice surgery.

1.8 GRAPHICAL USER INTERFACES

- It is common now for software packages to provide a graphical interface.
- A major component of a graphical interface is a window manager that allows a user.
- To display multiple-window areas. Each window can contain a different process that can contain graphical or non-graphical displays. To make a particular window active, we simply click in that window using an interactive pointing device.
- Interfaces also display menus and icons for fast selection of processing options or parameter values.
- An icon is a graphical symbol that is designed to look like the processing option it represents.
- The advantages of icons are that they take up less screen space than corresponding textual descriptions and they can be understood more quickly if well designed.
- Menus contain lists of textual descriptions and icons.
- A typical graphical interface, containing a window manager, menu displays, and icons. In this example, the menus allow selection of processing options, color values, and graphics parameters. The icons represent options for painting, drawing, zooming, typing text strings, and other operations connected with picture construction.

  Eg: Acrobat Reader, photo shop etc.

2. VIDEO DISPLAY DEVICES

Typically, the primary output device in a graphics system is a video monitor**.** The operation of **most** video monitors is based on the standard **cathode-ray tube (CRT)** design, but several other technologies exist and solid-state monitors may eventually predominate.

2.1 Refresh Cathode-Ray Tubes

The basic operation of a CRT. **A** beam of electrons ***(cathode*** rays) emitted by an **electron gun,** passes through focusing and deflection systems that direct the beam toward specified positions on the phosphor coated screen. Fig.1.

- The phosphor then emits a small spot of light at each position contacted by the electron beam. Because the light emitted by the phosphor fades very rapidly, some method is needed for maintaining the screen picture. One way to keep the phosphor glowing is to redraw the picture repeatedly by quickly directing the electron beam back over the same points. This type of display is **called a refresh CRT.**

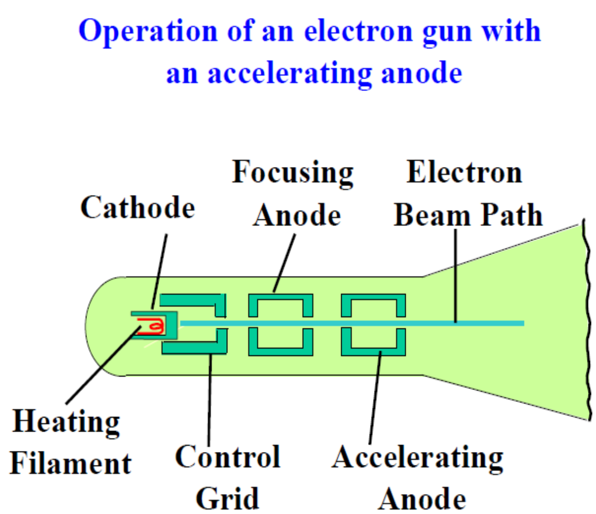


Fig.1

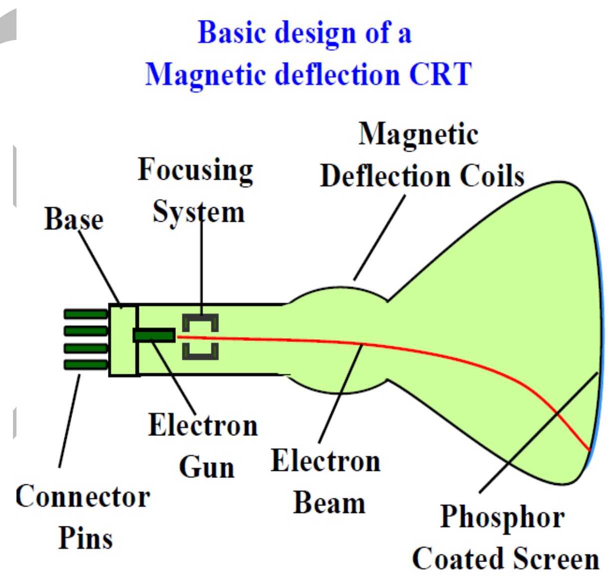


Fig.2

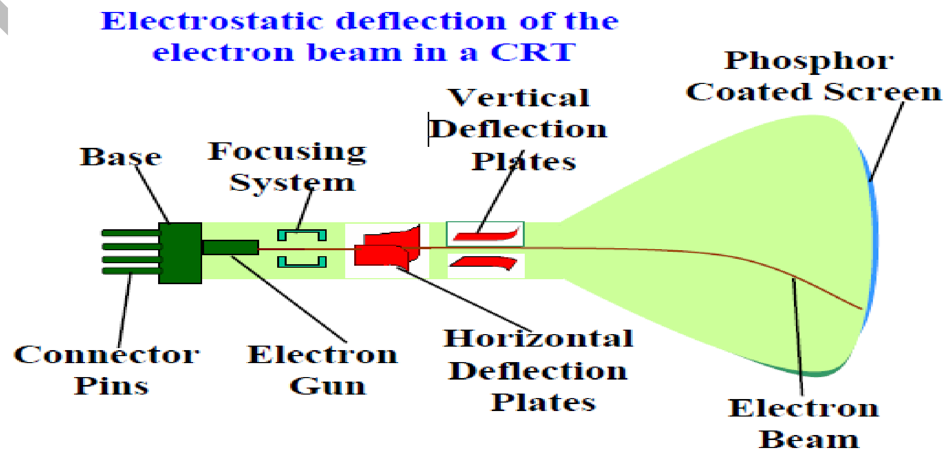


Fig.3

- The primary components of an **electron gun** in a CRT are the heated metal cathode and a control grid
- Heat is supplied to the cathode by directing a current through a coil of wire, called the filament, inside the cylindrical cathode structure. This causes electrons to be boiled off" the hot cathode surface. In the vacuum inside the CRT envelope, the free, negatively charged electrons are then accelerated toward the phosphor coating by a high positive voltage. The accelerating voltage can be generated with a positively charged metal coating on the inside of the CRT envelope near the phosphor screen, or an accelerating anode can be used, as in Fig.**3.**
- Sometimes the electron gun is built to contain the accelerating anode and focusing system within the same unit. Intensity of the electron beam is controlled by setting voltage levels on the control grid, which is a metal cylinder that fits over the cathode. A **high negative voltage** applied to the control grid will **shut OFF** the beam by repelling electrons and stopping them from passing through the small hole at the end of the control grid structure. A **smaller negative voltage** on the control grid simply **decreases** the number of electrons passing through. Since the amount of light emitted by the phosphor coating depends on the number of electrons striking the screen,
- The **focusing system** in a CRT is needed to force the electron beam to ***converge*** into a small spot as it strikes the phosphor. Otherwise, the electrons would r***epel*** each other, and the beam would spread out as it approaches the screen. Focusing is accomplished with either ***electric or magnetic fields***.
- The distance that the electron beam must travel to different points on the screen varies because the radius of curvature for most CRTs is greater than the distance from the focusing system to the screen center. Therefore, the electron beam will be focused properly only at the center to the screen.

- As the beam moves to the outer edges of the screen, displayed images become blurred. To compensate for this, the system can adjust the focusing according to the screen position of the beam.
- As with focusing, deflection of the electron beam can be controlled either with electric fields or with magnetic fields.
- **Magnetic deflection** has two pairs of coils are used, with the coils in each pair mounted on opposite sides of the neck of the CRT envelope. One pair is mounted on the top and bottom of the neck and the other pair is mounted on opposite sides of the neck. The magnetic, field produced by each pair of coils results in a transverse deflection force that is perpendicular both to the direction of the magnetic field and to the direction of travel of the electron beam. Horizontal deflection is accomplished with one pair of coils, and vertical deflection by the other pair. The proper deflection amounts are attained by adjusting the current through the coils.

- **Electrostatic deflection** has two pairs of parallel plates are mounted inside the CRT envelope. One pair coil plates is mounted horizontally to control the vertical deflection, and the other pair is mounted vertically to control horizontal deflection (Fig. 3**).** Spots of light are produced on the screen by the transfer of the CRT beam energy to the phosphor. When the electrons in the beam collide with the phosphor coating, they are stopped and then kinetic energy is absorbed by the phosphor. Part of the beam energy is converted by friction into heat energy, and the remainder causes electrons in the phosphor atoms to move up to higher quantum-energy levels. After a short time, the "excited phosphor electrons begin dropping back to their stable ground state, giving up their extra energy as small quantum’s of Light energy. The **frequency** (or color) of the light emitted by the phosphor is proportional to the energy difference between the excited quantum state and the ground state. Different kinds of phosphors are available for **use** in a CRT.

Besides color, a major difference between phosphors is their persistence.

- **Persistence**: How long they continue to emit light (that is, have excited electrons returning to the ground state) after the CRT beam is removed.

  Persistence is defined as “the time it takes the emitted light from the screen to **decay to one- tenth** of its original intensity”.

  Lower persistence phosphors require higher refresh rates to maintain a picture on the screen without flicker. It is useful for **animation**

  High-persistence phosphor is useful for displaying highly complex, static pictures.

  Although some phosphors have persistence greater than 1 second, graphics monitors are usually constructed with persistence in the range from 10 to 60 microseconds.

- **Resolution:** The maximum number of points that can be displayed without overlap on a **CRT** is referred to as the resolution.

  Resolution is the number of points per centimeter that can be plotted horizontally and vertically, although it is often simply stated as the total number of points in each direction.

- **Spot intensity** has a Gaussian distribution, so two adjacent spots will appear distinct as long **as** their separation is greater than the diameter at which each spot has an intensity of about 60 percent of that at the center of the spot.

  Typical resolution on high-quality systems is **1280** by **1024,** with higher resolutions available on many systems. High resolution systems are often referred to as ***high-definition*** systems. The physical size of a graphics monitor is given as the length of the screen diagonal, with sizes varying from about **12** inches to **27** inches or more.

- **Aspect Ratio**: This number gives the ratio of vertical points to horizontal points necessary to produce equal-length lines in both directions on the screen. (Sometimes aspect ratio is stated in terms of the ratio of horizontal to vertical points.) An aspect ratio of 3/4 means that a vertical line plotted with three points has the same length as a horizontal line plotted with four points.

2.2 RASTER-SCAN DISPLAYS

- The most common type of graphics monitor employing a CRT is the raster-scan display, based on **television technology**.

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

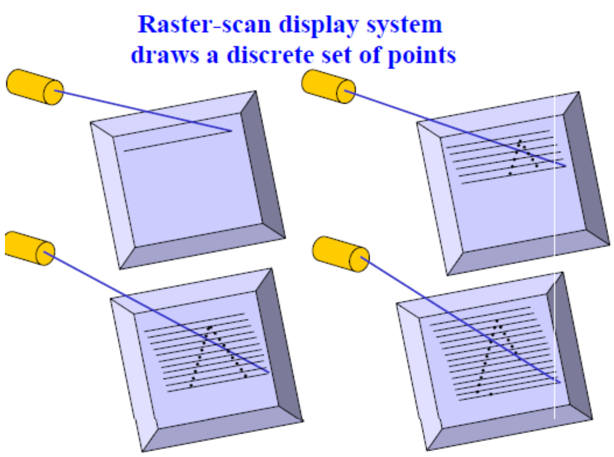


Fig.4

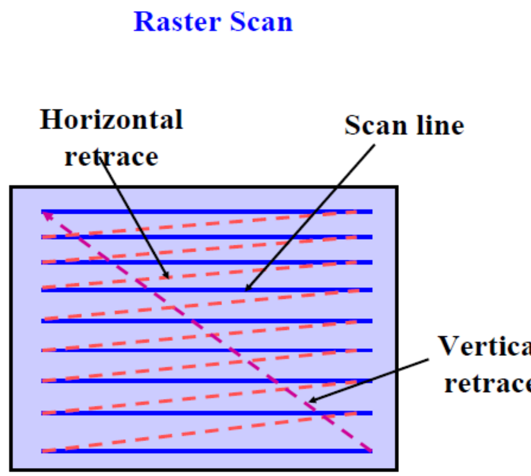


Fig.5

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

- **PIXEL**: Each screen point is referred to as a **pixel or pel** (shortened forms of **picture element**).
- The capability of a raster-scan system to store intensity information for each screen point makes it well suited for the realistic display of scenes containing subtle shading and color patterns.

  Eg: Home Television sets and Printers.

Intensity range for pixel positions depends on the capability of the raster system.

- In a simple black-and-white system, each screen point is either on or off, so only one bit per pixel is needed to control the intensity of screen positions.

  For a bit level system,

  A **bit value of 1** indicates that the electron beam is to be turn **ON** at that position.

  A bit value of 0 indicates that the beam intensity is to be turn **OFF**.

  Additional bits are needed when color and intensity variations can be displayed.

- Up to **24** bits per pixel are included in high-quality systems, which can require several megabytes of storage for the frame buffer, depending on the resolution of the system.

  A system with **24 bits per pixel** and a screen resolution of **1024** bv **1024** requires **3 Mega Bytes** of storage for the frame buffer.

- **Bitmap**: On a black-and-white system with ***one bit per pixel***, the frame buffer is commonly called a **Bitmap**.
- **Pixmap**: Systems with ***multiple bits per pixel***, the frame buffer are often referred to as a **Pixmap**.

- Refreshing on raster-scan displays is carried out at the rate of **<u>60 to 80 frames per second</u>**, although some systems are designed for higher refresh rates. Sometimes, refresh rates are described in units of ***cycles per second, or Hertz (Hz),*** where a cycle corresponds to one frame.
- A refresh rate of **<u>60 frames per second</u>** as simply **60 cycle per second** or **60 Hz**.
- At the end of each scan line, the electron beam returns to the left side of the screen to begin displacing the next scan line.

  <u>Horizontal Retrace</u>: The return to the left of the screen, after refreshing each scan line, is called the <u>horizontal retrace</u> of the electron beam.

  <u>Vertical Retrace</u>: At the end of each frame (displayed in 1/80th to 1/60th of a second), the electron beam returns (<u>vertical retrace</u>) to the top left comer of the screen to begin the next frame.
- On some raster-scan systems (and in **TV** sets), each frame is displayed in two passes using an interlaced refresh procedure. In the first pass, the beam sweeps across every other scan line from top to bottom. Then after the vertical retrace, the beam sweeps out the remaining scan lines (Fig. 6).
- **<u>Interlacing</u>**: Interlacing of the scan lines in this way allows us to **see”** the entire screen displayed in **<u>one-half the time</u>**” it would have taken to sweep across all the lines at once from top to bottom.

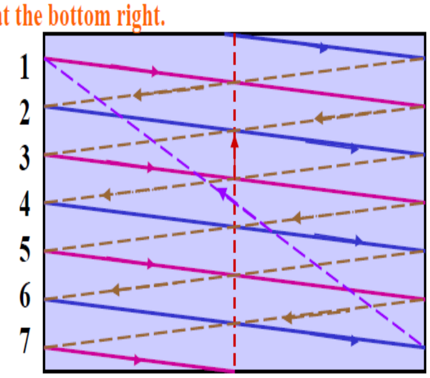
  Interlacing is primarily used with <u>slower refreshing rates</u>.

  On an older, **30** frame per-second, non-interlaced display, for instance, some flicker is noticeable. But with interlacing, each of the two passes can be accomplished in ***<u>1/60th of a second</u>***, which brings the refresh rate nearer to ***60*** frames per second.

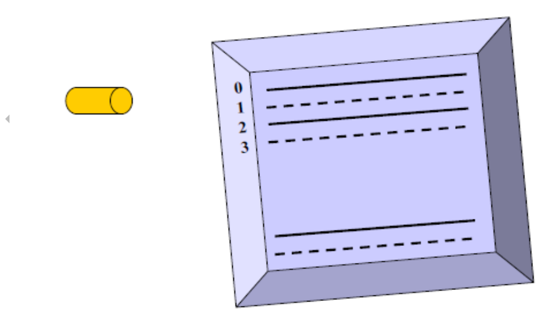
  This is an effective technique for avoiding flicker, providing that adjacent scan lines contain similar display information.

Schematic of a 7-line interlaced scan line pattern.

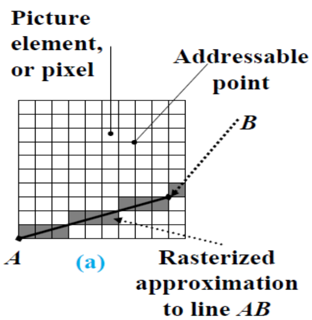
The odd field begins with line 1. The horizontal retrace is shown dashed. The odd field vertical retrace starts at the bottom center. The even field vertical retrace starts at the bottom right.

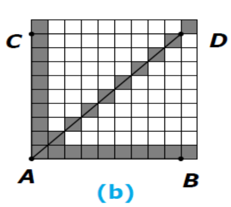


Interlacing scan lines on a raster scan display; First, all points on the even-numbered (solid) scan lines are displayed; then all points along the odd-numbered (dashed) lines are displayed



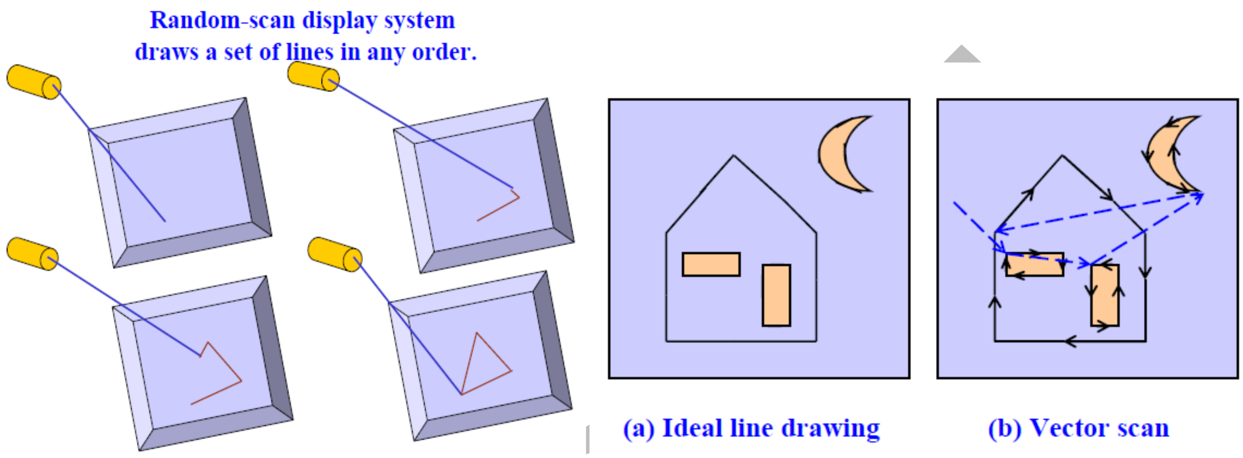
Rasterization: (a) General line ; (b) special cases





2.3 Random-Scan Displays

- When operated as a random-scan display unit, a CRT has **"the electron beam directed only to the parts of the screen where a picture is to be drawn".**
- Random scan monitors **draw a picture one line at a time** and for this reason are also referred to as **vector displays *(or* stroke-writing or calligraphic displays).**



- The component lines of a picture can be drawn and refreshed by a random-scan system in any specified order (Fig.). A **pen plotter** operates in a similar way and is an example of a random-scan, hard-copy device.
- **Refresh rate** on a random-scan system depends on ***the number of lines to be displayed***.
- **Picture** definition is now stored as a set of ***line drawing commands*** in an area of memory r e f e d to as the **refresh display file**.
- Sometimes the **refresh display file** is called the **display list, display program, or simply the refresh buffer.**
- To display a specified picture, the system cycles through the **set of commands** in the display file, drawing each component line in turn. After all line drawing commands have been processed, the system cycles back to the first line command in the list.
- Random-scan displays are designed to draw all the component lines of a picture **30 to 60 times** each second.
- High quality vector systems are capable of handling approximately 100,000 "short" lines at this refresh rate. When a small set of lines is to be displayed, each refresh cycle is delayed to avoid refresh rates greater than 60 frames per second. Otherwise, faster refreshing is the set of lines could burn out the phosphor.
- Random-scan systems are designed for **line drawing applications** and ***cannot* display realistic shaded scenes**. Since picture definition is stored as a set of line drawing instructions and not as a set of intensity values for all screen points, vector displays generally have **higher resolution** than raster systems.
- Also, vector displays produce **smooth line drawings** because the CRT beam directly follows the line path.
- A raster system, in contrast, produces **jagged lines** that are plotted as discrete end point sets.

2.4 Color CRT Monitors

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

1. The **Beam-Penetration** method**.**
2. The **Shadow-Mask** method.

2.4.1. BEAM-PENETRATION METHOD

The beam-penetration method for displaying color pictures has been used with **random-scan** monitors. **Two layers of phosphor**, usually **RED** and **GREEN,** are coated onto the inside of the CRT screen, and the displayed color depends on how far the electron beam penetrates into the phosphor layers.

A beam of **slow electrons** excites only the **outer RED layer**.
A beam of **very fast electrons** penetrates through the **RED** layer and **excites** the inner **GREEN** layer. At **intermediate beam speeds**, combinations of **red and green** light are emitted to show **two additional** colors, **ORANGE** and **YELLOW**.
The speed of the electrons, and hence the screen color at any point, is controlled by the beam-acceleration voltage.

Advantage: Beam penetration has been an **inexpensive** way to produce color in random-scan monitors,
Disadvantage: only four colors are possible, and the quality of pictures is not as good as with other methods.

2.4.2. SHADOW-MASK METHODS

- Shadow-mask methods are commonly used in **raster scan systems** (including color **TV)** because they produce a much wider range of colors than the beam penetration method.
- A shadow-mask CRT has **three phosphor** color dots at each pixel position.
- One phosphor dot emits a **RED *Light***, another emits a **GREEN *light***, and the third emits a **BLUE *light***.
- This type of CRT has three electron guns, one for each color dot, and a shadow-mask grid just behind the phosphor-coated screen.

   1. **Delta-Delta Shadow-Mask** method, commonly used in color CRT systems. The three electron beams are deflected and focused as a group onto the shadow mask, which contains a series of holes aligned with the phosphor-dot patterns. 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.

   2.**In-Line arrangemen**t in which the three electron guns, and the corresponding red-green-blue color dots on the screen, are aligned along one scan line instead of in a triangular pattern.
   This in-line arrangement of electron guns is easier to keep in alignment and is commonly used I n high-resolution color CRTs.

Operation of a delta-delta, shadow-mask CRT. Three electron guns, aligned with the triangular color-dot patterns on the screen, are directed to each dot triangle by a shadow mask.

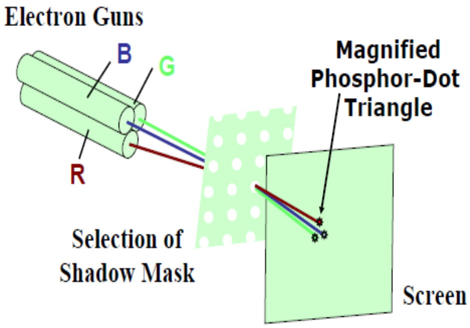


Fig.2.1

Color CRT electron gun and shadow mask arrangement

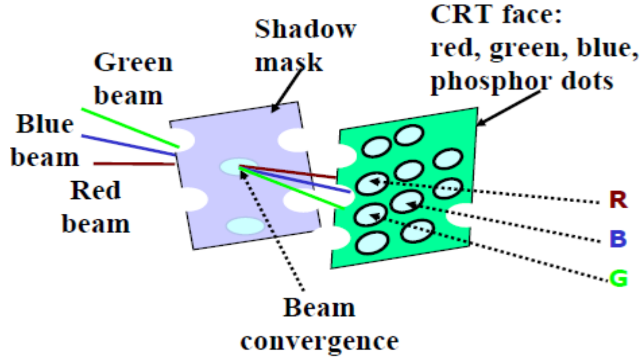
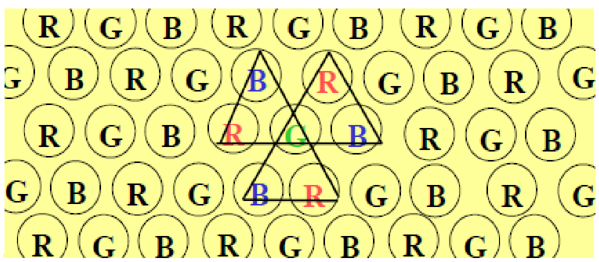


Fig. 2.2

Phosphorus dot pattern for a shadow mask CRT



- The color variations in a shadow-mask CRT by varying the intensity levels of the three electron beams.
- By turning **OFF** the **RED** and **GREEN** guns**,** gets the color coming from the **BLUE** phosphor.
- Other combinations of beam intensities produce a small light spot for each pixel position, since our eyes tend to merge the three colors into one composite.
- The color depends on the amount of excitation of the red, green, and blue phosphors.
- **White (or gray)** area is the result of ***activating*** all ***three dots*** with ***equal intensity***.
- **Yellow** is produced with the ***green and red*** dots only.
- **Magenta** is produced with the ***blue and red dots***.
- **Cyan** shows up when **blue and green** are activated equally.
- In some **low-cost systems**, the electron beam can only be set to on or off, limiting displays to **Eight Colors.**

RED	GREEN	BLUE	COLOR
0	0	0	Black
0	0	1	Blue
0	1	0	Green
0	1	1	Cyan
1	0	0	Red
1	0	1	Magenta
1	1	0	Yellow
1	1	1	White

- More **sophisticated systems** can set intermediate intensity levels for the electron beams, allowing several **million different colors** to be generated.
- Color graphics systems can be designed to be used with several types of CRT display devices. Some inexpensive home-computer systems and video games are designed for use with a color **TV set and an RF (radio-frequency) modulator.**
- The purpose of the **RF** modulator is to simulate the signal from a broadcast TV station. This means that the color and intensity information of the picture must be combined and superimposed on the broadcast-frequency carrier signal that the TV needs to have as input. The **RF** modulator and TV circuitry decreases the quality of displayed images.
- These monitors use shadow-mask methods and take the intensity level for each electron gun (red, green, and blue) directly from the computer system without any intermediate processing.
- High-quality raster-graphics systems have **24 bits per pixel** in the frame buffer, allowing **256 voltage** settings for each electron gun and nearly **17 million color** choices for each pixel.

- An RGB color system with 24 bits of storage per pixel is generally referred to as a **Full-Color System** or a **True-Color System**.

2.3. Direct-View Storage Tubes

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

A **direct-view storage tube (DVST**) "stores the picture information as a **charge distribution** just behind the phosphor-coated screen".

Two electron guns are used in a DVST.

1. **Primary gun**: It is used to **store** the **picture pattern**
2. **Flood gun**: It **maintains** the **picture display**.

A DVST monitor has both disadvantages and advantages compared to the refresh CRT.

Advantages

1. Because **no refreshing is needed**.
2. **Very complex pictures** can be displayed at very **high resolutions without flicker**.

Disadvantages

1. DVST systems are that they ordinarily **do not display color** and that selected parts of a picture cannot he erased.
2. To **eliminate a picture section**, the **entire screen must be erased** and the modified picture redrawn.
3. The **erasing and redrawing process** can take **several seconds** for a complex picture.
4. For these reasons, storage displays have been largely replaced by raster systems.

2.4 FLAT-PANEL DISPLAYS

Although most graphics monitors are still constructed with CRTs, other technologies are emerging that may soon replace CRT monitors.

The term flat-panel display refers to a class of video devices that have

1. **Reduced volume**
2. **Weight**
3. **Power requirements** compared to a CRT.

A significant feature of it is that they are **thinner** than CRTs, and can **hang them on walls** or **wear them on our wrists.**

Current uses for flat-panel displays include **small TV monitors, calculators, pocket video games, laptop computers, armrest** viewing of **movies on airlines,** as **advertisement boards in elevators,** and as **graphics displays** in applications requiring rugged**, portable monitors and pocket notepads.**

Flat-panel displays into two categories:

1. **Emissive displays**
2. **Non-Emissive displays**.

1. Emissive displays (or emitters): These devices that convert electrical energy into light.

Examples:

1. **Plasma panels.**
2. **Thin-film electroluminescent.**
3. **Light-Emitting Diodes (LED)**.

Flat CRTs have also been devised, in which electron beams arts accelerated **parallel to the screen**, then **deflected 90'** to the screen. But flat CRTs have not proved to be as successful as other emissive devices.

2. Non-emissive displays (or non-emitters): These device use optical effects to convert sunlight or light from some other source into graphics patterns.

Example:

1. **Liquid-Crystal Device (LCD)**

2.4.1 PLASMA PANELS:

- **Plasma panels** also called **gas-discharge displays**.
- These are constructed by filling the **region between two glass plates** with a mixture of gases that usually includes **neon.**
- A series of **vertical conducting ribbons** is placed on one glass panel, and a set of **horizontal ribbons** is built into the other glass panel (Fig.**).**
- Firing voltages applied to a pair of horizontal and vertical conductors cause the gas at the intersection of the two conductors to break down into glowing plasma of electrons and ions.
- **Picture definition** is stored in a refresh buffer, and the firing voltages are applied to refresh the pixel positions (at the intersections of the conductors) 60 times per second.

- Alternating methods are used to provide faster application of the firing voltages, and thus brighter displays.
- Separation between pixels is provided by the electric field of the conductors.
- One **disadvantage** of plasma panels has been that they were strictly monochromatic devices, but systems have been developed that are now capable of displaying color and grayscale.

2.4.3 Thin-Film Electroluminescent:

- Thin-film electroluminescent displays are similar in construction to a plasma panel.
- The difference is that the region between the glass plates is filled with a phosphor, such as **zinc sulfide doped with manganese,** instead of a gas.
- When a sufficient high voltage is applied to a pair of crossing **electrodes,** the phosphor becomes a conductor in the area of the intersection of the two electrodes.
- Electrical energy is then absorbed by the manganese atoms, which then release the energy as a spot of light similar to the glowing plasma effect in a plasma panel.

Disadvantage: These displays require **more power** than plasma panels, and **good color and gray scale displays are hard to achieve.**

2.4.4 Light-Emitting Diode (LED):

- A matrix of diodes is arranged to form the pixel positions in the display, and picture definition is stored in a refresh buffer.
- As in scan-line refreshing of a CRT**,** information is read from the refresh buffer and converted to voltage levels that are applied to the diodes to produce the light patterns in the display.

2.4.5 Liquid-Crystal Device (LCD):

- These are commonly **used in small systems**, such as **calculators and portable, laptop computers**
- These non-emissive devices produce a picture by passing polarized light from the surroundings or from an internal light source through a liquid-crystal material that can be aligned to either block or transmit the light.
- The term ***liquid crystal*** refers to the fact that these compounds have a crystalline arrangement of molecules, yet they flow like a liquid.
- Flat-panel displays commonly use nematic (threadlike) liquid-crystal compounds that tend to keep the long axes of the rod-shaped molecules aligned.
- A flat-panel display can then be constructed with a nematic liquid crystal.
- **Passive-Matrix LCD**: Two glass plates, each containing a light polarizer at right angles to the-other plate, sandwich the liquid-crystal material. Rows of horizontal transparent conductors are built into one glass plate, and columns of vertical conductors are put into the other plate. The intersection of two conductors defines a pixel position. Normally, the molecules are aligned as shown in the "on state".

- Polarized light passing through the material is twisted so that it will pass through the opposite polarizer. The light is then reflected back to the viewer.
- To turn off the pixel, apply a voltage to the two intersecting conductors to align the molecules so that the light is not .twisted.
- This type of flat-panel device is referred to as a **passive-matrix LCD**. Picture definitions are stored in a refresh buffer, and the screen is refreshed at the rate of 60 frames per second, as in the emissive devices.
- Back lighting is also commonly applied using solid-state electronic devices, so that the system is not completely dependent on outside light sources be displayed by using different materials or dyes and by placing a triad of color pixels at each screen location.
- **Active-Matrix Displays:** Another method for constructing LCD is to place a **transistor at each pixel location**, using thin-film transistor technology. The transistors are used to control the voltage at pixel locations and to prevent charge from gradually leaking out of the liquid-crystal cells. These devices are called **active-matrix displays.**

Refresh Rate, Video basics and Scan Conversion (contd.)

- Two fields are presented alternately for each frame. So we present 60 frames per second.
- In NTSC, generally 483 lines are visible.
- This is because, the vertical retrace after each field requires a time equivalent of 21 scan lines
- So for each field we have time to display: 262.5 *(=525/2)* – 21 = 241.5 lines.
- So with both fields together, we have: 241.5*2 = 483 lines to display.
- This is the reason for 42 (= 525-483) invisible lines.

Refresh Rate, Video basics and Scan Conversion (contd.)

- Let the time available for each scan line be T.
- Thus, we have: T * 525 * 30 = 1 sec.
- Thus, T = 63.5 ms/scan-line
- This includes the vertical retrace time.
- When we consider the horizontal retrace time, the actual time to display all pixels in a scan line (time to scan from left to right only): T' = 0.83*T = 53 ms
- Considering 4:3 aspect ratio, the number of pixels per scan line = 483*4/3 = 644
- Thus, time available for the beam to access and display a pixel = 82.3 ns (nano-second).

Refresh Rate, Video basics and Scan Conversion (contd.)

Some examples of pixel access times:

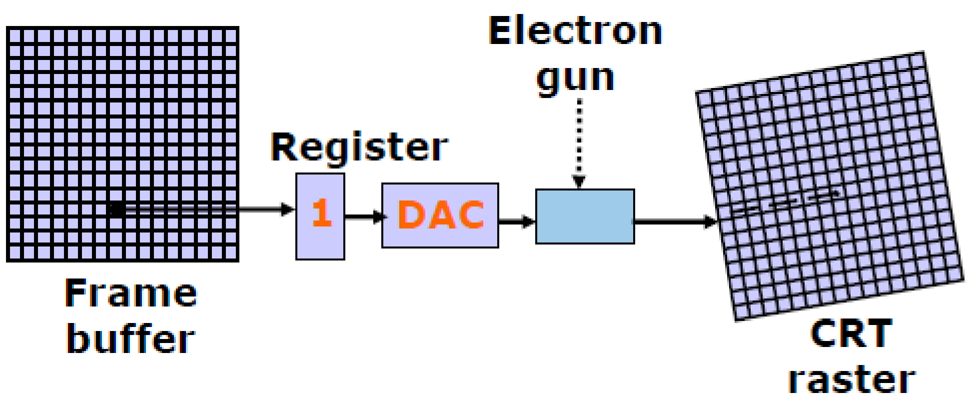
Frame Rate	Display Resolution	Pixel access time
30	512 x 512	105 ns
25	500 x 625	105 ns
60	1000 x 1000	26 ns
60	1024 x 1024	24 ns

N-bit plane gray level Frame buffer

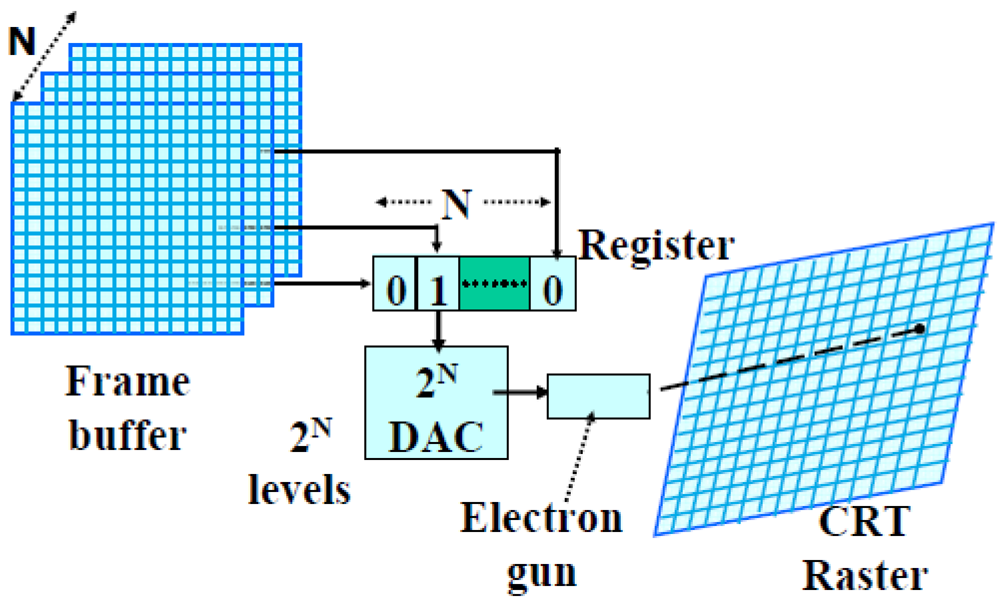
- Choice of the number of gray scales and colors depend on the value of N (bit plane size)
  - N = 1 – two colors (B&W)
  - N = 3 – 8 gray scales or colors
  - N = 8 – 256 gray scales or colors
  - N = 24 – 16 million colors

- For colored displays (raster-scan), three separate color guns must be used.
- Each bit/byte plane drives a color gun.

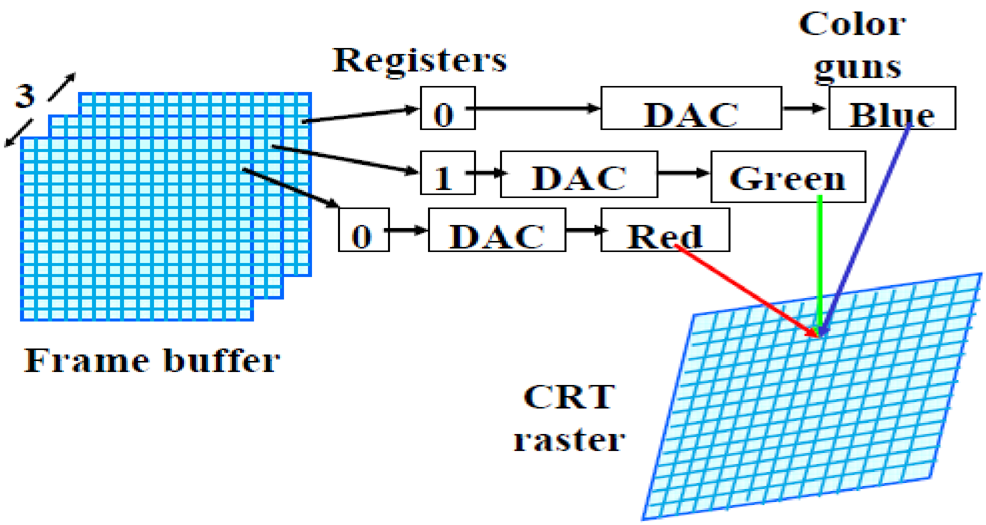
A single bit-plane black&white frame buffer raster CRT graphics device.



An N-bit plane gray level frame buffer



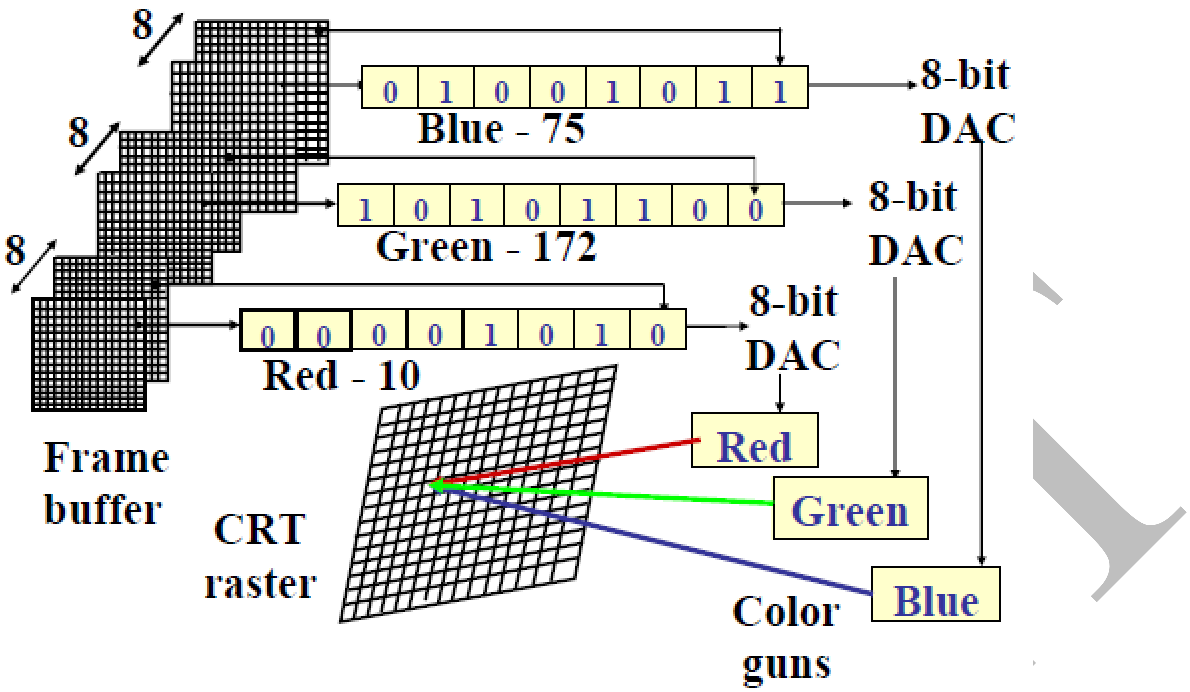
Simple color frame buffer



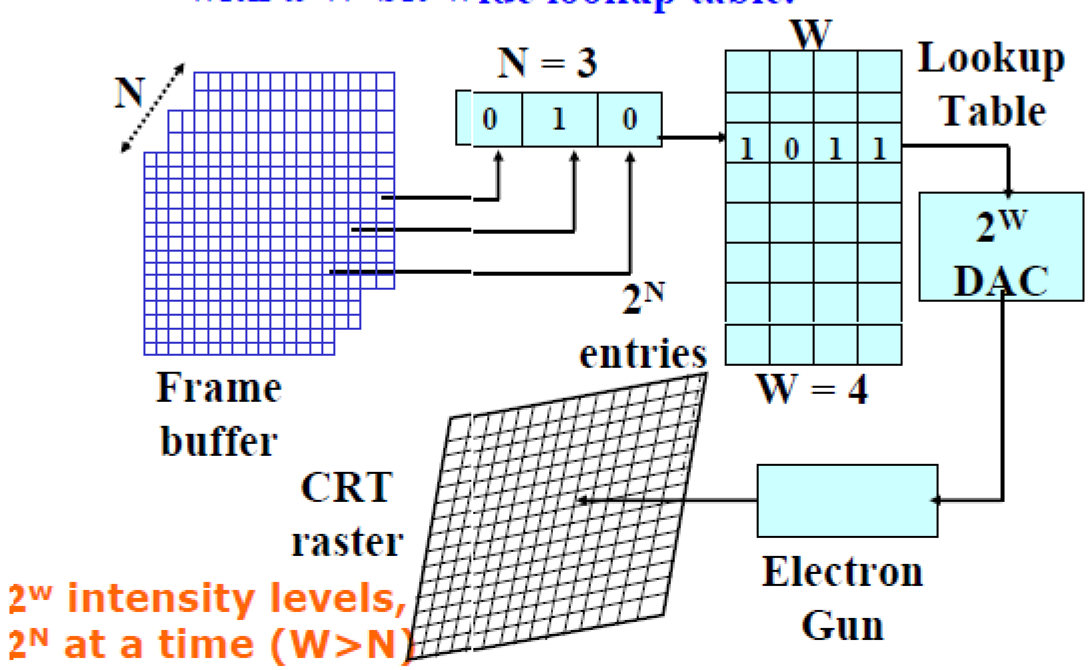
N-bit plane gray level Frame buffer (Contd.)

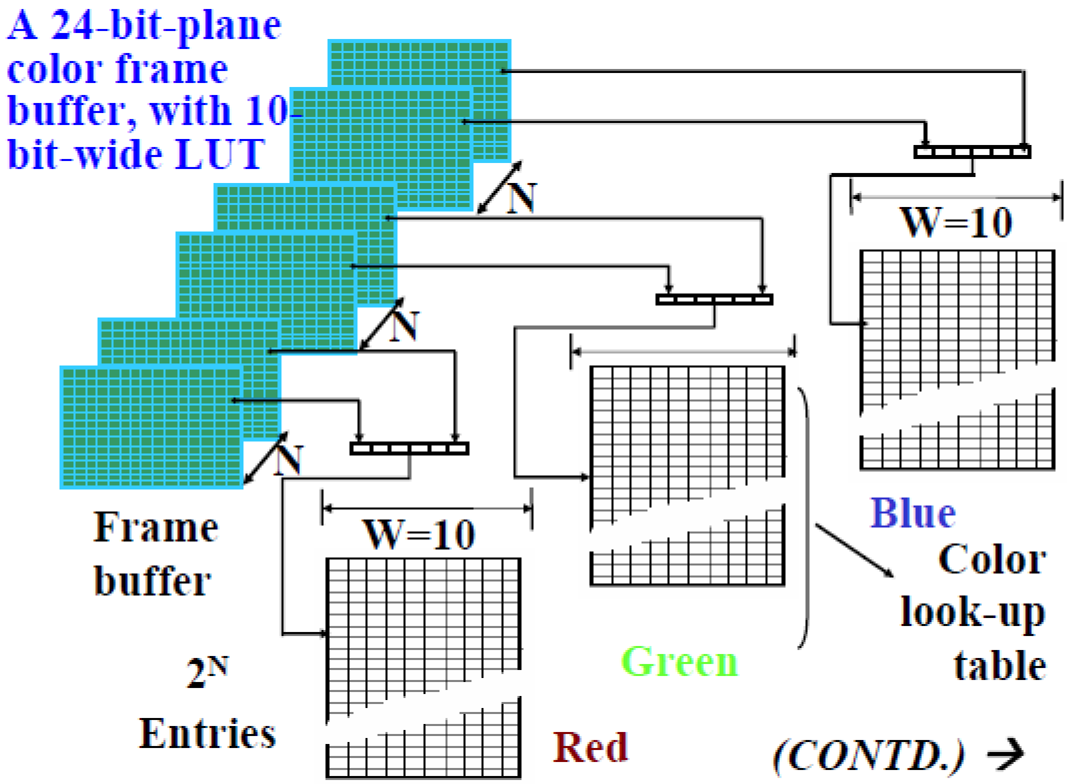
- Typically 8-bit planes per color is used, which gives a 24-bit plane frame buffer
- Each group of bit-planes drives an 8-bit DAC
- Each group generates 256 shades of intensities of red, green or blue
- Hence we obtain 2^{24} = 16,777,216 possible colors.
- This is called a FULL COLOR FRAME BUFFER

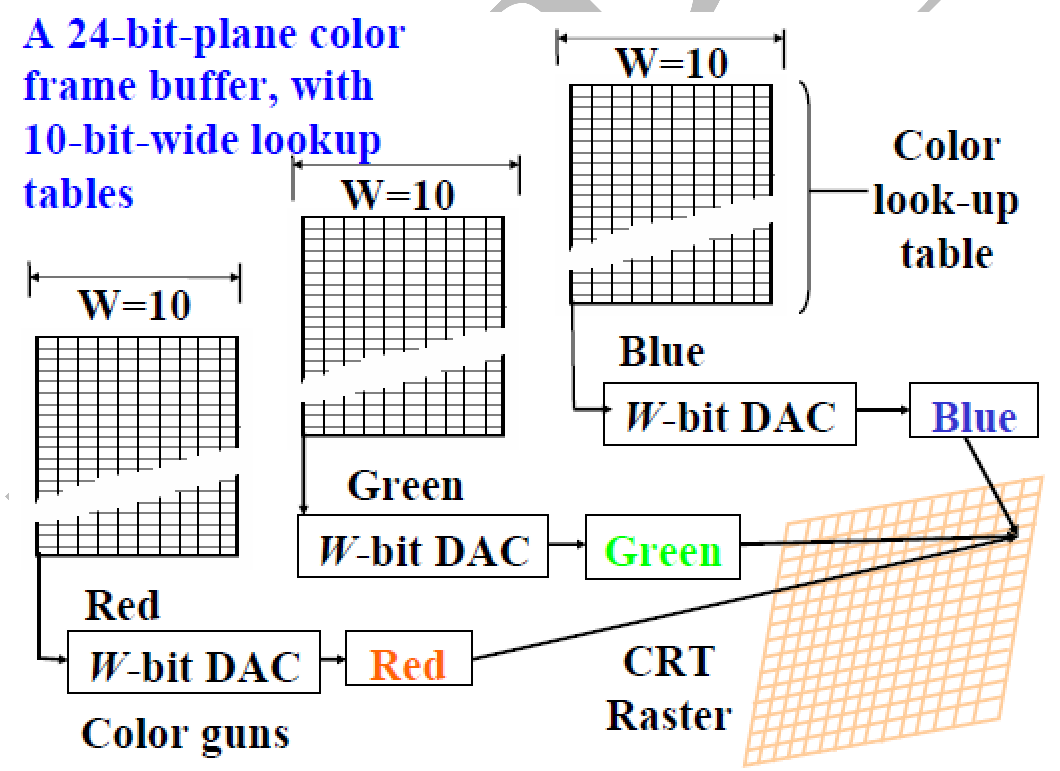
A 24-bit-plane color frame buffer



An N-bit-plane gray level frame buffer with a W-bit-wide lookup table.




A 24-bit-plane color frame buffer, with 10-bit-wide LUT
N
N
N
W=10
W=10
Frame buffer
2N Entries
Red
Green
Blue
Color look-up table
(CONTD.) →


A 24-bit-plane color frame buffer, with 10-bit-wide lookup tables
W=10
W=10
W=10
Color look-up table
Blue
W-bit DAC
Blue
Green
W-bit DAC
Green
Red
W-bit DAC
Red
Color guns
CRT Raster