Display Devices

Terminologies

Pixel

The **smallest number of phosphor dots that the electron gun can focus** on is called a **pixel**, it comes from the term **picture element**. Each pixel has a **unique address**, which the computer uses to locate the pixel and control its appearance. Some electron guns can focus on pixels as small as a single phosphor dot.

Fluorescence / Phosphorescence

When the electron beam strikes the phosphor-coated screen of the CRT the individual electrons are moving with the kinetic energy proportional to the acceleration voltage.

Some of this energy is dissipated as heat but the rest is transferred to the electron of the phosphor atoms making them jump to *higher quantum energy levels*

In returning to their previous quantum levels these excited electrons give up their extra energy in the form of light at frequencies that is colors predicted by the quantum theory

Any given phosphor has several different quantum levels to which electrons can be excited each corresponding to a color associated with return to an unexcited state

Further, electrons on some levels are less stable and turn to the unexcited state more rapidly than others.

A phosphors fluorescence is the light emitted as these 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

Since fluorescence usually last just a fraction of a microsecond the most of the light emitted is phosphorescence for a give phosphor

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 rate

The refresh rate is the number of times per second the image is redrawn to give a feeling of un-flickering pictures and it 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

The refresh rate above which a picture sops flickering and fuses into a steady image is called the critical fusion frequency (CFF)

The factors affecting the CFF are:

i. Persistence: longer the persistence the lower the CFF But the relation between the CFF and persistence is non linear

ii. Image intensity: Increasing the image intensity increases the CFF with non linear relationship

iii. Ambient room light Decreasing the ambient room light increases the CFF with nonlinear relationship

iv. Wave lengths of emitted light

v. Observer

Horizontal scan rate:

The horizontal scan rate is the number of scan lines per second The rate is approximately the product of the refresh rate and the number of scan lines

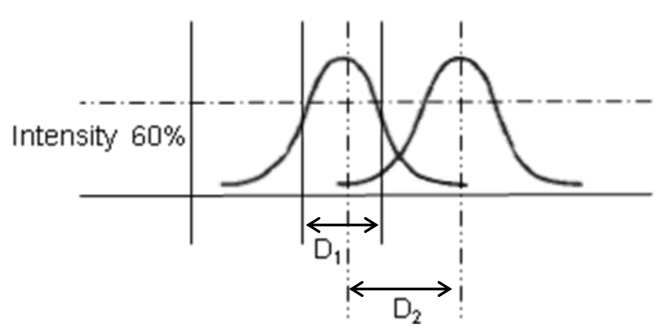
Resolution

Resolution is defined as the maximum number of points that can be displayed horizontally and vertically with out overlap on a display device

A monitor's resolution is determined by the **number of pixels on the screen**, expressed as a matrix. The more pixels a monitor can display, the higher its resolution and the dearer its images appear. For example, a resolution of 640 X 480 means that there are 640 pixels horizontally across the screen and 480 pixels vertically down the screen. The **actual resolution** is determined by the video controller not by the monitor itself—most monitors can operate at several different resolutions e.g. 800 x 600, 1024 x 768, 1152 x 864, 1280 x 1024. As the **resolution increases, the image on the screen gets smaller**.

Factors affecting the resolution are as follows

i. Spot profile The spot intensity has a Gaussian distribution as depicted in figure. So two adjacent spots on the display device appear distinct as log as their separation D2 is greater than the diameter of the spot D1 at which each spot has an intensity of about 60 percent of that at the center of the spot



ii. Intensity: as the intensity of the electron beam increases the spot size on the display tends to increase because of spreading of energy beyond the point of bombardment

This phenomenon is called *blooming* Consequently , the resolution decreases.

Thus it is noted that resolution is no necessarily a constant and it is not necessarily equal to the resolution of a pix-map, which is allocated in a buffer memory

Color CRTs

Color depends on the light emitted by phosphor.

Two type:

i. Beam Penetration Method

ii. Shadow Mask Method

i. Beam Penetration Method:

Two different layers of phosphor coating used Red (outer) and Green (inner)
Display of color depends on the depth of penetration of the electron beam into the phosphor layers

i. A beam of slow electrons excites only the outer red layer

ii. A beam of very fast electrons penetrates thru the red phosphor and excites the inner green layer

iii. When quantity of red is more than green then color appears as orange

iv. When quantity of green is more than red then color appears as yellow

Screen color is controlled by the beam acceleration voltage.

Only four colors possible, poor picture quality

ii. Shadow Mask Method

The inner side of the viewing surface of a color CRT consists of closely spaced groups of red, green and blue phosphor dots.

Each group is called a *triad*

A thin metal plate perforated with many small holes is mounted close to the inner side of the viewing surface. This plate is called *shadow mask*

The shadow mask is mounted in such a way that each hole is correctly aligned with a triad in color CRT

There are three electron guns one for each dot in a triad

The electron beam form each gun therefore hits only the corresponding dot of a triad as the three electron beams deflect

A triad is so small that light emanating from the individual dots is perceived by the viewer as a mixture of the three colors

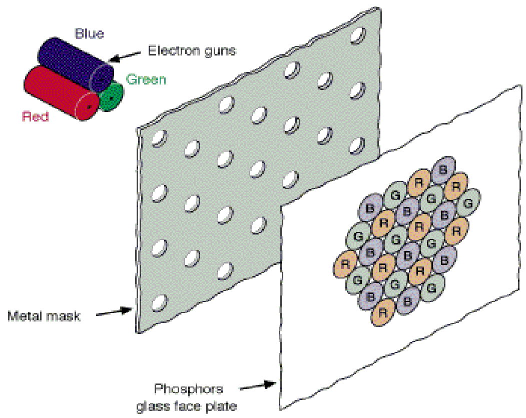
Thus, a wide range of colors can be produced by each triad depending on how strongly each individual phosphor dot in a triad is excited.

Two types:

a. A Delta –Delta CRT

A triad has a *triangular (delta) pattern* as are the three electron guns

Main drawback of this type of CRT is that a high precision display is very difficult to achieve because of technical difficulties involved in the alignment of shadow mask holes and the triad on one to one basis



b. A Precision Inline CRT

A triad has an *in-line pattern* as are the three electron guns

The introduction of this type of CRT has eliminated the main drawback of a Delta-Delta CRT

But a slight reduction of image sharpness at the edges of the tube has been noticed

Normally 1000 scan lines can be achieved

The necessity of triad has reduced the resolution of a color CRT

The distance between the center of adjacent triads is called a *pitch*

In very high resolution tubes, pitch measures 0.21 mm (0.61 mm for home TV tubes)

The diameter of each electron beam is set at 1.75 times the pitch

For example if a color CRT is 15.5 inches wide and 11.6 inches high and has a pitch of 0.01 inches

The beam diameter is therefore 0.01 x 1.75 = 0.018 inches

Thus the resolution per inch is about 1/0.018 = 55 lines

Hence the resolution achievable for the given CRT is 15.5 x 55 = 850 by 11.6 x 55 = 638

The resolution of a CRT can there fore be increased by decreasing the pitch

But small pitch CRT is difficult to manufacture because it is difficult to set small triads and the shadow mask is more fragile owing to too many holes on it .

Besides the shadow is more likely to warp from heating by the electrons

Types of Displays

Emissive Displays

The emissive display converts electrical energy into light energy.

The image is Produced directly on the screen

Phosphors convert electron beams or UV light into visible light

- Cathode Ray Tube (CRT)
- Field emission display (FED)
- Surface-conduction Electron-emitter Display (SED)
- Vacuum Fluorescent Display (VFD)
- Electroluminescent Displays (ELD)
- Light- Emitting Diode Displays (LED)
- Plasma Display Panel (PDP)
- Electrochemical Display (ECD)

Non-Emissive Displays

Light is produced behind the screen and the image is formed by filtering this light

The Non emissive are optical effects to convert the sunlight or light from any other source to graphic form. Liquid crystal display is an example.

Light Emitting Diode Monitors

Light Emitting Diode (LED) is an improved version of LCD monitor and manufacturers have tried to eliminate the drawbacks of LCD monitors.

They differ in backlighting as LCD monitors use Cold Cathode Fluorescent Light and LED monitors are based on light emitting diode.

The backlighting impacts badly on the image and decreases its sharpness and brightness.

WLED and RGB LED are the two types of LED monitors, depending on the way LED placed in the panel.

Benefits of LED over CRT and LCD Monitors

LED monitors give a high-quality image with vibrant colors and viewing comfort.

LCD monitors are unable to display black and white image while LED monitors are capable of producing true black hues.

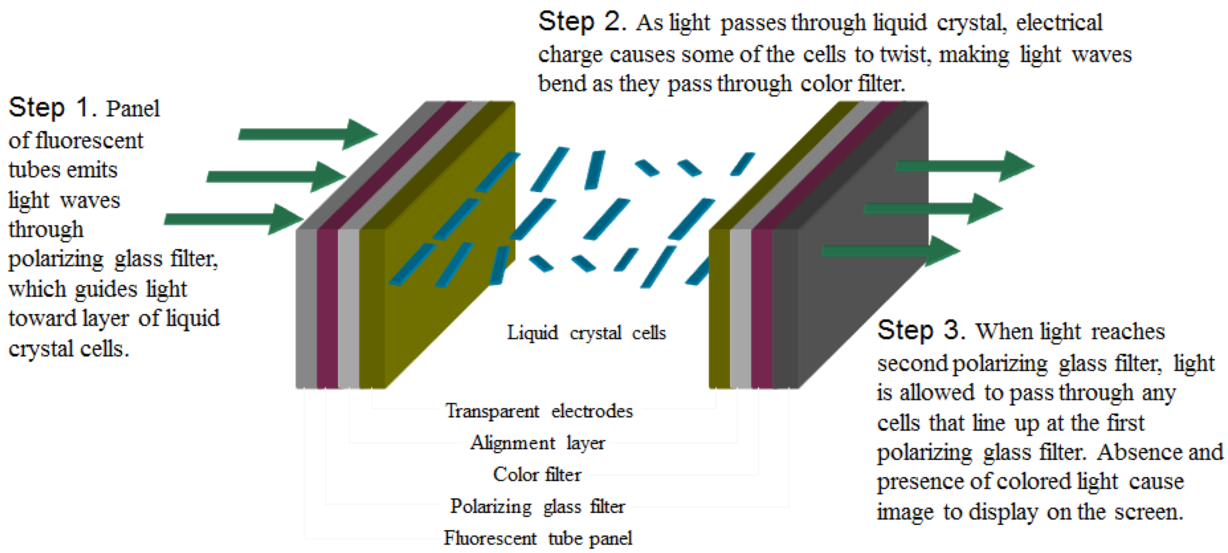
It consumes less electrical energy than CRT and LCD monitors as a cold cathode fluorescent lamp is embedded in the panel.

The absence of mercury makes it eco-friendly while zero percent flickering removes the chances of strain on the eyes

LCD (Liquid Crystal Display)

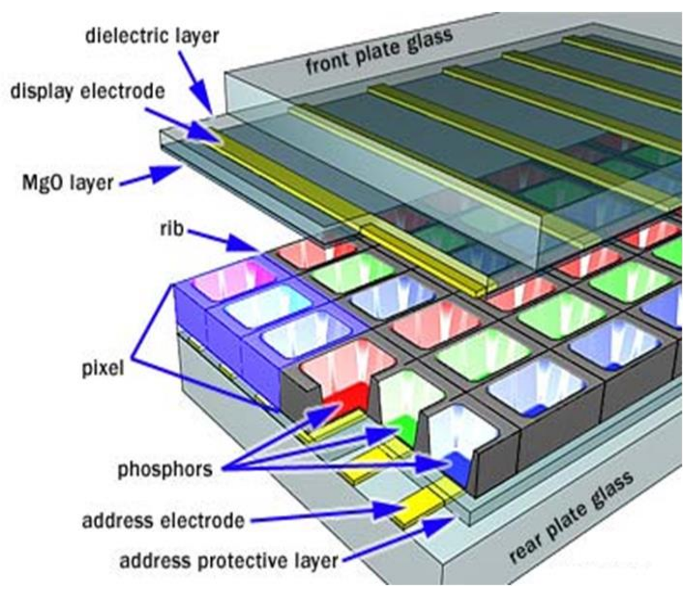
- A type of flat-panel display
- Uses liquid crystals between two sheets of material to present information on a screen
- An electric current passes through the liquid crystals, they twist
- Depending on how much they twist, some light waves are passed through while other light waves are blocked. This creates the variety of color that appears on the screen

- LCD monitors produce color using either passive-matrix or active-matrix technology
- Active-matrix display, also known as a TFT (thin-film transistor) display, uses a separate transistor to apply changes to each liquid crystal cell and thus display high-quality color that is viewable from all angles
- Passive-matrix display uses fewer transistors and requires less power than an active-matrix display
- The color on a passive-matrix display often is not as bright as an active-matrix display
- Users view images on a passive-matrix display best when working directly in front of it
- Passive-matrix displays are less expensive than active-matrix displays
- An importance measure of LCD monitors is the response time, which is the time in millisecond (ms) that it takes to turn a pixel on or off
- LCD monitors' response times average 25 ms
- The lower the number, the faster the response time
- Brightness of an LCD monitor is measured in nits
- Nit is a unit of visible light intensity equal to one candela meter
- Resolution and dot pitch determines quality of LCD monitor



Plasma Panel

- A flat-panel display that uses gas plasma technology
- A layer of gas between two sheets of material
- When voltage is applied, the gas releases ultraviolet (UV) light that causes the pixels on the screen to glow and form an image
- Larger screen sizes and higher display quality than LCD, but much more expensive



Hard Copy Devices

- Printed output is referred to as hard copy and do not require electric power as they are printed on papers to read after printing and provide permanent readable form information
- According to how they print printers can be of different types:

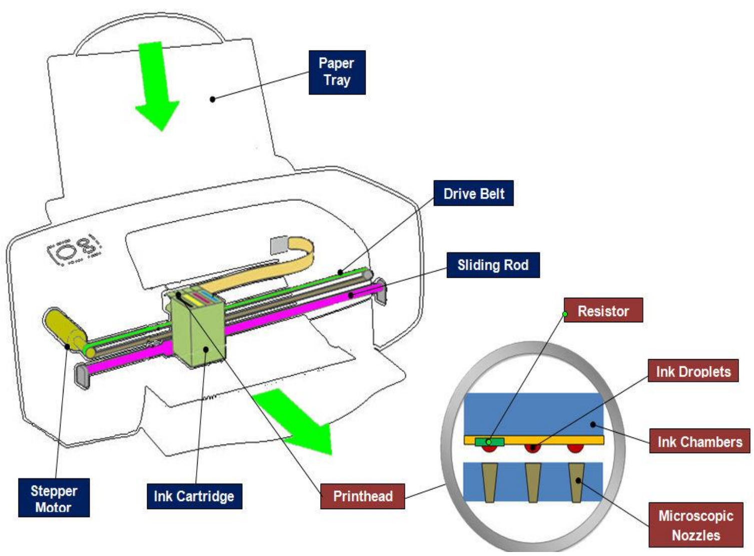
- Character printers prints one character of a text at a time
- Line printer prints one line of the text at a time
- A page printer prints one page of the text a t a time
- According to the technology used printers produce output by either impact or non impact methods

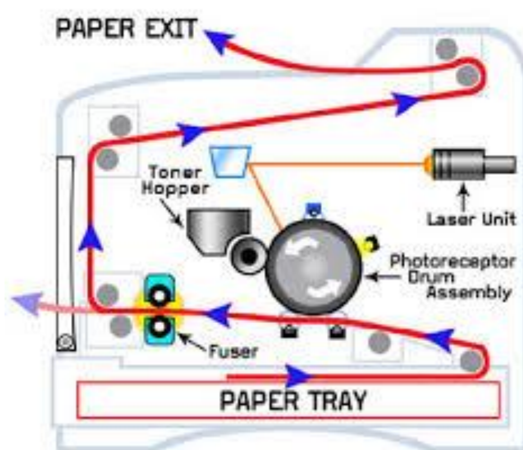
Impact printers Impact printers press the formed character faces against an inked ribbon onto paper

Character impact printers often have a dot matrix print head containing a rectangular array of protruding wire pins with a number of pins depending on the quality of the printer

Individual characters or graphics patterns are obtained by retracting certain pins so that the remaining pins form the pattern to be printed.

Non-Impact Printers Non impact printers use laser techniques, ink-jet sprays etc to get images onto paper.

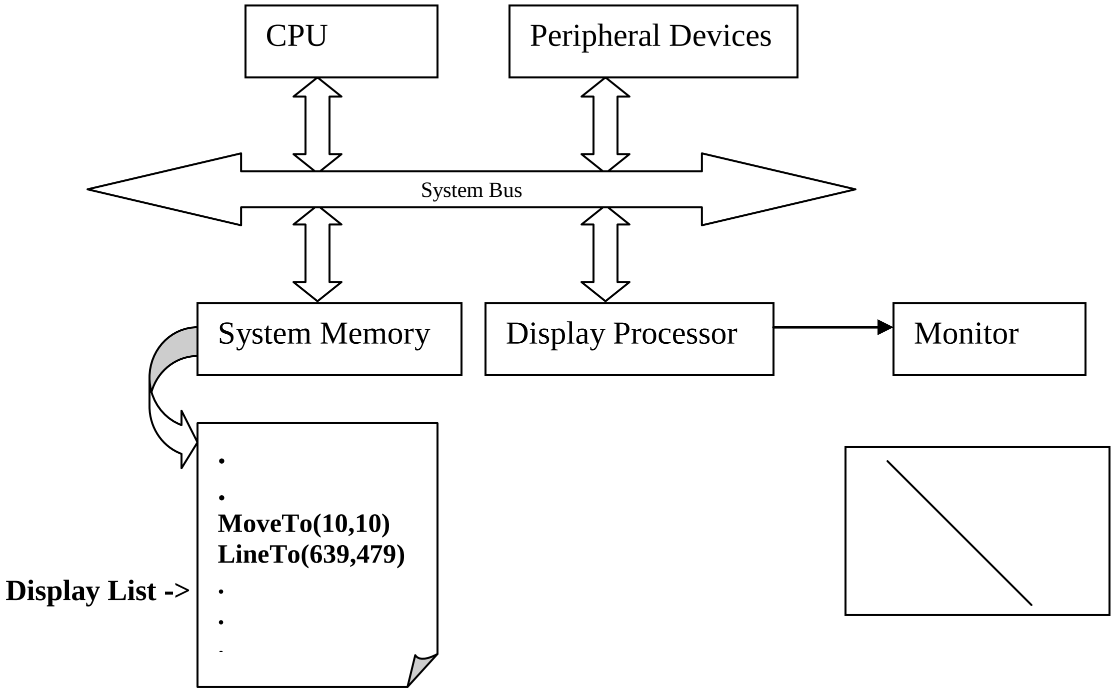




Display Technology

i. Vector Display Technology

Vector display technology was developed in 60's and used as a common display device until 80's , It is also called *random scan*, *a stroke*, *a line drawing* or *calligraphic display*



It consists of a central processing unit, a display processor , a monitor , system memory and peripheral devices such as mouse and key board

A display processor is also called a *display processing unit* or *graphics controller*

The application program and *graphics subroutine package* both reside in the system memory and execute on CPU . A graphics subroutine package creates a *display list* and stores in the system memory

A display list contains point and line plotting commands with end point coordinates as well as character plotting commands

The DPU interprets the commands in the display list and plots the respective output primitives such as point, line and characters

As a matter of fact the DPU sends digital point coordinates to a vector generator that converts the digital coordinate values to analog voltages for circuits that displace an electron beam hitting on the CRT's phosphor coating

Therefore the beam is deflected from endpoint to endpoint as dictated by the arbitrary order of the commands in the display list, hence the name *Random Scan Display* Since the light output of the phosphor decays in tens or at most hundreds of microseconds the DPU must cycle thru the display list to refresh the image around 50 times per second to avoid flicker. A portion of the system memory where display list resides is called a *refresh buffer*.

This display technology is used with mono chromatic CRTs or beam penetration color CRTs

Advantages:

i. It can produce a smooth output primitives with higher resolution unlike the raster display technology

ii. It is better than raster display for real time dynamics such as animation

iii. For transformation, only the end points has to be moved to the new position in vector display but in raster display it is necessary to move those end points and at the same time all the pixels between the end points must be scan converted using appropriate algorithm No prior information on pixels can be reused

Disadvantages:

i. A vector display can not fill areas with patterns and manipulate bits

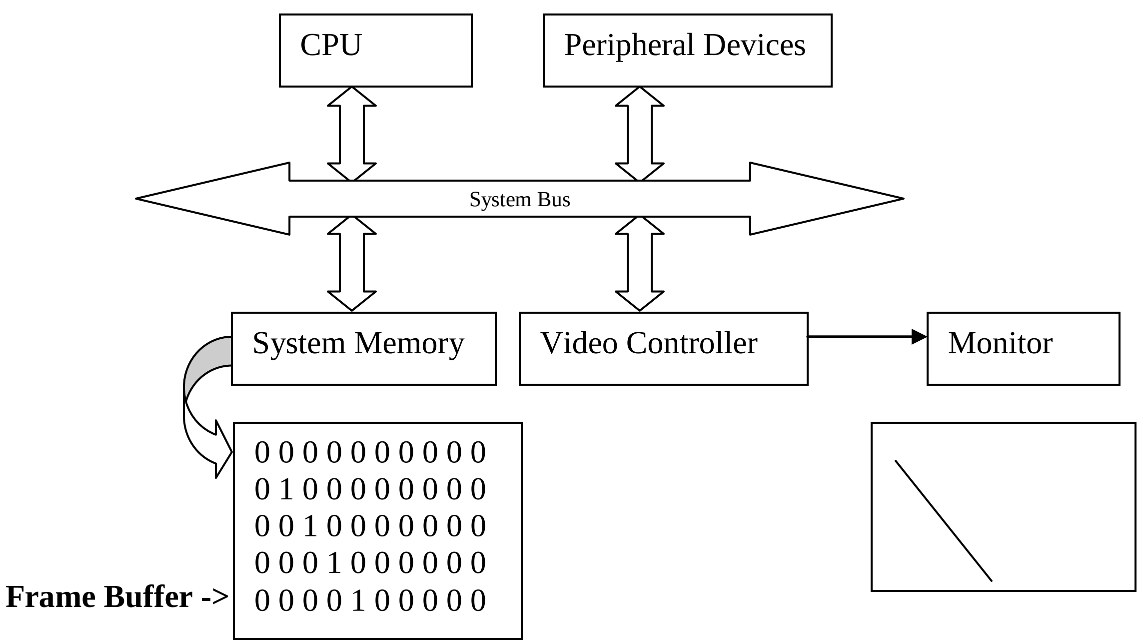
ii. Time required for refreshing an image depends upon its complexity (more the lines , longer the time) the flicker may therefore appear as the complexity of the image increases. The fastest vector display can draw about 100000 short vectors in a refresh cycle without flickering

ii. Raster Display Technology

This technology based on television technology was developed in early 70s

It consists of central processing unit, a video controller, a monitor, system memory and peripheral devices such as mouse and keyboard.

The application program and graphics subroutine package both reside in the system memory and execute on CPU.



When a particular command such as a `line(x1,y1,x2,y2)` is called by the application program the graphics subroutine package sets the appropriate pixels in the *frame buffer*, a portion of the system memory

The *video controller* then cycles thru the frame buffer, one scan line at a time typically 50 times per second.

It brings a value of each pixel contained in the buffer and uses it to control the intensity of the CRT electron beam.

So there exists a one to one relationship between the pixel in the frame buffer and that on the CRT screen

A 640 pixels by 480 lines is an example of *medium resolution* raster display

A 1600 by 1200 is a *high resolution* one

A pixel in a frame buffer may be represented by one bit as in monochromatic system where each pixel on CRT screen is either on '1' or off '0'

Or it may be represented by eight bits resulting $2^8 = 256$ gray levels for continuous shades of gray on CRT screen

In color system each of the three color red, green and blue is represented by eight bits producing $2^{24} = 16$ million colors

A medium resolution color display having 640 x 480 pixels will thus require (640 x 480 x 24) / 8 = 9kb of RAM

Advantages

i. It has an ability to fill the areas with solid colors or patterns

ii. The time required for refreshing is independent of the complexity of the image

iii. Low cost

Disadvantages

i. For Real-Time dynamics not only the end points are required to move but all the pixels in between the moved end points have to be scan converted with appropriate algorithms Which might slow down the dynamic process

ii. Due to scan conversion "*jaggies*" or "*stair-casing*" are unavoidable

Video Controller/Video Cards

The quality of the images that a monitor can display is defined by the video card (also called the video controller or the video adapter) and the monitor. The video controller is an intermediary device between the CPU and the monitor. It contains the **video-dedicated memory** and other circuitry necessary to send information to the monitor for display on the screen.

In most computers, the video card is a separate device that is plugged into the motherboard. In many newer computers, the video circuitry is built directly into the motherboard, eliminating the need for a separate card.

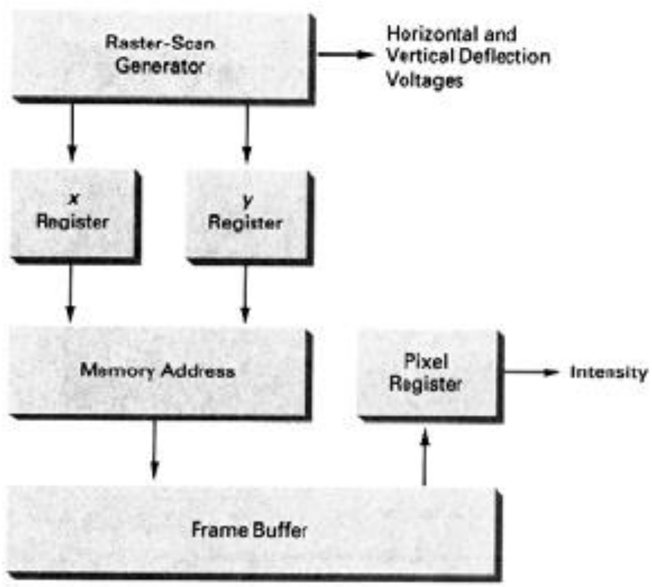
The screen changes constantly as a user works—the screen is updated many times each second, whether anything on the screen actually changes or not.

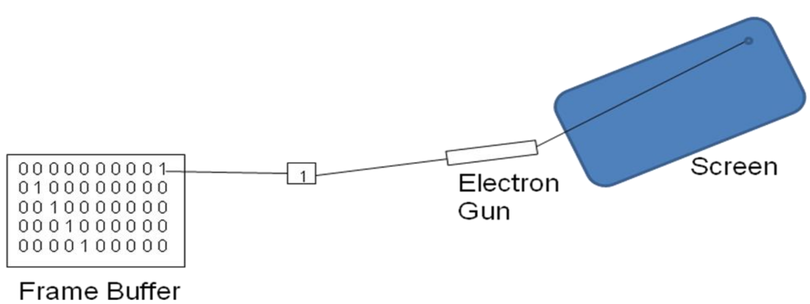
If the user wants more colors or a higher resolution, the amount of data can be much higher For example, for “**high color**" (24 bits, or 3 bytes per pixel will render 16 million colors) at a resolution of 1024 x 768, the computer must send 2,359,296 bytes to the monitor for each screen.

Today's video controllers feature their own built-in microprocessors , which frees the CPU from the burden of making the millions of calculations required for displaying graphics. The speed of the video controller’s chip determines the speed at which the monitor can be refreshed.

Video controllers also feature their own built-in video RAM, or VRAM (which is separate from the RAM that is connected to the CPU). VRAM is dual-ported, meaning that it can send a screen full of data to the monitor and at the same time receive the next screen full of data from the CPU.

Basic Raster Scan Video Controller Operation





Frame Buffer

Frame buffer is the portion of memory used to store intensity information of physical pixels to be displayed on the screen. There is a one to one mapping of the physical pixel on the screen and its logical representation in the memory (frame buffer) in the form of pixel intensity values. In case of a raster system, there is at least one bit assigned for each physical pixel on the screen but if more bits are assigned to the pixel then different intensities can be generated out of the single pixel.

Color Manipulation Technique

In general, the size of the frame buffer depends upon the total number of bits assigned per pixel and the total resolution of the screen

```
Frame Buffer size  = total resolution * bits assigned per pixel
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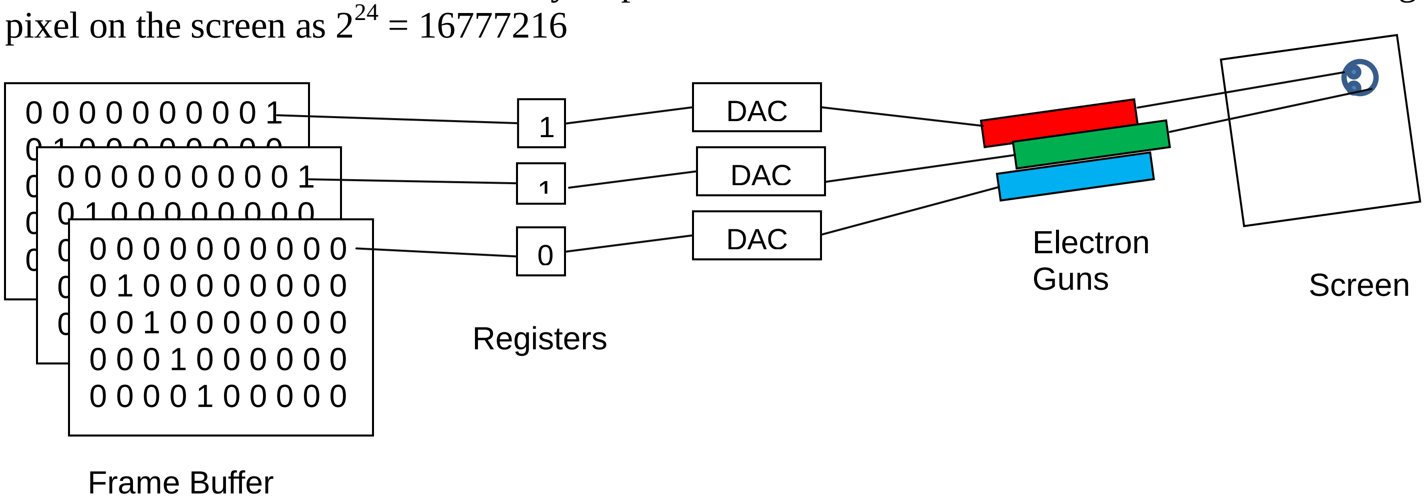
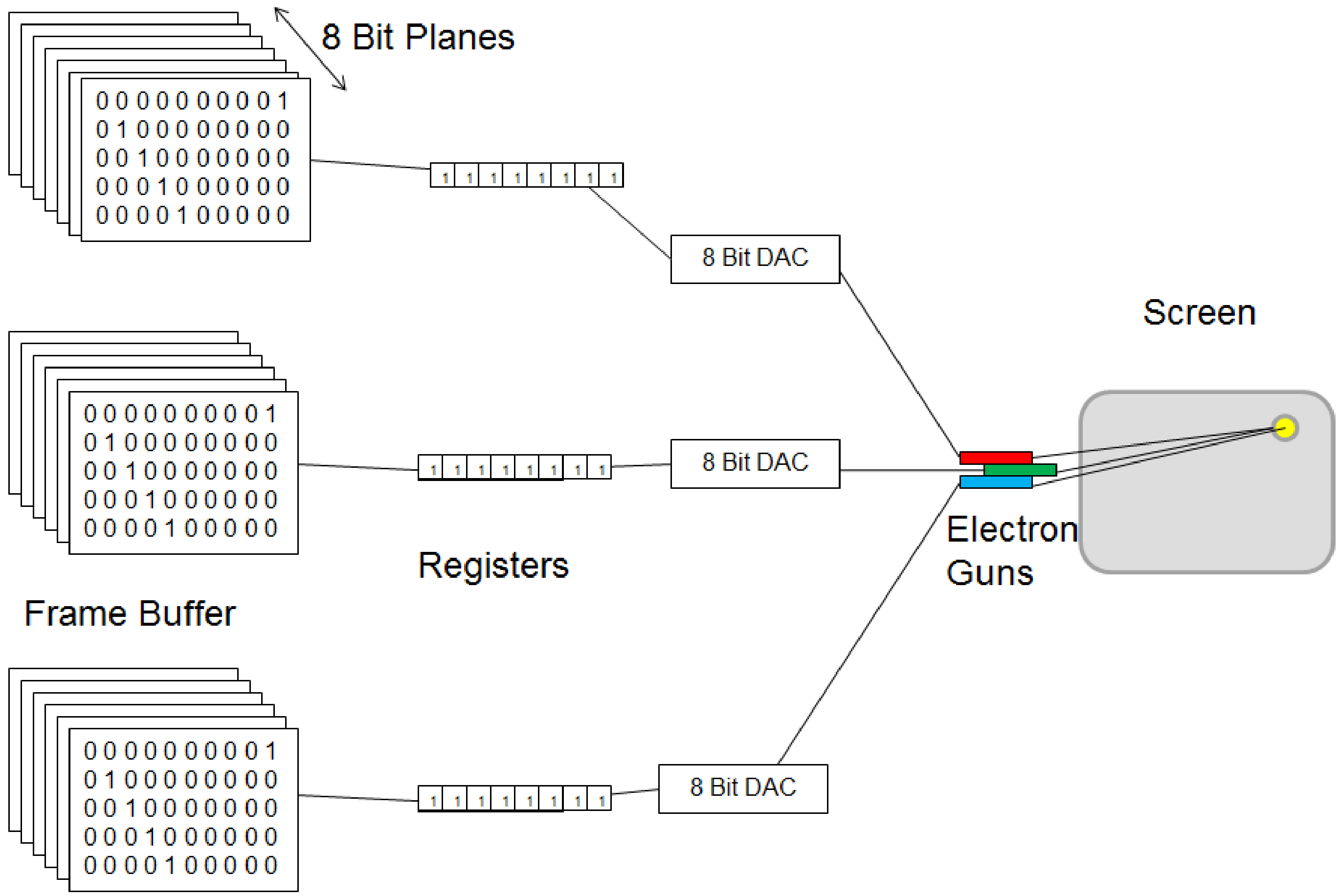
So if the total resolution of the screen is 640 * 480 and 8 bits are assigned per pixel then the total size of the frame buffer will be 640 * 480 * 8

The total number of intensities that can be produced out of a single pixel on the screen depends upon the total number of bits assigned for that pixel

Total number of intensities that can be produced out of a single pixel $= 2^{\text{number of bits assigned per pixel}}$

So a 24 bit video card has the ability to produce 16 million different intensities out of a single pixel on the screen as $2^{24} = 16777216$




8 Bit Planes
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
8 Bit DAC
Screen
Registers
Electron
Guns
Frame Buffer