Computer Graphics (CGA)
& Interactive Computer Graphics (ICG)

L T P

4 1 -

TIT-404

Computer Graphics The computer is an information processing unit. It is a tool for storing, manipulating & correlating data. There are many ways to communicate the processed information to the user. The computer graphics is one of the most effective & commonly used way to communicate with the user. Thus computer graphics makes it possible to express data in pictorial form.

Hence CG is" the use of a computer to define, store, manipulate, interrogate and present pictorial output. Thus CG is interface of man & m/c - it is a tool to present information.

Here when the observer has no direct control over the picture being presented is Non-interactive or passive computer graphics.

In interactive graphics the observer can influence the picture as it is being presented i.e the observer interact with the picture in real time. This can be done by providing user with some input device.

- It involves two way comm^n b/w computer & user
- The computer on receiving signals from the I/P device, can modify the displayed picture
- To the user, the picture is changing instantaneously in response to his commands

In this way, he maintains a dialogue with the computer

Advantages of Computer graphics

- A high quality graphic displays of personal computer provide one of the most natural means of communicating with computer
- It has an ability to show moving pictures, and thus it is possible to produce animations with computer graphics.
- With Computer graphics one can adjust animation by speed, total portion of scene, amount of detail shown
- The CG also provide facility called update dynamics.
- It can also provide audio feedback along with video feedback

Application of Computer Graphics

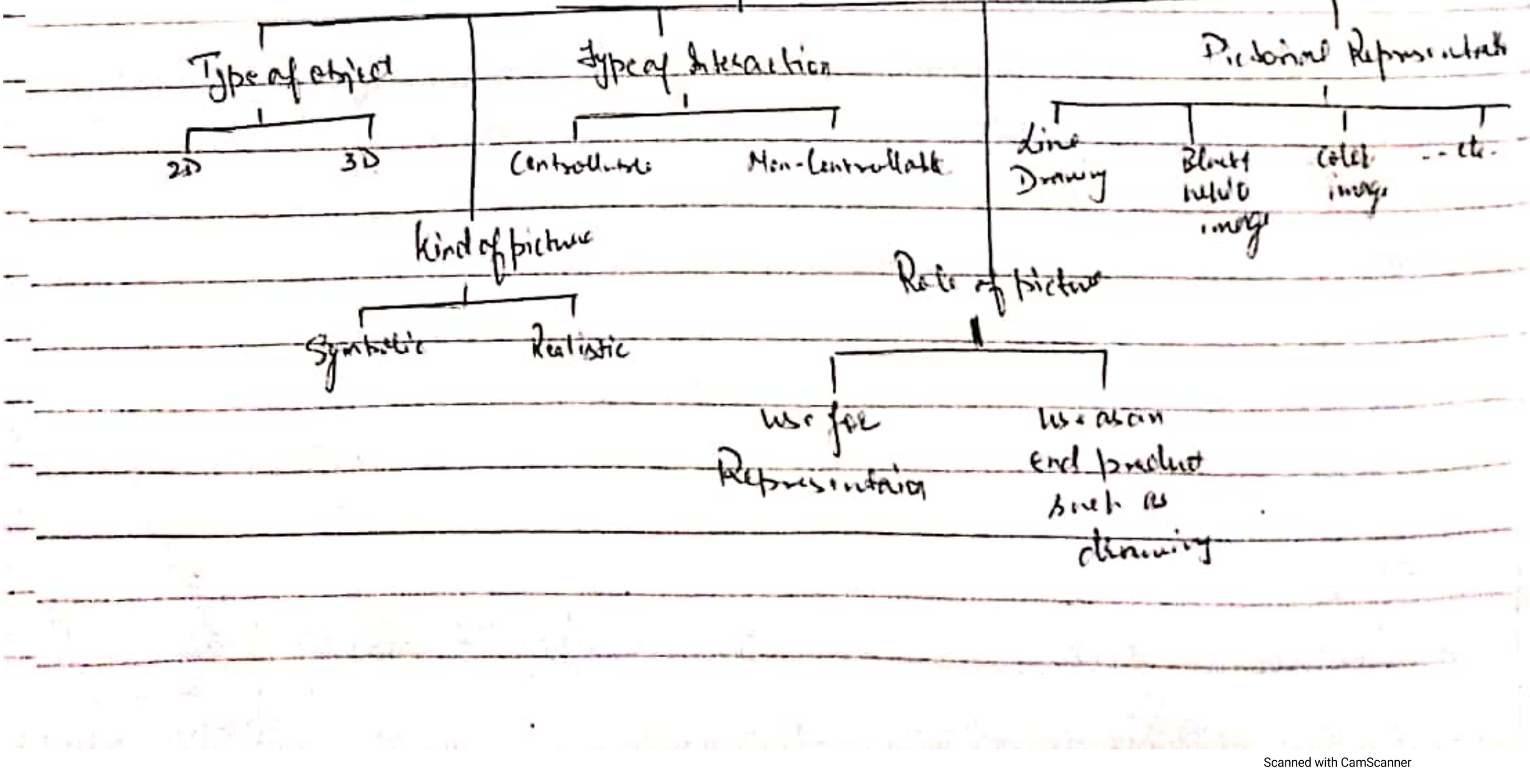
- User Interfaces Graphical interfaces provide an attractive & easy interaction

Shikha Goswami
AP, ITD

- Plotting of graphs and charts: Mathematical, economic, scientific & physical f° can be used to create 2D & 3D graphs in form of histograms, bars, pie charts using CG.
- Computer-aided drafting & design: Computer aided drafting uses graphics to design components & systems of electrical, mechanical, electromechanical & electronic devices.
- Simulation & animation: use of graphics in simulation makes mathematic models and mechanical systems more realistic and easy to study. Graphics supporting animation may be used to provide animated movies & cartoons.
- Art & Commerce: It allows uses to creat artistic pictures which express message and attract attentions.
- Process control: the process system & processing parameters can shown by graphic symbols & identifications.
- Cartography: CG is also used to represent geographic maps, weather maps, oceanographic charts, contour maps, population density maps etc.
- So on.

- Education & training:
- Image processing
- Office Automation
- Network design
- Sports
- Advertising (Advertising)
- Medical technology
- Aerospace industry
- Building design & construction

Classification of computer graphics:



In computer graphics pictures or graphics objects are presented as a collection of discrete picture elements called pixels. The pixel is the smallest addressable element. It is the smallest piece of display screen which we can control. The control is achieved by setting the intensity & color of the pixel which composes the screen.

Each pixel on the graphic display does not represent mathematical point. It instead is a region which theoretically can contain an infinite no of points. eg. pt (4.4, 3.8) & pt (4.7, 3.3) represent same pixel (4,3).

Procedures are used to find which pixels provide best approximation of the object & picture. This process is known as rasterization i.e determining the appropriate pixels. The process of representing continuous picture as collection of discrete pixels is called scan conversion.

Working of interactive graphic display:

It consists of three parts:

* A digital memory or frame buffer in which the displayed image is stored as a matrix of intensity values
* A monitor
* A display controller, which is a simple interface that passes the value of frame buffer to the monitor. Inside the frame buffer the image is stored as a pattern of binary digital numbers, which represent a rectangular array of picture elements or pixel. It is the smallest addressable screen element. In simplest black & white image we can represent a black pixel by 0 & a white pixel by 1. The controller simply reads the successive bytes of data & convert 0 & 1 to corresponding video signals. These are fed to monitor. To modify the image we need to change the content of frame buffer.

The controller repeats this operation & thus maintains a steady picture on the TV monitor.

Problems: & How do we display straight lines? How are curves drawn on the display?

⇒ Pixels to be white or black can chosen using various algo using eqn of the line or curve

staircase like effects. This can solved by using line drawing ~~display~~ display.

§ Fully speed is so important in displaying pictures.

=> Any display based on the CRT must be refreshed by repeadly passing to it the image to be displayed.

Until the image is transfered at least 25 times a second (point by point) the image will begin to flicker.

§ How picture is made to shrink, grow or rotate?

-> this transformations are based on mathematical techiques.

- Co-ordinate geometry
- Trignometry
- matrix methods

§ What happens to picture that are two large to fit on screen?

=> Clipping can be used to select those parts of the picture that lie on the screen & to discard the rest.

§ How can the user of the display draw on the screen?

=> Input devices can be used to for this

Video display devices :→

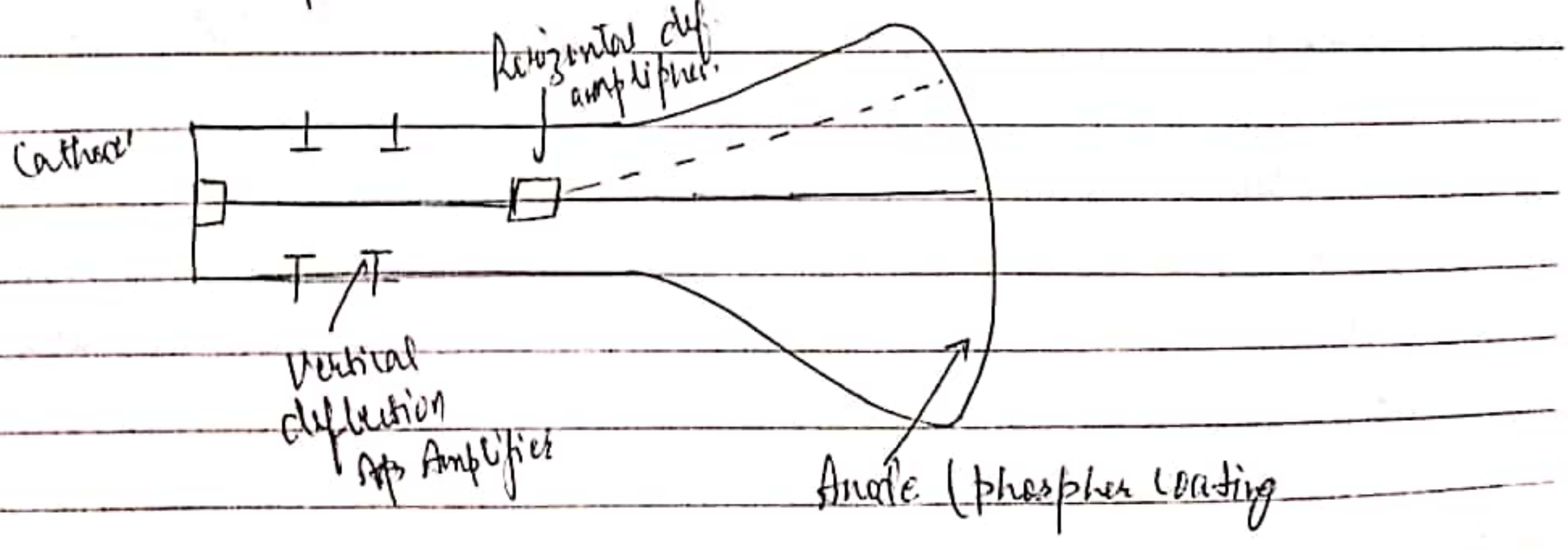
The display devices are known as o/p devices. The most common used o/p device is graphic video monitor. The operation of most video monitors are based on st. cathode ray tube (CRT)

⇒ Cathode Ray Tube :→

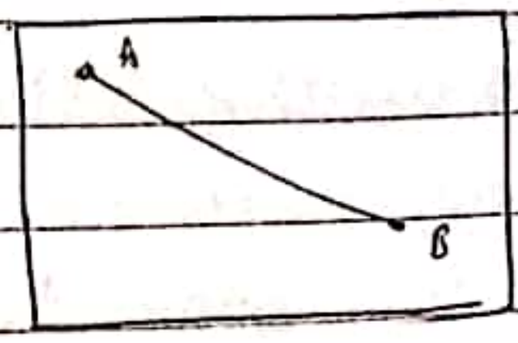
A CRT is an evacuated glass tube An electron gun at the rear of the tube produces a beam of electrons which is directed towards the front of the tube (Screen). The inner side of the screen is coated with phosphor substance which gives off light when it is stroked by electrons. It is possible to control the point at which the electron beam strikes the screen, and therefore the position of the dot upon the screen by deflecting the electron beam. The fig. shows the electrostatic deflection of the electron beam by the CRT.

The deflection system of the CRT consisting two pairs of parallel plates, referred to as the vertical and horizontal deflection plates. The voltage applied to vertical plate controls the vertical deflection of the electron beam and voltage applied to the horizontal deflection plate control the horizontal deflection of the electron beam. There are two techiques to produce image.

Vector scan/random scan and Raster Scan.



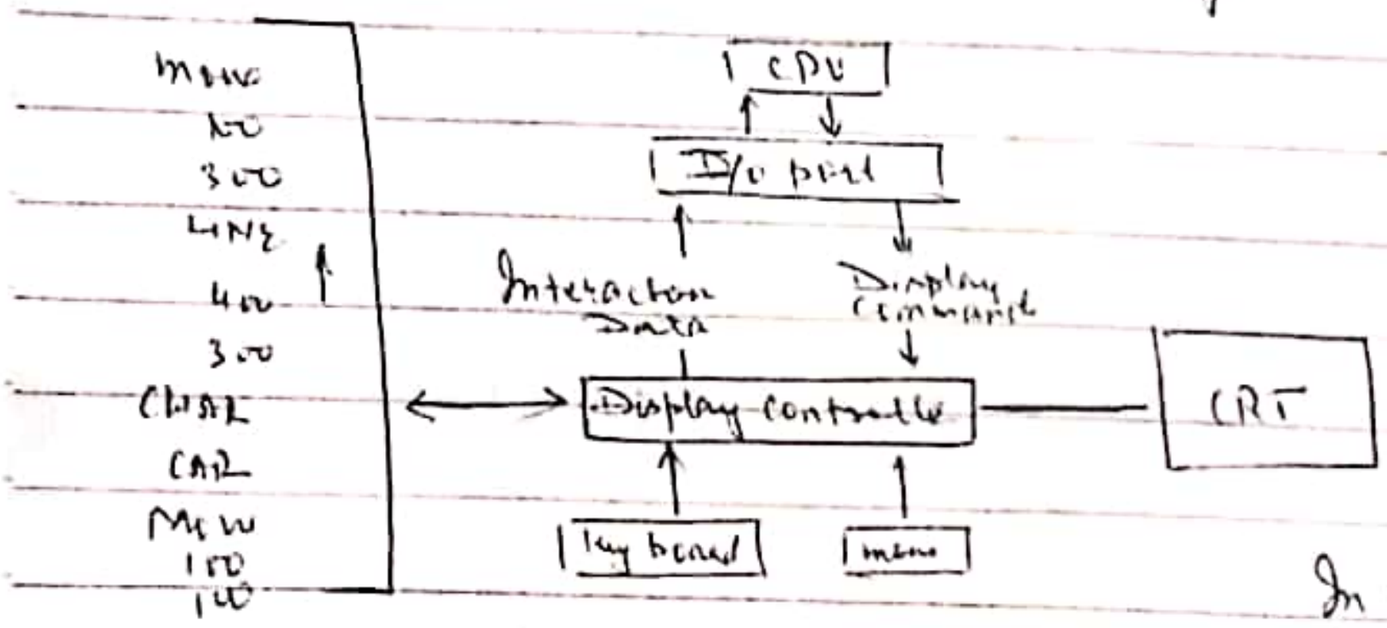
Vector Scan/Random Scan display



As shown in fig. vector scan CRT display directly traces and only the desired line on CRT i.e. If we want a line connecting A & B on a vector graphic display we simply drive the beam deflection circuitry, which will cause beam to go directly from point A to B. If we want to

move the beam from point A to point B without showing a line between points, we can blank the beam as we move it. To move the beam across CRT, the info about magnitude and direction is required this info is generated using vector graphic generators.

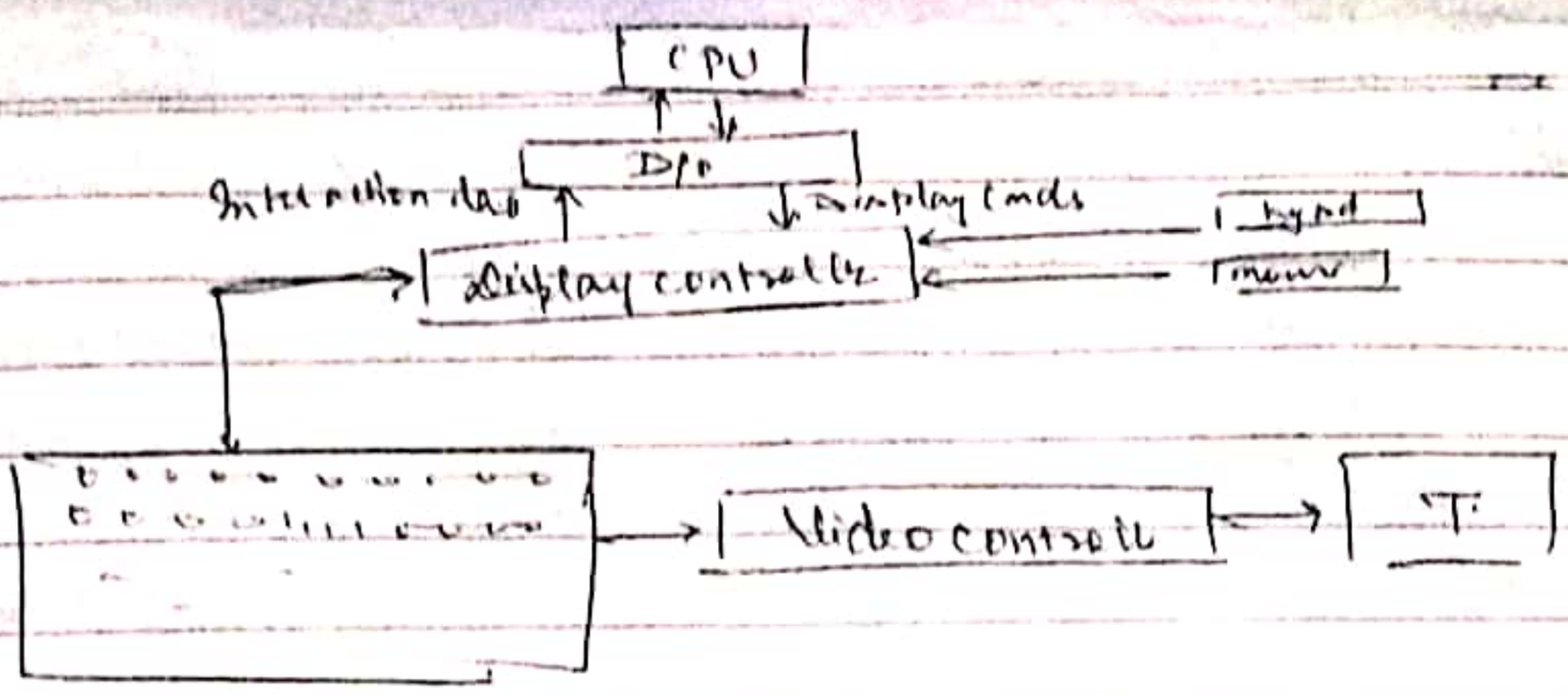
The fig: shows a typical vector display arch. It consist of a display controller, CPU, display buffer memory & CRT. Display cont is connected as an I/O peripheral to CPU. The display buffer mem stores the computer generated display list or display prog. The prog contains point & line plotting commands with (x,y) or (x,y,z) end points co-ordinate, as well as character plotting commands. The display cont controller interprets commands for plotting pts. lines & characters and signals (digital) and pt co-ordinates to vector generator. The vector generator then converts the digital pt co-ordinates to analog voltage for beam-deflection circuit that displaces an electron beam writing on CRT's phosphor coating.



In vector display beam is deflected from end points, hence this technique is also called random scan. The beam strikes phosphor emits light, but the phosphor light decays after few millisecond & therefore it is necessary to repeat thro' the display list to refresh that phosphor at least 30 times per sec to avoid flicker. i.e. it is also called refresh buffer.

Raster Scan display: the fig. below shows arch of a raster display. It consist of display controller, CPU, video cntr, refress buffer, kybd, mouse and the CRT.

As shown the display image is stored in the form of 1s and 0s in the refresh buffer. The video cntrlr reads this refresh buffer & produces the actual image on the screen. It does this by scanning one scan line at a time, from top to bottom & then



Raster Scan is the most common method of displaying images. Horizontal & vertical deflection signals are generated to move the beam all over the screen in a pattern.

Here, the beam is swept back and forth from the left to right. When it moves from left to right it is on and while from right to left it is off.

When it reaches the bottom of screen it is off & retraced back to top left side.

Memory in this schem is called frame buffer. Holding the set of intensities values for all the screen points. These are shown on the screen one row at a time. Each point is known as pixel. Pixels are addressed using row & col no.

Intensity range for pixel depends on capability of raster. It can be simply black and white or color. In B&W one bit per pixel is req. to show ON & OFF state of pixel but additional bits are req in color & varied intensity values. Upto 24-bits per pixel are included in high quality image requiring several megabytes of memory. In case of B&W system with one bit per pixel is called bit map. System with multiple bits per pixel are called pixmap.

Colour display Techniques :-

A CRT monitor displays color pictures by using combination of phosphors that emit diff. colored light. A range of colors can be generated by combining the emitted light from the different phosphors.

The two basic tech for producing colour displays are

→ Beam penetration method

§ The beam-penetration CRT:-

• The normal CRT can generate images of only a single color, due to limitation of its phosphor.

The color CRT uses a multilayer phosphor & achieves color control by modulating a normal constant parameter, namely the beam accelerating potential

In this multilayer phosphor usually Red & Green are used by layering Red phosphor deposited behind the initial layer of Green phosphor & the displayed color depends on how far the electron beam penetrates into phosphor layers.

In this a beam of low potential electron beam strikes the tube face, it excites only the red phosphor producing red color, by increasing the accelerating potential the velocity of the beam is increased and it strikes the Green phosphor by penetrating it. The intermediate beam produces a mix of red & green colors.

Thus the speed of the electron & hence the screen color at any pt is controlled by the beam-accelerate voltage.

Adv :→ It is inexpensive

Disadv :→ - only 4 colors are possible
- Quality of pic is not as good as with other.
- Accelerating pot. has to be varied significantly.

§ Used in Random scan display.

Shadow mask CRT → Used with Raster Scan system & produces a wider range of colors.

It has 3 phosphor ~~dots~~ color dots at each pixel position. One for red light, another for Green light and the third for blue light.

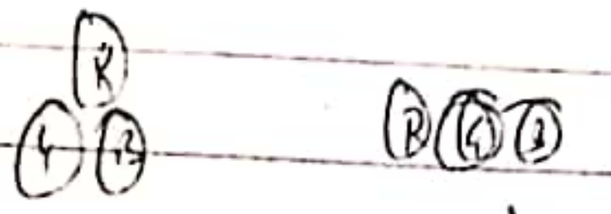
It has 3 electron guns one for each color dot and a shadow mask grid just behind the phosphor coated screen.

Shadow mask grid is pierced with small holes in a triangular pattern. The three electron guns are arranged together in a Δ (delta).

The deflection system of the CRT operates on all the 3 electron guns simultaneously by deflecting and focussed as a group onto the shadow mask, which contain a series of hole aligned with the phosphor-dot patterns.

When the beams passes thri' a hole in the shadow mask they activate a dot triangle. each gun activates its corresponding dot only as it passes thri' the shadow mask

Apart from this triad arrangement the inline Arrangement can be used to provide high resolution color CRTs



Triad inline

Color variation in shadow mask CRT

A shadow mask CRT color variation in achieved by varying the intensity level of all three electron guns. Combination of beam intensity produces a small light spot for each pixel position, since our eyes tend to merge the three colors into one. Composite

The color we see depend upon the amount of excitation of the Red, green + blue phosphors.

In some low-cost system the beams can be set to only on or off limiting the colors to 8 only.

More sophisticated system can set intermediate intensity levels for the electron beams, allowing several million diff colors to be generated.

Adv:

- produces much wider range of color display.

- Expensive - performance in pixel - poor resolution
- Reducing total brightness.

Problem

Convergence - When 3 beams are not converged on same hole

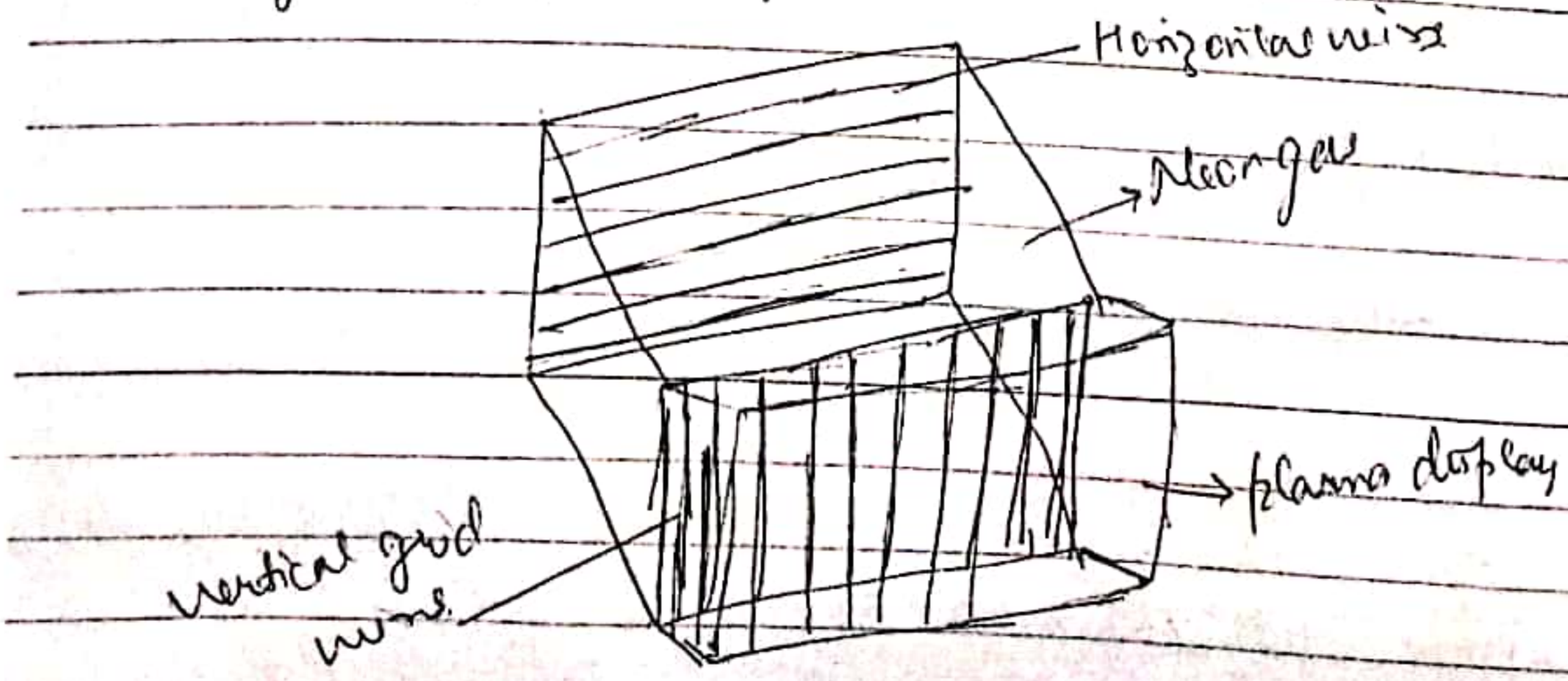
Flat panel display devices
& Plasma panel display.

In the CRT display minor distortion of picture can occur at the top and bottom of the screen. The optical system and the CRT focus the electron gun so that the beam converge exactly at the CRT plate. To accomodate this the CRT screens convave with high radious of curvature. Thus the gap between two adjacent line increase near the CRT edges. Here is the distortion.

The most popular flat panel display are the plasma panel and liquid crystal display. Plasma panel are emissive displays which internally convert electrical energy into light LED are example of non-emissive type which general graphic patterns utilizing the light energy of the environment.

The construction of plasma panel are roughly compared with that of neon lamps. It is a sandwich of two glass plates with a gaseous mixture primerly neon in between.

Horizontal & vertical wires are embedded in the glass plate. Horizontal in one & the vertical in the other. Appropriate Vol. is applied in corresponding row and col wire. The neon gas at the junction point of the row and col, the "neon bulb pixel" glows & stays on until the voltage is reversed. The gas at the intersection breaks down at the into a glowing plasma of electrons & ions.



The picture of the plasma panel is defined in the frame buffer the voltage at the row & col wise junction is controlled depending on the content of the frame buffer. The refresh rate may be as low, depending on the voltage and time the "neon bulb" glows on and sustains the brightness level.

The cells in plasma display can be switched on or off selectively by modifying. Thus the plasma panel allows both selective writing & selective erasing, at the speed of about 20 ms/cm.

Advantages:-

- It produces a very steady image, totally free of flicks.
- Less bulky device than a CRT of comparable screen size
- Because of large size it is attractive

Disadvantage

- Poor resolution of about 60 dots/inch
- Addressing & wiring requirements are complex
- They are used in raster display devices.

Liquid Crystal display:- LCD employ the special flow-like properties of the crystalline molecules. Similar to plasma panels, they are also a kind of sandwich of polarizer & intra thin grid wires. Instead of neon gas in between, there are liquid crystal layers. The front panel is a vertical polarizer followed by vertical grid wires, liquid crystal layer, horizontal grid wires, horizontal polarizer and finally the reflecting layer, all in order.

Usually liquid crystal molecules take spiral shape first the light entering thru' the front panel polarizes vertically with the first vertical polarizer layer) and then turns to the horizontal direction due to the spherical nature of molecules. These rays are then polarized horizontally using the last but one layer subsequent to which it is reflected back (by the last reflecting layer) and return the path. This makes ...

the crystalline structure retain a spherical shape the influence of the electrical field makes all molecule line up in same direction. This field can be controlled by appropriate voltage by horizontal & vertical direction wise grid wise. So initially vertically polarized light can't Subsequently polarized horizontally. LCD because of the alignment of liquid crystal molecules act as an optical filter all some place of front panel. Thus locations appear as dark spots. Thus by controlling the grid voltage. a graphic defination can be constructed in the screen. The graphics are generally stored in frame buffer the screen is refreshed 60 time.

This arrangement of applying voltage then withdrawing it to make the pixel spot bright again is known as passive matrix LCD.

Transistor can be placed at all vertical-horizontal grid junction points the transistor quickly control the state changes of crystal at the junction it they may also influence the degree of state change. implying a variation of intensity. Full active than monochrome ON & OFF state. this type of LCD is known as Active matrix LCD. Color LCD uses primary colours dyes in form of triad at each screen location.

§ Direct view Storage (device) tube: DVST behaves like a CRT with an extremely long-persistence phosphor. The line written on the screen remains visible for upto hours before it fades from sight. In this a fine-mesh wire grid, coated with dielectric and mounted just behind the screen. The beam writes on this screen. A pattern of the charge is deposited on the grid & this pattern is transferred to the phosphor by a continuous flood of electrons issuing from a separate flood gun.

Just behind the storage mesh is a collector whose purpose is to smooth out the flow of flood electrons. They pass thro' the collector at a low velocity & are attracted to the truly charged portions of the storage mesh but repelled by the rest. Electrons not repelled by the storage mesh pass right thro' it & strike the phosphor. In order to increase the speed of electrons & thus create a bright picture, the screen is maintained at a high dc potential by means of a voltage applied to a thin aluminum coating between tube face & the phosphor.

Problems with this is the dc charge to be applied to remove the stored charge on the mesh & thus giving a unpleasant flash. Other problem is the poor contrast.

~~Color Grayscale level~~:-

§ Color lookup tables: In 256-color model, the PC uses only 8-bits. This means like 2 bits for blue & 3 bits each for green & red.

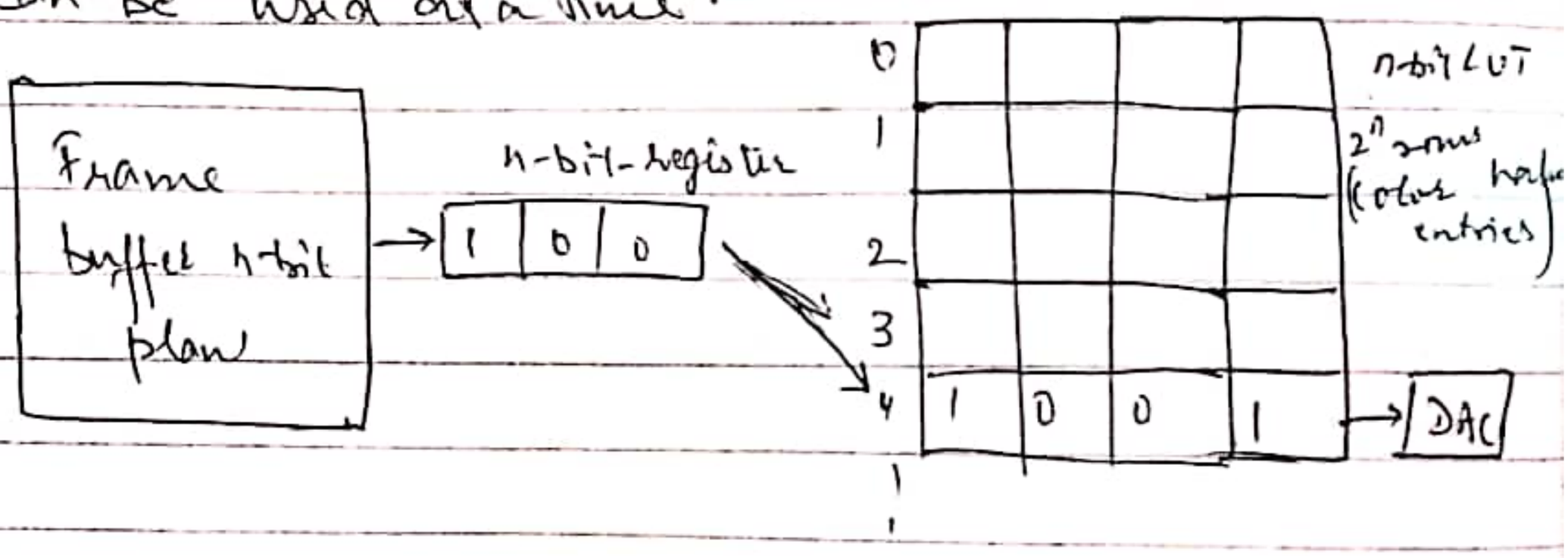
There are chances that most of the colors of a given picture are not available & choosing between only 4 or 8 diff values for each primary color would result in rather blocky looking look of the displayed image. A palette or lookup table is used here.

- A colorup table is a separate memory block created containing 256 diff colors.

- The intensity values stored therein are not constrained within the range 0 to 3 for blue & 0 to 7 each for green & red.
- Rather each color is defined using the 24-bit color def" that is used in the frame color. This int. values for each color (3 primary) can be anything b/w 0 & 255 in each of the table entry.
- Upon using the bit planes, the resulting number is used as a ptr to the 3-byte color value entry in the look-up tables, rather of directly specifying the pixel color.

eg. if the color number read from the bit-plans is 10 for a given pixel, then the intensities of red, green & blue to be displayed for that pixel will be found in the 10th entry of the table.

So the full range of the colors can be accessed, but only 256 of the available 16 million colors can be used at a time.



Advantages:

- It allows fewer bits of the frame buffer to be used to specify each color in an image & allows the creator of the image to decide what the 256 colors in the image to display using the 256 colors in the image.
- The look up table can be relocated any time with diff. combination of 256 colors out of 16 million w/o changing the frame buffer values.
- Since visually, no image contain an even distribution of colors, this allows for more precision in an image by using more colors than would be feasible by assigning each pixel a 2-bit value for blue & 3-bit

Display processors: The display adapter circuitry in a raster graphic system typically employs a special purpose processor called display processor or graphic controller or display co-processor which is connected as an I/O peripheral to CPU i.e IOP

This helps/ assist the CPU in scan-converting the i/p from timer/dir. circuit etc/ to bitmaps in frame buffer and also perform some operations of moving copying & many modifying operations

The o/p unit also include another specialized circuit called video controller which actually drives the CRT & produces the display on the screen.

Hence Display processor free CPU from graphic overheads.

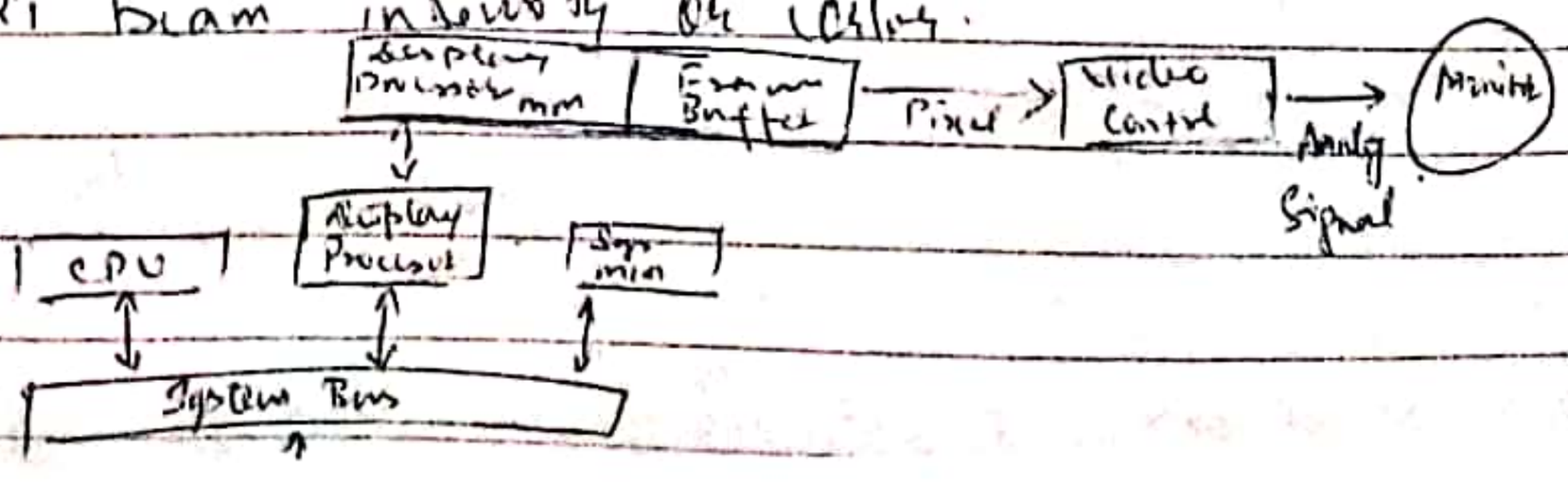
Construction:

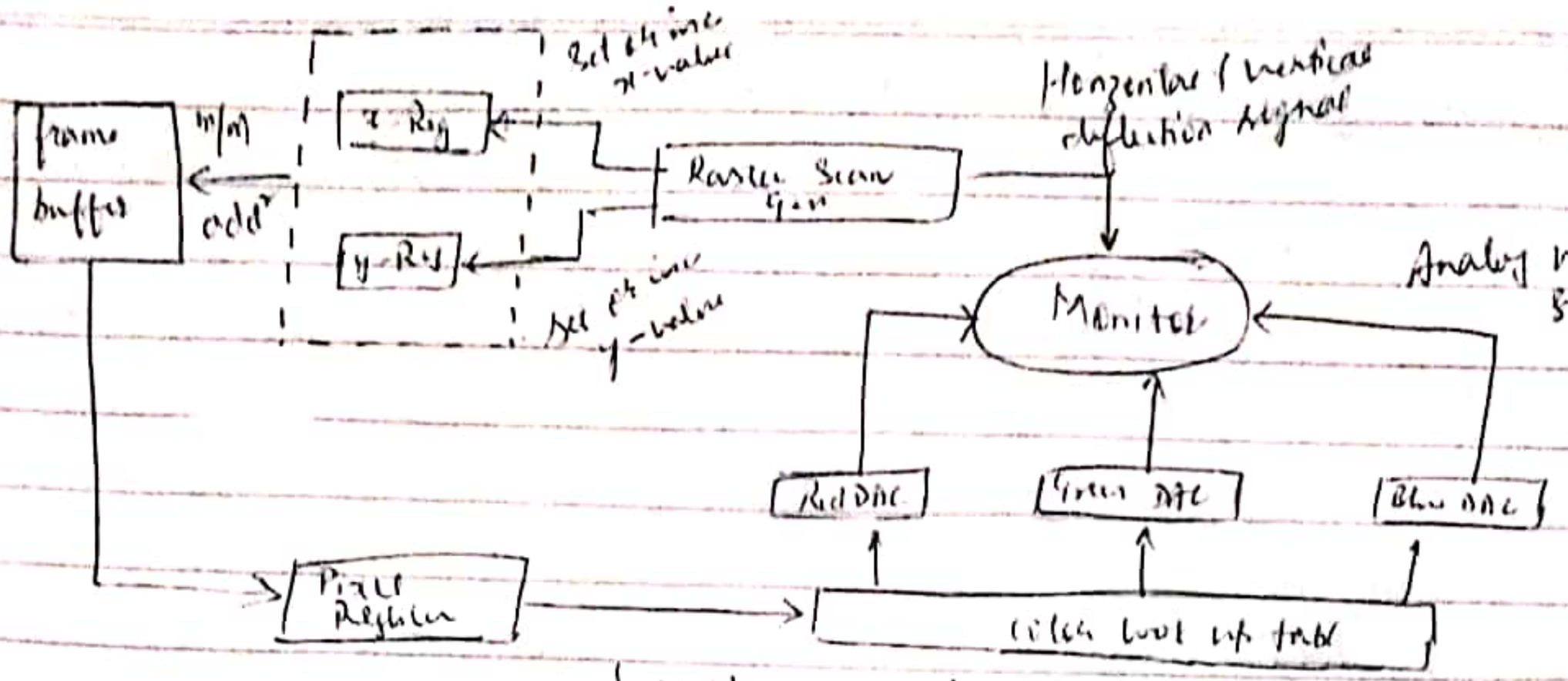
The monitor is connected to display adapter. (It (there) is 15-pin connector typically) In the cable are 3 analog signals showing brightness info about R, G, B in parallel of each pixel. Two digital signal lines in the cable for vertical & horizontal drive signals and three signal lines which carry specific information about the monitor to the display adapter. In addition the system may a separate display processor may also can also be provided.

Working:

- The video controller in the o/p circuitry generates the horizontal & vertical drive signals so that the monitor can sweep its beam across the screen during raster scan.

- Mem ref. addresses are generated in synch. with the raster scan & the contents of the memory are used to control the CRT beam intensity or color.

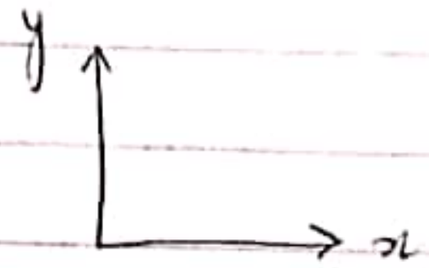




(Video Card)

As shown 2 registers (x & y) are used to store the coordinate of the screen pixel. Assume that y values of the adjacent scan lines increase by 1 in upward dir^n starting from 0 at the bottom of the screen to y_{max} at the top. & along each scan line the screen pixel position or x value are incremented by 1 from 0 at the leftmost position to x_{max} at the rightmost position.

The origin is at the lower left corner of the screen as in a standard cartesian co-ordinate system.



- At a start of of refresh cycle x-register is set to 0 & y-register is set to y-max. This (x,y) address is translated into a mm address of frame buffer where the color value for this pixel position stored.
- The controller recieves this color value from frame buffer, breaks it up into three parts & sends each part to a separate digital to analog converter.

These voltages in turn controls the intensity of 3 beam that are formed at the (x,y) screen positions by the horizontal & vertical drive signals.

This process is repeated for each pixel along the top scan-line, each time incrementing the x reg. by 1.

As pixels on the first scanline are generated the x

the x register is reset to 0 & y register is decremented by 1 to access the next scan line.

Pixels along with each scan line are processed & the procedure is repeated for each scan line until pixels on the last scan line (y=0) are generated.

For the display system employing a color look-up table frame buffer values is not directly used to control the CRT beam intensity.

For displays employing color-look-up table frame buffer values is not

It is used as an index to find the actual color value from the look-up table. This look-up operation is done for each pixel on each display cycle.

Now multiple adjacent pixel values are fetched to the frame buffer in a single access & stored in the register.

Applications:

1) Digitizing a picture definition given in an application program into a set of pixel intensity values for storage in the frame buffer (called scan conversion)

2) These operations like generating various line styles, displaying color areas & performing certain transformation & manipulation on displayed objects.

3) They are typically designed to interface with interactive I/P std devices, such as mouse

Hard copy color printers:

There are large number of hardcopy o/p devices.
Few are discussed here:

- Electrostatic plotters: It is a raster scan device. It operates by depositing small particles of toner onto electrostatically charged areas of a special paper.
A specially coated medium that will hold an electrostatic charge is passed over a writing head, which contains one or more rows of small writing nibs or styli. Higher densities eg. multiple rows of styli. As material medium is passed over the styli, an individual dot of the electrostatic charge is deposited by each stylus. The medium is then passed over a toner applicator, where positively charged particles of liquid toner are attracted to the -vely charged dots on the ~~maximum~~ medium, making them visible. The carbon toner particles are subsequently dried & fixed to the medium to make them permanent.
- Inkjet plotters: Inkjet printers are laser scan device. They particularly suited for generating low cost color o/p. The basic idea is to shoot tiny droplets of ink onto a medium. In the continous flow inkjet a stream of droplets by spraying ink out of a nozzle. The stream of ink from nozzle is broken into droplets by ultrasonic waves. droplets are electrostatically charged. deflection plates are used to then direct the droplets onto the medium. If not req. on medium the droplets (stream) is send to trash plate.
Drop-on-demand: It fires ink at the medium only if a dot is required at a particular location. In this piezoelectric crystal is used to fire the ink on paper as medium thread is passed thro' the medium.
- Thermal plotters: Direct thermal transfer uses temp. sensitive paper that changes color when heated the image is formed by the selective heat dots on the

the paper as the head moves across it. In indirect thermal transfer thin film or paper ribbon coated with wax-based ink.

Dye sublimation printers: (Highest quality) It ~~depend~~ is continous tone printing the plastic dye sublimation transfer ribbon which contain dye of 3 or 4 colors lying between the print head containing the heating element and the paper. By controlling the temp, precise amount of each primary color dye are transfered the dyes, heat, amount used to vary the intensity of color. This produces a cont- tone picture.

Pen & Ink plotters: They are of flatbed, pinch roller or drum.

In a moving-arm flatbed plotter the medium is fixed in position on the bed of plotter. the arm moves in 2-D across the width of medium to obtain the printing

In ~~moving~~ drum plotters, the plotting head moves along a fixed arm to provide 1-D movement. the medium itself is rolled back & forth under the fixed arm to provide third dimension.

In the pinch roller the medium is moved back & forth under a fixed arm on which the plotting head moves.

Laser printer: It is a raster scan device. the print engine containing a drum is coated with a photoconductive material. the drum is scanned by either a gas or semiconductor diode laser. the laser light selectively discharges areas on the drum to form a -ve image i.e. the charge is removed from dots that do not appear on final image. A black toner is attracted to the remaining charged areas on

Character generation: It is a computer graphic system used widely in closed circuit and broadcast television.

- It creates letters and numbers in a variety of sizes & fonts
- Requires no special skill for the user to make flawless letters.
- A character generator has a solid state keyboard similar in appearance to a micro computer keyboard, except it contains additional keys for specific CG functions
- As you create text, you may store it in RAM & recall it as needed.
- Most CGs uses a floppy or hard disk system for permanent text storage

Some of the more CGs features:

* 14 to 16 lines of 32 ch within a full-screen scanning area line by line mm recall
* automatic centering
* word flash
* word or line underline
* Stand and no fitting
* fitting over video
* two speed roll over all or part of the mm
* you may even frog the letters in certain color arrangements by using Colorizer

The overall design style for a set of ch is called typeface or fonts.

. This can be divided into 2 broad grps:-

a) Serif: It has small lines at ends at the end of the main ch strokes.

b) sans-serif: It does not have serifs.

Bitmap font: A simple method for representing the ch

rectangular grid pattern.

Outline fonts: More flexible scheme is to describe ch shapes using st-line and curve-selections as in postscript the set of ch is called outline fon.