CSE411
Computer Graphics

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Course Objectives

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- To understand the **basic concepts** of computer graphics and to have knowledge about the different hardware and software that supports computer graphics.
- To provide students with an understanding of the **algorithms and theories** that forms the basis for graphical objects.
- To understand the underlying algorithms and mathematical concepts that supports **2D and 3D viewing transformations** and projections.
- To understand the different techniques used for **rendering** the graphical models.
- To analyse the characteristics of different **color models**.

Syllabus

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- **Introduction to Computer Graphics:** Overview of Computer Graphics-Raster refresh graphics displays- CRT Flat Panel Displays- Hard copy output devices- Logical interactive Devices-Physical interactive devices-Data generation devices-Graphical user interfaces
- **Raster Scan Graphics:** Line Drawing algorithms- Digital Differential Analyser- Bresenham's algorithm:-Integer Bresenham's algorithm, General Bresenham's algorithm, Faster line rasterisation algorithm- Circle generation- Ellipse generation-General function rasterisation- Scan conversions- Displaying line character and polygons-
- **Polygon filling:** Scan converting polygons, Edge fill algorithm, Seed fill algorithms- Antialiasing-Halftoning

Syllabus

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- **Two dimensional transformations:** Representation of points- Transformations and matrices- transformation of points- Transformations of lines- Rotation- Reflection- Scaling- Combined transformations- Homogeneous coordinates **Windowing and clipping:** Viewing transformations- Point clipping- Cohen Sutherland line clipping 2D Line clipping- Sutherland Hodge man Polygon clipping- Curve clipping-Text clipping
- **Three Dimensional Transformations and Projections:** Three dimensional scaling, shearing, rotation, reflection, translations - Rotation about arbitrary axis Parallel to coordinate axis- Rotation about arbitrary axis in space- Affine and perspective geometry-Ortho graphic projections-Taxonomic projections- Oblique projections.

- **Rendering and color models:** Illumination model- Determining surface normal and reflection vector- Gouraud shading- Phong Shading-Texture mapping-Ray tracing- Color- Chromacity- Tristimulus theory of color-RGB color system - CMYK color system -HSV color system -HLS color system- Ostwald color System

Prerequisites

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- Basic concepts of C programming language and
- Basic mathematics

Textbooks/References

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1. David F.Rogers, *Procedural Elements for Computer Graphics*, Second Edition, Tata McGraw-hill, 2001,
2. David F.Rogers, *Mathematical Elements for Computer Graphics*, Second Edition, Tata McGraw- Hill,2001,
3. Francis S. Hill, Stephen M. Kelley, *Computer Graphics using OpenGL*, Third Edition, Person Education India, 2015,
4. Donald D. Hearn, M. Pauline Baker, Warren Carithers, *Computer Graphics using OpenGL*, Fourth Edition, Person Education India, 2013.
5. Amarendra N Sinha, Aurn D Udai, *Computer Graphics*, Tata McGraw-hill, 2011,
6. Donald Hearn ,Pauline Baker, *Computer Graphics C version*, 2/E Pearson Education ,2003.

Textbooks/References … Contd.

7. Donald Hearn, M Pauline Baker, *Computer Graphics with OpenGL*, 3/E, Pearson Education ,2004,
8. James D.Foley, Andries Van Dam, Steven K.Feiner, John F. Hughes, *Computer Graphics Principles and Practice in C* , 2/2, Pearson education, 2007.
9. Newmann W and Sproull R.F., *Principles of Interactive Computer Graphics*, 2/e, McGraw-Hill,1997.
10. C.S.Verma, *Computer Graphics*, Ane Books, 2011,
11. Edward Angel, *Interactive Computer Graphics A Top-Down approach Using OpenGL*, 5/e,

Evaluation

1. Assignments-20
2. Quiz-20
3. Mid Term Examination-20
4. End Semester Examinations-40

Chapter 1

Introduction to Computer Graphics

Syllabus

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- **Introduction to Computer Graphics:**
  - Overview of Computer Graphics
  - Raster refresh graphics displays
  - CRT Flat Panel Displays
  - Hard copy output devices
  - Logical interactive Devices
  - Physical interactive devices
  - Data generation devices
  - Graphical user interfaces

Textbooks/References

1. David F. Rogers, *Procedural Elements for Computer Graphics*, Second Edition, Tata McGraw-hill, 2001

Overview of Computer Graphics

What is Computer Graphics?

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- Computer graphics is the art of drawing pictures, lines, charts, etc. on the computer screen.

- It is the use of computers to create and manipulate pictures on a display device.

- It comprises of software techniques to create, store, modify and represent pictures.

- To display a picture of any size on a computer screen is a very difficult process.
- This is simplified by using Computer graphics.
- Graphics on the computer screen are produced by using various techniques and algorithms.
- **Computer graphics is the branch of computer science that deals with generating images with the aid of computers**.

Introduction … Contd.

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- Computer Graphics involves display, manipulation and storage of pictures and experimental data for proper visualization using a computer.
- Computer graphics is a complex & diversified technology.
- Typical **Graphics system** comprises of
  - a host computer with support of fast processor, large memory, frame buffer and
  - Display devices (color monitors),
  - Input devices (mouse, keyboard, joystick, touch screen, trackball)
  - Output devices (LCD panels, laser printers, color printers. Plotters etc.)
  - Interfacing devices such as, video I/O, TV interface etc.

Applications of Computer Graphics

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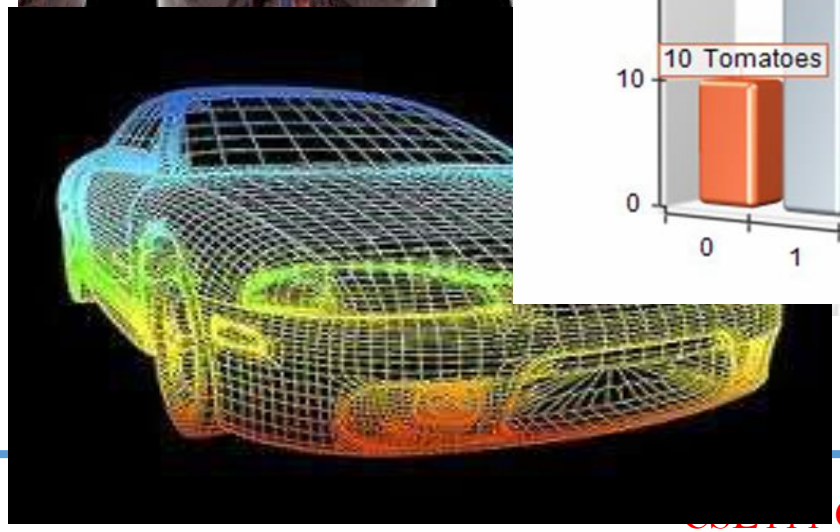
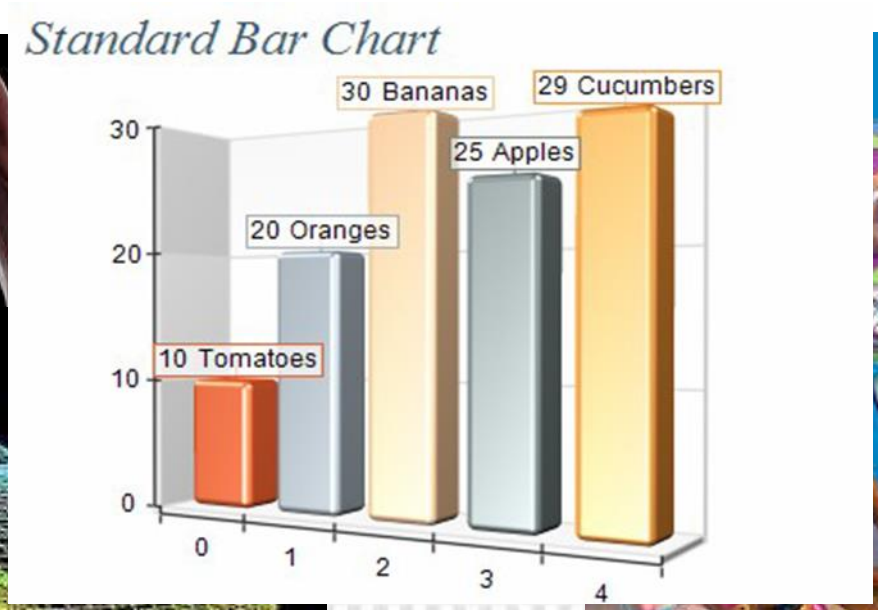
- In daily use, Computer graphics is in the field of science, engineering, medicine, entertainment, advertising, the graphic arts, fine arts, business education, and training, etc.





Applications

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- Application of Computer Graphics
  - **Education and Training**
  - **Simulations**
  - **Computer-Generated Maps**
  - **Architectures**
  - **Presentations**
  - **Computer Art**
  - **Entertainment**
  - **Visualization**
  - **Printing Technology**

2 types of CG based on interaction

1. Interactive Graphics : (ACTIVE)

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- Involves a two way communication between computer and user.
- Here the observer is given some control over the image by providing him with an input device.
- The computer can modify the displayed picture appropriately.
- To the user it appears that the picture is changing instantaneously in response to his commands' graphical response from the computer.
- In this way he maintains a conversation, or dialogue, with the computer

Video Games

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2. Non Interactive Graphics : (PASSIVE)

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- The picture is produced on the computer screen, and the user does not have any control over the image.
- The user cannot make any change in an image.
- The produced image cannot be changed by the user.
- It is one-way-communication between user and computer.

Gif Files

Growth in computer graphics

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Now

Tens of thousands of people in SIGGRAPH

Early 1970s

Only a few hundred people in SIGGRAPH annual conference

Introduction … Contd.

- The pictorial representation and manipulation of data by a computer
  - **clip art** - ready-made pieces of computerized graphic art that can be used to decorate a document
  - **frame buffer** - (computer science) a buffer that stores the contents of an image pixel by pixel
  - **graphics** - the drawings and photographs in the layout of a book
  - **antialiasing** - (computer graphics) a technique that is used to smooth jagged distortions in curves and diagonal lines so they appear smoother

Introduction … Contd.

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- End product of Computer graphics??
- A picture is a fundamental cohesive concept in computer graphics.
- Pictures are represented in computer graphics as a collection of points, lines, text, etc., displayed on graphic device

We Must consider how:

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Pictures are represented in Computer graphics

Pictures are prepared for presentation

Previously prepared pictures are presented

Interaction with pictures is accomplished

1. Representing pictures

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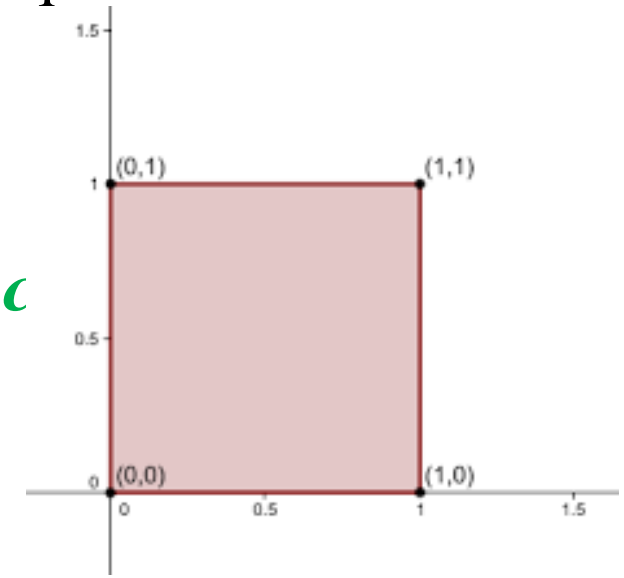
- Points-Fundamental building block of picture representation.
- Algorithm-tells how to organize these points.



- An associated description will be
- ***Connect P1 P2 P3 P4 P1 in sequenc***

Or

- ***Connect E1 E2 E3 E4 in sequence***
- Lines, Polygons, Text etc. are formed with these collection of points.

2. Preparing pictures for presentation

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- Pictures ultimately consist of points and a drawing algorithm to display them.
- This information is generally stored in a file before it is used to present the picture.
- This file is called a **Database**.
- Complex pictures require complex databases.
- Data will be organized in various ways such as B-tree, quad tree structures, generally referred to as **Data structures**.

3. Presenting Previously Prepared Pictures

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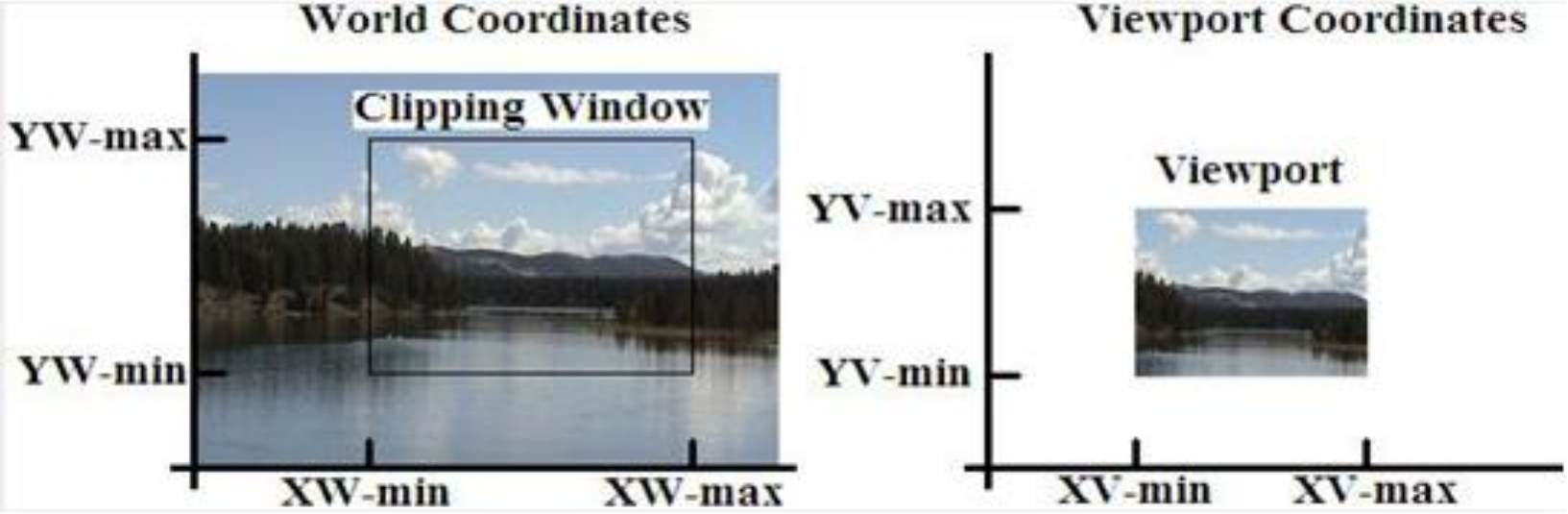
- Data used to prepare the picture to presentation is rarely the same as that used to present the picture.
- The data used to present the picture is usually called a **'Display file'.**
- It represents some portion, view or scene of the picture represented by the total database.
- The displayed picture is usually formed by **rotating, translating, scaling and performing various projections** on the data.

Two important concepts associated with presenting a picture are

- Windows
- Viewports



- **Windowing**-the process of extracting a portion of a database by clipping the database to the boundaries of the window.
- **Clipping windows** determines which lines or portions of lines in the picture lie outside the window.
- **Viewport** is an area of the display device on which window data is presented.

4. Interaction with pictures

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- Before discussing this, we have to learn about displays.

We discussed how:

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Pictures are represented in Computer graphics- Points, lines with respect to dimensions

Pictures are prepared for presentation-Database to store pictures such as data structures

Previously prepared pictures are presented- Transformations on images and other operations

Interaction with pictures is accomplished

Computer Graphics Display Devices

Examples of Computer Graphics Devices

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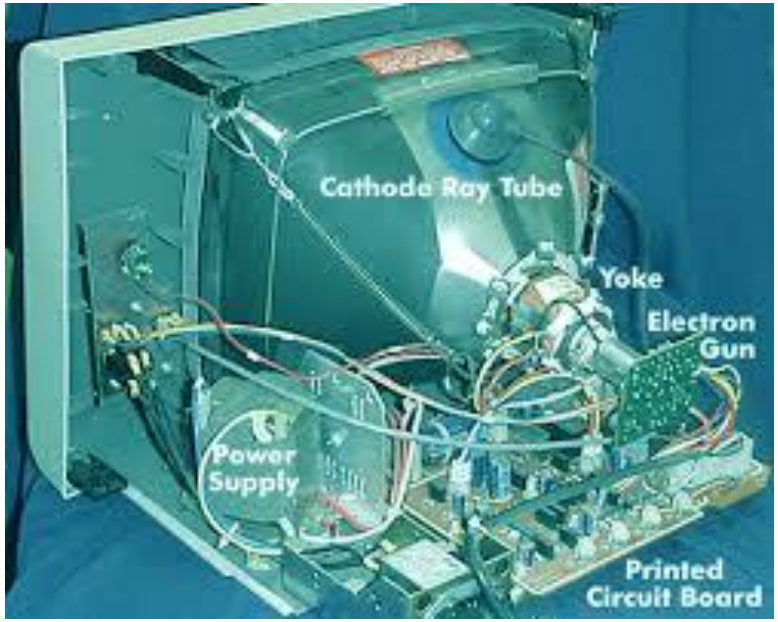
- CRT, CGA/EGA/VGA/SVGA monitors, plotters, dot matrix, laser printers, Films, Flat panel devices, Video digitizers, scanners, LCD panels, keyboard, joystick, mouse, touch screen, track ball, etc.

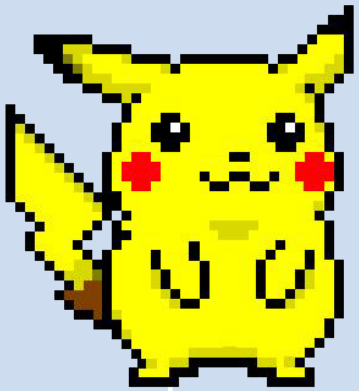
Cathode Ray Tube (CRT) monitors



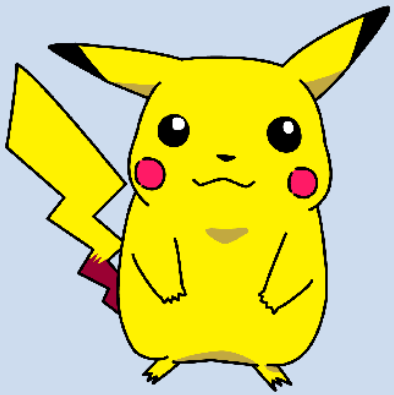
- Types of CRT display devices
  1. Calligraphic or Random Scan display system
  2. Refresh and Raster scan display system
  3. DVST (Direct View Storage Tube)
  4. Flat Panel Displays:

     LCD (**Non-Emissive Display**) & LED (**Emissive Display**)

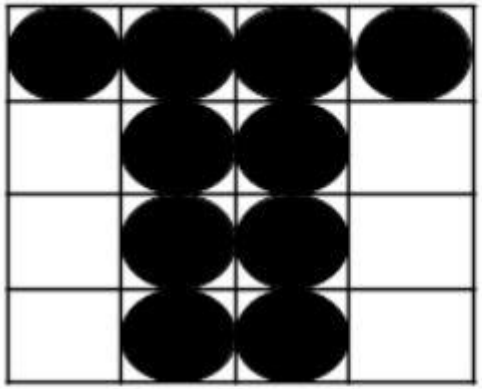
Raster Scan System Random Scan System



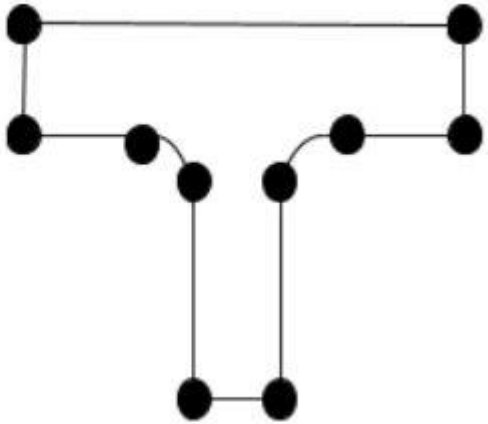
VS



Letter 'T' in raster and random scan displays

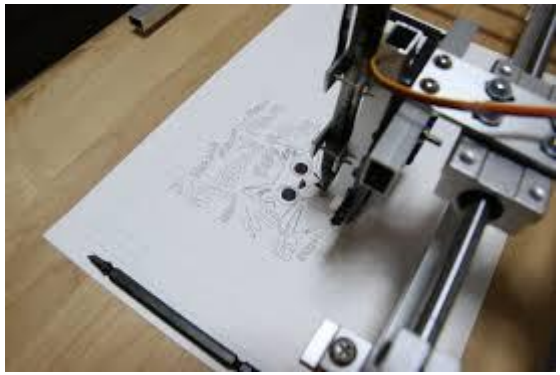


A Character (T) defined in a grid of pixel positions.



A Character (T) defined as a curve outline.

Random scan(Calligraphic) Devices



Raster Refresh Graphics Displays

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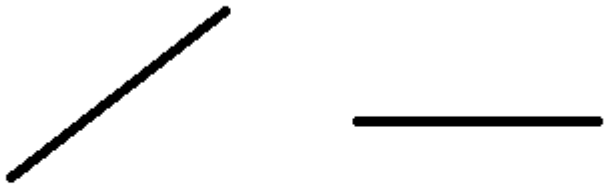
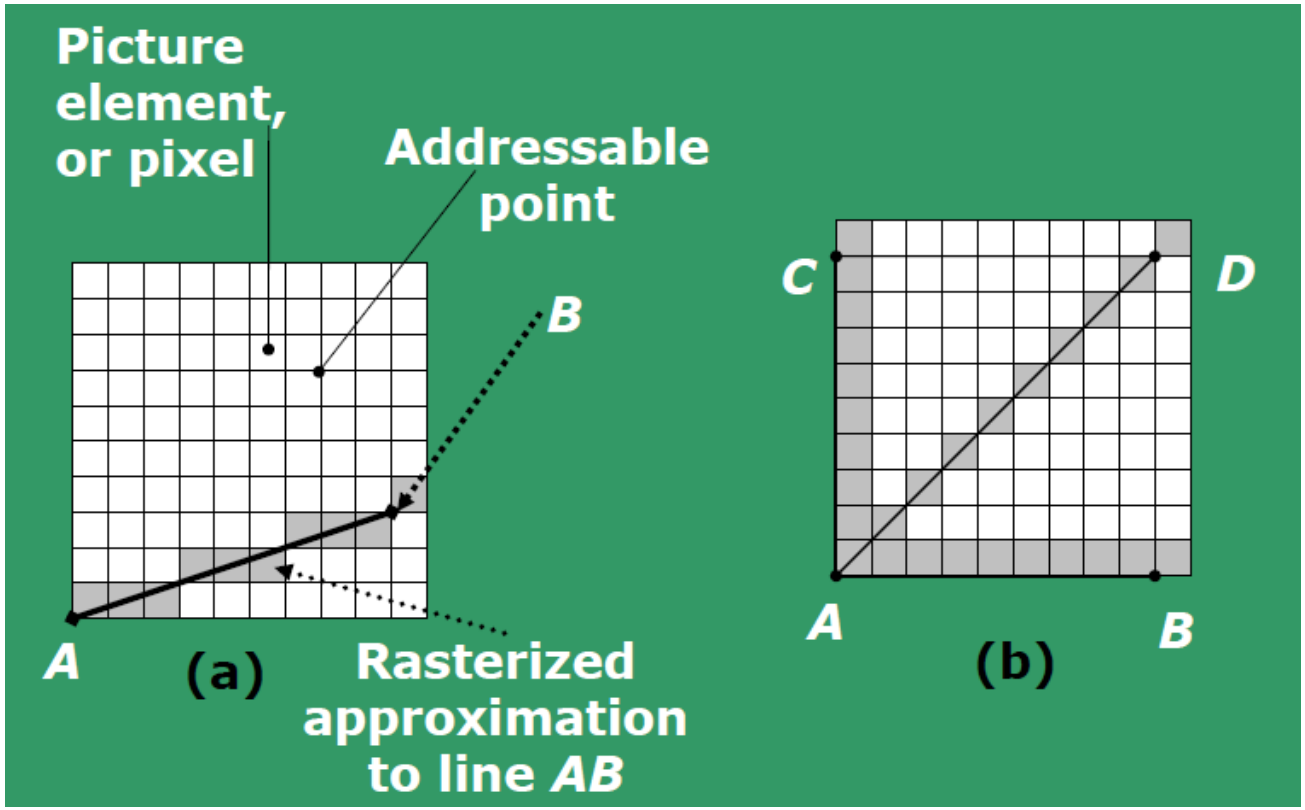
- Can be considered as a matrix of discrete cells, each of which can be made bright.
- A line can be approximated by a series of dots(pixels) close to the path of the line.



Rasterization:

(a) General line

(b) special cases- Horizontal, vertical or 45° lines



Raster-scan display system draws a discrete set of points

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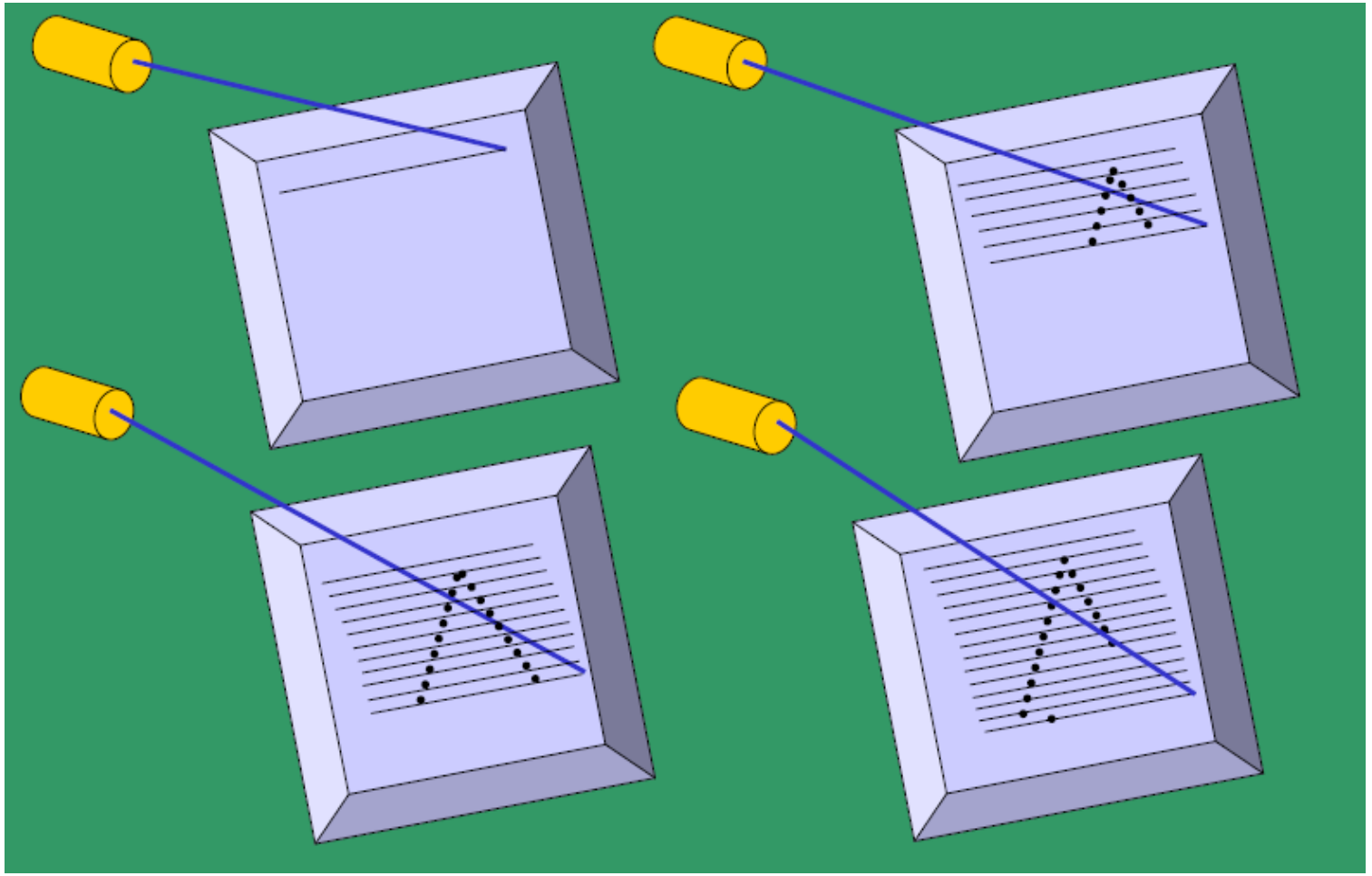

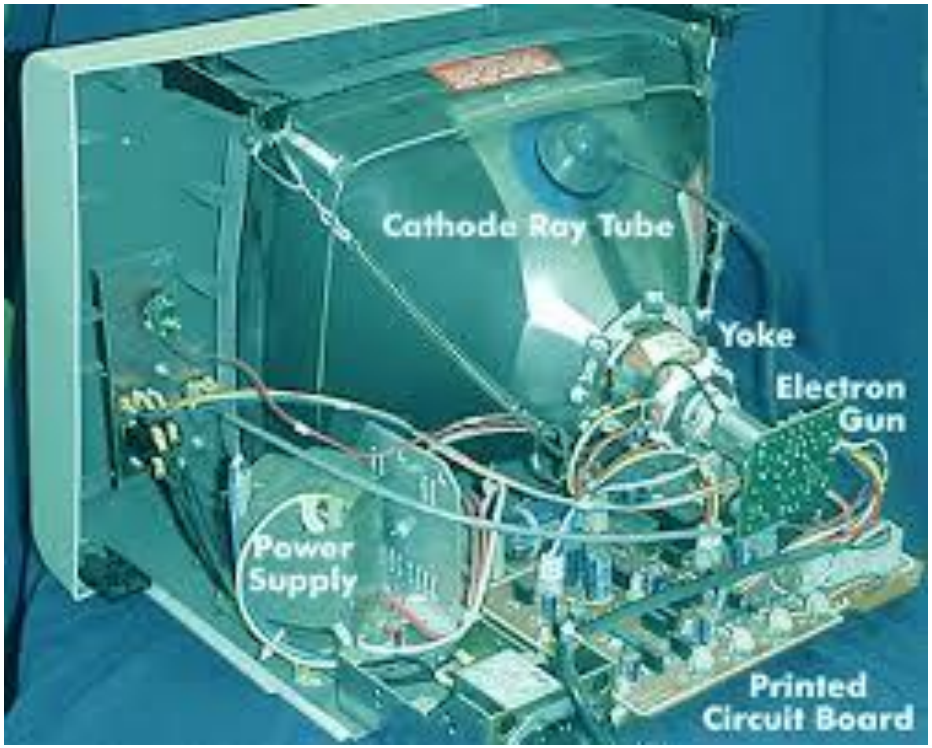
Cathode Ray Tube
Yoke
Electron Gun
Power Supply
Printed Circuit Board

Refresh Rate, Video basics, and Scan Conversion

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- Raster is stored as a matrix of pixels representing the entire screen area
- Entire image is scanned out sequentially by the video controller (one raster line at a time)
- The raster lines are scanned from top to bottom and then back to the top
- The intensity of the beam decides the brightness of the pixel
- To get the intensity details, we use a frame buffer.

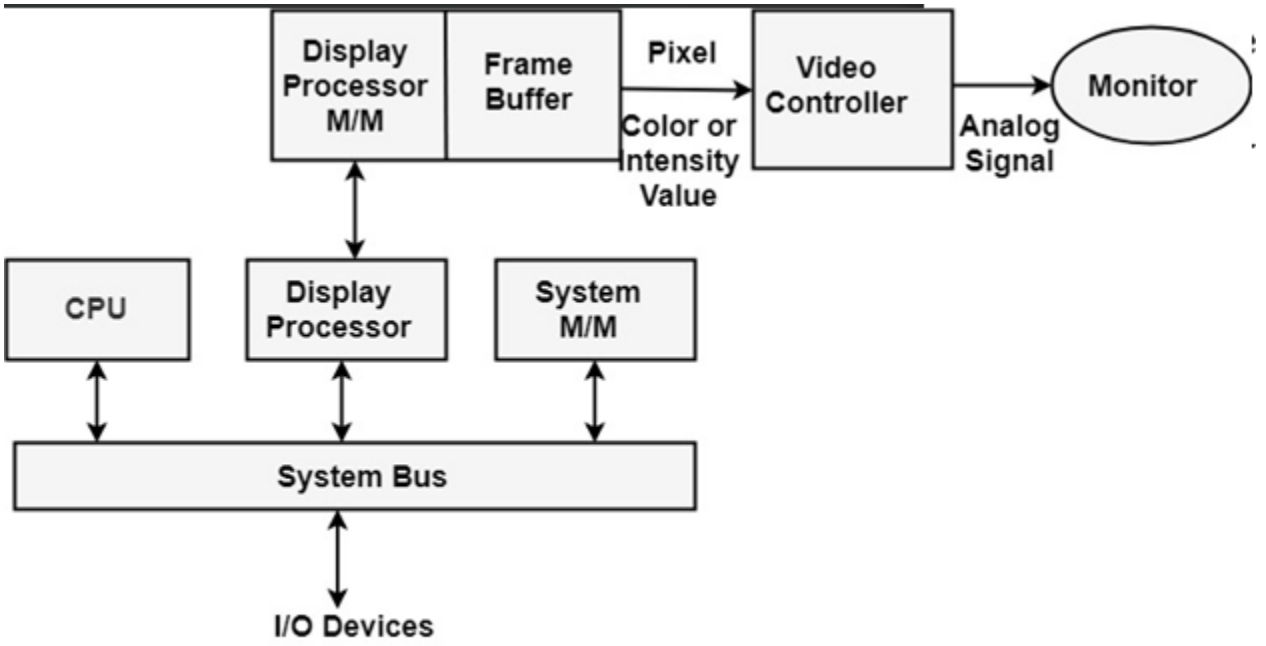

Fig: Architecture of a Raster Display System with a Display Processor

Frame Buffers

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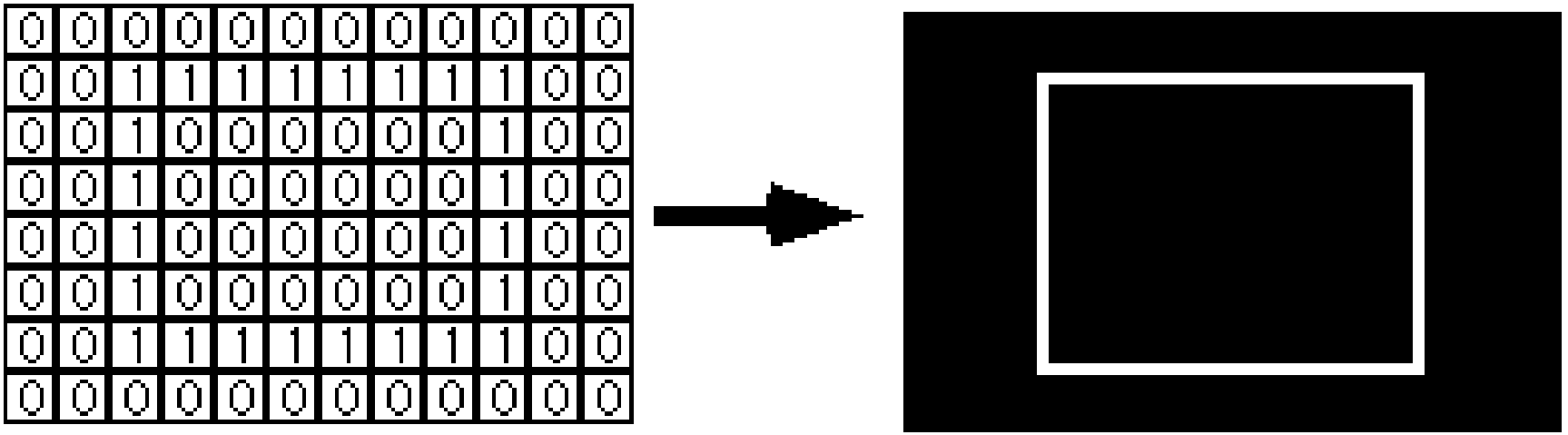
- To implement a raster CRT graphics device, a frame buffer is used.
- A frame buffer is a large, contiguous piece of computer memory.
- At a minimum, there is one memory bit for each pixel, this amount of memory is called 'bit plane'.
- A 1024X1024 element square raster display requires 2^{20} memory bits in a single bit plane.
- Because a memory bit has only 2 states(0 or 1), we get a monochrome display output.

Video Controller



Frame buffer

Screen

- Here, frame buffer is digital and rasterCRT display is analog.
- So, when the information is read from frame buffer and displayed on raster CRT display, there should be a conversion.
- This is taken place by using a DAC (Digital to Analog Converter).

Black and white raster CRT display

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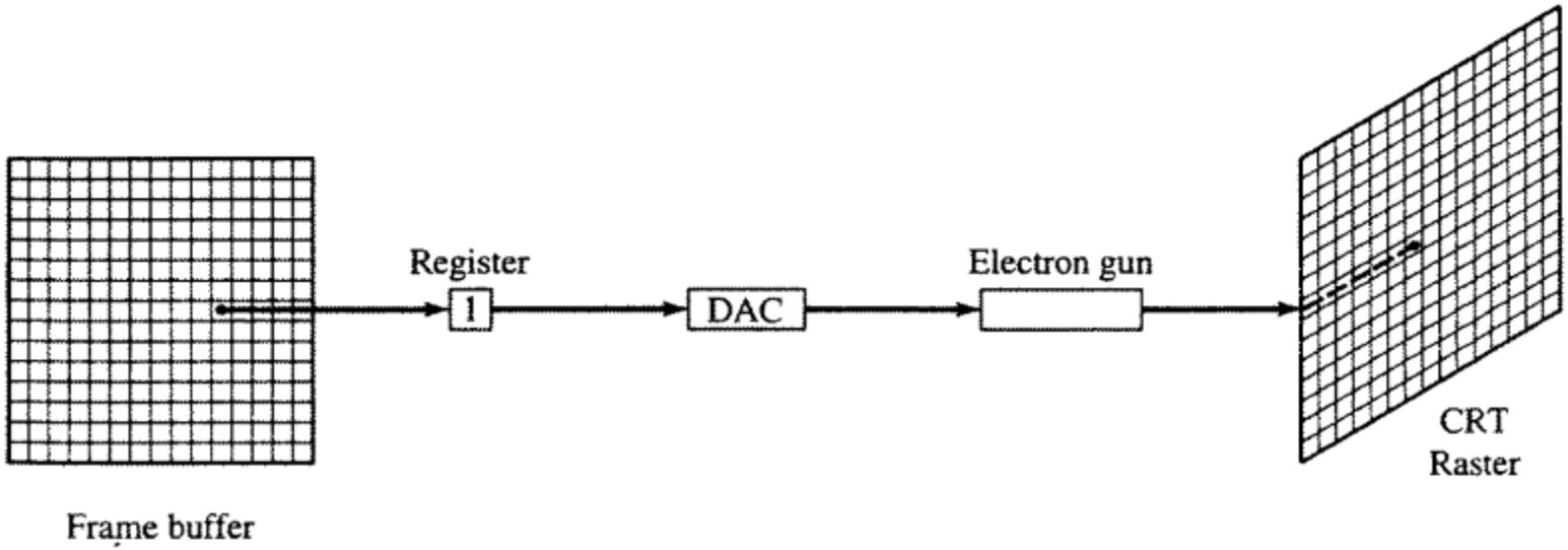
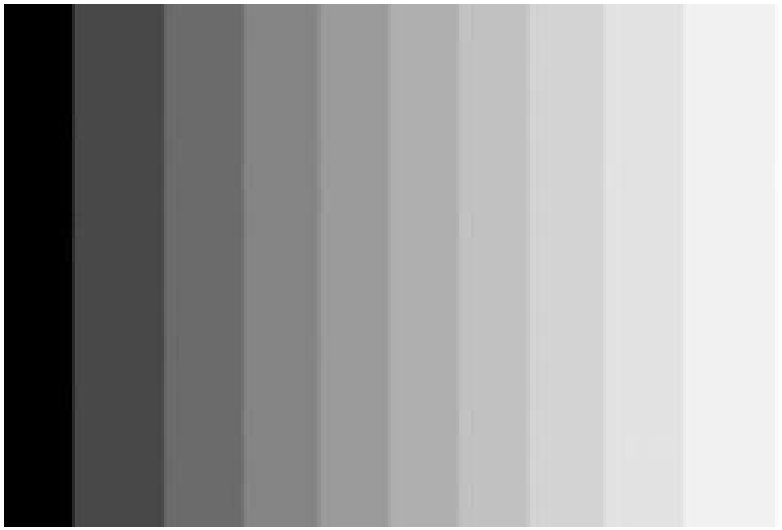
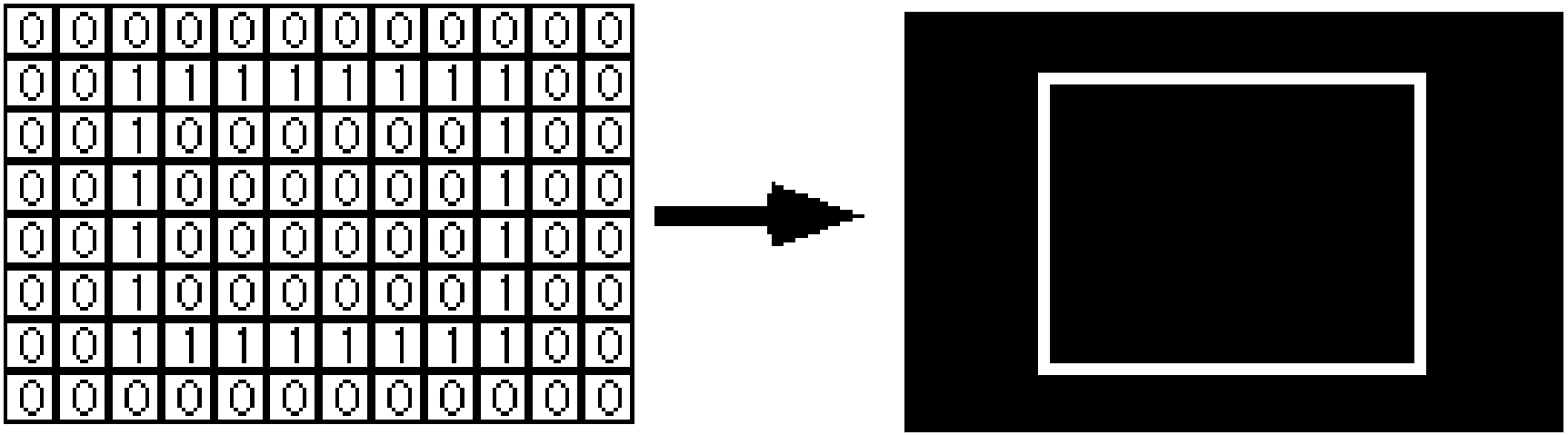


Figure A single-bit-plane black-and-white frame buffer raster CRT graphics device.

- Grey scale images??





Use more bits for a single pixel in the frame buffer to get grey scale images.

N-bit plane gray level Frame buffer

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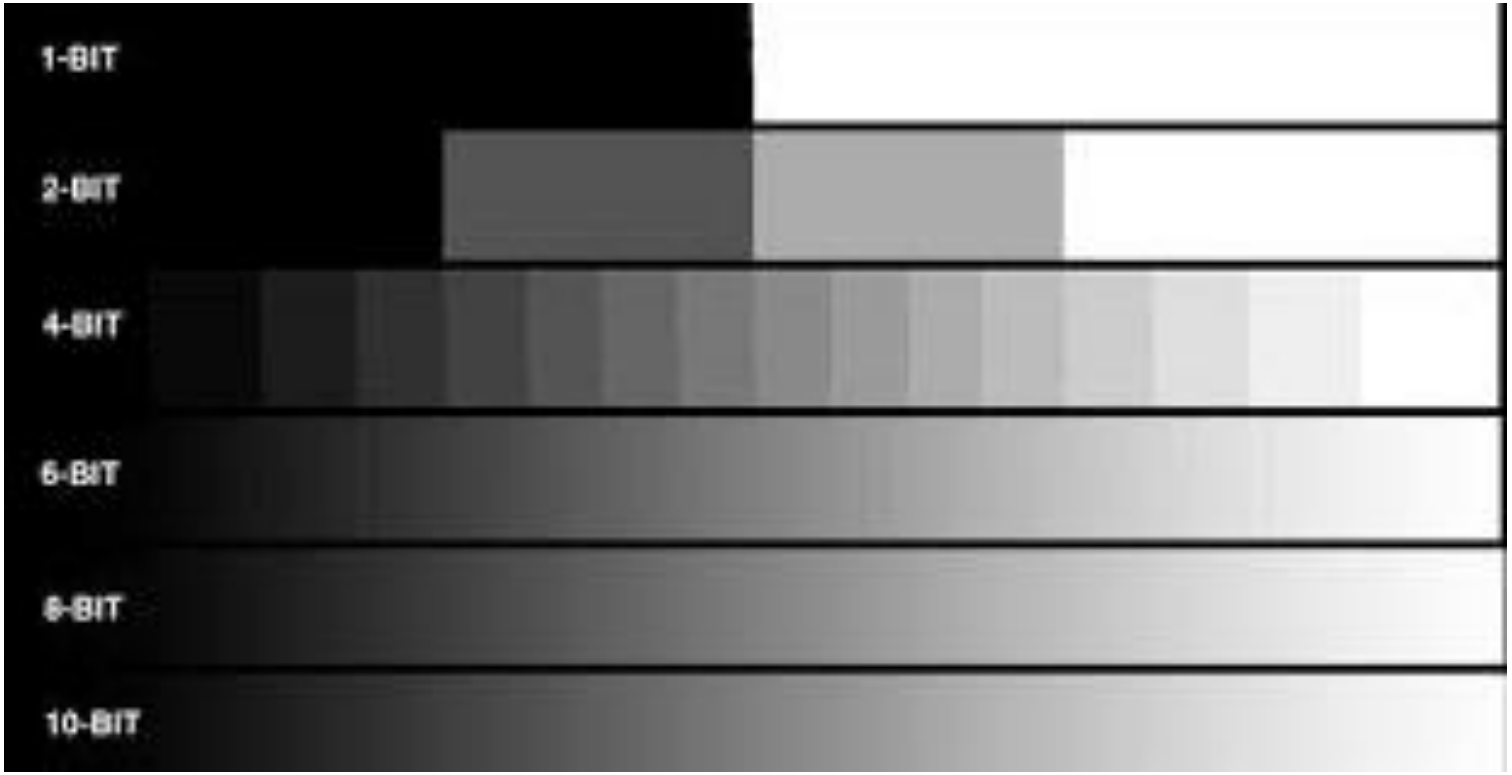
- N-bit plane gray level Frame buffer.

- 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


1-BIT
2-BIT
4-BIT
6-BIT
8-BIT
10-BIT

N-bit plane gray level Frame buffer

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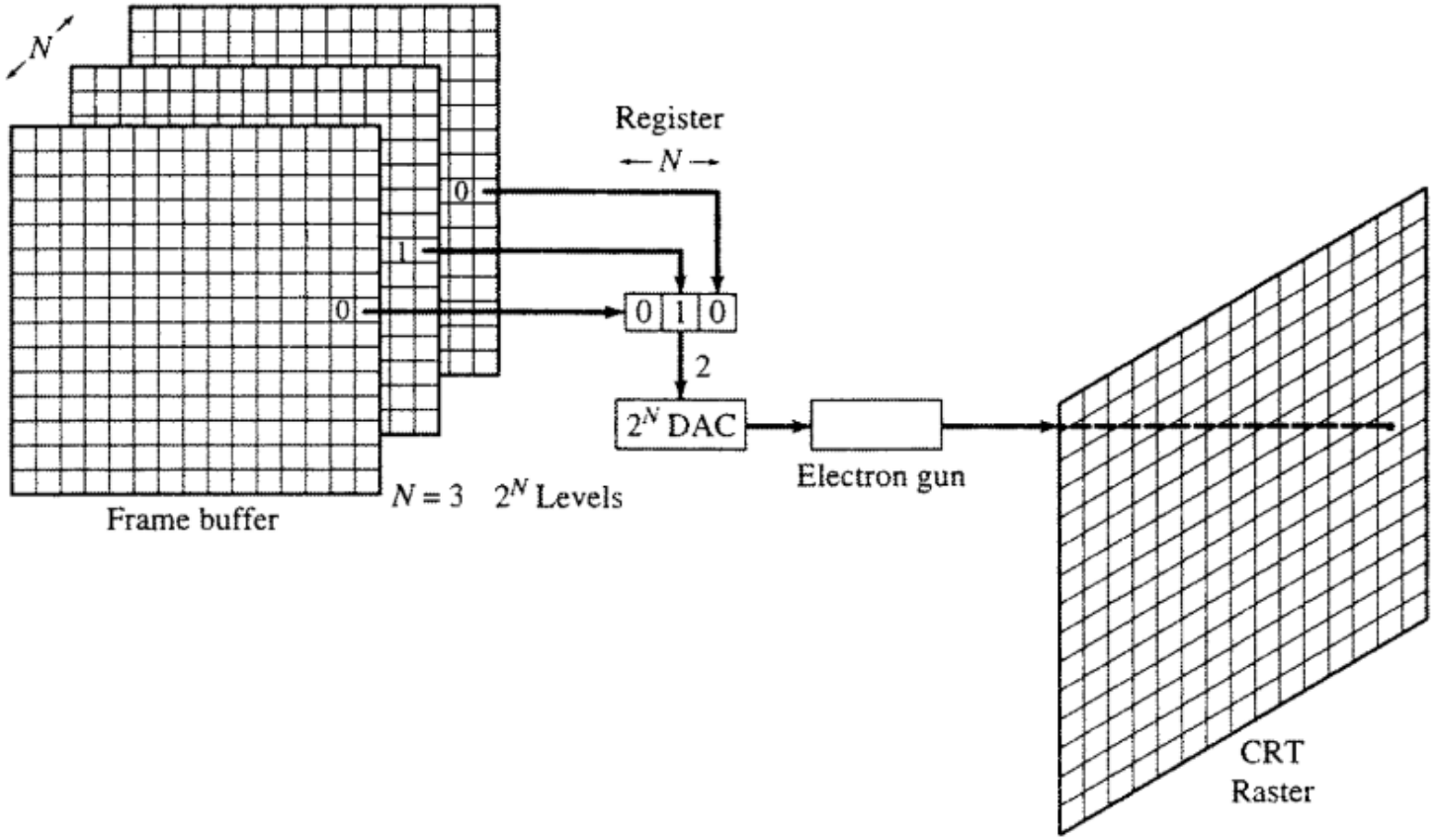

Figure 1–7 An N-bit-plane gray level frame buffer.

0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

An increase in the number of available intensity levels is achieved for a modest increase in required memory by using a lookup table; this is shown schematically in Fig. 1–8. Upon reading the bit planes in the frame buffer, the resulting number is used as an index into the lookup table. The lookup table must contain 2^N entries. Each entry in the lookup table is W bits wide. W may be greater than N. When this occurs, 2^W intensities are available; but only 2^N different intensities are available at one time. To get additional intensities, the lookup table must be changed (reloaded).

Look up Tables(Stores intensity values)

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3 bits as used index

0	**0**	**0**	**0**
0	0	1	**1**
0	1	0	**2**
0	1	1	**3**
1	0	0	**4**
1	0	1	**5**
1	1	0	**6**
1	1	1	**7**

0	**0**	**0**	**0**
0	0	0	1
0	0	1	0
0	0	1	1
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1

1	**0**	**0**	**0**
1	0	0	1
1	0	1	0
1	0	1	1
1	0	1	1
1	1	0	0
1	1	0	1
1	1	1	0
1	1	1	1

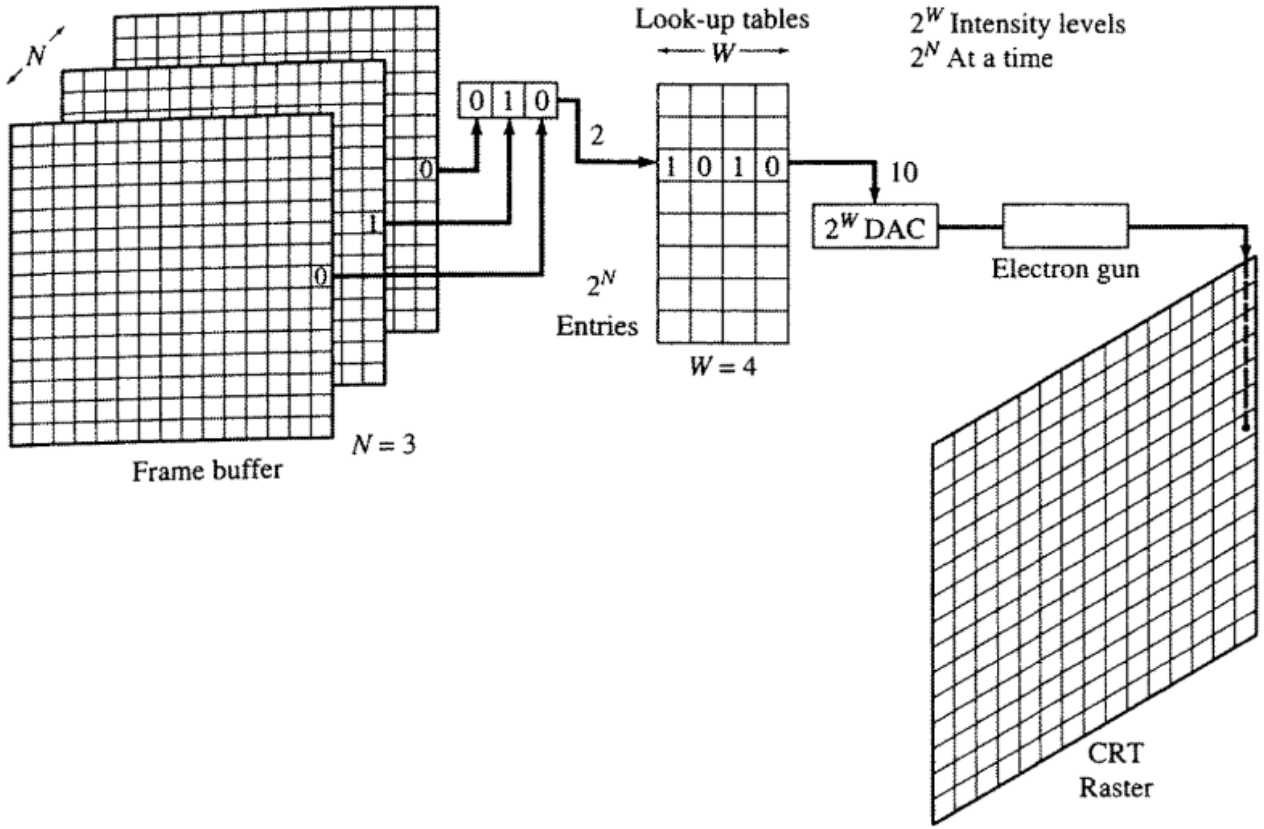

Figure 1–8 An N-bit-plane gray level frame buffer, with a W-bit-wide lookup table.

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

Simple color frame buffer

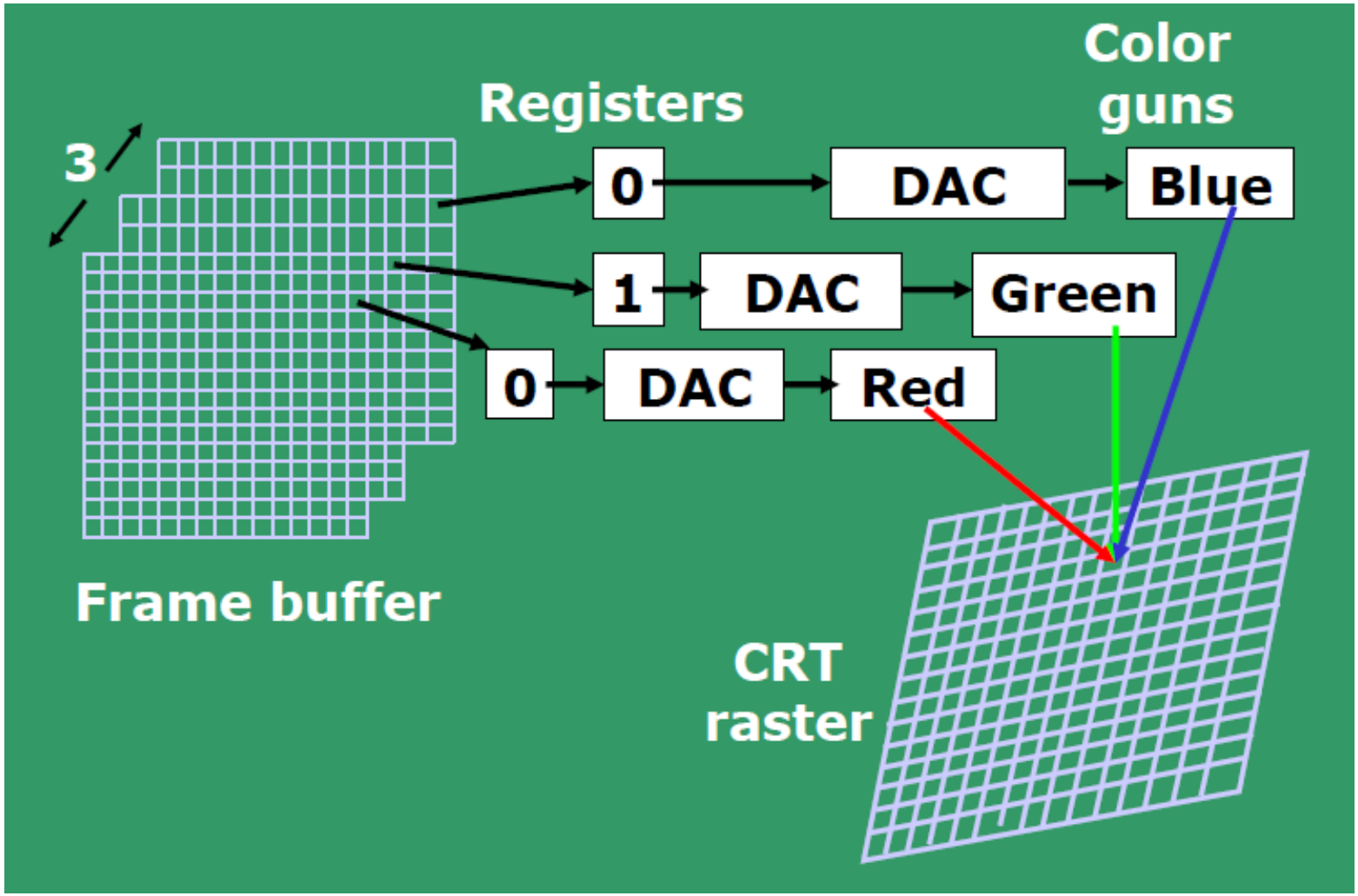

Table 1–1 Simple 3-bit plane frame buffer color combinations

	Red	Green	Blue
Black	0	0	0
Red	1	0	0
Green	0	1	0
Blue	0	0	1
Yellow	1	1	0
Cyan	0	1	1
Magenta	1	0	1
White	1	1	1

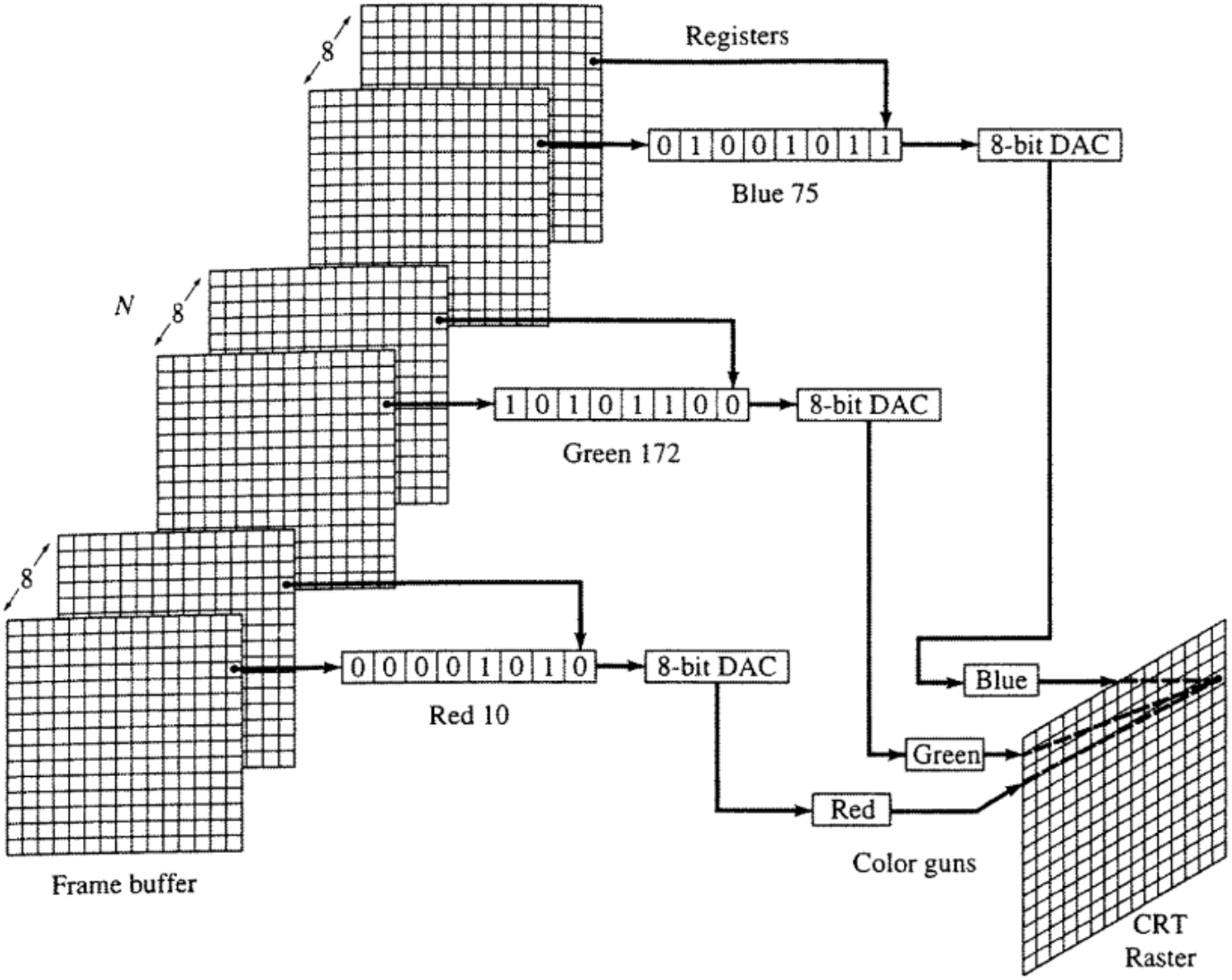

Figure 1–10 A 24-bit-plane color frame buffer.

N-bit plane gray level Frame buffer … Contd.

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- 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

N-bit plane gray level Frame buffer … Contd.

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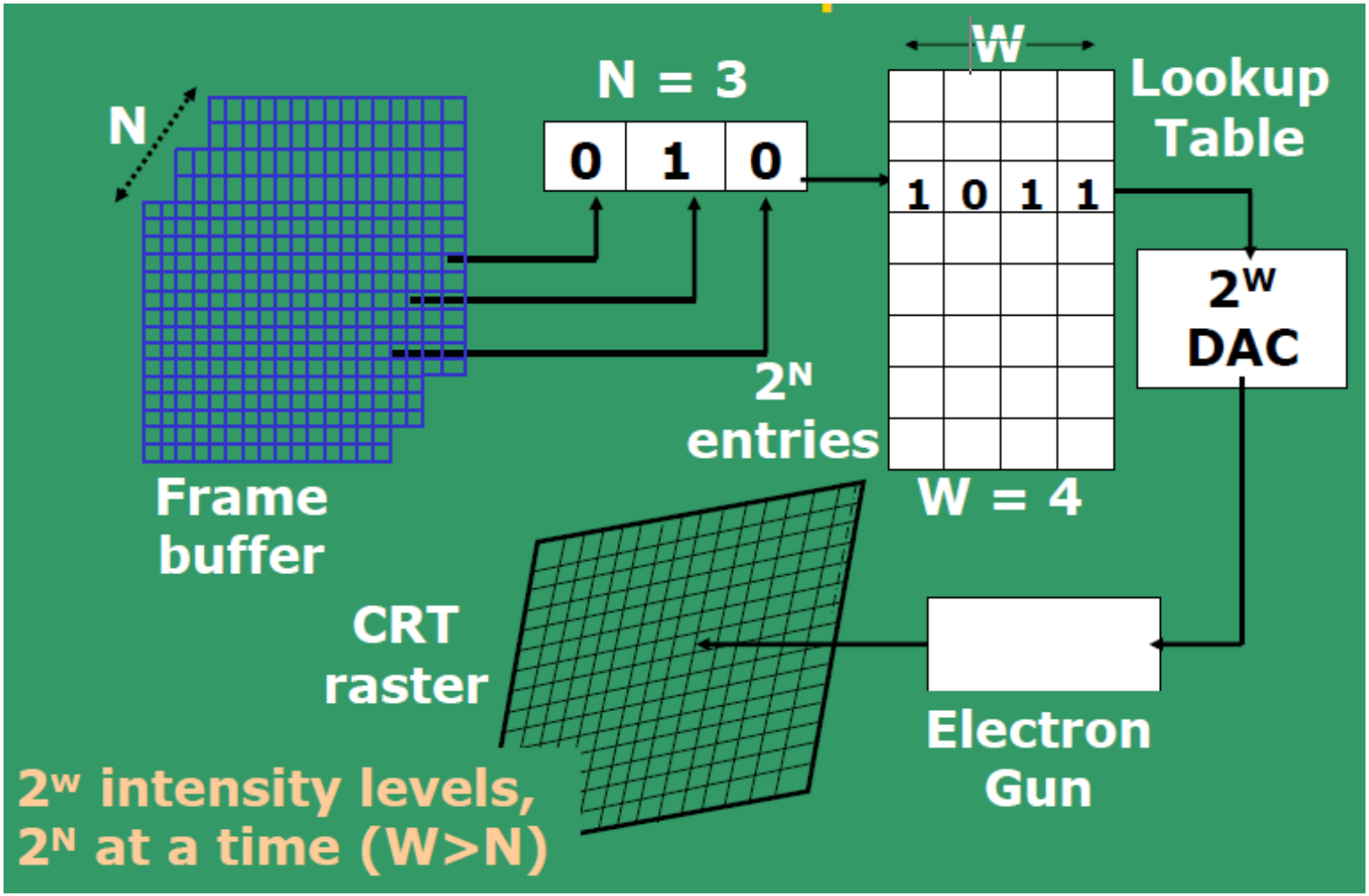
- Use of LUT (Look-up-table)
- N-bit plane gray level/color frame buffer with W-bit wide LUT
- Typically W > N
- The N-bit register content acts as an index into the lookup table
- Thus out of 2W possible intensities, that are available, only 2N different intensities are usable at any time
- The programmer must choose 2N different intensities, based on his requirement, and load the LUT (addressable in memory) before use

N-bit plane gray level Frame buffer … Contd.



N-bit plane gray level Frame buffer … Contd.

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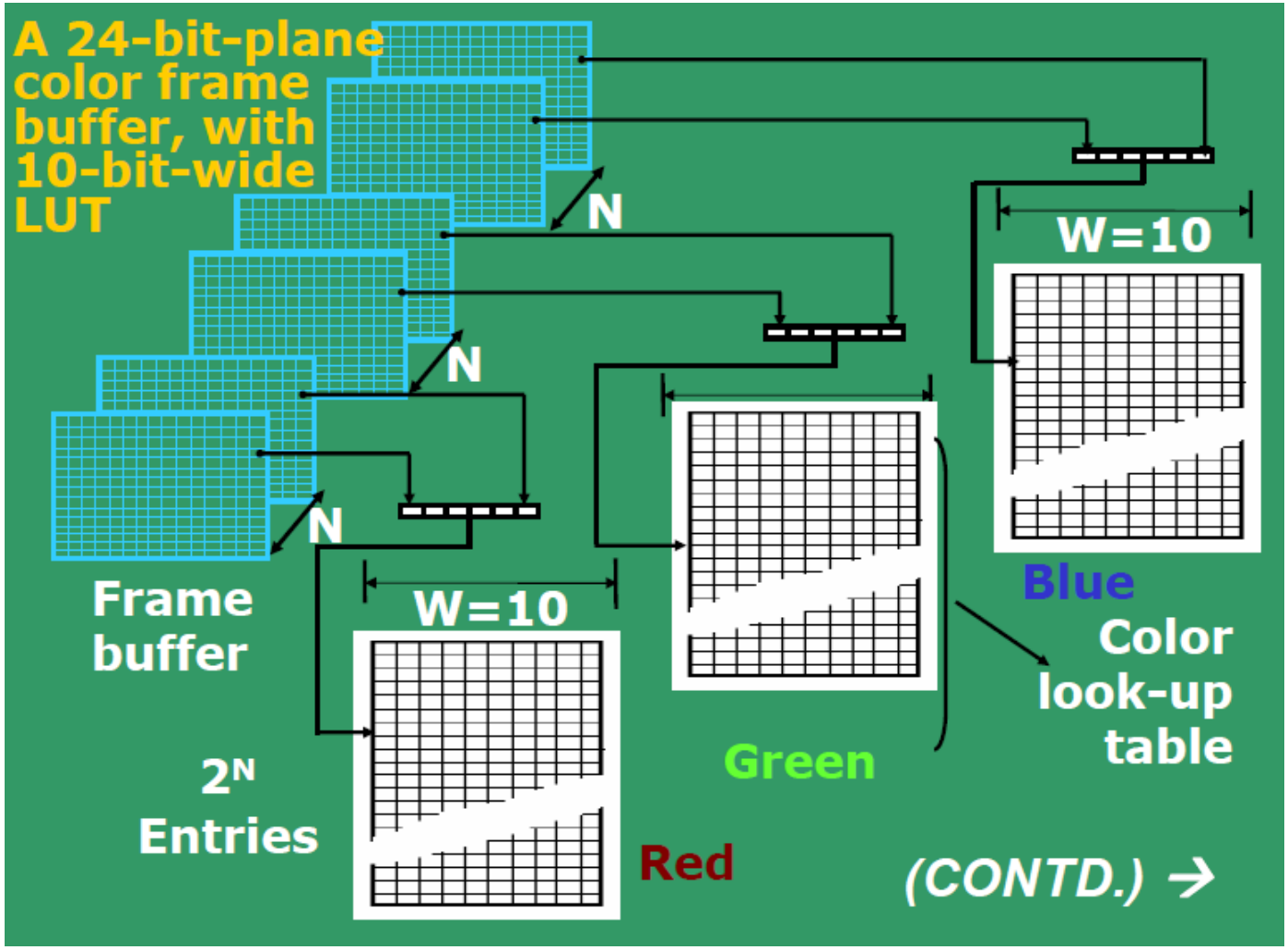

N-bit plane gray level Frame buffer … Contd.

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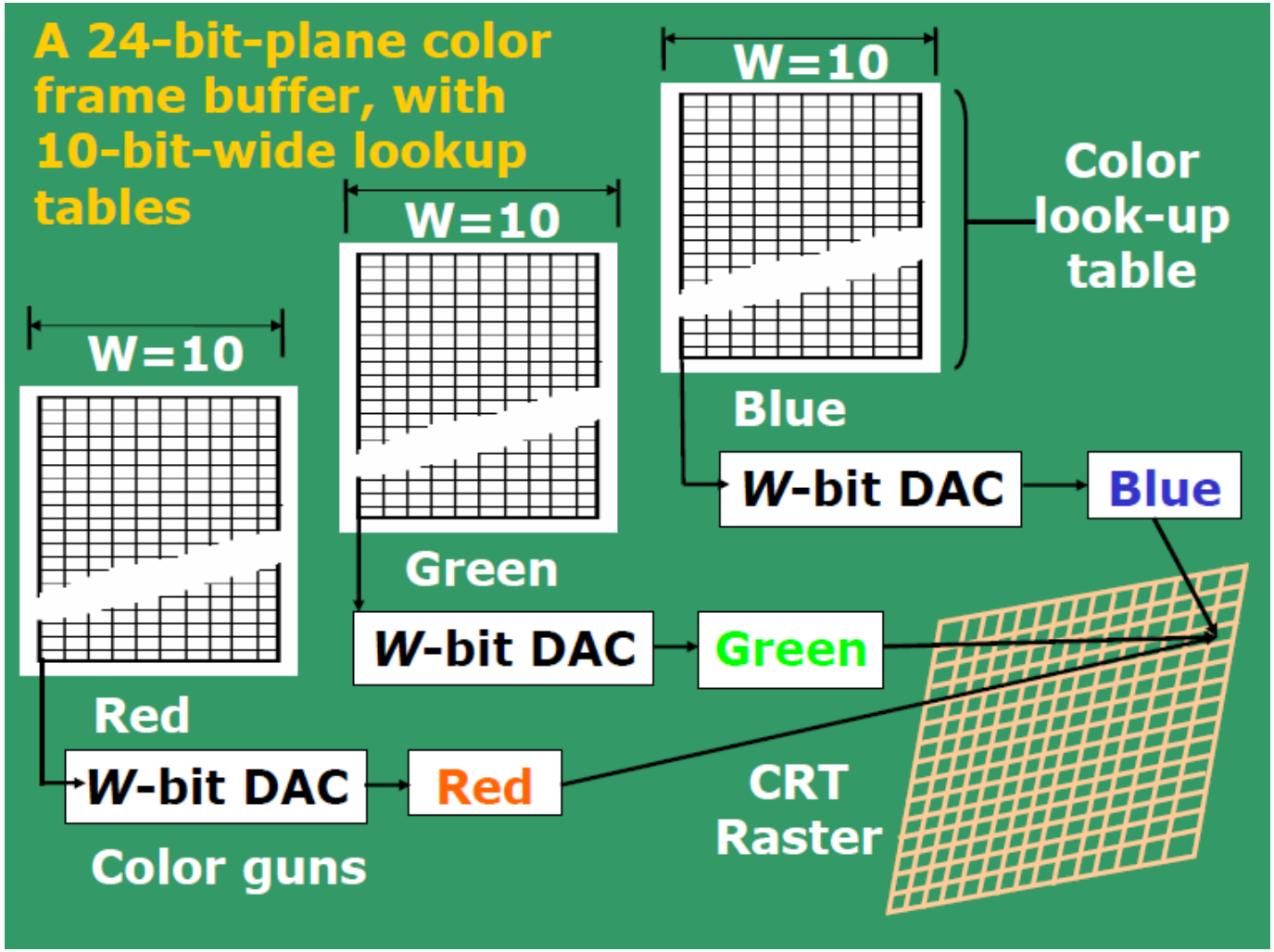
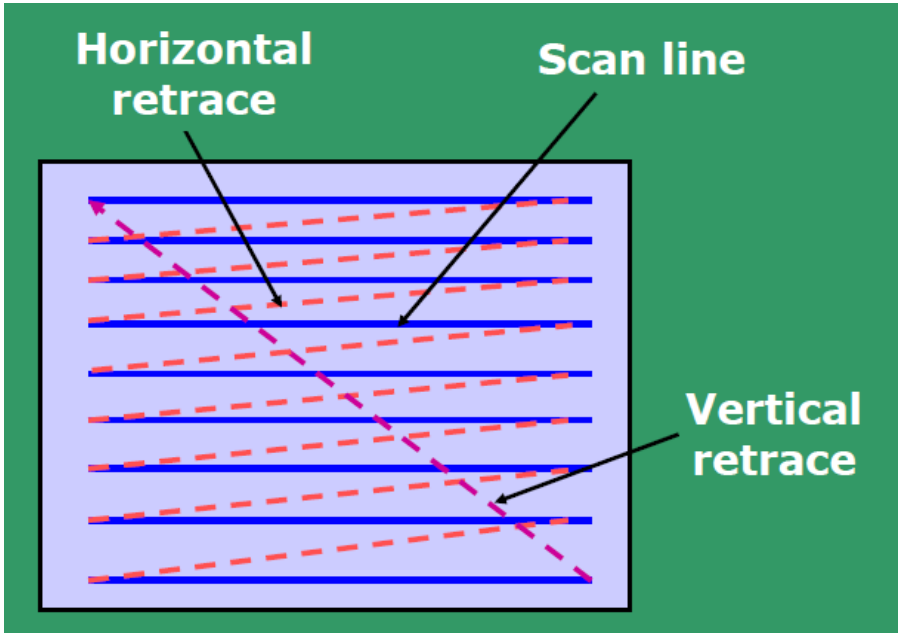
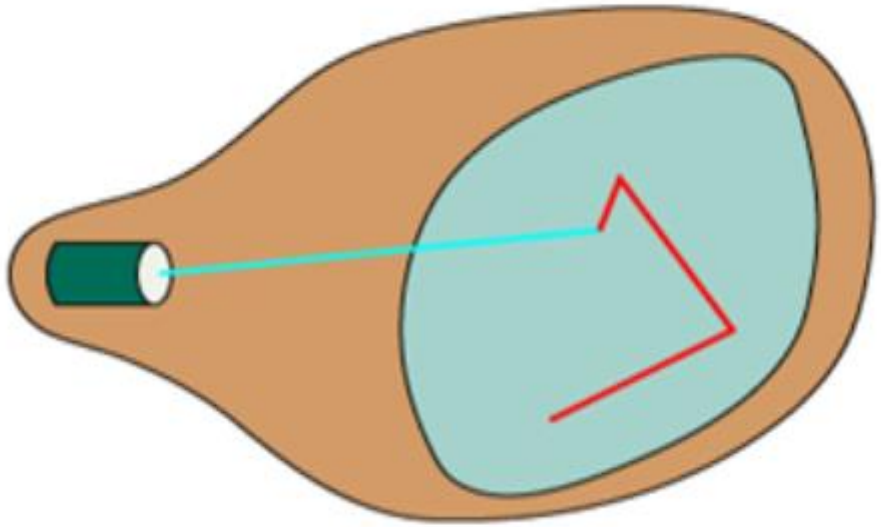
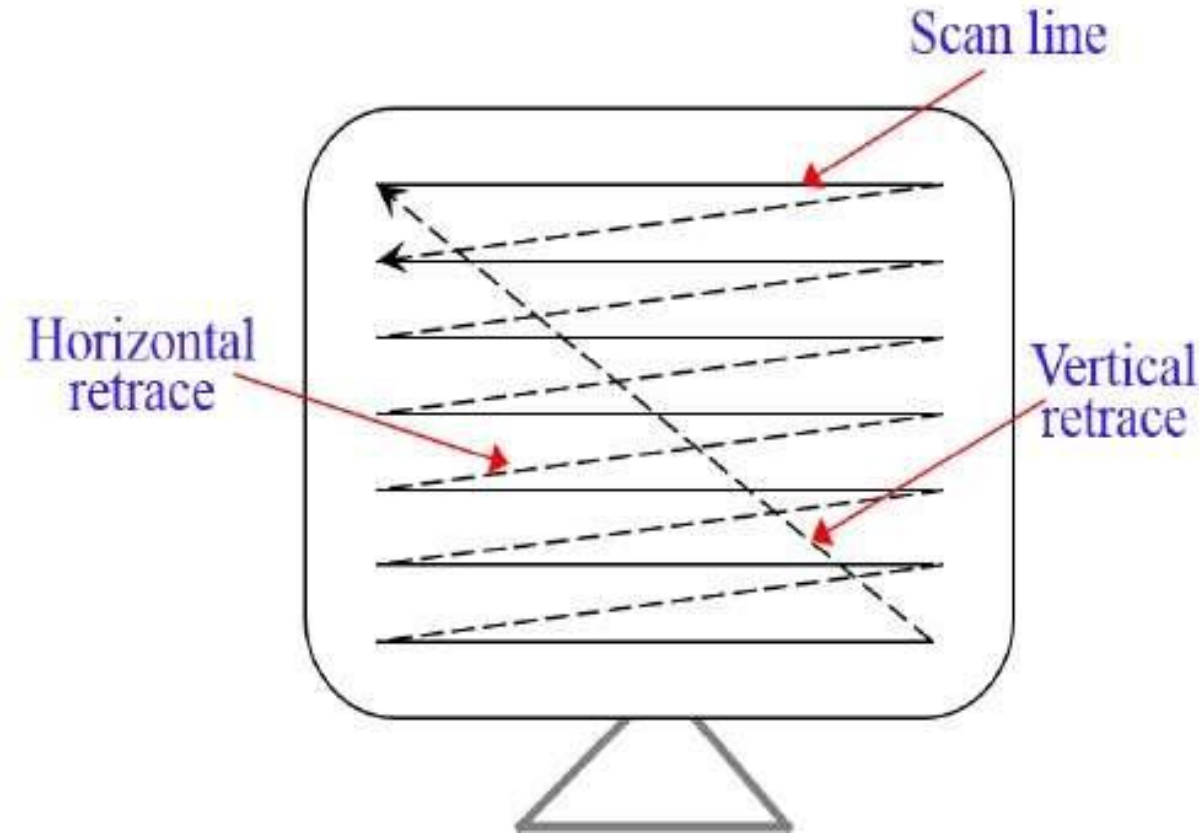


Raster Scan VS Random Scan





Movement of electron gun



Refresh Rate, Video basics, and Scan Conversion … Contd.

Indian Institute of Information Technology Kottayam

- **Refresh rate** of a CRT is the number of times the image is drawn on the screen per second.
- Reducing refresh rate increases flicker.

- **Horizontal scan rate** is the number of scan lines the circuit drives a CRT display per second

  = refresh rate X number of scan lines

- **Resolution** of the screen depends on spot size
- For larger spot size, resolution decreases

Refresh Rate, Video basics, and Scan Conversion … Contd.

Indian Institute of Information Technology Kottayam

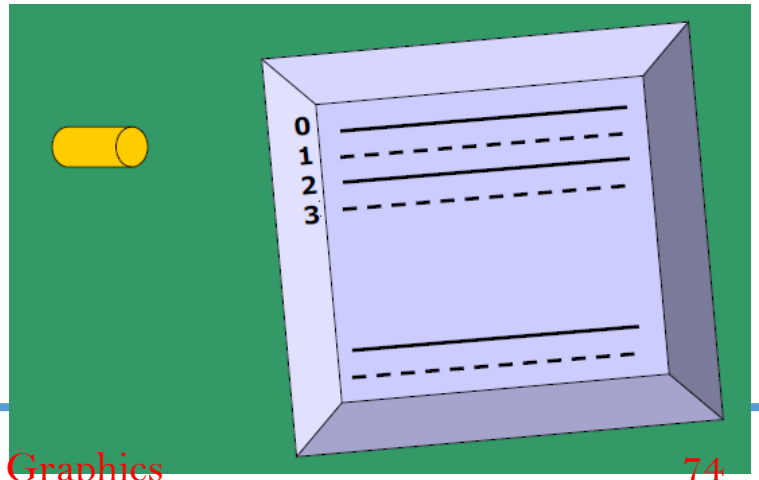
- **Bandwidth of the display:** The rate at which the beam can be turned OFF to ON and vice-versa.

- The **aspect ratio** is the proportional relationship between an image's width and height.

Interlacing technique

Indian Institute of Information Technology Kottayam

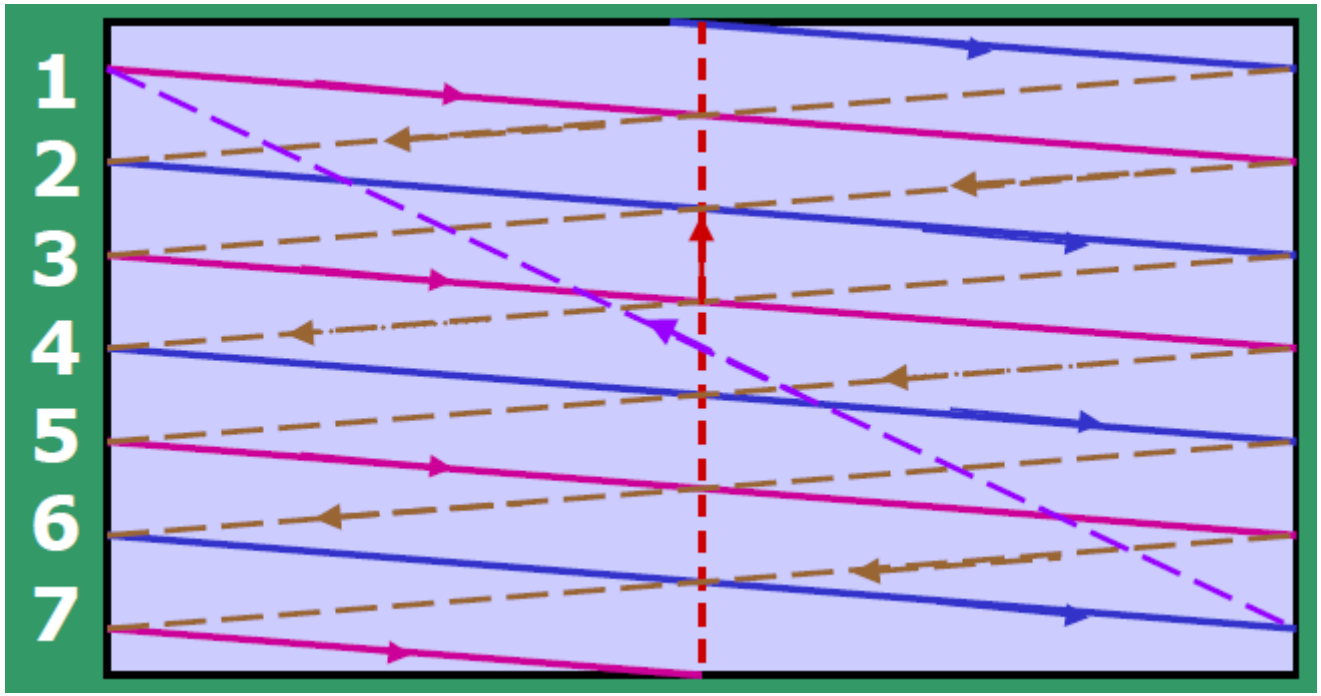
- Normally, the gun scans the screen repeatedly from first cell to last cell.
- This can be replaced with interlacing technique(alternative lines will be scanned).
- Interlacing scan lines on a raster scan display; First, all points on the even-numbered (solid) scan lines are displayed; then all points along the odd-numbered (dashed) lines are displayed

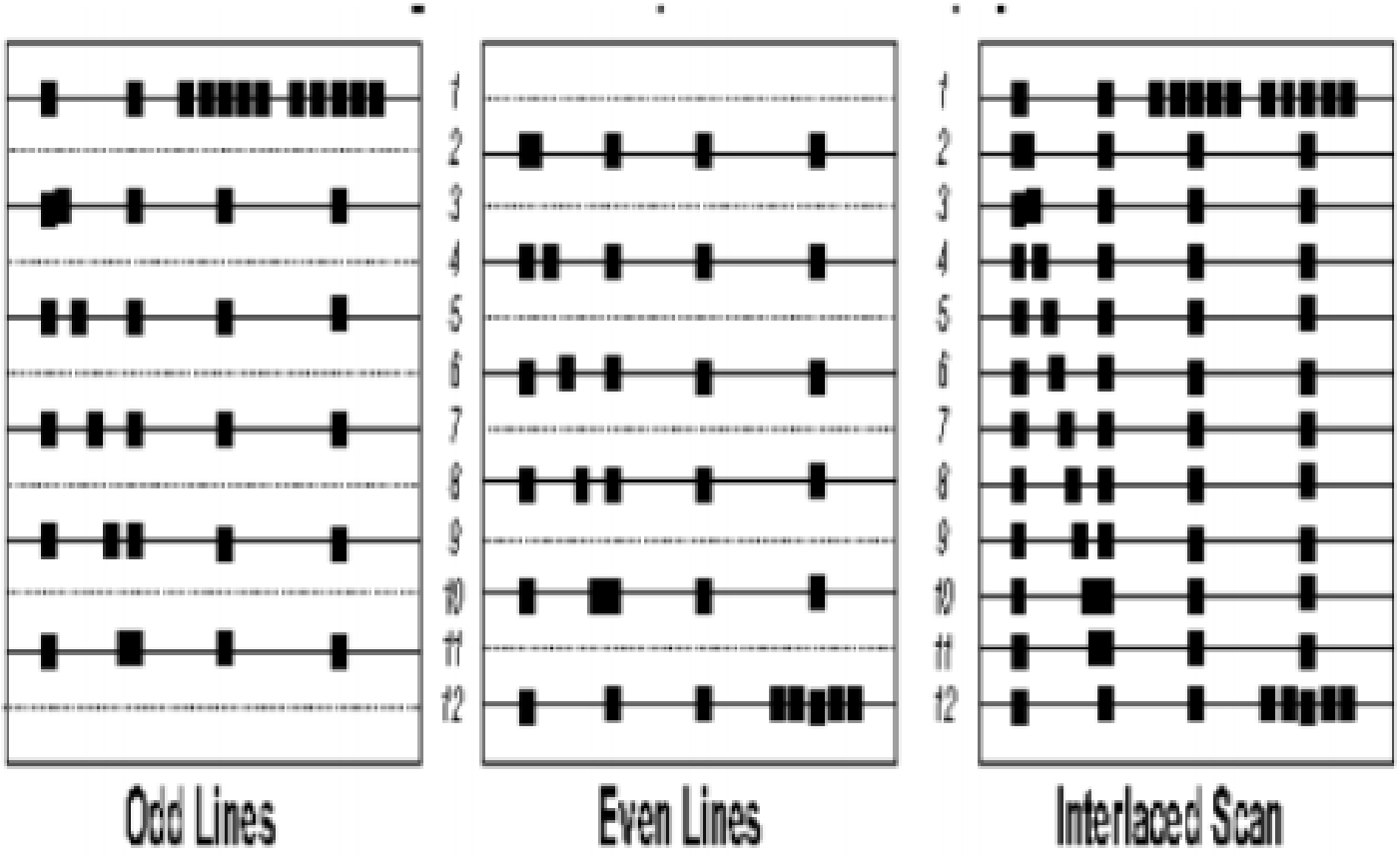


Schematic of a 7-line interlaced scan line pattern

Indian Institute of Information Technology Kottayam

- 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.




1
2
3
4
5
6
7
8
9
10
11
12
Odd Lines
Even Lines
Interlaced Scan

Refresh Rate, Video basics, and Scan Conversion … Contd.

Indian Institute of Information Technology Kottayam

- Horizontal retrace - As the electron beam reaches the right edge of the screen, it is made invisible and rapidly returns to the left edge
- Time taken for horizontal retrace is typically 17% allotted for a scan line.
- After odd field scan conversion is complete, the beam is at the bottom center of the screen.
- After even field scan conversion is complete, the beam is at the bottom right of the screen.
- Odd field vertical retrace returns the beam (switched OFF) to the top center of the screen
- Even field vertical retrace returns it to the upper left corner of the screen

2 types of color CRT monitors

Indian Institute of Information Technology Kottayam

1. Beam penetration CRT
2. Shadow mask CRT

1. Beam penetration CRT

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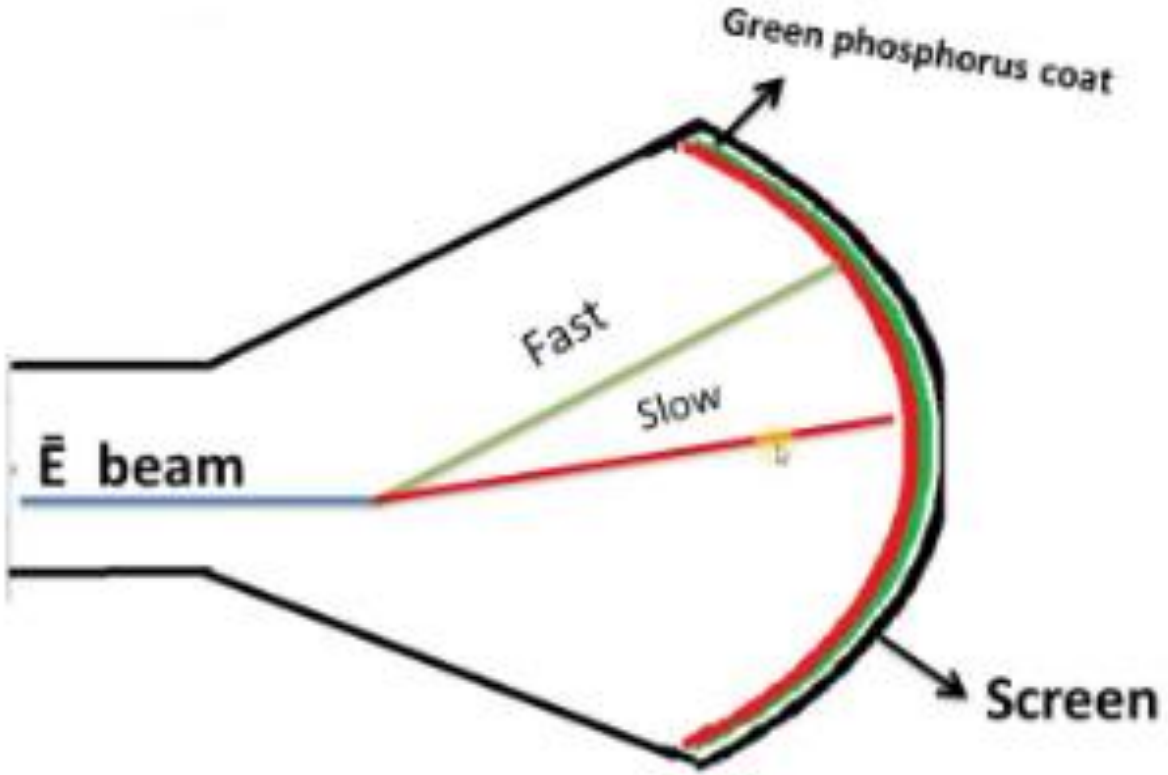
- The arrangement of beam penetration CRT is similar to the normal CRT.
- The only unusual component is the use of multilayer phosphorus inside beam penetration.
- In multilayer phosphorus, a layer of red phosphorus is deposited behind the initial layer of green phosphorus.
- This method produces four colors only, red, green, orange, and yellow. The electron beam is produced by using an electron gun.

- If a low potential electron beam strikes the face, it excites only the red phosphor and produces red traces.
- If a high potential electron beam strikes the tube face, it excites the green phosphor and produces green traces.
- If an electron beam of intermediate potential and velocity, then it produces a combination of red and green i.e., orange and yellow.


Green phosphorus coat
Fast
Slow
Ē beam
Screen

2. Shadow mask CRT

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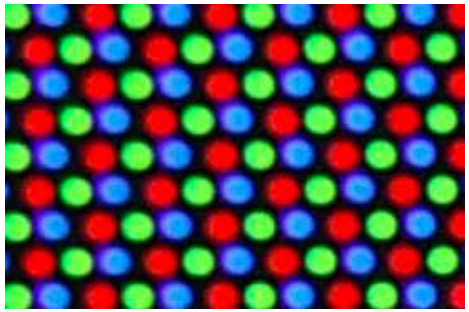
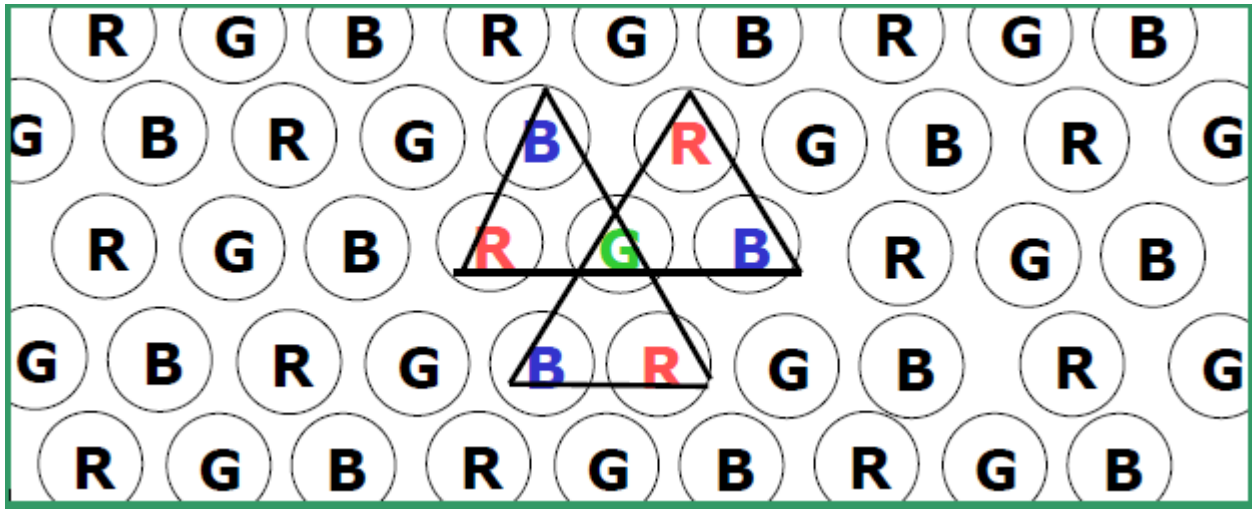
- A type of CRT color display.
- Screen consists of R,G,B dots arranged in triangular pattern.
- A shadow mask is used to focus electrons to these dots, as shown in next slide.

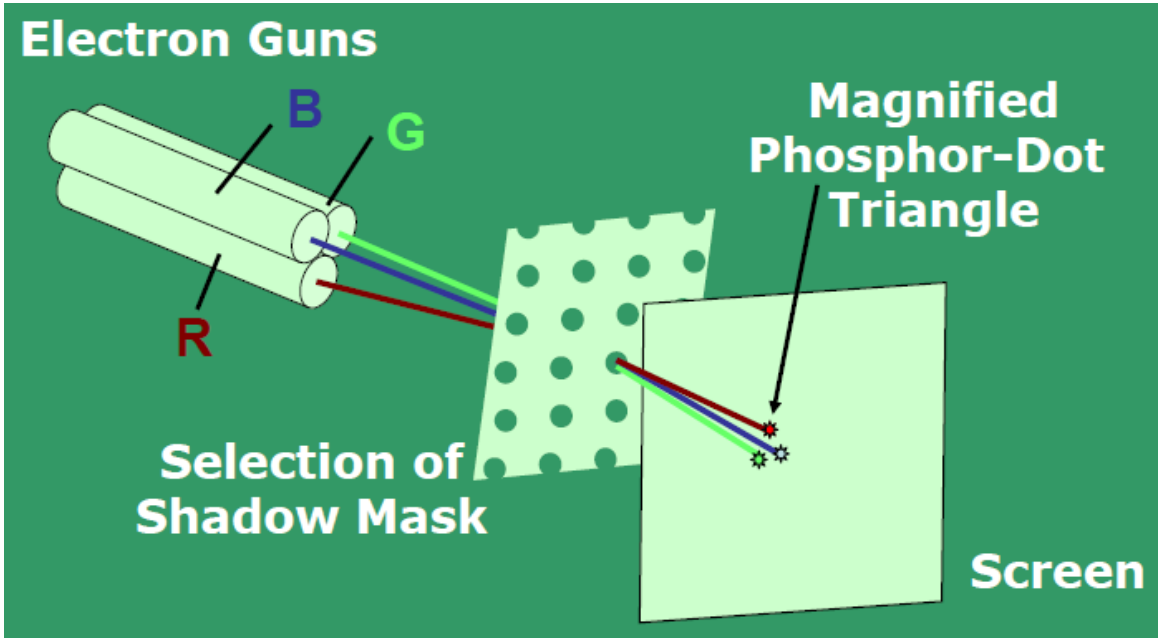


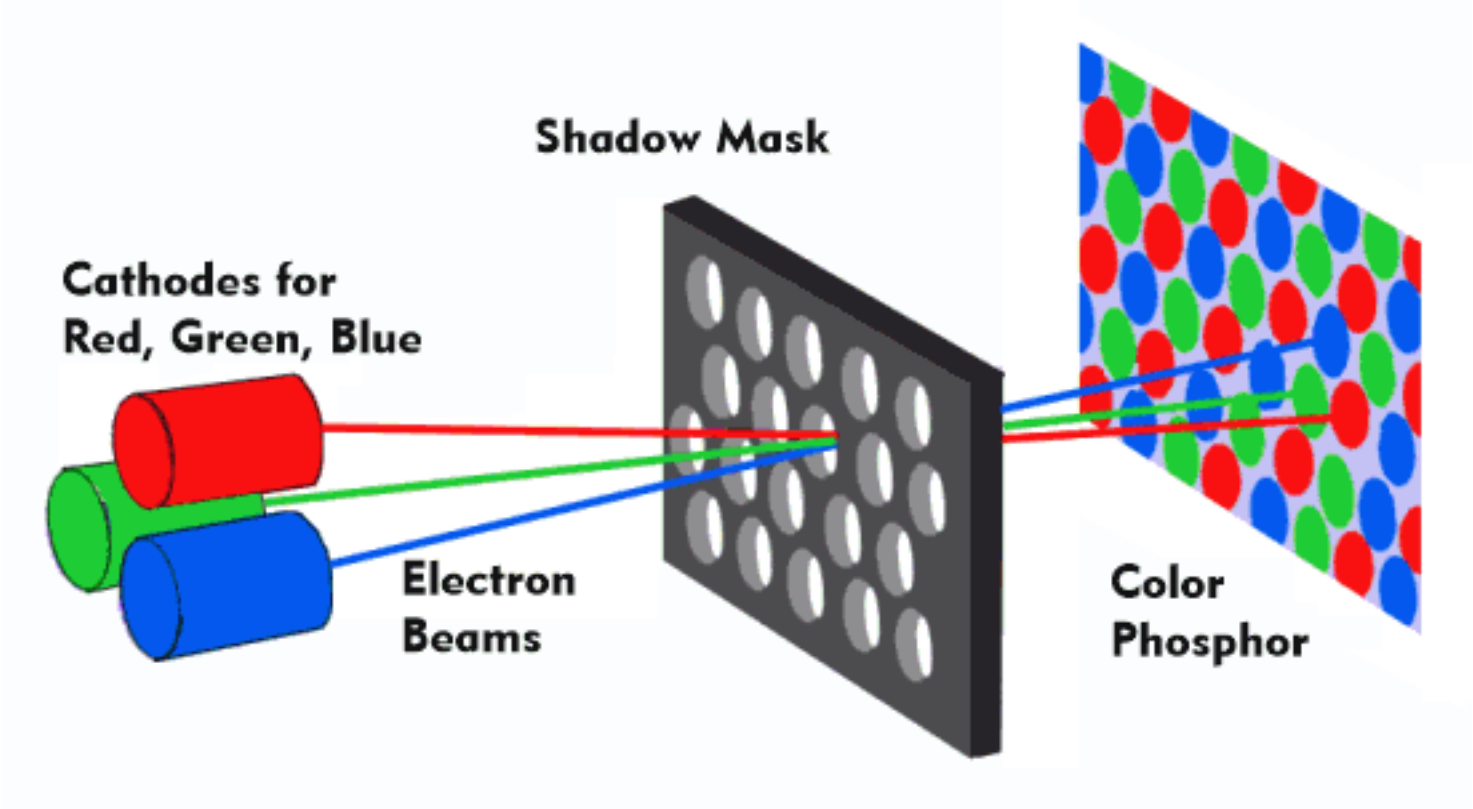
- Phosphorus dot pattern for a shadow mask CRT



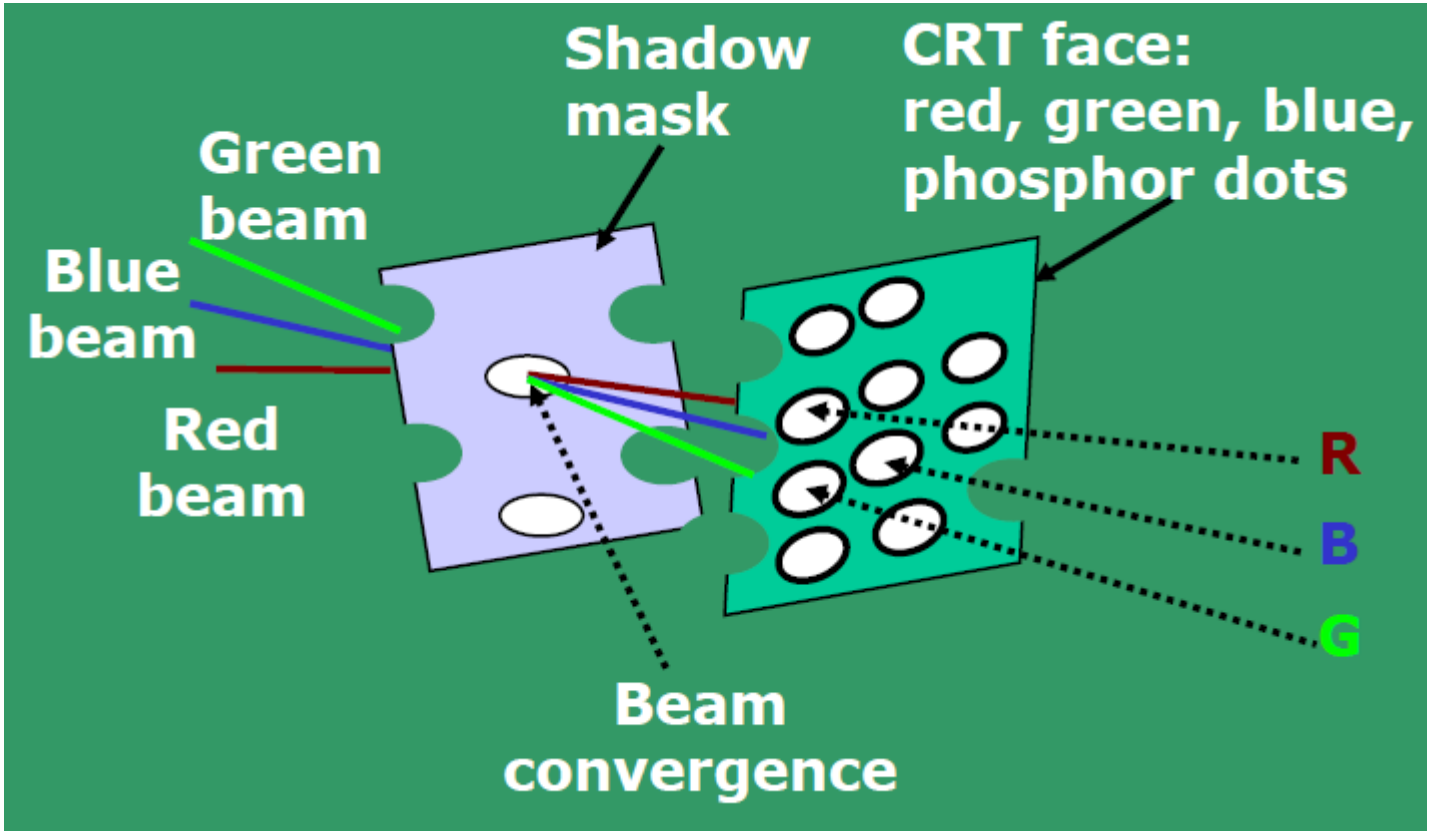
- Operation of a delta-delta, shadow-mask CRT.
- Three electron guns, aligned with the triangular

color-dot patterns on the screen, are directed to each dot triangle by a shadow mask.

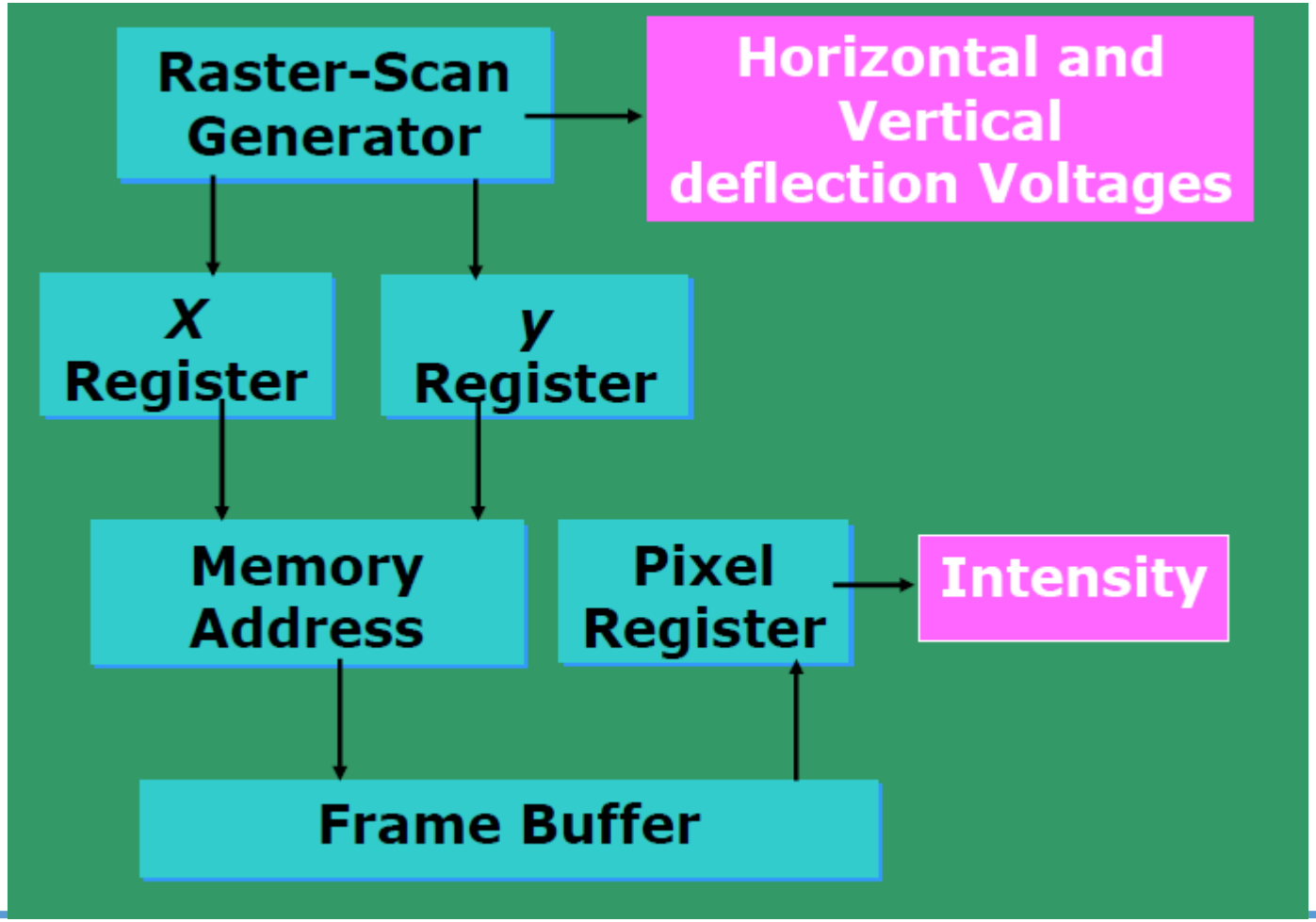



Shadow Mask
Cathodes for
Red, Green, Blue
Electron
Beams
Color
Phosphor

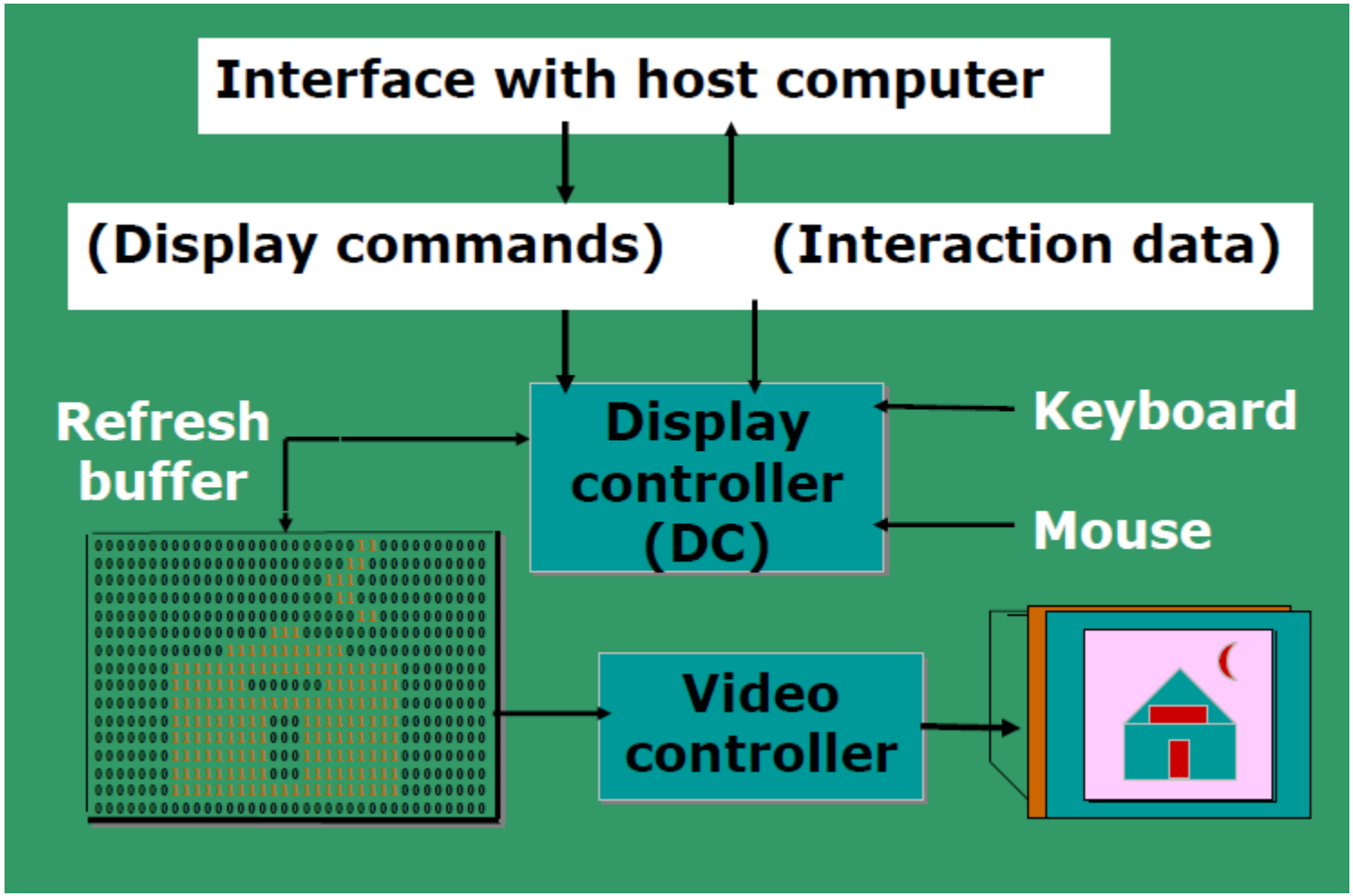
- Color CRT electron gun and shadow mask arrangement



Basic video-controller refresh operations



Architecture of a raster display



Raster scan with outline primitives & Filled primitives

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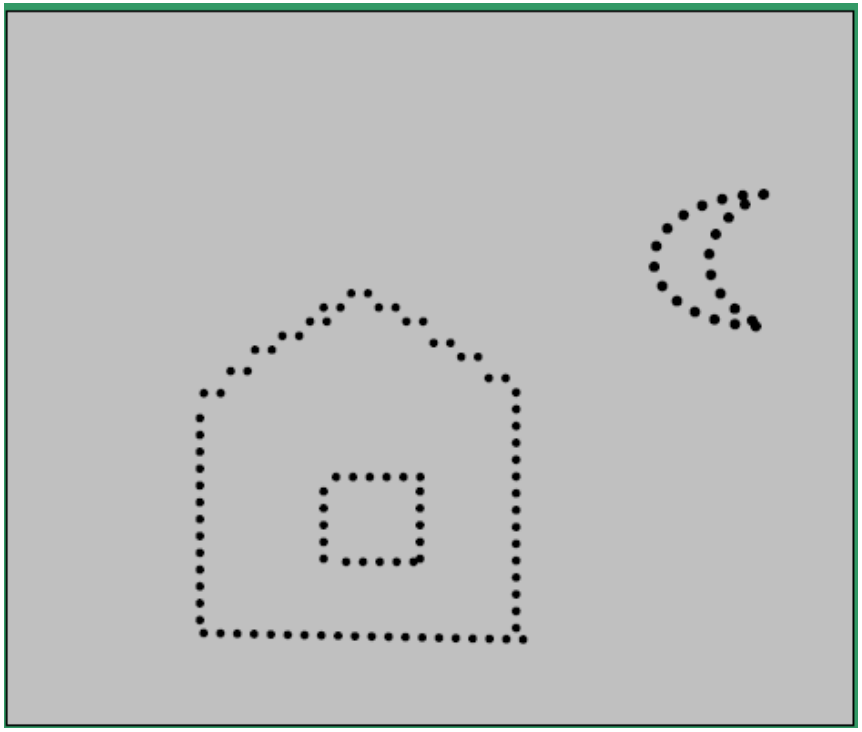
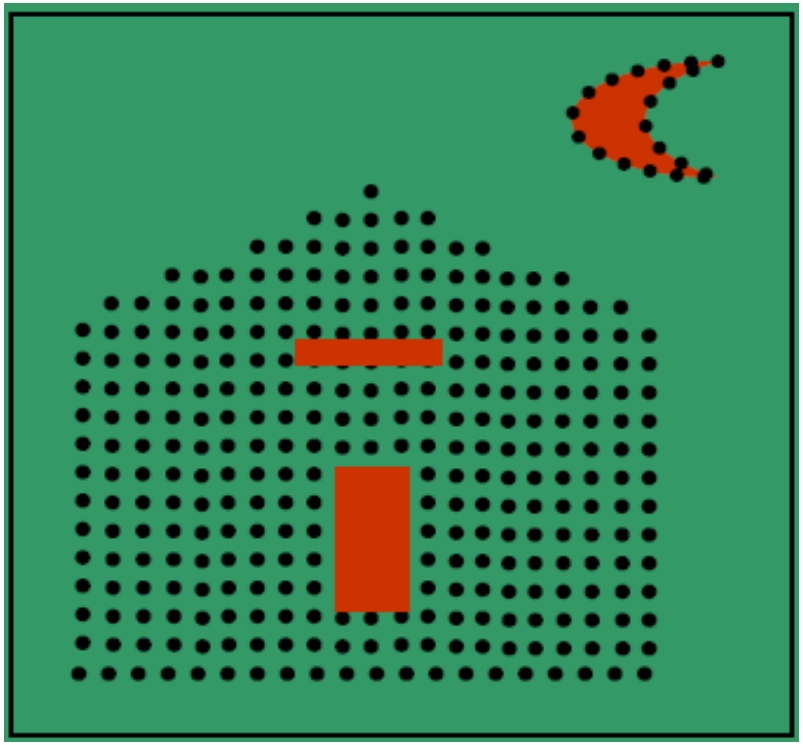
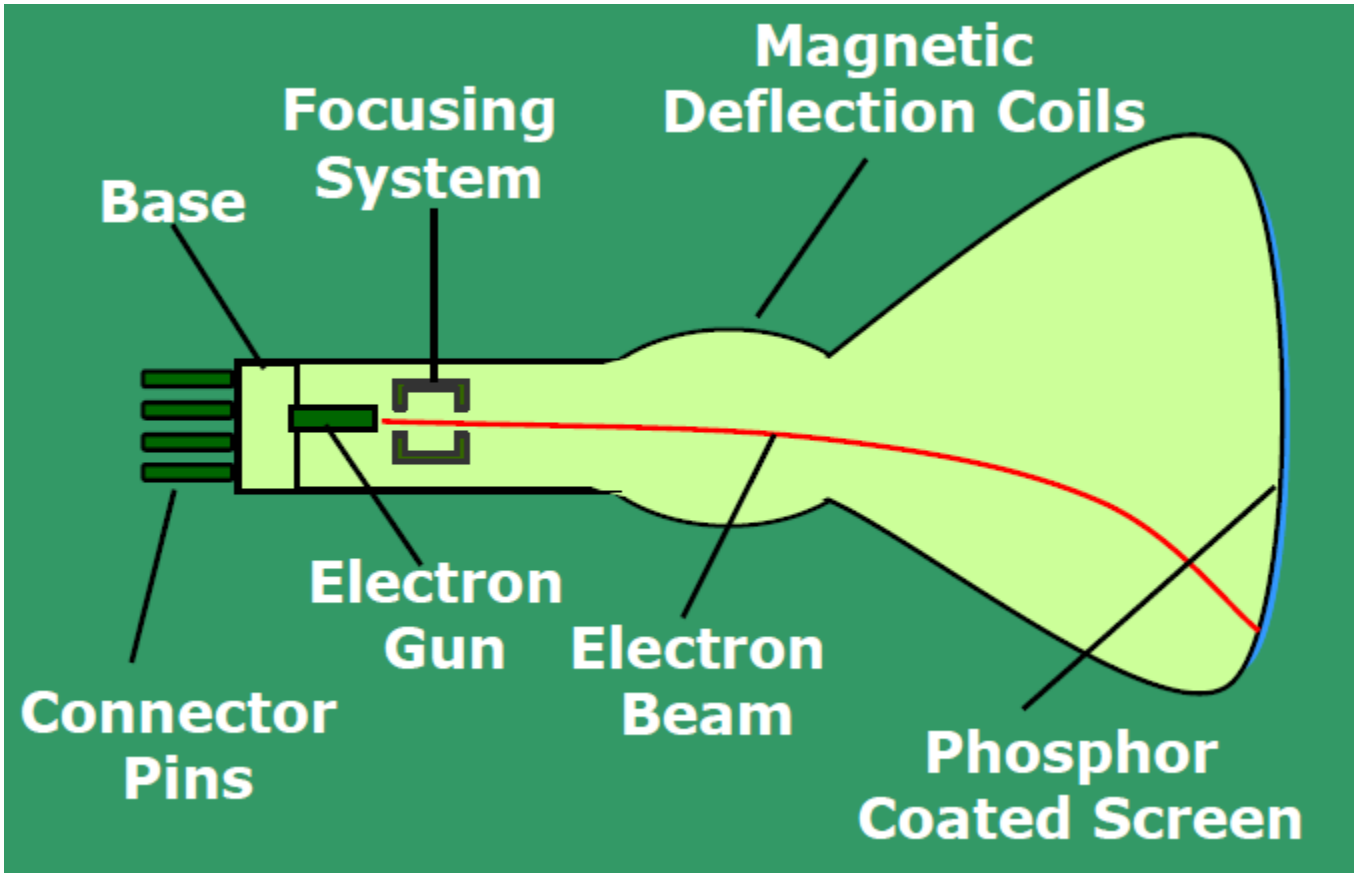




Working of CRT

Basic design of a Magnetic deflection CRT



Electrostatic deflection of the electron beam in a CRT

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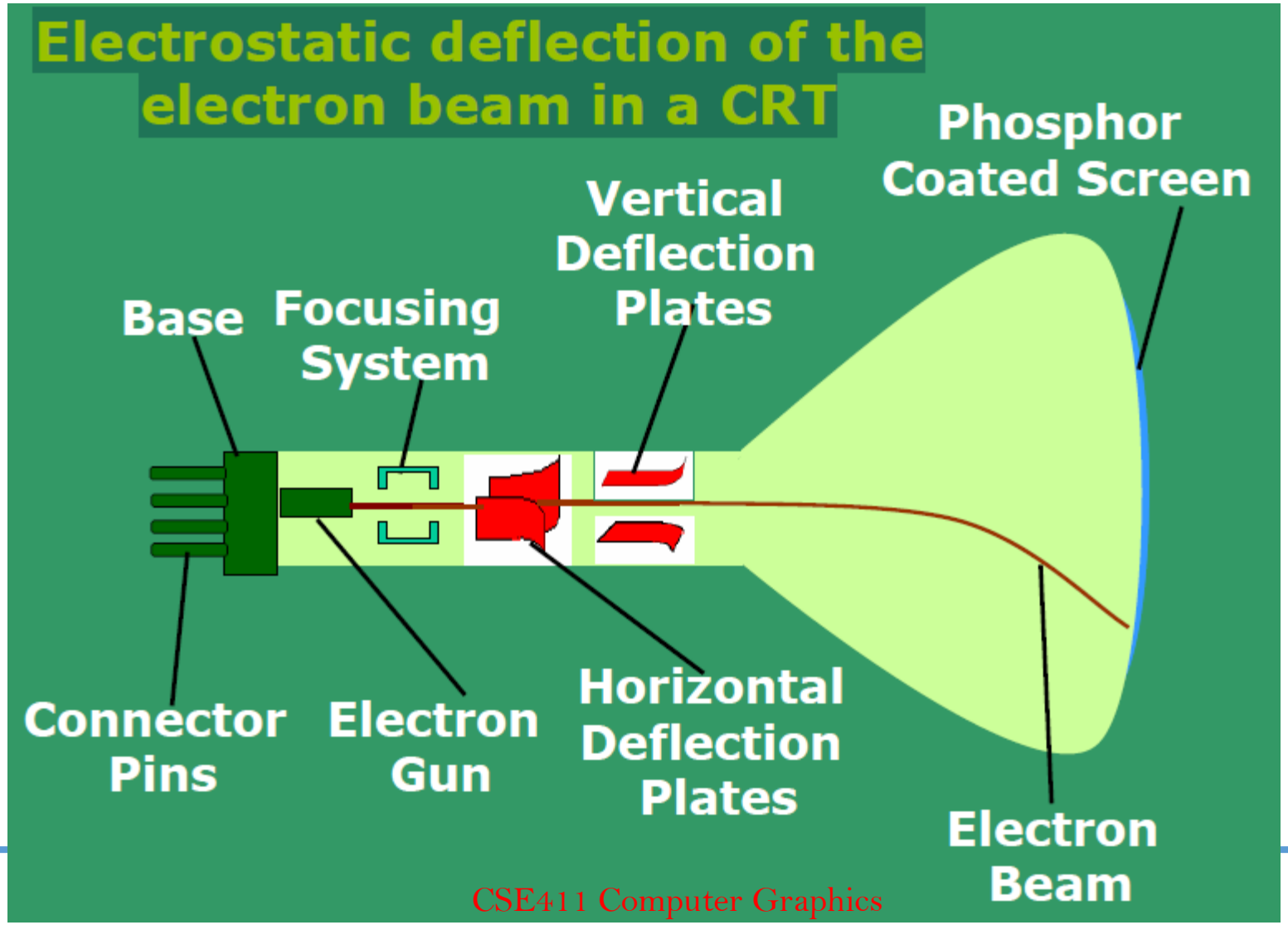
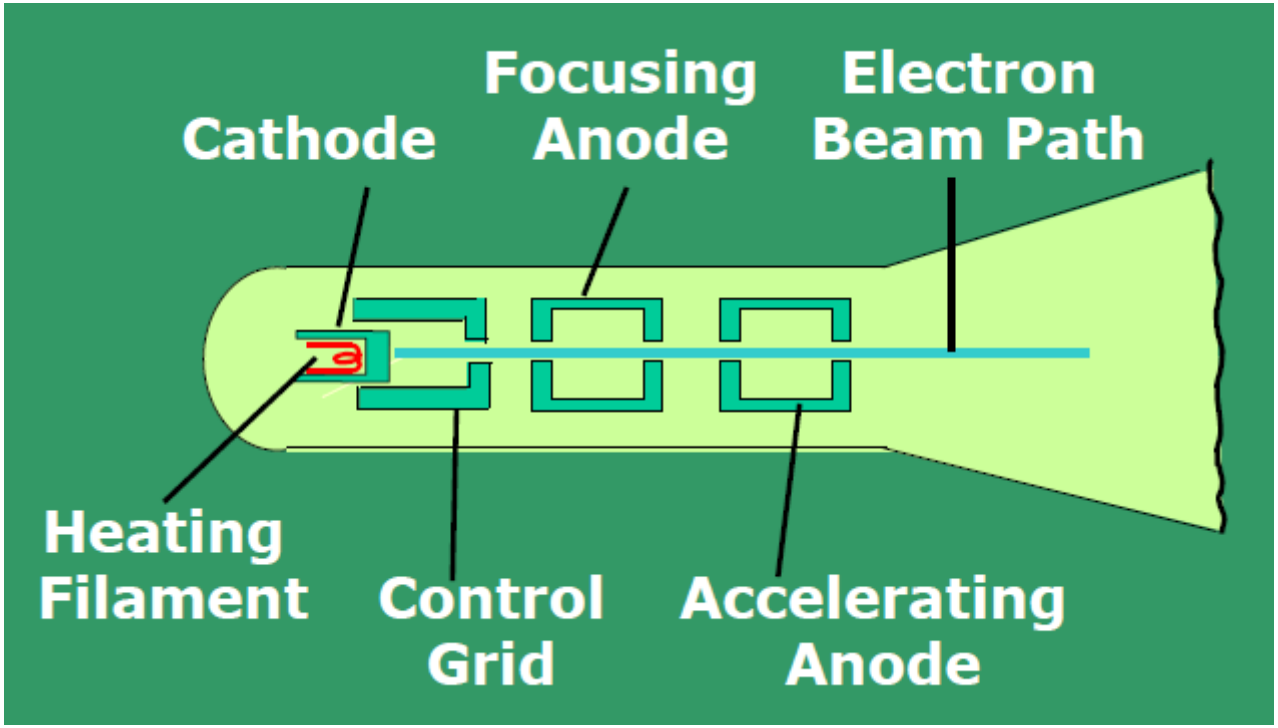


Operation of an electron gun with an accelerating anode



Factors affecting on CRT

- Resolution : Number of pixels per inch that can be drawn horizontally and vertically.
  - It is nothing but clarity and sharpness of the picture.
  - High quality resolution is 1280*1024
- Persistance : The time taken to emit light from the screen to decay to $1/10^{th}$ of its original intensity.
- Addressability : It is a measure of the spacing between the centres of vertical and horizontal lines.
- Aspect Ratio: It gives the ratio between vertical and horizontal points necessary to produce equal lines in both directions on the screen.

Types of CRT displays

Indian Institute of Information Technology Kottayam

- Raster refresh scan displays (Completed)
- DVST (not mentioned in syllabus)
- Calligraphic or Random Scan display system(not mentioned in syllabus)
- Flat panel displays

Types of CRT displays

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- Raster refresh scan displays
- DVST
- Calligraphic or Random Scan display system
- Flat panel displays

FLAT PANEL DISPLAYS

FLAT PANEL DISPLAYS

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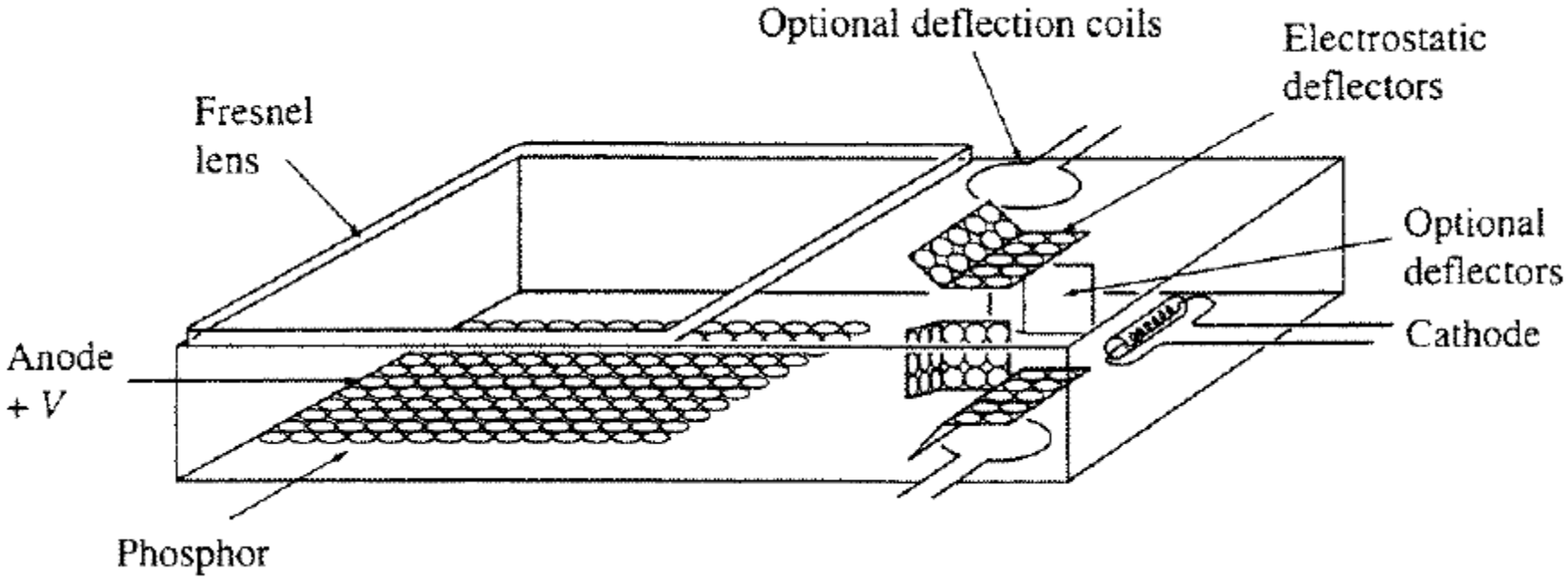
- All flat panel displays are raster refresh displays
- Divided into 2 based on
  - active (light-emitting) and
  - passive (Light-modulating) technologies
- **Active:**
  - Flat CRTs,
  - Plasma-gas discharge,
  - Electroluminescent (EL),
  - Vacuum fluorescent displays
- **Passive:**
  - LCD (Liquid crystal Display)
  - LED (light Emitting Diodes)

1. FLAT CRT


Optional deflection coils
Electrostatic deflectors
Fresnel lens
Optional deflectors
Cathode
Anode
+ V
Phosphor

2. Plasma Display

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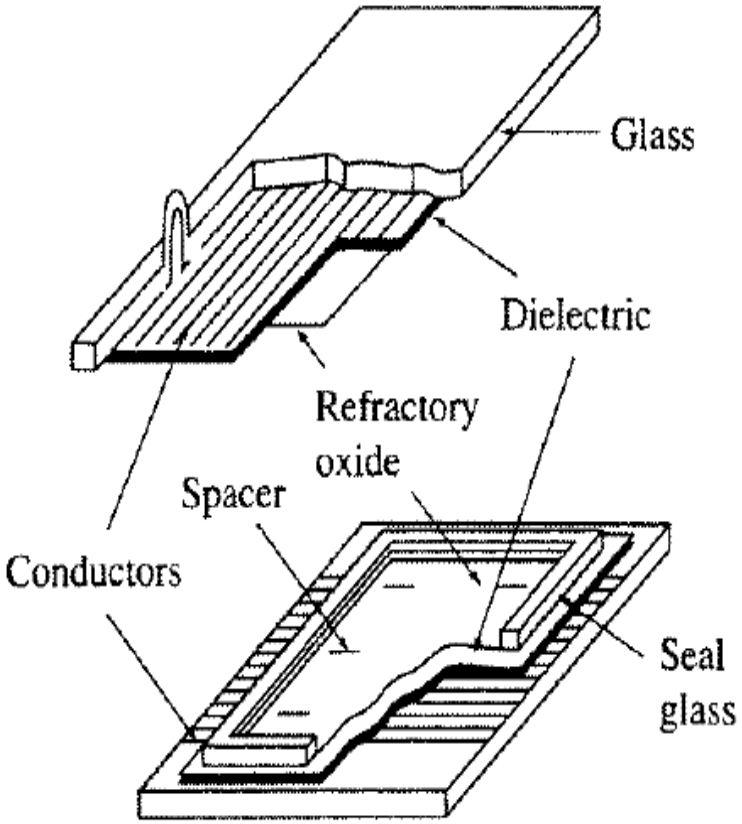
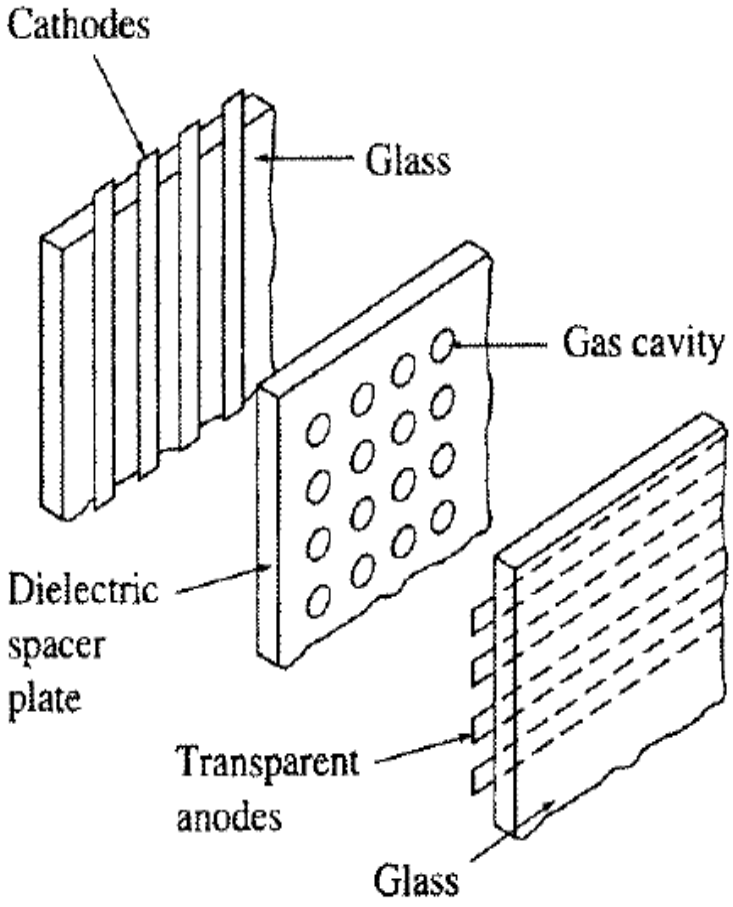
- Consist of a matrix of individual pixel locations on a raster
- Each pixel contains mechanism or material activated by application with a voltage or current, that either emits light or modulates the light incident
- Display consist of matrix of cells in a glass envelope
- Each cell filled with gas (neon or neon/argon mixture) at low pressure
- When high voltage is applied; gas dissociates i.e., electrons are stripped from the atoms. The disassociated gas is called plasma
- Energy is released in the form of photons when electrons are recombined and gas glows with characteristic bright orange-red hue.

Plasma Display … Contd.

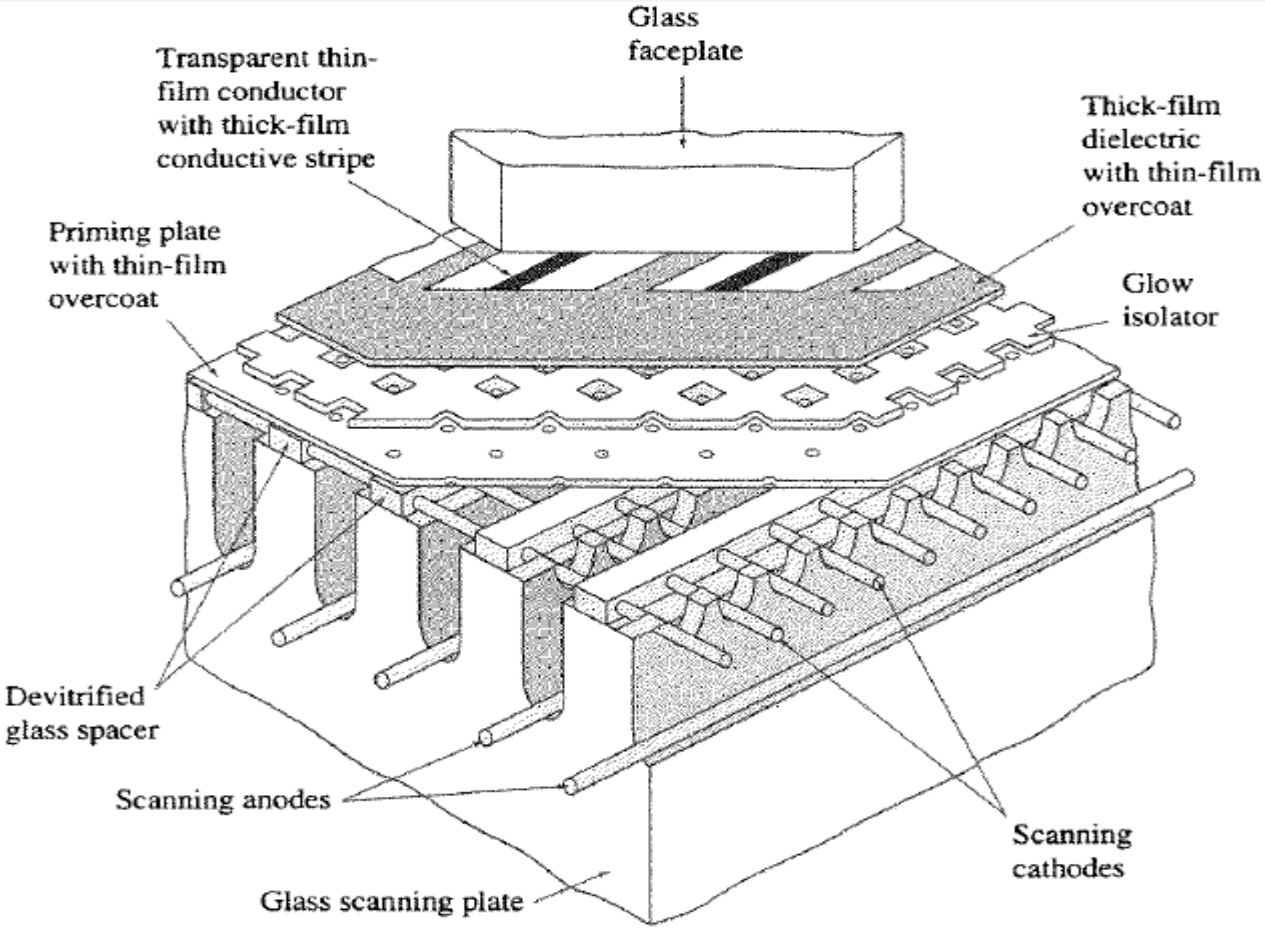


(a) AC Activated Plasma displays



(b) DC Activated Plasma displays

Plasma Display … Contd.



(c) AC/DC Activated Plasma displays

3. Electroluminescent Display

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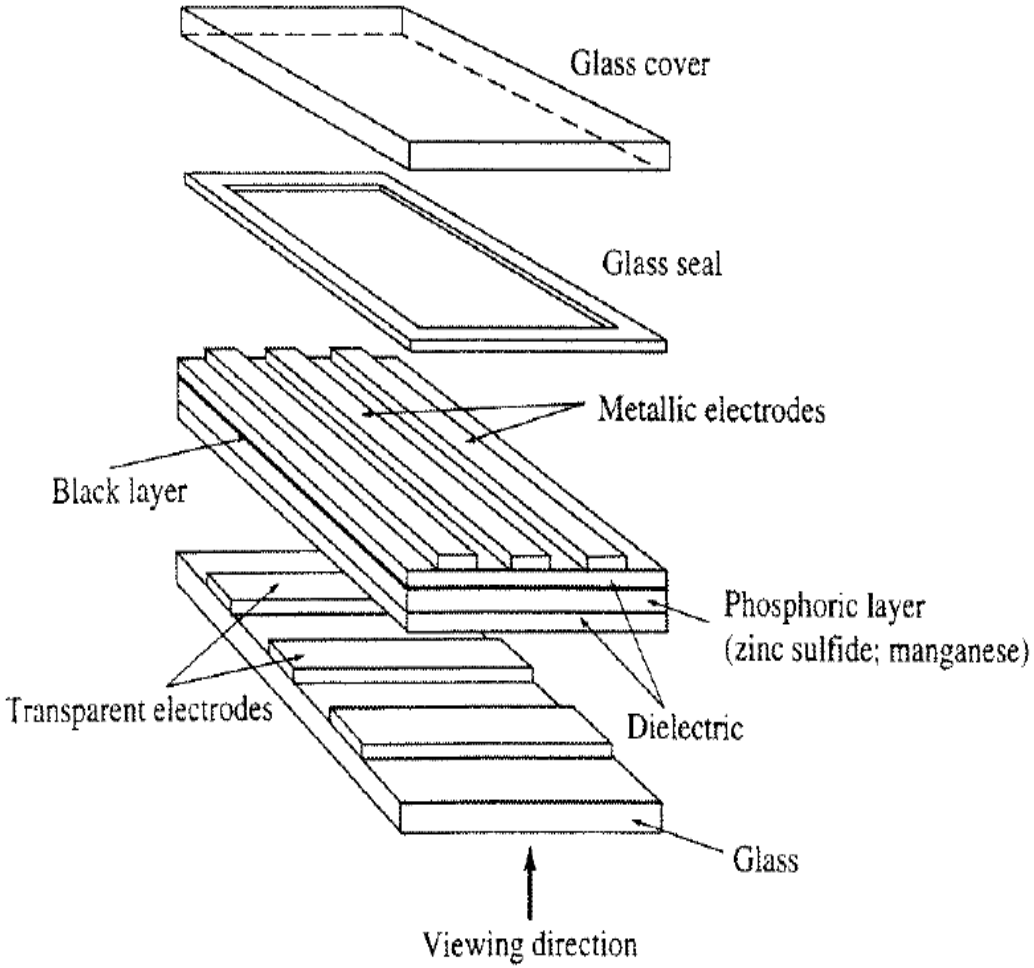
- A phosphorescent material emits light when excited by an AC or DC electric field.
- It typically has yellow color because phosphorescent material is zinc sulfide doped with manganese.



4. LCD

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- LCD is made up of 6 layers – vertical polarizer plane; layer of thin grid wires; layer of LCDs; layer of horizontal grid wires; horizontal polarizer; and finally a reflector.
- LCD material is made up of long crystalline molecules; When the crystals are in an electric field, they all line up in the same direction.
- Active matrix panels have a transistor at each grid point (X, Y). Crystals are dyed up to provide color. Transistors act as memory, and also cause the crystals to change their state quickly.
- LCD displays are low cost, low weight, small size and low power consumption

LCD … Contd.

Indian Institute of Information Technology Kottayam

- The display contains two polarizers, aligned 90^0 to each other.
- With the display in its OFF (or twisted) state, light entering the display is plane polarized by the first polarizer.
- This polarized light passes through the liquid crystal sandwich and then through the second polarizer and is reflected back to the display.
- Turning the pixel ON (by applying and electric field) causes the crystal to untwist.
- Light now passing through the liquid crystal sandwich is now absorbed by the second polarizer. The pixel now appears dark.

Hardcopy Output Devices

Hardcopy output devices

Indian Institute of Information Technology Kottayam

- Electrostatic plotters
- Ink Jet plotters
- Thermal plotters
- Dye sublimation printers
- Pen & ink plotters
- Laser printers
- Color film cameras

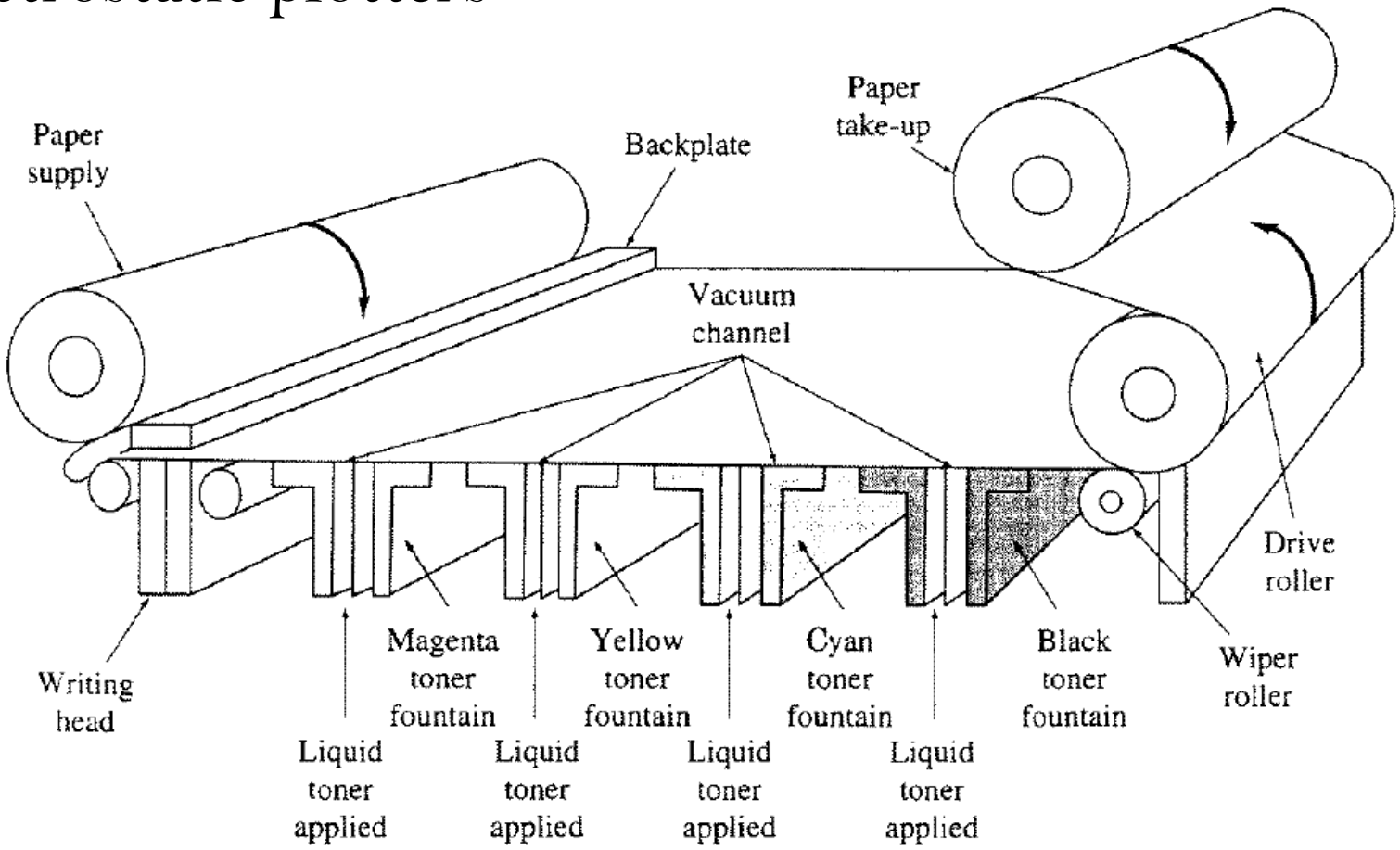
Hardcopy output devices

Indian Institute of Information Technology Kottayam

- Electrostatic plotters
- Ink Jet plotters
- Thermal plotters
- Dye sublimation printers
- Pen & ink plotters
- Laser printers
- Color film cameras

Hardcopy output devices … Contd.

1. Electrostatic plotters



Electrostatic plotters

Hardcopy output devices … Contd.

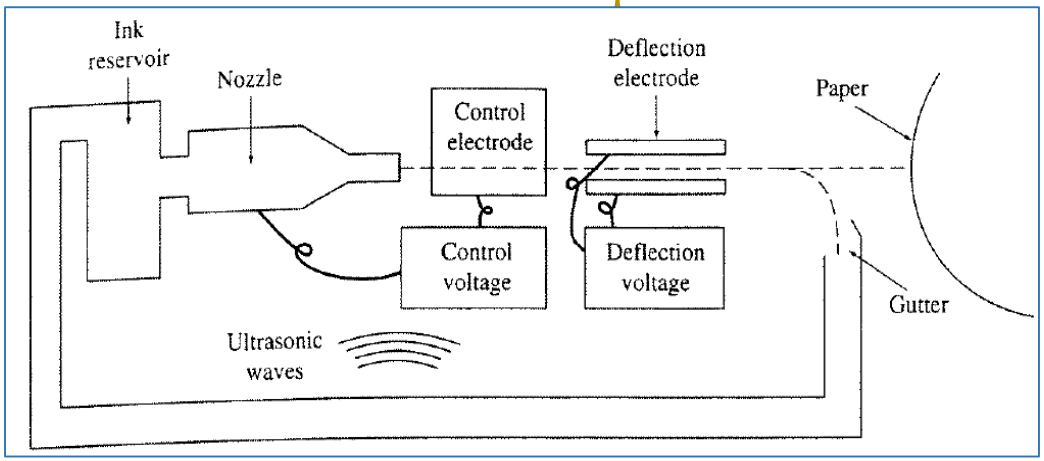
- Electrostatic plotters:
  - Is a raster scan device
  - Operates by depositing small particles of toner onto electrostatically charged areas of a special paper
  - A specially coated medium that will hold an electrostatic charge is passed over writing head, which contains one or more rows of small writing *nibs* or *styli*
  - As the medium is passed over styli, an individual dot of negative 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 medium, making them visible

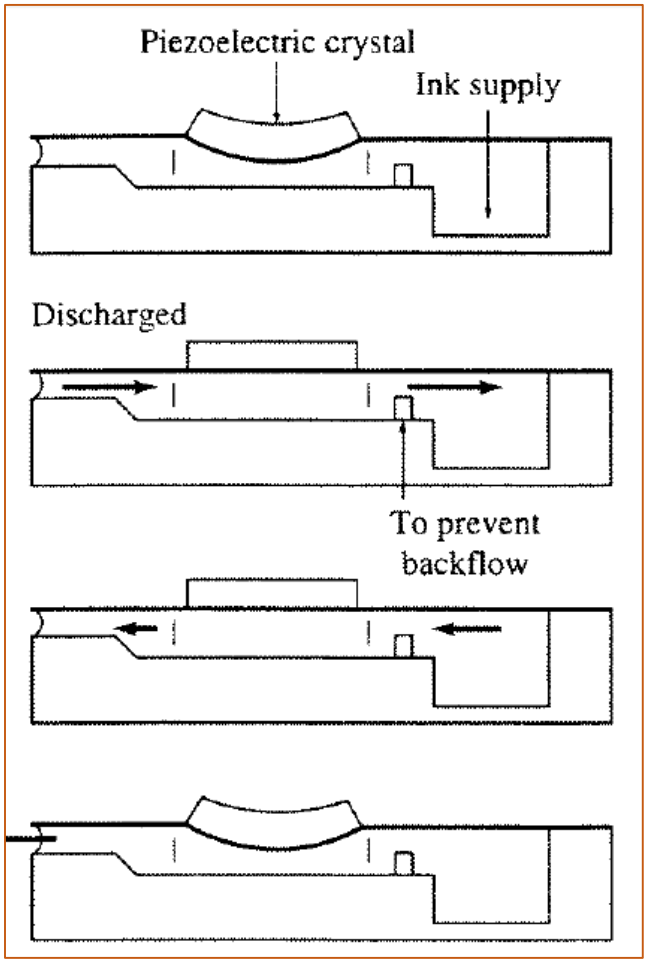
Hardcopy output devices … Contd.

2. Ink Jet plotters

- Raster scan devices
- Suited for low cost color output
- Basic idea is to shoot tiny droplets of ink onto a medium
- Two types:

  continuous and drop-on-demand





Hardcopy output devices … Contd.

Indian Institute of Information Technology Kottayam

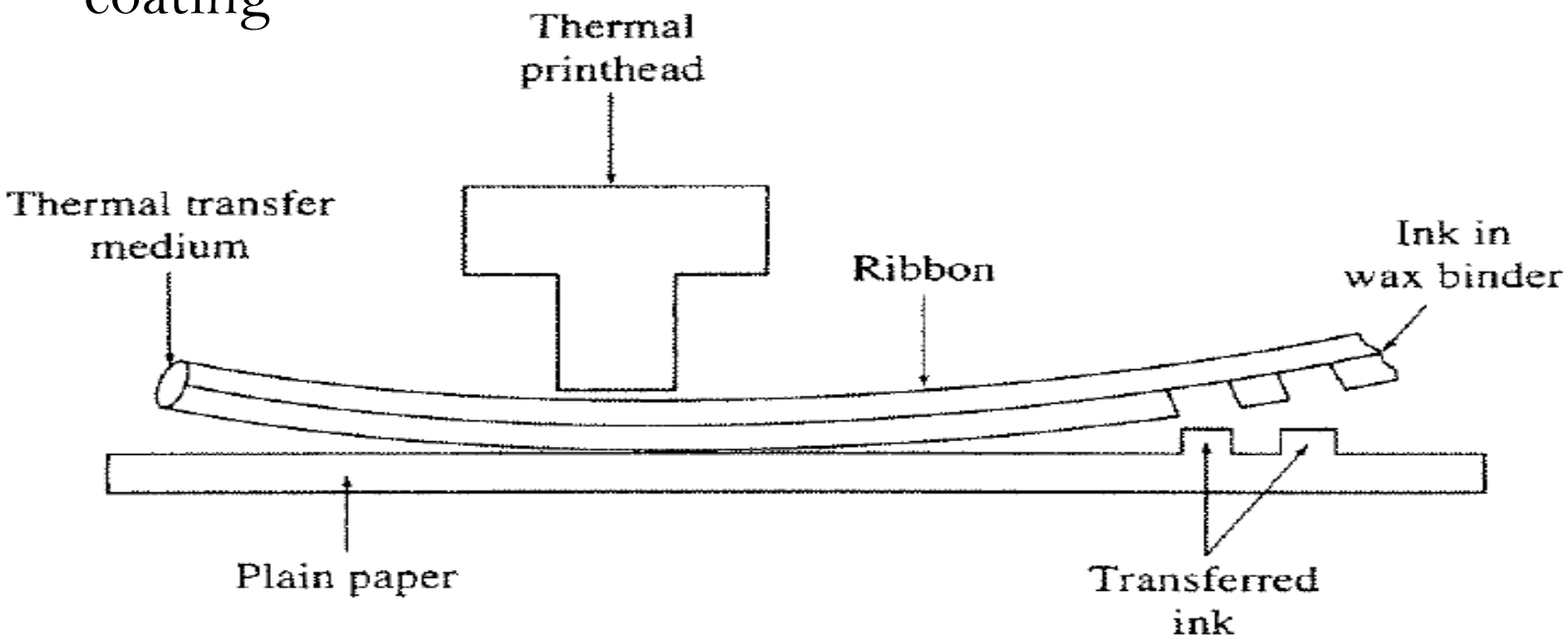
3. Thermal plotters

- Two types: Direct & Indirect thermal transfer
- ***Direct thermal transfer technique:*** uses a **temperature sensitive paper** that changes color when heated.
- Print head will form the image that selectively heat dots on the paper as the head moves across it.
- Limitation: special paper required and it unfortunately fades with time

Hardcopy output devices … Contd.

Indian Institute of Information Technology Kottayam

- Thermal plotters
  - ***Indirect thermal transfer technique:*** uses a thin film or paper ribbon coated with a wax-based ink.
  - Heating element located behind the ribbon melt the wax coating



Hardcopy output devices … Contd.

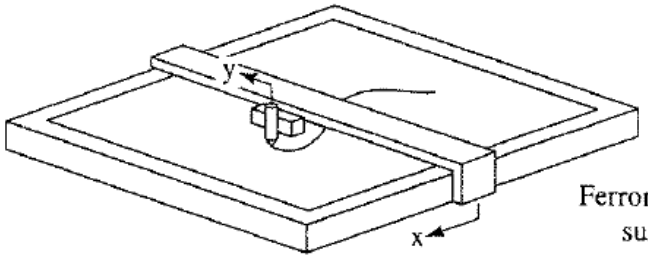
4. Dye sublimation printers

- Also called as dye diffusion, dye transfer or sublimable dye technology
- Dye sublimation printing is continuous tone.
- It transfers a ribbon contains CMYK color dye, lies between the print head containing heating element and the paper
- **Heating the dye on the ribbon** to various temperatures causes varying amount of dye to change the color from solid to a gas
- Varying the dot size significantly increases the number of possible colors

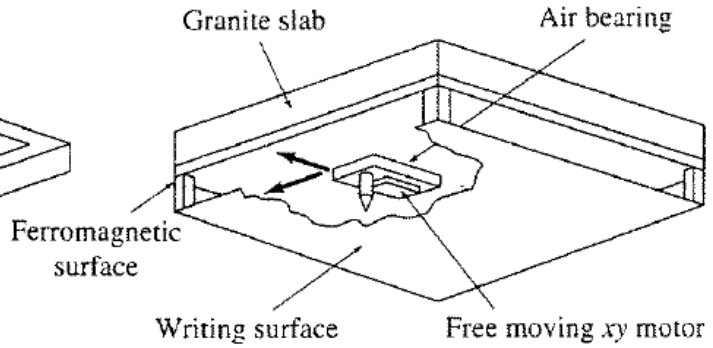
Dye sublimation Printer

Hardcopy output devices … Contd.

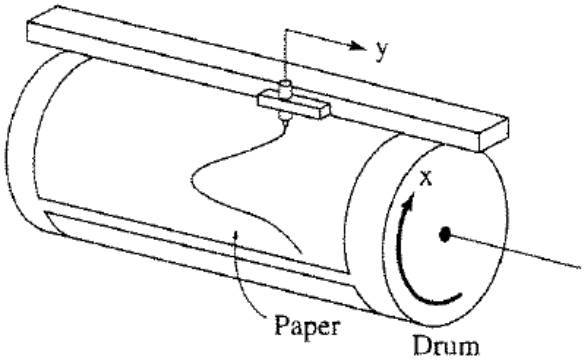
5. Pen & ink plotters



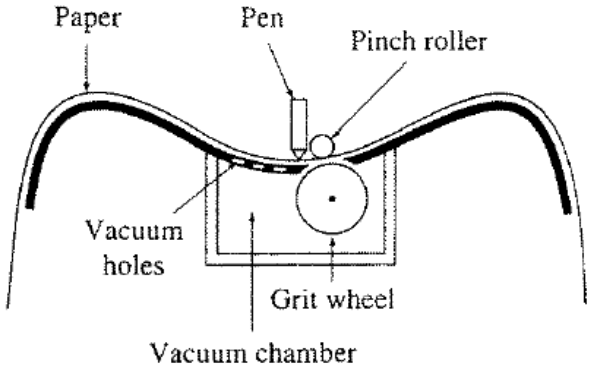
Flatbed moving arm



Flatbed moving head

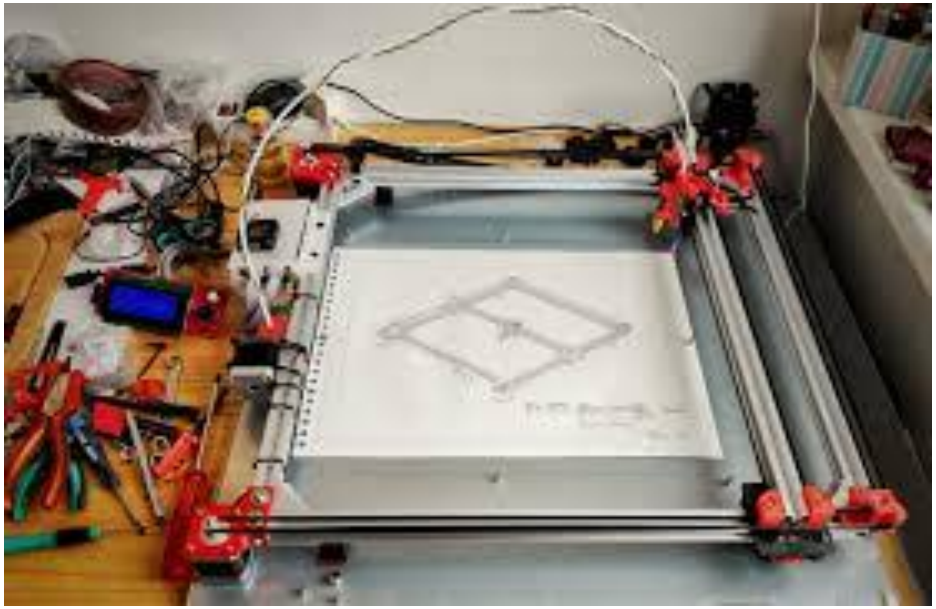


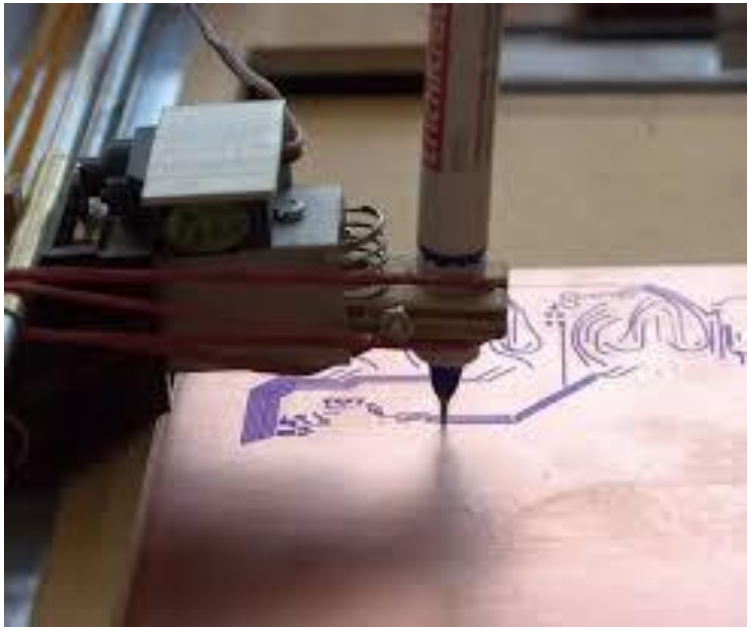
Drum



Pinch roller

Pen plotters





Hardcopy output devices … Contd.

6. Laser printers
   - Mainly designed for computer graphics output
   - It is also a raster scan device.
   - Similar to xerography

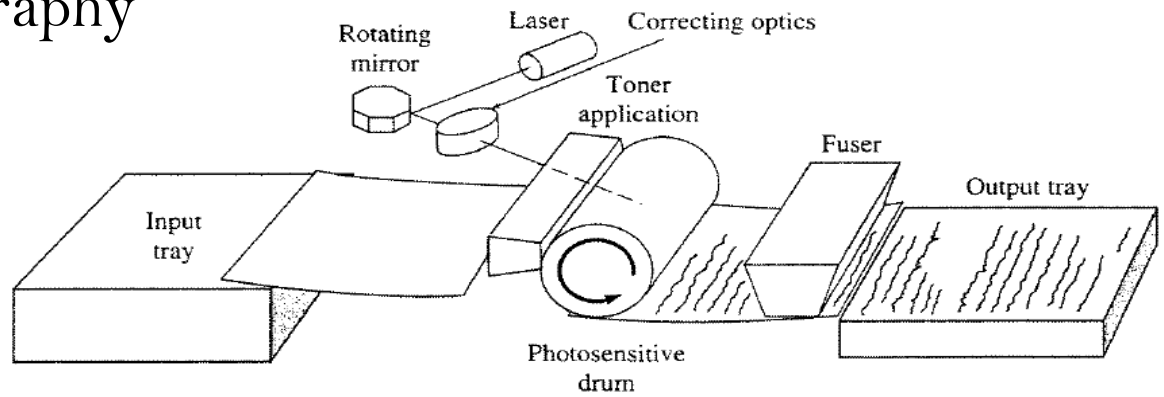
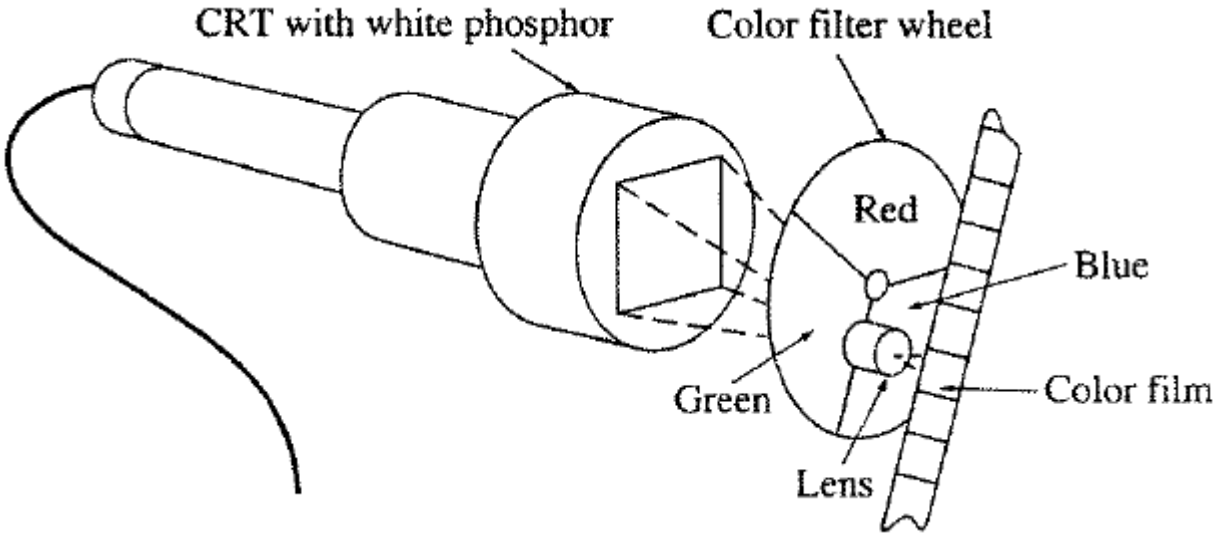


Fig.: Laser print engine

Fig.: Laser printer system semantic

Hardcopy output devices … Contd.

7. Color film cameras
   - Based on photographic film
   - Able to display 16 million colors



Assignment 1

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1. Explain hard copy output devices.
2. Explain the working of a mobile phone camera.

II. Logical Interactive Devices

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The functional capabilities/device types of interactive graphic devices are:

Locator

Valuator

Button

Pick

III. Physical Interactive Devices

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- Tablets
- Touch panels
- Control dials
- Joystick
- Trackball
- Mouse
- Function Switches
- Light pen
- Space ball
- Data glove
- Simulation of alternative devices

IV. Data Generation Devices

- Scanners
- Three dimension digitizers
- Motion capture

V. Graphical User interfaces

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- Cursors
- Radio buttons
- Valuators
- Scroll bars
- Grids
- Dialog boxes
- Menus
- Icons
- Sketching
- 3-D Interaction

Summary

Indian Institute of Information Technology Kottayam

- Raster Refresh Graphics Displays
- Flat panel Displays
- Hardcopy output devices
- Input or interactive devices
  - Logical
  - physical
- Data generation devices
- GUIs

Thank You