COMPUTER AIDED DESIGN
(BME-42)

Credits : 5

Lecture : 3

Tutorial : 1

Practical : 2

Lecture 1

Topics Covered

Course Outcomes

Syllabus

Experiments

Books & References

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Course Outcomes

- The importance, benefits and applications and essential elements of CAD such as Graphics input, Graphics display and Graphics output devices.
- The knowledge of graphics software, graphics standards, configuration and functions, skill of writing the algorithm for generating 2D graphic elements; and understanding the mathematics behind 2D & 3D individual and combined geometric transformations.
- The ability of mathematical representation of parametric form of analytic planar curves and synthetic space curves such as Hermite, Bezier and B-spline curves and knowledge of their properties.
- The knowledge of polygonal, quadric and superquadric surfaces, blobby objects, color models and different solid modeling techniques and skill of developing 3D geometric models in CAD software.

Computer Aided Design (BME-42)

L: 3 T:1 P:2

Syllabus

Unit I

Introduction (Lecture : 3)

Computer in Engineering design, Classical vs. Computer Aided Design, CAD/CAE/CAPP, Elements of CAD, Essential requirements of CAD, CAD Tools, Concepts of integrated CAD/CAM, Essential requirements of CAD system, Necessity & benefits, Engineering Applications

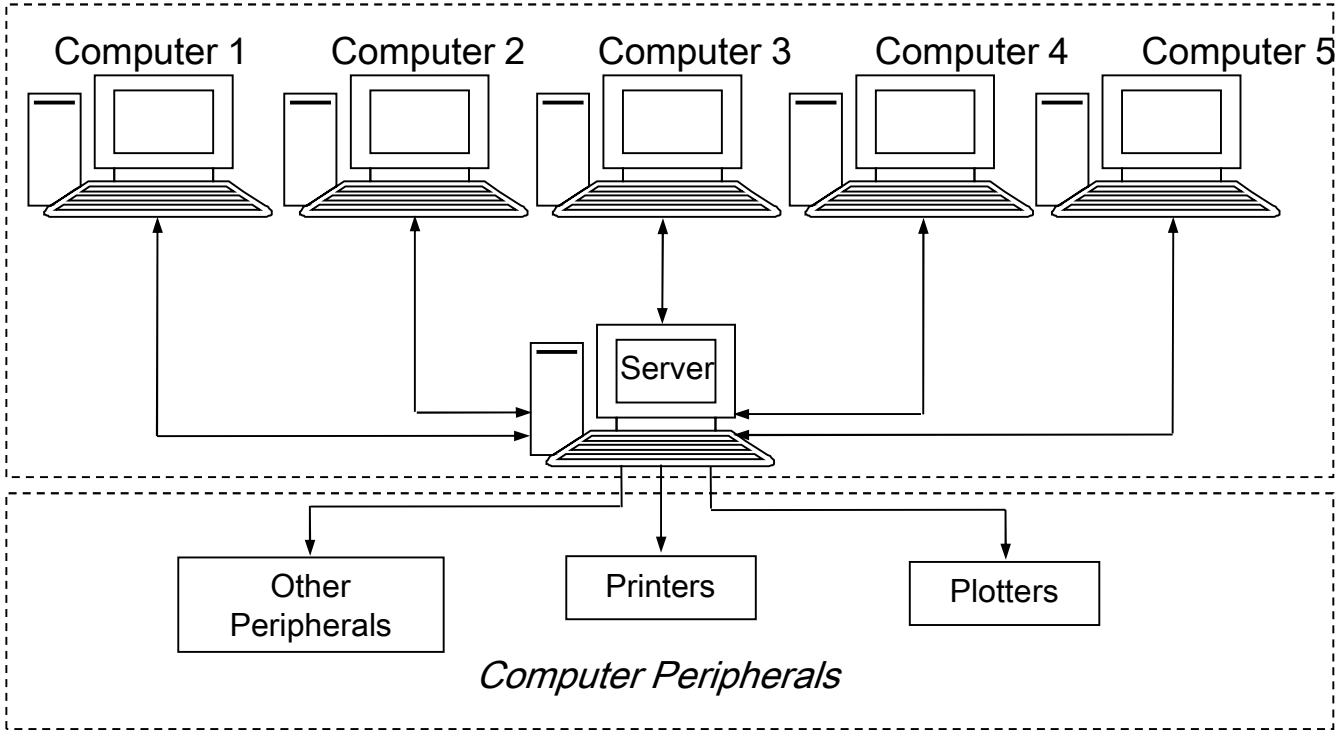
Computer Graphics Hardware (Lecture : 6)

Graphics systems, Graphics Input devices-cursor control devices, Digitizers, Image scanner, Speech oriented devices, Graphics display devices-Cathode Ray Tube, Calligraphic display, DVST, Raster display, Color frame buffer, Color CRT monitors, Solid state monitors-emissive displays, non-emissive displays, Graphics output devices-Hard copy printers and plotters

Computer Aided Design (BME-42)

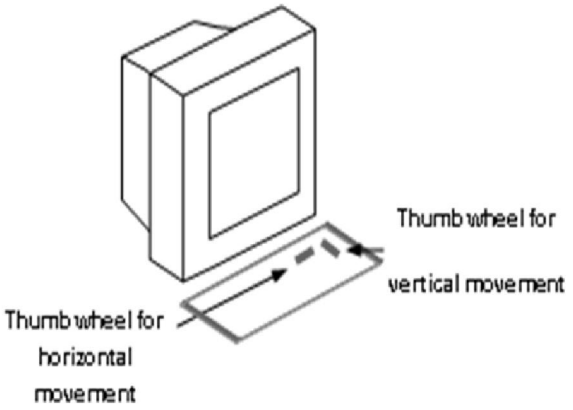
L: 3 T:1 P:2

Syllabus...



Computer Graphics System

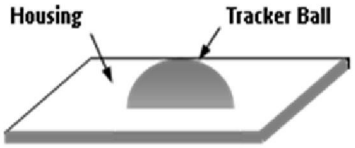
Syllabus...



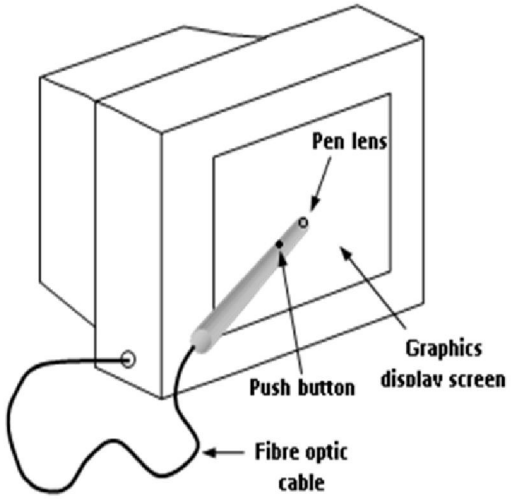
(a)

(b)

Cursor Control Input Devices
(a) Thumbwheels (b) Joystick



(a)



(b)

Cursor Control Input Devices
(a) Tracker ball (b) Light Pen

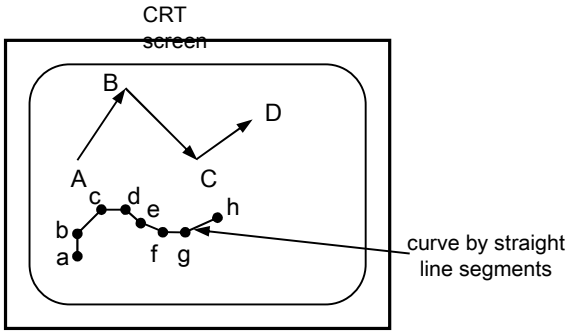
Graphics Input Devices

Computer Aided Design (BME-42)

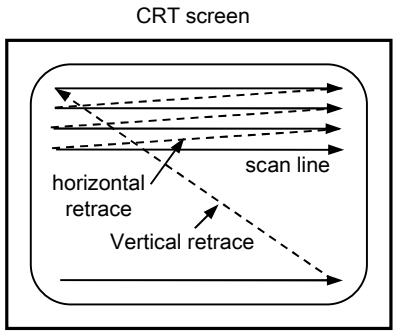
L: 3 T:1 P:2

Syllabus...

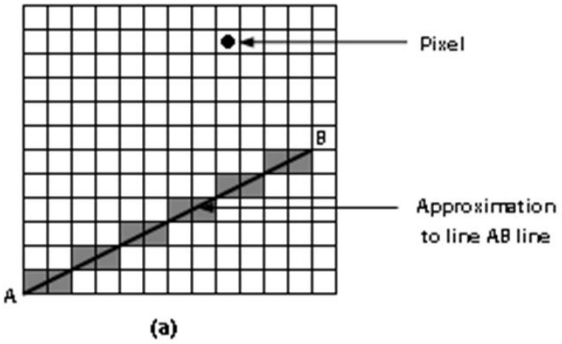
Random Scan Image Generation Technique



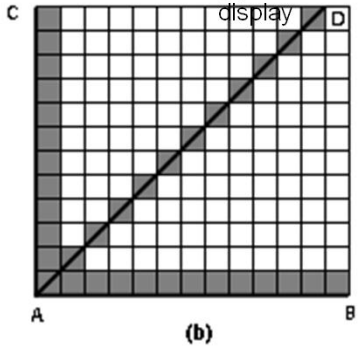
(a) Random scan display



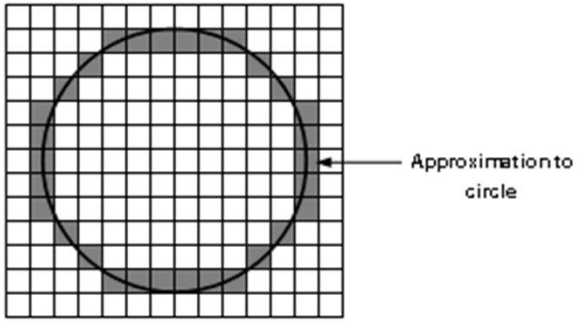
(b) Raster scan display



(a)



(b)



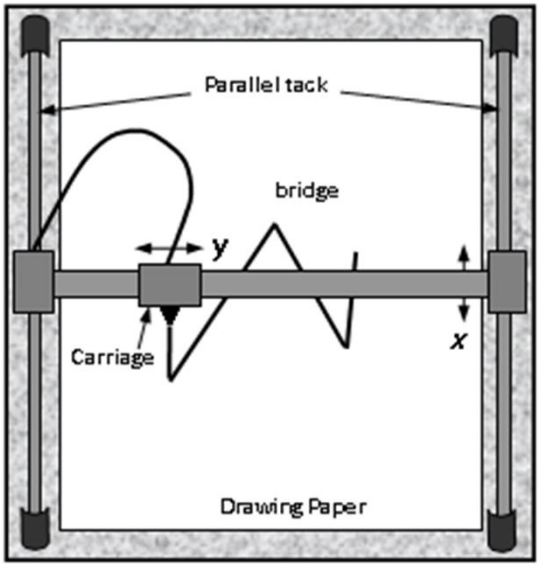
(c)

Raster Scan Image Generation Technique

Computer Aided Design (BME-42)

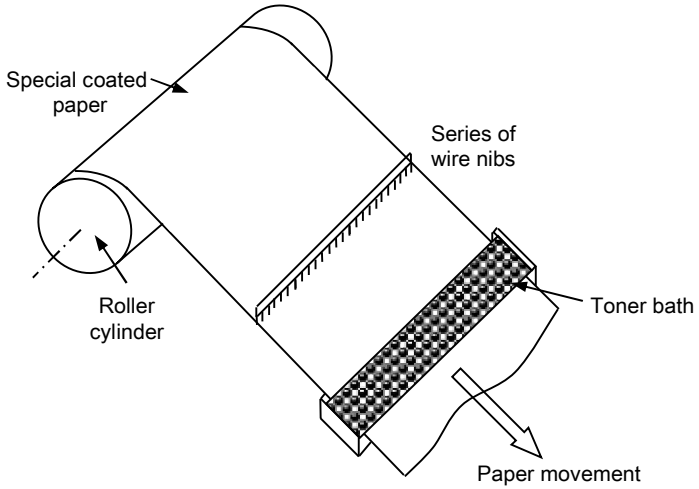
L: 3 T:1 P:2

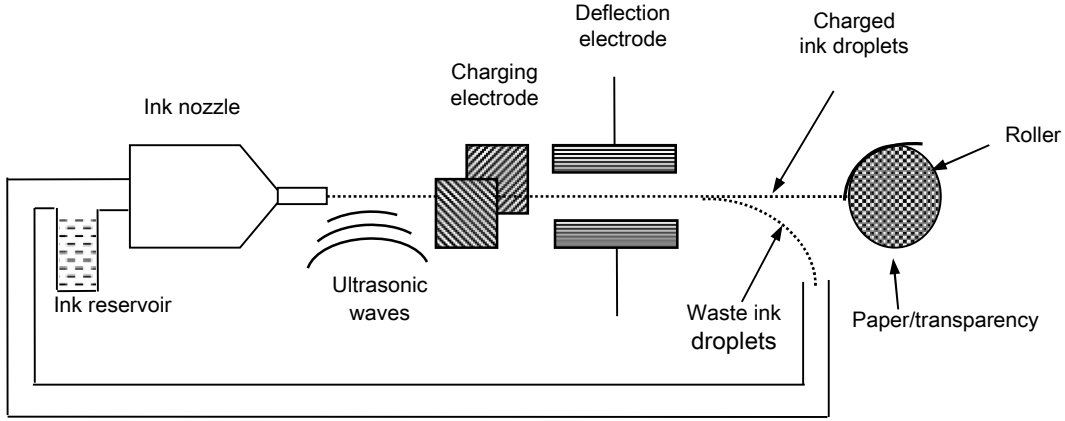
Syllabus...



Flatbed Plotter

Electrostatic Plotter





Inkjet printer

Syllabus...

Unit II

Computer Graphics Software (Lecture : 3)

Graphics Software, Software Configuration, Coordinate system, Graphics software functions, Viewing transformations-windowing and clipping, Graphics software standards

Output primitives (Lecture : 3)

Scan conversion of primitives, Line generation algorithms-DDA and Bresenham's line drawing algorithm, Circle generating algorithm-Cartesian coordinates, Polar coordinates and Bresenham's algorithm

Geometric Transformations (Lecture : 3)

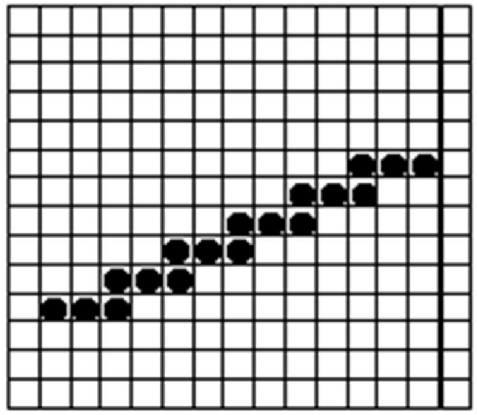
2D Geometric transformations-Translation, Scaling, Shearing, Rotation & Reflection Matrix representation-homogeneous coordinates, Rotation and scaling about arbitrary point, Reflection through arbitrary line, Composite transformation, 3 D transformations, multiple transformation

Computer Aided Design (BME-42)

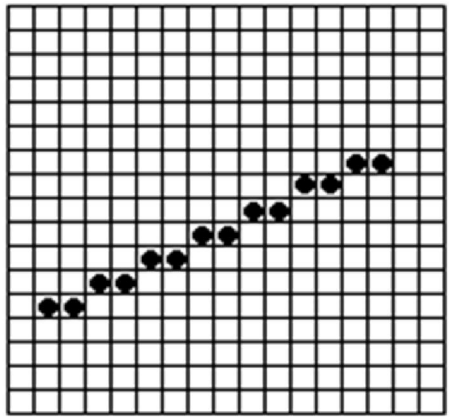
L: 3 T:1 P:2

Syllabus...

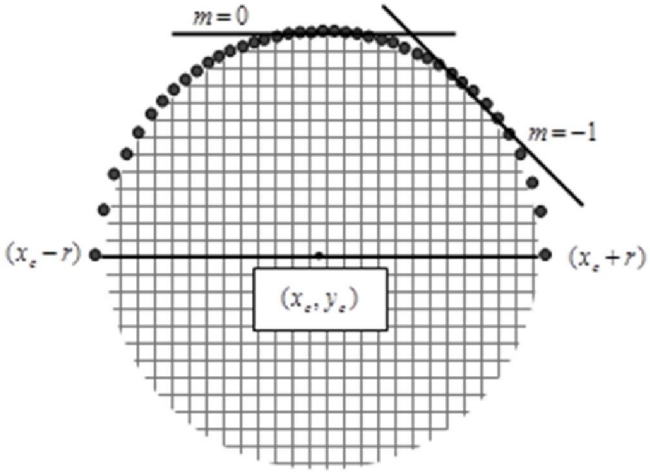
Staircase Effect on Raster Display



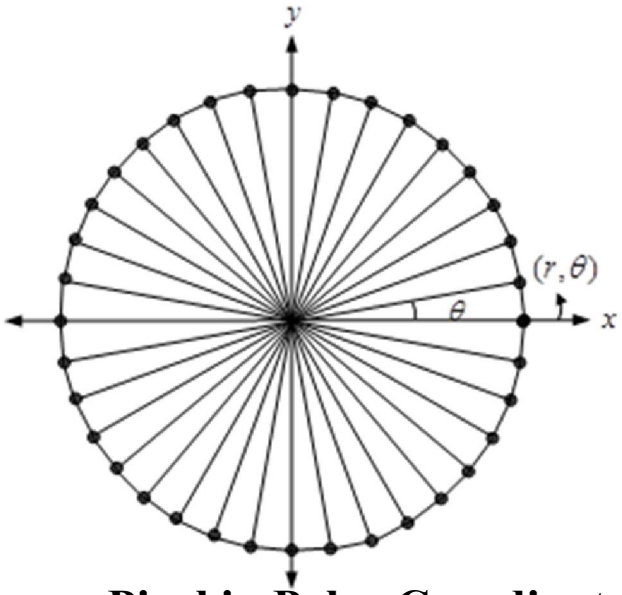
Line in low resolution device



Line in high resolution device



Pixel in Cartesian Coordinates



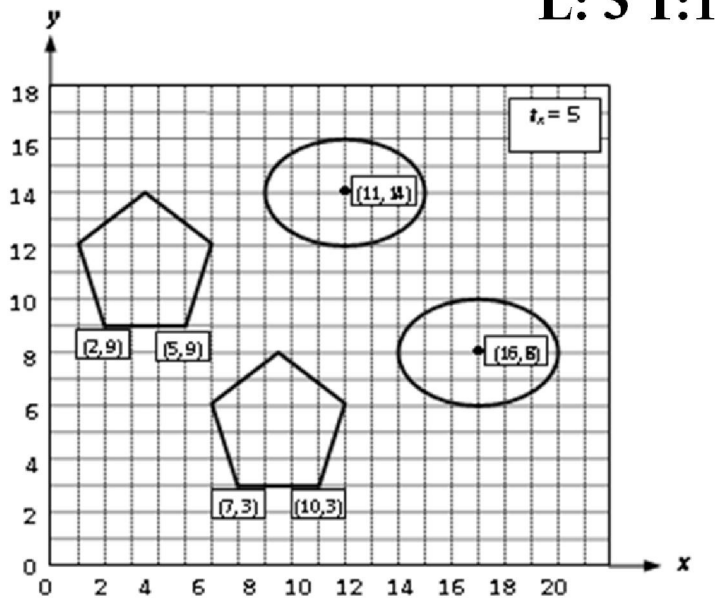
Pixel in Polar Coordinates

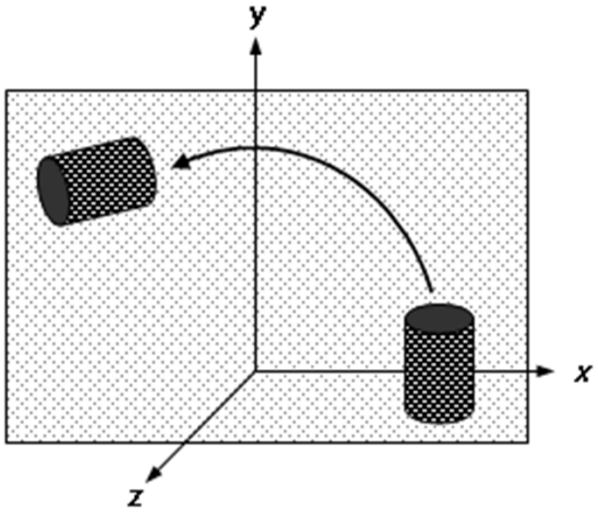
Computer Aided Design (BME-42)

L: 3 T:1 P:2

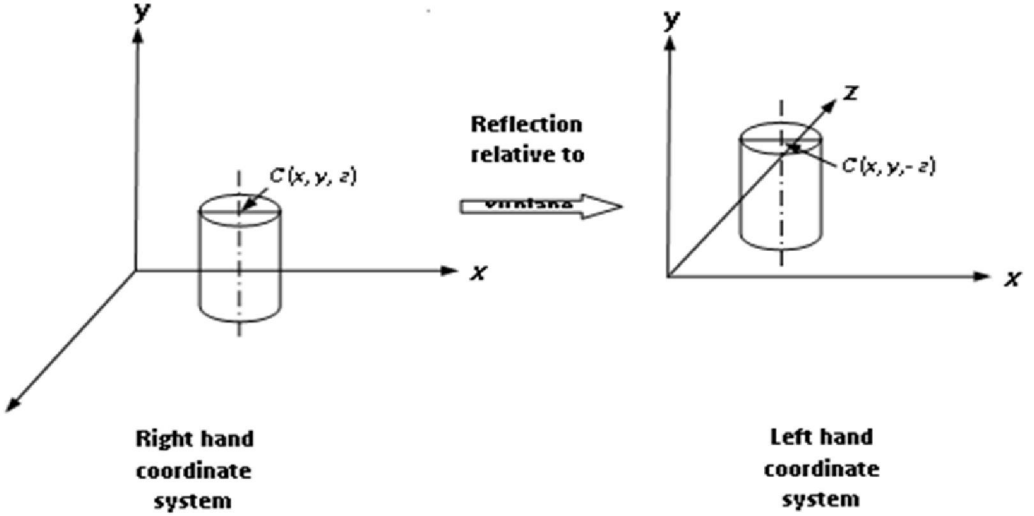
Syllabus...

Transition of Lamina and an Ellipse





Rotation of object about the z-ais



Reflection relative to xy-plane

Syllabus...

Unit III

Planar Curves (Lecture : 3)

Curves representation, Interpolation vs approximation, Classical representation of curves, Parametric analytic curves-lines, circles, ellipses, parabolas and hyperbolas

Space Curves (Lecture : 6)

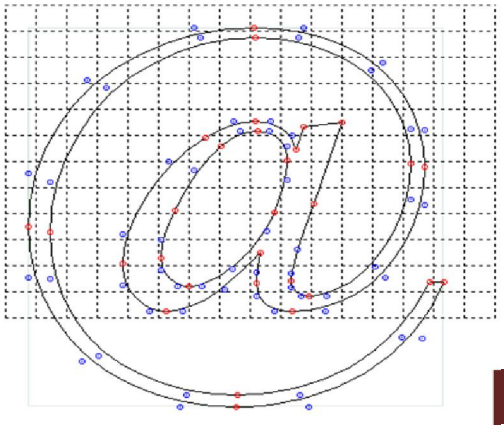
Properties for curve design, Parametric continuity, Parametric representation of synthetic curves, Spline curves and specifications, Parametric representation of synthetic curves, Hermite curves-Blending functions formulation, shape control, properties, Bezier curves-Blending functions formulation, properties, Composite Bezier curves, Non-rational B-spline curves- Blending functions formulation, knot vector, B-spline blending functions, properties

Syllabus...

Why Designing Curves?

- Design of products (e.g. CAD)

  Automotive, Aerospace, hydrospace industries
- Calculation of the path for a robot
- Design of fonts
  - Large sized fonts must be smooth
- Interpolating measuring data
- Approximating measuring data



Syllabus...

How to get Specific Shapes?

Different types of constraints are applied

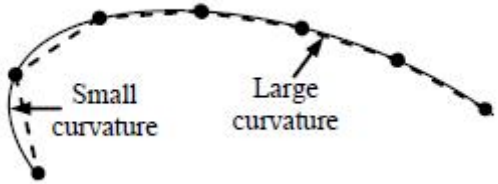
- Continuity conditions at the joint
- Curvature required

Non-evenly spaced data points

Different tools are available for manual drawing

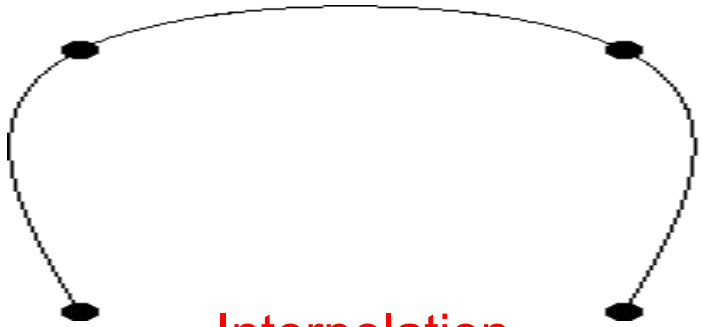
- Knives
- French Curves
- Compasses
- Splines
- Templates, etc.

Each tool is used for specific work



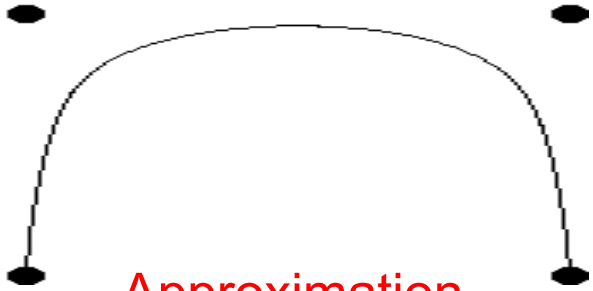
Evenly spaced data points

Syllabus...



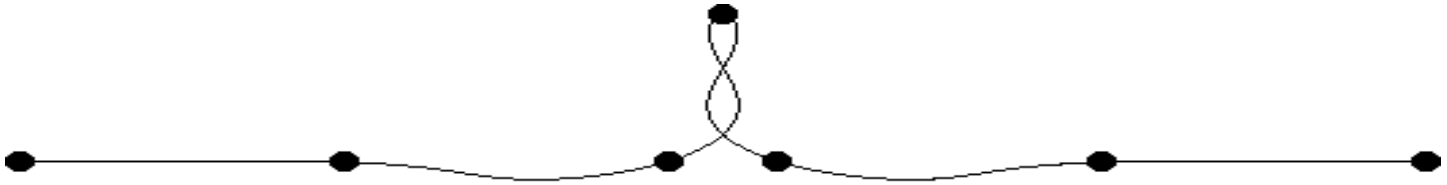
Interpolation

curve must pass through control points

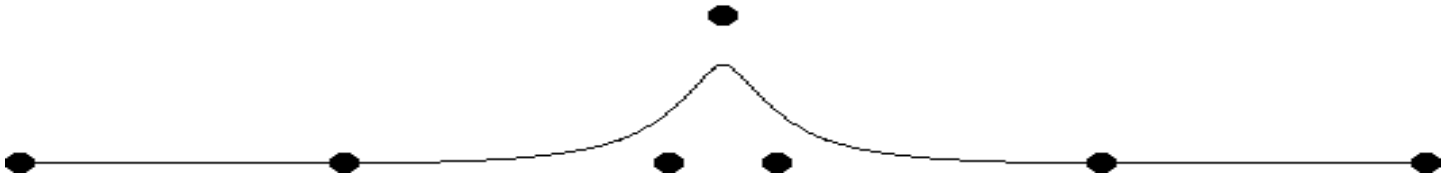


Approximation

curve is influenced by control points



Interpolation Curve – over constrained → lots of (undesirable?) oscillations

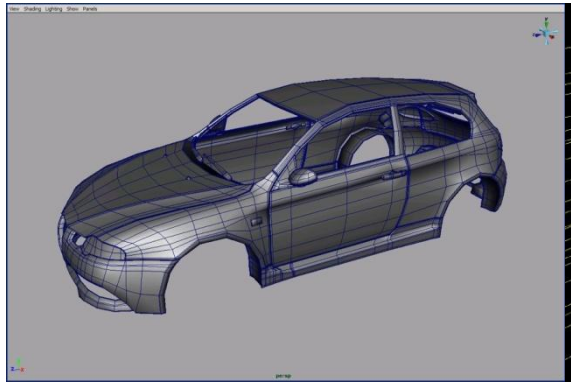


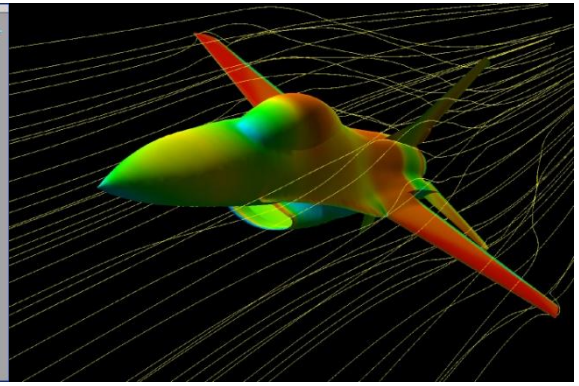
Approximation Curve – more reasonable?

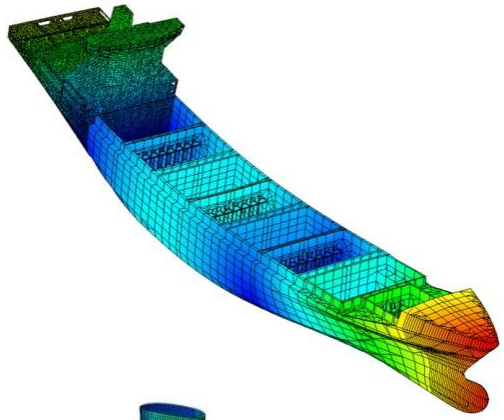
Syllabus...

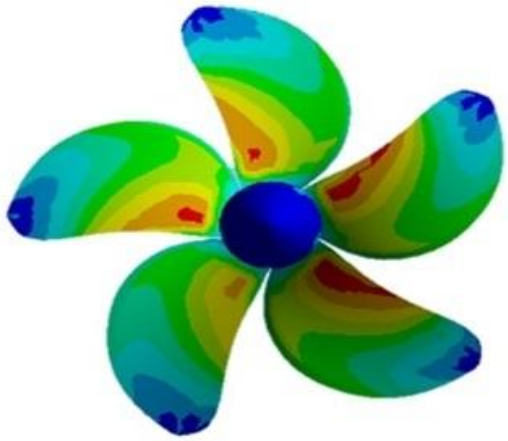
Synthetic Curves

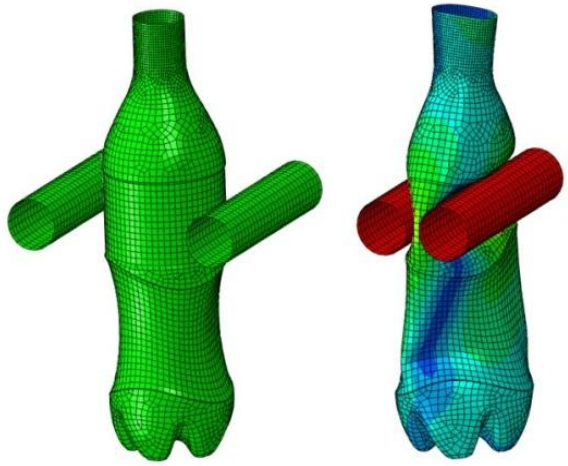
Space (three-dimensional) curves are mostly used in the design of automobile bodies, aerospace wings, ship hulls, propeller blades, shoes, bottles, etc.





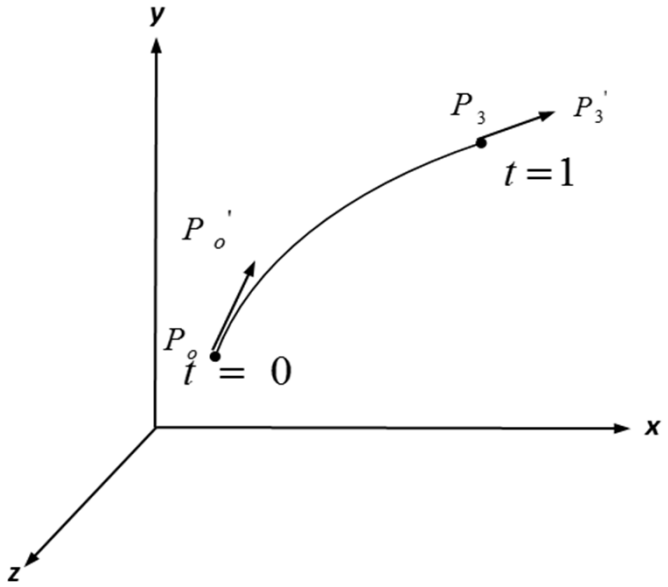




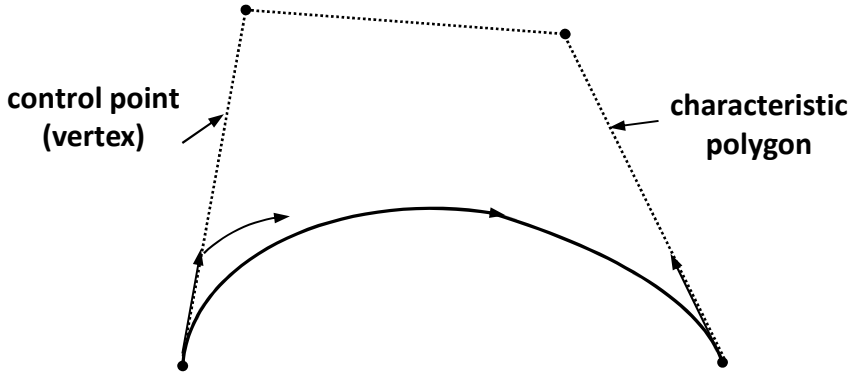


Syllabus...

Synthetic Curves…

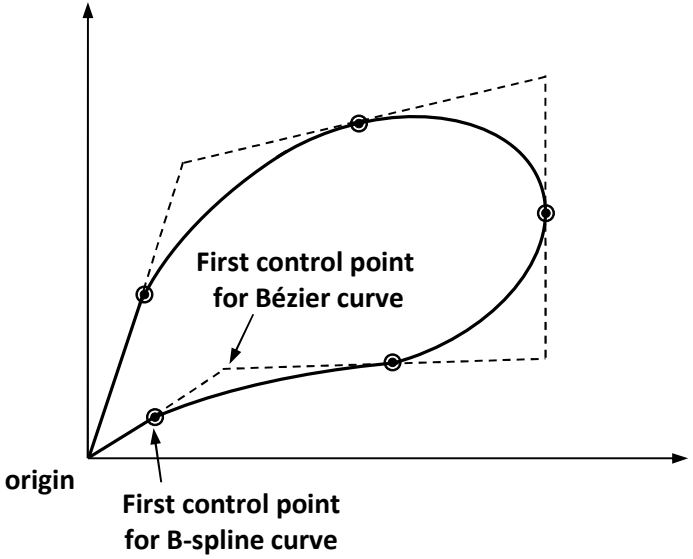


Hermite Curve



Bezier Curve

B-Spline Curve



Synthetic Curves

Unit IV

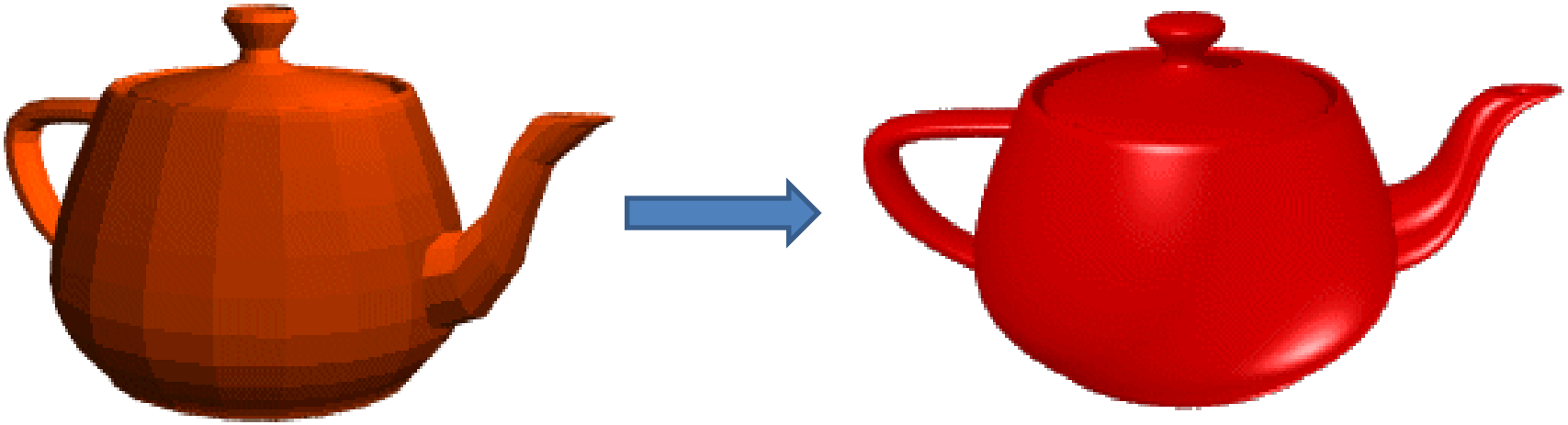
3D Graphics (Lecture : 7)

Introduction, Wireframe modeling, Surface modeling, Polygon surfaces-polygon meshes, polygon equations, Quadric and Superquadric surfaces, Blobby objects, Solid modeling-Boolean set operations, regularized set operations, Primitive instancing, Sweep representation-translational, rotational and hybrid sweeps, Boundary representation-topology, geometry, boundary models, Constructive solid geometry-unbounded and bounded primitives

Color models (Lecture : 2)

Coloring in computer graphics, RGB, CMY, YIQ, HSV and HLS color models

Syllabus...



Can We Disguise the Facets?

Experiments

Minimum Eight experiments are to be conducted from the followings:

1. Understanding and use of drafting software AutoCAD
2. Sketching and solid modeling of a machine component in any CAD software
3. Sketching and solid modeling of machine assembly in any CAD software
4. Writing and validation of line drawing algorithm
5. Writing and validation of circle drawing algorithm
6. Writing and validation of computer program for individual 2D/3D Geometric Transformation such as translation/ rotation/scaling
7. Writing and validation of computer program for 2D/3D Combined Geometric Transformations
8. Writing and validation of computer program for design of shaft under the combined bending and torsional loading
9. Writing and validation of a computer program for generating planar curves
10. Writing and validation of computer program for generating space curves

Computer Aided Design (BME-42)

L: 3 T:1 P:2

Books & References

1. Computer Graphics-Hearn & Baker, Prentice Hall of India
2. Computer Aided Engineering Design-Anupam Saxena & B. Sahay, Anamaya Publishers
3. CAD/CAM Theory and Practice- Ibrahim Zeid & R Sivasubramaniam, McGraw Hill
4. Mathematical Elements for Computer Graphics- DF Rogers & JA Adams, McGraw Hill
5. CAD/CAM-HP Groover & EW Zimmers, Jr, Prentice Hall India Ltd
6. Computer Aided Design-S.K. Srivastava, IK International Publications
7. Computer Aided Design-R.K. Srivastava, Umesh Publications

COMPUTER AIDED DESIGN
(BME-42)

Unit-I: Introduction

- Computer in Engineering Design
- Classical Vs. Computer Aided Design
- Elements of CAD
- Essential Requirements of CAD
- CAD Tools
- Concepts of Integrated CAD/CAM
- Necessity and Benefits
- Engineering Applications

Lecture 2

Topics Covered

Conventional Product Cycle

Engineering Design

Design Process

Shigley Design Process

Computer in Engineering Design

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CONVENTIONAL PRODUCT CYCLE

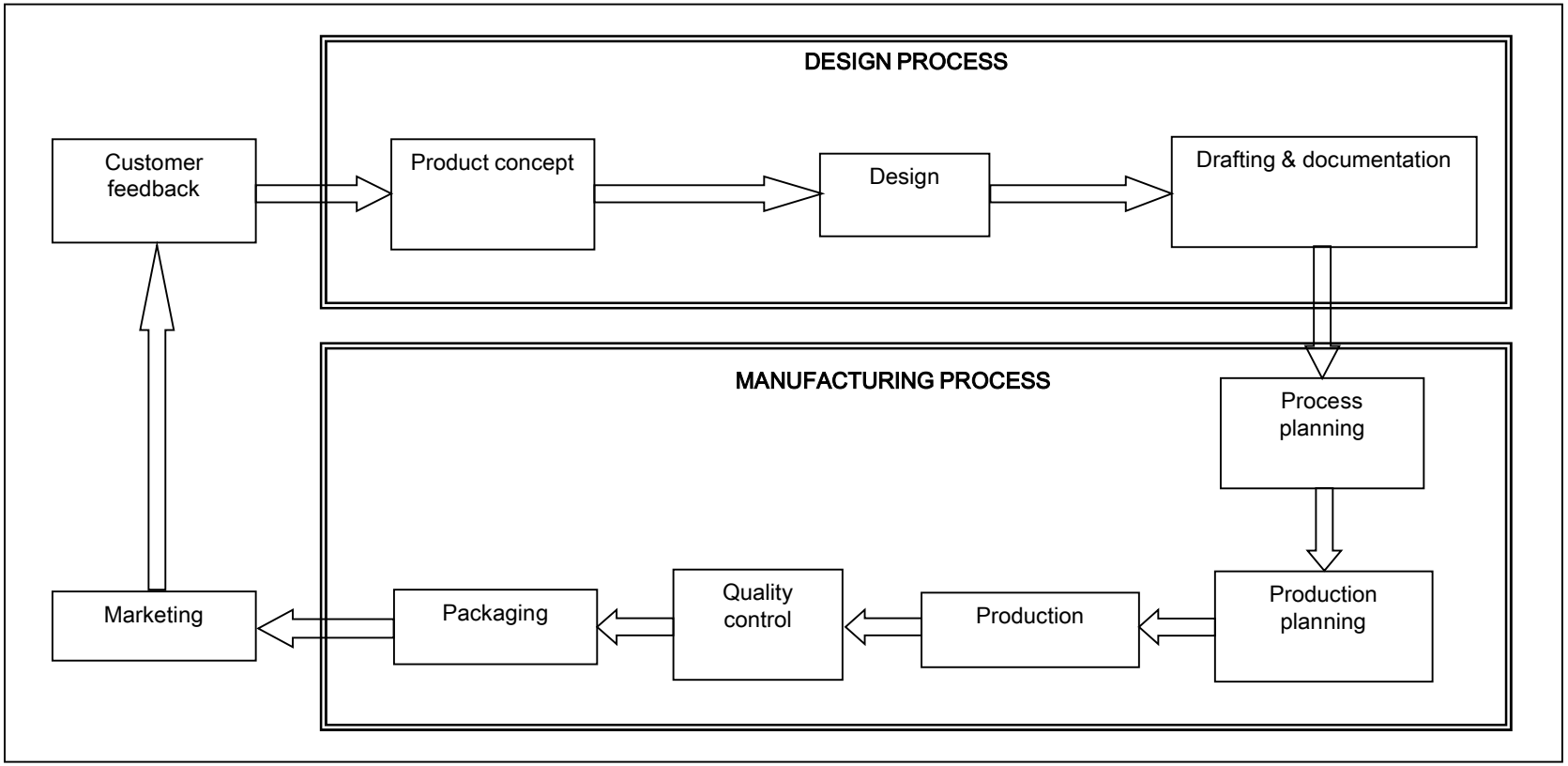
Stages In Design to Draft and Document

- Synthesis, Analysis, Optimization, etc.
- Components drawing, Assembly drawing,
- Material specifications, etc.

Stages In Manufacture

- Process planning (sequence of the manufacturing operations)
- Production planning and actual manufacture
- Inspection and testing of products
- Packing and Shipping for Marketing

CONVENTIONAL PRODUCT CYCLE



ENGINEERING DESIGN

Engineering design is a creative activity; where creative skills of the designer are used with the help of engineering knowledge, he/she has acquired to produce the design of an engineering component or a system.

OR

Design is an activity that facilitates the realization of new products and processes through which technology satisfy the human needs and aspirations.

OR

Design is a plan to develop a component/contrivance (device or mechanical invention) to satisfy the human needs, e.g. low cost, high reliability, good appearance, etc.

CONVENTIONAL DESIGN PROCESS

There are many ways of defining the steps in a traditional design process. In **1975, Deutschman** summarized the design process in the following Nine steps:

1. Recognition of need
2. Problem definition and specification
3. Feasibility study
4. Design synthesis
5. Analysis and preliminary design
6. Detailed design
7. Prototype building and testing
8. Design for mass production
9. Product release

SHIGLEY DESIGN PROCESS…

(Conventional or Classical Design)

In 1983, Shigley has combined few of the design steps and redefined the design process in **Six** steps as follows:

1. Recognition of Need

The product begins with a need based on market survey and customers' demand. The data is collected via *observation* and/or a *detailed survey*. There may be:

- **Adoption of existing design**
- **Modifications in the existing design**
- **Completely new design**

2. Problem Definition (Specification)

The designer's task is defined and criterion for the performance of designed product is specified. The designer collects different information

- *about the existing products of similar type,*
- *about the market potential,*
- *about the manufacturing constraints,*
- *about the legal requirements and standards, and so on.*

The specifications, constraints and design criteria may be:

- *Specifications* (power required, life of product, efficiency, reliability, cost, temperature range, etc.)
- *Constraints* (maximum and minimum values of the specifications)
- *Criteria* (used to decide the goodness of the design amongst the alternative design process)

For example, for shaft design, the strength and stiffness criteria should be specified; diameter of the shaft based on particular theory of failure, etc.

SHIGLEY DESIGN PROCESS…

(Conventional or Classical Design)

3. Synthesis (Conceptualization)

Synthesis requires a sound technical background, creativity and experience of the designer.

- Synthesis forms, a design solution to satisfy the need.
- The end goal of synthesis is a conceptual design of the product.
- Synthesis subprocess generates the information regarding design of the product.
- In this phase, sketches of different components and assembly are drawn.

The feedback received from the marketing professionals also helps to build up a strong concept of design.

The design parameters are adjusted to get a perfect fit; if fit does not occur, the designer can change the specifications or sometimes even modify the Need specified in Step 1.

SHIGLEY DESIGN PROCESS…

(Conventional or Classical Design)

4. Analysis and Optimization

- Every synthesis must follow the analysis.
- Analysis is a highly iterative process and requires a good mathematical knowledge.
- Analysis means critically examining an already existing or proposed design to judge the suitability for the task that is to be performed by the designer.
- Analysis determines whether the performance complies with the requirements or not.
- The analysis subprocess selects suitable material and its associative mechanical properties.

Calculations are performed to determine the *size* or *parameters* using the physical laws (i.e., laws of momentum, motion, energy conservation etc.).

4. Analysis and Optimization…

The different types of engineering analyses are

- *Stress-strain* analysis,
- *Kinematic* analysis,
- *Dynamic* analysis,
- *Vibration* analysis,
- *Thermal* analysis,
- *Fluid-flow* analysis, etc.

Optimization means the best possible solution for the given objectives. All possible solutions are analyzed and optimum is selected.

After every phase of design process, the designer may go to the previous steps and modify them.

SHIGLEY DESIGN PROCESS…

(Conventional or Classical Design)

5. Design Review (Evaluation)

- Measuring the design against the specifications set in the problem definition.
- Involves prototype building and testing of the product to ascertain operating performance or factors such as reliability.
- Evaluation phase may yield a satisfactory design or it may lead to the further modifications in the design parameters.
- The changes into the prototype assembly are incorporated during continued testing of the product.
- Process is repeated until satisfactory performance of the component and/or assembly is achieved.

After every phase of design process, the designer may go to the previous steps and modify them.

SHIGLEY DESIGN PROCESS…

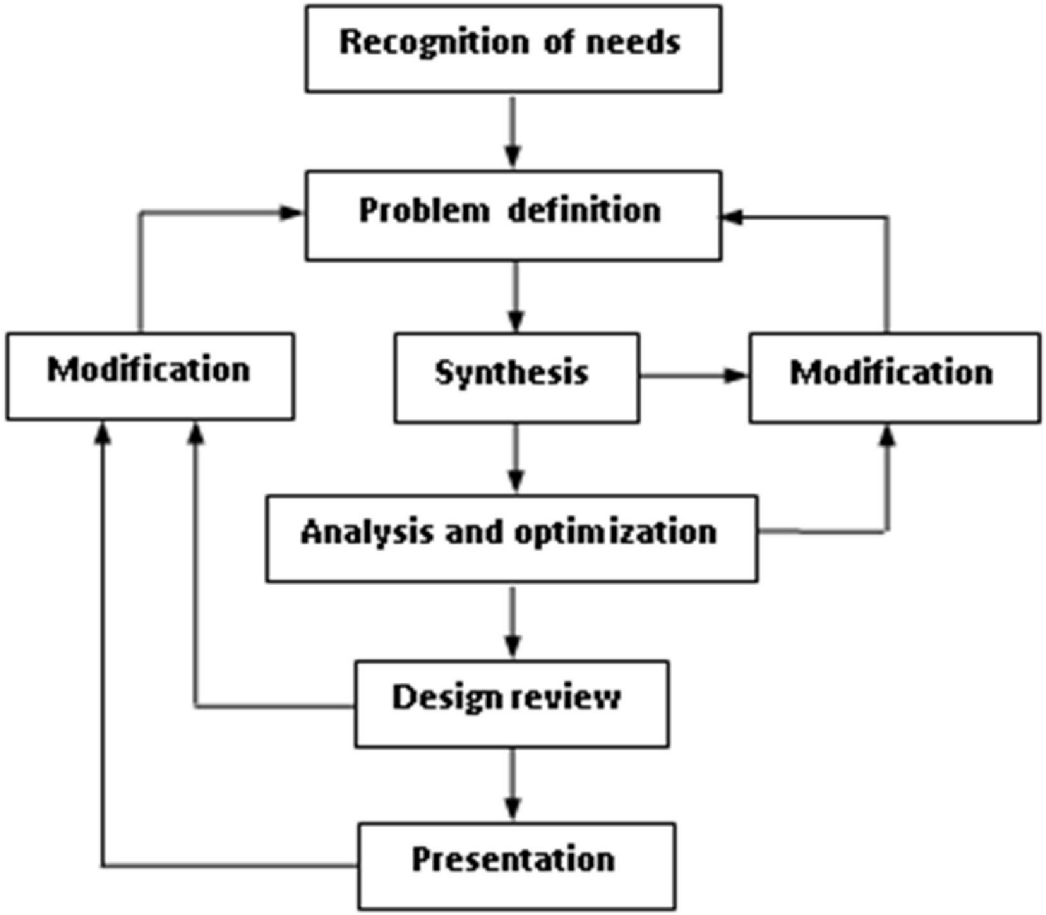
(Conventional or Classical Design)

6. Presentation (Drafting)

- The final stage in design process is the presentation and documentation of design on the paper.
- This forms an interface between the *design* and the *manufacture*.
- Production drawing shows various design parameters, machining parameters, tolerances, etc.
- The design is presented using the drawings, parts list, materials specifications, etc.
- The design is not complete if one cannot sell it; therefore, a great deal of effort should be applied in the presentation of design.

If presentation is not satisfactory, the designer may go to the previous steps and modify them.

SHIGLEY DESIGN PROCESS…



Block Diagram of Conventional or Classical Design

COMPUTER IN ENGINEERING DESIGN

- In recent years, there is rapid development in the fields of Computers in both **Hardware** and **Software**.
- It has become the most important tool in all the technological development due to **larger in memory** and **faster in computation speed**.
- With the advancement of very large scale integration technology (VLASI), the computer hardware is gradually getting cheaper and they are within the financial range of most of the industries/organizations.
- The entry of computers in design and manufacturing has led to the emergence of new areas known as **Computer Aided Design (CAD)** and **Computer Aided Manufacturing (CAM).**

COMPUTER IN ENGINEERING DESIGN…

- Traditionally, the Design and Manufacturing are the two **separate activities**.
- The integration of CAD/CAM systems is a **boon** for the design and manufacturing of engineering products.
- The term CAD/CAM is associated with the application of computers to-
  - the manufacture of products starting from the drawing office to the machine tools on production floor,
  - assembly shop to the quality control department,
  - stores department for the shipping, and
  - finally to the dealers for the marketing.

COMPUTER IN ENGINEERING DESIGN…

Designer Vs Computer

- A designer has a creative skill, imagination, judgment, based on his engineering knowledge and experience. However, a computer can perform systematic reasoning using the program stored in it called as *Artificial Intelligence or Expert Systems*.
- A designer can use his organs such as eyes, ears etc. to pass the information to the brain in parallel. However, computer requires sequential input through the graphics input devices.
- Computer requires large amount of programming to properly organize and store the information as compared to little effort done by the designer for the same.
- The volume of information stored by the designer is far less than that stored by the computer during the same time. However, the human brain cannot store the information for a longer period.

COMPUTER IN ENGINEERING DESIGN…

Designer Vs Computer

- The errors committed by the designer are more frequent as compared to that of a computer.
- The designer has good intuitive analysis capability whereas computer possesses excellent analytical power.
- The Computer can perform finite element analysis of complex shape mechanical components subjected to the complicated loading conditions very effectively and efficiently. Computer is fast and accurate.
- Design iteration and improvement activities is performed in computer very efficiently once the product is generated through the geometric modeling techniques such as wireframe, surface or solid modeling.
- A designer can perform the finite element analysis and optimization simultaneously.

COMPUTER IN ENGINEERING DESIGN…

Designer Vs Computer…

- The benefits of use of computer in drafting process is thought of due to the higher drafting productivity, fast editing, easy and compact storage and consistency of the drawing.
- Prototype of the product is cost effective in computer compared to the same obtained by the conventional design process.
- Computers are capable of performing *simulation* and *animation* of a model for the known input conditions.

COMPUTER IN ENGINEERING DESIGN…

Computer as a Design Tool

- Designers use the paper and pencil to carry out the designs of components/assembly.
- Design starts from conceptualization to the drafting stage, the ideas are expressed on a paper which is a passive activity.
- Computer Aided Design uses computer as a tool/medium that consists of input and output devices, arithmetic and control units, and a memory.
- The software (program of instructions), tells the computer how to process data, i.e., it includes all types of programming instructions that facilitate the utilization of computer hardware.
- A designer should have software and hardware knowledge to carry out the design process **effectively** and **efficiently**.

COMPUTER AIDED DESIGN
(BME-42)

Unit-I: Introduction

- Computer in Engineering Design
- Classical Vs. Computer Aided Design
- Elements of CAD
- Essential Requirements of CAD
- CAD Tools
- Concepts of Integrated CAD/CAM
- Necessity and Benefits
- Engineering Applications

Lecture 3

Topics Covered

Computer Aided Design

Computer Supports in Design and Manufacturing

Activities of CAD

Flow Chart for CAD

CAD Tools for Design Process

Integrated CAD/CAM System

Essential Requirements of CAD System

Application Software

Necessity & Benefits of CAD

Engineering Applications of CAD

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COMPUTER AIDED DESIGN

CAD creates 3D geometric model on computer to examine the geometric and manufacturing requirements of an object.

CAD is defined as-

- *Computer aided design is the **automation** of design process.*

OR

- *CAD is the use of computer to aid in the design process of an **individual part, a subsystem or a total system.***

OR

- *CAD is the process of **creation and development of a prototype** on a computer to assist the engineer in the design process.*

The powerful Hardware and Software tools of CAD offers scope in conventional design process, which results into the improvement of quality of the product.

COMPUTER SUPPORTS IN DESIGN AND MANUFACTURING

Computer Aided Design and Drafting (CADD)

Combining the CAD system with drafting software to generate the production drawing of the product

Computer Aided Engineering (CAE)

The use of computer to support basic error checking, analysis, optimization, manufacturability, etc. of a product

Computer Aided Process Planning (CAPP)

The use of computer to generate the process plans for the complete manufacture of a product

Computer Aided Planning (CAP)

The use of computers for different planning functions such as materials requirement planning, scheduling, etc. of a product

COMPUTER SUPORTS IN DESIGN AND MANUFACTURING…

Computer Aided Manufacturing (CAM)

- CAM is the automation of manufacturing process.
- CAM uses the software for the development of Computer Numerical Control (CNC) part programs for machining and other processing applications.

Computer Integrated Manufacturing (CIM)

- CIM integrates CAD/CAM system that controls all activities from *planning*, *design*, *manufacturing* and *shipping* of the products.
- The aim of CIM is to *optimize* the entire operation from *design to manufacture to sale* of a product.

ACTIVITIES OF CAD

1. Computer Aided Synthesis

- The designer creates components to meet the functional requirements of design.
- The process of selecting the mechanism (or configuration) of the system, size and shapes of the components to achieve the desired output for the given input.
- The information gathered is *qualitative*; therefore, the use of computer in design synthesis is hard to justify.
- Instead of putting ideas on the paper, they are created on the computer screen.

Geometric Modeling

Geometric modeling (synthesis subprocess) generates the mathematical model in the computer database, and generates the image on graphics screen using the following **three** types of commands:

I. Generate the 2D (points, lines, circles, etc.) and 3D (sphere, cylinder, cube, etc.) geometric entities on the screen

II. Apply appropriate geometric transformations (translation, rotation, reflection, etc.) to these graphics elements

III. Join these elements into the desired shape to generate the model

ACTIVITIES OF CAD…

1. Computer Aided Synthesis…

- In synthesis subprocess, it is required to modify the shape of different components number of times to get the desired object.
- Since the geometric model is stored in the computer database; therefore, number of iterations are required.
- A suitable computer program accepts the ideas from the designer and transforms it on the computer for proper presentation.

Artificial Intelligence (AI) or Expert Systems

- These programs can solve the design problems by utilizing the same domain of **knowledge** and **heuristics** as used by the experts.
- Expert systems can perform the tasks of experts because they simulate the expert judgement.
- The use of Expert Systems have revolutionized the process of synthesis during the design phase; however, good decisions require huge **experience** and as much **information** as possible.

ACTIVITIES OF CAD…

2. Computer Aided Analysis and Optimization

- For the complex shaped objects, it is very difficult or sometimes impossible to carry out the manual analysis number of times until the optimum solution is obtained.
- Optimum solution gives the best design for the given ***objective function*** (e.g., low cost, least weight, high efficiency, etc) under the specified ***constrains*** (minimum and maximum values of the design parameters).
- Use of specialized and/or general-purpose software to perform the normal calculations.
- Problems, which are difficult to solve manually, can be solved using computer as a tool.
- As a relief from routine calculations, the designer's ***creativity*** and ***efficiency*** increases drastically.

ACTIVITIES OF CAD…

2. Computer Aided Analysis and Optimization…

- The analyses of complex shape objects are carried out using the **Finite Element Analysis (FEA)** software.
- FEA is applicable for the ***complex geometry*** and **complicated loading** conditions.
- The finite element computational method models the **complex shapes** (e.g., turbine blades, machinery shapes, aerodynamic shapes, etc) with a set of **simple elements** interconnected at finite set of points called ***nodes***.
- The stiffness of each element expresses in terms of the stiffness matrix.
- By combining all the stiffness matrices and applying ***kinematics*** and **stress boundary conditions**, the unknown ***displacements*** or ***stresses*** for each element can be calculated, and presented in textual and graphical form on the graphics display devices.

ACTIVITIES OF CAD…

3. Computer Aided Drafting

- Design is finally represented in the form of drawing to carry out the production.
- For most of the design process, the drafter consumes about sixty percent time for the preparation of drawings.
- Use of computers in drafting process has been recognized as a separate field known as *Computer Aided Drafting* or *Computer Aided Presentation*.
- The replacement of present manual drawings with the computers and specialized peripherals requires large investments.
- Computer aided drafting utilizes the computer for creation of 2D drawings directly from the geometric model.
- For better visualization, computer aided drafting generates automatically different sectional views of the parts/assembly.

ACTIVITIES OF CAD…

3. Computer Aided Drafting…

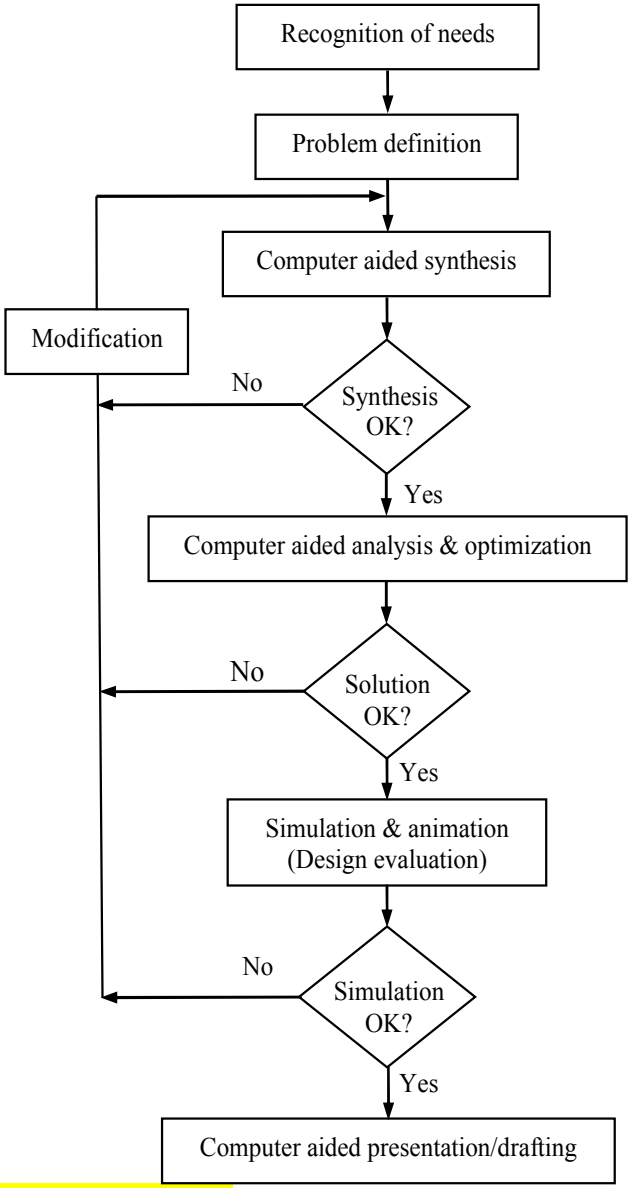
- In CAD, it is possible to visualize a 3D solid model from any orientation on the computer screen.
- The visualization is improved by incorporating different colors and shades. Apart from the visualization, CAD also generates the textual information of parts/assembly like parts list, materials properties, preparation of bar charts and other graphical information directly from the geometric model.

The benefits of use of computer in the drafting process are:

- **Improved quality of drawings**
- **Fast speed of drafting productivity (approximately four times faster than the conventional drafting) with improved consistency**
- **Fast editing facility**
- **Capability of easy and compact storage**

FLOW CHART FOR CAD

Block Diagram of Computer Aided Design



CAD TOOLS FOR DESIGN PROCESS

Table lists the CAD tools required to support various activities of the design process.

Design Phases	**CAD tool(s)**
Computer aided synthesis, modeling and simulation	3D modeling techniques, graphics manipulation and visualization
Computer aided analysis	Analysis packages for customized applications
Computer aided optimization	Structural optimization packages
Computer aided evaluation	Dimensioning, tolerance analysis, bill of materials, NC packages
Computer aided communication and documentation	Drafting and detailing, components and assembly drawing, color and shaded images

INTEGRATED CAD/CAM SYSTEM

The integrated CAD/CAM is concerned with the application of computers in the manufacturing of engineering products starting from-

- the drawing office
- to the production department
- to the machine and assembly shops
- to the quality control department
- to the finished part storage

The CAD/CAM integration presents an *efficient, accurate and consistent* method to design and manufacture the high quality products.

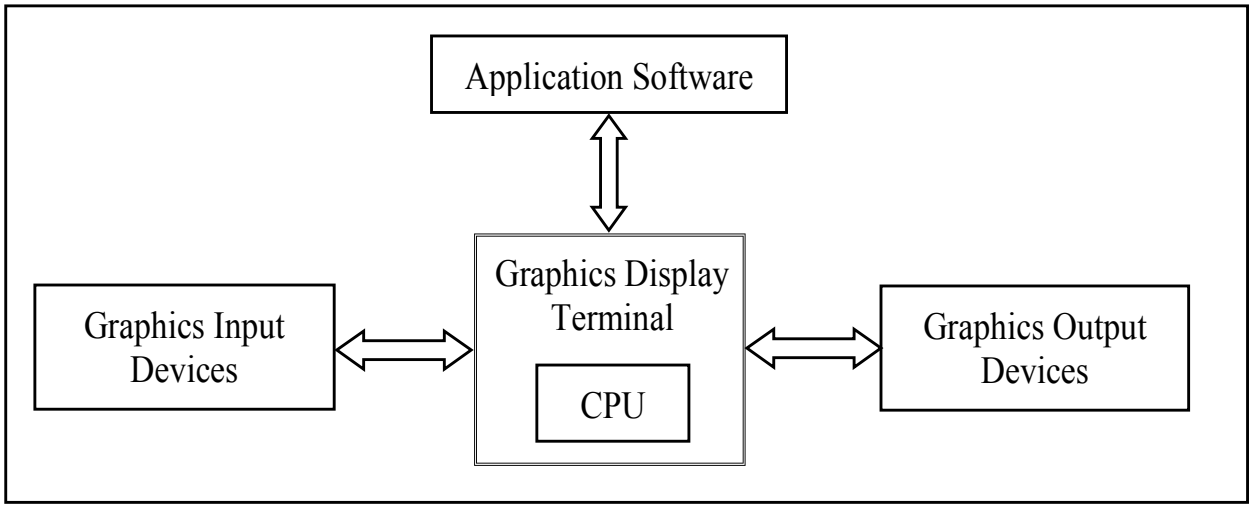
Here, the CAD and CAM activities are connected with a central server/database.

ESSENTIAL REQUIREMENTS OF CAD SYSTEM

Figure shows the complete CAD system which consists

- Central processing Unit (CPU)
- Graphics display terminal (for controlling the size, color and resolution of graphics and text),
- Graphics input devices (keyboard, scanner, digitizer, light pen, etc.),
- Graphics output devices (CD, printer, plotter, film, magnetic tape recorder, etc.)
- Application software such as
  - Analysis software
  - Drafting software
  - Complete CAD software

ESSENTIAL REQUIREMENTS OF CAD SYSTEM



CAD Hardware and Software

APPLICATION SOFTWARE

- No software is complete in itself
- Some are better in modeling while some are suitable for the manufacturing, simulation and some are better for the analysis.
- The selection of particular software for the specific applications depends upon the experience gained by the designer.
- In general, there are three types of application software:
  - ***Analysis Software***

    ANSYS, NISA, NASTRAN, ABAQUS, LISA, ALGOR, VisualFEA, SAP, COSMOS, ASKA, ADAMS, etc.
  - ***Drafting Software***

    AutoCAD, Solidedge, Versa CAD, SmartDraw, AutoSketch, DOGS, etc.
  - ***Complete CAD Software***

    ProEngineer, SolidWorks, IDEAS, CATIA, Unigraphics, MicroStation, etc.

NECESSITY & BENEFITS OF CAD

In recent years, designers debated the values of the followings:

- 3D model over 2D model
- Good visualization of solid model over wireframe model
- Shaded images over black/white images
- Coloured solids over grayscale solids.

- Due to enhancements in the computer hardware technology and its configuration, good visualization techniques, the designer's productivity and satisfaction level has increased drastically.
- Thus, it is desirable to equip the workstation with high-level graphics capabilities, which enhances the realism as well as increases the overall efficiency of the designer.
- The introduction of a CAD system increases the productivity and reduces the lead-time.

NECESSITY & BENEFITS OF CAD…

- Due to relief from the routine calculations, the use of CAD tool increases creativity of the designer with powerful innovative ideas.
- CAD has tremendous impact in automobile, aircraft and shipbuilding industries and in particular aircraft industries for developing the complex and aerodynamic surfaces.

Some of the important benefits of CAD are:

- CAD is faster, consistent and more accurate than the classical design process.
- The manipulation of various dimensions, attributes is easily possible under the CAD environment. Some CAD software is parametric and possesses parent-child relationship between the component and assembly.
- The efficiency, effectiveness and creativity of the designer improve drastically, leading to high quality engineering designs.

NECESSITY & BENEFITS OF CAD…

- The added advantages of CAD are excellent graphical representation and production drawing of product with exchange facility between different phases through *e*-drawing.
- Easy modification and improvement of product is possible in CAD environment taking care of future needs.
- In CAD, it is not required to repeat the design or drawing of any component with modified dimensions. It is possible to copy and modify the designs as per the new dimensions within seconds, including geometric transformations, material replacements, if needed.
- Graphics simulation and animation makes it possible to study the real time behaviour of CAD assembly. This is useful for inspecting tolerance and interference between the matching components of the model.

NECESSITY & BENEFITS OF CAD…

- Use of standard components in part libraries makes very fast CAD modeling. For specific task, various components/subassembly may be stored in part libraries for the future use.
- 3D visualization of model from several orientations eliminates the need of making prototype.
- The documentation at various design phases is efficient, easier, flexible and economical.
- The coordination among the groups and sharing of design data and results is possible in CAD environment.
- Most CAD software can link the geometric model directly to its manufacturing counterpart, i.e., CAM to carry out production.

ENGINEERING APPLICATIONS OF CAD

The CAD system is extensively used in mechanical engineering and manufacturing industries. The engineering applications of CAD are:

- ***Structural design of Aircraft***: CAD analyzes the turbulent flow pattern in aerospace structures.
- ***Aircraft Simulation***: The complex situation during the flight can be simulated in flight simulator using the CAD software, which avoids lengthy delay, saves fuel cost and provides better safety to the pilots.
- ***Real-time Simulation***: It is possible to study the real-time behavior and inspection of critical parts subjected to repeated stresses due to the mechanical loading. For example, the analysis of dynamic behavior of tractor parts when it travels on rough terrain. The parts prone to failure are redesigned.
- ***Automobiles Industries***: CAD provides various types of space curves for the aerodynamic designs of automobile surfaces.

ENGINEERING APPLICATIONS OF CAD…

- ***Architectural Design***: CAD has tremendous scope in architectural design of bridges, buildings, structures, etc. It is possible to estimate the building materials requirements for the similar designs with different design parameters.

- ***Pipe Routing and Plant Layout Design***: CAD design optimizes the pipe layout and plant layout in a chemical plant.

- ***Electronic Industries***: CAD is applicable in the design of Integrated Circuits (ICs) and printed circuit board design used in electronic equipment/machines.

- ***Dynamic Analysis of Mechanical Systems***: CAD design is useful for estimating the dynamic forces, reactive forces of mechanical systems at various time intervals.

ENGINEERING APPLICATIONS OF CAD…

- ***Kinematic Analysis***: Similar to dynamic force analysis, CAD estimates the kinematic quantities such as displacement, velocity and acceleration of various links for different configurations of the mechanism.

- ***Mesh Data Preparation for Finite Element Analysis***: The input data for FEA of a structure consists of geometrical and mechanical properties, loading and boundary conditions. CAD systems generate the best mesh data suitable to a particular problem. It is possible to represent data graphically to quickly guess the results.

COMPUTER AIDED DESIGN
(BME-42)

Unit-I: Computer Graphics Hardware

(6 Lectures)

- **Graphics systems**
- **Graphics Input devices: Cursor control devices,** Digitizers, Image scanner, Speech oriented devices,
- Graphics display devices-Cathode Ray Tube, Calligraphic display, DVST, Raster display, Color frame buffer, Color CRT monitors, Solid state monitors-emissive displays, non-emissive displays,
- Graphics output devices- Hard copy printers and plotters

Lecture 4

Topics Covered

Computer Graphics Systems
Interactive Computer Graphics
Graphics System Hardware
Graphics Input Devices
Cursor Control Devices
Thumbwheels, Joysticks, Mouse
Tracker ball, Light Pen,

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COMPUTER GRAPHICS SYSTEM

- Computer Graphics is a powerful tool for communication among members of design, manufacturing and sales of a product.
- It involves the creation, storage, manipulation of models and images of objects.
- The shaded and colored 2D, 3D and higher-dimensional models are generated to bring the realism such as natural scene, animation, flight simulation, navigation, commerce, etc.
- Possible to create the virtual reality such as walk through building, highways, flying in the sky using the graphics images.
- Tremendous impact on entertainment, automobile and aviation industries, business management, architecture, education, research, engineering, etc.
- Computer graphics is very powerful tool for the development of high quality pictures rapidly, consistently and economically.

INTERATIVE COMPUTER GRAPHICS

- Important tool in CAM wherein graphical data of the object, converted into machine data, operates CNC machines for the production.
- The presentation of stored information through pictures is a passive operation. The observer has no control over the pictures.
- A modern CAD system works on the principle of *Dynamic or Interactive Computer Graphics (ICG)*.
- Observer interacts with images on displays in real-time using graphics input devices such as keyboard, mouse, digitizers, touch sensitive panels, electronic tablet, etc.
- Interactive refers to the devices and systems that facilitate the man-machine graphics interaction in a way, which is more convenient than writing computer programs.
- To draw a straight line, one has to input end coordinates and run the software; however, in computer graphics, input devices directly generate the line.

Advantages and Applications

- The proverb ***a picture is worth ten thousand words*** became meaningful after the advent of simple and cost effective technology for producing pictures through ICG.
- The 2D and 3D patterns developed on the screen allow us to process pictorial data rapidly and efficiently.
- The dynamically varying (real time behavior) pictures present a better understanding during the simulation and animation process.
- The use of dynamics is more effective when the operator can control the animation by adjusting the speed, the portion of scene in view and other operating parameters.
- With increase in ability to understand the data, ICG creates higher quality precise products, with greater productivity and reduced analytical efforts and design costs.

GRAPHICS SYSTEMS HARDWARE

- ICG is extremely useful tool in teaching, research and industries.
- During the process of improvement, the simulation process evaluates the product. The interference between the various mating components is observed;
- The graphics capabilities of a computer system mainly depend on the **Hardware** attached to it and on the **Software** supports available.
- The conventional alphanumeric key-board together with the laser printer can be used for the image generation; however, the **quality** of images is not sufficient for many CAD applications.
- High quality graphics images are obtained from graphics hardware that consists of
  - **Graphics input devices**
  - **Graphics display devices**
  - **Graphics output devices**

GRAPHICS SYSTEMS HARDWARE…

Broadly, there are **Two** types of interaction between the user and graphics system.

- Graphics system that models ***one-to-many*** interaction wherein more than one designer team can interact with the host computer on time sharing basis
- Graphics system that models ***one-to-one*** interaction wherein each designer is allowed one-to-one interaction at a time

Based on host computer that drives the graphics system, there are **Three** types of graphics hardware:

I. Mainframe-based graphics systems

II. Minicomputer or workstation-based graphics systems

III. Microcomputer-based graphics systems

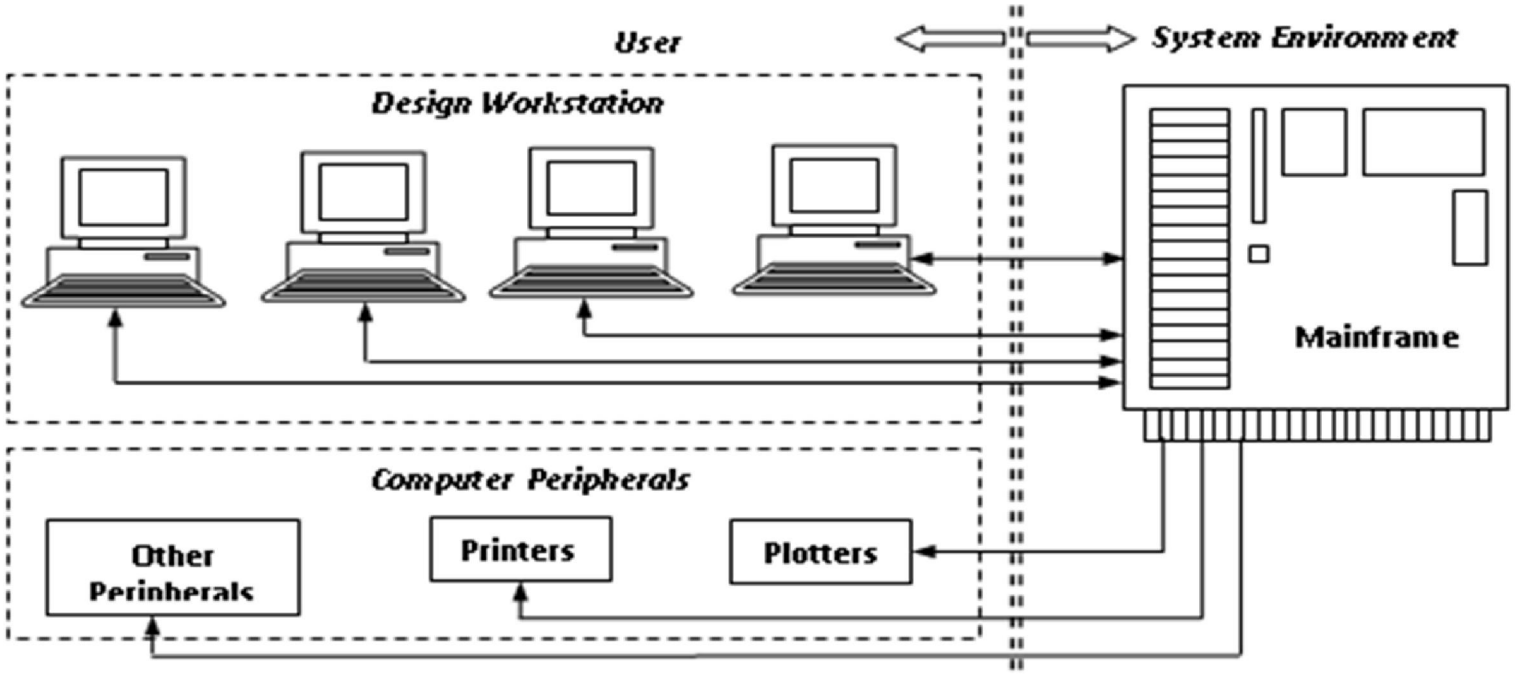
GRAPHICS SYSTEMS HARDWARE…

I. Mainframe-based Graphics Systems

- It uses a large mainframe computer on which the software is installed.
- The graphics system is networked to many design stations with separate graphics display and graphics input devices for each station, leading to ***one-to-many*** interface for the designer.
- Mainframe-based graphics systems can handle the ***intricate assemblies*** of engineering components such as aircrafts, ships, rockets that require different groups of designer.
- Overall graphics system is divided into the ***user*** environment and ***system*** environment.
- The user has access to the design stations and peripheral devices.
- The design workstation consist of ***graphics input devices*** and ***graphics display devices*** and ***graphics output devices*** The display screen shows the graphics images.

GRAPHICS SYSTEMS HARDWARE…

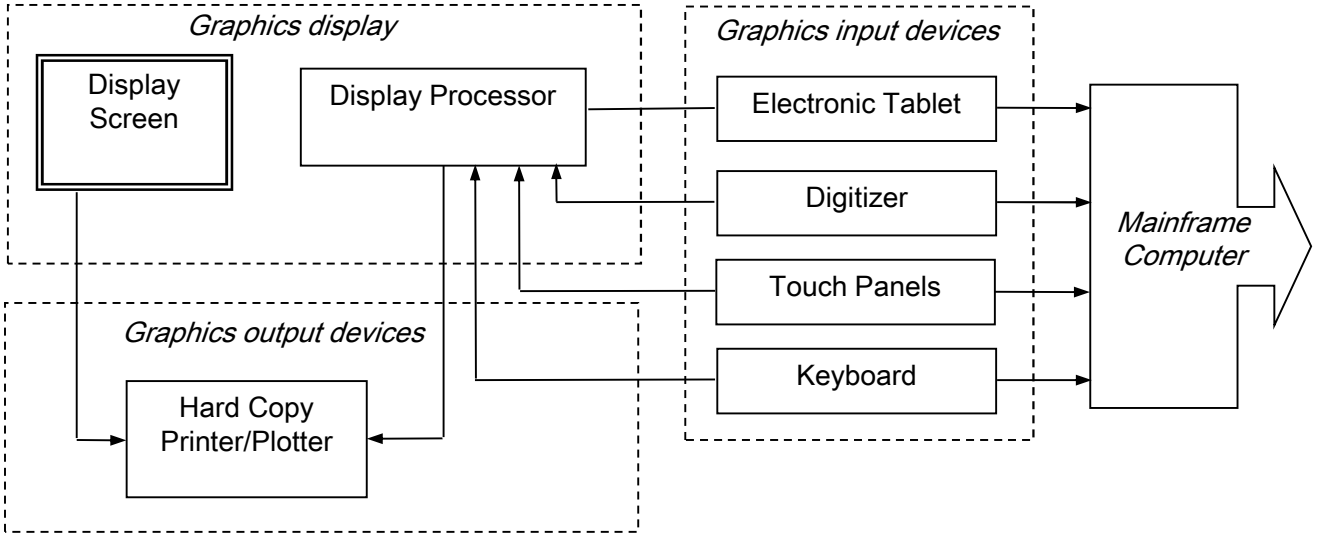
I. Mainframe-based Graphics Systems…



Mainframe-based graphics system
(divided into the *user* environment and *system* environment)

GRAPHICS SYSTEMS HARDWARE…

I. Mainframe-based Graphics Systems…



Design Workstation

Graphics input devices: Mouse, joystick, electronic tablet, digitizer, thumbwheel, etc.

Graphics output devices: Laser, inkjet, electrostatic, electrothermal type's hardcopy printer/plotter, etc.

GRAPHICS SYSTEMS HARDWARE…

II. Minicomputer-based Graphics Systems

- These systems also employ *one-to-many* interfaces between the designer and computer.
- The minicomputers employ LSI (Large Scale Integrated) and VLSI (Very Large Scale Integrated) circuit technologies.
- The graphics communication networked with *minicomputer systems is less costly than the mainframe-based systems.*
- The hardware for the minicomputer-based graphics system is like the mainframe system.
- These systems are smaller than the mainframe systems with limited numbers of display monitors and graphics input devices, and host computer is mini.
- The speed of minicomputer is low as compared to the mainframe system, but it is possible to increase it by using the additional devices such as array processors and other special purpose hardware chips.

GRAPHICS SYSTEMS HARDWARE…

III. Microcomputer-based Graphics Systems

- Microcomputer-based OR Personal Computer (PC), graphics systems provide ***one-to-one*** interaction between the computer and designer.

- Large number of CAD software (e.g., AutoCAD, ProEngineer, Solidworks, etc.) is compatible for the PCs from 2D drafting/presentation to 3D geometric modeling.

- Microcomputers have great impact on CAD/CAM systems, free from the problem of speed, size and accuracy and presents complete design and manufacturing solution.

- The microcomputers of 64-bit word length or more are available with very large memory (1 TB or more) and good clock rate speed (3 MHz or more).

Clock Rate Speed is the speed at which a microprocessor executes instructions

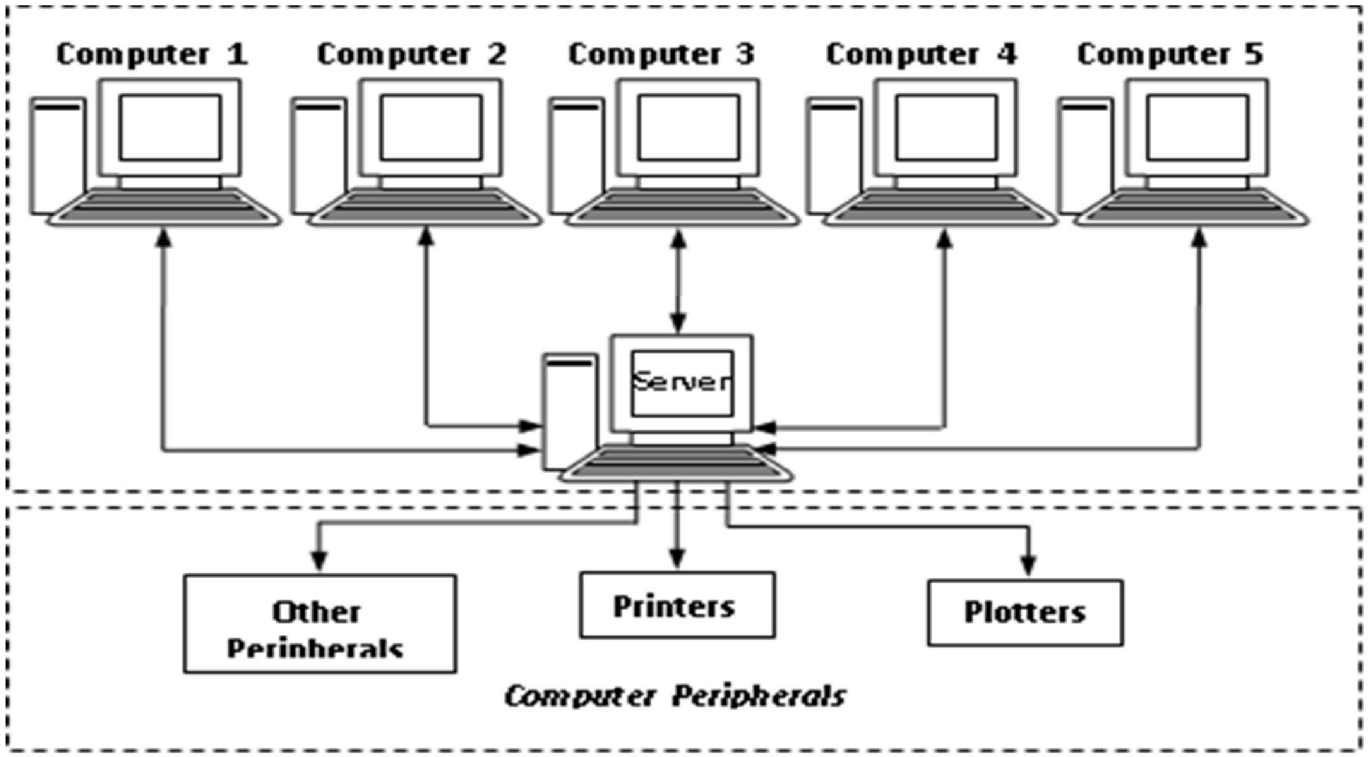
GRAPHICS SYSTEMS HARDWARE…

III. Microcomputer-based Graphics Systems…

- In PC based systems, one computer system works as a server. The other units are networked to the server.
- The peripherals are connected to the server and data is stored and retrieved from the server through the software installed in the server.

GRAPHICS SYSTEMS HARDWARE…

III. Microcomputer-based Graphics Systems…



The workstation-based system has the advantages of distributed computation and networking potential with low cost as compared with the mainframe graphics system.

GRAPHICS INPUT DEVICES

- Graphics input devices are the tools with which the designer interacts with the graphics system.
- The graphics software manipulates the object as per the design requirements and generates the results on the graphics display devices.
- The software driver is required for the graphics input devices to interpret the information (received from the input devices) and transform it to the output devices.
- The input devices are hardware independent after the acceptance of graphics standards such as GKS (Graphics Kernel System).
- Generally, *textual* and *graphical* information are required on the display devices
- Keyboards are normally suitable for the alphanumeric character input but keyboard arrow keys (cursor direction) are inadequate for most of the graphics applications.
- Commonly used graphics input devices are cursor control devices, digitizers, image scanners and speech-oriented devices.

GRAPHICS INPUT DEVICES…

Cursor Control Devices

- These graphics input devices specify locations of cursor on the screen, also called as *locators*.
- Thumb wheels, joysticks, tracker balls are the devices which controls the cursor without touching the screen by the user
- In other devices, the control of cursor occurs by directly touching the screen. All locating devices, except joystick, are 2D graphics input devices.

1. Thumb wheels

- Thumb wheel device uses two thumb wheels, one to control horizontal position of the cursor, the other to control vertical position.
- Sometimes, thumb wheels may be an integral part of the CRT (Cathode Ray Tube) terminal or keyboard.

Cursor Control Devices…

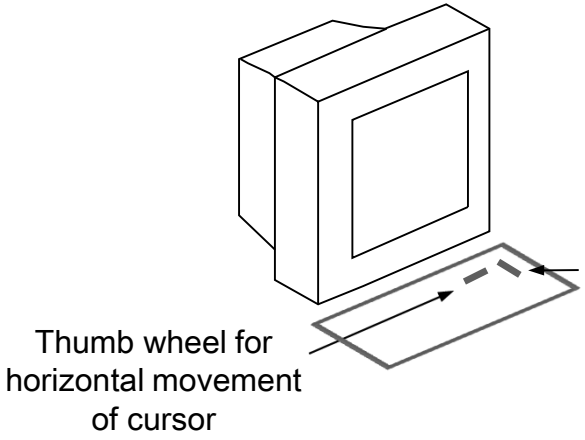
2. Joystick

- Joysticks consist of a box with a vertical toggle stick that works by pushing backward and forward or to the left or right causing the cursor to move in that direction.
- The stick is capable of moving towards the four corners of the screen; therefore, allowing eight directional movements of the cursor.
- A joystick indicates the direction, speed and duration of cursor motion, by the movement of the stick.
- A joystick is used as 3D input device by attaching a rotating knob on the top of stick that can be used to enter the third axis value.
- The stick can be twisted in the clockwise and anticlockwise directions. Due to an amplification factor, a slight change in the stick position significantly changes the cursor position; hence not preferred when accurate movement of cursor is desirable.

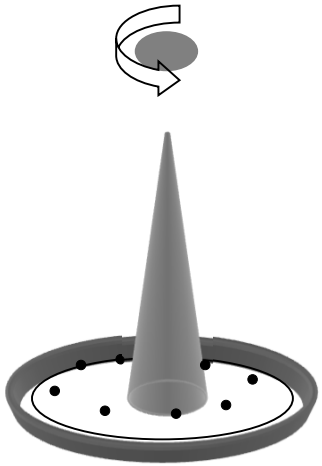
GRAPHICS INPUT DEVICES…

Cursor Control Devices…

- However, due to quick response compared to the other cursor control devices, joysticks are frequently used to control the velocity or force in simulation applications such as in video games.



Thumbwheel



Joysticks

Cursor Control Devices…

3. Mouse

- Mouse was invented in the late 1960s as a locator device, used to control cursor location.
- More popular due to its convenient use with icons, pop-up, and pull-down menus.
- The mouse generally comes with a varying number of buttons in which each button can be programmed for different input values.

In general, there are three types of mice available:

Mechanical mouse

- Mechanical mouse works on a smooth table/pad having two rollers located on its base, one fixed perpendicular to the other, to record the mouse motion in X and Y directions.
- When rollers roll on the table, its relative positions convert into the electronic signals and position of cursor on the screen.

Cursor Control Devices…

Mechanical mouse…

- These positions may be stored when a mouse pushbutton is depressed, in the mouse registers accessible by the application program.

Electrical mouse

- Electrical mouse has a base plate, which generates a magnetic field in the mouse.
- The circuitry in the mouse interprets its relative position on the base and corresponding position of cursor on the screen.

Optical mouse

- In optical mouse, movement over the mouse pad is measured by a light beam modulation and optical encoding techniques.

Cursor Control Devices…

Optical mouse…

- The light source is located at the bottom and mouse must be in contact with the surface for the screen cursor to follow its movements.
- Pushbutton mounted on top of the mouse is used to record the cursor position and can be programmed to other functions.

4. Tracker balls

- A tracker ball is more precise compared to a joystick.
- The tracker ball often describes as an upside-down mechanical mouse. The ball rotates freely within its housing, with the help of user's palm, in the desired direction.
- The joystick and tracker ball were used in early radar and flight control systems.

Cursor Control Devices…

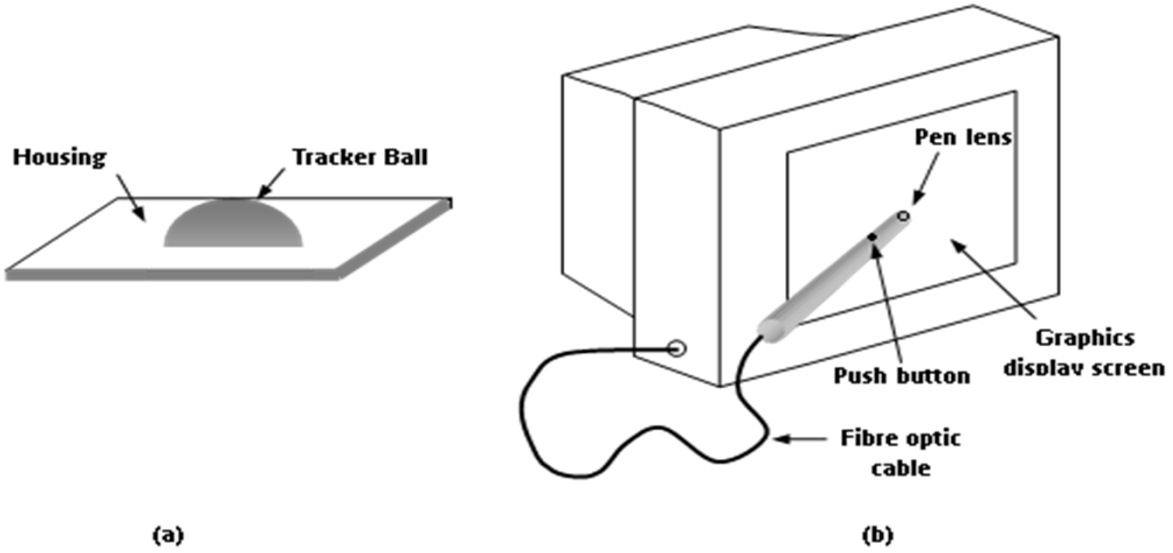
5. Light pen

- It is very similar to a fountain pen in the method of holding but it works on the principle of photoelectricity.
- It detects only sharp intensity of light of the graphics image displayed by using the photodiode, phototransistor or some form of other optical sensor, when light pen is hold perpendicularly against the refreshed type CRT displays.
- The location of pen tip on the graphics screen is recorded when the photocell fixed at pen tip senses the light.
- After the amplification, light pen sends output of the photocell to computer through the light pen interface.
- The light pen is not suitable for the storage tube type of displays due to the lack of refresh cycle.

GRAPHICS INPUT DEVICES…

Cursor Control Devices…

- The light pen did not gain much popularity because of the need to hold it perpendicular to the display screen for a longer time.



(a) Tracker Ball (b) Light Pen

COMPUTER AIDED DESIGN
(BME-42)

Unit-I: Computer Graphics Hardware

(6 Lectures)

- Graphics systems
- Graphics Input devices: **Cursor control devices, Digitizers, Image scanner, Speech oriented devices**,
- **Graphics display devices-Cathode Ray Tube**, Calligraphic display, DVST, Raster display, Color frame buffer, Color CRT monitors, Solid state monitors-emissive displays, non-emissive displays,
- Graphics output devices- Hard copy printers and plotters

Lecture 5

Topics Covered

Graphics Input Devices

Cursor Control Devices

Electronic Tablet, Touch Panels

Digitizers, Image Scanners

Speech oriented Devices

Performance of Input Devices

Graphics Display Devices

Cathode Ray Tube

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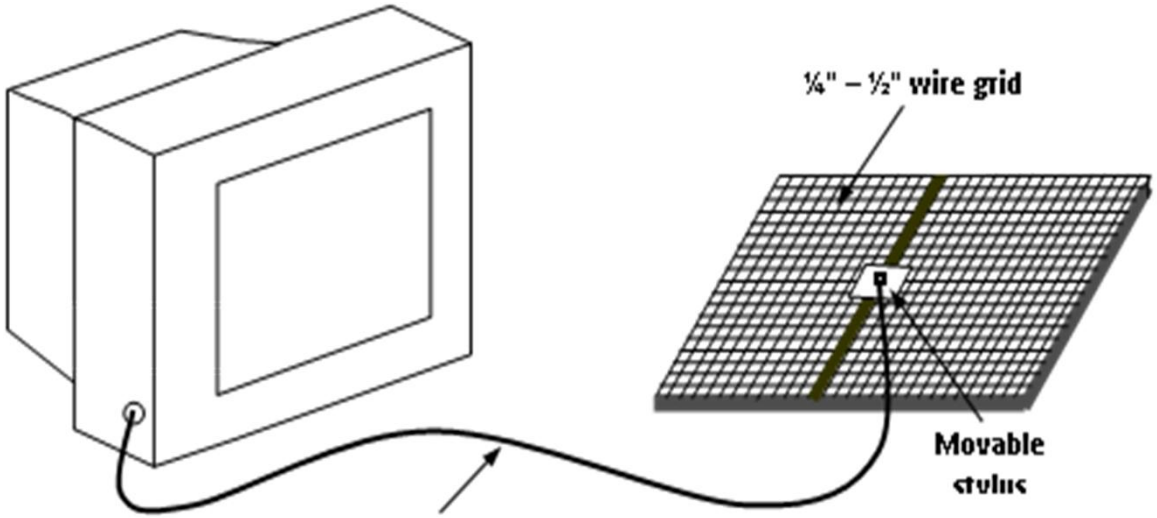
Cursor Control Devices…

6. Electronic Tablets

- A tablet is a flat surface of size in the range 6" x 6" to 48" x 72" or more that can detect the position of a movable stylus in the user's hand.
- Most tablets use an electronic sensing mechanism to determine the position of stylus tip. A grid of wires on ¼ -½ inch apart is embedded on the tablet surface.
- The electrical pulse applied in sequence to the grid wire, which in turn induces electrical signals, transmitted to the computer before converting it into the electromagnetic signals.
- The user writes on the graphics surface of tablet and position of stylus(x, y) records into the computer, normally at the rate of 30 to 60 times per second.
- The strength of each pulse determines the position of stylus,(x, y) and the cursor displayed on computer screen is an echo of the position of the stylus on the tablet.

GRAPHICS INPUT DEVICES…

Cursor Control Devices…



Electronic Tablet

Cursor Control Devices…

7. Touch panels

- Touch panels are frequently used to locate the cursor on the screen for transmitting the input information to the computer.
- They allow displayed objects or graphics position just by touching the panel at that location.
- The Banks ATM (Automatic Taylor Machine), railway/flight enquiry, insurance office, control panel of CNC machines, etc. are equipped with touch panels.

Based on techniques used for transmitting the input information to the computer, the touch panels are classified as:

Optical touch panel

- Optical touch panel uses a set of infrared Light Emitting Diodes (LED's) and light detectors along the vertical and horizontal edges of the graphics screen. The LED's operate at infrared frequencies, so the light is invisible to the users.

Cursor Control Devices…

Optical touch panel…

- Large numbers of LED's are placed on the horizontal and vertical edges of the screen, whereas light detectors are fixed on the opposite edges, to receive the infrared light
- When the panel is pressed (alternatively, the light receiving is interrupted), it records the cursor position and transmits the command to computer for the processing.

Electrical touch panel

- Electrical touch panel consists of two transparent plates separated by a small distance. One plate coated with a conducting material and other with a resistive material.
- A contact between the two plates occurs when finger touches the outer plate.
- Consequently, small electric current flows between the two plates and a small voltage drop across the plate records the location of cursor and transmit the command to computer for the processing.

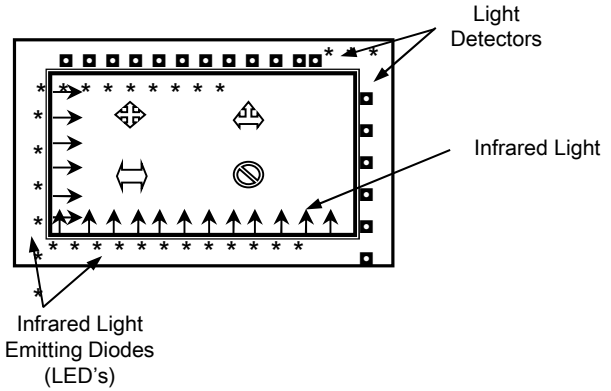
Cursor Control Devices…

Acoustic touch panel

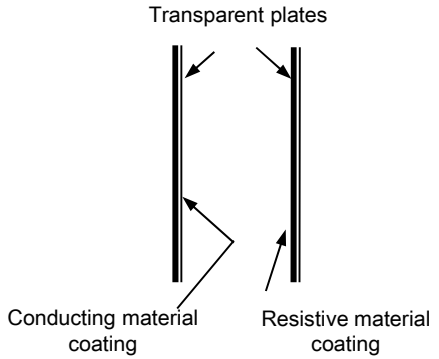
- Acoustic touch panel uses high frequency sound waves generated in horizontal and vertical directions across the glass plates.
- When the screen is touched, it causes part of the wave to reflect towards the wave emitter.
- The time interval between the transmission of each wave and its reflection back to the emitter calculates the cursor location on the touch panel.

GRAPHICS INPUT DEVICES…

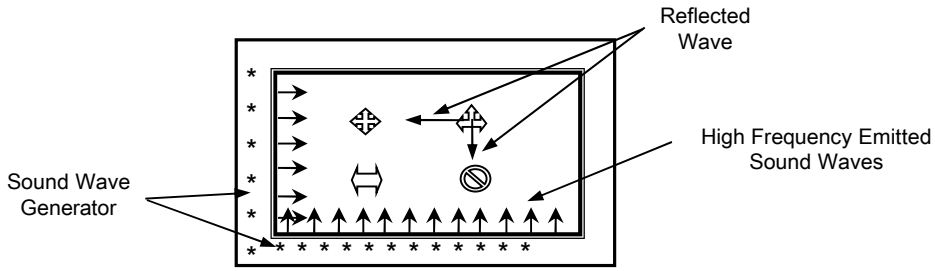
Cursor Control Devices…



(a) Optical Touch Panel



(b) Electrical Touch Panel



(c) Acoustic Touch Panel

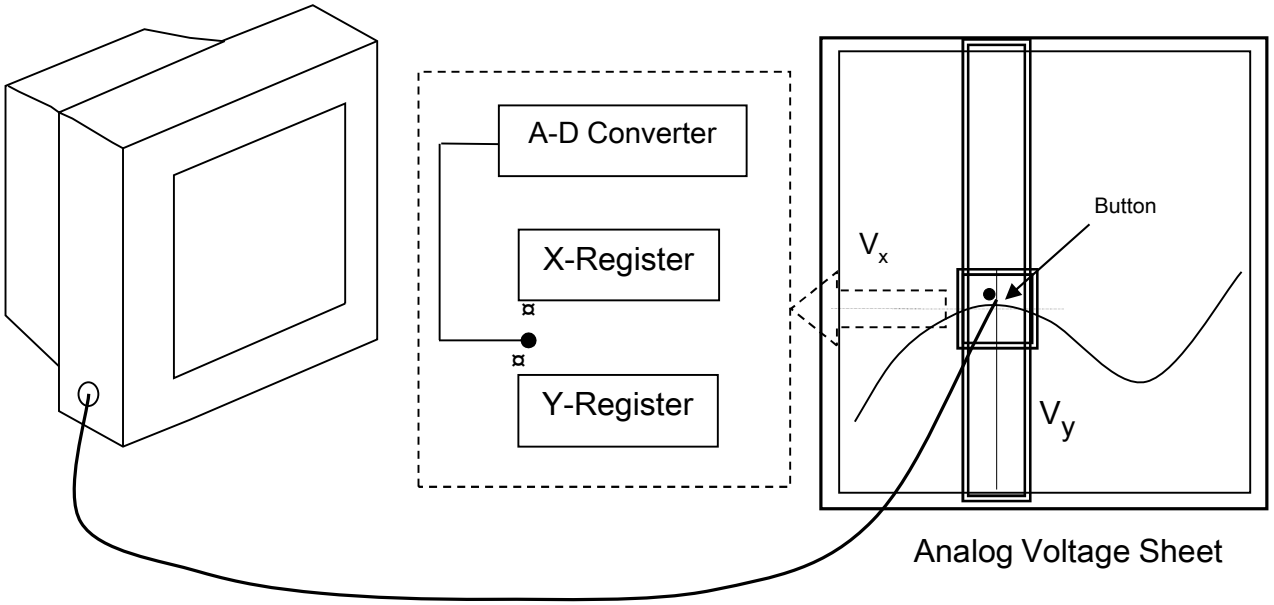
Touch Panels

GRAPHICS INPUT DEVICES…

8. Digitizers

- A digitizer is a **two-dimensional** operator input device with **high resolution** and **accuracy**.
- Available in different sizes (42"x60" or more), and consist of a large smooth board and an electronic tracking device (stylus), that moves over the drawing to follow the paths.
- It is a common technique for generating the (*x, y*) coordinates of any drawing; therefore, considered electronic drafting board.
- The **stylus** of the digitizer acts as a **mouse**. Thus, any drawing can be **digitized** or forwarded to the computer, or to some other secondary storage device.
- The intermediate coordinates, between the recorded points, be evaluated using the software at the desired level of accuracy.
- Typical accuracies of digitizers vary from 0.005" to 0.05".

GRAPHICS INPUT DEVICES…



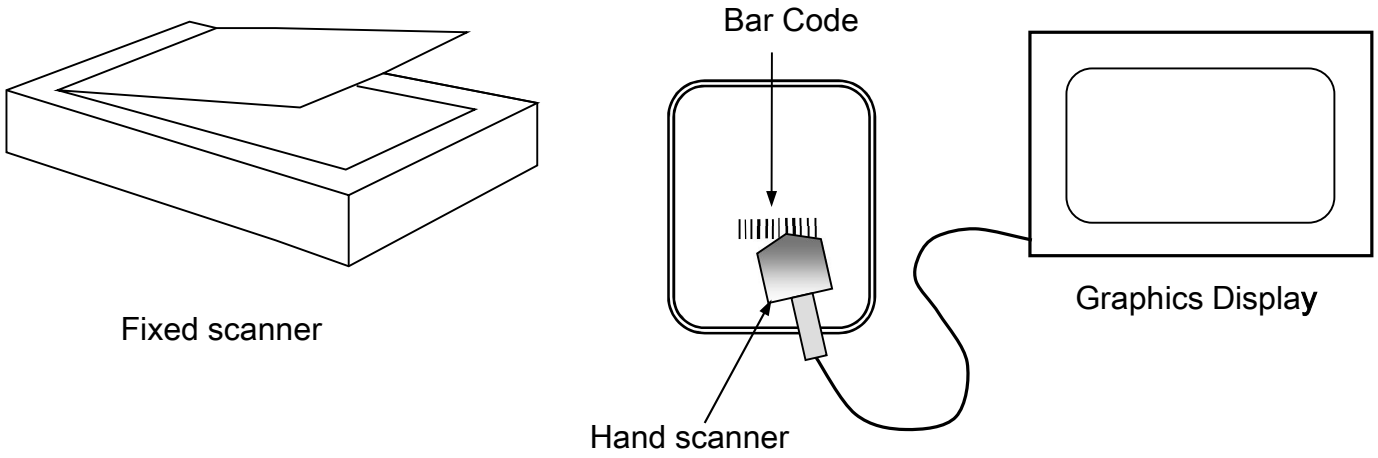
Digitizer

GRAPHICS INPUT DEVICES…

9. Image Scanners

- The electronic images of drawing, graphics and black & white or color photographs can be stored for computer processing with an image scanner.
- The image is stored by passing the optical mechanism over the graphics. The gradation of grayscale or colored images are recorded and stored, in the digital form.
- The image is stored in array form, which can be modified using different image processing techniques.
- Similar to the image scanners, video digitizers, in which digitizer is connected to a video source, also convert the analog signals into digital bitmap file.
- Image scanners are available in different sizes (stationary and portable) and used for the conversion of paper drawing into CAD database.

GRAPHICS INPUT DEVICES…



Fixed Type and Portable Image Scanners

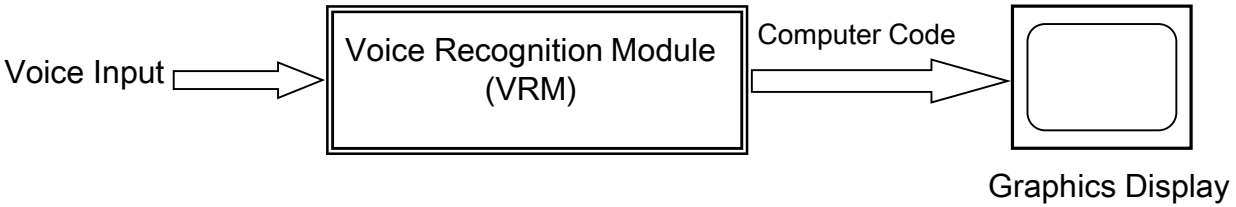
10. Speech Oriented Devices

- In graphics applications, almost all the graphics input devices are visible whereas hands and eyes of user are busy.
- The voice of user can be used as an input thereby giving some relief to the user, which in turn, may increase the productivity of the designer.

GRAPHICS INPUT DEVICES…

10. Speech Oriented Devices…

- The accuracy of the input information can be improved by using the voice of user.
- In this device, the speech input is fed to a Voice Recognition Module (VRM), which generates a unique computer code corresponding to the particular voice.
- The software recognizes the input from VRM in the same way as it receives from the keyboard.



Voice Recognition System

PERFORMANCE OF GRAPHICS INPUT DEVICES

The performance of graphics input devices are measured by the four parameters:

- *Resolution*
- *Accuracy*
- *Repeatability,* and
- *Linearity*

Resolution

The resolution of displays is the smallest distance between the two adjacent points. Alternatively, the maximum number of points that can be displayed without overlap is referred to as *resolution*.

Generally, the resolution of a digitizer is better than that of an electronic tablet.

PERFORMANCE OF GRAPHICS INPUT DEVICES…

Accuracy

The error in the measurement of data defines the accuracy of an input device. Error is the amount of deviation of actual measurement compared to the given location. Thus, how much close is the measured point relative to its actual location, on the electronic drafting board, is measured by the error parameter.

Repeatability

Repeatability is the measure of closeness of recorded point if the user operates a device many times.

Linearity

Similarly, linearity measures the increase or decrease of input values of the device in accordance with the user's hand movements.

GRAPHICS DISPLAY DEVICES

- The graphics display is most important component of a graphics system. The quality of image influences the perception of the designer.
- A designer communicates his ideas by ***adding, moving*** and ***deleting*** the 2D & 3D graphics entities on the displays; thus, making it *interactive*.
- In passive display devices such as television, the user **cannot** modify the displayed object.
- There are Two types of graphics output devices
  - **Soft devices**
  - **Hard devices**
- **Graphics display devices** come under the category of **soft** devices. The graphics information displayed on the computer screen is of **temporary** nature.
- **Printers/plotters**, which provide the **hard** copies of graphics images are referred as **graphics output devices**.

GRAPHICS DISPLAY DEVICES…

- In interactive computer graphics (**soft devices**), the image presented on a CRT display can be dynamically **modified**, **erased** **or** **regenerated**.
- **On hardcopy device**, images are created on the paper; therefore, **dynamic modification is not possible.** However, hardcopy is used for the further activities.

There are various types of display technologies available to the user. The purpose of these devices is to generate the desired digital visible image on the screen at high speeds.

Broadly, the graphics displays are classified into **Two** categories based on the technology used:

1. **Cathode Ray Tube (CRT)**
2. **Solid State Monitors or Flat Panel Display (FPD)**

Cathode Ray Tube

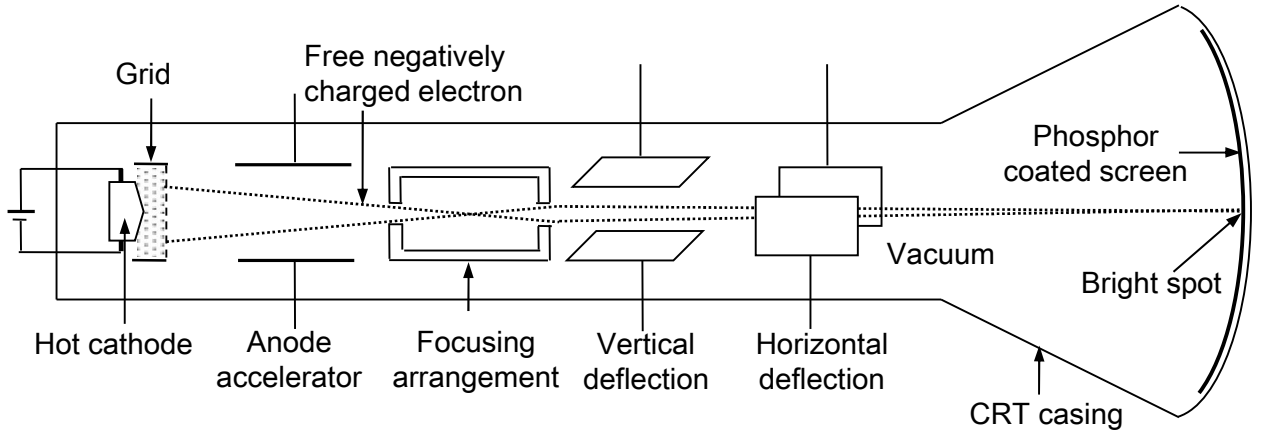
- This display device works on the principle of Cathode Ray Tube (CRT).
- It is the most popular and dominating technology being widely used in *refreshed* and *storage* type of graphics display devices.
- The *monochromatic* CRTs are essentially the same as those used in Black & White television sets.

Principle of CRT

- The principle of CRT is based on the generation of high-speed electron beam that strikes on the phosphor-coated glass screen.
- The impact of electron beam causes it to illuminate and produce a bright spot (or glow) on the screen at the desired location until next time the beam is focused.

Cathode Ray Tube

Construction and Working



The CRT consists of

- **An electron gun forming cathode rays**
- **Optical focusing device**
- **Deflection system, and**
- **Phosphor-coated glass screen.**

Cathode Ray Tube…

Construction and Working

- The electrons are generated by an electron gun (i.e., cathode) in the form of showers.
- The electrons are ***boiled off*** from the cathode surface when a direct current, through a filament, heats metal cathode.
- The electrons are focused in the form of a **beam** by a focusing system.
- A **high vacuum** in the cathode tube is maintained wherein, a high positive voltage, using anode accelerator, accelerates free negatively charged particles.
- Suitable deflection voltages, applied to horizontal and vertical deflection plates, causing electron beam to impinge on the **phosphor-coated** glass screen at the desired location.
- The illumination of phosphor dot takes place where the electron beam strikes, referred to as display.

Cathode Ray Tube…

Resolution

- The intensity of bright spot is **greatest at the centre** and decreases with **Gaussian distribution** out towards the edges.

- The **number of pixels** that are available on the viewing surface of a display unit gives a **qualitative** idea on the sharpness of images generated.

Maximum number of points (dots) displayed without overlap on the CRT screen is referred to its resolution.

The resolution of CRT screen is dependent on the following parameters:

- **Type of phosphor (material) dot**
- **Intensity of dot to be displayed**
- **Optical focusing arrangement**
- **Deflection system of electron beam**

Cathode Ray Tube…

Resolution…

There are Two ways to specify the resolution of display surfaces:

- **Number of pixels in the horizontal direction and vertical direction, and diagonal size of the screen**
- **Number of pixels per unit length in horizontal and the number of pixels per unit length in vertical direction**

➢ In many CRT displays, the pixels may not be square and the number of pixels per unit length in horizontal and vertical directions varies.

➢ The physical size of the monitor used in CAD workstations has a range of about 640x480 pixels on a 14" diagonal monitor to 1280x1024 pixels on 19" diagonal monitor and very high resolution 4096x4096 on a 19" (or more) diagonal monitor.

Cathode Ray Tube…

Resolution…

- Thus, for the same numbers of pixels along the horizontal and vertical directions, the physical lengths of horizontal and vertical lines may be different, leading to distortion of the images.
- The difference in physical lengths of lines in horizontal and vertical directions results into aspect ratio, which is not equal to one.

Aspect ratio is the ratio of the number of vertical pixels to the number of horizontal pixels required to produce equal length lines in vertical and horizontal directions on the screen, respectively.

- It is ideal to have square pixels and an aspect ratio equal to 1.

Cathode Ray Tube…

Resolution…

Spatial resolution

The measurement of **number of pixels** on the display surfaces measuring the *sharpness* of image

Tonal resolution

The number of colors or different levels of brightness of the images provide another measure of quality of images. The number of **memory bits associated with every pixel** measures this quality of display surfaces.

COMPUTER AIDED DESIGN
(BME-42)

Unit-I: Computer Graphics Hardware

(6 Lectures)

- Graphics systems
- Graphics Input devices: Cursor control devices**, Digitizers, Image scanner, Speech oriented devices**,
- **Graphics display devices-Cathode Ray Tube**, Calligraphic display, DVST, Raster display, Color frame buffer, Color CRT monitors, Solid state monitors-emissive displays, non-emissive displays,
- Graphics output devices- Hard copy printers and plotters

Lecture 6

Topics Covered

Graphics Display Devices

Color CRT Monitors

Solid State Monitors

Emissive Displays

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IMAGE GENERATION TECHNIQUES

Based on the way of controlling the electron beam in CRT displays, there are two types of image generation techniques: ***Random*** scan and ***Raster*** scan.

Random scan Display

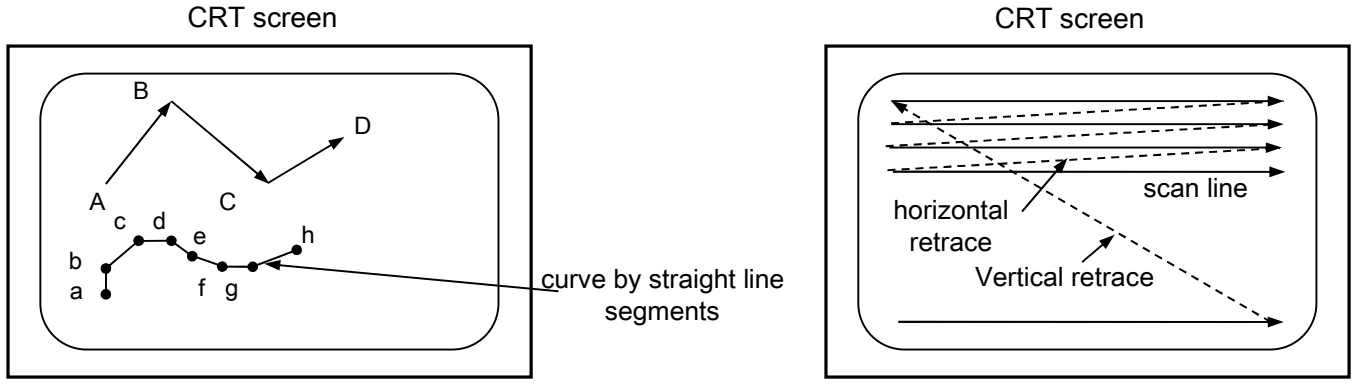
***(or* stroke writing, vector display, line drawing, directed beam or calligraphic (refresh) display)**

- The electron beam works like a **pencil** to create a line image connecting two given points on the CRT screen.
- Images generated using line drawing technique is **sharper** as compared to the raster scan.
- The word **random** indicates that screen is not scanned in a **particular order**.
- Each line segment is generated by directing the electron beam from one point to the other. Each point is defined by x and y coordinates values.
- The images consisting of **curves** are generated by **approximating the small line segments of very short length**.

IMAGE GENERATION TECHNIQUES…

Raster Scan Display

- Raster scan display, based on **Television** technology, is the most common type of graphics display.
- In this technique, a matrix of **closely spaced dots** is used to form the images.
- Compared to the random display or **line** drawing device, it is referred to as a **point** plotting device or digital scan.
- The computer screen is divided into many discrete phosphor dots, called ***pixel* (*pi*cture *el*ement).** These pixels form the display screen.



Random scan display

Raster scan display

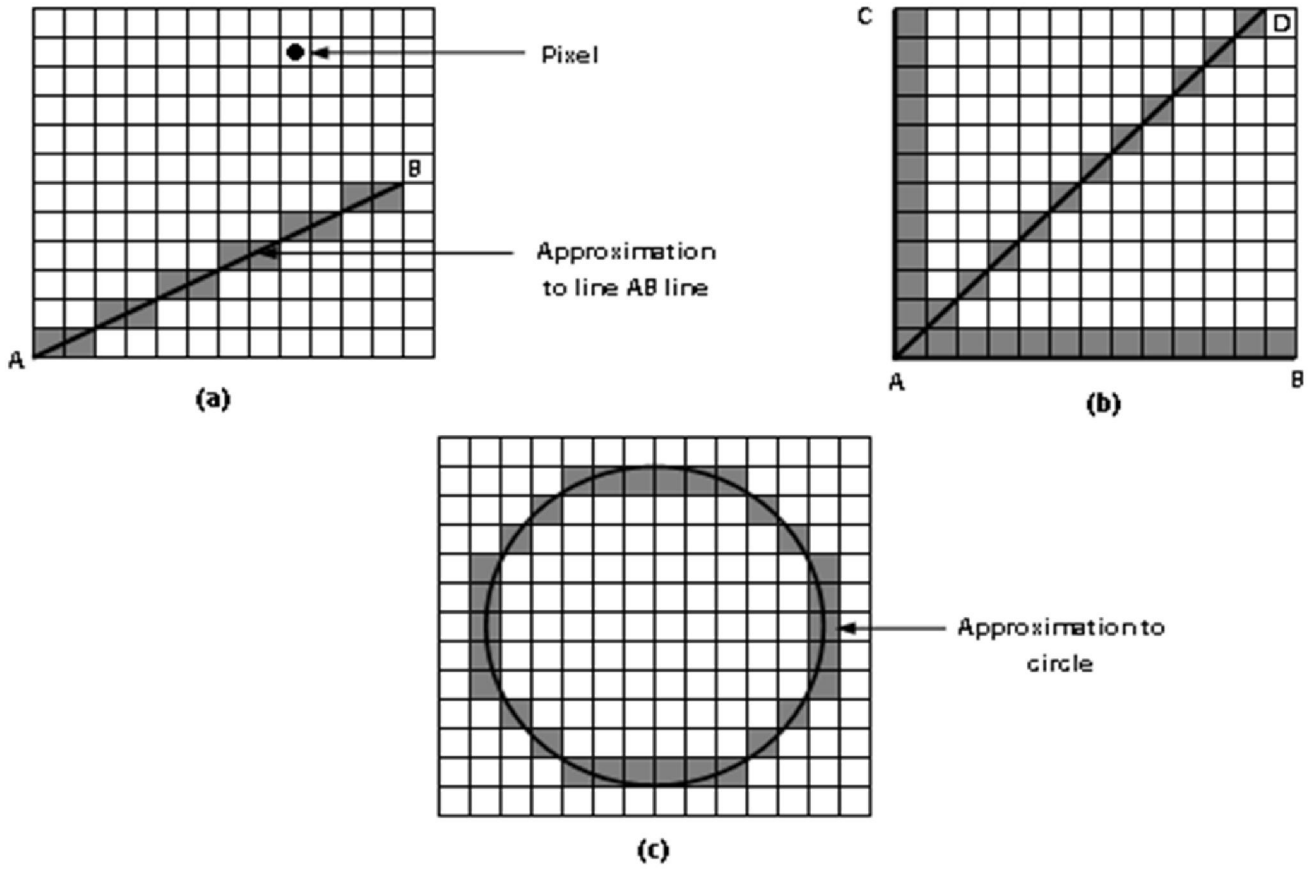
IMAGE GENERATION TECHNIQUES…

Raster Scan Display…

- The number of pixels in a raster display may vary from **256x256** (over 65000 dots) to **4096x4096** (over 16,000,000 or sixteen million pixels) or more.
- Each pixel can be made to glow with **different intensity** giving rise to **gray scale black/white images.**
- On the other hand, **color screens** may provide the pixels to have **different colors** as well as **brightness**.
- It is not possible to draw a straight line from one pixel to another, except in special cases, when the line is completely **horizontal, vertical** or **45^{o} lines** (for square pixels).
- All other lines show a **stair-steps** called ***jaggies*** **(staircase appearance)**. This can be easily observed on **low-resolution** display devices.

IMAGE GENERATION TECHNIQUES

Raster Scan Display…



Line (AB), special lines (AB, AC & AD) and circle, respectively, visible on the screen during rasterization.

IMAGE GENERATION TECHNIQUES…

Raster Scan Display…

- In raster scan system, the electron beam scans the images from **left to the right** along a horizontal line and energizes the pixels in that line.
- After sweeping one line, the electron beam moves to the next line just below, forming **horizontal retrace**, and proceeds to a final point at the right bottom corner of CRT screen.
- During this sweeping, the deflection voltages are adjusted in such a way that the entire scanning of screen takes place.
- When final point reaches, the electron beam again goes back to the initial point (left top corner of CRT screen) forming the **vertical retrace**.
- The entire scanning of screen repeats at a rate of 30-60 scans per sec.

GRAPHICS DISPLAY DEVICES

Random and Raster scan techniques are used in majority of current computer graphics CRT display.

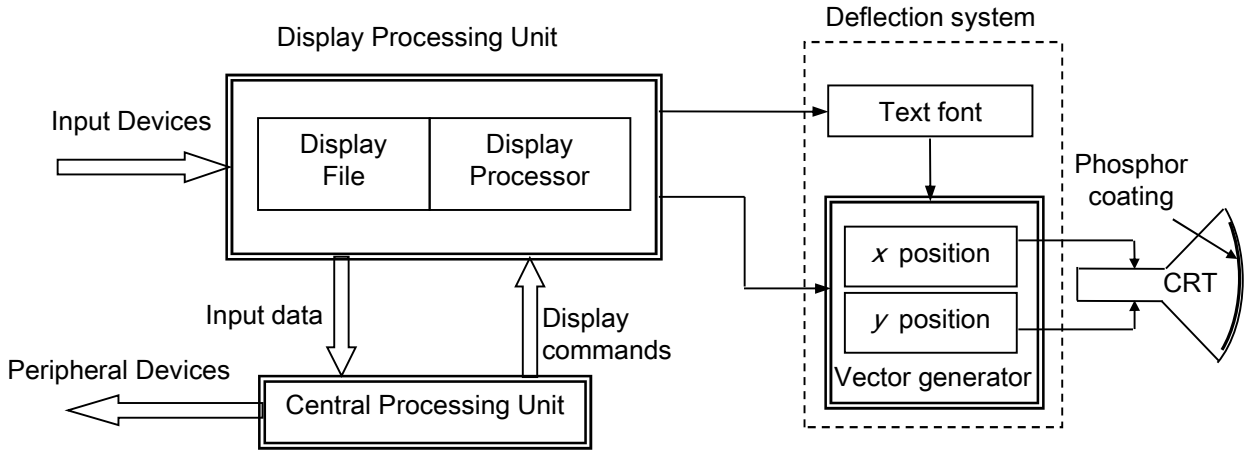
Based on these two image generation techniques, the **Three** types of graphics display devices are:

- **Refresh or Calligraphic display** (Random scan technique)
- **Direct View Storage Tube (DVST)** (Random scan technique)
- **Raster display (Digital TV)** (Raster scan technique)

GRAPHICS DISPLAY DEVICES…

1. Refresh or Calligraphic Display

- The refresh graphics display processor is often called a Display Processing Unit (DPU) or a ***Graphics Controller***.
- The refresh buffer/display file stores the image information consisting of 2D & 3D *primitives, text, characters* and other *attributes* of the image to be drawn on the computer screen.



Refresh Display System

GRAPHICS DISPLAY DEVICES…

1. Refresh or Calligraphic Display…

- For the display of image, the DPU processes through the set of commands (program) and *draw each line in sequence*.
- The commands are interpreted and processed by the display processor and passed to the *deflection system* that controls the movement of electron beam.
- Any changes made to the display file (refresh buffer) by the commands must synchronize with the display refresh cycle, which in turn, prevents the display of an incomplete image.
- After processing all the commands, the display system cycles *back to the first line* command.

GRAPHICS DISPLAY DEVICES…

1. Refresh or calligraphic display…

Advantages…

a) Refresh (vector) display is characterized by its *high resolution* (4096x4096 pixels) leading to *high-quality image*.

b) Vector display generates *smooth line drawings* compared to the raster scan jagged line system because the electron beam follows the line path.

c) Selective erasure of a portion of image is possible due to the continuous refreshing (redrawing) of display screen.

d) Refresh display results into the image with *high brightness*.

e) The *animation* (viz., simulation of movements) of object is possible due to the fast refreshing of display screen.

GRAPHICS DISPLAY DEVICES…

1. Refresh or calligraphic display…

Limitations

The refresh displays are designed for the line drawing applications. The devices based on random or refresh scan principles are not preferred for CAD systems due to following:

a) It is a *binary display device*; hence, able to generate only *two levels of color intensity*.

b) Refresh display *cannot produce shaded colored images*.

c) It could display only the *limited number of line segments* on the screen *without flicker*.

d) The images involving curves may require *large number of short line segments* (alternatively, substantial amount of data); therefore, the need of refreshing the image at 30-60 Hz rate places a limit on the number of lines that can be displayed without flicker.

The refresh display devices are expensive due to the need of refresh buffer memory and fast display processor.

IMAGE GENERATION TECHNIQUES…

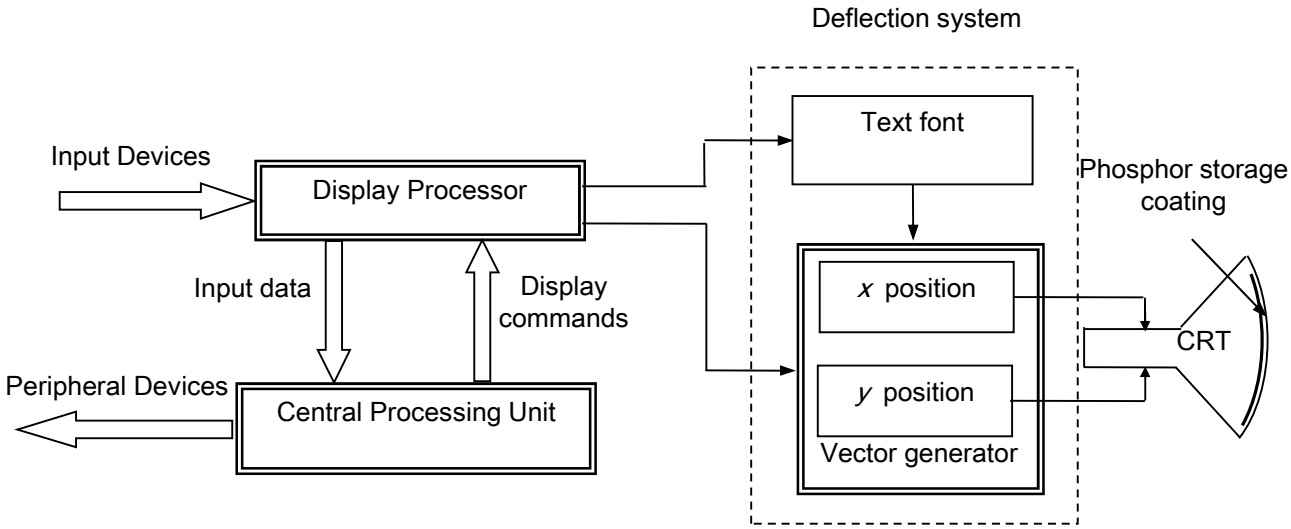
2. Direct View Storage Tube

- Once the picture is generated, it is to be *retained* on the CRT phosphor coating.
- The duration of time that a phosphor continues to glow, after the electron beam excites it, is termed *persistence*.
- As the persistence of CRT display is very short, it is necessary to retain the images for more time.
- In early 1960s, the Direct View Storage Tube (DVST) was come into existence as an alternative display device.
- A *storage* tube physically *retains the image generated until it is erased*, whereas a refreshed tube continuously regenerates the image at some frequency.
- Because of the *elimination of refresh buffer*, DVST was *less expensive* as compared to the refresh/calligraphic type devices.

IMAGE GENERATION TECHNIQUES…

2. Direct View Storage Tube…

- Similar to refresh display, DVST also employs the *vector display technique* for the image generation.
- The storage tube refers to the ability of *retaining the image* on CRT screen by the *special type of phosphor coating*; thus, avoid the need of continuous refreshing.



DVST Display System (Display file is missing)

IMAGE GENERATION TECHNIQUES…

2. Direct View Storage Tube…

- In DVST, the *refresh buffer/display file is completely removed*. Thus, the speed of electron beam is *slow* as compared to the refresh type displays.
- DVST stores the picture information by activating the phosphor dots by the *primary* electron gun and keeps illuminating the dots by the *secondary* electron gun.
- Therefore, *flicker-free images*, consisting of large number of short line segments, can be obtained at *high resolution* on the CRT screen.
- As it is a vector drawing device, and has high resolution, the *images are sharp* and have *crisp edges*. *The images retain until erased*.
- The resolution of display with storage capacity of 4000 displayable points on 19" screen is possible.

IMAGE GENERATION TECHNIQUES…

2. Direct View Storage Tube…

Limitations

(i) Selective eraser of images is not possible (due to the absence of display file).

(ii) During the process of image generation, if a portion of image is required to be erased (selective erasure) the entire screen must be cleared before redrawing the modified image. This technology brought down the popularity of DVSTs in ICG.

(iii) DVST cannot provide the *vector images of different colors* and *simulation of movements* (animation).

(iv) Due to the absence of continuous refreshing, the DVST is not suitable for display devices with light pen as an input device.

Despite these limitations, the advantages of inexpensive price and high-resolution capability have motivated the early CAD/CAM systems to adopt DVST display.

IMAGE GENERATION TECHNIQUES…

3. Raster Display

- There is continuous demand of *colors, shaded images* and *animation* of designs in CAD/CAM applications.
- This has motivated the hardware engineers to develop the graphics display devices based on the Television Technology (TV). A TV uses *analog signal* generated by a *video camera*.
- During 1970s, the raster scan CRT screens were introduced which uses the *digital signals* generated by a computer.
- Raster display became very popular due to its capability of presenting *realistic display of colored, shaded and flicker-free graphics images* on the CRT screen.

3. Raster Display…

CRT Display Surface

- The viewing surface of a raster display unit has a matrix of tiny picture elements, called *pixels*.
- Every display has a *finite number of pixels* both in horizontal and vertical directions.
- The size of these picture elements is the size of smallest dot that can be displayed on the monitor.
- Every pixel on viewing surface has a *unique address* by referring to its position in the matrix by specifying the row and the column.
- It is possible to control the *brightness or color* of each of these pixels by a hardware known as *display controller*.

IMAGE GENERATION TECHNIQUES…

3. Raster Display…

- The *sharpness* of images generated with raster displays depend on the *number of pixels* available on the viewing surface.
- The sharpness is termed as *resolution* of the viewing surface. The resolution of raster display is as high as 4096 x 4096 pixels or more.

Monochrome display

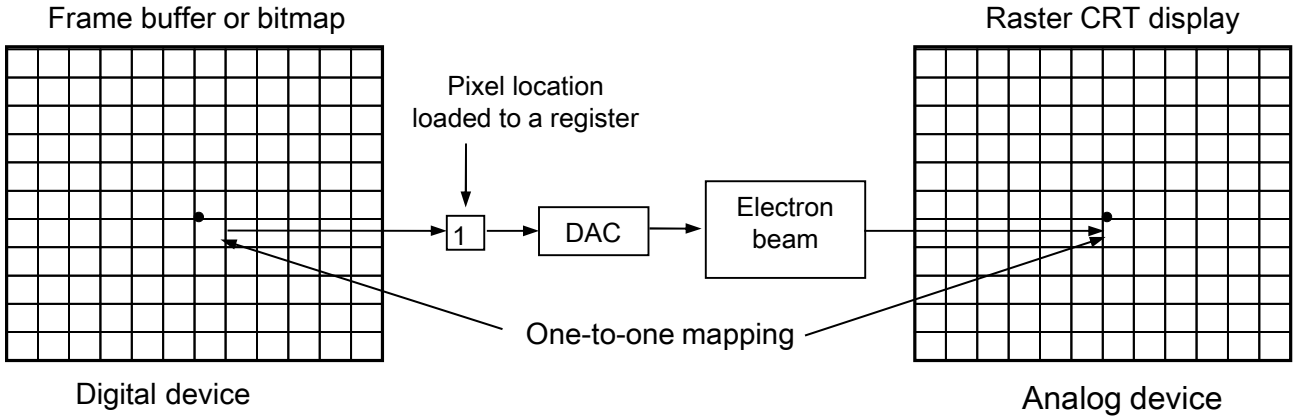
- Figure shows a *single bit-plane monochrome* (black/white) frame buffer for the raster CRT display. The picture definition is stored in the frame buffer called *bitmap* refresh buffer.
- *One-to-one mapping between bitmap memory and corresponding pixel location.*
- The refreshing of entire screen takes place at a rate of *30-60 Hz*, which is *independent of the complexity* of image and number of graphics items displayed on the CRT screen.

IMAGE GENERATION TECHNIQUES…

3. Raster Display…

Monochrome display…

- There is *no possibility of flickering* with increased complexity of the image, as in the case of refresh display.
- In black/white raster display, *1 bit per pixel memory* is required corresponding to either *on* (bright) or *off* (dark) position of pixel.



Single-bit-plane monochrome frame buffer raster CRT display

3. Raster Display…

Monochrome display…

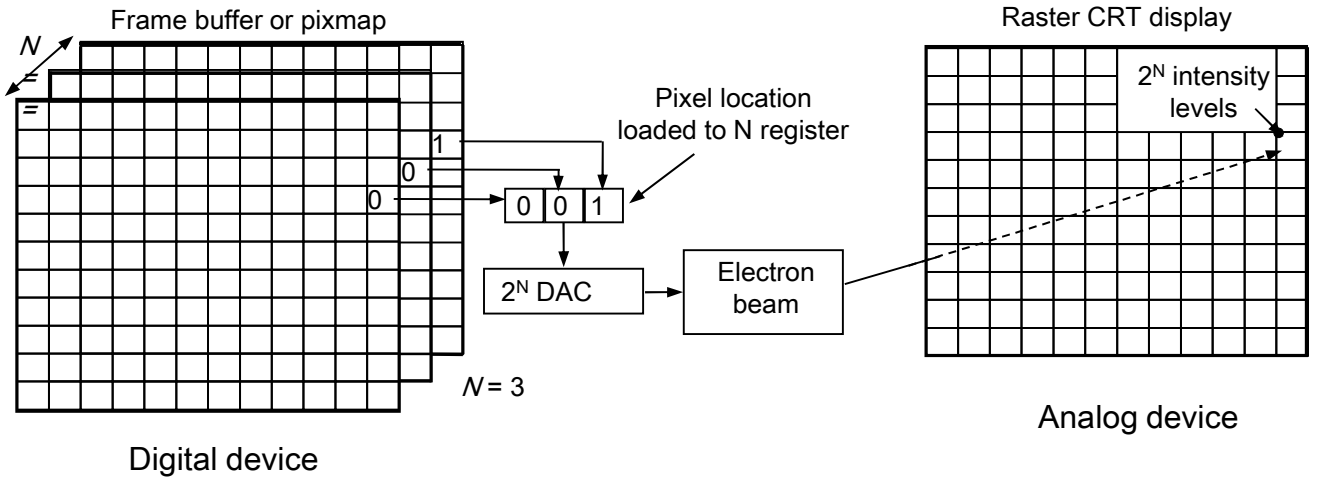
- The frame buffer is termed as a *bitmap*. For monochrome display device (1bit/pixel, i.e., *bright or dark* phosphor dot) with 1024 x 1024 pixels density, 2^{10} x 2^{10} = 2^{20} or 1,048,576 bits memory is required in a single-bit-plane.
- A *digital to analog conversion* between the *frame buffer (digital device)* and *CRT screen (analog device)* must take place before a pixel is visible on the screen.
- For gray levels (gradation between the perfect black and perfect white color), additional bit-plane is employed by the frame buffer.
- Figure shows N-bit-plane gray level frame buffer. The binary value gives an intensity level between 0 (*dark*) and 2^N-1 (*full intensity*) on the raster screen after the digital to analog conversion.
- Therefore, a total of 2^N intensity levels are possible with N-bit-plane.

IMAGE GENERATION TECHNIQUES…

3. Raster Display…

Monochrome display…

- For N = 3, 2^3 or *8 intensity levels* will be visible for each pixel location, and frame buffer requires 3 x 1024 x 1024 = 3.14 MB memory for each monochrome image.



N-bit-plane Monochrome gray level frame buffer raster CRT display

COMPUTER AIDED DESIGN
(BME-42)

Unit-I: Computer Graphics Hardware

(6 Lectures)

- Graphics systems
- Graphics Input devices: Cursor control devices, Digitizers, Image scanner, Speech oriented devices,
- Graphics display devices-Cathode Ray Tube, Calligraphic display, DVST, **Raster display, Color frame buffer, Color CRT monitors, Solid state monitors-emissive displays, non-emissive displays**,
- Graphics output devices- Hard copy printers and plotters

Lecture 7

Topics Covered

Image Generation Techniques

Raster Display

Color CRT Monitors

Beam penetration Method

Shadow Mask method

Solid State Monitors

Emissive Displays

Plasma Panels,

Thin film Electroluminescent Displays

Flat CRT Displays

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IMAGE GENERATION TECHNIQUES…

3. Raster Display…

Color Display

- The two levels of image (black/white) are not satisfactory for various ICG applications. For color and intensity variations, additional bits are required.
- Practically, continuous gray shades for the monochrome display require a memory of 8 bits/pixel and it increases up to 24 bits/pixel (8-bits for each Red, Blue and Green primary colors) for colored images.
- Thus, 24 bits/pixel, i.e., 2^{24} (viz., 16,777,216) different colors would be available on a pixel location. For multiple bits/pixel, the frame buffer is termed *pixmap*.
- For colored images, a display system with 24 bits/pixel and a screen resolution of 1024x1024$\approx$1x10^6 pixels requires approximately 1x10^6x24, i.e., 24 MB memory of storage in the frame buffer.

IMAGE GENERATION TECHNIQUES…

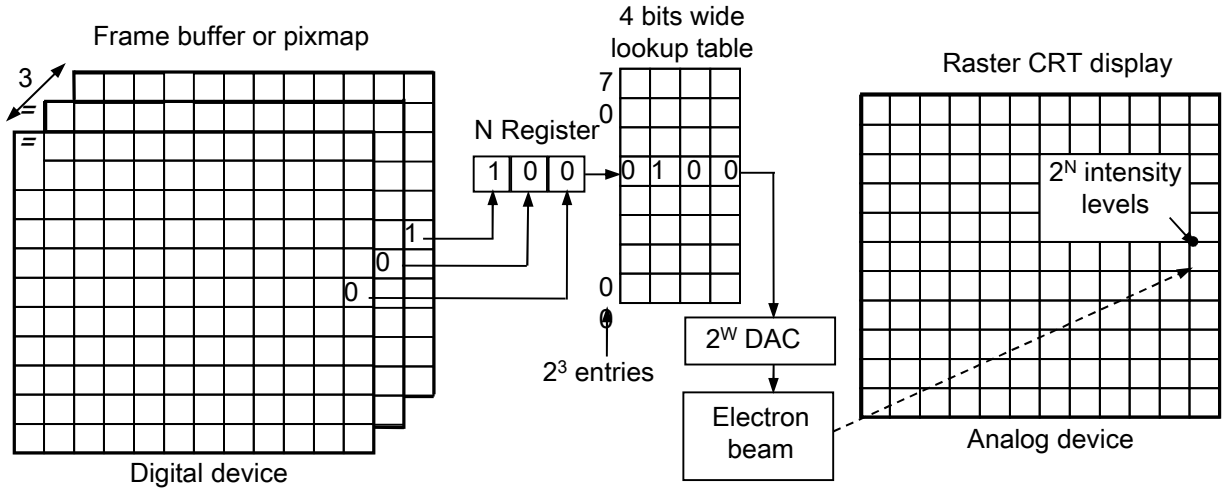
3. Raster Display…

Color display…

- A further increase in the intensity levels of colored images is possible by using the lookup table.
- The number of intensity levels available at one time in frame buffer or pixmap is used as an index in the lookup table.
- Each intensity level in the lookup table is W bits wide (W>N). Thus, 2^N different intensity levels are always available at the pixel location on CRT display, out of total 2^W intensity levels.
- This would mean that when N = 3 and W = 4, a total of 2^3 or 8 different intensities are available at a time out of 2^4 or 16 intensity levels.
- Figure shows a 3-bit-plane gray level frame buffer with 4-bits wide lookup table.

IMAGE GENERATION TECHNIQUES…

3. Raster Display…



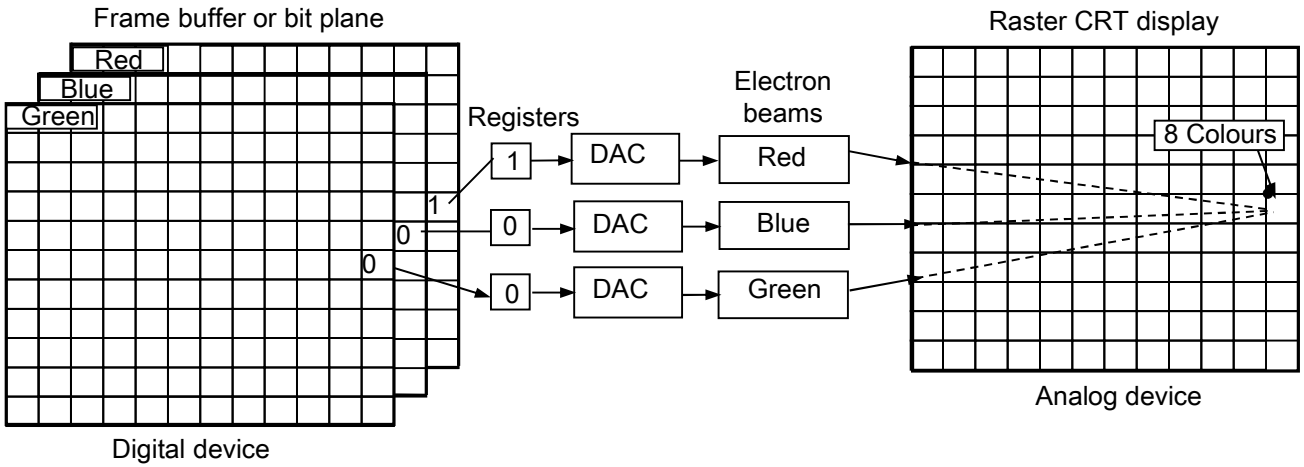
A 3-bit-plane monochrome gray level frame buffer with 4-bits wide lookup table

IMAGE GENERATION TECHNIQUES…

3. Raster Display…

Color Frame Buffer

- A simple color frame buffer consists of 3-bit-plane corresponding to Red, Blue and Green primary colors.
- Each bit plane controls the individual electron beam.
- Table gives eight different colors at the pixel location (in frame buffer) on raster CRT display obtained by various combinations of the three primary colors.



Simple color frame buffer (Single-bit-plane for each primary color)

IMAGE GENERATION TECHNIQUES…

3. Raster Display…

Simple 3-bit plane Color Combinations

Color	Red Electron Beam	Blue Electron Beam	Green Electron Beam
Black	0	0	0
Red	1	0	0
Blue	0	1	0
Green	0	0	1
Yellow	1	0	1
Cyan	0	1	1
Magenta	1	1	0
White	1	1	1

IMAGE GENERATION TECHNIQUES…

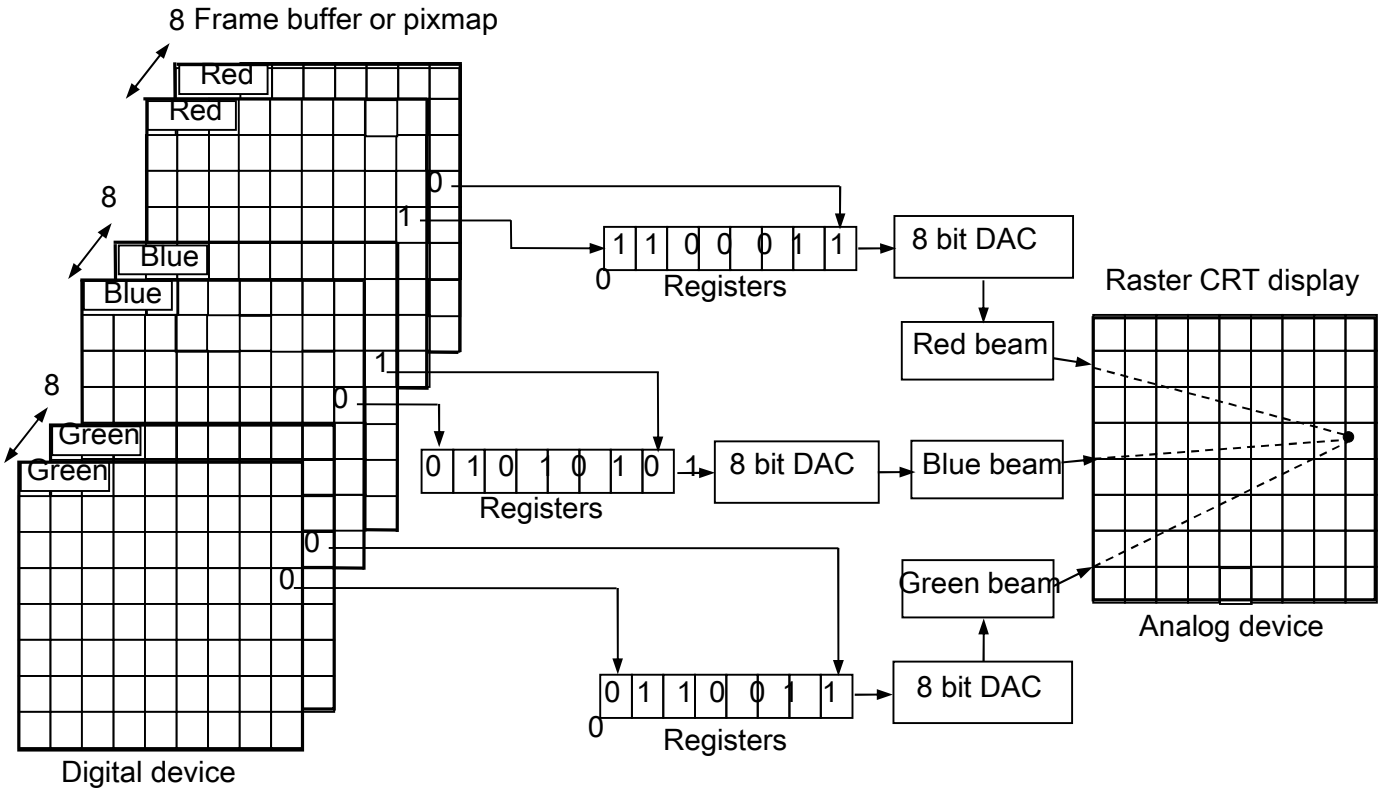
3. Raster Display…

Full Color Frame Buffer

- Full color frame buffer generates 16.77 million colors on CRT raster display.
- Each primary color uses multiple bit planes instead of single-bit-plane.
- For example, 8-bit-plane for each color, i.e., 24-bit- plane frame buffer generates 2^8 or 256 intensity levels for each red, blue and green primary color.
- These intensities are further combined into $(2^8)^3$ or **16,777,216** or 16.77 million possible color shades, known as full color frame buffer.

IMAGE GENERATION TECHNIQUES…

3. Raster Display…



24 bit-plane full color frame buffer (8 bit-plane for each primary color)

3. Raster Display…

Full Color Frame Buffer with Lookup Table

- The color shades can be improved by using the lookup tables.
- For N-bit-plane per color with W bits wide color lookup tables (three lookup tables for each primary color) gives $(2^3)^N$ colors from a palette of $(2^3)^W$ possible colors available at a time.
- For example, N = 8 and W = 10 gives $(2^3)^8$ or 16,777,216 colors from a palette of $(2^3)^{10}$ or 1,073,741,824 colors comprising a real-world image.

Color CRT Monitors

- The quality of colored images and animated pictures depends on the hardware used.
- For excellent quality images, refresh display and DVST are better, whereas color capability of refresh display is moderate compared to the raster display devices.
- Raster display can handle a large amount of data; however, its animation capability is moderate.
- The mixing of colored light emitted from different phosphor dots results into the colored images on CRT monitors.

Color CRT Monitors…

There are two basic techniques for the color displays on CRT screen:

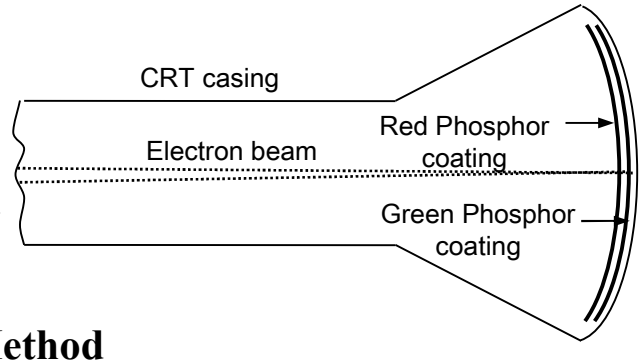
1. Beam Penetration Method

- This method utilizes the *random* scan technique for displaying colored images on the CRT displays.
- Figure shows the inner side of CRT screen, coated with two layers of phosphor dots. The color of emitted light depends on the depth of penetration of electron beam on the phosphor coating.
- Slow moving electron beam energizes the outer red layer of coating, emits ***red*** light; whereas very fast-moving electrons penetrate through the red coating and energizes the inner green phosphor coating, emits *green* light.
- At intermediate electron speeds, red and green light combines and emits two additional colors *orange* and *yellow*.

Color CRT Monitors…

- Beam penetration method is an inexpensive way to produce images in random scan CRT display devices but only *four* colors of moderate quality are possible.

Slow electron speed : Red colour
Fast electron speed : Green colour
Moderate electron speed : Orange and Yellow colour



Beam Penetration Method

2. Shadow mask method

- Shadow mask method utilizes the *raster* scan technique for displaying colored images on the CRT displays.
- A wide range of colors can be produced with shadow mask method.
- A shadow mask color CRT display has three primary phosphor colored dots (Red, Blue and Green) compared to single phosphor dot, used in beam penetration method.

Color CRT Monitors…

Shadow mask method…

- The three electron beams, one for each colored phosphor dots, energize these dots. In between the electron guns and phosphor-coated screen, one perforated shadow mask grid is placed.
- At each pixel location, one dot emits *red* light, another emits *blue* and third emits *green* light.
- When these three colored lights of different intensities (obtained from 8-bit-plane) combine, they produce wide range of colors as high as 16.77 million colors; however, the range of actual colors depends on the amount of excitation.
- The shadow mask method could be cost effective if three electron beams are set to either *on* or *off*, limiting to the display of only *eight* colors.

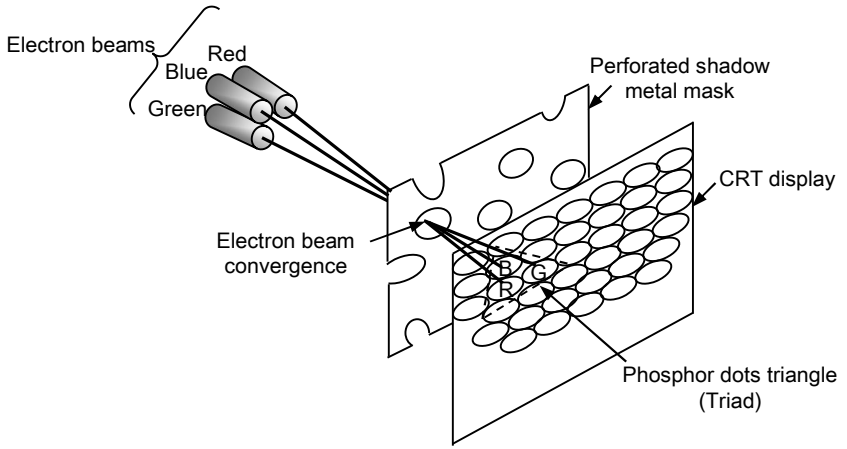
Color CRT Monitors…

Shadow mask method…

There are two types of dots arrangement:

Delta-delta Arrangement

- This pattern of colored dots is termed as *triad*. The shadow mask contains series of holes, which aligns the Red, Blue and Green electron beams to the corresponding red, blue and green dots.
- When three electron beams activate the corresponding dots, the combined intensities of emitted light from these dots produce a small color spot on the screen.



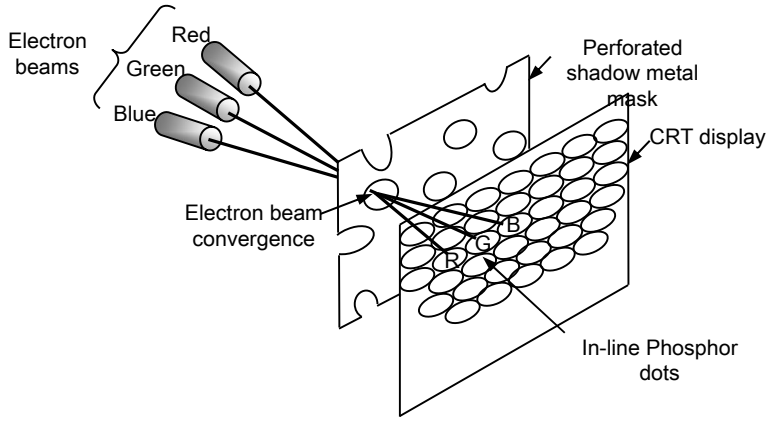
Delta-delta dots Arrangement

Color CRT Monitors…

Shadow mask method…

Inline Dots Arrangement

- The other dots arrangement for the three electron beams is an *inline* arrangement in which the electron guns and RGB dots aligned on the same scan line.
- This arrangement of dots is easier as compared to the delta pattern; therefore, preferred in high-resolution colored CRTs.



Inline RGB dots Arrangement

Solid State Monitors (Flat Panel Display)

Limitations of CRT Display

The application of display devices based on CRT has now become limited due to the following reasons:

- The reduction in the portability of CRT display devices because it is bulky, fragile and limited size to about 30 inches diagonally.
- It consumes considerable power; therefore, requires the arrangement to dissipate heat generated during the operation.

Development of Solid-State Monitors

- These monitors employ flat screen; therefore, also termed as Flat Panel Display (FPD).
- The FPDs are being extensively used for laptop computers, calculators, pocket video games, notebook, advertisement boards, etc.

Solid State Monitors (Flat Panel Display)…

Development of Solid-State Monitors…

The salient features of flat panel displays are:

- ✓ *Considerably thinner than the CRT display devices*
- ✓ *Less volume, weight and power consumption as compared to the CRT display devices*
- ✓ *Can be hanged on walls*
- ✓ *Can wear on our wrist*
- ✓ *One can even write on some flat panel display devices*

GRAPHICS DISPLAY DEVICES…

Solid State Monitors (Flat Panel Display)…

Classification of Solid-state Monitors…

- ***Emissive* display viz. active or light emitting display and**
- ***Non-emissive* display viz. passive or light modulating display.**

Emissive Displays

- Emissive displays are the devices that convert electrical energy into the light energy.
- Plasma gas-discharge and electroluminescent display devices are currently the most suitable for large sizes and high resolutions graphics applications.

Solid State Monitors (Flat Panel Display)…

Classification of Solid-State Monitors…

There are mainly three types of emissive display devices:

1. Plasma Panels

- Plasma panels are also termed as gas-discharge display.
- In this display device, a mixture of gases including Neon is filled between the two glass plates.
- There is a series of vertical conducting ribbons on one glass plate and horizontal conducting ribbons on another glass plate.
- The gas at the intersection of two ribbons breaks into electrons and ions causing a glow of plasma when a potential difference is maintained between the two conductors.
- The intersection points between the two carbon conductors are termed as pixels.

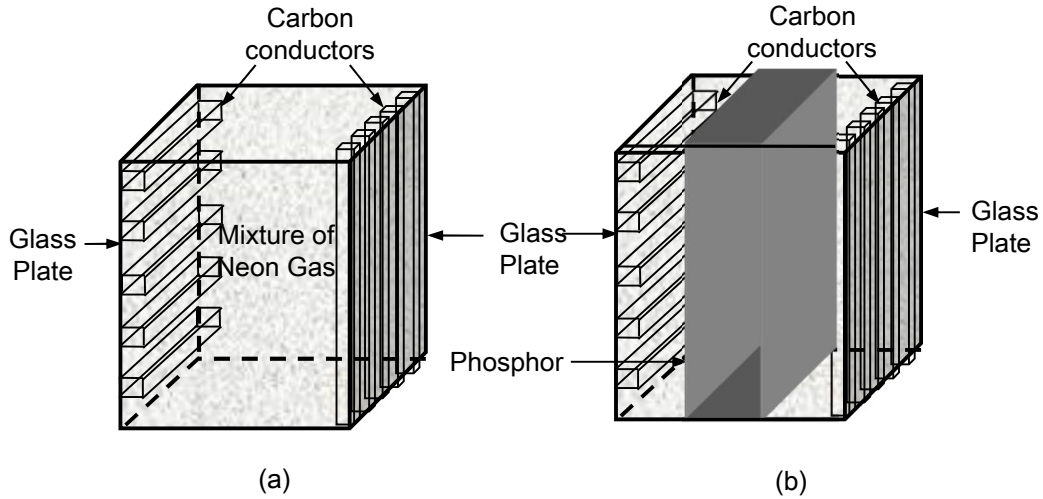
GRAPHICS DISPLAY DEVICES…

Solid State Monitors (Flat Panel Display)…

Emissive Displays…

1. Plasma Panels…

- The image information is stored in the refresh buffer and firing voltages are applied to refresh the pixel at 60 Hz.
- Early plasma panel display devices were monochromatic type, but they are now capable of displaying gray scale (between black and white) and colored images.



(a) Plasma panels

(b) Thin film electroluminescent displays

Solid State Monitors (Flat Panel Display)…

Emissive Displays…

2. Thin Film Electroluminescent Displays

- The construction of Thin Film Electroluminescent Display (TFED) is like the plasma panel.
- In contrast to plasma display, phosphor such as Zinc Sulphide doped with Manganese is filled in the region between the glass plates.
- The phosphor becomes a conductor in the area of intersection of two carbon electrodes, when subjected to firing voltages.
- The Manganese atoms present in the phosphor absorb electrical energy, which releases as a spot of light at the junction of two carbon electrodes.
- The light emitted is similar to the glowing plasma effect.
- These display devices consume more power as compared to the plasma panels; however, it is very difficult to display good colors and gray scale.

Solid State Monitors (Flat Panel Display)…

Emissive Displays…

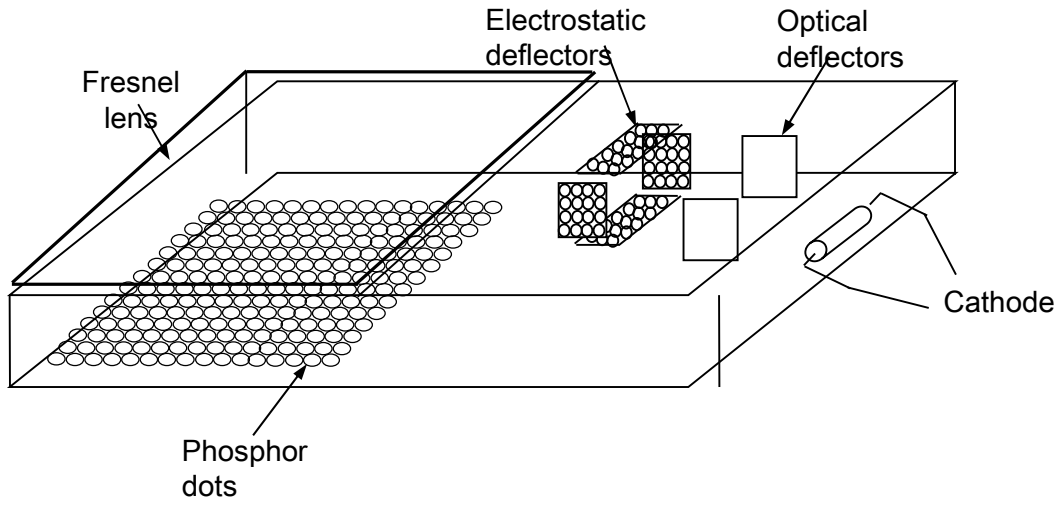
3. Flat CRT Displays

- In flat CRT, an electron beam is initially projected, parallel to the display screen and then reflected through 90^{o}, before impinging on the CRT screen.
- The reflection of electron beam significantly reduces the depth of CRT display device.
- Flat CRT has all the advantages of conventional CRT display, but they are available in very small sizes only.

GRAPHICS DISPLAY DEVICES…

Solid State Monitors (Flat Panel Display)…

Emissive Displays…



Flat CRT Displays

COMPUTER AIDED DESIGN
(BME-42)

Unit-I: Computer Graphics Hardware

(6 Lectures)

- Graphics systems
- Graphics Input devices: Cursor control devices, Digitizers, Image scanner, Speech oriented devices
- Graphics display devices-Cathode Ray Tube, Calligraphic display, DVST, Raster display, Color frame buffer, Color CRT monitors, Solid state monitors-emissive displays, non-emissive displays,
- **Graphics output devices- Hard copy printers and plotters**

Lecture 8

Topics Covered

Solid State Monitors

Non-Emissive Display

Graphics Output Devices

Resolution of an Output Devices

Impact Printers/Plotters

Non-impact Printers/Plotters

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SOLID STATE MONITORS…
(FLAT PANEL DISPLAY)…

Non-Emissive Displays…

- Non-emissive displays or passive display devices are those, which use optical effects to convert sunlight or light from some other sources into the graphics image.
- Light Emitting Diodes (LED) and Liquid Crystal Displays (LCD) are the most popular examples of non-emissive displays.

Light Emitting Diodes

- In this display device, a matrix of light emitting diodes forms the pixel positions and image information is stored in the refresh buffer.
- During scanning, refresh buffer supplies the image information, which converts into different voltage levels.
- These voltages produce light patterns of the images when applied to a series of LEDs.

Non-Emissive Displays…

Liquid Crystal Displays

- A Liquid Crystal Display (LCD) either transmits or reflects incident light.
- The polarizing characteristics of certain organic compounds can modify the characteristics of incident light from surroundings or from the internal light source.
- Some organic compounds have crystalline arrangement of molecules, yet they flow like a liquid.
- Flat panel displays commonly use *nematic* (thread like) liquid crystal organic compounds that tend to align the longitudinal axis of the rod shaped molecules.
- A flat panel display constructed with liquid crystal is termed liquid crystal display.
- LCDs based display devices such as calculators, laptops, notebooks, etc., commonly used in graphics systems, have less space requirements and small power consumptions.

SOLID STATE MONITORS…
(FLAT PANEL DISPLAY)…

Non-Emissive Displays…

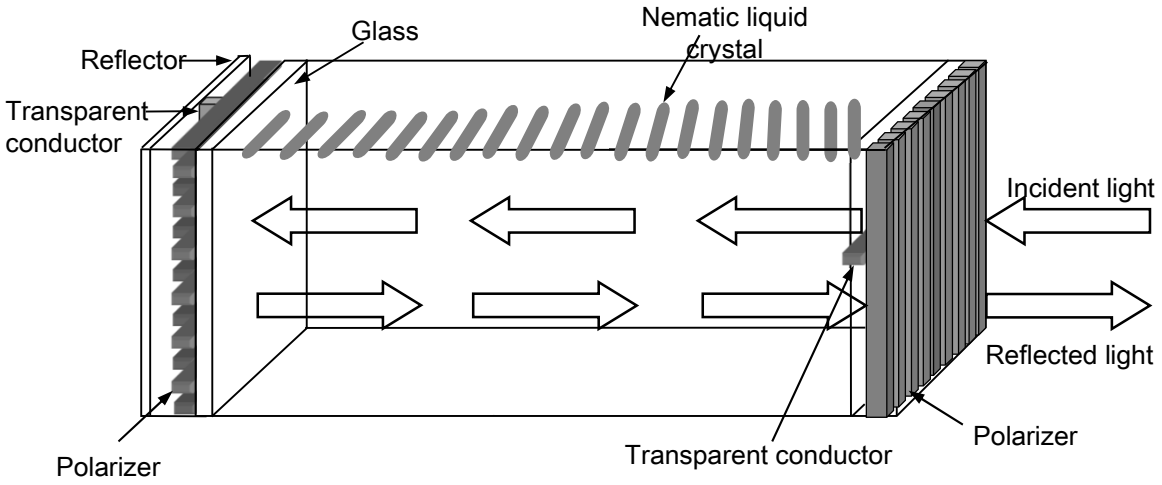
Liquid crystal displays…

Construction & Working

- The liquid crystal compound is sandwiched between the two glass plates, each containing a light polarizer, perpendicular to each other.
- The polarized light passing through one light polarizer (say, vertical) can be either blocked or made to transmit the light when passed through the liquid crystal compounds.
- Rows of horizontal transparent conductors, built in one glass plate and columns of vertical transparent conductors, built in another glass plate.
- Pixel position is obtained at the intersection of horizontal and vertical conductors.
- In *on state*, the polarized light in vertical direction twists through the liquid crystal material, and pass through the opposite horizontal polarizer.

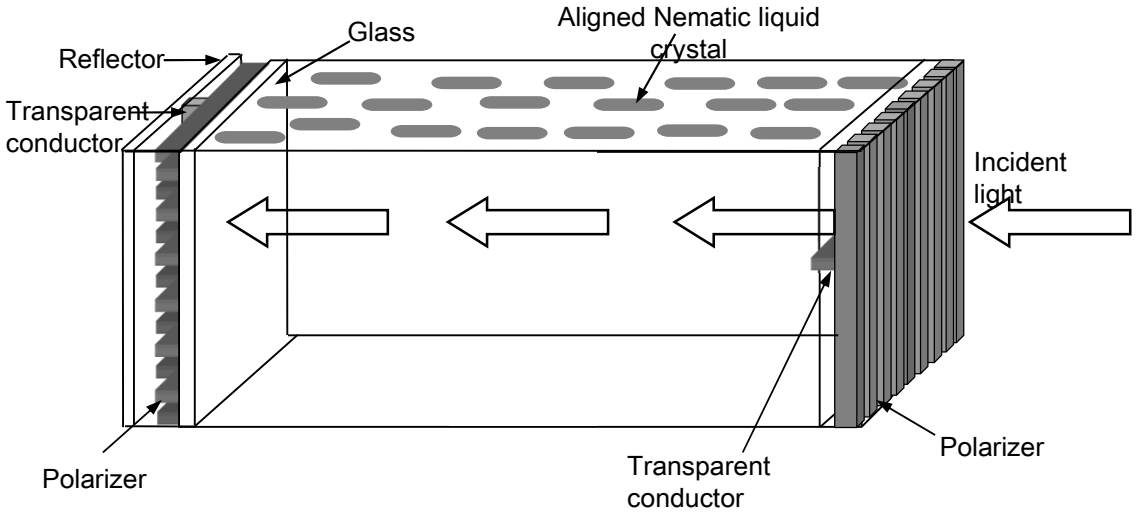
SOLID STATE MONITORS…
(FLAT PANEL DISPLAY)…

Non-Emissive Displays…



ON STATE

Liquid crystal displays



OFF STATE

Non-Emissive Displays…

Liquid Crystal Displays…

Construction & Working

- This light reflects back to the viewer and generates the graphics image, as per the image information stored in the refresh buffer, at a refresh rate of 60 Hz.
- In *off state*, the voltage at the intersection of transparent conductors aligns the liquid crystal molecules; therefore, incident light is not twisted and do not pass through the horizontal polarizer.
- Color display is achieved by using the different materials and by placing a triad of color at each pixel location. This type of flat panel device is termed as passive-matrix LCD.

SOLID STATE MONITORS…
(FLAT PANEL DISPLAY)…

Non-Emissive Displays…

Liquid Crystal Displays…

Active-matrix LCD displays have also been developed by placing transistors at each pixel locations, using thin film transistor technology. The transistors control the voltages at pixel locations.

GRAPHICS OUTPUT DEVICES

The image quality in graphics hard copy output devices depends on the following factors:

- **Dot size**

It is the diameter of a single dot on the output device.

- **Addressability**

➢ Number of individual dots on the output device is termed as addressability.

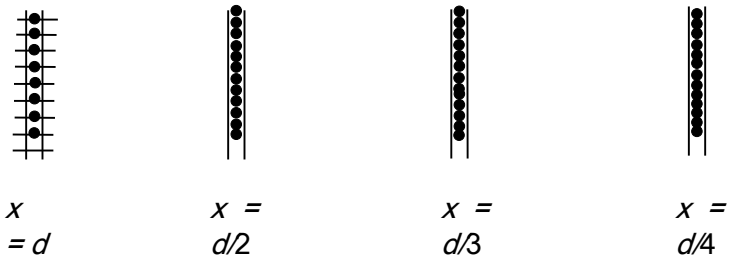
➢ The number of dots may differ in the horizontal and vertical directions.

➢ Addressability in horizontal direction is the reciprocal of the distance between the centers of two consecutive dots. The addressability in vertical direction is defined in a similar way.

➢ The reciprocal of addressability is termed *Interdot distance*.

GRAPHICS OUTPUT DEVICES

- Often it is desirable that dot size should be more than the interdot distance for the smooth graphics image.
- Figure shows the effect of interdot spacing on the quality of images generated on the hard copy.
- If dot size is equal to several times that of interdot distance, the printing becomes very smooth.



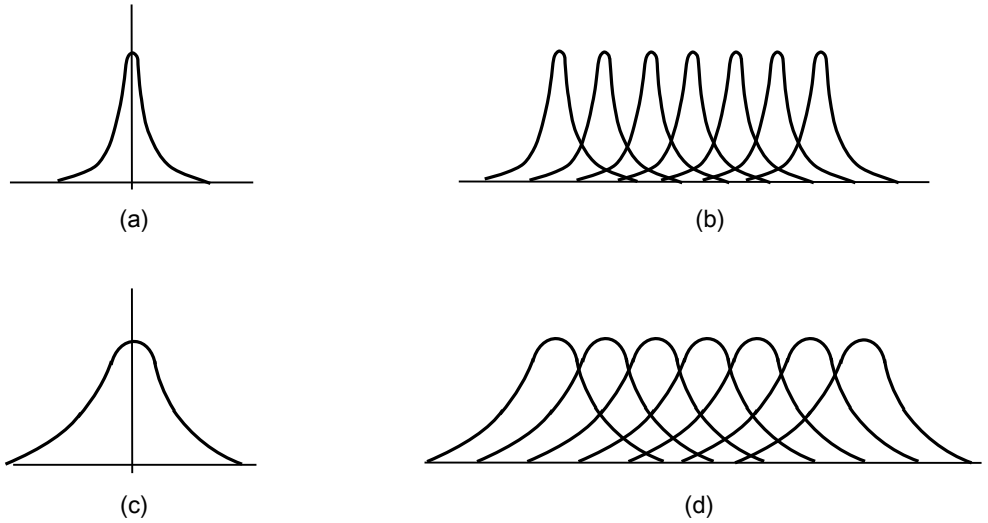
d = dot diameter, *x* = interdot distance

Resolution of an Output Device

- *Resolution* of an output device is the number of distinguishable lines created over a length of one inch.
- Resolution cannot be more than the addressability.
- Resolution is the closest spacing between the two adjacent black and white lines that is distinguishable by the observer.
- It may be different in horizontal and vertical directions. For example, if 20 black lines interleaved with 20 white lines across one inch, the resolution will be 40 lines per inch.
- Cross-sectional intensity distribution of a spot also defines the resolution.
- A spot with sharply delineated edges possesses higher resolution as compared to one whose edges are trailed-off.

Resolution of an Output Device…

- Figure shows the effect of cross-sectional spot intensity distribution of a single dot as well as multiple overlapping dots.
- The actual image intensity will be the sum of intensities of several overlapping spots. It can be observed that peaks (b) are more distinct as compared to the peaks in (d).



Effect of cross-sectional intensity on resolution (a) Spot with well defined edges (b) Several such overlapping spots (c) Wider spot with less height (d) Several wider overlapping spots

GRAPHICS OUTPUT DEVICES

Resolution of an Output Device…

- The quality of pictures obtained from hard copy output device depends on the dot size and the numbers of dots displayed per inch, or lines per inch.
- To produce smooth characters on hard copy, high quality printers shift dot positions so that adjacent dots overlap.
- Printers/plotters produce output either by impact or non-impact methods. The impact of characters on the inked ribbon results into impact printing onto the paper.
- Non-impact printers/plotters employ laser technology, inkjet sprays and xerographic processes, electrostatic and electrothermal methods.

GRAPHICS OUTPUT DEVICES

Impact Printers/Plotters

- The impact printing devices produce an image by hammering an inked ribbon on the surface of a paper; hence, named impact printers.
- The impact printers have a dot-matrix print head containing series of protruding wire pins. The number of pins on the printing head decides the quality of printer.
- Each pin strikes individually over the inked ribbon. The printing head moves across the paper one step at a time, the paper moves by one line, and printing head passes once again across the paper.
- The movement of printing head is similar to the raster scan system; therefore, such devices are termed *raster output devices*.
- These devices require scan conversion of vector images prior to printing on the paper.

Impact Printers/Plotters…

There are various mechanical printing technologies such as

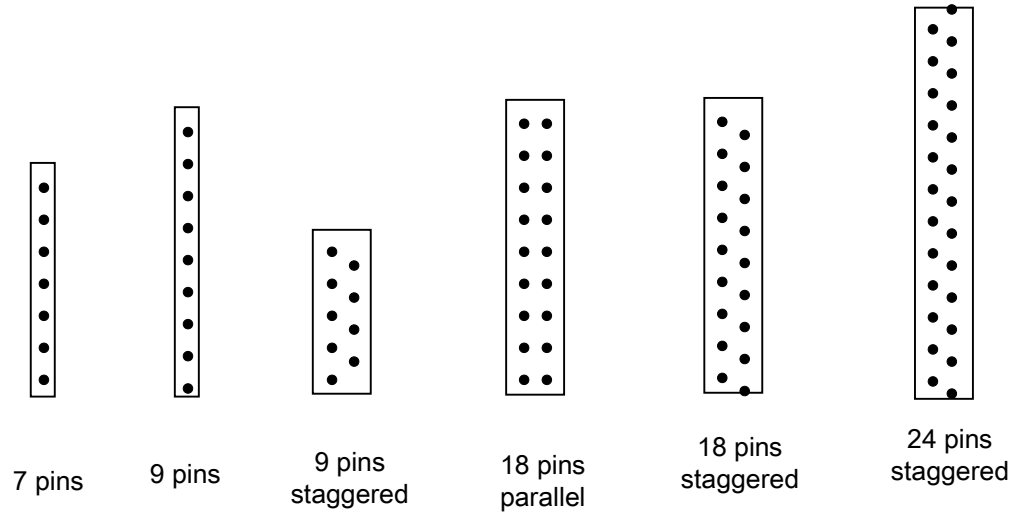
- ✓ **belt printer**
- ✓ **drum printer**
- ✓ **chain printer, and**
- ✓ **dot matrix printer**

- The addressability of a dot matrix printer does not depend on the physical distance between the wire pins.
- The two columns of pins replace single column of pins, offset vertically by one-half of the inter-pin spacing, thereby producing the same effect of printing that can be achieved by advancing the paper by one-half inter-pin spacing between the first and second pass.

GRAPHICS OUTPUT DEVICES

Impact Printers/Plotters…

- Figure shows various print head geometries of the dot matrix printers.
- Dot matrix printers are inexpensive but slow specially for printing the graphics image.
- It is possible to achieve a resolution as high as *300 dpi* (dots per inch) with dot matrix printers.



Dot matrix print head pins arrangement

Colored Impact Printers/Plotters

- The colored ribbons produce a colored hard copy against the print head.
- There are two ways for achieving a colored copy.
- It can be obtained either by using multiple print heads, each head with different colored ribbons, or by using single print head with multicolored ribbons.
- When different colors overstrike at the same dot, it results into multiple colors.
- For example, eight colors may be obtained by over striking of cyan, magenta and yellow colors.
- Although black color is achievable by striking all the colors, but the resulting image becomes quite *muddy*; therefore, a true black colored ribbon is separately used.

Non-Impact Printers/Plotters

Following devices come under the category of non-impact printers/plotters:

1. Pen Plotters

- Similar to random and raster displays, there are random and raster plotting devices.
- In pen plotters, a pen moves over the paper in random, vector style.
- In drawing, first the pen positions at the staring point, draws the line to the other end; raised and moved to the start point of next line.
- The quality and accuracy of the hard copy produced by the pen plotters, is considerably higher than the quality of images generated on the computer screen.

There are two types of pen plotters:

- Flatbed plotters
- Drum plotters

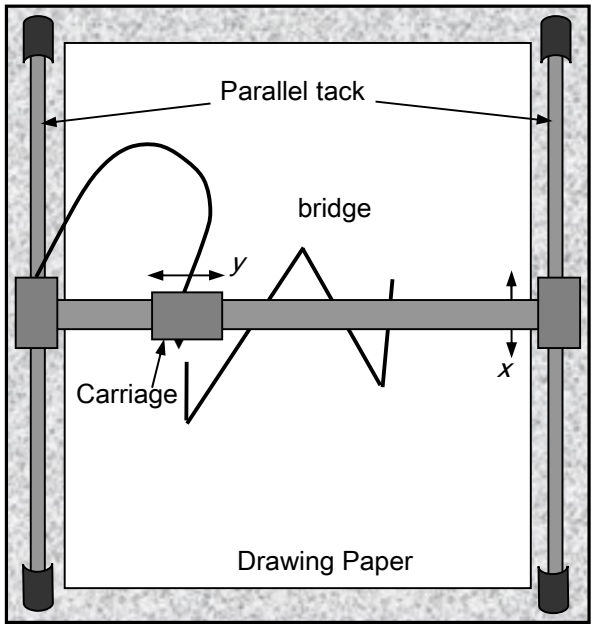
Non-Impact Printers/Plotters…

Flatbed Plotters

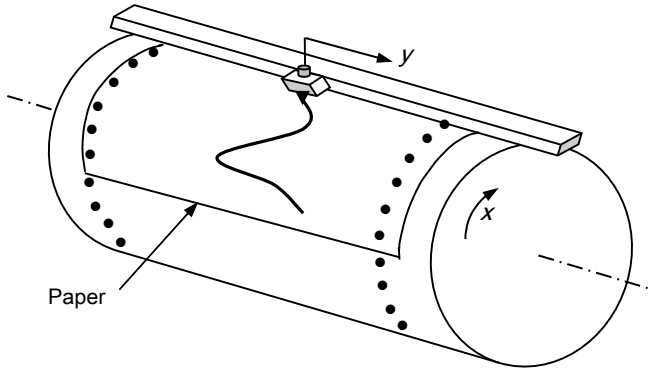
- The flatbed plotter uses a flat drawing surface of size up to 1.5 m x 6.0 m with a horizontal or vertical orientation.
- The paper is stationery and pen holding mechanism moves along the *x* and *y* axes.
- There are two parallel tracks located on two sides of a flat paper.
- A carriage containing a writing head can move along the tracks; thus, provides the *x*–direction motion.
- The movement of writing head relative to the carriage across the flat paper provides the y-direction motion.
- A pen/pencil mounted on the writing head, can be raised or lowered to provide the contact of pen with the paper whenever desired.
- The flatbed pen plotter plots the drawing with an accuracy of *0.025 mm (or 25 micron*

GRAPHICS OUTPUT DEVICES

Non-Impact Printers/Plotters…



Flat-bed plotter



Drum plotter

Non-Impact Printers/Plotters…

Drum Plotters

- Drum plotter uses a round drum mounted in the horizontal direction and a slider containing a pen moves along the axis of drum.
- The pre-punched paper wrapped on the drum, can advance with the help of pins provided on both sides of the drum plotter.
- Both paper and pen moves along the two perpendicular axes.
- The drum can rotate in forward and backward directions.
- The size of the drum plotter is limited to 0.21 m x 1.06 m.
- Since the paper wraps on the drum plotter; therefore, drawings of unlimited length at high speed is possible.
- Drum plotters are less expensive than the Flatbed plotters.

Non-Impact Printers/Plotters…

Multicolor plotters

- A multicolor plotter uses several pens of different colors.
- In some models, the pen is replaced by a highly focused, high intensity light source and conventional drafting paper by a photosensitive paper.
- Some flatbed plotters also combine the function of a digitizer, called digitizer-plotter.
- The plotter accept digitized data either on-line from a computer or off-line from some secondary storage devices.
- In microprocessor-based pen plotter, certain complex shapes such as circles or ellipses programmed to convert the digital data directly into the complex shapes in compact and efficient manner.

COMPUTER AIDED DESIGN
(BME-42)

Unit-I: Computer Graphics Hardware

(6 Lectures)

- Graphics systems
- Graphics Input devices: Cursor control devices**, Digitizers, Image scanner, Speech oriented devices**,
- **Graphics display devices-Cathode Ray Tube**, Calligraphic display, DVST, Raster display, Color frame buffer, Color CRT monitors, Solid state monitors-emissive displays, non-emissive displays,
- Graphics output devices- Hard copy printers and plotters

Lecture 9

Topics Covered

Graphics Output Devices

Non-impact Printers

Electrostatic Plotters

Laser Printers

Inkjet Printers

Electrothermal Plotters

Computer output to Microfilm

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NON-IMPACT PRINTERS/PLOTTERS

2. Electrostatic Plotters

- Electrostatic plotter works on the principle of *raster* scan system.
- The raster images in vector form such as lines, circles, symbols, alphanumeric characters are stored and printed by depositing small particles of toner on the electrostatically charged areas of a special paper.
- A typical electrostatic plotter with resolutions of 200 dots/inch or more can be achieved by overlapping the adjacent dots by 30 to 50 percent.

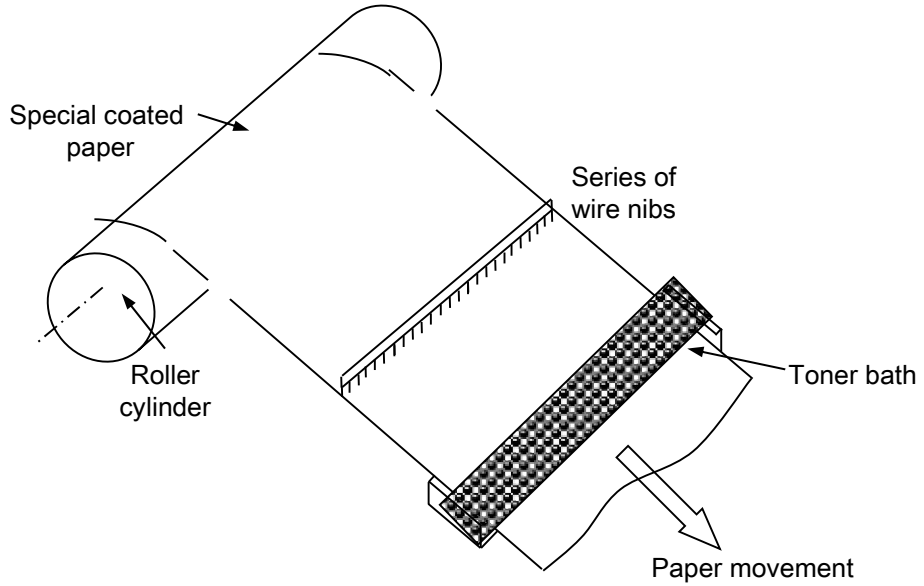
Construction and Working

- A specially coated paper, holding an electrostatic charge passes over a writing head, which consists of one to three rows of small nibs that impart electrostatic negative charge on the paper when paper passes over the nibs.

NON-IMPACT PRINTERS/PLOTTERS…

2. Electrostatic Plotters…

- The negative charged paper is exposed to the positive charged toner, where positive charged toner particles adhere to the negatively charged dots on the paper, thereby generating the graphics image.
- Normally, each dot is either black (i.e., *on* when imparts negative charge) or white (i.e., *off* when imparts no charge); therefore, produces a monochrome image.



NON-IMPACT PRINTERS/PLOTTERS…

2. Electrostatic Plotters…

- Color electrostatic plotter uses three subtractive primary colors cyan, magenta, yellow and black.
- These colors are applied either in single pass or four multiple passes.
- If colors are applied in single pass, separate rows of nibs (viz, multiple heads) are required.
- In multiple passes, black color calibration marks are placed near the edges of paper during the first pass to ensure the alignment of three colors during the successive passes.
- A typical plotter can provide as high as seven colors, but color shading is possible using dither (pulsate/vibrate) and patterning.

NON-IMPACT PRINTERS/PLOTTERS…

2. Electrostatic Plotters…

Advantages and Limitations

- Electrostatic plotters are ten times faster than the pen plotters.
- Pen plotters are highly accurate and present high-quality contrast images than the electrostatic plotters but plotting time is more for the complex drawings.
- Color electrostatic plotters are quite expensive.
- The main limitation of electrostatic plotter is the conversion of data into raster format before converting it into a hard copy.
- The scan-conversion capability may be included in the electrostatic plotters or the CPU can do it separately.

NON-IMPACT PRINTERS/PLOTTERS…

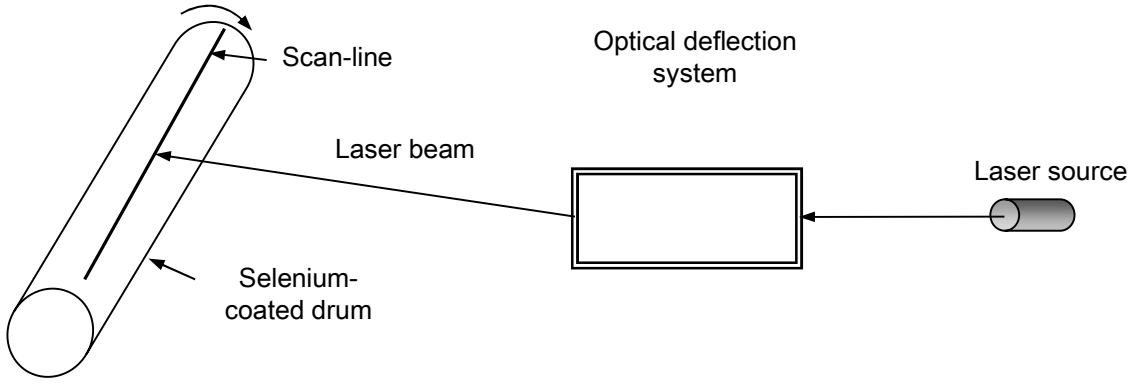
3. Laser Printers

- Computer graphics extensively uses laser printers for the hard copy of graphics image.
- It works on the principle of raster scanning of images by a laser beam across a positively charged rotating drum coated with selenium.
- The positioning of laser beam on the drum is accomplished by an optical deflection system whereas the scan conversion and control of laser printer is obtained using a microprocessor.
- During scanning, the laser beam loses their charge on the drum; thus, provides positive charge in the portions where black image is required.
- A negatively charged toner adheres to the positive charged areas of the drum and transfers toner to the paper using heat and pressure to form the permanent image.

NON-IMPACT PRINTERS/PLOTTERS…

3. Laser Printers…

- Similar to electrostatic plotter, the images with black spot (when positive charge is present) and white spot (when positive charge is not present) can be produced. Figure shows the working principle of a monochrome laser printer.
- In color laser printer, this process is repeated three times corresponding to the three primary colors.
- Laser printers are available with a resolution as high as 600 dpi x 600 dpi with practical upper limit of 800 to 1000 dpi beyond which the fusion of toner particles starts.



NON-IMPACT PRINTERS/PLOTTERS…

4. Inkjet Printers

- Inkjet printers, a raster scan device, produce low cost color output.
- The printer sprays cyan, magenta, yellow, and sometimes black color in the form of tiny droplets on the paper medium.

Broadly, there are Two categories of inkjet printers:

Continuous Flow Inkjet Printers

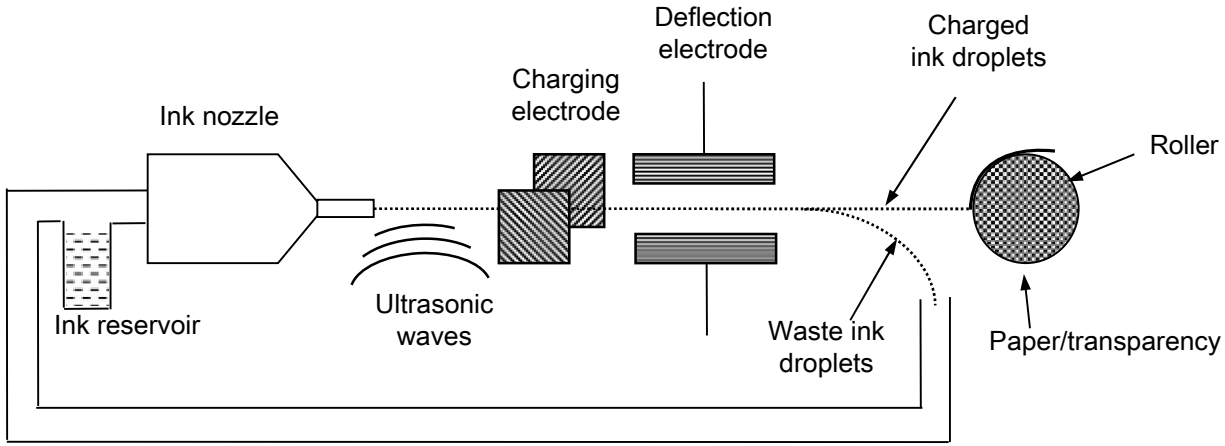
- The continuous flow inkjet printer produces a stream of tiny droplets of ink spraying out of a nozzle by the ultrasonic waves.
- These droplets move towards the medium (paper or transparency) before passing through the electrostatic charged system and deflection system.

NON-IMPACT PRINTERS/PLOTTERS…

4. Inkjet Printers…

Continuous flow inkjet printers…

- The electrostatic charged tiny droplets fall on the paper/medium at the desired locations by the deflection system.
- The uncharged droplets are deflected into a reservoir for the recycling.



Schematic of continuous flow inkjet printer

NON-IMPACT PRINTERS/PLOTTERS…

4. Inkjet Printers…

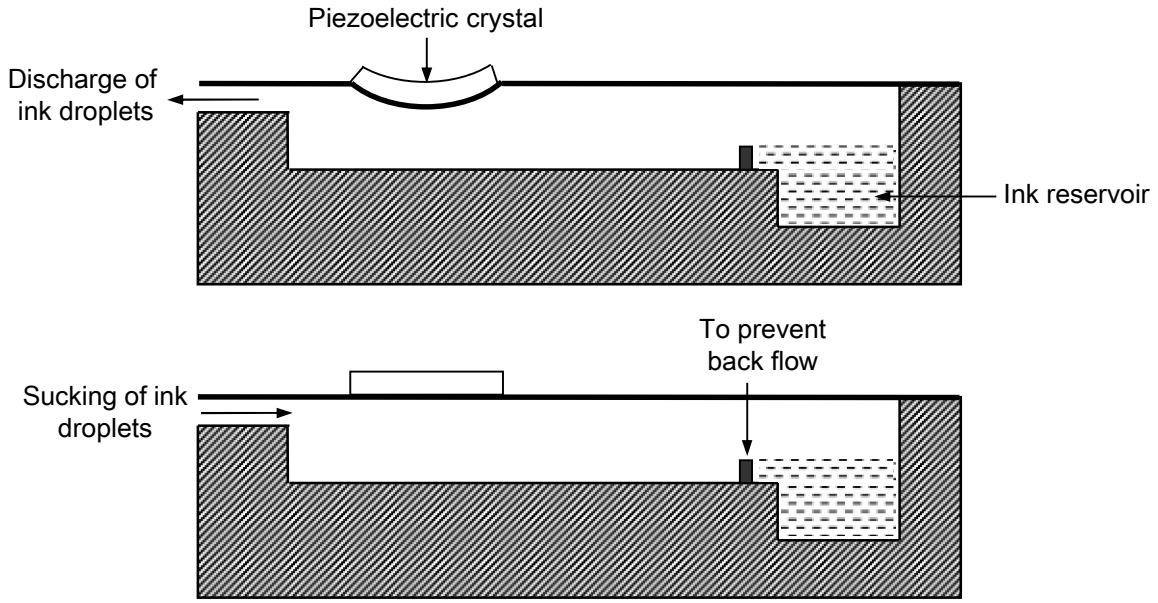
Drop-on-demand inkjet printers

- The drop-on-demand inkjet printer fires the ink droplet from a reservoir to the paper/medium, whenever required by the dot.
- The piezoelectric crystal controls firing of ink droplets. When voltage is applied on the piezoelectric crystal, it expands and releases the ink from nozzle in the form of tiny droplets.
- The release of voltage causes sucking of ink back to the reservoir. Figure shows the schematic of drop-on-demand type inkjet printing technology.
- The typical resolution of inkjet printers vary from 120–900 dpi.
- Color inkjet printers replace single nozzle by the four nozzles, each for three primary colors cyan, magenta, yellow and one for the black.

4. Inkjet Printers…

Drop-on-demand inkjet printers

- Due to the liquid droplets, blending of colors together before drying provides good depth of colors, as compared to the other technologies.



Schematic of drop-on-demand inkjet printer

NON-IMPACT PRINTERS/PLOTTERS…

5. Electrothermal plotters

- Electrothermal plotters, similar to electrostatic plotters, are another type of *raster* scan hard copy output device in which graphics image transfers on the heat sensitive paper through the heated nibs of dot matrix print head.
- The selectively heated nibs transfer the colored ink, coated with wax on the ribbon, onto the plain paper.
- The wax paper and plain paper together passes over the heated nibs to produce the graphics image.

Electrothermal plotters employ two types of thermal printing techniques:

Direct thermal transfer

- Direct thermal transfer technique uses heat sensitive paper that changes the color when heated.

NON-IMPACT PRINTERS/PLOTTERS…

5. Electrothermal plotters…

Direct thermal transfer…

- The print head nibs selectively heat the dots on the paper and generates image when cooling of dots takes place.
- A resolution of 400 dpi is possible by this method.
- The special paper (although fades with time) requirement is the prominent limitation of this method.

Indirect thermal transfer

- Indirect thermal transfer technique uses a ribbon, coated with ink in the wax binder.
- The heating of print head nibs causes melting of wax behind the ribbon, which allows transfer of ink on the plain paper.
- The method produces brilliant colors because the paper does not absorb ink.

NON-IMPACT PRINTERS/PLOTTERS…

5. Electrothermal plotters…

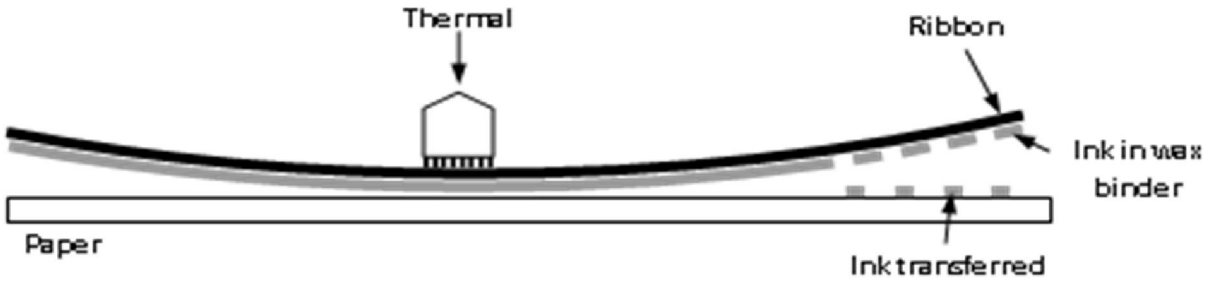
Indirect thermal transfer…

- Figure shows the mechanism of ink transfer on the paper through the indirect thermal transfer technique.
- For color printing, the multicolored ribbons with alternate wax coating of cyan, magenta, yellow, and black color is used.
- Because the nibs heat and cool very rapidly; therefore, produces fast single-color printing of graphics image.
- This technique is capable of providing a typical resolution of 100-400 dpi.
- The image generated by the indirect thermal transfer method shows excellent life.

NON-IMPACT PRINTERS/PLOTTERS…

5. Electrothermal plotters…

Indirect thermal transfer…



6. Computer output to Microfilm

- No technique discussed so far is capable of displaying 16.77 million colors on a medium (paper/transparency) produced by the raster displays.
- In spite of all the efforts, pictures obtained on the paper have possibility of fading with time.

NON-IMPACT PRINTERS/PLOTTERS…

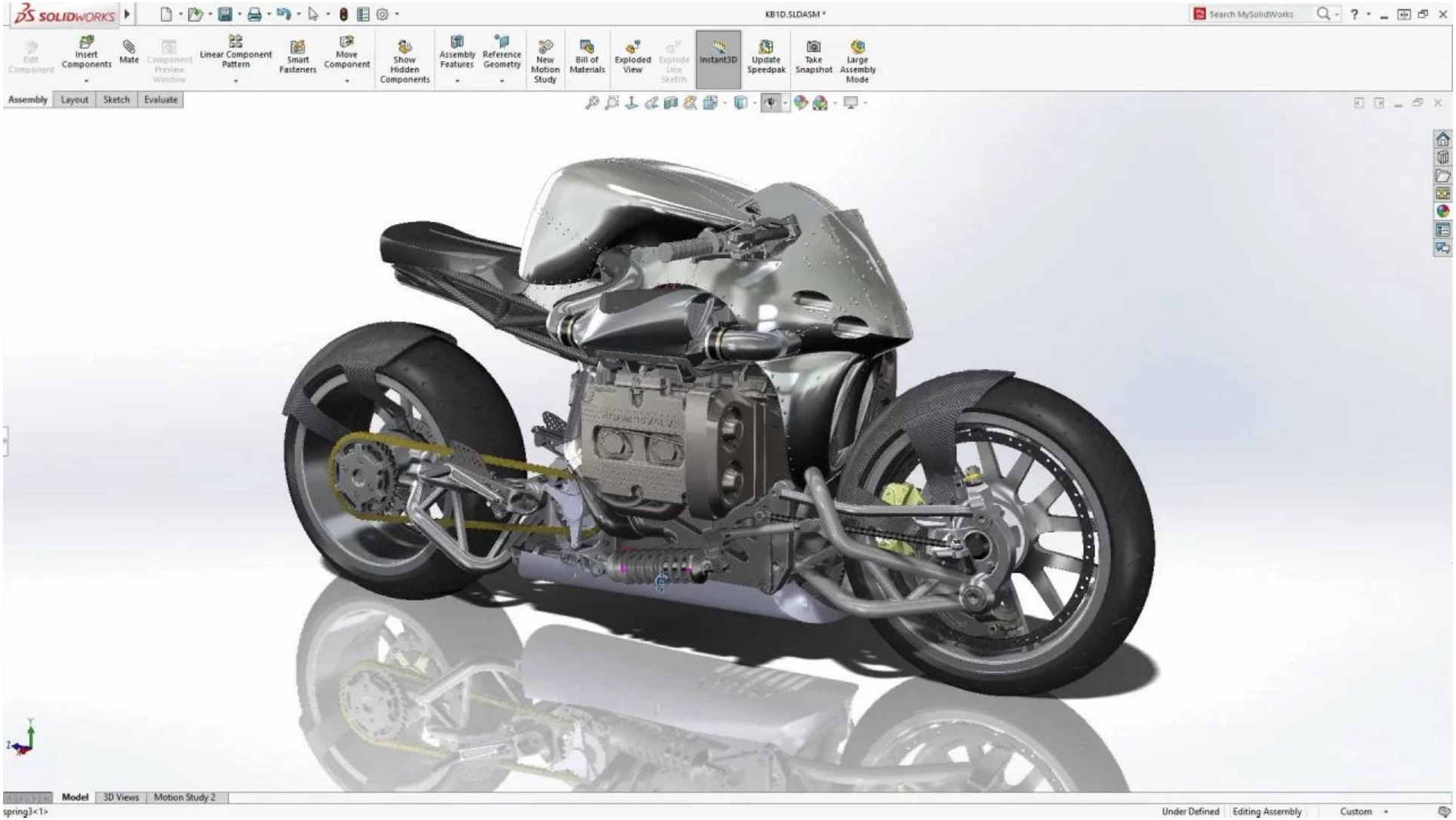
6. Computer output to Microfilm…

- Currently, the only technique for preserving the good quality graphics image on the computer screen is the photographic film.
- In most of the computer graphics system, a color film camera remains a part of the computer system as Computer Output to Microfilm (COM) unit.
- The COM unit produces the drawings on microfilm rather than on the full size paper.
- The COM units have large storage capacity and capable of producing the drawings several hundred times faster than the pen plotters, and faster than the electrostatic plotters.
- The microfilm can reproduce the drawings of exactly similar quality with enlarged size, whenever required in future.

NON-IMPACT PRINTERS/PLOTTERS…

6. Computer output to Microfilm…

- The microfilm supplies quickly the image data.
- The drawbacks of COM units are that the user cannot write notes on the microfilm, as it is possible with the paper drawings.
- The output drawing with enlarged size is possible at the cost of quality, compared to the same obtained with pen plotters.
- COM is expensive due to high technology adopted for its production; hence, not preferred by the designer.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THANK YOU