UNIT-2

Graphics Display: There are two types of types of graphics display available: random scan display and raster scan display.

- ✓ **Random/Vector Scan Display:**
- ✓ Vector scan display directly traces out only the desired lines on CRT.
- ✓ If we want line between point p1 & p2 then we directly drive the beam deflection circuitry which focus beam directly from point p1 top2.
- ✓ If we do not want to display line from p1 to p2 and just move, then we can blank the beam as we move it.
- ✓ Random Scan System uses an electron beam which operates like a pencil to create a line image on the CRT screen.
- ✓ The picture is constructed out of a sequence of straight-line segments. Each line segment is drawn on the screen by directing the beam to move from one point on the screen to the next, where its x & y coordinates define each point.
- ✓ After drawing the picture. The system cycles back to the first line and design all the lines of the image 30 to 60 time each second. The process is shown in fig:

  Random-scan monitors are also known as vector displays or stroke-writing displays or calligraphic displays.

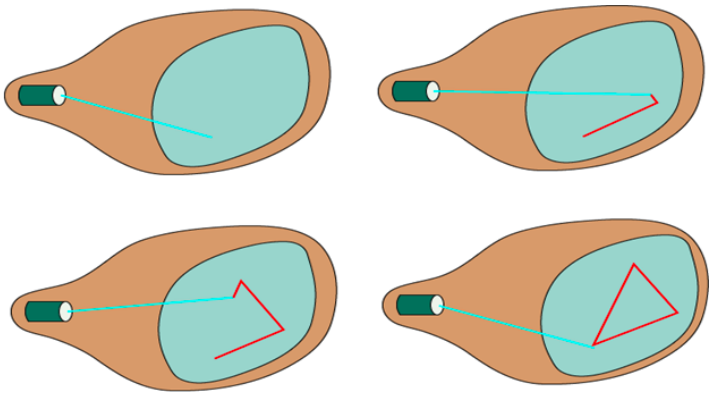


Fig: Random Scan Display

1. **Raster Scan Display:**

- ✓ **I**t consists of display controller, CPU, video controller, refresh buffer, keyboard, mouse and CRT.
- ✓ The display image is stored in the form of 1's and 0's in the refresh buffer.
- ✓ It will scan one line at a time from top to bottom & then back to the top.
- ✓ In this method the horizontal and vertical deflection signals are generated to move the beam all over the screen in a pattern shown in figure.
- ✓ Here beam is swept back & forth from left to the right.

- ✓ When beam is moved from right to left it is OFF and process of moving beam from right to left after completion of row is known as Horizontal Retrace.
- ✓ When beam is reach at the bottom of the screen. It is made OFF and rapidly retraced back to the top left to start again and process of moving back to top is known as Vertical Retrace.
- ✓ The screen image is maintained by repeatedly scanning the same image. This process is known as Refreshing of Screen.
- ✓ In raster scan displays a special area of memory is dedicated to graphics only. This memory is called Frame Buffer.
- ✓ Frame buffer holds set of intensity values for all the screen points.
- ✓ That intensity is retrieved from frame buffer and display on screen one row at a time.

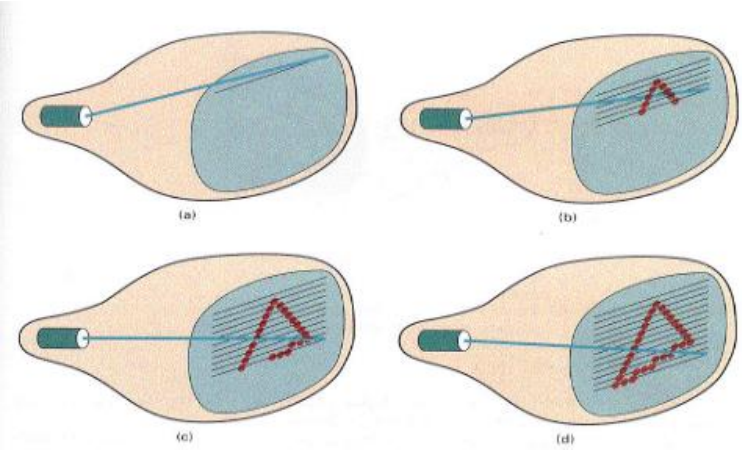
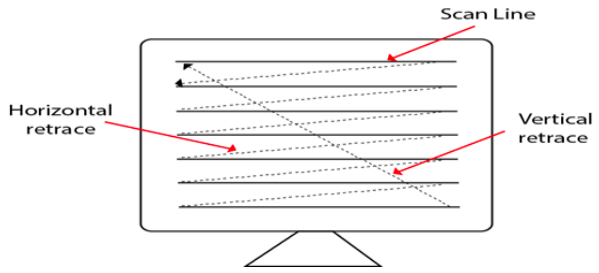


Fig: Raster Scan Display

A Raster Scan Display is based on intensity control of pixels in the form of a rectangular box called Raster on the screen. Information of on and off pixels is stored in refresh buffer or Frame buffer. Televisions in our house are based on Raster Scan Method. The raster scan system can store information of each pixel position, so it is suitable for realistic display of objects. Raster Scan provides a refresh rate of 60 to 80 frames per second.

Frame Buffer is also known as Raster or bit map. In Frame Buffer the positions are called picture elements or pixels. Beam refreshing is of two types. First is horizontal retracing and second is vertical retracing. When the beam starts from the top left corner and reaches the bottom right scale, it will again return to the top left side called at vertical retrace. Then it will again more horizontally from top to bottom call as horizontal retracing shown in fig:



S.NO	Base of Difference	Random Scan	Raster Scan
1.	Resolution	The resolution of random scan is higher than raster scan.	While the resolution of raster scan is lesser or lower than random scan.
2.	Cost	It is costlier than raster scan.	While the cost of raster scan is lesser than random scan.
3.	Modification	In random scan, any alteration is easy in comparison of raster scan.	While in raster scan, any alteration is not so easy .
4.	Interlacing	In random scan, interlacing is not used.	While in raster scan, interlacing is used.
5.	Line Drawings	In random scan, mathematical function is used for image or picture rendering. It is suitable for applications requiring polygon drawings.	While in which, for image or picture rendering, raster scan uses pixels. It is suitable for creating realistic scenes.
6.	Motion of Electron Beam	Electron Beam is directed to only that part of screen where picture is required to be drawn, one line at a time.	Electron Beam is directed from top to bottom and one row at a time on screen. It is directed to whole screen.
7.	Picture Definition	It stores picture definition as a set of line commands in the Refresh buffer.	It stores picture definition as a set of intensity values of the pixels in the frame buffer.
8.	Refresh Rate	Refresh rate depends on the number of lines to be displayed i.e. 30 to 60 times per second.	Refresh rate is 60 to 80 frames per second and is independent of picture complexity.
9.	Solid Pattern	In random scan, Solid Pattern is tough to fill.	In raster scan, Solid Pattern is easy to fill.
10.	Example	Pen Plotter	TV Sets

Video Controller:

A video controller, or video card and graphics card as they are now more commonly known, is an expansion card whose function is to generate and output images to a display. When referring to early machines, the card is sometimes referred to as a video controller or graphics controller, when the cards were typically integrated onto the motherboard itself.

- ✓ Two register are used to store the co-ordinates of the screen pixel.
- ✓ Initially the X register is set 0 and Y register is set to ymax.
- ✓ The value stored in the frame buffer for this pixel position is then retrieved and then used to set the intensity of CRT beam.
- ✓ Then the x register is increased by one and process Repeated for the next pixel in the top scan line.
- ✓ This process is repeated for each pixel along line.

- ✓ When the last pixel of the top scan line has been processed the x register is reset to zero and y register is decremented by 1 pixel on the screen lines are processed against inturn; and the process is repeated for each successive scan line.

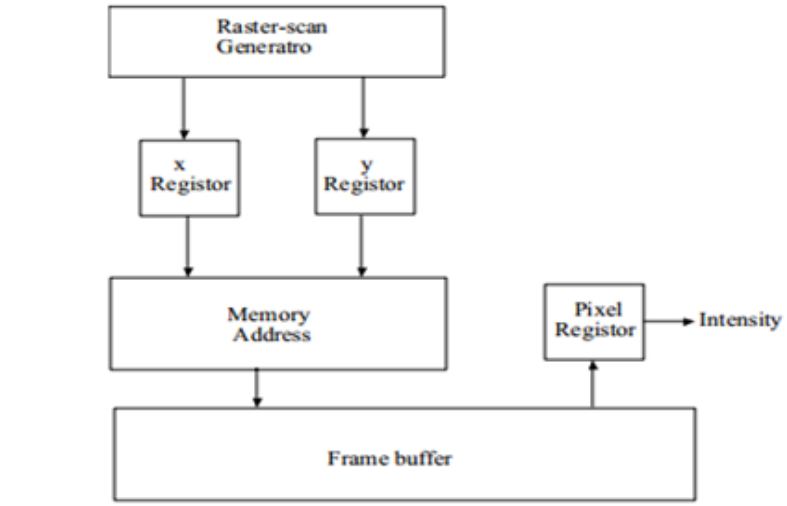


Fig. Basic video controller Refresh operation.

- ✓ After cycling though each pixel along the bottom scan line (y =0) the video controller resets the register the first pixel poison on the top scan line and refresh process starts over.
- ✓ Screen must be refreshing at least at the rate of 60 frames per second.
- ✓ To speed of the pixel processing video controller can retrieve multiple pixel values from the refresh buffer on each pass. The multiple pixel intensity are then stored in a separate register and used to control the CRT bit intensity for a group of adjacent pixel. When that group of pixel has been processes the next block of pixel values is retrieved from the frame buffer.
- ✓ Besides these refresh operation video controller also performs different operation video controller retrieved pixel intensity from different memory area on different refresh cycle.
- ✓ In high quality system, for example, two frame buffers are often provided so that gun buffer can be used for refreshing while the other is being filled with intensity values.
- ✓ This provides a fast mechanism for generating real time animations seans different views of moving object can be successively loaded in the refresh buffer.
- ✓ Video controller also contains a look up table instead of controlling CRT beam intensity directly. This provides a fast mechanism for changing screen intensity values.

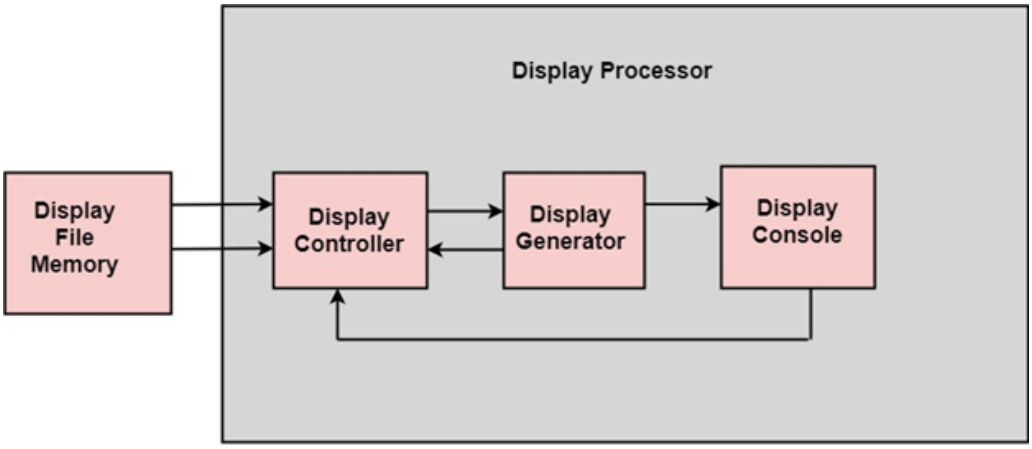
Display Processor:

It is interpreter or piece of hardware that converts display processor code into pictures. It is one of the four main parts of the display processor

Parts of Display Processor

1. Display File Memory

2. Display Processor
3. Display Generator
4. Display Console



Block diagram of Display System

Display File Memory: It is used for generation of the picture. It is used for identification of graphic entities.

Display Controller:

1. It handles interrupt
2. It maintains timings
3. It is used for interpretation of instruction.

Display Generator:

1. It is used for the generation of character.
2. It is used for the generation of curves.

Display Console: It contains CRT, Light Pen, and Keyboard and deflection system.

The raster scan system is a combination of some processing units. It consists of the control processing unit (CPU) and a particular processor called a display controller. Display Controller controls the operation of the display device. It is also called a video controller.

Working: The video controller in the output circuitry generates the horizontal and vertical drive signals so that the monitor can sweep. Its beam across the screen during raster scans.

As fig showing that 2 registers (X register and Y register) are used to store the coordinate of the screen pixels. Assume that y values of the adjacent scan lines increased by 1 in an upward direction starting from 0 at the bottom of the screen to y_{max} at the top and along each scan line the screen pixel positions or x values are incremented by 1 from 0 at the leftmost position to x_{max} at the rightmost position.

The origin is at the lowest left corner of the screen as in a standard Cartesian coordinate system.

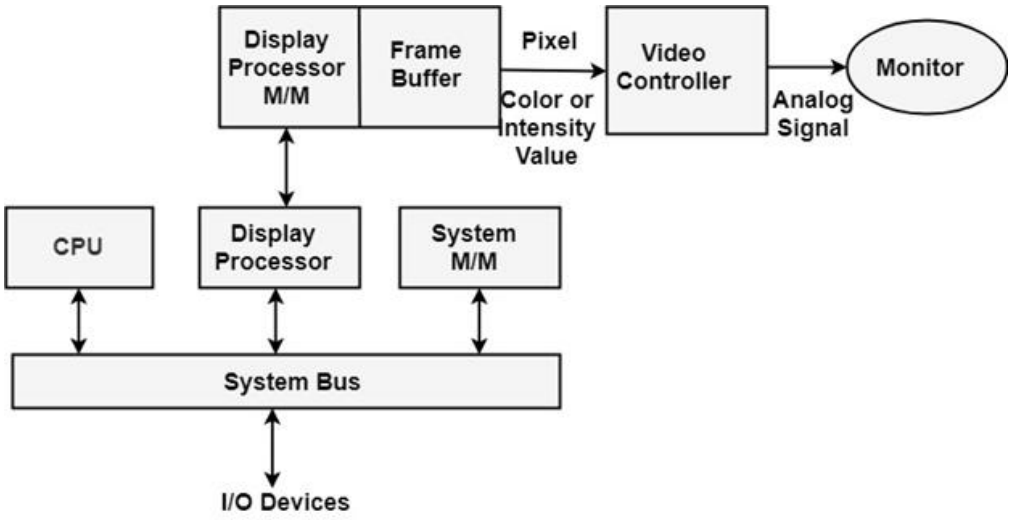


Fig: Architecture of a Raster Display System with a Display Processor

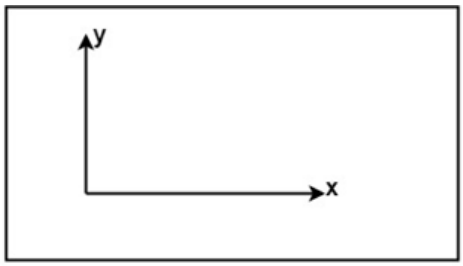


Fig:The origin of the coordinate system for identifying screen positions is usually specified in the lower-left corner.

At the start of a **Refresh Cycle**:

X register is set to 0 and y register is set to y_{max}. This (x, y') address is translated into a memory address of frame buffer where the color value for this pixel position is stored.

The controller receives this color value (a binary no) from the frame buffer, breaks it up into three parts and sends each element to a separate Digital-to-Analog Converter (DAC).

These voltages, in turn, controls the intensity of 3 e-beam that are focused at the (x, y) screen position by the horizontal and vertical drive signals.

This process is repeated for each pixel along the top scan line, each time incrementing the X register by Y.

As pixels on the first scan line are generated, the X register is incremented throughx_{max}.

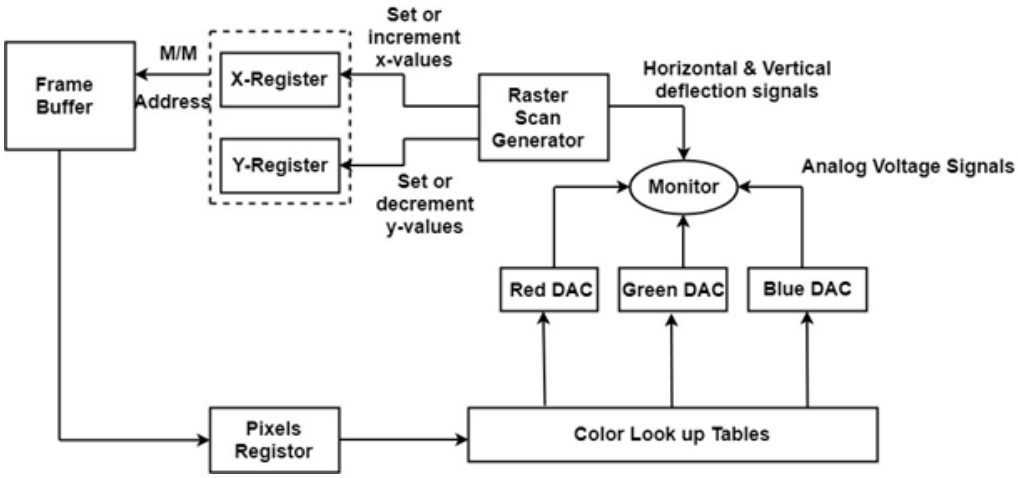
Then x register is reset to 0, and y register is decremented by 1 to access the next scan line.

Pixel along each scan line is then processed, and the procedure is repeated for each successive scan line units pixels on the last scan line (y=0) are generated.

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

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

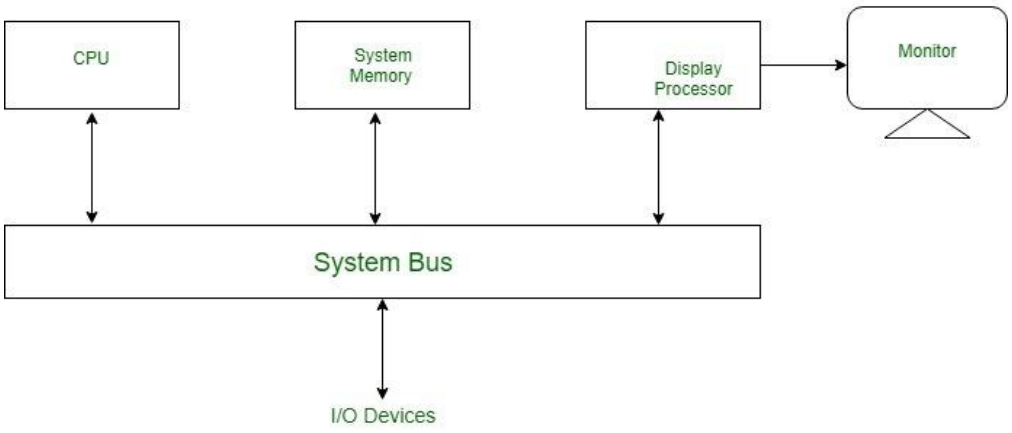
As the time available to display or refresh a single pixel in the screen is too less, accessing the frame buffer every time for reading each pixel intensity value would consume more time what is allowed:



Multiple adjacent pixel values are fetched to the frame buffer in single access and stored in the register.

After every allowable time gap, the one-pixel value is shifted out from the register to control the warm intensity for that pixel.

The procedure is repeated with the next block of pixels,and so on, thus the whole group of pixels will be processed.



Random-Scan Display Processors:

Input in the form of an application program is stored in the system memory along with graphics package. Graphics package translates the graphic commands in application program into a display file stored in system memory. This display file is then accessed by the display processor to refresh the screen. The display processor cycles through each command in the display file program. Sometimes the display processor in a random-scan is referred as *Display Processing Unit / Graphics Controller*.

The structure of a simple random scan is shown below:

Advantages:

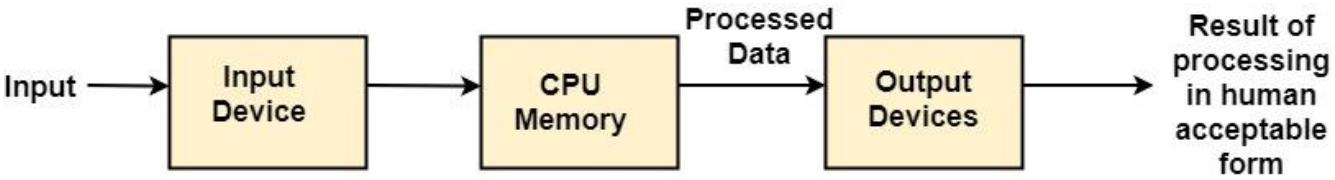
- Higher resolution as compared to raster scan display.
- Produces smooth line drawing.
- Less Memory required.

Disadvantages:

- Realistic images with different shades cannot be drawn.
- Colour limitations.

Input Devices for Operator Interaction:

The Input Devices are the hardware that is used to transfer transfers input to the computer. The data can be in the form of text, graphics, sound, and text. Output device displays data from the memory of the computer. Output can be text, numeric data, line, polygon, and other objects.



These devices include:

1. Keyboard
2. Mouse
3. Trackball
4. Spaceball
5. Joystick
6. Lightpen
7. Digitizer
8. Touch Panel
9. Voice Recognitition
10. Image Scanner

1. **Keyboard:** The most commonly used input device is a keyboard. The data is entered by pressing the set of keys. All keys are labeled. A keyboard with 101 keys is called a QWERTY keyboard. The keyboard has alphabetic as well as numeric keys. Some special keys are also available.

   Function of Keyboard:

   1. Alphanumeric Keyboards are used in CAD. (Computer Aided Drafting)
   2. Keyboards are available with special features line screen co-ordinates entry, Menu selection or graphics functions, etc.
   3. Special purpose keyboards are available having buttons, dials, and switches. Dials are used to enter scalar values. Dials also enter real numbers. Buttons and switches are used to enter predefined function values.

   Advantage:

   1. Suitable for entering numeric data.
   2. Function keys are a fast and effective method of using commands, with fewer errors.

   Disadvantage:

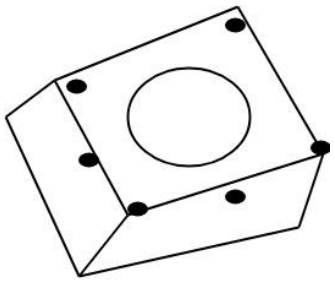
   1. Keyboard is not suitable for graphics input.

2. **Mouse:** A Mouse is a pointing device and used to position the pointer on the screen. It is a small palm size box. There are two or three depression switches on the top. The movement of the mouse along the x-axis helps in the horizontal movement of the cursor and the movement along the y-axis helps in the vertical movement of the cursor on the screen. The mouse cannot be used to enter text. Therefore, they are used in conjunction with a keyboard.

   ## Advantage:

   1. Easy to use
   2. Not very expensive

3. **Trackball:** It is a pointing device. It is similar to a mouse. This is mainly used in notebook or laptop computer, instead of a mouse. This is a ball which is half inserted, and by changing fingers on the ball, the pointer can be moved.



TrackBall

Advantage:

1. Trackball is stationary, so it does not require much space to use it.
2. Compact Size

4. **Spaceball:** It is similar to trackball, but it can move in six directions where trackball can move in two directions only. The movement is recorded by the strain gauge. Strain gauge is applied with pressure. It can be pushed and pulled in various directions. The ball has a diameter around 7.5 cm. The ball is mounted in the base using rollers. One-third of the ball is an inside box, the rest is outside.

Applications:

1. It is used for three-dimensional positioning of the object.
2. It is used to select various functions in the field of virtual reality.
3. It is applicable in CAD applications.
4. Animation is also done using spaceball.
5. It is used in the area of simulation and modeling.

5. **Joystick:** A Joystick is also a pointing device which is used to change cursor position on a monitor screen. Joystick is a stick having a spherical ball as its both lower and upper ends as shown in fig. The lower spherical ball moves in a socket. The joystick can be changed in all four directions. The function of a joystick is similar to that of the mouse. It is mainly used in Computer Aided Designing (CAD) and playing computer games.

6. **Light Pen:** Light Pen (similar to the pen) is a pointing device which is used to select a displayed menu item or draw pictures on the monitor screen. It consists of a photocell and an optical system placed in a small tube. When its tip is moved over the monitor screen, and pen button is pressed, its photocell sensing element detects the screen location and sends the corresponding signals to the CPU.

Light Pen

Uses:

1. Light Pens can be used as input coordinate positions by providing necessary arrangements.
2. If background color or intensity, a light pen can be used as a locator.
3. It is used as a standard pick device with many graphics system.
4. It can be used as stroke input devices.
5. It can be used as valuators

7. **Digitizers:** The digitizer is an operator input device, which contains a large, smooth board (the appearance is similar to the mechanical drawing board) & an electronic tracking device, which can be changed over the surface to follow existing lines. The electronic tracking device contains a switch for the user to record the desire x & y coordinate positions. The coordinates can be entered into the computer memory or stored or an off-line storage medium such as magnetic tape.

Digitizer

Advantages:

1. Drawing can easily be changed.
2. It provides the capability of interactive graphics.

Disadvantages:

1. Costly
2. Suitable only for applications which required high-resolution graphics.

8. **Touch Panels:** Touch Panels is a type of display screen that has a touch-sensitive transparent panel covering the screen. A touch screen registers input when a finger or other object comes in contact with the screen. When the wave signals are interrupted by some contact with the screen, that located is recorded. Touch screens have long been used in military applications.

9. **Voice Systems (Voice Recognition):** Voice Recognition is one of the newest, most complex input techniques used to interact with the computer. The user inputs data by speaking into a microphone. The simplest form of voice recognition is a one-word command spoken by one person. Each command is isolated with pauses between the words.

   Voice Recognition is used in some graphics workstations as input devices to accept voice commands. The voice-system input can be used to initiate graphics operations or to enter data. These systems operate by matching an input against a predefined dictionary of words and phrases.

   Advantage:

   1. More efficient device.
   2. Easy to use
   3. Unauthorized speakers can be identified

   Disadvantages:
   1. Very limited vocabulary
   2. Voice of different operators can't be distinguished.

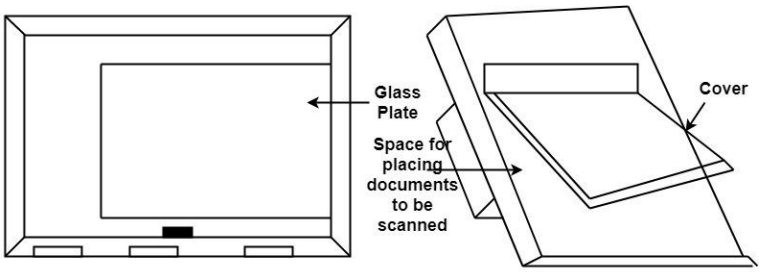
10. **Image Scanner:** It is an input device. The data or text is written on paper. The paper is feeded to scanner. The paper written information is converted into electronic format; this format is stored in the computer. The input documents can contain text, handwritten material, picture extra.

By storing the document in a computer document became safe for longer period of time. The document will be permanently stored for the future. We can change the document when we need. The document can be printed when needed.

Scanning can be of the black and white or colored picture. On stored picture 2D or 3D rotations, scaling and other operations can be applied.

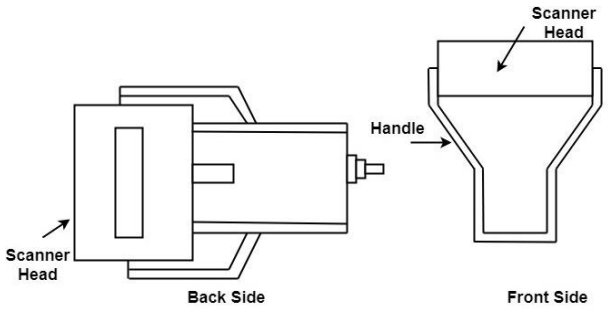
Types of image Scanner:

a. **Flat Bed Scanner:** It resembles a photocopy machine. It has a glass top on its top. Glass top in further covered using a lid. The document to be scanned is kept on glass plate. The light is passed underneath side of glass plate. The light is moved left to right. The scanning is done the line by line. The process is repeated until the complete line is scanned. Within 20-25 seconds a document of 4" * 6" can be scanned.



Flat Bed Scanner

b. **Hand Held Scanner:** It has a number of LED's (Light Emitting Diodes) the LED's are arranged in the small case. It is called a Hand held Scanner because it can be kept in hand which performs scanning. For scanning the scanner is moved over document from the top towards the bottom. Its light is on, while we move it on document. It is dragged very slowly over document. If dragging of the scanner over the document is not proper, the conversion will not correct.



Hand Held Scanner

Clipping

When we have to display a large portion of the picture, then not only scaling & translation is necessary, the visible part of picture is also identified. This process is not easy. Certain parts of the image are inside, while others are partially inside. The lines or elements which are partially visible will be omitted.

For deciding the visible and invisible portion, a particular process called clipping is used. Clipping determines each element into the visible and invisible portion. Visible portion is selected. An invisible portion is discarded.

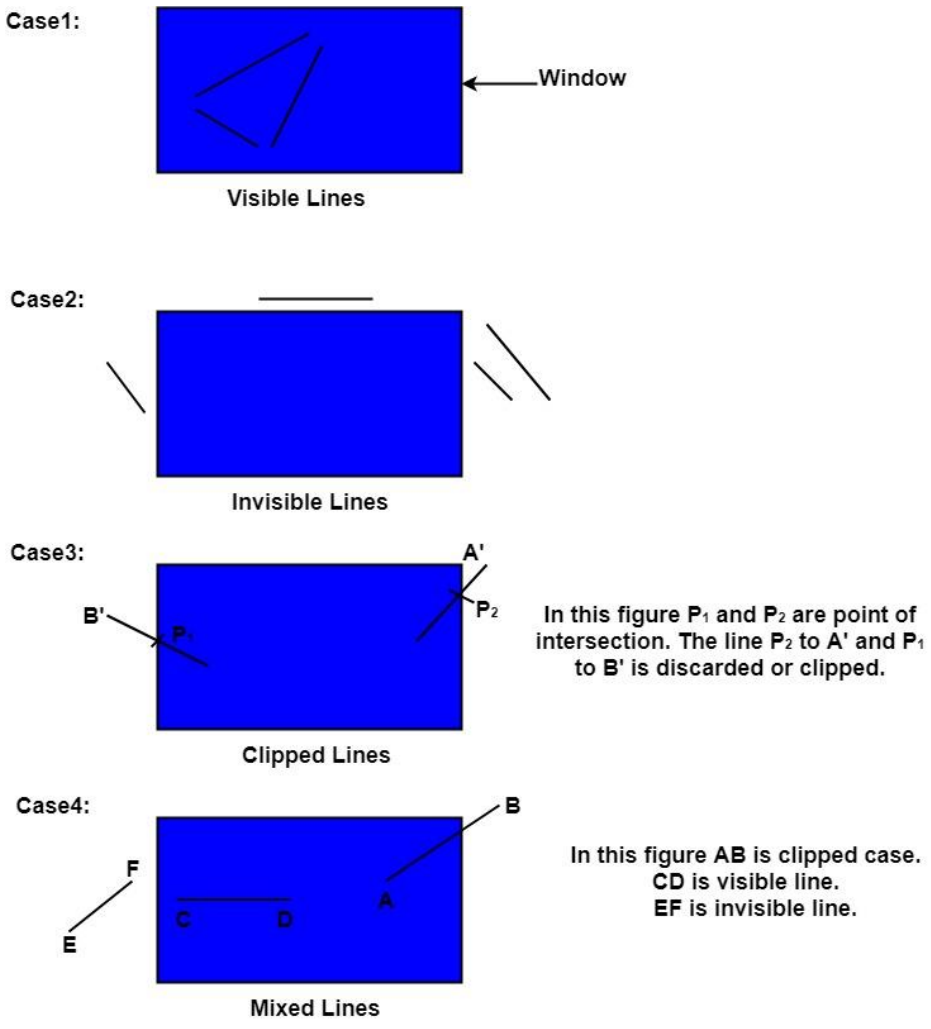
Types of Lines:

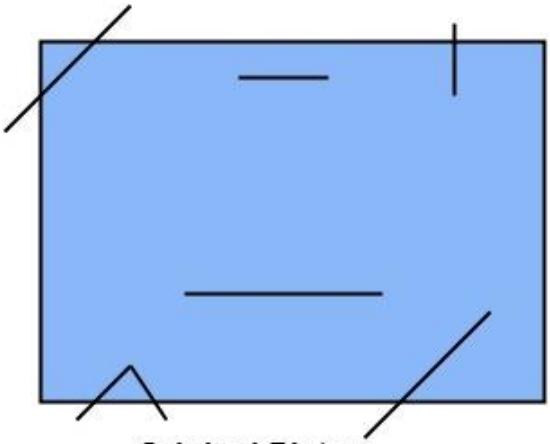
Lines are of three types:

1. **Visible:** A line or lines entirely inside the window is considered visible
2. **Invisible:** A line entirely outside the window is considered invisible
3. **Clipped:** A line partially inside the window and partially outside is clipped. For clipping point of intersection of a line with the window is determined.

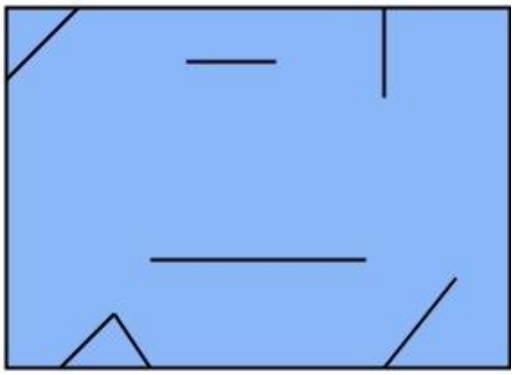
Clipping can be applied through hardware as well as software. In some computers, hardware devices automatically do work of clipping. In a system where hardware clipping is not available software clipping applied.

Following figure show before and after clipping





Original Picture
or
Before Clipping



After Clipping

The window against which object is clipped called a clip window. It can be curved or rectangle in shape.

Applications of clipping:

1. It will extract part we desire.
2. For identifying the visible and invisible area in the 3D object.
3. For creating objects using solid modeling.
4. For drawing operations.
5. Operations related to the pointing of an object.
6. For deleting, copying, moving part of an object.

Clipping can be applied to world co-ordinates. The contents inside the window will be mapped to device co-ordinates. Another alternative is a complete world co-ordinates picture is assigned to device co-ordinates, and then clipping of viewport boundaries is done.

Types of Clipping:

1. Point Clipping
2. Line Clipping
3. Area Clipping (Polygon)
4. Curve Clipping
5. Text Clipping
6. Exterior Clipping

1. **Point Clipping:** Clipping a point from a given window is very easy. Consider the following figure, where the rectangle indicates the window. Point clipping tells us whether the given point X,Y is within the given window or not; and decides whether we will use the minimum and maximum coordinates of the window.

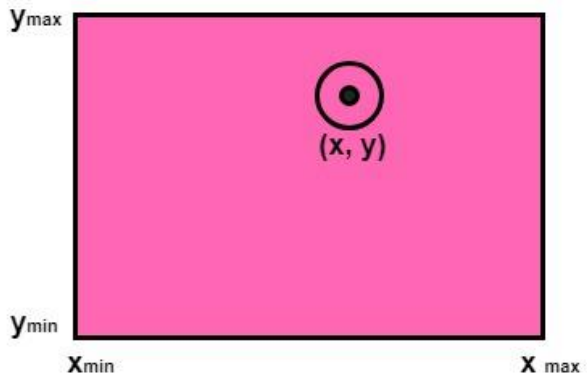
Point Clipping is used to determining, whether the point is inside the window or not. For this following conditions are checked.

$x \leq x_{max}$

$x \geq x_{min}$

$y \leq y_{max}$

$y \geq y_{min}$



The (x, y) is coordinate of the point. If anyone from the above inequalities is false, then the point will fall outside the window and will not be considered to be visible.

2. **Line Clipping:** It is performed by using the line clipping algorithm. The line clipping algorithms are:

    1. Cohen Sutherland Line Clipping Algorithm
    2. Midpoint Subdivision Line Clipping Algorithm
    3. Liang-Barsky Line Clipping Algorithm

    (1) Cohen-Sutherland Line Clipping Algorithm: In the algorithm, first of all, it is detected whether line lies inside the screen or it is outside the screen. All lines come under any one of the following categories:

        (a) Visible

        (b) Not Visible

        (c) Clipping Case

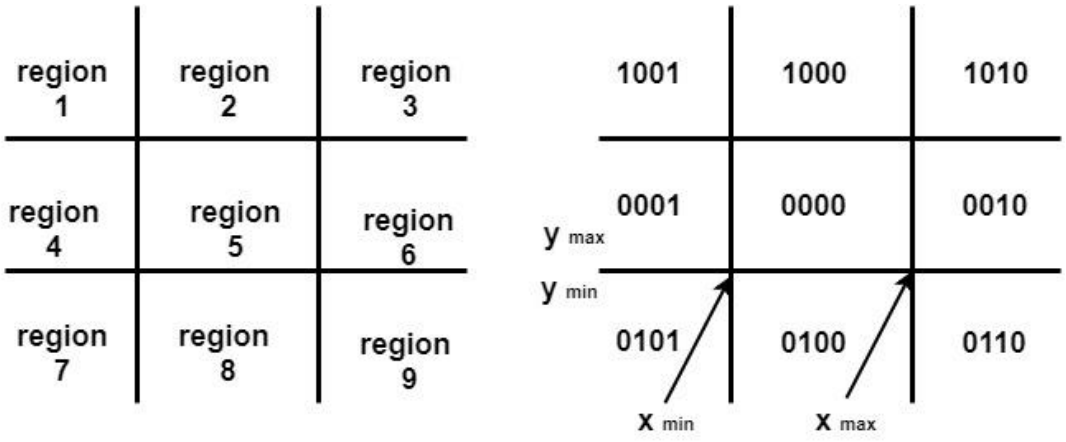
    a. Visible: If a line lies within the window, i.e., both endpoints of the line lies within the window. A line is visible and will be displayed as it is.

    b. Not Visible: If a line lies outside the window it will be invisible and rejected. Such lines will not display. If any one of the following inequalities is satisfied, then the line is considered invisible. Let A (x_1,y_2) and B (x_2,y_2) are endpoints of line.

x_{min},x_{max} are coordinates of the window.
y_{min},y_{max} are also coordinates of the window.

$x_1 > x_{max}$
$x_2 > x_{max}$
$y_1 > y_{max}$
$y_2 > y_{max}$
$x_1 < x_{min}$
$x_2 < x_{min}$
$y_1 < y_{min}$
$y_2 < y_{min}$

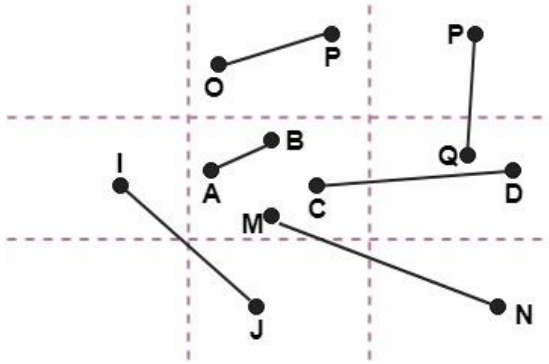
c. Clipping Case: If the line is neither visible case nor invisible case. It is considered to be clipped case. First of all, the category of a line is found based on nine regions given below. All nine regions are assigned codes. Each code is of 4 bits. If both endpoints of the line have end bits zero, then the line is considered to be visible.



9 region bits assigned to 9 regions

The center area is having the code, 0000, i.e., region 5 is considered a rectangle window.

Following figure show lines of various types



Line AB is the visible case
Line OP is an invisible case
Line PQ is an invisible line
Line IJ are clipping candidates
Line MN are clipping candidate
Line CD are clipping candidate

Advantage of Cohen Sutherland Line Clipping:

- It calculates end-points very quickly and rejects and accepts lines quickly.
- It can clip pictures much large than screen size.

Algorithm:

Step1: Calculate positions of both endpoints of the line
Step2: Perform OR operation on both of these end-points
Step3: If the OR operation gives 0000
Then
line is considered to be visible
else
Perform AND operation on both endpoints
If And ≠ 0000
then the line is invisible
else
And=0000
Line is considered the clipped case.
Step4: If a line is clipped case, find an intersection with boundaries of the window
$m=(y_2-y_1)/(x_2-x_1)$

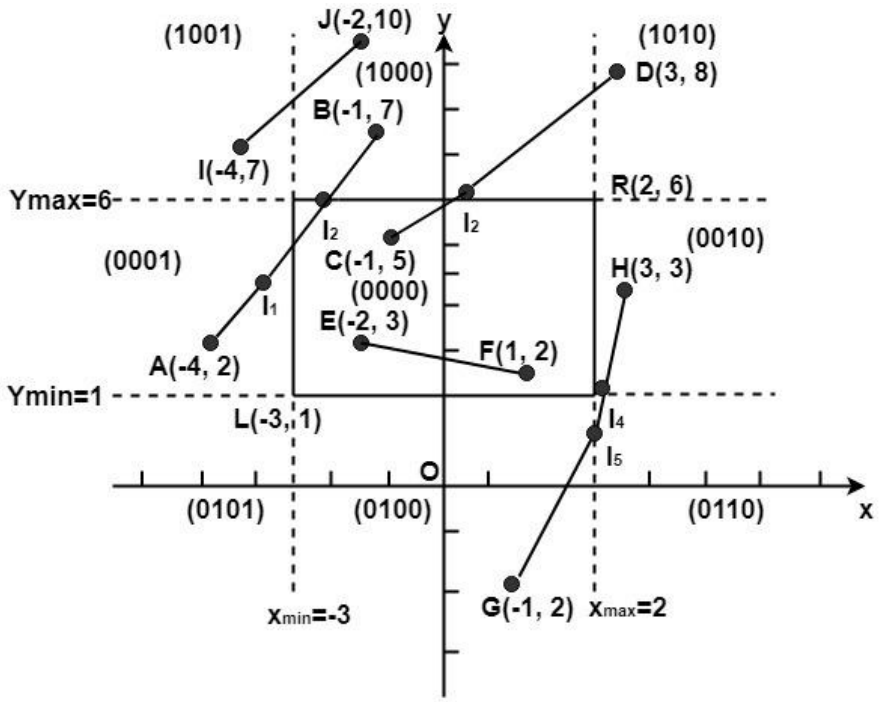
(a) If bit 1 is "1" line intersects with left boundary of rectangle window
$y_3=y_1+m(x-X_1)$
where $X = X_{wmin}$
where $X_{wmin}$is the minimum value of X co-ordinate of window

(b) If bit 2 is "1" line intersect with right boundary
$y_3=y_1+m(X-X_1)$
where $X = X_{wmax}$
where X more is maximum value of X co-ordinate of the window

(c) If bit 3 is "1" line intersects with bottom boundary
$X_3=X_1+(y-y_1)/m$
where $y = y_{wmin}$
y_{wmin} is the minimum value of Y co-ordinate of the window

(d) If bit 4 is "1" line intersects with the top boundary
$X_3=X_1+(y-y_1)/m$
where $y = y_{wmax}$
y_{wmax} is the maximum value of Y co-ordinate of the window

Example: Let R be the rectangular window whose lower left-hand corner is at L (-3, 1) and upper right-hand corner is at R (2, 6). Find the region codes for the endpoints in fig:



The region code for point (x, y) is set according to the scheme
Bit 1 = sign $(y-y_{max})$=sign (y-6) Bit 3 = sign $(x-x_{max})$= sign (x-2)
Bit 2 = sign $(y_{min}-y)$=sign(1-y) Bit 4 = sign $(x_{min}-x)$=sign(-3-x)

Here

$$\text{sign}(a) = \begin{cases} 1 & \text{if a is positive} \\ 0 & \text{otherwise} \end{cases}$$

So

A (-4, 2)→ 0001 F (1, 2)→ 0000
B (-1, 7) → 1000 G (1, -2) →0100
C (-1, 5)→ 0000 H (3, 3) → 0100
D (3, 8) → 1010 I (-4, 7) → 1001
E (-2, 3) → 0000 J (-2, 10) → 1000

We place the line segments in their appropriate categories by testing the region codes found in the problem.

Category1 (visible): EF since the region code for both endpoints is 0000.
Category2 (not visible): IJ since (1001) AND (1000) =1000 (which is not 0000).

Category 3 (candidate for clipping): AB since (0001) AND (1000) = 0000, CD since (0000) AND (1010) =0000, and GH. since (0100) AND (0010) =0000.

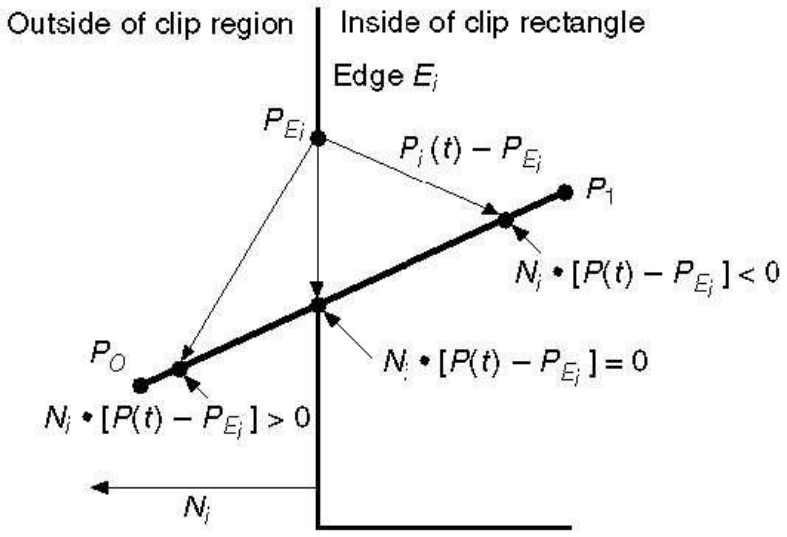
The candidates for clipping are AB, CD, and GH.
In clipping AB, the code for A is 0001. To push the 1 to 0, we clip against the boundary line x_{min}=-3. The resulting intersection point is I_1 (-3,3 $\frac{2}{3}$). We clip (do not display) AI_1 and I_1 B. The code for $I_1$is 1001. The resulting intersection point is I_1 (-3, $3\frac{2}{3}$). We clip (do not display) AI_1 and I_1 B. The code for I_1 is 1001. The clipping category for I_1 B is 3 since (0000) AND (1000) is (0000). Now B is outside the window (i.e., its code is 1000), so we push the 1 to a 0 by clipping against the line y_{max}=6. The resulting intersection is l_2 (-1 $\frac{3}{5}$, 6). Thus I_2 B is clipped. The code for I_2 is 0000. The remaining segment I_1 I_2 is displayed since both endpoints lie in the window (i.e., their codes are 0000).

For clipping CD, we start with D since it is outside the window. Its code is 1010. We push the first 1 to a 0 by clipping against the line y_{max}=6. The resulting intersection I_3 is $(\frac{3}{5}, 6)$ and its code is 0000. Thus I_3 D is clipped and the remaining segment CI_3 has both endpoints coded 0000 and so it is displayed.

For clipping GH, we can start with either G or H since both are outside the window. The code for G is 0100, and we push the 1 to a 0 by clipping against the line y_{min}=1.The resulting intersection point is I_4 $(2\frac{1}{5}, 1)$ and its code is 0010. We clip GI_4 and work on I_4 H. Segment I_4 H is not displaying since (0010) AND (0010) =0010.

(2) CYRUS-BECK LINE CLIPPING ALGORITHM:

This algorithm is more efficient than Cohen-Sutherland algorithm. It employs parametric line representation and simple dot products.



Parametric equation of line is –

$P_0P_1:P(t) = P_0 + t(P_1 - P_0)$

Let N_i be the outward normal edge E_i. Now pick any arbitrary point P_{Ei} on edge E_i then the dot product $N_i.[Pt – P_{Ei}]$ determines whether the point Pt is "inside the clip edge" or "outside" the clip edge or "on" the clip edge.

The point Pt is inside if $N_i.[Pt – P_{Ei}] < 0$

The point Pt is outside if $N_i.[Pt – P_{Ei}] > 0$

The point Pt is on the edge if $N_i.[Pt – P_{Ei}] = 0$ $Intersectionpoint$

$N_i.[Pt – P_{Ei}] = 0$

$N_i.[P_0 + t(P_1 - P_0) – P_{Ei}] = 0$ $ReplacingP(t$ with $P_0 + t(P_1 - P_0))$

$N_i.[P_0 – P_{Ei}] + N_i.t[P_1 - P_0] = 0$

$N_i.[P_0 – P_{Ei}] + N_i \cdot tD = 0$ (substituting D for $[P_1 - P_0]$)

$N_i.[P_0 – P_{Ei}] = - N_i \cdot tD$

The equation for t becomes,

$$t = \frac{N_i.[P_0 - P_{Ei}]}{-N_i.D}$$

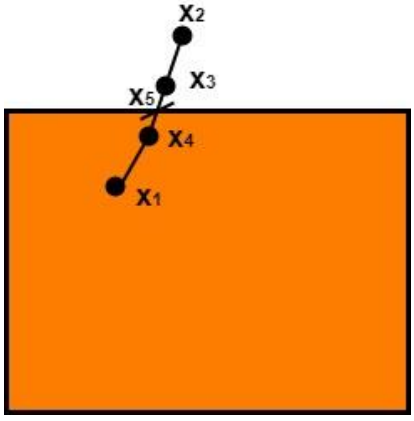
It is valid for the following conditions –

- $N_i \neq 0$ $errorcannothappen$
- $D \neq 0$ $(P_1 \neq P_0)$
- $N_i \cdot D \neq 0$ (P_0P_1 not parallel to E_i)

(3) MID-POINT SUBDIVISION LINE CLIPPING ALGORITHM:

It is used for clipping line. The line is divided in two parts. Mid points of line is obtained by dividing it in two short segments. Again division is done, by finding midpoint. This process is continued until line of visible and invisible category is obtained. Let (x_i,y_i) are midpoint

$$x_m = \frac{x_1 + x_2}{2} \qquad y_m = \frac{y_1 + y_2}{2}$$



Step1: Find $\frac{x_2+x_1}{2}$ i. e. $x_3 = \frac{x_2+x_1}{2}$

Step2: Find $x_4 = \frac{x_3+x_1}{2}$

Step3: Find $x_5 = \frac{x_4+x_3}{2}$

x_5 lie on point of intersection of boundary of window.

Advantage of midpoint subdivision Line Clipping:

It is suitable for machines in which multiplication and division operation is not possible. Because it can be performed by introducing clipping divides in hardware.

Algorithm of midpoint subdivision Line Clipping:

Step1: Calculate the position of both endpoints of the line

Step2: Perform OR operation on both of these endpoints

Step3: If the OR operation gives 0000
then
Line is guaranteed to be visible
else
Perform AND operation on both endpoints.
If AND ≠ 0000
then the line is invisible
else
AND=6000
then the line is clipped case.

Step4: For the line to be clipped. Find midpoint
$X_m=(x_1+x_2)/2$
$Y_m=(y_1+y_2)/2$
X_m is midpoint of X coordinate.
$Y_m$is midpoint of Y coordinate.

Step5: Check each midpoint, whether it nearest to the boundary of a window or not.

Step6: If the line is totally visible or totally rejected not found then repeat step 1 to 5.

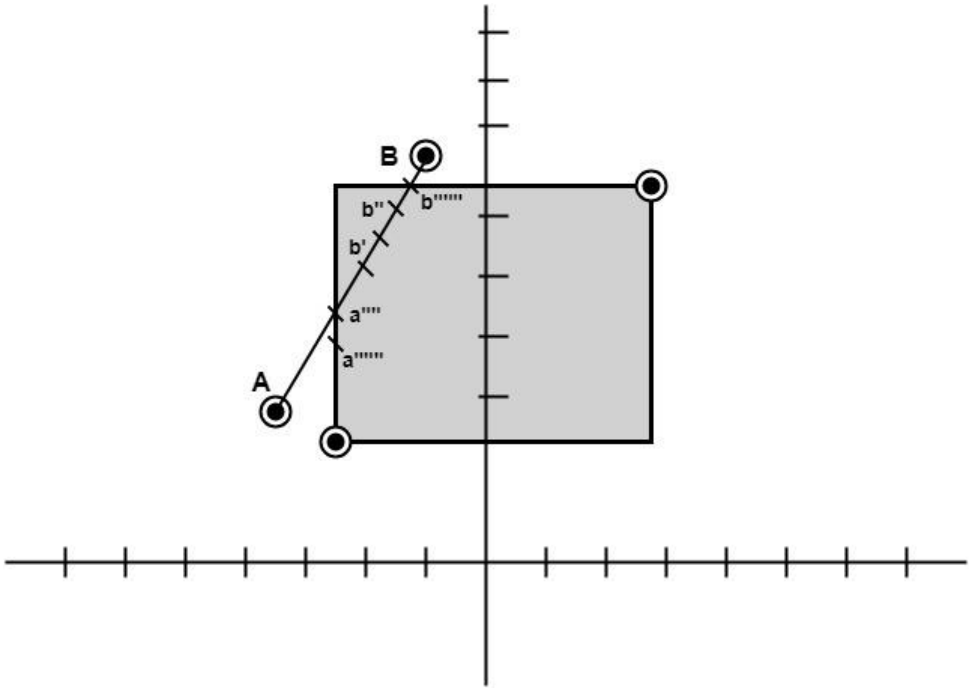
Step7: Stop algorithm.

Example: Window size is (-3, 1) to (2, 6). A line AB is given having co-ordinates of A (-4, 2) and B (-1, 7). Does this line visible? Find the visible portion of the line using midpoint subdivision?

Solution:

Step1: Fix point A (-4, 2)

$$b = \left(\frac{-4+(-1)}{2}, \frac{2+7}{2}\right) = \frac{-5}{2}, \frac{9}{2} = (-2,4)$$



Step2: Find b"=mid of b'and b

$$b" = \left(\frac{-2+(-1)}{2}, \frac{4+7}{2}\right)$$

$$b" = (-1, 5)$$

So (-1, 5) is better than (2, 4)
Find b"& b, b"(-1, 5) b (-1, 7)

$$b"" = \left(\frac{-1+(-1)}{2}, \frac{5+7}{2}\right)$$

$$b = (-1,6)$$

So B""to B length of line will be clipped from upper side

Now considered left-hand side portion.

A and B""are now endpoints

Find mid of A and B""

$$a' = \left(\frac{-4+(-1)}{2}, \frac{2+6}{2}\right)$$

$$a' = (-2.5,4)$$

$$a' = (-2,4)$$

Now good a (-4, 2) and $a'(-2,4)$

$$a'' = \left(\frac{-4+(-2)}{2}, \frac{2+4}{2}\right)$$

$$a'' = (-3,3)$$

Now find mid of a'' and a

a'''''=a (-4, 2) and $a''(-3, 3)$

$$= \left(\frac{-4+(-3)}{2}, \frac{2+3}{2}\right)$$

$$= \left(\frac{-7}{2}, \frac{5}{2}\right)$$

$$= (-3.5,2.5)$$

a'''''= (-3, 2)

So line from A to a'''''will clipped

Line after clipping from both sides will be $a'''''$to b'''''

a'''''= (-1, 6)

b'''''= (-3, 2)