

Computer Graphics

Computer has become a powerful tool for rapid and economical production of pictures. There is virtually no area in which graphical displays cannot be used to some advantage. Today computer graphics is used extensively in such areas as science, medicine, Engineering etc.

Application of computer graphics :

- (1) **Computer - Aided Design** : Generally used in the design of building, automobiles, aircrafts, textiles and many other products.
- (2) **Presentation Graphics** : This is used to produce illustration for or to generate 35-cm slides or transparencies for use with projectors.
- (3) **Computer Art** : Computer graphics methods are widely used in both fine arts and Commercial Arts Applications.
- (4) **Entertainment** : Computer graphics methods are now commonly used in making motion pictures, music videos, television shows.
- (5) **Education and Training** : Computer generated models of physical, financial, and economic systems are often used as education aids.
- (6) **Visualization** : This is used in connection with data sets related to commerce, industry and other scientific areas.
- (7) **Image Processing** : It applies techniques to modify or interpret existing pictures such as photographs.
- (8) **Graphical user Interface** : It is common now for software packages to provide a graphical Interface.

Video Display Devices

The primary output device in a graphics system is a video controller. The operation of most video monitors is based on the standard cathode-ray tube (CRT) design.

Refresh Cathode Ray Tube : Fig (1) illustrates the basic operation of a CRT

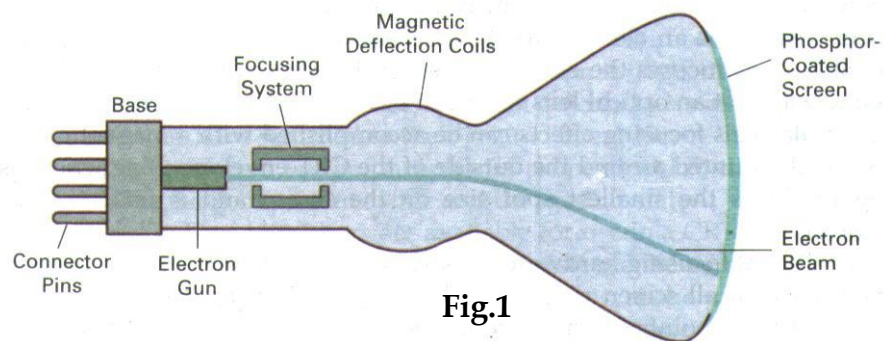


Figure 2-2
Basic design of a magnetic-deflection CRT.

Here electron beam is emitted by the electron gun in a CRT. It passes through focusing and deflection system that directs the beam towards specified position on the phosphor coated system. The light emitted by the phosphor fades very rapidly. In order to maintain the screen picture or to keep the phosphor is to redraw the picture repeatedly by quickly directing the electron beam over the same point. This process is called refresh CRT.

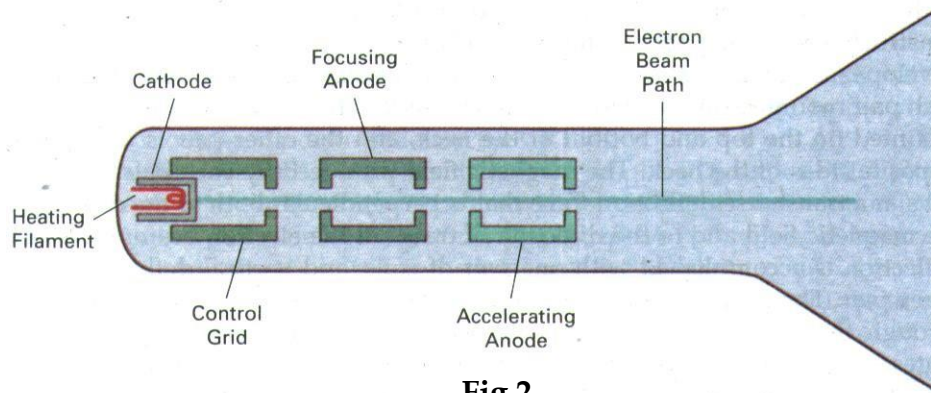


Fig.2

The primary components of an electron gun in a CRT are the heated metal cathode and control guide as in Fig 2.

Heat is supplied to the cathode by directing a current through a coil of wire called filament, inside the cylindrical cathode structure this heats up the electrons & the heated up electrons move with high positive voltage towards the phosphor screen.

Intensity of the electron beam is controlled by setting voltage levels on the control grid. A high negative voltage will shut off the beam by repelling electrons & stopping them from passing through. Amount of light emitted depend on number of electron striking the screen.

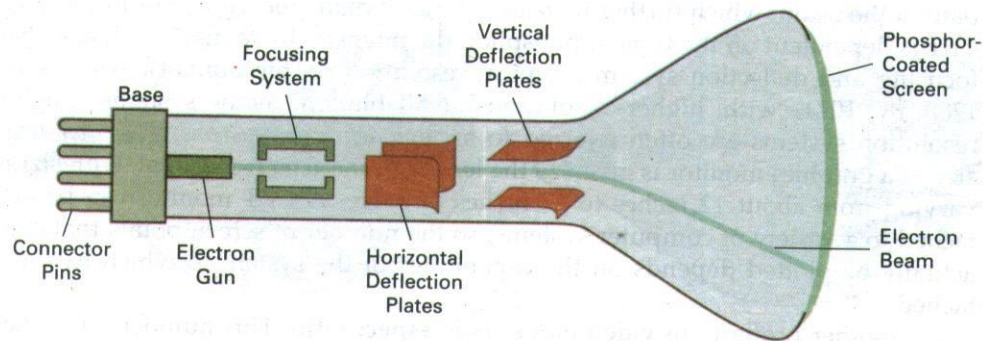
Focusing system in a CRT is needed to force the electron beam to coverage into a small spot as it strikes the phosphor. Otherwise electron would repel each other.

Focusing is accomplished with either electric or magnetic fields. Electrostatic focusing is commonly used in television and computer graphics monitors. With electrostatic focusing, the electron beam passes through a positively charged metal cylinder that forms an electron lens, as shown in Fig. 2-3, The action of the electrostatic lens focuses the electron beam at the center of the screen, in exactly the same way that an optical lens focuses a beam of light at a particular focal distance. Similar lens focusing effects can be accomplished with a magnetic field setup by a coil mounted around the outside of the CRT envelope. Magnetic lens focusing produces the smallest spot size on the screen and is used in special purpose device.

Additional focusing hardware is used in high-precision system to keep the beam in focus at all screen position. The distance that the electron beam

must travel to different points on the screen varies because the radius of curvature for most CRTs is greater than the distance from the focusing system to the screen center. Therefore, the electron beam properly only at the center of the screen. As the beam moves to the outer edges of the screen, displayed images become blurred. To compensate for this, the system can adjust the focusing according to the screen position of the beam.

As with focusing, deflection of the electron beam can be controlled either with electric fields or with magnetic fields. Cathode-ray tubes are now commonly constructed with magnetic deflection coils mounted on the outside of the CRT envelope, as illustrated in Fig. 2-2. Two pairs of coils are used, with the coils in each pair mounted on opposite sides of the neck of the CRT envelop. One pair is mounted on the top and bottom of the neck, the magnetic field produced by each pair of coils results in a transverse deflection force that is perpendicular both to the direction of the magnetic field and to the direction of travel of the electron beam. Horizontal deflection is accomplished with one pair of coils, and vertical deflection by the other pair. The proper deflection amounts are attained by adjusting the current through the coils. When electrostatic deflection is used, two pairs of parallel palates are mounted inside the CRT envelope. One pair of plates is mounted horizontally to control the vertical deflection, and the other pair is mounted vertically to control horizontal deflection (Fig. 2-4).



Spots of light are produced on the screen by the transfer of the CRT beam energy to the phosphor. When the electrons in the beam collide with the phosphor coating, they are stopped and their energy is absorbed by the phosphor. Part of the beam energy is converted by friction into heat energy, and the remainder causes electrons in the phosphor atoms to move up to higher quantum-energy levels. After a short time, the "excited" phosphor electrons begin dropping back to their stable ground state, giving up their

extra energy as small quantum“s of light energy. What we see on the screen is the combined effect of all the electron light emissions: a glowing spot that quickly fades after all the excited phosphor electrons have returned to their ground energy level. The frequency (or color) of the light emitted by the phosphor is proportional to the energy difference between the excited quantum state and the ground state.

Different kinds of phosphor are available for use in a CRT. Besides color, a major difference between phosphor is their **persistence** : how long they continue to emit light (that is, have excited electrons returning to the ground states) after the CRT beam is removed. Persistence is defined as the time it takes the emitted light from the screen to decay to one-tenth of its original intensity. Lower-persistence phosphor requires higher refresh rates to maintain a picture on the screen without flicker. A phosphor with low persistence is useful for displaying highly complex, static, graphics monitors are usually constructed with persistence in the range from 10 to 60 microseconds.

Figure 2-5 shows the intensity distribution of a spot on the screen. The intensity is greatest at the center of the spot, and decreases with a Gaussian distribution out to the edge of the spot. This distribution corresponds to the cross-sectional electron density distribution of the CRT beam.

The maximum number of points that can be displayed without overlap on a CRT is referred to as the **resolution**. A more precise definition of resolution is the number of points per centimeter that can be plotted horizontally and vertically, although it is often simply stated as the total number of points in each direction. Spot intensity has a Gaussian distribution (Fig. 2-5), so two adjacent spots will appear distinct as long as their separation is greater than the diameter at which each spot has intensity in Fig. 2-6. Spot size also depends on intensity. As more electrons are accelerated toward the phosphor per second, the CRT beam diameter and the illuminated spot increase. In addition, the increased excitation energy tends to spread to neighboring phosphor atoms not directly in the path of the beam, which further increases the spot diameter. Thus, resolution of a CRT is dependent on the type of phosphor, the intensity to be displayed, and the focusing and deflection system. Typing resolution on high-quality systems is 1280 by 1024, with higher resolution available on many systems. High resolution systems are often referred to as high-

definition system. The physical size of a graphics monitor is given as the length of the screen diagonal, with sizes varying from about 12 inches to 27 inches or more. A CRT monitor can be attached to a variety of computer systems, so the number of screen points that can actually be plotted depends on the capabilities of the system to which it is attached.

Another property of video monitors is **aspect ratio**. This number gives the ratio of vertical points to horizontal points necessary to produce equal-length lines in both directions on the screen. (Sometimes aspect ratio is stated in terms of the ratio of horizontal to vertical points.) An aspect ratio of $\frac{3}{4}$ means that a vertical line plotted with three points has the same length as a horizontal line plotted with four points.

Raster-Scan Displays and Random Scan Displays.

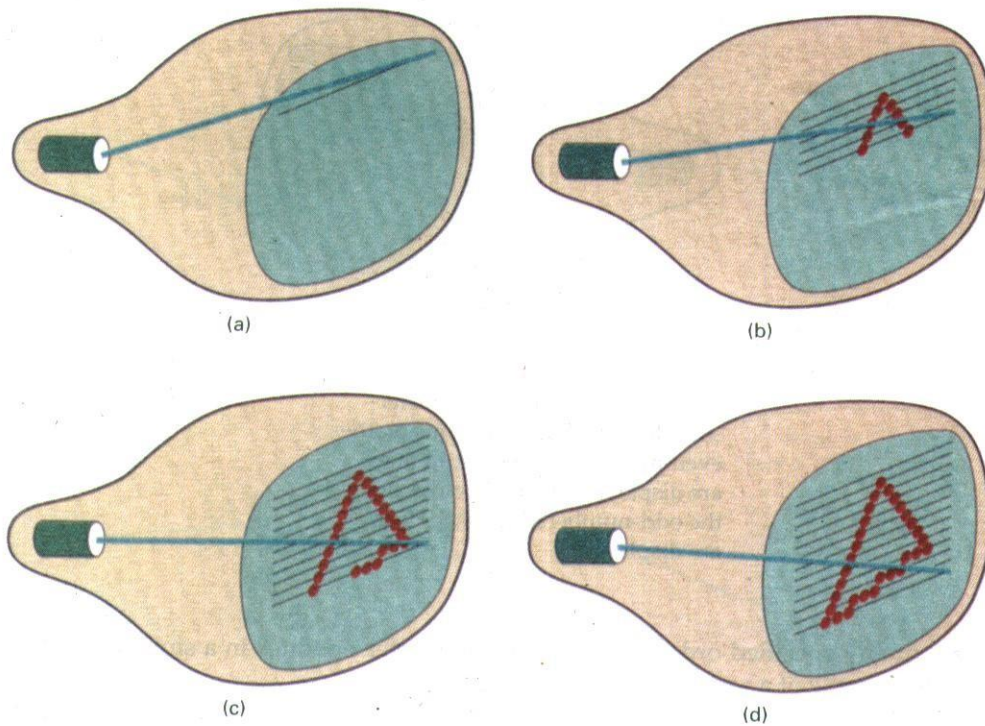
Raster-Scan Displays : The most common type of graphics monitor employing a CRT is the **raster-scan** display, based on television technology. In a raster-scan system, the electron beam is swept across the screen, one row at a time from top to bottom. As the electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots. Picture definition is stored in a memory area called the **refresh buffer** or **frame buffer**. This memory area holds the set of intensity values for all the screen points. Stored intensity values are then retrieved from the refresh buffer and "Painted" on the screen one row (**scan line**) at a time (Fig. 2-7). Each screen point is referred to as a **pixel** or

pel (shortened form of **picture element**). The capability of a raster-scan system to store intensity information for each screen point makes it well suited for the realistic display of scenes containing subtle shading and color patterns. Home television sets and printers are examples of other systems using raster-scan methods.

Intensity range for pixel positions depends on the capability of the raster system. In a simple black-and-white system, each screen point is either on or off, so only one bit per pixel is needed to control the intensity of screen position. For a bi-level system, a bit value of 1 indicates that the electron beam is to be turned on at that position, and a value of 0 indicates that the beam intensity is to be off. Additional bits are needed when color and intensity variations can be displayed. Up to 24 bits per pixel are included

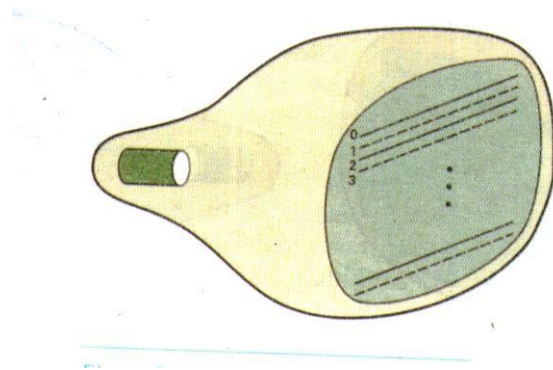
in high-quality system, which can require several megabytes of storage for the frame buffer, depending on the resolution of the system. A system with 24 bits per pixel and a screen resolution of 1024 by 1024 requires 3 megabytes of storage for the frame buffer. On a black-and-white system with one bit per pixel, the frame buffer is commonly called a **bitmap**. For system with multiple bits per pixel, the frame buffer is often referred to as a **pixmap**.

Refreshing on raster-scan displays is carried out at the rate of 60 to 80 frames per second, although some systems are designed for higher refresh rates. Sometimes, refresh rates are described in units of cycle per second, or Hertz (Hz), where a cycle corresponds to one frame. Using these units, we would describe a refresh rate of 60 frames per second as simply 60 Hz. At the end of each scan line, the electron beam returns to the left side of the screen to begin displaying the next scan line. The return to the left of the screen, after refreshing each scan line, is called the **horizontal retrace** of the electron beam. And at the end of each frame (displayed in $1/80^{\text{th}}$ to $1/60^{\text{th}}$ of a second), the electron beam returns (**vertical retrace**) to the top left corner of the screen to begin the next frame.



On some raster-scan system (and in TV sets), each frame is displayed in two passes using an interlaced refresh procedure. In the first pass, the beam sweeps across every other scan line from top to bottom. Then after the vertical retrace, the beam sweeps out the remaining scan lines (Fig. 28). Interlacing of the scan lines in this way allows us to see the entire screen displayed in one-half the time it would have taken to sweep across all the lines at once from top to bottom. Interlacing is primarily used with slower refreshing rates. On an older, 30 frame-per-second, no interlaced display, for instance, some flicker is noticeable. But with interlacing, each of the two passes can be accomplished in $1/60^{\text{th}}$ of a second, which brings the refresh rate nearer to 60 frames per second. This is an effective technique for avoiding flicker, providing that adjacent scan lines contain similar display information.

Random Scan Displays : When operated as a **random-scan** display unit, a CRT has the electron beam directed only to the parts of the screen where a picture is to be drawn. Random-scan monitor draw a picture one line at a time and for this reason are also referred to as **vector** displays (or **strokewriting** of **calligraphic** displays). The component lines of a picture can be drawn and refreshed by a random-scan system in any specified order (Fig. 2-9). A pen plotter in a similar way and is an example of a randomscan, hard-copy device.



Refresh rate on a random-scan system depends on the number of lines to be displayed. Picture definition is now stored as a set of line-drawing commands in an area of memory referred to as the **refresh display file**. Sometimes the refresh display file is called the **display list**, **display program**, or simply the refresh **buffer**. To display a specified picture, the system cycles through the set of commands in the display file, drawing each

component line in turn. After all line drawing commands have been processed, the system cycle back to the first line command in the list. Random-scan displays are designed to draw all the component lines of a picture 30 to 60 times each second. High-quality vector systems are capable of handling approximately 100,000 "short" lines at this refresh rate. When a small set of lines is to be displayed, each refresh cycle is delayed to avoid refresh rates greater than 60 frames per second. Otherwise, faster refreshing of the set of lines could burn out the phosphor.

Random-scan systems are designed for line-drawing applications and cannot display realistic shaded scenes. Since picture definition is stored as a set of line-drawing instruction and not as a set of intensity values for all screen points, vector displays generally have higher resolution than raster system. Also, vector displays produce smooth line drawings because the CRT beam directly follows the line path. A raster system, in contrast, produces jagged lines that are plotted as discrete point sets.

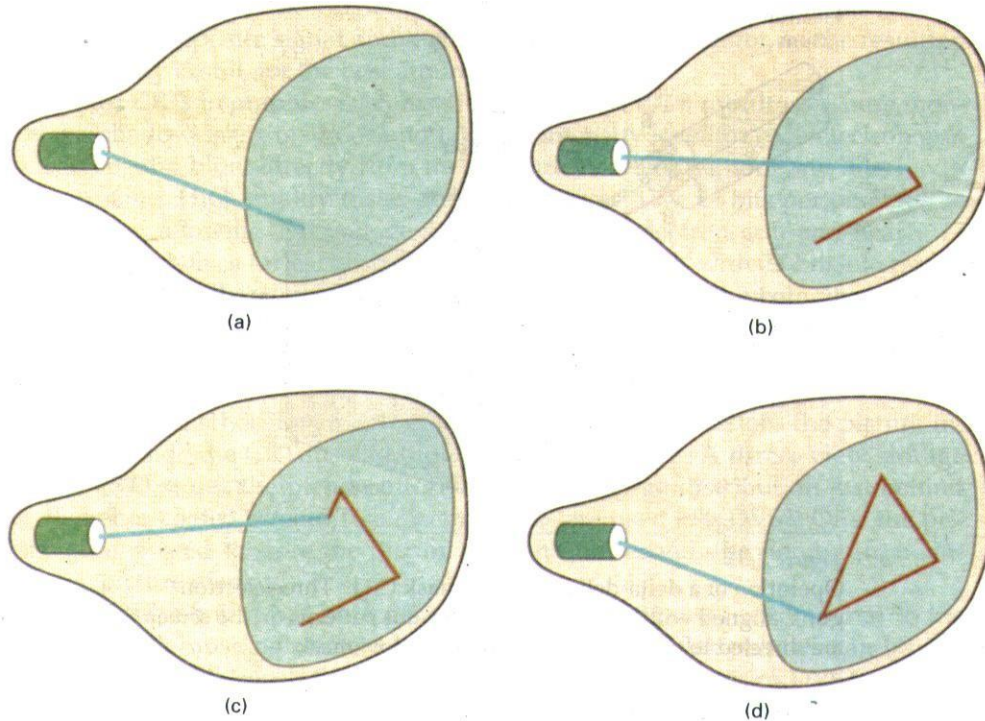
Color CRT Monitor

Shadow Mask Method.

A CRT monitor displays color picture by using a combination of phosphor that emit different-colored light. By combining the emitted light from the different phosphor, a range of colors can be generated. The two basic techniques for producing color displays with a CRT are the beam-penetration method and the shadow-mask method.

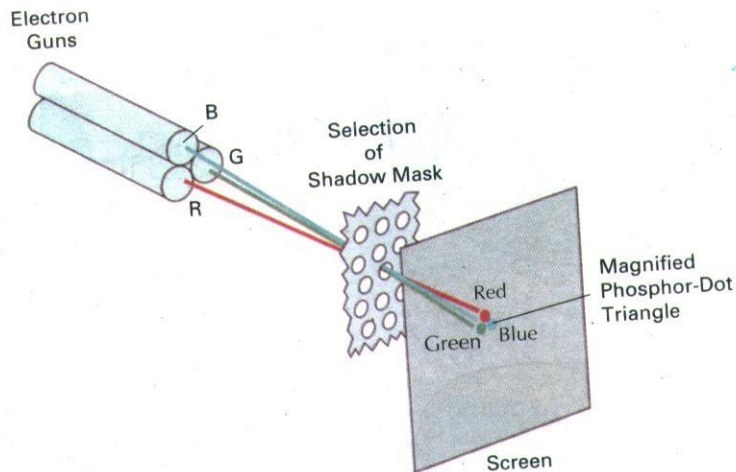
The **beam-penetration** method for displaying color pictures has been used with random-scan monitors. Two layers of phosphor, usually red and green, are coated onto the inside of the CRT screen, and the displayed color depends on how far the electron beam penetrates into the phosphor layers. A beam of slow electrons excites only the outer red layer. A beam of very fast electron penetrates through the red layer and excites the inner green layer. At intermediate beam speeds, combinations of red and green light are emitted to show two additional colors, orange and yellow. The speed of the electrons, and hence the screen color at any point, is controlled by the beam-acceleration voltage. Beam penetration has been an inexpensive way

to produce color in random-scan monitor, but only four colors are possible, and the quality of picture is not as good as with other methods.



Shadow-mask methods are commonly used in raster-scan system (including color TV) because they produce a much wider range of colors than the beam penetration method. A shadow-mask CRT has three phosphor color dots at each pixel position. One phosphor dot emits a red light, another emits a green light, and the third emits a blue light. This type of CRT has three electron guns, one for each color dot, and a shadowmask grid just behind the phosphor-coated screen. Figure 2-10 illustrates the delta-delta shadow-mask method, commonly used in color CRT system. The three beams are deflected and focused as a group onto the shadow mask, which contains a series of holes aligned with the phosphor dot patterns. When the three beams pass through a hole in the shadow mask, they activate a dot triangle, which appears as a small color spot on the screen. The phosphor dots in the triangles are arranged so that each electron beam can activate only its corresponding color dot when it passes through the shadow mask. Another configuration for the three electron guns is an in-line arrangement in which the three electron guns, and the corresponding red-green-blue color dots on the screen, are aligned along

one scan line instead of in a triangular pattern. This in-line arrangement of electron guns is easier to keep in alignment and is commonly used in high-resolution color CRTs.



We obtain color variations in a shadow-mask CRT by varying the intensity levels of the three electron beams. By turning off the red and green guns, we get only the color coming from the blue phosphor. Other combinations of beam intensities produce a small light spot for each pixel position, since our eyes tend to merge the three colors into one composite. The color we see depends on the amount of excitation of the red, green, and blue phosphors. A white (or gray) area is the result of activating all three dots with equal intensity. Yellow is produced with the green and red dots only, magenta is produced with the blue and red dots, any cyan shows up when blue and green are activated equally. In some low-cost systems, the electron beam can only be set to on or off, limiting displays to eight colors. More sophisticated systems can set intermediate intensity level for the electron beam, allowing several million different colors to be generated.

Color graphics systems can be designed to be used with several types of CRT display devices. Some inexpensive home-computer system and video games are designed for use with a color TV set and an RF (radiofrequency) modulator. The purpose of the RF modulator is to simulate the signal from a broad-cast TV station. This means that the color and intensity information of the picture must be combined and superimposed on the broadcast-frequency carrier signal that the TV needs to have as input. Then the circuitry in the TV takes this signal from the RF modulator, extracts the picture information, and paints it on the screen. As we might expect, this

extra handling of the picture information by the RF modulator and TV circuitry decreased the quality of displayed images.

Differentiate between Raster Scan and Random Scan Display

S. No.	Raster Scan	Random Scan
1.	In this, the electron beam is swept across the screen, one row at a time from top to bottom.	In this, the electron beam is directed only to the parts of the screen where a picture is to be drawn.
2.	The pattern is created by illuminated spots.	Here a picture is drawn one line at a time.
3.	Refreshing on Raster Scan display is carried out at the rate of 60 to 80 frames per second.	Refresh cycle is displayed to avoid refresh rate greater than 60 frames per second for small set of lines. Refresh rate depends on number of lines to be displayed.
4.	This display produces smooth line drawings as the CRT beam directly follows the line path.	In this display it produces jagged lines that are plotted as discrete point sets.
5.	This provides higher resolution.	This provides lower resolution.

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