UNIT- 1 Content

Overview of Graphics Systems

1. Video-display devices
2. Raster scan systems
3. Random scan systems
4. Graphics monitors and work stations
5. Input devices
6. Hardcopy devices and Graphics software

1. Video display devices

Typically, the primary output device in a graphics system is a video monitor (Fig. 2-1). The operation of most video monitors is based on the standard cathode-ray tube (CRT) design.

Figure 2-1
A computer graphics workstation.

Fig 2-2 illustrates the basic operation of a CRT. A beam of electrons (cathode rays), emitted by an electron gun, passes through focusing and deflection systems that direct the beam toward specified positions on the phosphor-coated screen.

The phosphor then emits a small spot of light at each position contacted by the electron beam. Because the light emitted by the phosphor fades very rapidly, some method is needed for maintaining the screen picture. One way to keep the phosphor glowing is to redraw the picture repeatedly by quickly directing the electron beam back over the same points. This type of display is called a refresh CRT.

The primary components of an electron gun in a CRT are the heated metal cathode and a control grid Fig. 2-3. Heat is supplied to the cathode by directing a current through a coil of wire, called the filament, inside the cylindrical cathode structure. This causes electrons to be “boiled off" the hot cathode surface. In the vacuum inside the CRT envelope, the free, negatively charged electrons are then accelerated toward the phosphor coating by a high positive voltage.

Voltage can be generated with a positively charged metal coating on the inside of the CRT envelope near the phosphor screen, or an accelerating anode can be used, as in Fig. 2-3. Sometimes the electron gun is built to contain the accelerating anode and focusing system within the same unit.

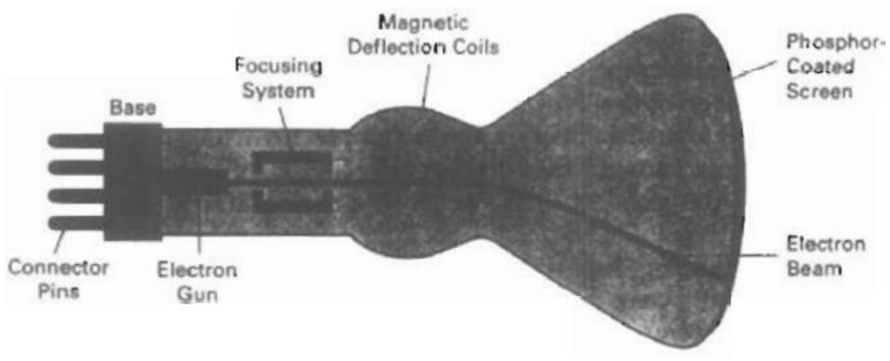


Figure 2-2
Basic design of a magnetic-deflection CRT.

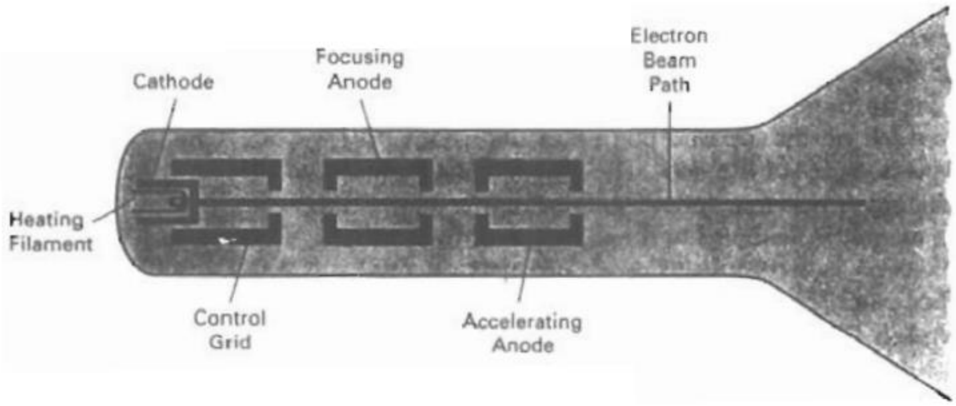


Figure 2-3
Operation of an electron gun with an accelerating anode.

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 envelope. One pair is mounted on the top and bottom of the neck, and the other pair is mounted on opposite sides of the neck.

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 plates are mounted inside the CRT envelope. One pair oi plates is mounted horizontally to control the vertical deflection, and the other pair is mounted vertical 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 kinetic 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.

Different kinds of phosphors are available for use in a CRT. Besides a color, a major difference between phosphors is their persistence: how long they continue to emit light (that is, have excited electrons returning to the ground state) 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.

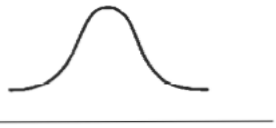


Figure 2-5
Intensity distribution of an illuminated phosphor spot on a CRT screen.

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 an intensity of about 60 percent of that at the center of the spot.

Typical **resolution on high-quality systems** is 1280 by 1024, with higher resolutions available on many systems. High resolution systems are often referred to as high-definition systems. 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 3/4 means that a vertical line plotted with three points has the same length as a horizontal line plotted with four points.

2. Raster Scan System

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 forms 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.

Intensity range for pixel positions depends on the capability of the raster system.

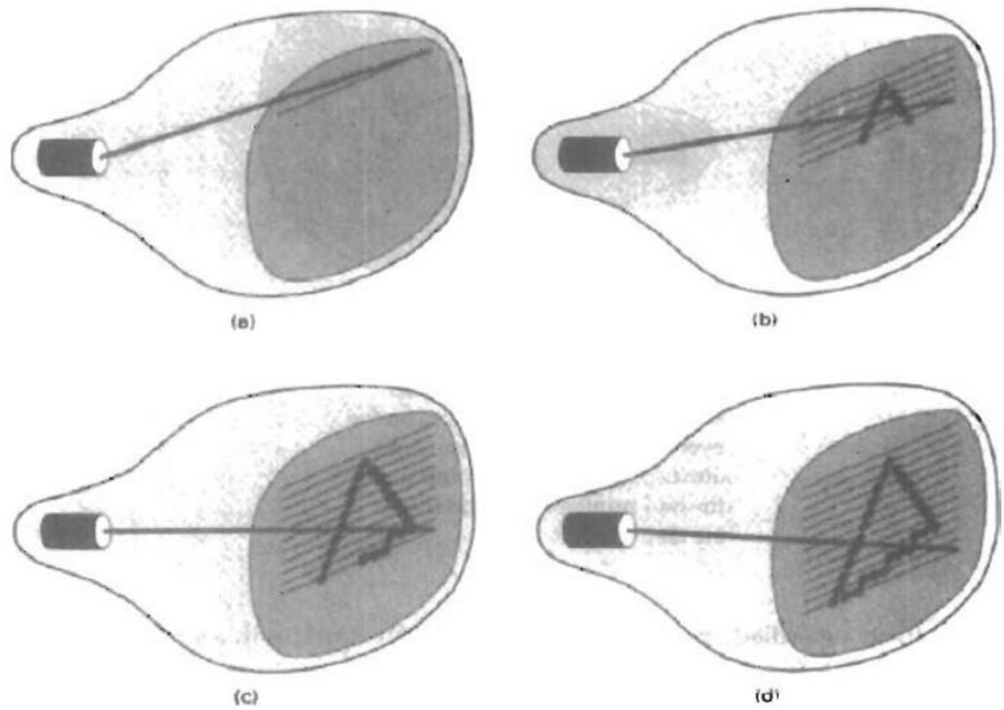


Figure 2-7
A raster-scan system displays an object as a set of discrete points across each scan line.

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 positions. For a bilevel system, a bit value of 1 indicates that the electron beam is to be turn4 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 systems, 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 pixeI, the frame buffer is commonly called a bitmap. For systems with multiple bits per pixel, the frame buffer is Aten 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 cycles 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.

Interactive raster graphics systems typically employ several processing units. In addition to the central processing unit, or CPU, a special-purpose processor, called the video controller or display controller, is used to control the operation of the display device. Organization of a simple raster system is shown in Fig. 2-25.

Video Controller

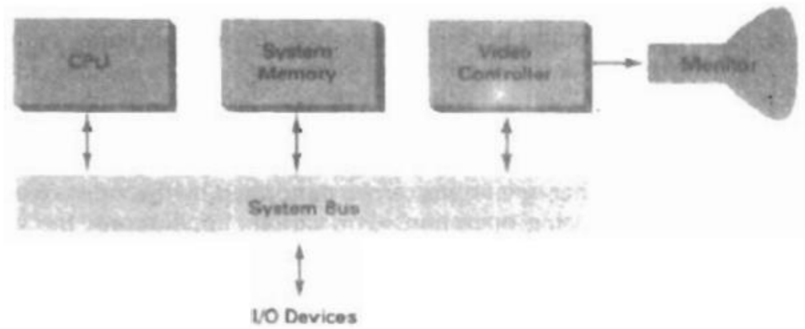


Figure 2-25
Architecture of a simple raster graphics system.

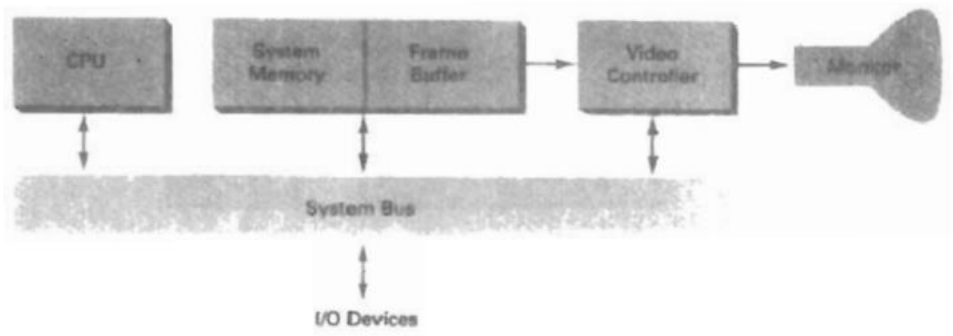


Figure 2-26
Architecture of a raster system with a fixed portion of the system memory reserved for the frame buffer.

Figure 2-26 shows a commonly used organization for raster systems. A fixed area of the system memory is reserved for the frame buffer, and the video controller is given direct access to the frame-buffer memory. Frame-buffer locations, and the corresponding screen positions, are referenced in Cartesian coordinates. For many graphics monitors, the coordinate origin is defined at the lower left screen comer (Fig. 2-27).

The screen surface is then represented as the first quadrant of a two-dimensional system, with positive x values increasing to the right and positive y values increasing from bottom to top. (On some personal computers, the coordinate origin is referenced at the upper left comer of the screen, so the y values are inverted.) Scan lines are then labeled from y, at the top of the screen to 0 at the bottom. Along each scan line, screen pixel positions are labeled from 0 to x,,.

In Fig. 2-28, the basic refresh operations of the video controller are diagrammed. Two registers are used to store the coordinates of the screen pixels. Initially, the x register is set to 0 and the y register is set to y,. The value stored in the frame buffer for this pixel position is then retrieved and used to set the intensity of the CRT beam. Then the x register is incremented by 1, and the process re peated for the next pixel on the top scan line.

Figure 2-27
The origin of the coordinate system for identifying screen positions is usually specified in the lower-left corner.

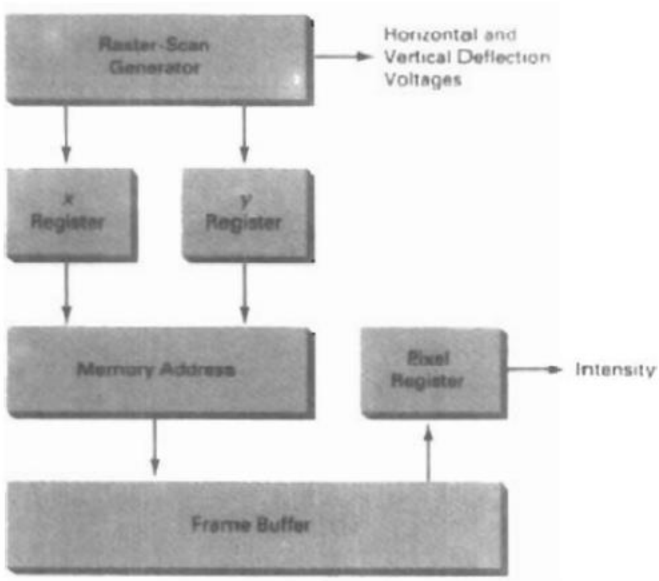


Figure 2-28
Basic video-controller refresh operations.

This procedure is repeated for each pixel along the scan line. After the last pixel on the top scan line has been processed, the x register is reset to 0 and the y register is decremented by 1. Pixels along this scan line are then processed in turn, and the procedure is repeated for each successive scan line. After cycling through all pixels along the bottom scan line (y = 0), the video controller resets the registers to the first pixel position on the top scan line and the refresh process starts over.

Here, the frame buffer can be anywhere in the system memory, and the video controller accesses the frame buffer to refresh the screen. In addition to the video controller, more sophisticated raster systems employ other processors as coprocessors and accelerators to implement various graphics operations.

Since the screen must be refreshed at the rate of 60 frames per second, the simple procedure illustrated in Fig. 2-28 cannot be accommodated by typical RAM chips. The cycle time is too slow. To speed up pixel processing, video controllers can retrieve multiple pixel values from the refresh buffer on each pass. The multiple pixel intensities are then stored in a separate register and used to control the CRT beam intensity for a group of adjacent pixels. When that group of pixels has been processed, the next block of pixel values is retrieved from the frame buffer.

Raster-Scan Display Processor

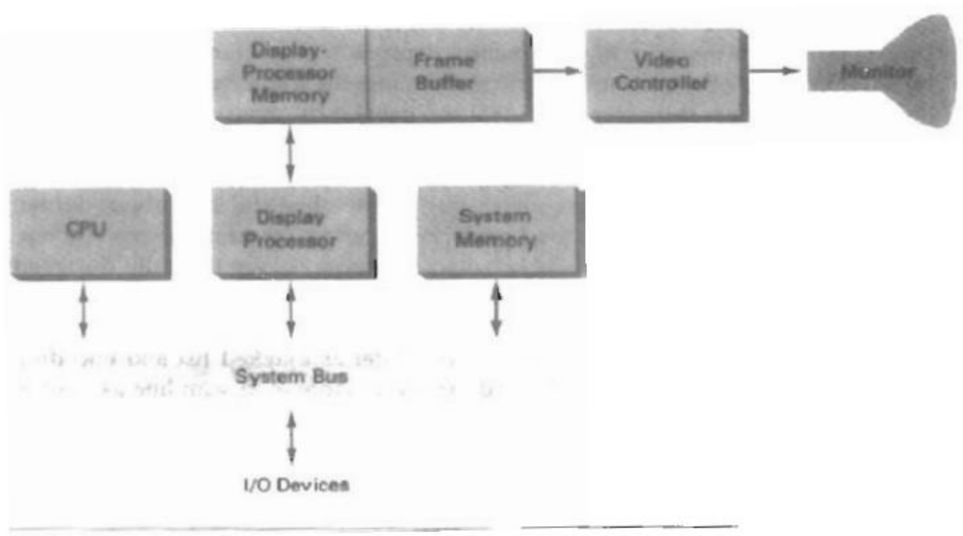


Figure 2-29
Architecture of a raster-graphics system with a display processor.

Figure 2-29 shows one way to set up the organization of a raster system containing a separate display processor, sometimes referred to as a graphics controller or a display coprocessor. The purpose of the display processor is to free the CPU from the graphics chores. In addition to the system memory, a separate display processor memory area can also be provided. A major task of the display pmcessor is digitizing a picture definition given in an application program into a set of pixel-intensity values for storage in the frame buffer. This digitization process is caIled scan conversion.

Characters can be defined with rectangular grids, as in Fig. 2-30, or they can be defined with curved outlines, as in Fig. 2-31. The array size for character grids can vary from about 5 by 7 to 9 by 12 or more for higher-quality displays. A character grid is displayed by superimposing the rectangular grid pattern into the frame buffer at a specified coordinate position. With characters that are defined as curve outlines, character shapes are scan converted into the frame buffer

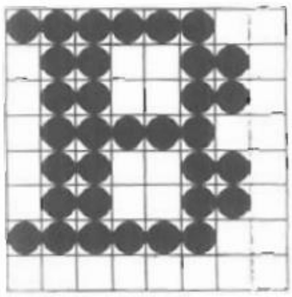


Figure 2-30
A character defined as a rectangular grid of pixel positions.

Figure 2-31
A character defined as a curve outline.

One number specifies the number of adjacent pixels on the scan line that are to have that intensity. This technique, called run-length encoding, can result in a considerable saving in storage space if a picture is to be constructed mostly with long runs of a single color each. A similar approach can be taken when pixel intensities change linearly. Another approach is to encode the raster as a set of rectangular areas (cell encoding)

3. Random – Scan Systems (or Random scan displays)

The organization of a simple random-scan (vector) system is shown in Fig. 2-32. An application program is input and stored in the system memory along with a graphics package. Graphics commands in the application program are translated by the graphics package into a display file stored in the 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 once during every refresh cycle. Sometimes the display processor in a random-scan system is referred to as a display processing unit or a graphics controller.

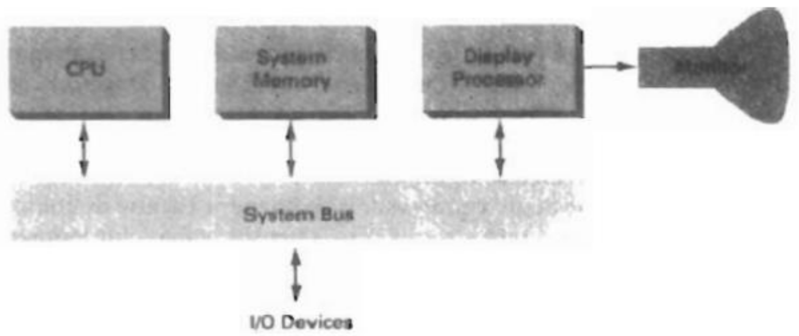


Figure 2-32
Architecture of a simple random-scan system.

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 monitors draw a picture one line at a time and for this reason are also referred to as vector displays (or stroke-writing or 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).

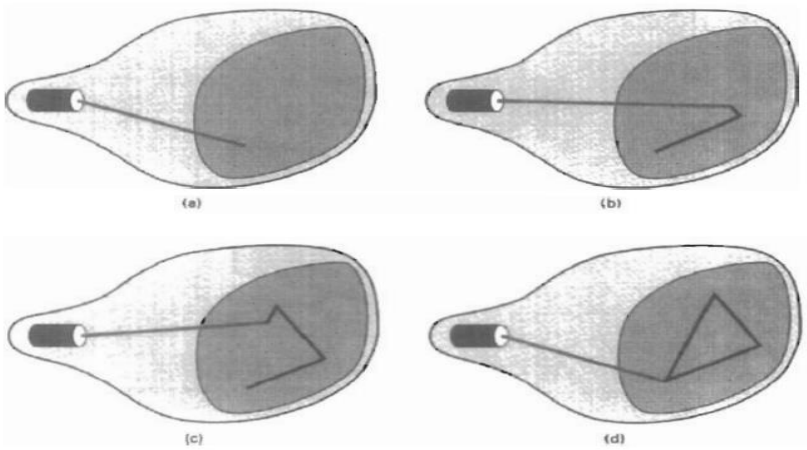


Figure 2-9
A random-scan system draws the component lines of an object in any order specified.

4. Graphics Work Stations and Monitors

Most graphics monitors today operate as raster scan displays, and here we survey a few of the many graphics hardware configurations available. Graphics systems range hm small general-purpose computer systems with graphics capabilities to sophisticated full color systems that are designed specifically for graphics applications (Fig. 2-34). A typical screen resolution for personal computer systems, such as the Apple Quadra shown in Fig. 2-33, is 640 by 480.

Diagonal screen dimensions for general-purpose personal computer systems can range from 12 to 21 inches, and allowable color selections range from 16 to over 32,000.

For workstations specifically designed for graphics applications, such as the systems shown in Fig. 2-34, typical screen resolution is 1280 by 1024, with a screen diagonal of 16 inches or more. Graphics workstations can be configured with from 8 to 24 bits per pixel (full-color systems), with higher screen resolutions, faster processors, and other options available in high-end systems.

Figure 2-35 shows a high-definition graphics monitor used in applications such as air traffic control, simulation, medical imaging, and CAD. This system has a diagonal screen size of 27 inches, resolutions ranging from 2048 by 1536 to 2560 by 2048, with refresh rates of 80 Hz or 60 Hz noninterlaced.

Figure 2-35
A very high-resolution (2560 by 2048) color monitor. (*Courtesy of BARCO Chromatics.*)

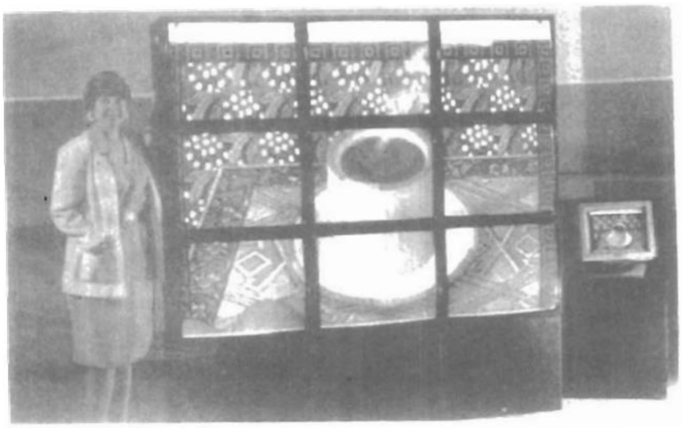


Figure 2-36
The MediaWall: A multiscreen display system. The image displayed on this 3-by-3 array of monitors was created by Deneba Software. (*Courtesy of RGB Spectrum.*)

A multiscreen system called the MediaWall, shown in Fig. 2-36, provides a large "wall-sized display area. This system is designed for applications that require large area displays in brightly lighted environments, such as at trade shows, conventions, retail stores, museums, or passenger terminals. MediaWall operates by splitting images into a number of Sections and distributing the sections over an array of monitors or projectors using a graphics adapter and satellite control units.

An array of up to 5 by 5 monitors, each with a resolution of 640 by 480, can be used in the MediaWall to provide an overall resolution of 3200 by 2400 for either static scenes or animations. Scenes can be displayed behind mullions, as in Fig. 2-36, or the mullions can be eliminated to display a continuous picture with no breaks between the various sections.

Many graphics workstations, such as some of those shown in Fig. 2-37, are configured with two monitors. One monitor can be used to show all features of an object or scene, while the second monitor displays the detail in some part of the picture. Another use for dual-monitor systems is to view a picture on one monitor and display graphics options (menus) for manipulating the picture components on the other monitor.

Figure 2-37
Single- and dual-monitor graphics workstations. (*Courtesy of Intergraph Corporation.*)

Figure 2-38
Multiple workstations for a CAD group. (*Courtesy of Hewlett-Packard Company.*)

Figures 2-38 and 2-39 illustrate examples of interactive graphics workstations containing multiple input and other devices. A typical setup for CAD applications is shown in Fig. 2-38. Various keyboards, button boxes, tablets, and mice are attached to the video monitors for use in the design process. Figure 2-39 shows features of some types of artist's workstations.

Figure 2-39
An artist's workstation, featuring a color raster monitor, keyboard, graphics tablet with hand cursor, and a light table, in addition to data storage and telecommunications devices. (*Courtesy of DICOMED Corporation.*)

5. Input Devices

Various devices are available for data input on graphics workstations. Most systems have a keyboard and one or more additional devices specially designed for interactive input. These include a mouse, trackball, spaceball, joystick, digitizers, dials, and button boxes. Some other input devices used in particular applications are data gloves, touch panels, image scanners, and voice systems.

Keyboards

An alphanumeric keyboard on a graphics system is used primarily as a device for entering text strings. The keyboard is an efficient device for inputting such nongraphic data as picture labels associated with a graphics display. Keyboards can also be provided with features to facilitate entry of screen coordinates, menu selections, or graphics functions.

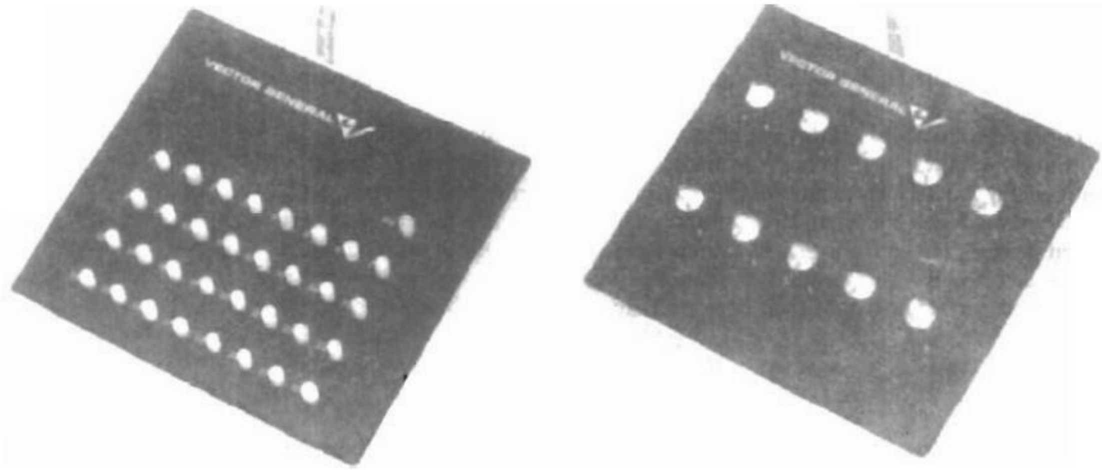
Figure 2-40
Ergonomically designed keyboard with removable palm rests. The slope of each half of the keyboard can be adjusted separately. (*Courtesy of Apple Computer, Inc.*)

Cursor-control keys and function keys are common features on general purpose keyboards. Function keys allow users to enter frequently used operations in a single keystroke, and cursor-control keys can be used to select displayed objects or coordinate positions by positioning the screen cursor.

Fig. 2-40 shows an ergonomic keyboard design.

Mouse

A mouse is small hand-held box used to position the screen cursor. Wheels or rollers on the bottom of the mouse can be used to record the amount and direction of movement. Another method for detecting mouse motion is with an optical sensor. For these systems, the mouse is moved over a special mouse pad that has a grid of horizontal and vertical lines. The optical sensor detects movement across the lines in the grid.



(a) (b)

Figure 2-41
A button box (a) and a set of input dials (b). (*Courtesy of Vector General.*)

Figure 2-42
The Z mouse features three buttons, a mouse ball underneath, a thumbwheel on the side, and a trackball on top. (*Courtesy of Multipoint Technology Corporation.*)

Trackball and Spaceball

As the name implies, a trackball is a ball that can be rotated with the fingers or palm of the hand, as in Fig. 2-43, to produce screen-cursor movement. Potentiometers, attached to the ball, measure the amount and direction of rotation. Trackballs are often mounted on keyboards (Fig. 2-15) or other devices such as the Z mouse (Fig. 2-42). While a trackball is a two-dimensional positioning device, a spaceball (Fig. 2-45) provides six degrees of freedom. Unlike the trackball, a spaceball does not actually move. Str applied to the spaceball to provide input for spati pushed or pulled in various directions. Spaceballs and selection operations in virtual-reality systen applications.

Figure 2-45
A virtual-reality scene, displayed on a two-dimensional video monitor, with input from a data glove and a spaceball. (*Courtesy of The Computer Graphics Center, Darmstadt, Germany.*)

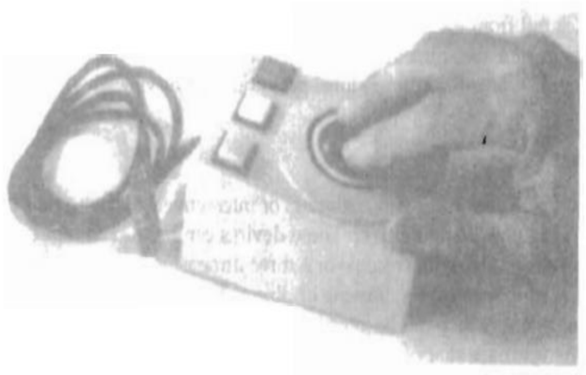


Figure 2-43
A three-button track ball. (*Courtesy of Measurement Systems Inc., Norwalk, Connecticut.*)

Data Glove

Figure 2-45 shows a data glove that can be used to grasp a "virtual" object. The glove is constructed with a series of sensors that detect hand and finger motions. Electromagnetic coupling between transmitting antennas and receiving antennas is used to provide information about the position and orientation of the hand. The transmitting and receiving antennas can each be structured as a set of three mutually perpendicular coils, forming a three-dimensional Cartesian coordinate system. Input from the glove can be used to position or manipulate objects in a virtual scene. A two-dimensional projection of the scene can be viewed on a video monitor, or a three-dimensional projection can be viewed with a headset.

Joystick

A joystick consists of a small, vertical lever (called the stick) mounted on a base that is used to steer the screen cursor around. Most joysticks select screen positions with actual stick movement; others respond to pressure on the stick. Fig. 2-44 shows a movable joystick. Some joysticks are mounted on a keyboard; others function as stand-alone units. The distance that the stick is moved in any direction from its center position corresponds to screen-cursor movement in that direction. Potentiometers mounted at the base of the joystick measure the amount of movement, and springs return the stick to the center position when it is released. One or more buttons can be programmed to act as input switches to signal certain actions once a screen position has been selected.

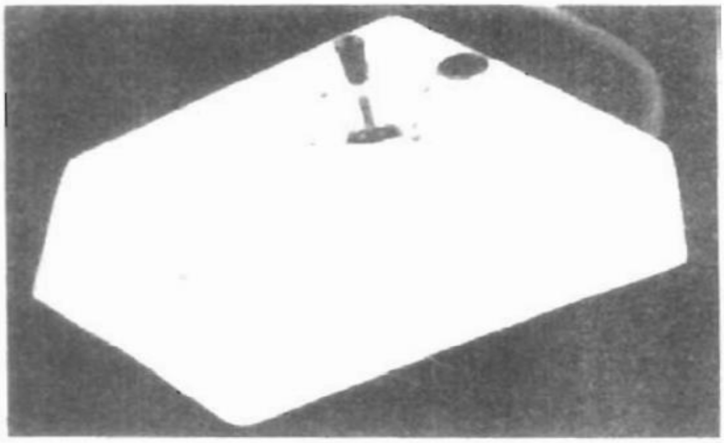


Figure 2-44
A moveable joystick. (*Courtesy of CalComp Group; Sanders Associates, Inc.*)

Digitizers

A common device for drawing, painting, or interactively selecting coordinate positions on an object is a digitizer. These devices can be used to input coordinate values in either a two-dimensional or a three-dimensional space. Typically, a digitizer is used to scan over a drawing or object and to input a set of discrete coordinate positions, which can be joined with straight-Iine segments to approximate the curve or surface shapes. One type of digitizer is the graphics tablet (also referred to as a data tablet), which is used to input two-dimensional coordinates by activating a hand cursor or stylus at selected positions on a flat surface. A hand cursor contains cross hairs for sighting positions, while a stylus is a pencil-shaped device that is pointed at positions on the tablet. Figures 2-46 and 2-47 show examples .of desktop and floor-model tablets, using hand cursors that are available with 2,4, or 16 buttons.

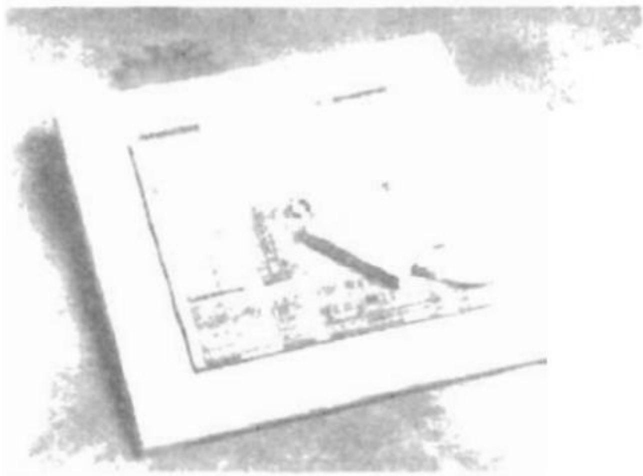


Figure 2-46
The SummaSketch III desktop tablet with a 16-button hand cursor. (*Courtesy of Summagraphics Corporation.*)

Figure 2-47
The Microgrid III tablet with a 16-button hand cursor, designed for digitizing larger drawings. (*Courtesy of Summagraphics Corporation.*)

Examples of stylus input with a tablet am shown in Figs. 2-48 and 2-49. The artist's digitizing system in Fig. 2-49 uses electromagnetic resonance to detect the three-dimensional position of the stylus. This allows an artist to produce different brush strokes with different pressures on the tablet surface.

Figure 2-48
The NotePad desktop tablet with stylus. *(Courtesy of CalComp Digitizer Division, a part of CalComp, Inc.)*

Figure 2-49
An artist's digitizer system, with a pressure-sensitive, cordless stylus. *(Courtesy of Wacom Technology Corporation.)*

Three-dimensional digitizers use sonic or electromagnetic transmissions to word positions. One election magnetic transmission method is similar to that used in the data glove: A coupling between the transmitter and receiver is used to compute the location of a stylus as it moves over the surface of an object. Figure 2-50 shows a three-dimensional digitizer designed for Apple Macintosh computers. As the points are selected on a non metallic object, a wireframe outline of the surface is displayed on the computer screen. Once the surface outline is constructed, it can be shaded with lighting effects to produce a realistic display of the object. Resolution of this system is hm 0.8 mm to 0.08 mm, depending on the model.

Figure 2-50
A three-dimensional digitizing system for use with Apple Macintosh computers. (*Courtesy of Mira Imaging.*)

Image Scanners

Drawings, graphs, color and black-and-white photos, or text can be stored for computer processing with an image scanner by passing an optical scanning mechanism over the information to be stored. The gradations of grey scale or color are then recorded and stored in an array. Once we have the internal representation of a picture, we can apply transformations to rotate, scale, or crop the picture to a particular screen area. We can also apply various image-processing methods to modify the array representation of the picture. For scanned text input, various editing operations can be performed on the stored documents. Some scanners are able to scan either graphical representations or text, and they come in a variety of sizes and capabilities.

Thunderware, Inc.)

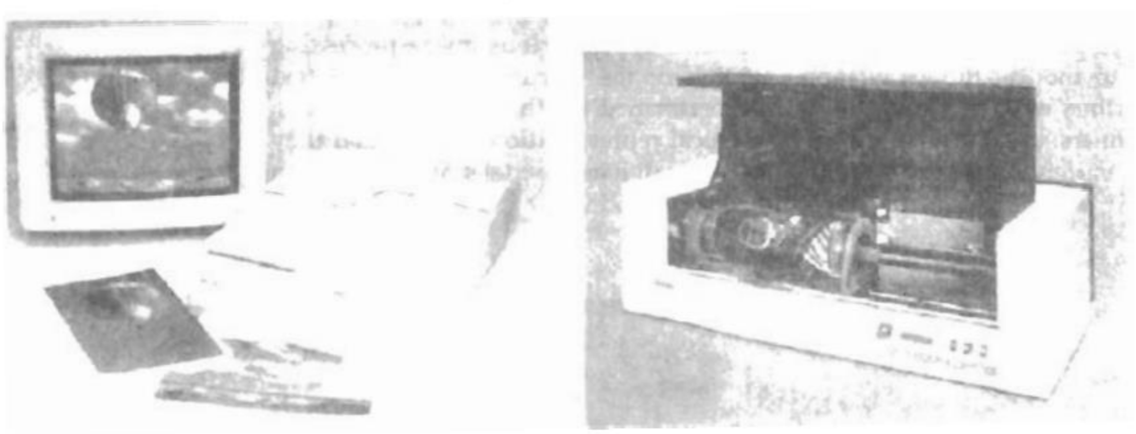


Figure 2-52
Desktop full-color scanners: (a) Flatbed scanner with a resolution of 600 dots per inch. (*Courtesy of Sharp Electronics Corporation.*) (b) Drum scanner with a selectable resolution from 50 to 4000 dots per inch. (*Courtesy of Howtek, Inc.*)

Touch Panels

As the name implies, touch panels allow displayed objects or screen positions to be selected with the touch of a finger. A typical application of touch panels is for the selection of processing options that are represented with graphical icons. Some systems, such as the plasma panels shown in Fig. 2-54, are designed with touch screens. Other systems can be adapted for touch input by fitting a transparent device with a touch sensing mechanism over the video monitor screen. Touch input can be recorded using optical, electrical, or acoustical methods.

Figure 2-54
Plasma panels with touch screens. (*Courtesy of Photonics Systems.*)

Light Pens

Figure 2-56 shows the design of one type of light pen. Such pencil-shaped devices are used to select screen positions by detecting the light coming from points on the CRT screen. They are sensitive to the short burst of light emitted from the phosphor coating at the instant the electron beam strikes a particular point. Other Light sources, such as the background light in the room, are usually not detected by a light pen. An activated light pen, pointed at a spot on the screen as the electron beam lights up that spot, generates an electrical pulse that causes the coordinate position of the electron beam to be recorded. As with cursor-positioning devices, recorded Light-pen coordinates can be used to position an object or to select a processing option.

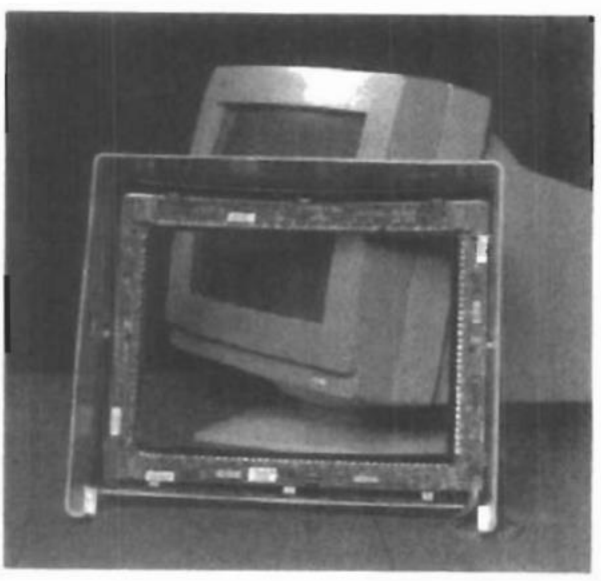


Figure 2-55
An optical touch panel, showing the arrangement of infrared LED units and detectors around the edges of the frame. (*Courtesy of Carroll Touch, Inc.*)

Voice Systems

Speech recognizers are 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 phrase. A dictionary is set up for a particular operator by having, the operator speak the command words to be used into the system. Each word is spoke several times, and the system analyzes the word and establishes a frequency pattern for that word in the dictionary along with the corresponding function to be performed. Later, when a voice command is given, the system searches the dictionary for a frequency-pattern match. Voice input is typically spoken into a microphone mounted on a headset, as in Fig. 2-57. The microphone is designed to minimize input of other background sounds

Figure 2-57
A speech-recognition system. (*Courtesy of Threshold Technology, Inc.*)

6. Hardcopy Devices

The quality of the pictures obtained from a device depends on dot size and the number of dots per inch, or Lines per inch, that can be displayed. To produce smooth characters in printed text strings, higher-quality printers shift dot positions so that adjacent dots overlap.

Printers produce output by either impact or nonimpact methods. Impact printers press formed character faces against an inked ribbon onto the paper.

A line printer is an example of an impact device, with the typefaces mounted on bands, chains, drums, or wheels. Nonimpact printers and plotters use laser techniques, ink-jet sprays, xerographic processes(as used in photocopying machines), electrostatic methods, and electrothermal methods to get images onto Paper.

Character impact printers often have a dot-matrix print head containing a rectangular array of protruding wire pins, with the number of pins depending on the quality of the printer. Individual characters or graphics patterns are obtained by retracting certain pins so that the remaining pins form the pattern to be printed.

Figure 2-58 shows a picture printed on a dot-matrix printer. In a laser device, a laser beam mates a charge distribution on a rotating drum coated with a photoelectric material, such as selenium. Toner is applied to the dm and then transferred to paper. Figure 2-59 shows examples of desktop laser printers with a resolution of 360 dots per inch. Ink-jet methods produce output by squirting ink in horizontal rows across a roll of paper wrapped on a drum. The electrically charged ink stream is deflected by an electric field to produce dot-matrix patterns.

Figure 2-58
A picture generated on a dot-matrix printer showing how the density of the dot patterns can be varied to produce light and dark areas. (*Courtesy of Apple Computer, Inc.*)

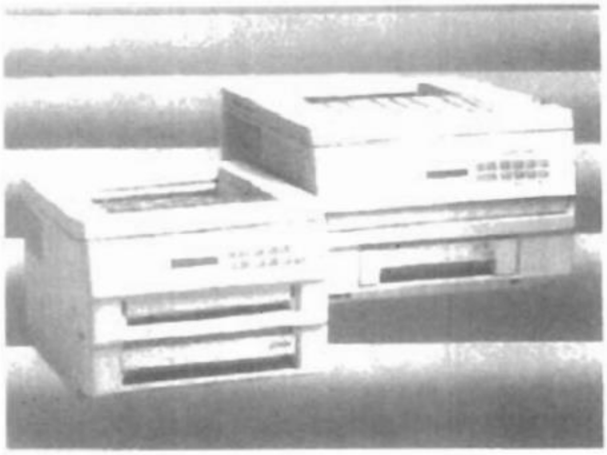


Figure 2-59
Small-footprint laser printers. (*Courtesy of Texas Instruments.*)

A desktop ink-jet plotter with a resolution of 360 dots per inch is shown in Fig. 2-60, and examples of larger high-resolution ink-jet printer/plotters are shown in Fig. 2-61.

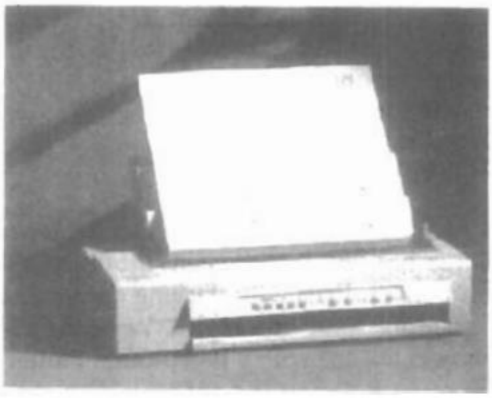
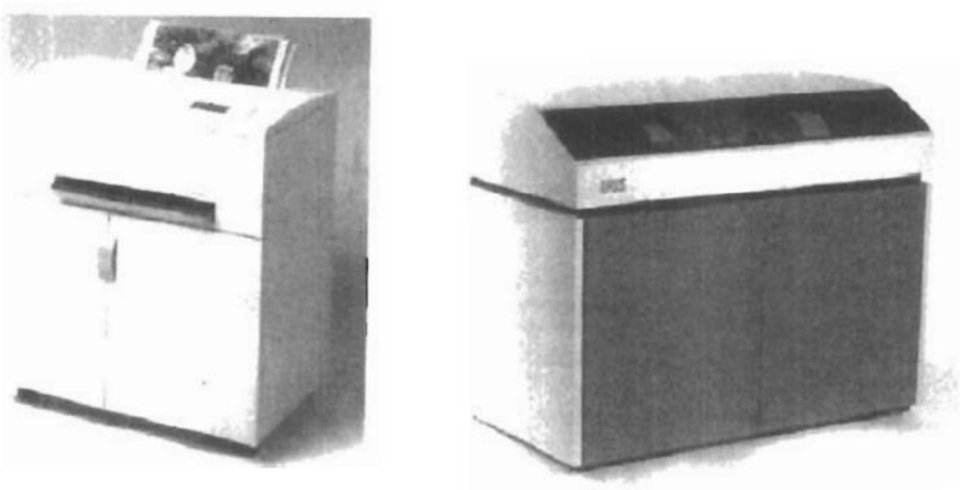


Figure 2-60
A 360-dot-per-inch desktop ink-jet plotter. (*Courtesy of Summagraphics Corporation.*)

An electrostatic device places a negative charge on the paper, one complete row at a time along the length of the paper. Then the paper is exposed to a toner. The toner is positively charged and so is attracted to the negatively charged areas, where it adheres to produce the specified output. A color electrostatic printer/plotter is shown in Fig. 2-62.

A pen plotter has one or more pens mounted on a carriage, or crossbar, that spans a sheet of paper. Pens with varying colors and widths are used to produce a variety of shadings and line styles. Wet-ink, ball-point, and felt-tip pens are all possible choices for use with a pen plotter. Plotter paper can lie flat or be rolled onto a drum or belt. Crossbars can be either moveable or stationary, while the pen moves back and forth along the bar. Either clamps, a vacuum, or an electrostatic charge hold the paper in position. An example of a table-top flatbed pen plotter is given in Fig 2-63, and a larger, rollfeed pen plotter is shown in Fig. 2-64.



(a) (b)

Figure 2-61
Floor-model, ink-jet color printers that use variable dot size to achieve an equivalent resolution of 1500 to 1800 dots per inch. (*Courtesy of IRIS Graphics Inc., Bedford, Massachusetts.*)

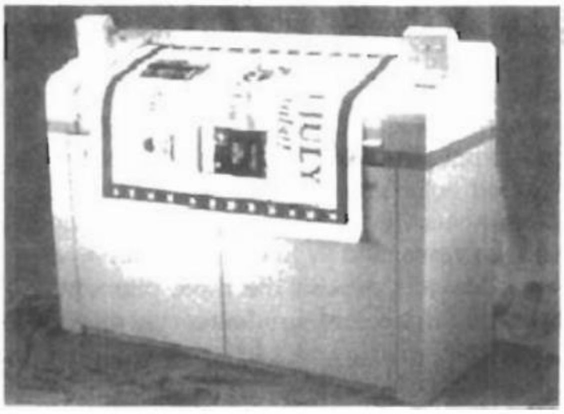


Figure 2-62
An electrostatic printer that can display 400 dots per inch. (*Courtesy of CalComp Digitizer Division, a part of CalComp, Inc.*)

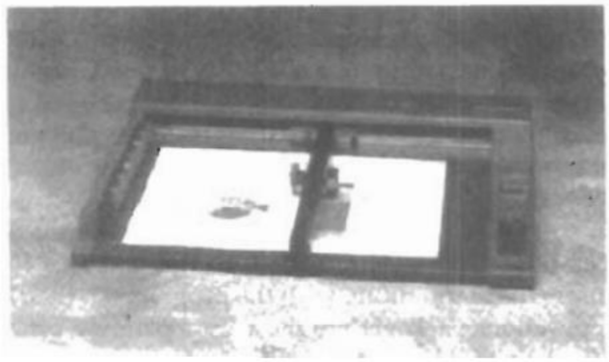


Figure 2-63
A desktop pen plotter with a resolution of 0.025 mm. (*Courtesy of Summagraphics Corporation.*)

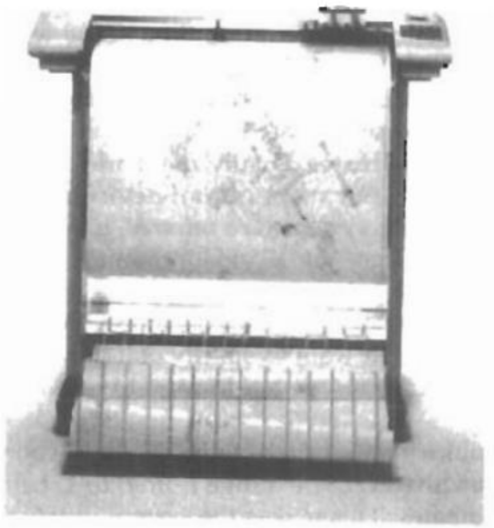


Figure 2-64
A large, rollfeed pen plotter with automatic multicolor 8-pen changer and a resolution of 0.0127 mm.
(*Courtesy of Summagraphics Corporation.*)