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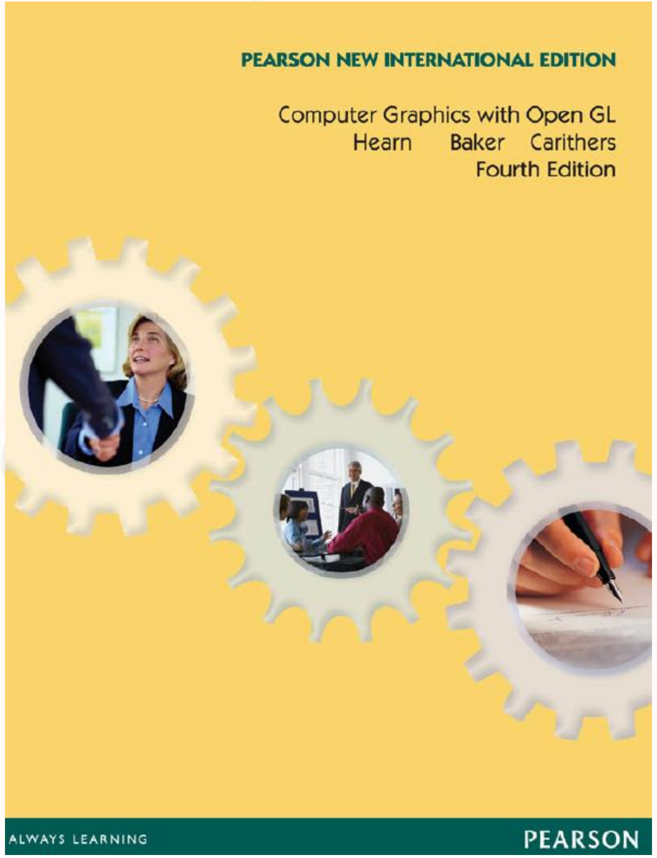
Adham University College
الكلية الجامعية بأضم
Computer Science Department
قسم الحاسب الآلي

Computer Graphics Course, 3-6803430

T.Mariah Khayat

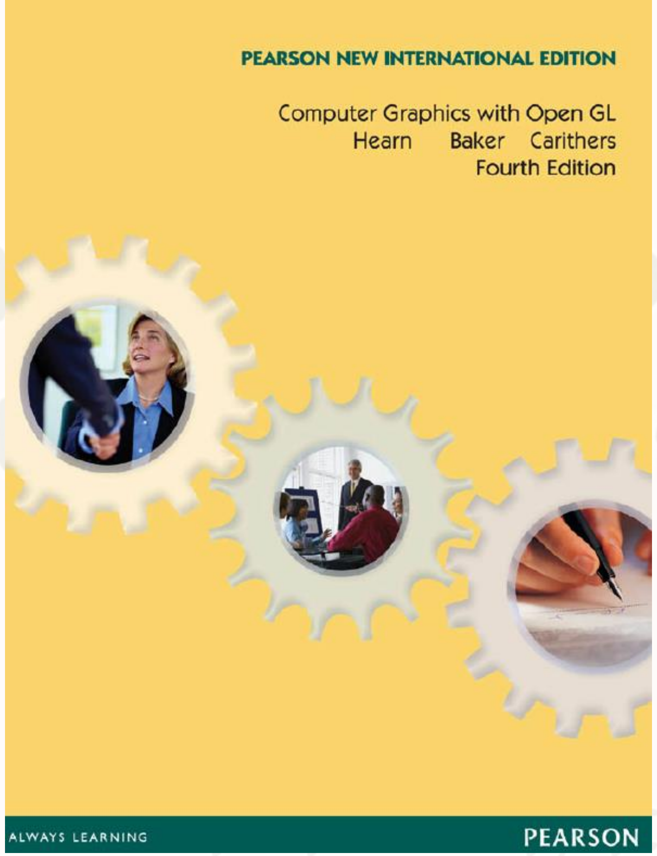
Main Reference

- *Computer Graphics with Open GL, 4th edition, Hearn, Baker & Carithers.*



Chapter One

Computer Graphics Hardware -Part One-



content

1. Video Display Devices
2. Raster-Scan Systems

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CS Department
Computer Graphics Course, 3-6803430
T.Mariah Khayat

Computer Graphics Hardware

- The power and utility of computer graphics is widely recognized, and a broad range of graphics hardware and software systems is now available for applications in virtually all fields.
- Graphics capabilities for both two-dimensional and threedimensional applications are now common, even on general-purpose computers and handheld calculators.
- With personal computers, we can use a variety of interactive input devices and graphics software packages.
- For higher-quality applications, we can choose from a number of sophisticated special-purpose graphics hardware systems and technologies.
- In this chapter, we explore the basic features of graphics hardware components and graphics software packages.

1. Video Display Devices

- The primary output device in a graphic system is a video monitor.
- The operation of most video monitors was based on the standard **cathode-ray tube (CRT)** design.
- In recent years, **flat-panel** displays have become significantly more popular due to their reduced power consumption and thinner designs.

Refresh Cathode-Ray Tubes

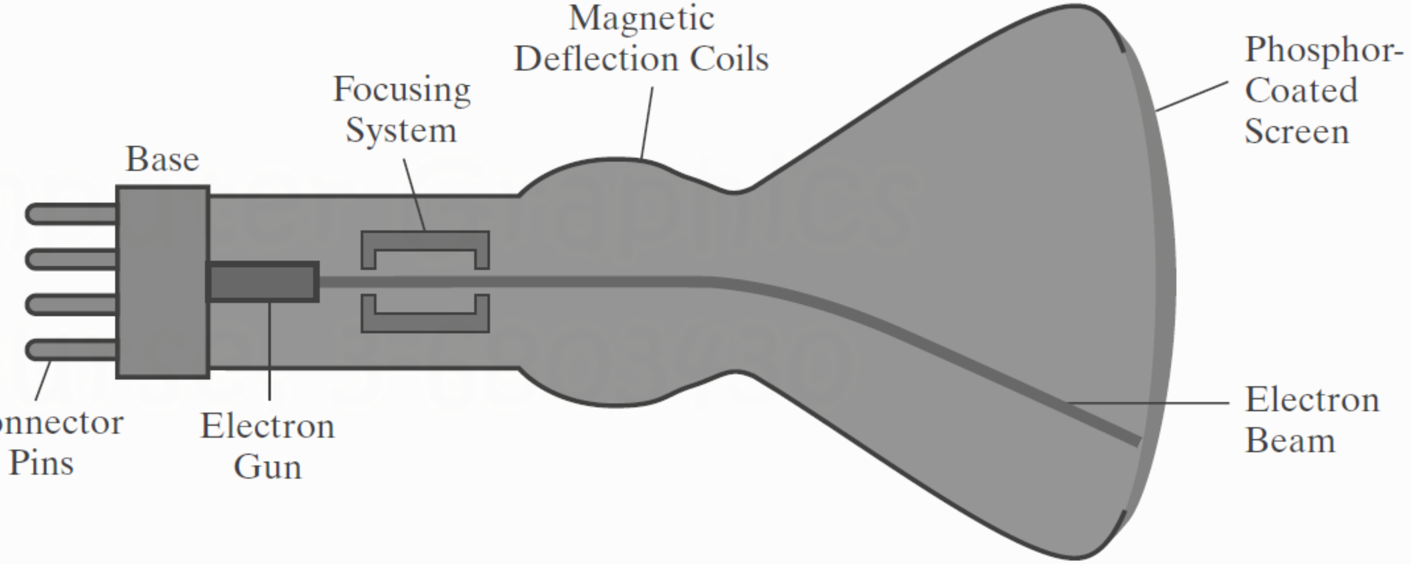

FIGURE 1
Basic design of a magnetic-deflection CRT.

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As in Figure 1, The basic operation of a CRT is:

- 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 do this is to store the picture information as a charge distribution within the CRT. This charge distribution can then be used to keep the phosphors activated.
- The most common method now employed for maintaining phosphor glow is to redraw the picture repeatedly by quickly directing the electron beam back over the same screen points.
- This type of display is called a **refreshCRT**, and the frequency at which a picture is redrawn on the screen is referred to as the **refresh rate**.

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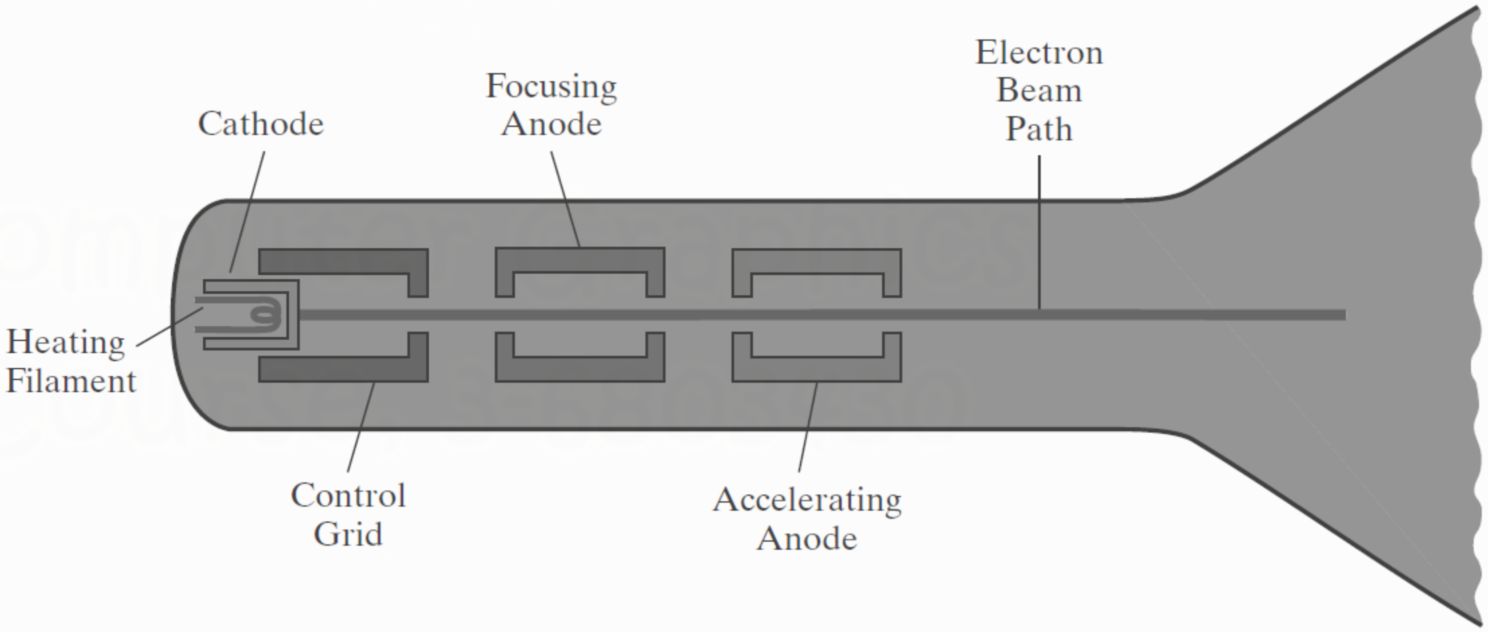

FIGURE 2
Operation of an electron gun with an accelerating anode.

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- The primary components of an electron gun in a CRT are the heated metal cathode and a control grid (Fig. 2).
- 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.
- The accelerating 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, as in Figure 2, can be used to provide the positive voltage.
- Sometimes the electron gun is designed so that the accelerating anode and focusing system are within the same unit.

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- Intensity of the electron beam is controlled by the voltage at the control grid, which is a metal cylinder that fits over the cathode.
- A high negative voltage applied to the control grid will shut off the beam by repelling electrons and stopping them from passing through the small hole at the end of the controlgrid structure.
- A smaller negative voltage on the control grid simply decreases the number of electrons passing through.
- Since the amount of light emitted by the phosphor coating depends on the number of electrons striking the screen, the brightness of a display point is controlled by varying the voltage on the control grid.
- This brightness, or intensity level, is specified for individual screen positions with graphics software commands.

Refresh cathode-Ray Tubes

- The focusing system in a CRT forces the electron beam to converge to a small cross section as it strikes the phosphor. Otherwise, the electrons would repel each other, and the beam would spread out as it approaches the screen.
- Focusing is accomplished with either electric or magnetic fields. With electrostatic focusing, the electron beam is passed through a positively charged metal cylinder so that electrons along the center line of the cylinder are in an equilibrium position.
- This arrangement forms an electrostatic lens, as shown in Figure 2, and the electron beam is focused at the center of the screen in 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 set up by a coil mounted around the outside of the CRT envelope, and magnetic lens focusing usually produces the smallest spot size on the screen.

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- Additional focusing hardware is used in high-precision systems to keep the beam in focus at all screen positions.
- 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 will be focused 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.

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- As with focusing, deflection of the electron beam can be controlled with either electric or magnetic fields.
- Cathode-ray tubes are now commonly constructed with magnetic-deflection coils mounted on the outside of the CRT envelope, as illustrated in Figure 1.
- Two pairs of coils are used for this purpose. One pair is mounted on the top and bottom of the CRT neck, and the other pair is mounted on opposite sides of the neck.
- The magnetic field produced by each pair of coils results in a transverse deflection force that is perpendicular to both the direction of the magnetic field and the direction of travel of the electron beam.
- Horizontal deflection is accomplished with one pair of coils, and vertical deflection with 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 of plates is mounted horizontally to control vertical deflection, and the other pair is mounted vertically to control horizontal deflection (Fig. 3).

Refresh cathode-Ray Tubes

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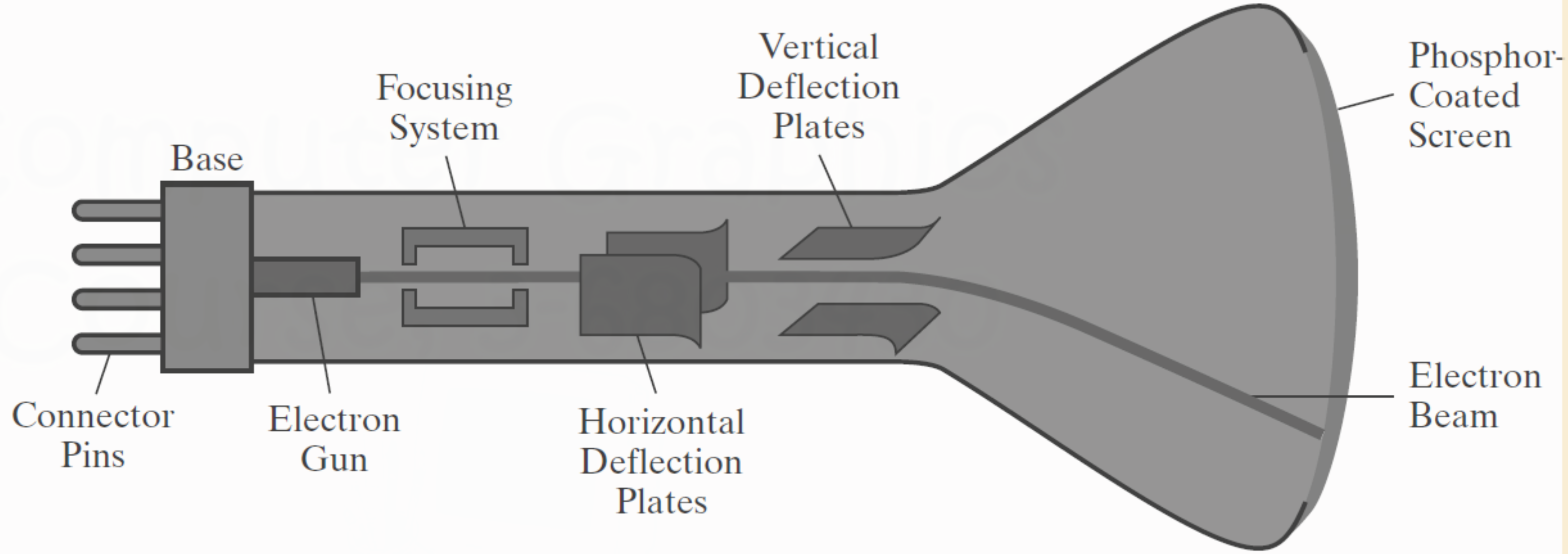

FIGURE 3
Electrostatic deflection of the electron beam in a CRT.

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- 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 quantums of light energy called photons.
- 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 in proportion to the energy difference between the excited quantum state and the ground state.

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- Different kinds of phosphors are available for use in CRTs. Besides color, a major difference between phosphors is their **persistence**: how long they continue to emit light (that is, how long it is before all excited electrons have returned to the ground state) after the CRT beam is removed.
- Persistence is defined as the time that it takes the emitted light from the screen to decay to one-tenth of its original intensity.
- Lower-persistence phosphors require higher refresh rates to maintain a picture on the screen without flicker.
- A phosphor with low persistence can be useful for animation, while high-persistence phosphors are better suited for displaying highly complex, static pictures.
- Although some phosphors have persistence values greater than 1 second, general-purpose graphics monitors are usually constructed with persistence in the range from 10 to 60 microseconds.

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- Figure 4 shows the intensity distribution of a spot on the screen.
- The intensity is greatest at the center of the spot, and it decreases with a Gaussian distribution out to the edges of the spot.
- This distribution corresponds to the cross-sectional electron density distribution of the CRT beam.

FIGURE 4
Intensity distribution of an illuminated phosphor spot on a CRT screen.

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- 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. 4), 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.
- This overlap position is illustrated in Figure 5.

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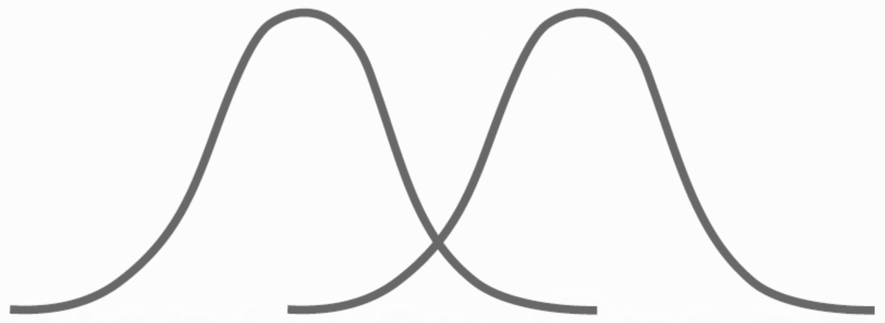

FIGURE 5
Two illuminated phosphor spots are distinguishable when their separation is greater than the diameter at which a spot intensity has fallen to 60 percent of maximum.

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- Spot size also depends on intensity.
- As more electrons are accelerated toward the phosphor per second, the diameters of the CRT beam 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 systems.

Refresh Cathode-Ray Tubes

- 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, on the other hand, 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 also depends on the capabilities of the system to which it is attached.

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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.
- Each row is referred to as a **scan line**.
- As the electron beam moves across a scan line, the beam intensity is turned on and off (or set to some intermediate value) to create a pattern of illuminated spots.
- Picture definition is stored in a memory area called the **refresh buffer** or **frame buffer**, where the term **frame** refers to the total screen area.

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Raster-Scan Displays

- This memory area holds the set of color values for the screen points.
- These stored color values are then retrieved from the refresh buffer and used to control the intensity of the electron beam as it moves from spot to spot across the screen.
- In this way, the picture is "painted" on the screen one scan line at a time, as demonstrated in Figure 6.
- Each screen spot that can be illuminated by the electron beam is referred to as a **pixel** or **pel** (shortened forms of picture element).

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Raster-Scan Displays

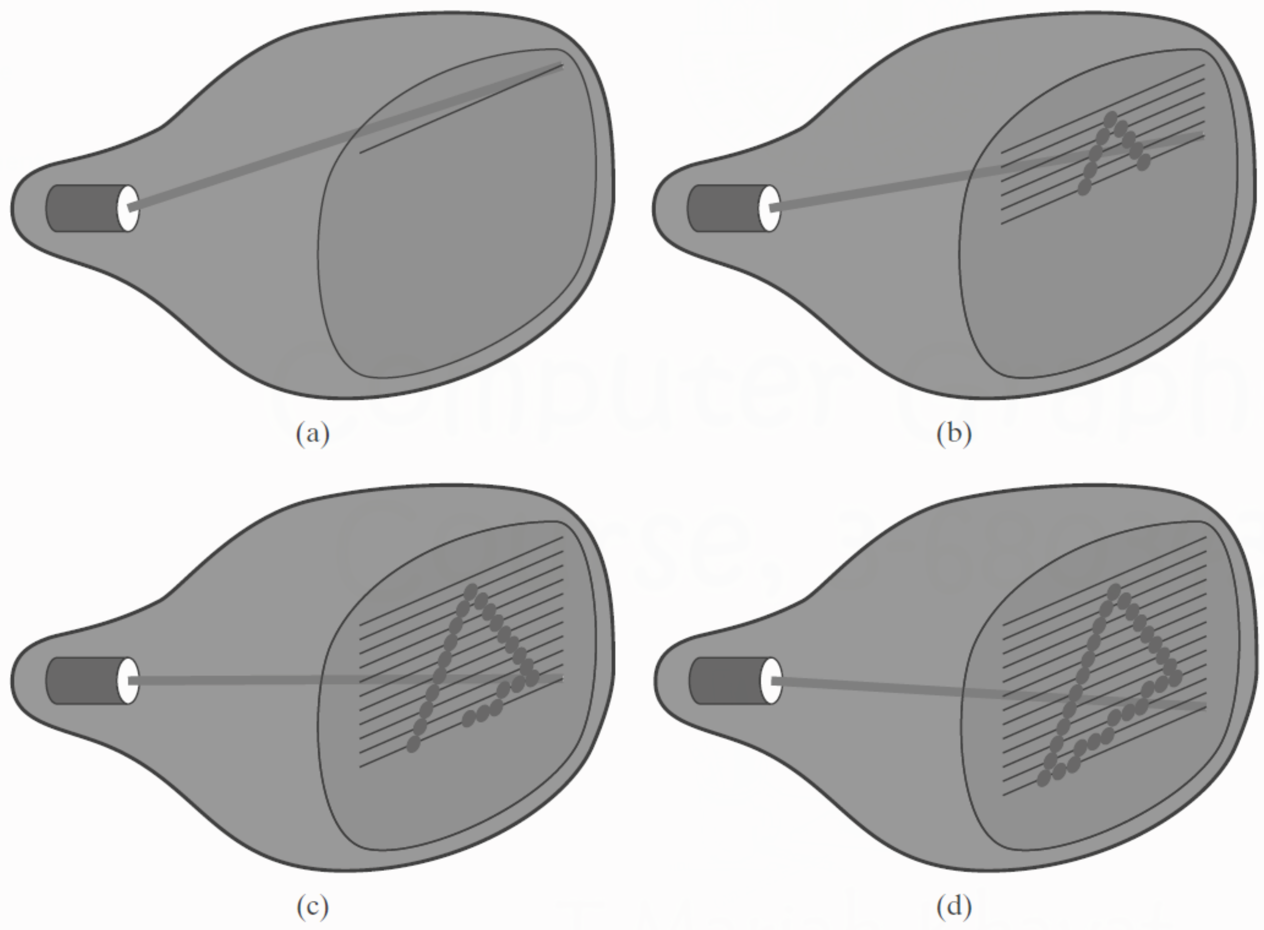

FIGURE 6
A raster-scan system displays an object as a set of discrete points across each scan line.

Raster-Scan Displays

- Since the refresh buffer is used to store the set of screen color values, it is also sometimes called a **color buffer**.
- Also, other kinds of pixel information, besides color, are stored in buffer locations, so all the different buffer areas are sometimes referred to collectively as the "frame buffer."
- The capability of a raster-scan system to store color 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.

Raster-Scan Displays

- Raster systems are commonly characterized by their resolution, which is the number of pixel positions that can be plotted.
- Another property of video monitors is **aspect ratio**, which is now often defined as the number of pixel columns divided by the number of scan lines that can be displayed by the system. *(Sometimes this term is used to refer to the number of scan lines divided by the number of pixel columns.)*
- Aspect ratio can also be described as the number of horizontal points to vertical points (or vice versa) necessary to produce equal-length lines in both directions on the screen.
- Thus, an aspect ratio of 4/3, for example, means that a horizontal line plotted with four points has the same length as a vertical line plotted with three points, where line length is measured in some physical units such as centimeters.
- Similarly, the aspect ratio of any rectangle (including the total screen area) can be defined to be the width of the rectangle divided by its height.

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Raster-Scan Displays

- The range of colors or shades of gray that can be displayed on a raster system depends on both the types of phosphor used in the CRT and the number of bits per pixel available in the frame buffer.
- For 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.
- A bit value of 1, for example, indicates that the electron beam is to be turned on at that position, and a value of 0 turns the beam off.
- Additional bits allow the intensity of the electron beam to be varied over a range of values between “on” and “off.”
- 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.
- For example, a system with 24 bits per pixel and a screen resolution of 1024 by 1024 requires 3 MB of storage for the refresh buffer.

Raster-Scan Displays

- The number of bits per pixel in a frame buffer is sometimes referred to as either the **depth** of the buffer area or the number of **bit planes**.
- A frame buffer with one bit per pixel is commonly called a **bitmap**, and a frame buffer with multiple bits per pixel is a **pixmap.**
- These terms are also used to describe other rectangular arrays, where a bitmap is any pattern of binary values and a pixmap is a multicolor pattern.

Raster-Scan Displays

- As each screen refresh takes place, we tend to see each frame as a smooth continuation of the patterns in the previous frame, so long as the refresh rate is not too low.
- Below about 24 frames per second, we can usually perceive a gap between successive screen images, and the picture appears to flicker.
- Old silent films, for example, show this effect because they were photographed at a rate of16 frames per second.
- When sound systems were developed in the 1920s, motion picture film rates increased to 24 frames per second, which removed flickering and the accompanying jerky movements of the actors.
- Early raster-scan computer systems were designed with a refresh rate of about 30 frames per second.
- This produces reasonably good results, but picture quality is improved, up to a point, with higher refresh rates on a video monitor because the display technology on the monitor is basically different from that of film.
- A film projector can maintain the continuous display of a film frame until the next frame is brought into view.

Raster-Scan Displays

- On a video monitor, a phosphor spot begins to decay as soon as it is illuminated.
- Therefore, current raster-scan displays perform refreshing at the rate of 60 to 80 frames per second, although some systems now have refresh rates of up to 120 frames per second.
- And some graphics systems have been designed with a variable refresh rate.
- For example, a higher refresh rate could be selected for a stereoscopic application so that two views of a scene (one from each eye position) can be alternately displayed without flicker.
- But other methods, such as multiple frame buffers, are typically used for such applications.

Raster-Scan Displays

- 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.
- 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 $\frac{1}{80}$ to $\frac{1}{60}$ of a second), the electron beam returns to the upper-left corner of the screen (**vertical retrace**) to begin the next frame.

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Raster-Scan Displays

- On some raster-scan systems and 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.
- After the vertical retrace, the beam then sweeps out the remaining scan lines (Fig. 7).
- Interlacing of the scan lines in this way allows us to see the entire screen displayed in half the time that it would have taken to sweep across all the lines at once from top to bottom.
- This technique is primarily used with slower refresh rates.
- On an older, 30 frame per-second, non-interlaced display, for instance, some flicker is noticeable.
- But with interlacing, each of the two passes can be accomplished in $\frac{1}{60}$ of a second, which brings the refresh rate nearer to 60 frames per second.
- This is an effective technique for avoiding flicker—provided that adjacent scan lines contain similar display information.

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Raster-Scan Displays

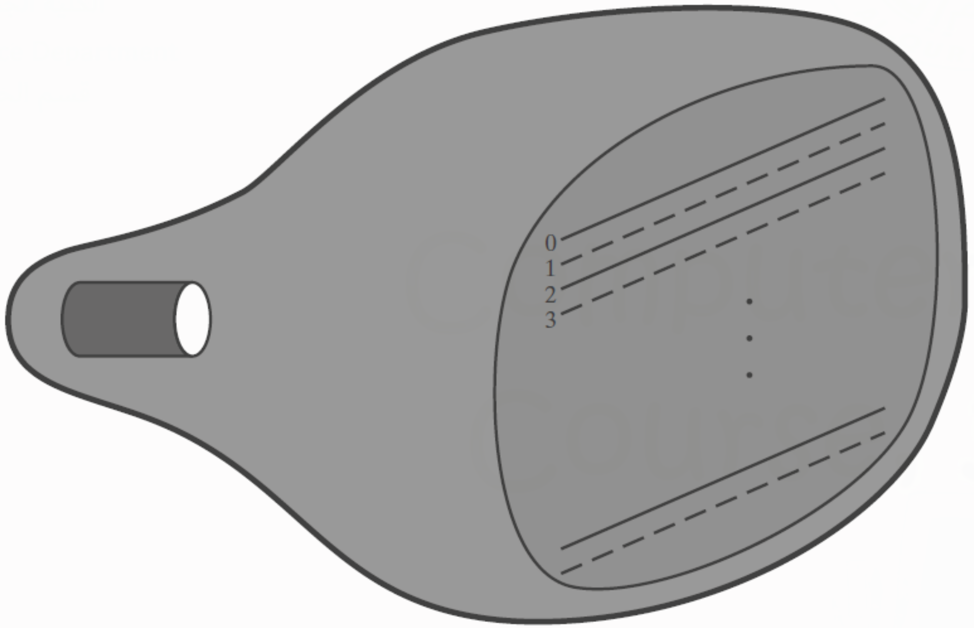

FIGURE 7
Interlacing scan lines on a raster-scan display. First, all points on the even-numbered (solid) scan lines are displayed; then all points along the odd-numbered (dashed) lines are displayed.

Random-Scan Displays

- When operated as a **random-scan display** unit, a CRT has the electron beam directed only to those parts of the screen where a picture is to be displayed.
- Pictures are generated as line drawings, with the electron beam tracing out the component lines one after the other.
- For this reason, random-scan monitors are also referred to as **vector displays** (or **stroke-writing displays** or **calligraphic displays**).
- The component lines of a picture can be drawn and refreshed by a random-scan system in any specified order (Fig. 8).
- A pen plotter operates in a similar way and is an example of a random-scan, hard-copy device.

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Random-Scan Displays

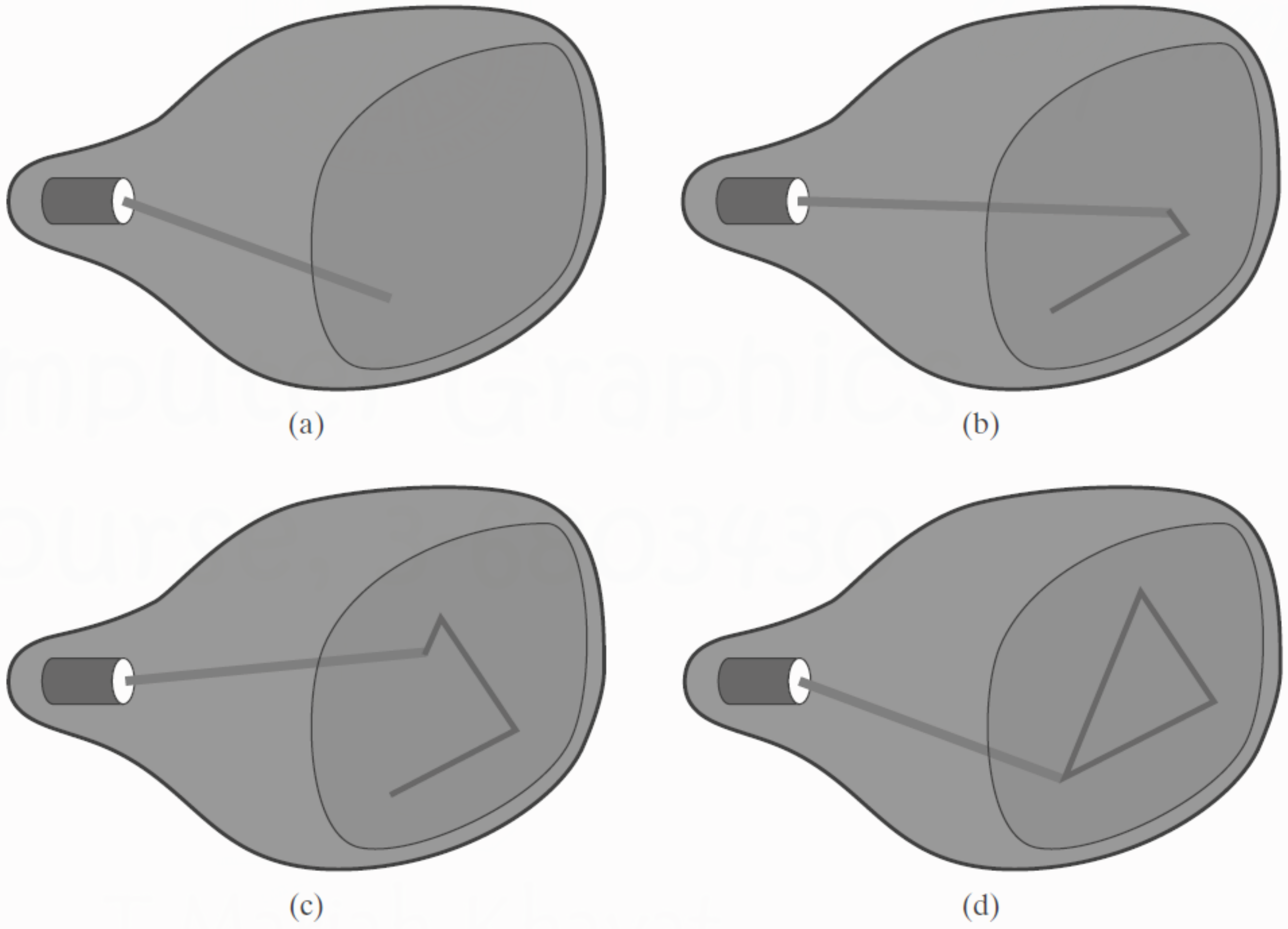

FIGURE 8
A random-scan system draws the component lines of an object in any specified order.

Random-Scan Displays

- Refresh rate on a random-scan system depends on the number of lines to be displayed on that system.
- Picture definition is now stored as a set of line-drawing commands in an area of memory referred to as the **display list**, **refresh display file**, **vector file**, or **display program**.
- 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 cycles 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, with up to 100,000 "short" lines in the display list.
- When a small set of lines is to be displayed, each refresh cycle is delayed to avoid very high refresh rates, which could burn out the phosphor.

Random-Scan Displays

- Random-scan systems were designed for line-drawing applications, such as architectural and engineering layouts, and they cannot display realistic shaded scenes.
- Since picture definition is stored as a set of line-drawing instructions rather than as a set of intensity values for all screen points, vector displays generally have higher resolutions than raster systems.
- Also, vector displays produce smooth line drawings because the CRT beam directly follows the line path.
- A raster system, by contrast, produces jagged lines that are plotted as discrete point sets.
- However, the greater flexibility and improved line-drawing capabilities of raster systems have resulted in the abandonment of vector technology.

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color CRT Monitors

- A CRT monitor displays color pictures by using a combination of phosphors that emit different-colored light.
- The emitted light from the different phosphors merges to form a single perceived color, which depends on the particular set of phosphors that have been excited.
- One way to display color pictures is to coat the screen with layers of different colored phosphors.
- The emitted color depends on how far the electron beam penetrates into the phosphor layers.
- This approach, called the **beam-penetration** method, typically used only two phosphor layers: red and green.

Color CRT Monitors

- A beam of slow electrons excites only the outer red layer, but a beam of very fast electrons penetrates 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, but only a limited number of colors are possible, and picture quality is not as good as with other methods.

Color CRT Monitors

- **Shadow-mask** methods are commonly used in raster-scan systems (including color TV) because they produce a much wider range of colors than the beam penetration method.
- This approach is based on the way that we seem to perceive colors as combinations of red, green, and blue components, called the **RGB color model.**
- Thus, a shadow-mask CRT uses 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 shadow-mask grid just behind the phosphor-coated screen.

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- The light emitted from the three phosphors results in a small spot of color at each pixel position, since our eyes tend to merge the light emitted from the three dots into one composite color.
- Figure 9 illustrates the *delta-delta* shadow-mask method, commonly used in color CRT systems.
- The three electron 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.

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color CRT Monitors

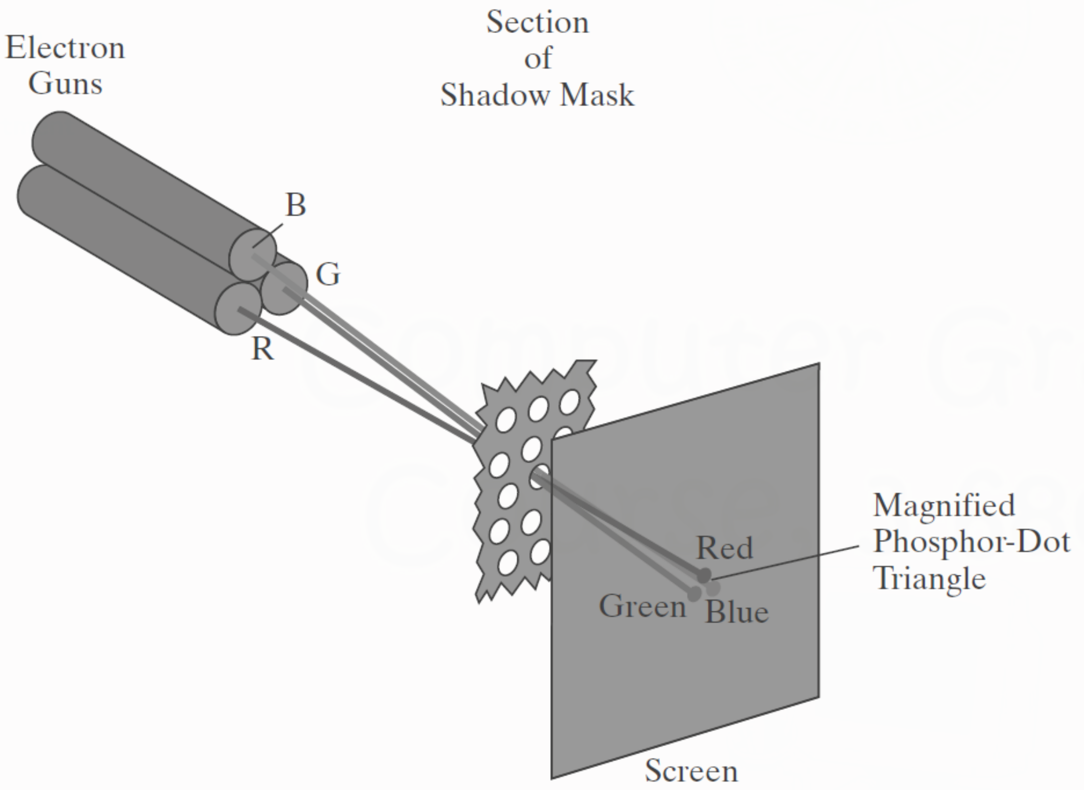

FIGURE 9
Operation of a delta-delta, shadow-mask CRT. Three electron guns, aligned with the triangular color-dot patterns on the screen, are directed to each dot triangle by a shadow mask.

Color CRT Monitors

- Another configuration for the three electron guns is an in-line arrangement in which the three electron guns, and the corresponding RGB 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.

Color CRT Monitors

- We obtain color variations in a shadow-mask CRT by varying the intensity levels of the three electron beams.
- By turning off two of the three guns, we get only the color coming from the single activated phosphor (red, green, or blue).
- When all three dots are activated with equal beam intensities, we see a white color.
- Yellow is produced with equal intensities from the green and red dots only, magenta is produced with equal blue and red intensities, and cyan shows up when blue and green are activated equally.
- In an inexpensive system, each of the three electron beams might be restricted to either on or off, limiting displays to eight colors.
- More sophisticated systems can allow intermediate intensity levels to be set for the electron beams, so that several million colors are possible.

Color CRT Monitors

- Color graphics systems can be used with several types of CRT display devices.
- Some inexpensive home-computer systems and video games have been designed for use with a color TV set and a radio-frequency (RF) modulator.
- The purpose of the RF modulator is to simulate the signal from a broadcast 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 requires 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 decreases the quality of displayed images.

Color CRT Monitors

- **Composite monitors** are adaptations of TV sets that allow bypass of the broadcast circuitry.
- These display devices still require that the picture information be combined, but no carrier signal is needed.
- Since picture information is combined into a composite signal and then separated by the monitor, the resulting picture quality is still not the best attainable.
- Color CRTs in graphics systems are designed as **RGB monitors.** These monitors use shadow-mask methods and take the intensity level for each electron gun (red, green, and blue) directly from the computer system without any intermediate processing.
- High-quality raster-graphics systems have 24 bits per pixel in the frame buffer, allowing 256 voltage settings for each electron gun and nearly 17 million color choices for each pixel.
- An RGB color system with 24 bits of storage per pixel is generally referred to as a **full-color system** or a **true-color system.**

Flat-Panel Displays

- Although most graphics monitors are still constructed with CRTs, other technologies are emerging that may soon replace CRT monitors.
- The term **flat-panel display** refers to a class of video devices that have reduced volume, weight, and power requirements compared to a CRT.
- A significant feature of flat-panel displays is that they are thinner than CRTs, and we can hang them on walls or wear them on our wrists.
- Since we can even write on some flat-panel displays, they are also available as pocket notepads.
- Some additional uses for flat-panel displays are as small TV monitors, calculator screens, pocket video-game screens, laptop computer screens, armrest movie-viewing stations on airlines, advertisement boards in elevators, and graphics displays in applications requiring rugged, portable monitors.

Flat-Panel Displays

- We can separate flat-panel displays into two categories: **emissive displays** and **nonemissive displays.**
- The emissive displays (or **emitters**) are devices that convert electrical energy into light.
- Plasma panels, thin-film electroluminescent displays, and light-emitting diodes are examples of emissive displays.
- Flat CRTs have also been devised, in which electron beams are accelerated parallel to the screen and then deflected 90^0onto the screen.
- But flat CRTs have not proved to be as successful as other emissive devices.
- Nonemissive displays (or **nonemitters**) use optical effects to convert sunlight or light from some other source into graphics patterns. The most important example of a nonemissive flat-panel display is a liquid-crystal device.

Flat-Panel Displays

- Plasma panels, also called gas-discharge displays, are constructed by filling the region between two glass plates with a mixture of gases that usually includes neon.
- A series of vertical conducting ribbons is placed on one glass panel, and a set of horizontal conducting ribbons is built into the other glass panel (Fig. 10).
- Firing voltages applied to an intersecting pair of horizontal and vertical conductors cause the gas at the intersection of the two conductors to break down into a glowing plasma of electrons and ions.
- Picture definition is stored in a refresh buffer, and the firing voltages are applied to refresh the pixel positions (at the intersections of the conductors) 60 times per second.
- Alternating-current methods are used to provide faster application of the firing voltages and, thus, brighter displays.
- Separation between pixels is provided by the electric field of the conductors.
- One disadvantage of plasma panels has been that they were strictly monochromatic devices, but systems are now available with multicolor capabilities.

Flat-Panel Displays

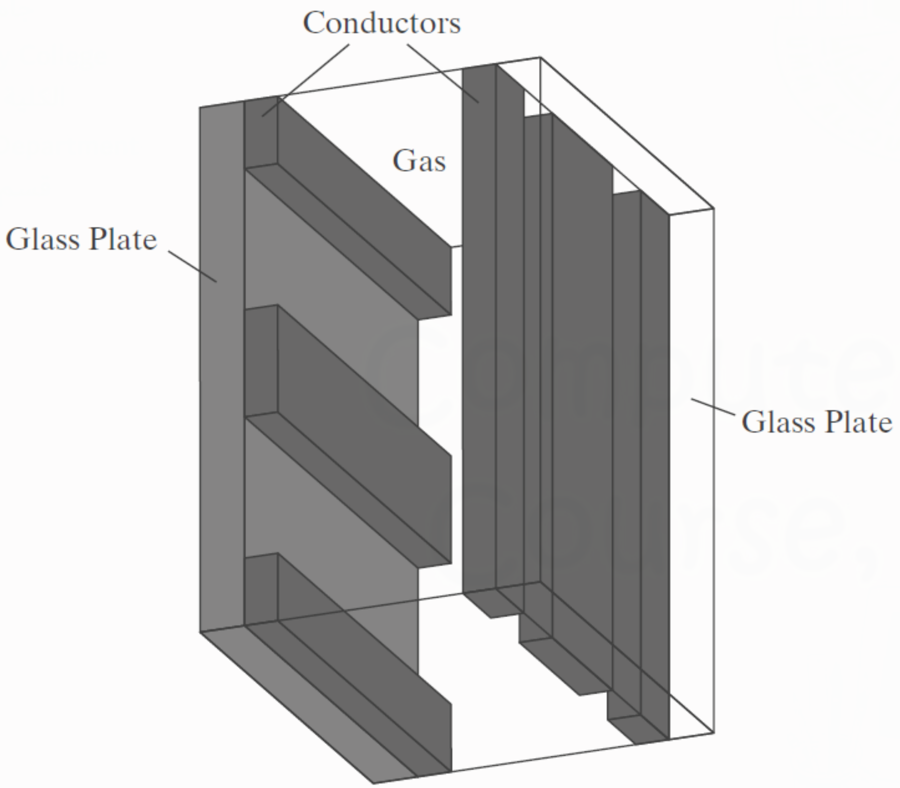

FIGURE 10
Basic design of a plasma-panel display device.

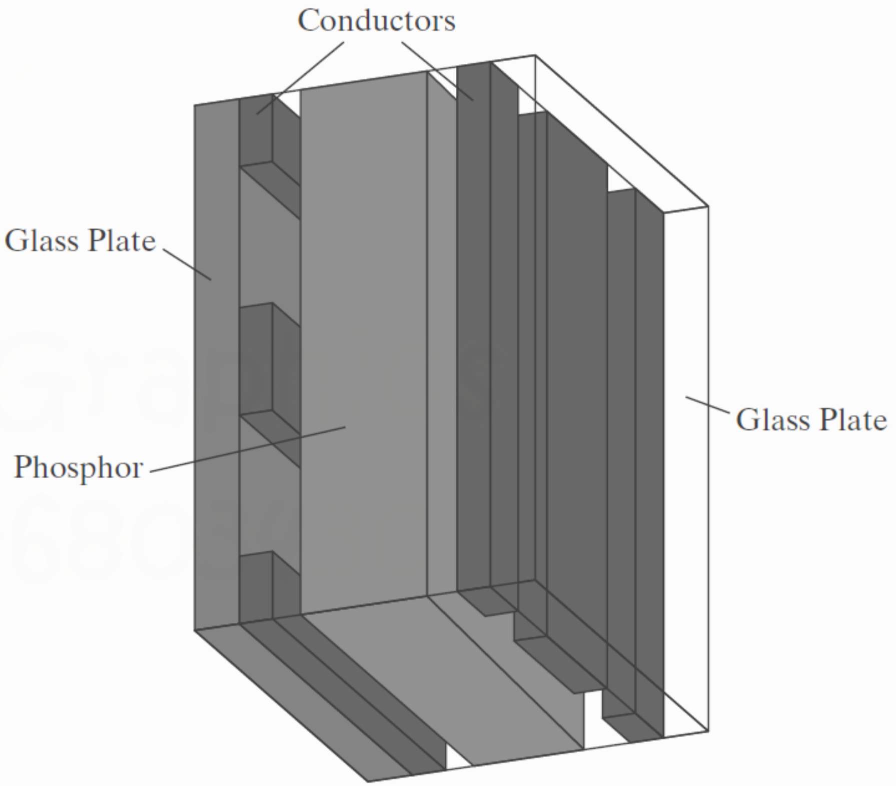

FIGURE 11
Basic design of a thin-film electroluminescent display device.

Flat-Panel Displays

- **Thin-film electroluminescent displays** are similar in construction to plasma panels. The difference is that the region between the glass plates is filled with a phosphor, such as zinc sulfide doped with manganese, instead of a gas (Fig. 11).
- When a sufficiently high voltage is applied to a pair of crossing electrodes, the phosphor becomes a conductor in the area of the intersection of the two electrodes.
- Electrical energy is absorbed by the manganese atoms, which then release the energy as a spot of light similar to the glowing plasma effect in a plasma panel.
- Electroluminescent displays require more power than plasma panels, and good color displays are harder to achieve.

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Flat-Panel Displays

- A third type of emissive device is the **light-emitting diode** (**LED**).
- A matrix of diodes is arranged to form the pixel positions in the display, and picture definition is stored in a refresh buffer.
- As in scan-line refreshing of a CRT, information is read from the refresh buffer and converted to voltage levels that are applied to the diodes to produce the light patterns in the display.

- **Liquid-crystal displays** (**LCD**s) are commonly used in small systems, such as laptop computers and calculators (Fig. 12).

- These nonemissive devices produce a picture by passing polarized light from the surroundings or from an internal light source through a liquid-crystal material that can be aligned to either block or transmit the light.

Flat-Panel Displays

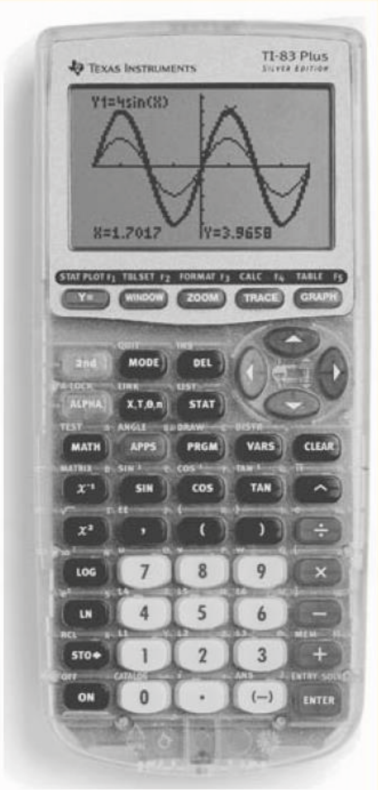

FIGURE 12
A handheld calculator with an LCD screen. (*Courtesy of Texas Instruments.*)

Flat-Panel Displays

- The term *liquid crystal* refers to the fact that these compounds have a crystalline arrangement of molecules, yet they flow like a liquid.
- Flat-panel displays commonly use nematic (threadlike) liquid-crystal compounds that tend to keep the long axes of the rod-shaped molecules aligned.
- A flat-panel display can then be constructed with a nematic liquid crystal, as demonstrated in Figure 13.
- Two glass plates, each containing a light polarizer that is aligned at a right angle to the other plate, sandwich the liquid-crystal material.
- Rows of horizontal, transparent conductors are built into one glass plate, and columns of vertical conductors are put into the other plate.
- The intersection of two conductors defines a pixel position.

Flat-Panel Displays

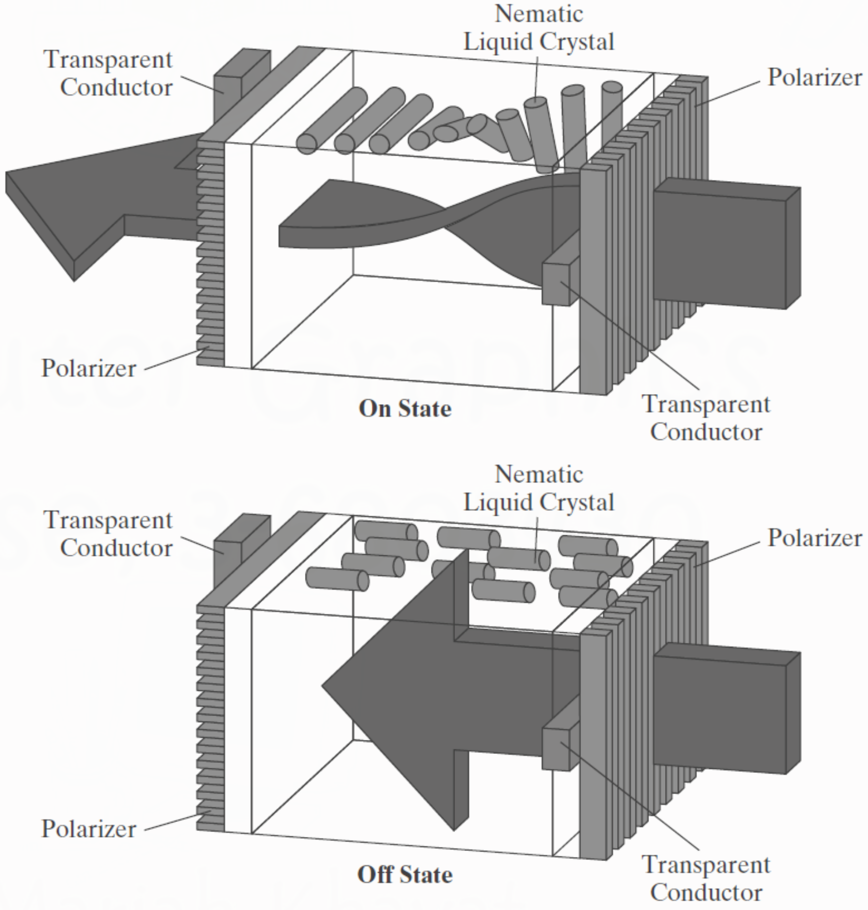

FIGURE 13
The light-twisting, shutter effect used in the design of most LCD devices.

Flat-Panel Displays

- Normally, the molecules are aligned as shown in the “on state” of Figure 13.
- Polarized light passing through the material is twisted so that it will pass through the opposite polarizer.
- The light is then reflected back to the viewer.
- To turn off the pixel, we apply a voltage to the two intersecting conductors to align the molecules so that the light is not twisted.
- This type of flat-panel device is referred to as a **passive-matrix** LCD.
- Picture definitions are stored in a refresh buffer, and the screen is refreshed at the rate of 60 frames per second, as in the emissive devices.

Flat-Panel Displays

- Backlighting is also commonly applied using solid-state electronic devices, so that the system is not completely dependent on outside light sources.
- Colors can be displayed by using different materials or dyes and by placing a triad of color pixels at each screen location.

- Another method for constructing LCDs is to place a transistor at each pixel location, using thin-film transistor technology.
- The transistors are used to control the voltage at pixel locations and to prevent charge from gradually leaking out of the liquid-crystal cells.
- These devices are called **active-matrix** displays.

Three-Dimensional Viewing Devices

- Graphics monitors for the display of three-dimensional scenes have been devised using a technique that reflects a CRT image from a vibrating, flexible mirror (Fig. 14).
- As the varifocal mirror vibrates, it changes focal length.
- These vibrations are synchronized with the display of an object on a CRT so that each point on the object is reflected from the mirror into a spatial position corresponding to the distance of that point from a specified viewing location.
- This allows us to walk around an object or scene and view it from different sides.

Three-Dimensional Viewing Devices

- In addition to displaying three-dimensional images, these systems are often capable of displaying two-dimensional cross-sectional “slices” of objects selected at different depths, such as in medical applications to analyze data from ultrasonography and CAT scan devices, in geological applications to analyze topological and seismic data, in design applications involving solid objects, and in three-dimensional simulations of systems, such as molecules and terrain.

Three-Dimensional Viewing Devices

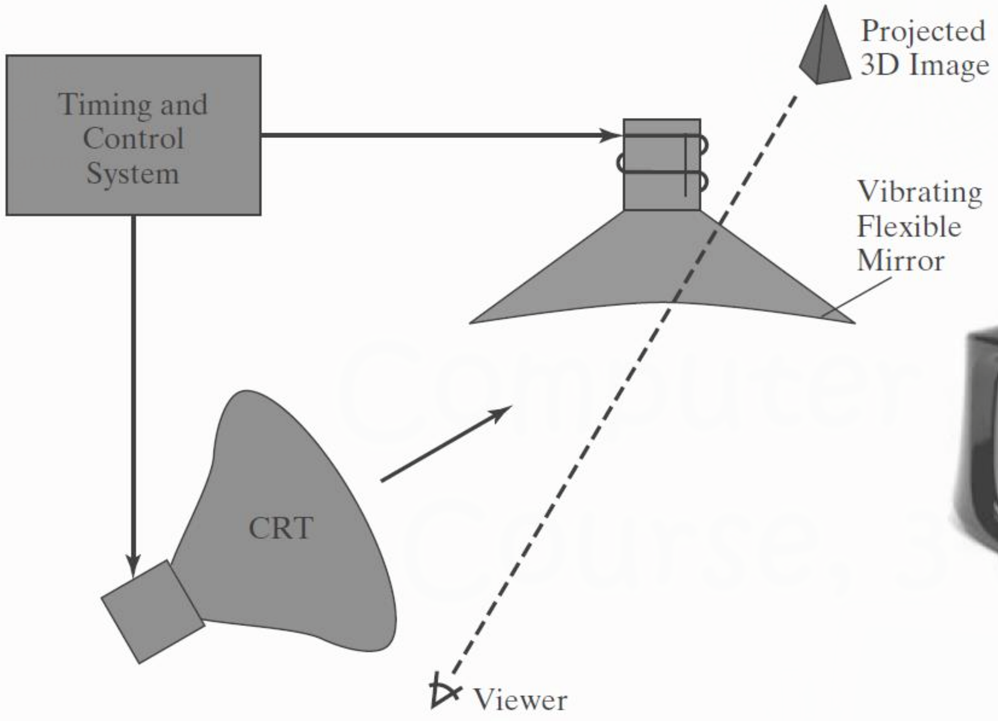

FIGURE 14
Operation of a three-dimensional display system using a vibrating mirror that changes focal length to match the depths of points in a scene.

FIGURE 15
Glasses for viewing a stereoscopic scene in 3D. (*Courtesy of XPAND, X6D USA Inc.*)

Stereoscopic and Virtual-Reality Systems

- Another technique for representing a three-dimensional object is to display stereoscopic views of the object.
- This method does not produce true three dimensional images, but it does provide a three-dimensional effect by presenting a different view to each eye of an observer so that scenes do appear to have depth.

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المملكة العربية السعودية
Ministry of Education
وزارة التعليم
Umm AlQura University
جامعة أم القرى
Adham University College
Computer Science Department
Computer Graphics Course, 3-6803430
T.Mariah Khayat

Stereoscopic and Virtual-Reality Systems

- To obtain a stereoscopic projection, we must obtain two views of a scene generated with viewing directions along the lines from the position of each eye (left and right) to the scene.
- We can construct the two views as computer-generated scenes with different viewing positions, or we can use a stereo camera pair to photograph an object or scene.
- When we simultaneously look at the left view with the left eye and the right view with the right eye, the two views merge into a single image and we perceive a scene with depth.

Stereoscopic and Virtual-Reality Systems

- One way to produce a stereoscopic effect on a raster system is to display each of the two views on alternate refresh cycles.

- The screen is viewed through glasses, with each lens designed to act as a rapidly alternating shutter that is synchronized to block out one of the views.

- One such design (Figure 15) uses liquid-crystal shutters and an infrared emitter that synchronizes the glasses with the views on the screen.

Stereoscopic and Virtual-Reality Systems

- Stereoscopic viewing is also a component in **virtual-reality** systems, where users can step into a scene and interact with the environment.
- A headset containing an optical system to generate the stereoscopic views can be used in conjunction with interactive input devices to locate and manipulate objects in the scene.
- A sensing system in the headset keeps track of the viewer's position, so that the front and back of objects can be seen as the viewer "walks through" and interacts with the display.

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Ministry of Education
وزارة التعليم
Umm AlQura University
جامعة أم القرى
Adham University College
CS Department
Computer Graphics Course, 3-6803430
T.Mariah Khayat

Stereoscopic and Virtual-Reality Systems

- Another method for creating a virtual-reality environment is to use projectors to generate a scene within an arrangement of walls, where a viewer interacts with a virtual display using stereoscopic glasses and data gloves.

- Lower-cost, interactive virtual-reality environments can be set up using a graphics monitor, stereoscopic glasses, and a head-tracking device.
- The tracking device is placed above the video monitor and is used to record head movements, so that the viewing position for a scene can be changed as head position changes.

2. Raster-Scan Systems

- Interactive raster-graphics systems typically employ several processing units.
- In addition to the central processing unit (CPU), a special-purpose processor, called the **video controller** or **display controller**, is used to control the operation of the display device.

- 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.

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Umm AlQura University
جامعة أم القرى
CS Department
Computer Graphics
T.Mariah Khayat

2. Raster-Scan Systems

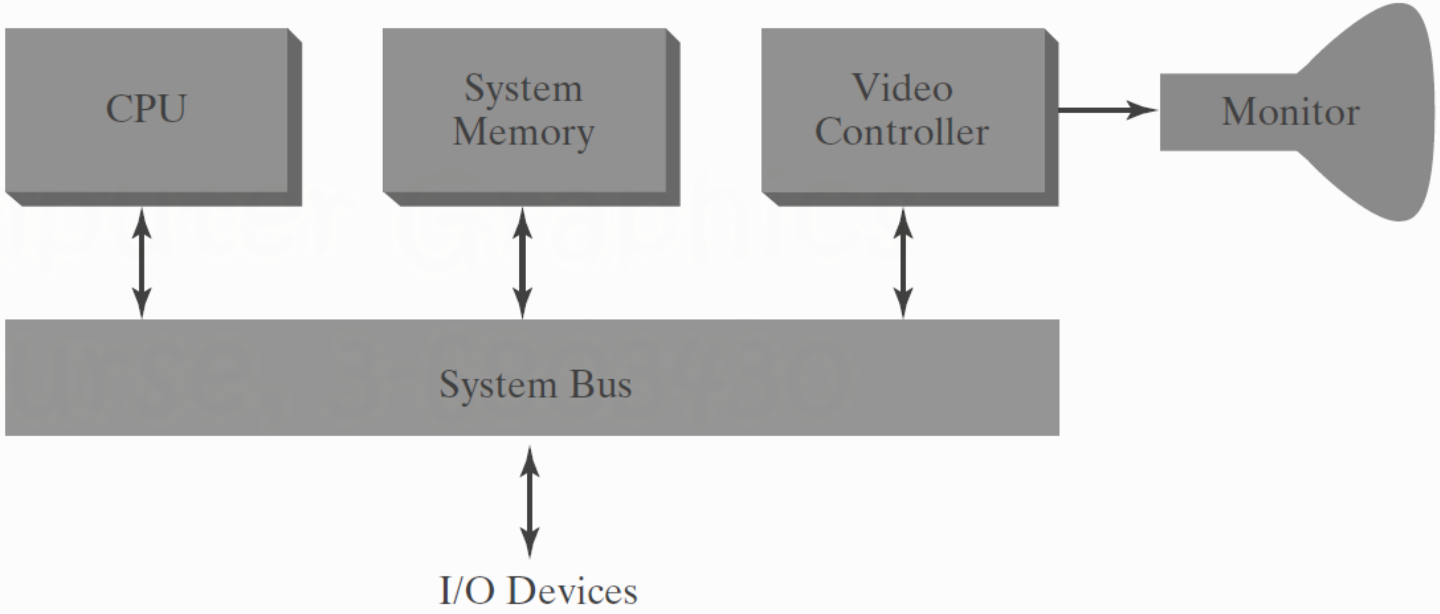

FIGURE 16
Architecture of a simple raster-graphics system.

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Video controller

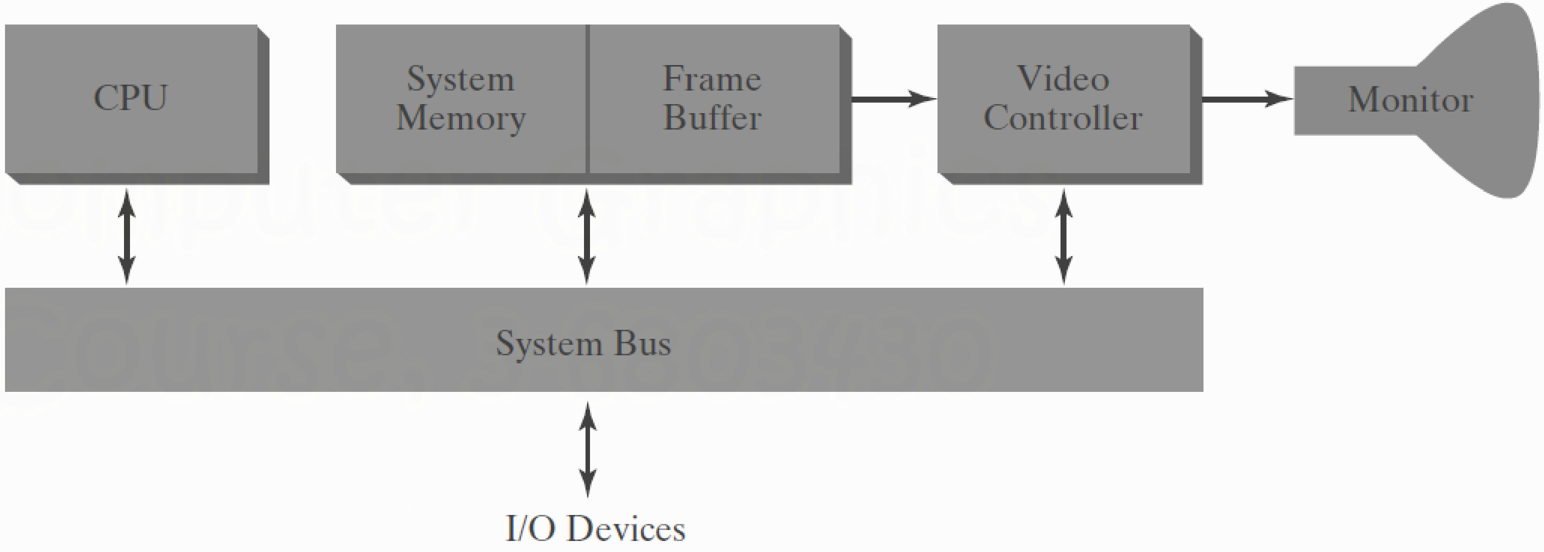

FIGURE 17
Architecture of a raster system with a fixed portion of the system memory reserved for the frame buffer.

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Video controller

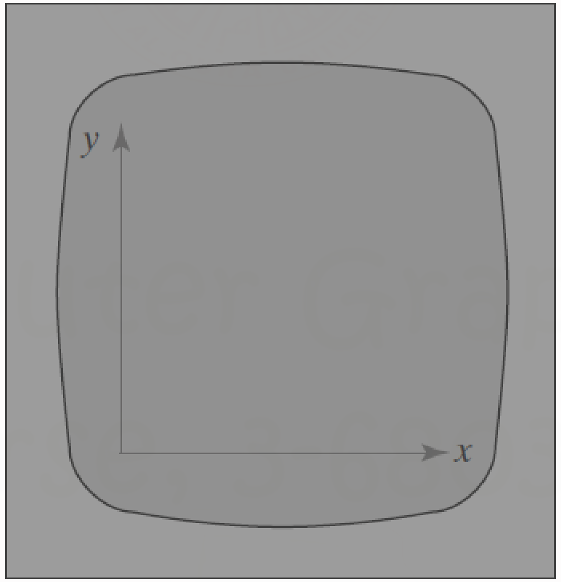

FIGURE 18
A Cartesian reference frame with origin at the lower-left corner of a video monitor.

Video controller

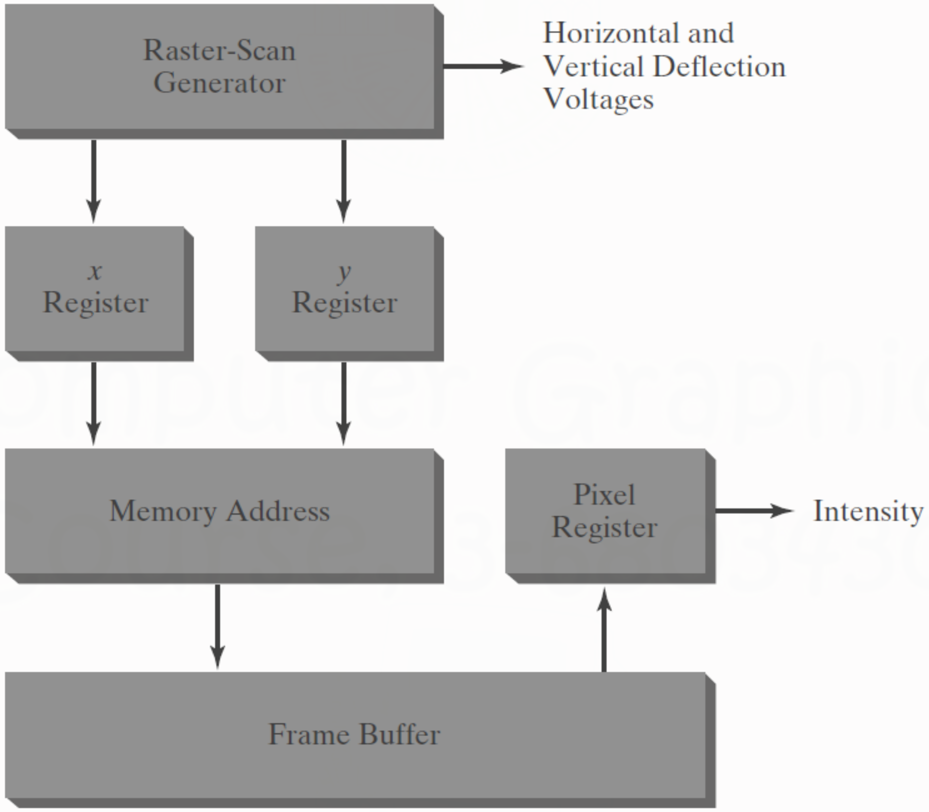

FIGURE 19
Basic video-controller refresh operations.

Raster-Scan Display Processor

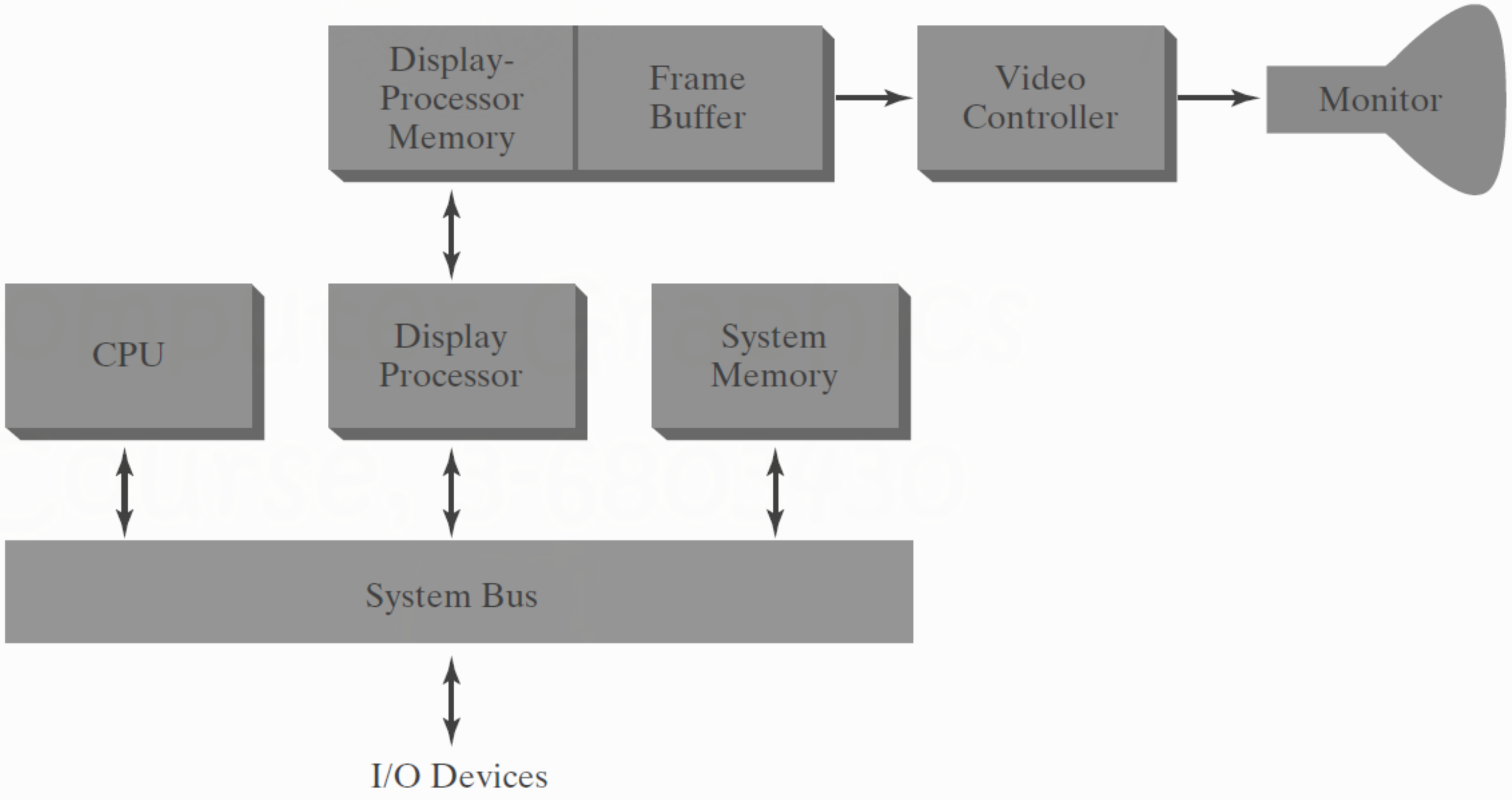

FIGURE 20
Architecture of a raster-graphics system with a display processor.

Raster-Scan Display Processor

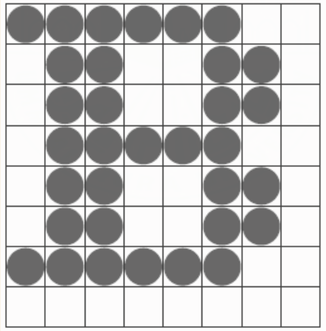

FIGURE 21
A character defined as a rectangular grid of pixel positions.

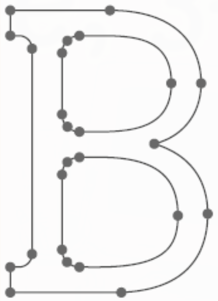

FIGURE 22
A character defined as an outline shape.

وصلّى الله وبارك على نبيّنا محمد

The End Summary of Chapter One
-Part One-

T.Mariah Khayat
الأستاذة/ مارية خياط
Adham University College
الكلية الجامعية بأضم

mskhayat@uqu.edu.sa