

Chapter 4: The Machine

I. THE COMPONENTS OF A COMPUTER GRAPHICS SYSTEM

The components of computer graphics system are related to the scope of the graphics projects involved. It seems logical that an artist may need different tools from a musician. Although they all use the computer, each one may be using the computer in different ways and produce different products. As in the material world, designers use their own set of tools, in their own way, to produce their work. With computers, designers can use different computer components in many different ways to produce their work.

The computer industry has developed numerous different computer components each one designed to do a specific task. Each of these components can be connected to one another in a modular way to produce specialized systems. Although the main diagram of any computer graphics system is based on the three-module scheme shown below, there are many alterations when we focus on each of these module.

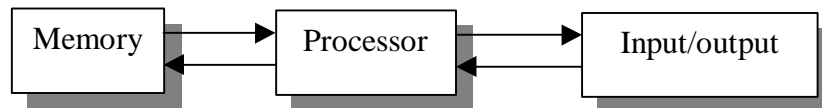


Figure 1. The basic scheme of a computer architecture

Memory modules and storage devices can vary depending on the type of computer activity. Processors can be combined with other processors or graphics cards to increase speed and performance. Input/output devices can vary tremendously according to the

nature of the graphics work. The following scheme shows the computer components of a simple multimedia system:

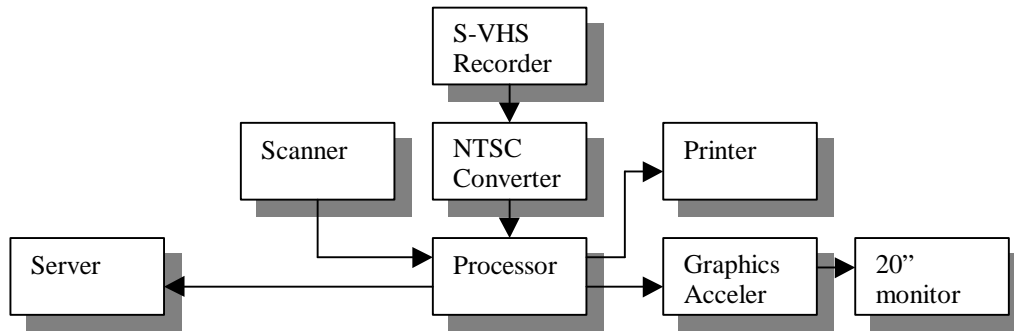


Figure 2. A multimedia hardware scheme

In the following sections, we will show most of the different components of a computer graphics system, the function that each one perform, and their relationship to one another and to the software they support.

II. ENVIRONMENTS AND SOFTWARE

In the same way that computer hardware components can be composed into interrelated schemes for a specific type of graphic design, computer software can also be used as interrelated schemes, each one contributing to the end product. Different programs do different things or do the same thing in different ways. The graphic designer should be able to make the best out of many different programs. Unfortunately, there is not one program that does everything. Even worst, sometimes one needs different software running on different hardware to complete the work. The selection of software can be harder than the selection of computer hardware.

Software can be hardware specific, that is, some software may run only on specific machines. This makes the selection of software a function of hardware and vice-versa. A lot of hardware companies constraint the software developers to make their software only for their machines, and reversibly, many software companies agree to develop software only for specific hardware in order to sell more of those machines. A good example is AutoDesk, the developer of AutoCAD. For many years, AutoCAD was designed to run only on PCs and not on Macintoshes. This became one of the main reasons that most CAD offices were pushed to purchase PCs over Macs.

Another issue of software is that of copyright. Unlike hardware components where systems have to be purchased, many computer users choose to copy programs for free. *Software piracy* is illegal in almost all countries of the world and is punished with severe penalties. Many computer programs have security devices, such as hardware locks or security codes to prevent copying. Although software seems to have no material value attached to it, software companies do spend a lot of money to produce their products and many people work hard to come up with ideas. Software products should not be any different from hardware products in terms of value and appreciation.

III. TOOLS AND PURPOSES

Any creative artist uses tools to produce works of art. With computers, the process is the same except the tools are simulated as icons on the computer screen. Various input/output devices allow the artist to control the devices that produce his or her work.

In general, the process of creating any kind of work with a computer, including graphics work, is the following: information about the project is entered in the computer using various input devices, such as scanners, digitizers, cameras, microphones, etc. That or new information is processed through computer programs that simulate the process using virtual tools and materials. When done, the user outputs the simulated end product using the appropriate output devices, such as printers, plotters, video output, speakers, etc. This

general process, which applies to any computer user either draftsman or musician is shown below. The difference for each user is in the application programs and input/output devices.

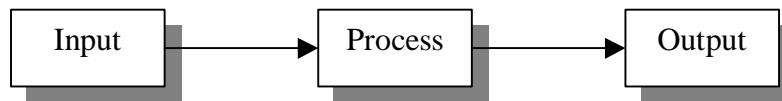


Figure 3. A simple action scheme

The difference between traditional manual tools and virtual tools is in the ease, accuracy, clarity, ability to reverse, and speed of development. Virtual tools are simulations of actual tools designed to behave in the same way manual tools do. Of course, many argue that they are not quite the same as manual, since there is no feeling, touch, smell, resistance, etc. material qualities that are lacking from virtual tools. On the other hand, virtual tools can do things that material tools cannot. Since they are related to computer devices, which are using mathematical and logical operations, virtual tools can perform operations that often cannot be predicted. Morphing, video composite, 3D visualization are processes that use tools that are not available in the material world because they are based on mathematical imagination.

In practice, many computer tools and devices exist each one doing something very well but not everything. Although it seems reasonable that there should be one painting program that would simulate all the processes of painting, in reality there are many each one doing different things in different ways. The task of the artist is to find out what tools exist, how well they perform, how expensive they are, and then make a strategic plan of using only those that would best fit the project and budget.

In the following chapters, we will show how different programs can be used through different machines in different ways to produce different graphic work. Not one method

exists, so we will emphasize on the principles of each program and the ways that each program communicates with one another. Independent of the devices, applications, or versions of software, there are general rules and principles that all programs use.

IV. COMPUTER HARDWARE

The term computer *hardware* refers to the material parts of a computer. Computer chips, cards, wires, components, are all hardware. In contrast, the set of mechanisms that use the computer hardware to perform calculations or logical operations is called *software*. Following the general three-component scheme (memory-processor-I/O devices) we will show some of the computer hardware used in graphic related work in the late 1990s.

Computer hardware changes fast. The average life of a computer component until a new version is released in the United States is about six months. The same applies to software. The reason for this is quite complex and it is related to research and development, stock quantities, and market trends. Each hardware version compared to its previous release is faster, more efficient, and more capable.

In the graphic arts, many specialized hardware devices exist. Computer graphics is a relatively recent area for computer implementation. Any graphic processing requires specialized and often very expensive equipment. However, the nature of graphically displayed information is much more well understood and remembered by common users and many hardware and software companies incorporate more and more graphics-related hardware and software. Almost all computers are equipped with CD-ROMs, color screens, speakers, and icon-based operating systems. This was not true a few years ago.

Mechanisms

Hardware devices are based on two basic concepts: the concept of *digital* and concept of *sampling*. All computational and logical processes are based on the binary arithmetic and logic, which is implemented within the computer's hardware as on-off switches. Memory is just binary patterns and a processor is a device that can perform binary operations. On the other hand, input devices are basically *converters* that take samples of information from the outside world and digitize it. Reversibly, output devices are devices that convert binary information into material samples. The concept of sampling exists because the world has infinite information but the computer has a limitation. Therefore one can select only that much information that a computer can store or handle. Input and output device manufacturers' compete on how much information their devices can handle. Processor manufacturers compete on the speed and performance of their processors.

The problem of how one represents an operation, say $1+1=2$ or (true AND true = true) in the most efficient and generalized way and the problem of where does one stop with decimal points, say 3.14158... are some of the most challenging and difficult problems of computer science. The interesting thing about computers is that once a method of handling operations is developed new information can be generated at speeds far superior than human thinking. Complex operations can be performed and new knowledge can be produced. These operations can be performed at electricity speed, that is, the speed of light. Computers are electrical devices and therefore they can handle information in any kind of format. A computer can handle radio waves, infrared rays, TV signals, X-rays at whatever sampling resolution the memory allows.

V. INPUT/OUTPUT DEVICES

1. Display

The most common device for displaying information is the *Cathode Ray Tube (CRT) monitor*, also referred to as the *computer screen*. The technology of the CRT monitor is based on stimulating light intensities on the surface of a screen. The screen is subdivided into a grid of tiny dots, called *pixels* (short for picture elements). Each pixel can be stimulated to illuminate light with percentages of red, green, or blue (RGB). In the absence of light the screen becomes black. The number of pixels per inch is called *ppi* and determines the clarity of the image displayed. The clarity can also be measured in the distance between two adjacent pixels (say 0.28 mm). The size of the screen is measured in inches along a diagonal line. A 17-inch monitor means that the screen is diagonally 17 inches long. CRT monitors cause pixels to light up by shooting electrons on a phosphor surface. To do that a monitor needs an electron gun and a void space enclosed in glass. This results in large and heavy devices.



Figure 1. A 17”, 19”, and 21” monitor

Based on the same principles, an alternative way of triggering pixels has been developed called the LCD (Liquid Crystal Display). The LCD triggers pixels to light up by

charging up crystals on the screen. The advantage is size and weight. LCD do not need a void space enclosed in glass, therefore the overall size and weight gets significantly reduced. LCDs are ideal for laptop computers or any other portable use. LCD screens (or LCD panels) are also measured in pixels per inch.

A *LCD projector* is a device that can project a computer screen. In a LCD projector, a tiny LCD panel (the size of a slide) is lit like a slide projector.



Figure 2. An LCD panel on a laptop (left) and an LCD projector (right)

2. Keyboard

A *keyboard* is a device that enters alphanumeric characters to the computer. It consists of a grid of buttons each corresponding to a symbol. Some keys change the functionality of the keyboard such as the shift, control, or alt keys. The set of alphanumeric characters of the English language that computers use is referred to as ASCII (American Standard Code for Information Interchange). In an ASCII file, each alphabetic, numeric, or special character is represented with a 7-bit binary number (a string of seven 0s or 1s). There are

128 ASCII characters. Each character corresponds to a number between 0 and 127. Each time a key is pressed, an alphanumeric symbol is sent to the computer.



Figure 3. A standard (left) and a natural keyboard (right)

3. Mouse

The *mouse* is a small hand-held box used to track the position of a screen cursor. Inside the box are a ball and two rollers perpendicular to one another. As the ball rolls on the desk surface the rollers rotate generating x and y coordinates that are used to track positions on the screen. In other words, the mouse movements are mapped to the monitor screen. Most general-purpose graphic systems include a mouse and a keyboard as input devices.



Figure 3. A one-, two-, and three-button mouse

A mouse can have one, two, or three buttons. Each buttons does specific functions. Clicking any of the buttons twice is called *double clicking*. The process of moving the mouse while pressing down one of the buttons is called *dragging*.

4. Trackball and Spaceball

A *trackball* is a reversed mouse. Instead of moving the ball by moving the mouse box, the ball is exposed and can be moved with the fingers. Potentiometers inside the trackball device measure the amount of direction of rotation.



Figure 4. Two trackballs

A *spaceball* looks like a trackball except the ball is detached from the base offering six degrees of freedom. Unlike the trackball, the spaceball is not moved. Strain gauges measure the amount of pressure applied to the spaceball to measure the degree of movement. Spaceballs are used in 3d navigation or modeling applications exactly because they can provide the feeling of 3D movement in space.

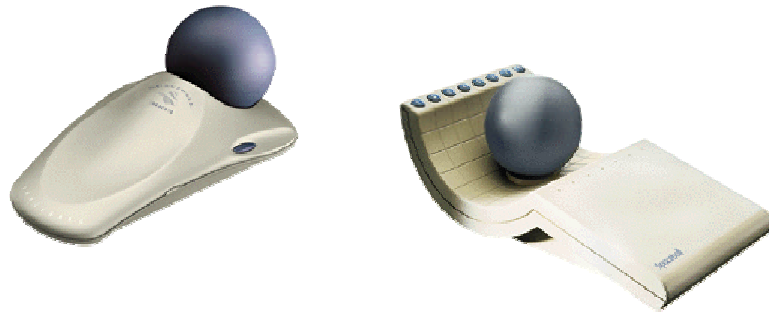


Figure 4.2. Two different types of spaceballs

5. Joysticks

A *joystick* consists of a vertical lever (called stick) mounted to a base. The stick can be tilted forwards, backwards, right, and left. It resembles the joystick that pilots uses to navigate planes. The computer joystick's function is similar to that of the mouse. As the joystick is tilted positions on the screen are addressed. Some joysticks called *haptic* are also force-sensitive. On the top of the stick usually there is a button that performs a selection or dragging function.



Figure 5. A joystick

6. Image Scanners

A *scanner* is a device that samples light intensities. As light is reflected from the surface of an object (paper, slide, transparency) some of the light rays are captured stimulating a matrix of sensors that convert the signal into binary information. The amount of light intensities that a scanner can capture per surface distance is called *resolution*. Apparently, the more the intensities captured the higher the resolution of the converted information. However, more capturing means more sensors, which means higher prices.

Scanner resolution is measured in *dots per inch* (dpi). An average scanner can sample up to 1,200 dpi. Some scanners can reach 2,400 dpi and others use software to sub-sample in-between light intensities. The latter technique is called enhanced resolution.



Figure 6.1. A flatbed scanner and a slide scanner

Scanners vary according to resolution, surface area, and speed. Some scanners may seem inexpensive but the catch may be in the speed of scanning. Usually, scanning is done in one pass but some scanners may still scan in three passes. Slides can be scanned in the same way paper is, except the resolution needs to be higher than paper.

Digital cameras are devices that look and function like regular cameras except they do not capture a picture on film but on digital media. They use a device called CCD (Charge Coupled Device) that is, an array of sensors that when triggered by opening the aperture

of the camera they codify the information in binary format and save it to a diskette. The result is, instead of film, a diskette with the pictures.



Figure 6.2. Three digital cameras

7. Data Glove and Headset

The data glove is a glove with sensors that can detect finger motion and hand position. It uses a series of electromagnetic sensors to capture movements. The data glove feeds the computer with position information that can be used to grab virtual objects on the screen.

The headset is a pair of small screens that are attached close to the eyes on a helmet. The screens can display (in stereo or not) the contents of the monitor. A series of sensors can detect the head-helmet position and orientation and feed that information back to update the picture on the screens.



Figure 7. A data glove, a headset, and a body data glove (courtesy General Reality)

8. Digitizers

Any device that can interactively select coordinate positions on the surface of an object is called a *digitizer*. If the surface is flat we refer to it as a graphic tablet and if the surface is in 3D we refer to it as a 3D digitizer. A two-dimensional digitizer consists of a tablet and a cursor that can be moved within the area of the tablet. Some digitizers are equipped with a tablet and a stylus. The tablet has a grid of sensors that can detect the position of the force of the stylus. The computer can process these two parameters and behave like a painter's canvas.

Three-dimensional digitizers can estimate 3D coordinates from the position of a surface using electromagnetic, sonar, or mechanical information.



Figure 8.2. A 3D digitizer (courtesy Micro-Scribe)

9. Touch Panels

A touch panel is a touch sensitive screen. By placing one's finger on the screen, commands can be executed. Typical applications of touch screens are the selection of options in the form of icons on the screen. The mechanisms for triggering the screen to respond to finger touching are based on optical, electrical, or acoustical methods. In each case the surface of the finger interrupt the order of the signals allowing detection of the

position and area of the obstacle. This information is given back to the computer to execute the commands.



Figure 9. A touch panel

10. Hard-Copy Devices

Printers and plotters are devices that produce hard copies of an image in several formats. Paper, transparency, or film is the most common formats. There are different types of printers depended on the technique used to print in the surface of the hard copy. Dot matrix printers use a rectangular head that moves across the paper. The head is constructed from an array of pins that can fire ink in certain patterns to create characters. Inkjet printers use electrically charged streams of ink that are squirted across the paper in horizontal lines. Depending on the sequence of ink colors squirted different a pattern results. In laser printers, a laser beam charges a photoelectric material with the image pattern. That pattern is used to transfer ink to the paper. In an electrostatic printer, a negative charge is placed on the paper. Positively charged ink is then stuck to the paper wherever there was negative charges.

In all cases, the clarity of the printed image is depended on the number of tiny dots that have been painted. The number of samples that have been taken to construct the printed image is called resolution. Resolution is measured in dots per inch (dpi). Usually inkjet printers can produce images with resolution up to 600 dpi. Laser printers can produce up to 2,400 dpi.



Figure 10.1. A desktop inkjet (left) and a laser printer (right)

A plotter is a device that uses a set of pens to draw on the surface of the paper. Each pen is mechanically moved right-left and as the paper is moved back and forth drawings are produced. The advantage of plotters over printers is that they can feed large pieces of paper since the only constraint is the movement of the pen. Another advantage is that they can produce perfect curves whereas printers can only produce curved up to the resolution of a grid.



Figure 10.2. Different size plotters

Rapid prototyping machines are devices that can produce hard copies of 3D objects using different materials. Originally, a piece of soft material such as plastic, or Styrofoam was sculpted using a milling machine that could move in many directions. Later on, a different technique is used where a liquid material is layered to create a 3D form. This technique is called *stereo-lithography*.



Figure 10.3. A milling machine (left) and a stereo lithography machine (right)

VI. MEMORY/STORAGE

Mechanisms

In computer terms, memory is any device that can hold information and then release it when needed. One piece of primitive information can be represented by a bit. A *bit* is a unit of digital information. It can be thought of as an alternative between two opposite states: black/white, in/out, solid/void, up/down, etc. But the main principle for selecting the bit to have a double status is its representation as a switch that can be set either on or off. Since computers work with electricity and electricity is the flow of electrons in a medium, a switch can control the flow of electrons by being on or off.



Figure 1. A bit

Computer memory can be thought of as a device with millions of switches. Similarly, storage devices can be thought of as devices with millions of on/off patterns. Information can be stored as patterns. Those patterns can be anything from bumps on the surface of an LP to positively or negatively charged particles on a magnetic surface.

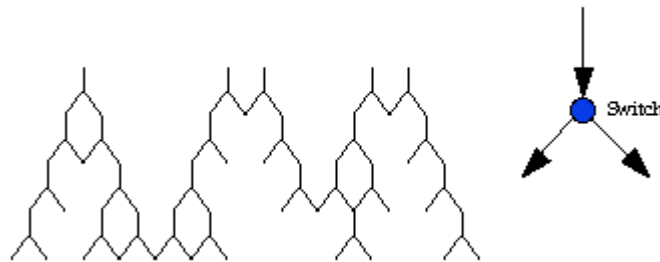


Figure 1.1. A pattern of switches

Think of a network of canals where the water can flow through switch points either left or right. As the water flows through the network of canal switch points it forms patterns of flow. Those patterns can represent something, for example the word apple. It is a pattern that is meaningful for humans when de-coded. When the water forms a specific pattern that, for us, means apple. Or when we want to store the word apple, we form that specific pattern.

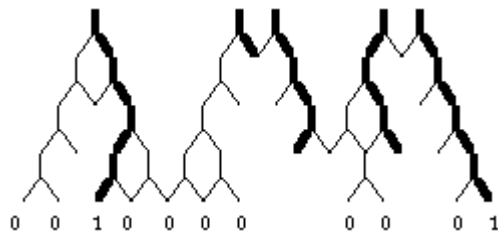


Figure 1.2. A pattern of flow

Bits can be measured in quantities. A byte is a group of eight (8) bits. A byte is a unit of information within the computer. A byte can represent a number from 0 to 255 because in digital arithmetic 0 is 00000000 and 255 is 11111111 and the rest of the numbers are all the possibilities in-between (i.e. 3 is 00000011).



Figure 1.3. Bits and bytes

Kilo-, Mega-, and Giga-Byte are measures of computer capacity:

- Kilo- means Thousand-,

- Mega- means Million,
- Giga- means Billion, and
- Tera- means Trillion

Therefore, 1 KB (KiloByte) is about a thousand bytes (1,024 bytes precisely or 2 to the power of 10); 1 MB (MegaByte) is about a million bytes (1,048,576 precisely or 2 to the power of 20); 1 GB (GigaByte) is about a billion bytes or 8 billion bits; 1 TB (TeraByte) is about a trillion bytes or 8 trillion bits.

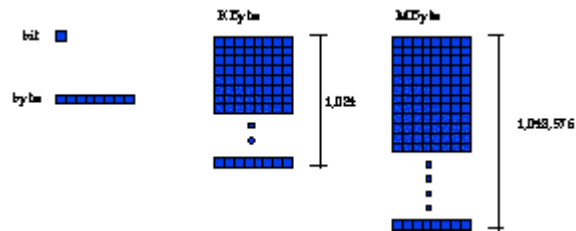


Figure 1.3. Memory measurement units

Computer memory is evaluated by the speed of retrieval, the permanence of the imprinted pattern, and the cost. In the following section, memory/storage devices are shown and evaluated in term of cost and performance. The memory/storage devices are:

1. RAM (Random Access Memory)
2. Diskette
3. Hard Disk
4. SyQuest
5. CD-ROM/CR-R/CD-RW
6. Data Cartridge
7. Zip/Jaz
8. DVD (Digital Versatile Disk)

1. Random Access Memory (RAM)

RAM stands for Random Access Memory and is the part of the computer that stores information in electronic form. It is composed of millions of tiny electronic switches (called flip-flops) that hold information as patterns of 0's and 1's. Usually, they come in the form of chips (tablets of silicon with the tiny switches inside and coated outside with plastic). These chips are called SIMMs (Single In-line Memory Modules) and are manufactured in sizes of 1, 4, 16, 32, 64, 128, etc. megabytes (for personal computers). By combining different sizes one can configure any memory size (i.e. 8 MB of RAM will need 8x1 MB or 2x4 MB SIMM chips).



Figure 1. Memory modules

RAM memory is dynamic and erasable, that is, information can change pattern or location inside the chip all the time and after the computer is shut-off the information is lost. The word Random refers to its ability to access any piece of information in the same time. Think of a tape and a CD. To hear the last song in a tape one needs to fast forward to the end, whereas in a CD the last song takes the same time access than the first. Therefore, a CD is a random access device. RAM works the same way except information is not distributed on the surface of a circle but on an orthogonal grid.

SIMMs used to be very expensive. Through the use of new manufacturing techniques SIMM manufacturing has become relatively easier and the prices of SIMMs have dropped dramatically. In the United States SIMMs cost an average of \$30 per MB.

2. Diskette

A *diskette* is a flat surface of plastic in the form of a circle. On the plastic surface there are tiny particles of iron. A *disk drive* is a device that has a motor that spins the diskette around its center and has a magnetic head that affects the iron particles on the surface of the diskette. As the diskette surface spins around its center, the magnetic head forms patterns, which are copies of the patterns, stored in the RAM. When a diskette is *formatted* the magnetic tape forces all the particles to orient in one direction. When the computer *saves* a file on a diskette, the particles are forced to form patterns that are copies of the patterns in the computer's memory (RAM). Reversibly, when a file is *opened*, the magnetic tape reads the pattern of the particles on the diskette's surface and makes a copy in the computer's memory (RAM).

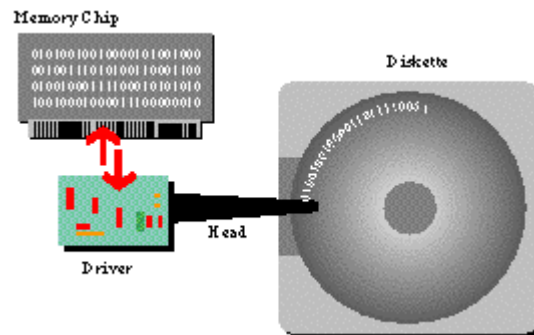


Figure 2. Information is transferred from RAM to diskette

Diskettes for personal computers are manufactured in a size of 3.5 inches and hold information up to 1.4 MB each. The initials HD stand for High density as opposed to older diskettes called Double Density (DD) that could hold only 0.7 MB. Diskettes are very cheap. In the United States they cost an average of \$1 each.

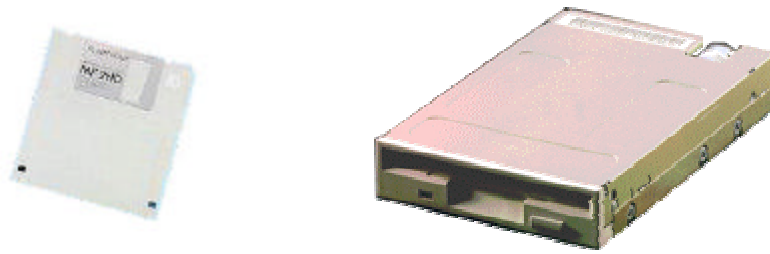


Figure2.2. A diskette and a disk drive

3. Hard Drive

A hard drive (or hard disk) is a magnetic device that can hold much more information than a single diskette. It uses more or less the same technology as the diskette but the density of the particles is much higher resulting in storing capacities of several hundred megabytes.



Figure 3. An external (left) and an internal (right) hard drive

Hard drives are usually located inside the computer box. Through the operating system they usually appears on the top right of the screen as an icon (MacOS-Windows) or is called C: or D: (DOS). Size varies from a several hundred megabytes to several

gigabytes, or terabytes. In the United States a hard drive can cost an average of \$0.5 per MB.

4. SyQuest Disk

A SyQuest is a removable hard drive. It uses the same technology as the hard drive only the magnetic surface of the hard disk can be portable. Therefore, adding new disks to the driver increases the memory storage infinitely.



Figure 4. A 200MB and 270 MB SyQuest disk (left) and a drive (right).

The SyQuest disks can hold 44MB, 88MB, 160MB, and 200MB. A SyQuest drive cost an average of \$2-300, and each disk range between \$50 to \$100.

5. Compact Disk CD-ROM/CD-R/CD-RW

A *CD-ROM* is similar to a regular music CD. The only difference is in the information it stores. The process of reading/writing patterns of information is almost the same as that of the hard disk except instead of using magnets and iron particles the CD uses a light-sensitive surface where a light-emitting source causes the CD's surface to alter its electric voltage patterns. CDs belong to a category of storage devices called *optical*. The result is higher memory capacities, going up to 600 MB.

$$\text{CD} = 600 \text{ MB} = 2,500 \text{ arch drawings} = 60,000 \text{ pages}$$

Figure 5.1. A CD can fit about 600 MB, which is equivalent to about 2,500 large drafts, or about 60,000 pages of text



Figure 5.2. A CD and a CD drive

The initials ROM stand for Read Only Memory, which means that a CD drive can only read information but cannot write to it. The writing part is done with special drives that used to cost a lot of money. Now these special drives are much cheaper and can write information on a CD. Those drives are called CD-R (R stands for Recordable). Once written a CD-R cannot be re-written. To solve that problem a new generation of CDs has been developed that can write information over and over. These devices are called CD-RW (RW stands for ReWritable).

In the United States any type of CD (either CD-ROM, CR-R, or CR-RW) costs about a \$1 each. Drives vary: a CD-ROM drive cost about \$150, and a CD-R or CD-RW drive about \$400.

6. Data Cartridge/Drive

A data cartridge looks like a video 8mm tape but it is made to hold digital information (as opposed to analog video). It can hold several gigabyte. It needs a drive, that is, a recording device to read and write information on the drive. Magnetic tapes are very slow but ideal for file backups.

In the United States, a data cartridge can cost about \$10 a tape and the driver can cost about \$500.



Figure 6. A data cartridge (left) and a tape drive (right).

7. Zip Disk/Drive



Figure 7. A Zip disk (left) and a Zip drive (right)

The Zip/Jaz drive is an evolution of the SyQuest technology that can store large amounts of information in small size diskettes (looks almost like a typical diskette). Each Zip diskette can hold up to 100 MB, costs about \$20 each in the United States and the driver

can go up to \$150. Each Jaz disk can hold up to 1 GB, costs about \$100 each in the United States and the driver can cost about \$150.

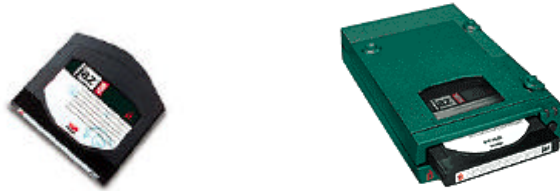


Figure 7. A Jaz disk (left) and a Jaz drive (right)

9. DVD (Digital Versatile Disc)

DVD is a new optical disk technology that is expected to rapidly replace the CD-ROM disk (as well as the audio compact disc) over the next few years. The digital versatile disk (DVD) holds 4.7 gigabytes of information on one of its two sides, or enough for a 133-minute movie. With two layers on each of its two sides, it will hold up to 17 gigabytes of video, audio, or other information. (Compare this to the current CD-ROM disk of the same physical size, holding 600 megabytes. The DVD can hold more than 28 times as much information!)

DVD-Video is the usual name for the DVD format designed for full-length movies and is a box that will work with your television set. DVD-ROM is the name of the player that will (sooner or later) replace your computer's CD-ROM. DVD-RAM is the writeable version. DVD-Audio is a player designed to replace the compact disc player.



Figure 9. A DVD (left) and a DVD player (right)

Software Compression

Occasionally, information need to be stored or archived compressed to fit in disks or to be transferred over a network. *Compression* is the reduction in size of data in order to save space or transmission time. For data transmission, compression can be performed on just the data content or on the entire transmission unit (including header data) depending on a number of factors.

Content compression can be as simple as removing all extra space characters, inserting a single repeat character to indicate a string of repeated characters, and substituting smaller bit strings for frequently occurring characters. This kind of compression can reduce a text file to 50% of its original size. Compression is performed by a program that uses a formula or algorithm to determine how to compress or decompress data. Graphic image file formats are usually designed to compress information as much as possible (since these can tend to become very large files).

When one needs to store information on a disk, larger text files, either singly or with others as part of an archive file, may be stored in a zip, gzip, or other compressed format. WinZip is a popular Windows program that compresses files when it packages them in an archive.

Memory/Storage Cost Comparison

In the following section a list of prices and functions of storage devices are presented. A comparison is made between different devices and the best fit is indicated. Costs are based on 1998 prices and estimates.

- SIMMs cost an average of \$30 per MB.
- Diskettes cost an average of \$1 each.
- Hard disks cost an average of \$0.5 per MB
- A SyQuest drive cost an average of \$2-300, and each disk range between \$50 to \$100.
- A CD costs about \$15, a CD-drive about \$300, and a CD-RW drive \$500 or more.
- A cartridge can cost about \$10 a tape and the driver can cost about \$500.
- A zip diskette cost about \$20 each and the driver can go up to \$150.
- A DVD can cost about \$10 but the drive can go up to \$600.

Suppose we have 500 MB of memory we would like to store in the most efficient and inexpensive way. It would cost:

- \$15,000 as RAM but the speed would be almost as fast as the computer itself
- \$500 as diskettes (about 400 of them)
- \$250 as a hard disk
- \$360 for six 88MB SyQuest plus the driver \$200 (total = \$560)
- \$15 for a CD-RW plus the CD-drive \$400 (total = \$415)
- \$10 for the cartridge (but extremely slow) plus \$650 for the drive (total = \$660)
- \$100 for 10 zip diskette + \$200 for the drive (total = \$300)
- \$10 for a DVD and about \$600 for the drive (total=\$610)

Therefore, it seems the best choice would be the zip drive.

VII. PROCESSORS

1. Mechanisms

Almost any computer system is composed of three basic components: Memory, Central Processing Unit (CPU), and input/output devices. Information is entered through input devices in the form of patterns that reside in memory. When needed this information move into the CPU where it is processed either arithmetically or logically and then put back in memory or exported out through output devices. During this transfer of information one thing becomes very important: speed of transfer. This is determined mostly by two factors: the clock and bus.

Computers have internal *clocks* that count time. In each click events happen. One event per second is called a *Hertz*. One million events per second are called a *Megahertz* or *MHz*. Computer clocks tick really fast. A 200 MHz clock ticks 200,000,000 times every second and 200 million events happen in that second.

All components of a computer are mounted on a silicon board, which is called *motherboard*. The transfer of information between different component inside the computer requires wires. We call the set of wires *bus*. Think of a bus like a highway. The more lanes available the more traffic can flow. The width of bus flow is measured in bits. A 32-bit bus allows pieces of information 32 bit long to flow though the bus.

The clock and bus are related to the structure of the central processing unit. In order to accommodate clock ticks and bus widths, the CPU must be structured correspondingly. The structure of the CPU is also referred to as the *architecture*. Different hardware companies create different CPUs. Computers usually are named after the architecture of their processor. The 386, 486, Pentium, powerPC, RISC, of G3, refer to the type of processor. Intel is one of the major companies that manufacture processors for the PCs. Motorola manufactures processors for the Macintosh. Digital, Silicon Graphics, Sun

Microsystems are some of the other hardware manufacturing companies in the United States.

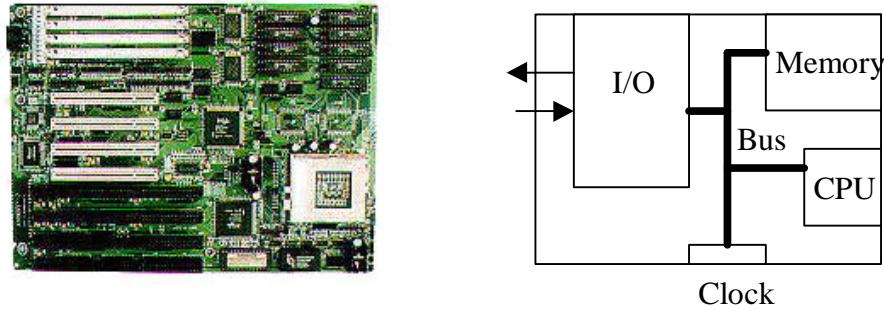


Figure 1. A motherboard (right) and a diagram of its components (left)

1. Computer Platforms

The combination of operating system and hardware is called *platform*. A platform consists of an operating system, the computer system's coordinating program, and a microprocessor, the microchip in the computer that performs logic operations and manages data movement in the computer. The operating system must be designed to work with the particular microprocessor's set of instructions. As an example, Microsoft's Windows 95 is built to work with a series of microprocessors from the Intel Corporation that share the same or similar sets of instructions. There are usually other implied parts in any computer platform such as a motherboard and a bus, but these parts have increasingly become modularized and standardized.

We distinguish four platforms: PC-Windows, Mac, workstation-Unix, and SGI platforms. Each one is described below:

2.1. PC (Personal Computer) - Windows

PC stands for Personal Computer. In the 1970s IBM came up with a computer that was affordable and easy to use. It was called then, the *personal computer*. The term is used until today to identify computers with Intel-based processors. Sometimes people refer to PCs as IBM-Compatible. In the late 1990s PCs continue to be the most affordable and broadly used computers in the business market.

In its more general usage, a PC (personal computer) is a computer designed for use by one person at a time. Prior to the PC, computers were designed for (and only affordable by) companies who attached terminals for multiple users to a single large computer called mainframe whose resources were shared among all users. Beginning in the late 1980s, technology advances made it feasible to build a small computer that an individual could own and use.

PCs started with the x86 series of processors, which evolved into the Pentium processor. A Pentium processor is based on the Reduced Instruction Set Code (RISC) architecture.



Figure 2.1. A desktop, a tower, and a laptop PC computer

2.2. Macintosh

Macintosh computers were introduced in the early 1970s by Apple, Inc. as an alternative to the PCs. Macintoshes (or Macs) were the first home computers to introduced an icon-based operating system which was copyrighted until the mid 1990s. Macs tried to target at the graphics design market. Easy to use and friendly as they were had a great impact on designers and artists who also tend to think in visual terms. Desktop publishing systems, paint programs, and user-friendly interfaces for hooking up external devices became major factors for their success in that market.

Macintosh started with the Motorola 68000 series processor, which then became powerPC and now is evolved into the third Generation (G3) powerPC processor by Motorola.



Figure 2.1. A desktop, a tower, and a laptop Macintosh computer (courtesy Apple, Inc.)

2.3. Workstation - Unix

A workstation is a computer intended for individual use but faster and more capable than a personal computer. It's intended for business or professional use (rather than home or recreational use). Workstations and applications designed for them are used by small engineering companies, architects, graphic designers, and any organization, department, or individual that requires a faster microprocessor, a large amount of random access memory (RAM), and special features such as high-speed graphics adapters. Historically,

the workstation developed technologically about the same time and for the same audience as the UNIX operating system, which is often used as the workstation operating system. Among the most successful makers of this kind of workstation are Sun Microsystems, Hewlett-Packard, DEC, and IBM.

2.4. SGI (Silicon Graphics)

Silicon Graphics Inc. (or SGI) is a company that develops computer systems that target at graphics and visualization applications. The architecture of their systems is quite sophisticated and ranges from workstation level computers to supercomputers with parallel processing.



Figure 2. The O2, Octane and Onyx2 Silicon Graphics Systems (courtesy SGI)

Silicon Graphics systems run a modified version of Unix called Irix. This operating system can be viewed as icon-based.

2. Super Computers and Parallel Processing

Supercomputers are computers that can perform tasks really fast. They take advantage of the circuit layout, the materials used, and the length of the wires. The CRAY series are

supercomputers, which can reach, speeds of Gips (billion instructions per second) These computers are used to simulate weather phenomena, car crashes, or real-time animation.

Parallel computers use a "production line" philosophy to perform tasks. They use several CPUs to perform a task. For example, if a task takes 10 seconds to perform and the computer has 10 processors, it can subdivide the task in 10 subtasks and perform each one at the same time using the 10 CPUs. Therefore, the same task will be finished in 1 second.

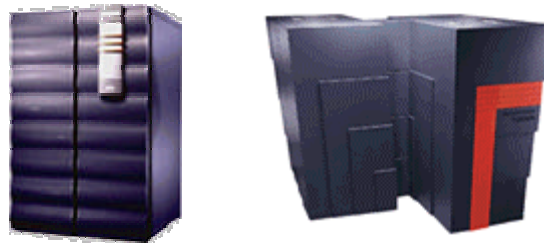


Figure 3. Supercomputers (courtesy Cray, Inc.)

3. Generations

The word "architectures" in computer terminology means the structure of computers, the way the computer components are put together. Since the end of the Second World War, these architectures went through many different phases, called generations. In any generation the main concern was size and speed.

- In the first generation (1953-59) vacuum tubes were used as switching devices. They were very large: the size of a light bulb each.
- In the second generation (1959-65) transistors were used (made out of silicon and copper and the size of half a thumbnail)
- In the third generation (1965-71), solid state circuits were used which are groups of small transistors.
- In the fourth generation (1971-present), microprocessors were used which are groups of small solid state circuits.

- In the fifth generation new devices such as fiber optics and nano-processors are to be used.

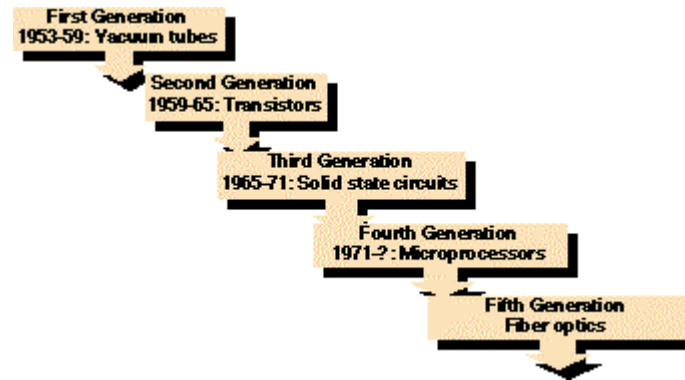


Figure 5. Computer Generations

VIII. GRAPHICS CARDS

1. General

Graphic cards are hardware devices that help the computer process faster and more efficiently graphical information, such as colors, number of pixels, video signals, or 3D transformations. There are three types of graphic cards:

- Video (S-VGA) cards
- Video capture cards
- 3D Accelerators

Graphics cards are usually in the form of a silicon card that connects internally with the computer's main processing card (motherboard) through connectors. There are two types of connector: PCI (Peripheral Component Interconnect) and AGP (Accelerated Graphics Port). The difference between the two connectors is mainly in the speed of the connection. In general, AGPs are faster than PCIs. Graphic cards are connected internally inside the computer as shown in the scheme below:

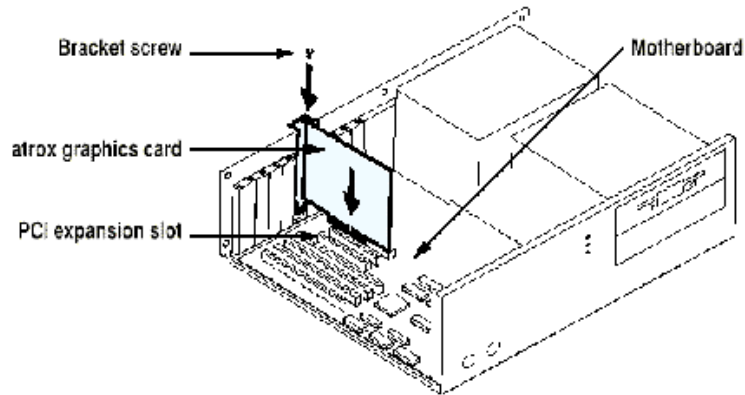


Figure 1. Installing a video card

The cards may have different input/output connectors. The output connector to the monitor is called 15-pin and comes in compact (5-5-5) for PCs or flat (7-8) for Macs. Video signals are handled though RCA or S-Video connectors.

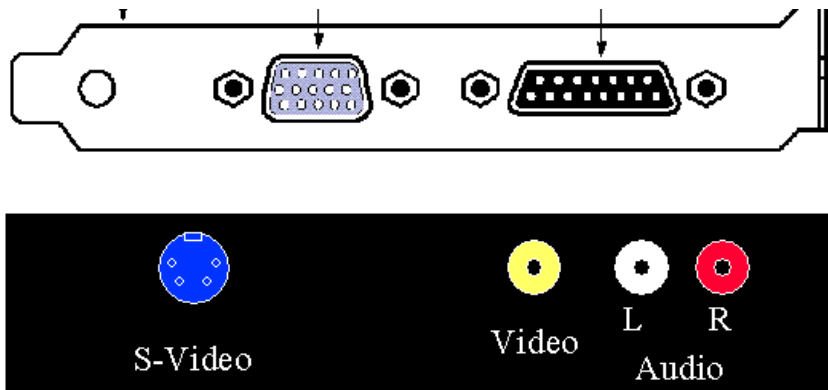


Figure 1.2. Various video card input/output connectors

2. Video (SVGA) Cards

SVGA cards take information from the computer and convert it into colors and pixel positions. They specify the amount of pixels on the screen and the number of colors. The amount of information they can display depends on video memory (VRAM) and the type of monitor. To increase the size and number of color that a screen can display one needs to add more VRAM. The minimum amount of VRAM provided by the manufacturer allows a minimum number of pixels (640x480) and a minimum number of colors (256).

Most PC screens incorporate the super video graphics array (SVGA) standard. This system can support a palette of up to 16,000,000 colors. Small SVGA monitors (14-inch diagonal) usually display 800 pixels horizontally by 600 pixels vertically. The largest monitors (20 inches or more diagonal measure) can display 1280 x 1024, or even 1600 x 1200, pixels.

Every pixel on the screen corresponds to a set of bits (8-, 24-, 32-bits) in VRAM. An 8-bit pixel can have $2^8 = 256$ possible bit combinations, therefore 256 different colors. A 24-bit will have $2^{24} = 16,777,216$ possible bit combinations.

In computer languages, every color can be denoted as a combination of 3 basic colors (Red, Green and Blue). Red would be (255,0,0) where numbers can vary between 0 and 255. Green would be (0,255, 0), and Blue (0,0,255). White would be (255, 255, 255) and black (0,0,0). Any other color would be a combination of R, G, and B.

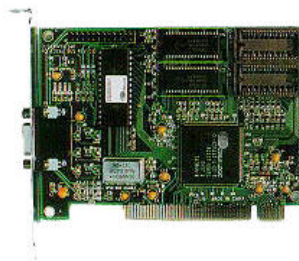


Figure 2. An SVGA card

Monitors are measured in diagonal lines (17", 19", 21"). The average screen today (1998) is 17". Costs are around \$300 for 17" and about \$1,000 for a 20" screen. VGA cards vary between \$50 to \$200 and VRAM costs and average of \$20 per MB.

3. Video Capture Cards

Video-capture cards basically convert TV signals (NTSC or PAL/SECAM) into computer RGB signals and vice versa. Their price and quality is measured in size of display, format, and speed of motion. The basic setup of a video capture card is by simply connecting the VCR/camcorder with the Video Capture Card through RCA or S-Video cables and then running the video capture software.

The prices of video capture cards vary according to their capabilities. Thing to consider are size of screen capture area, full-motion, number of colors, output formats. For example, in the following video card types:

Miro DC-10	(230x640)	\$200
Miro DC-20	(640x480)	\$600 TV screen = 570x570
Miro DC-30	(640x480)	\$800

The less the money one spends the less capture-area one gets. Also the DC-30 has Betacam output format and comes with more software.

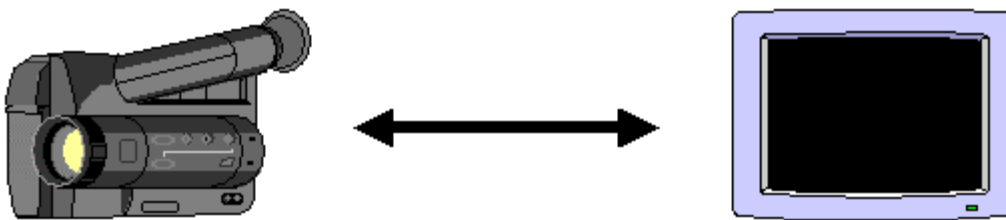


Figure 3. Conversion form TV signal to computer screen signal and vise versa

4. 3D Accelerators

3D accelerators are special hardware cards that increase the speed of 3D movements. They plug-in to the motherboard at the PCI or AGP port and they take care of special calculations. Mostly these calculations are mathematical and trigonometric. For example, a simple rotation of an object requires a set of sine and cosine calculations as shown below:

$$\begin{aligned} \text{newx} &= x \cdot \cos(\text{angle}) - y \cdot \sin(\text{angle}) \\ \text{newy} &= x \cdot \sin(\text{angle}) + y \cdot \cos(\text{angle}) \end{aligned}$$

Every sine or cosine function requires over 30 operations (+,-,*,/) to calculate the resulting rotation. Instead, if the sine and cosine of all possible angles, lets say 360, were pre-calculated and stored in memory, only one operation would be required, that of to fetching the sine and cosine. To do that we would need extra memory space to store all those possible sine/cosine values. In other words we would have to trade calculations for memory. 3D accelerators do that among other things. They are basically storage for angles indexes, pixel-maps, texture images, etc. making it easier for the computer to handle 3D movements.

Manufacturers' graphics 3D accelerators can be classified in three categories: low, medium, and high. This classification involves price and performance. Some of the available cards with their 1998 price list are shown below:

Company	Low	Medium	High
ELSA Gloria	Synergy	L/MX	XL
Oxygen	102	202	402
Diamond GL	1000 Pro	3000	4000
Accel	Star		Eclipse
Prices	\$2-300	\$1-200	\$2-3000

Figure 4. A comparison of prices for 3D accelerators

Graphics accelerators are supported by special software called *graphics libraries*. Many modeling commands, such as display, 3D rotation, zooming, etc. can be built-in the card's hardware. That makes developer's and user's life easier and faster. For example, the command $rot3D(vec3f, theta)$, allows one to rotate a 3D vector $vec3f$ by an angle $theta$ without having to actually calculate the sine/cosine values through the formulas shown earlier. These libraries are the software that tells the card what to do. Lately efforts have been made by companies to standardized them. *OpenGL* and *Direct3D* are such libraries that Silicon Graphics and Microsoft tried to put together.