INTERNAL COMPONENTS

The **motherboard** is the main printed circuit board and contains the buses, or electrical pathways, found in a computer. These buses allow data to travel between the various components that comprise a computer. Figure 1 shows a variety of motherboards. A motherboard is also known as the system board or the main board.

The motherboard accommodates the central processing unit (CPU), random access memory (RAM), expansion slots, heat sink and fan assembly, basic input/output system (BIOS) chip, chipset, and the circuitry that interconnects the motherboard components. Sockets, internal and external connectors, and various ports are also placed on the motherboard.

The form factor of motherboards pertains to the size and shape of the board. It also describes the physical layout of the different components and devices on the motherboard. The form factor determines how individual components attach to the motherboard and the shape of the

Form Factors		
AT	Advanced Technology	12 in (30.5 cm) X 13.8 in (35.1 cm)
ATX	Advanced Technology Extended	12 in (30.5 cm) X 9.6 in (24.4 cm)
Mini-ATX	Smaller footprint of Advanced Technology Extended	5.9 in (15 cm) X 5.9 in (15 cm)
Micro-ATX	Smaller footprint of Advanced Technology Extended	9.6 in (24.4 cm) X 9.6 in (24.4 cm)
LPX	Low-Profile Extended	13 in (33 cm) X 9 in (22.9 cm)
NLX	New Low-Profile Extended	8 in (20.3 cm) X 10 in (25.4 cm) to 9 in (22.9 cm) X 13.6 in (34.5 cm)
BTX	Balanced Technology Extended	12.8 in (32.5 cm) X 10.5 in (26.6 cm)
Mini-ITX	Smaller than the Micro-ATX format	6.7 in (17 cm) X 6.7 in (17 cm)
Nano-ITX	Smaller footprint of the Mini-ITX	4.7 in (12 cm) X 4.7 in (12 cm)
Pico-ITX	Half the size of the Nano-ITX	3.9 in (9.9 cm) X 2.8 in (7.1 cm)
Mobile-ITX	Smallest ITX motherboard	2.4 in (6 cm) X 2.4 in (6 cm)

computer case. Various form factors exist for motherboards, as shown in this chart.

The most common form factor in desktop computers was the AT, based on the IBM AT motherboard. The AT motherboard can be up to approximately 1 foot wide. This cumbersome size led to the development of smaller form factors. The placement of heat sinks and fans often interferes with the use of expansion slots in smaller form factors.

A newer motherboard form factor, ATX, improved on the AT design. The ATX case accommodates the integrated I/O ports on the ATX motherboard. The ATX power supply connects to the motherboard via a single 20-pin connector, instead of the confusing P8 and P9 connectors used with some earlier form factors. Instead of using a physical toggle switch, the ATX power supply can be powered on and off with signaling from the motherboard.

A smaller form factor designed to be backward-compatible with ATX is the Micro-ATX. Because the mounting points of a Micro-ATX motherboard are a subset of those used on an ATX board, and the I/O panel is identical, you can use the Micro-ATX motherboard in a full-size ATX case.

Because Micro-ATX boards often use the same chipsets (Northbridges and Southbridges) and power connectors as full-size ATX boards, they can use many of the same components. However, Micro-ATX cases are typically much smaller than ATX cases and have fewer expansion slots.

Some manufacturers have proprietary form factors based on the ATX design. This causes some motherboards, power supplies, and other components to be incompatible with standard ATX cases.

The ITX form factor has gained in popularity because of its very small size. There are many types of ITX motherboards. Mini-ITX is one of the most popular. The Mini-ITX form factor uses very little power, so fans are not needed to keep it cool. A Mini-ITX motherboard has only one PCI slot for expansion cards. A computer based on a Mini-ITX form factor can be used in places where it is inconvenient to have a large or noisy computer.

An important set of components on the motherboard is the chipset. The chipset is composed of various integrated circuits attached to the motherboard. They control how system hardware interacts with the CPU and motherboard. The CPU is installed into a slot or socket on the motherboard. The socket on the motherboard determines the type of CPU that can be installed.

The chipset allows the CPU to communicate and interact with the other components of the computer, and to exchange data with system memory, or RAM, hard disk drives, video cards, and other output devices. The chipset establishes how much memory can be added to a motherboard. The chipset also determines the type of connectors on the motherboard.

Most chipsets are divided into two distinct components, Northbridge and Southbridge. What each component does varies from manufacturer to manufacturer. In general, the Northbridge controls access to the RAM, video card, and the speeds at which the CPU can communicate with them. The video card is sometimes integrated into the Northbridge.

AMD and Intel have chips that integrate the memory controller onto the CPU die, which improves performance and power consumption. The Southbridge, in most cases, allows the CPU to communicate with the hard drive, sound card, USB ports, and other I/O ports.

CPU

The central processing unit (CPU) is considered the brain of the computer. It is sometimes referred to as the processor. Most calculations take place in the CPU. In terms of computing power, the CPU is the most important element of a computer system. CPUs come in different form factors, each style requiring a particular slot or socket on the motherboard. Common CPU manufacturers include Intel and AMD.

PGA CPU and Socket

The CPU socket or slot is the connection between the motherboard and the processor. Most CPU sockets and processors in use today are built around the architectures of the pin grid array (PGA), shown in Figure 1, and land grid array (LGA), shown in Figure 2. In a PGA architecture, pins on the underside of the processor are inserted into the socket, usually with zero insertion force (ZIF). ZIF refers to the amount of force needed to install a CPU into the motherboard socket or slot. In an LGA architecture, the pins are in the socket instead of on the processor. Slot-based processors, shown in Figure 3, are cartridge-shaped and fit into a slot that looks similar to an expansion slot, shown at the bottom left of Figure 4.
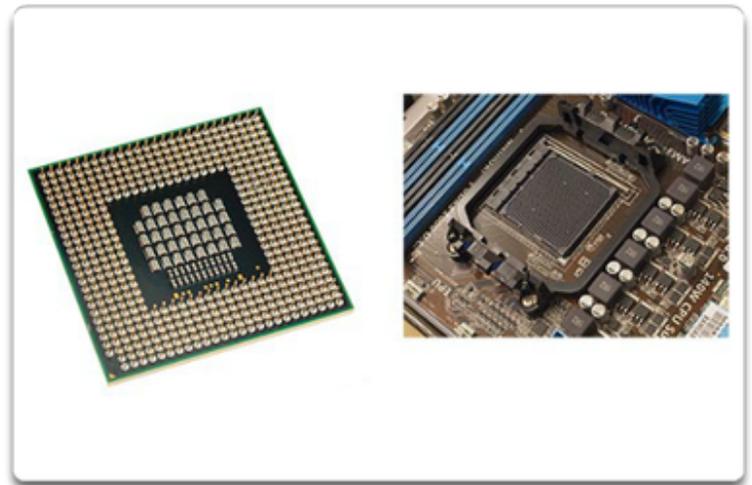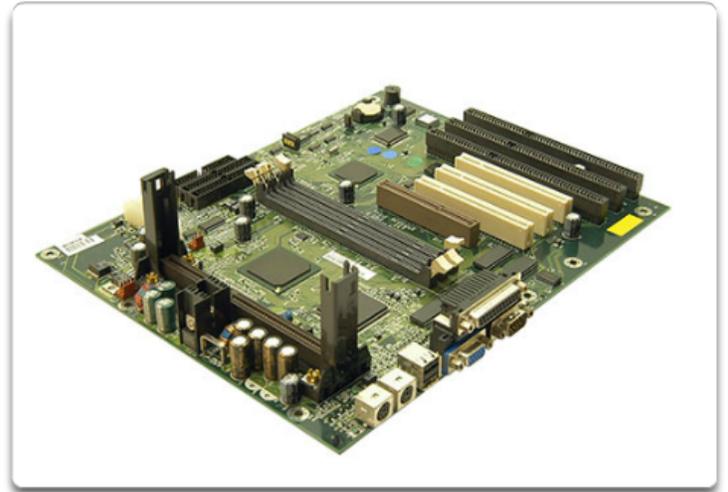
LGA CPU and Socket

Slot CPU

Motherboard with CPU Slot

The CPU executes a program, which is a sequence of stored instructions. Each model of processor has an instruction set, which it executes. The CPU executes the program by processing each piece of data as directed by the program and the instruction set. While the CPU is executing one step of the program, the remaining instructions and the data are stored nearby in a special memory called cache. Two major CPU architectures are related to instruction sets:

• Reduced Instruction Set Computer (RISC) - Architectures use a relatively small set of instructions. RISC chips are designed to execute these instructions very rapidly.

• Complex Instruction Set Computer (CISC) - Architectures use a broad set of instructions, resulting in fewer steps per operation.

Some Intel CPUs incorporate hyperthreading to enhance the performance of the CPU. With hyperthreading, multiple pieces of code (threads) are executed simultaneously in the CPU. To an operating system, a single CPU with hyperthreading performs as though there are two CPUs when multiple threads are being processed.
Some AMD processors use hypertransport to enhance CPU performance. Hypertransport is a high-speed, low-latency connection between the CPU and the Northbridge chip.
The power of a CPU is measured by the speed and the amount of data that it can process. The speed of a CPU is rated in cycles per second, such as millions of cycles per second, called megahertz (MHz), or billions of cycles per second, called gigahertz (GHz). The amount of data that a CPU can process at one time depends on the size of the front side bus (FSB). This is also called the CPU bus or the processor data bus. Higher performance can be achieved when the width of the FSB increases. The width of the FSB is measured in

bits. A bit is the smallest unit of data in a computer. Current processors use a 32-bit or 64-bit FSB.

Overclocking is a technique used to make a processor work at a faster speed than its original specification. Overclocking is not a recommended way to improve computer performance and can result in damage to the CPU. The opposite of overclocking is CPU throttling. CPU throttling is a technique used when the processor runs at less than the rated speed to conserve power or produce less heat. Throttling is commonly used on laptops and other mobile devices.

The latest processor technology has resulted in CPU manufacturers finding ways to incorporate more than one CPU core onto a single chip. These CPUs are capable of processing multiple instructions concurrently:

- Single Core CPU - One core inside a single CPU that handles all the processing. A motherboard manufacturer might provide sockets for more than one single processor, providing the ability to build a powerful, multiprocessor computer.

- Dual Core CPU - Two cores inside a single CPU in which both cores can process information at the same time.

- Triple Core CPU - Three cores inside a single CPU that is actually a quad-core processor with one of the cores disabled.

- Quad Core CPU - Four cores inside a single CPU

Case Fan

- Hexa-Core CPU - Six cores inside a single CPU

- Octa-Core CPU - Eight cores inside a single CPU

COOLING SYSTEMS

The flow of current between the electronic components generates heat. Computer components perform better when kept cool. If the heat is not removed, the computer may run slower. If too much heat builds up, computer components can be damaged.
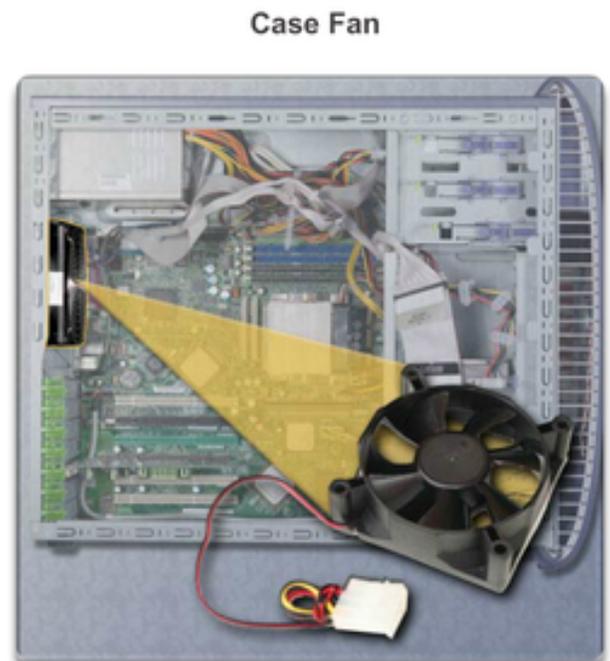
Increasing the air flow in the computer case allows more heat to be removed. A case fan installed in the computer case, as shown in Figure 1, makes the cooling process more efficient. In addition to a case fan, a heat sink draws heat away from the CPU core. A fan on top of the heat sink, as shown in Figure 2, moves the heat away from the CPU.
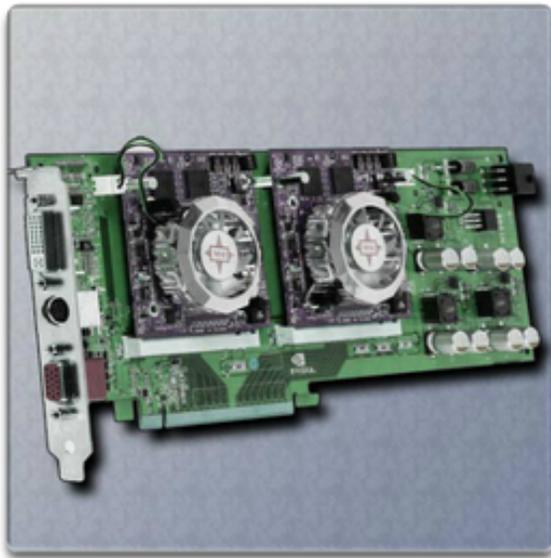
CPU Fan

Other components are also susceptible to heat damage and are sometimes equipped with fans. Video adapter cards also produce a lot of heat. Fans are dedicated to cool the graphics-processing unit (GPU), as shown in Figure 3.

Graphics Card Cooling System

Computers with extremely fast CPUs and GPUs might use a water-cooling system. A metal plate is placed over the processor, and water is pumped over the top to collect the heat that the processor generates. The water is pumped to a radiator to release the heat into the air and is then recirculated.

ROM

Memory chips store data in the form of bytes. Bytes represent information such as letters, numbers, and symbols. A byte is a grouping of digital information in computing. A byte is most commonly a block of eight bits. Each bit is stored as either 0 or 1 in the memory chip.

Read-only memory (ROM) chips are located on the motherboard and other circuit boards. ROM chips contain instructions that can be directly accessed by a CPU. Basic instructions for operation, such as booting the computer and loading the operating system, are stored in ROM. ROM chips retain their contents even when the computer is powered down. The contents cannot be erased or changed by normal means.

ROM: Read-only memory chips. Information is written to a ROM chip when it is manufactured. A ROM chip cannot be erased or re-written and is obsolete.

PROM: Programmable read-only memory. Information is written to a PROM chip after it is

manufactured. A PROM chip cannot be erased or re-written.

EPROM: Erasable programmable read-only memory.   Information is written to an EPROM chip after it is manufactured. An EPROM chip can be erased with exposure to UV light. Special equipment is required.

EEPROM: Electrically erasable programmable read-only memory. Information is written to an EEPROM chip after it is manufactured. EEPROM chips are also called Flash ROMs. An EEPROM chip can be erased and re-written without having to remove the chip from the computer.

NOTE: ROM is sometimes called firmware. This is misleading, because firmware is actually the software that is stored in a ROM chip.

RAM

RAM is the temporary storage for data and programs that are being accessed by the CPU. RAM is volatile memory, which means that the contents are erased when the computer is powered off. The more RAM in a computer, the more capacity the computer has to hold and process large programs and files. More RAM also enhances system performance. The maximum amount of RAM that can be installed is limited by the motherboard.

DRAM: Dynamic RAM is a memory chip that is used as main memory. DRAM must be constantly refreshed with pulses of electricity in order to maintain the data stored within the chip.

SRAM: Static RAM is a memory chip that is used as cache memory. SRAM is much faster than DRAM and does not have to be refreshed as often. SRAM is much more expensive than DRAM.

FPM MEMORY: Fast Page Mode DRAM is memory that supports paging. Paging enables faster access to the data than regular DRAM. FPM memory was used in Intel 486 and Pentium systems.

EDO MEMORY: Extended Data Out RAM is memory that overlaps consecutive data accesses. This speeds up the access time to retrieve data from memory, because the CPU does not have to wait for one data access cycle to end before another data access cycle begins.

SDRAM: Synchronous DRAM is DRAM that operates in synchronization with the memory bus. The memory bus is the data path between the CPU and the main memory. Control signals are used to coordinate the exchange of data between SDRAM and the CPU.

DDR SDRAM: Double Data Rate SDRAM is memory that transfers data twice as fast as SDRAM. DDR SDRAM increases performance by transferring data twice per clock cycle.

DDR2 SDRAM: Double Data Rate 2 SDRAM is a faster than DDR-SDRAM memory. DDR2 SDRAM improves performance over DDR SDRAM by decreasing noise and crosstalk between the signal wires.

DDR3 SDRAM: Double Data Rate 3 SDRAM expands memory bandwidth by doubling the clock rate of DDR2 SDRAM. DDR3 SDRAM consumes less power and generates less heat than DDR2 SDRAM.

RDRAM: RAMBus DRAM is a memory chip that was developed to communicate at very high rates of speed. RDRAM chips are not commonly used.

MEMORY MODULES

Early computers had RAM installed on the motherboard as individual chips. The individual memory chips, called dual inline package (DIP) chips, were difficult to install and often became loose. To solve this problem, designers soldered the memory chips on a special circuit board to create a memory module. The different types of memory modules are:

DIP: Dual Inline Package is an individual memory chip. A DIP has dual rows of pins used to attach it to the motherboard.

SIMM: Single Inline Memory Module is a small circuit board that holds several memory chips. SIMMs have 30-pin or 72-pin configurations.

DIMM MEMORY: Dual Inline Memory Module is a circuit board that holds SDRAM, DDR SDRAM, DDR2 SDRAM, and DDR3 SDRAM chips. There are 168-pin SDRAM DIMMs, 184-pin DDR DIMMs, and 240-pin DDR2 and DDR3 DIMMs.

RIMM: RAMBus Inline Memory Module is a circuit board that holds RDRAM chips. A typical RIMM has a 184-pin configuration.

SODIMM: Small Outline DIMM has a 72-pin and 100-pin configurations for support of 32-bit transfers or a 144-pin, 200-pin, and 204-pin configurations for support of 64-bit transfers. This smaller, more condensed version of DIMM provides random access data storage that is ideal for use in laptops, printers, and other devices where conserving space is desirable.

NOTE: Memory modules can be single-sided or double-sided. Single-sided memory modules contain RAM only on one side of the module. Double-sided memory modules contain RAM on both sides.

The speed of memory has a direct impact on how much data a processor can process, because faster memory improves the performance of the processor. As processor speed increases, memory speed must also increase. For example, single-channel memory is capable of transferring data at 64 bits per clock cycle. Dual-channel memory increases the speed by using a second channel of memory, creating a data transfer rate of 128 bits. Double Data Rate (DDR) technology doubles the maximum bandwidth of Synchronous Dynamic RAM (SDRAM). DDR2 offers faster performance and uses less energy. DDR3 operates at even higher speeds than DDR2. However, none of these DDR technologies are backward- or forward-compatible. Many common memory types and speeds are shown in here.

Common Memory Types and Characteristics			
Memory Type	Industry Name	Peak Transfer Rate	Front Side Bus
PC100 SDRAM	PC-100	800 MB/s	100 MHz
PC133 SDRAM	PC-133	1060 MB/s	133 MHz
DDR-333	PC-2700	2700 MB/s	166 MHz
DDR-400	PC-3200	3200 MB/s	200 MHz
DDR2-667	PC2-5300	5333 MB/s	667 MHz
DDR3-1600	PC3-12800	12800 MB/s	1600 MHz
DDR2-800	PC2-6400	6400 MB/s	400 MHz
DDR3-1333	PC3-10600	10667 MB/s	1333 MHz
DDR3-1866	PC3-14900	14933 MB/s	1867 MHz
DDR3-2133	PC3-17000	17066 MB/s	2133 MHz

Cache

Static RAM (SRAM) is used as cache memory to store the most recently used data and instructions. SRAM provides the processor with faster access to the data than retrieving it from the slower dynamic RAM (DRAM), or main memory. The three most common types of cache memory are:

L1: L1 cache is internal cache and is integrated into the CPU.

L2: L2 cache is external cache and was originally mounted on the motherboard near the CPU. L2 cache is now integrated into the CPU.

L3: L3 cache is used on some high-end workstations and server CPUs.

Error Checking
Memory errors occur when the data is not stored correctly in the RAM chips. The computer uses different methods to detect and correct data errors in memory. Different types of error checking are:

NONPARITY: Nonparity memory does not check for errors in memory.

PARITY: Parity memory contains eight bits for data and one bit for error checking. The error-checking bit is called a parity bit.

ECC: Error Correction Code memory can detect multiple bit errors in memory and correct single bit errors in memory.

ADAPTER CARDS AND EXPANSIONS SLOTS

Adapter cards increase the functionality of a computer by adding controllers for specific devices or by replacing malfunctioning ports. Figure 1 shows several types of adapter cards, many of which can be integrated into the motherboard. These are some common adapter cards that are used to expand and customize the capability of a computer:

Adapter Cards

Sound Adapter

NIC

RAID Adapter

Video Adapter

• Network Interface Card (NIC) - Connects a computer to a network using a network cable.

• Wireless NIC - Connects a computer to a network using radio frequencies.

• Sound adapter - Provides audio capability.

• Video adapter - Provides graphic capability.

- Capture card - Sends a video signal to a computer so that the signal can be recorded to the computer hard drive with Video Capture software.

- TV tuner card - Provides the ability to watch and record television signals on a PC by connecting a cable television, satellite, or antenna to the installed tuner card.

- Modem adapter - Connects a computer to the Internet using a phone line.

- Small Computer System Interface (SCSI) adapter - Connects SCSI devices, such as hard drives or tape drives, to a computer.

- Redundant Array of Independent Disks (RAID) adapter- Connects multiple hard drives to a computer to provide redundancy and to improve performance.

- Universal Serial Bus (USB) port - Connects a computer to peripheral devices.

- Parallel port - Connects a computer to peripheral devices.

- Serial port - Connects a computer to peripheral devices.

Computers have expansion slots on the motherboard to install adapter cards. The type of adapter card connector must match the expansion slot. The different types of expansion slots are shown below.
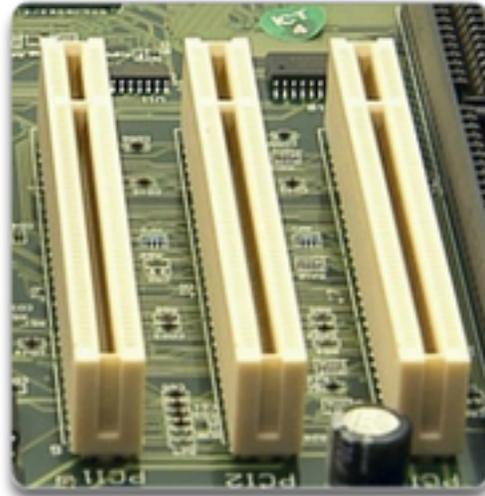
Expansion Slots

PCI

AGP

PCIe

ISA

EISA

MCA

PCI-X

Mini PCI

Peripheral Component Interconnect is a 32-bit or 64-bit expansion slot. PCI is the standard slot currently used in most computers.

Expansion Slots

PCI

AGP

PCIe

ISA

EISA

MCA

PCI-X

Mini PCI

AGP is designed to be used by video adapters. Advancements in the specification for AGP allow for bandwidth increases. The bandwidth of the port can be multiplied 2X, 4X, or 8X.

Expansion Slots

PCI

AGP

PCIe

ISA

EISA

MCA

PCI-X

Mini PCI

PCI Express is a serial bus expansion slot. PCIe has x1, x4, x8, and x16 slots. PCIe is replacing AGP as an explansion slot for video adapters and can be used for other types of adapters.

Expansion Slots

PCI

AGP

PCIe

ISA

EISA

MCA

PCI-X

Mini PCI

Industry Standard Architecture is an 8-bit or 16-bit expansion slot. This is older technology and is seldom used.
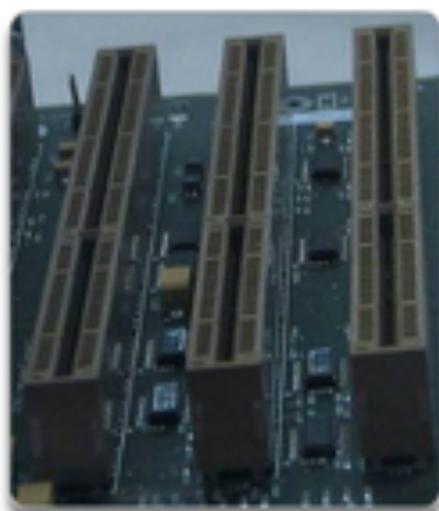
Expansion Slots

PCI
AGP
PCIe
ISA
EISA
MCA
PCI-X
Mini PCI

Extended Industry Standard Architecture is a 32-bit expansion slot. This is older technology and is seldom used.
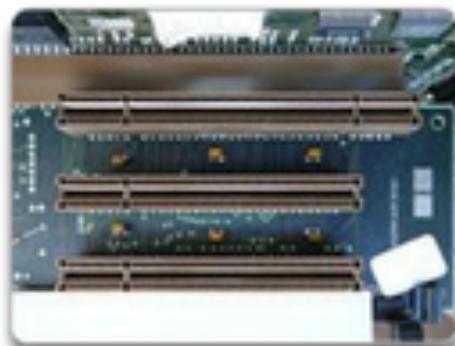
Expansion Slots

PCI
AGP
PCIe
ISA
EISA
MCA
PCI-X
Mini PCI

Microchannel Architecture is an IBM-proprietary 32-bit expansion slot. This is older technology and is seldom used.

Expansion Slots

PCI

AGP

PCIe

ISA

EISA

MCA

PCI-X

Mini PCI

PCI-Extended is a 32-bit bus with higher bandwidth than the PCI bus. PCI-X can run up to four times faster than PCI.

Expansion Slots

PCI

AGP

PCIe

ISA

EISA

MCA

PCI-X

Mini PCI

Mini PCI is a 32-bit bus used by laptops. Mini PCI has three different form factors, Type I, Type II, and Type III.

A riser card was used in computer systems with the LPX form factor to allow adapter cards to be installed horizontally. The riser card was mainly used in slim-line desktop computers.

Communications and Networking Riser (CNR) is a special slot used for some networking or audio expansion cards. The CNR is not in use any more because many of the functions of the CNR are now found on-board the motherboard.

STORAGE DEVICES

Storage drives, as shown in Figure 1, read information from or write information to magnetic, optical, or semiconductor storage media. The drive can be used to store data permanently or to retrieve information from a media disk. Storage drives can be installed inside the computer case, such as a hard drive. For portability,

Storage Drives

Floppy Drive

Hard Drive

Optical Drive

External Flash Drive

some storage drives can connect to the computer using a USB port, a FireWire port, eSATA, or a SCSI port. These portable storage drives are sometimes referred to as removable drives and can be used on multiple computers. Here are some common types of storage drives:

- Floppy drive

- Hard drive

- Optical drive

- Flash drive

Floppy Drive

A floppy drive, or floppy disk drive, is a storage device that uses removable 3.5-inch floppy disks. These magnetic floppy disks can store 720 KB or 1.44 MB of data. In a computer, the floppy drive is usually configured as the A: drive. The floppy drive can be used to boot the computer if it contains a bootable floppy disk. A 5.25-inch floppy drive is older technology and is seldom used.

Hard Drive

A hard drive, or hard disk drive, is a magnetic device used to store data. In a Windows computer, the hard drive is usually configured as the C: drive and contains the operating system and applications. The storage capacity of a hard drive ranges from gigabytes (GB) to terabytes (TB). The speed of a hard drive is measured in revolutions per minute (RPM). This is how fast the spindle turns the platters that hold data. The faster the spindle speed, the faster a hard drive can retrieve data from the platters. Common hard drive spindle speeds include 5400, 7200, 10,000, and up to 15,000 RPM in high-end server hard drives. Multiple hard drives can be added to increase storage capacity.

Traditional hard drives use magnetic-based storage. Magnetic hard drives have drive motors that are designed to spin the magnetic platters and move the drive heads. In contrast, the newer solid state drives (SSDs) do not have moving parts and use semiconductors to store data. Because an SSD has no drive motors and moving parts, it uses much less energy than a magnetic hard drive. Nonvolatile flash memory chips manage all storage on an SSD, which results in faster access to data, higher reliability, and reduced power usage. SSDs have the same form factor as magnetic hard drives and use ATA or SATA interfaces. You can replace a magnetic drive with an SSD.

Tape Drive

Magnetic tapes are most often used for backups or archiving data. The tape uses a

magnetic read/write head. Although data retrieval using a tape drive can be fast, locating specific data is slow because the tape must be wound on a reel until the data is found. Common tape capacities vary between a few gigabytes to many terabytes.

Optical Drive
An optical drive uses lasers to read data on the optical media. There are three types of optical drives:

- Compact disc (CD)

- Digital versatile disc (DVD)

- Blu-ray disc (BD)

CD, DVD, and BD media can be pre-recorded (read only), recordable (write once), or re-recordable (read and write multiple times). CDs have a data storage capacity of approximately 700 MB. DVDs have a data storage capacity of approximately 4.7 GB on a single-layer disc, and approximately 8.5 GB on a dual-layer disc. BDs have a storage capacity of 25 GB on a single-layer disc, and 50 GB on a dual-layer disc.
There are several types of optical media:

- CD-ROM - CD read-only memory media that is pre-recorded

- CD-R - CD recordable media that can be recorded one time

- CD-RW - CD rewritable media that can be recorded, erased, and re-recorded

- DVD-ROM - DVD read-only memory media that is pre-recorded

- DVD-RAM - DVD RAM media that can be recorded, erased, and re-recorded

- DVD+/-R - DVD recordable media that can be recorded one time

- DVD+/-RW - DVD rewritable media that can be recorded, erased, and re-recorded

- BD-ROM - Blu-ray read-only media that is pre-recorded with movies, games, or software

- BD-R - Blu-ray recordable media that can record high-definition (HD) video and PC data storage one time

- BD-RE - Blu-ray rewritable format for HD video recording and PC data storage

External Flash Drive
An external flash drive, also known as a thumb drive, is a removable storage device that connects to a USB port. An external flash drive uses the same type of nonvolatile memory chips as SSDs and does not require power to maintain the data. These drives can be accessed by the operating system in the same way that other types of drives are accessed.

Types of Drive Interfaces
Hard drives and optical drives are manufactured with different interfaces that are used to connect the drive to the computer. To install a storage drive in a computer, the connection interface on the drive must be the same as the controller on the motherboard. Here are some common drive interfaces:

- IDE - Integrated Drive Electronics, also called Advanced Technology Attachment (ATA), is an early drive controller interface that connects computers and hard disk drives. An IDE interface uses a 40-pin connector.

- EIDE - Enhanced Integrated Drive Electronics, also called ATA-2, is an updated version of the IDE drive controller interface. EIDE supports hard drives larger than 512 MB, enables Direct Memory Access (DMA) for speed, and uses the AT Attachment Packet Interface (ATAPI) to accommodate optical drives and tape drives on the EIDE bus. An EIDE interface uses a 40-pin connector.

- PATA - Parallel ATA refers to the parallel version of the ATA drive controller interface.

- SATA - Serial ATA refers to the serial version of the ATA drive controller interface. A SATA interface uses a 7-pin data connector.

- eSATA - External Serial ATA provides a hot-swappable, external interface for SATA

drives. Hot-swapping is the ability to connect and disconnect a device while a computer is powered on. The eSATA interface connects an external SATA drive using a 7-pin connector. The cable can be up to 6.56 ft (2 m) in length.

- **SCSI** - Small Computer System Interface is a drive controller interface that can connect up to 15 drives. SCSI can connect both internal and external drives. An SCSI interface uses a 25-pin, 50-pin, or 68-pin connector.

RAID provides a way to store data across multiple hard disks for redundancy. To the operating system, RAID appears as one logical disk. The chart shows a comparison of the different RAID levels. The following terms describe how RAID stores data on the various disks:

- **Parity** - Detects data errors.

- **Striping** - Writes data across multiple drives.

- **Mirroring** - Stores duplicate data on a second drive.

RAID Level Comparison

| RAID Level	Min # of Drives	Description	Advantages	Disadvantages
0	2	Data striping without redundancy	Highest performance	No data protection, failure of one drive results in all loss of all data
1	2	Disk mirroring	High performance, high data protection because all data is duplicated	High cost of implementation because an additional drive of equal or larger capacity is required
2	2	Error-Correcting Coding	This level is no longer used	Same performance can be achieved at a lower cost using RAID 3
3	3	Byte-level data striping with dedicated parity	For large, sequential data requests	Does not support multiple, simultaneous read and write requests
4	3	Block-level data striping with dedicated parity	Supports multiple read requests, if a disk fails the dedicated parity disk is used to create a replacement disk	Write requests are bottlenecked due to the dedicated parity drive
5	3	Combination of data striping and parity	• Supports multiple simultaneous reads and writes • Data is written across all drives with parity • Data can be rebuilt from information found on the other drives	Write performance is slower than RAID 0 and 1
6	4	Independent Data Disks with Double Parity	Block-level striping with parity data distributed across all disks, can handle two simultaneous drive failures	Lower performance than RAID 5, not supported on all disk controllers
RAID 0+1	4	Combination of data striping and mirroring	High performance, highest data protection	High cost overhead because duplication of data requires twice the storage capacity
10	4 (must be even number)	Mirrored set in a striped set	Provides fault tolerance and improved performance	High cost overhead because duplication of data requires twice the storage capacity

INTERNAL CABLES

Drives require both a power cable and a data cable. A power supply might have SATA power connectors for SATA drives, Molex power connectors for PATA drives, and Berg connectors for floppy drives. The buttons and the LED lights on the front of the case connect to the motherboard with the front panel cables.

Data cables connect drives to the drive controller, which is located on an adapter card or on the motherboard. Here are some common types of data cables:

Internal PC Cables

SATA data cable

FDD data cable

PATA 80-conductor data cable

- Floppy disk drive (FDD) data cable - Has up to two 34-pin drive connectors and one 34-pin connector for the drive controller.

- PATA (IDE/EIDE) 40-conductor data cable - Originally, the IDE interface supported two devices on a single controller. With the introduction of Extended IDE, two controllers capable of supporting two devices each were introduced. The 40-conductor ribbon cable uses 40-pin connectors. The cable has two connectors for the drives and one connector for the controller.

- PATA (EIDE) 80-conductor data cable - As the data rates available over the EIDE interface increased, the chance of data corruption during transmission increased. An 80-conductor cable was introduced for devices transmitting at 33.3 MB/s and over, allowing for a more reliable balanced data transmission. The 80-conductor cable uses 40-pin connectors.

- SATA data cable - This cable has seven conductors, one keyed connector for the drive, and one keyed connector for the drive controller.

- SCSI data cable - There are three types of SCSI data cables. A narrow SCSI data cable
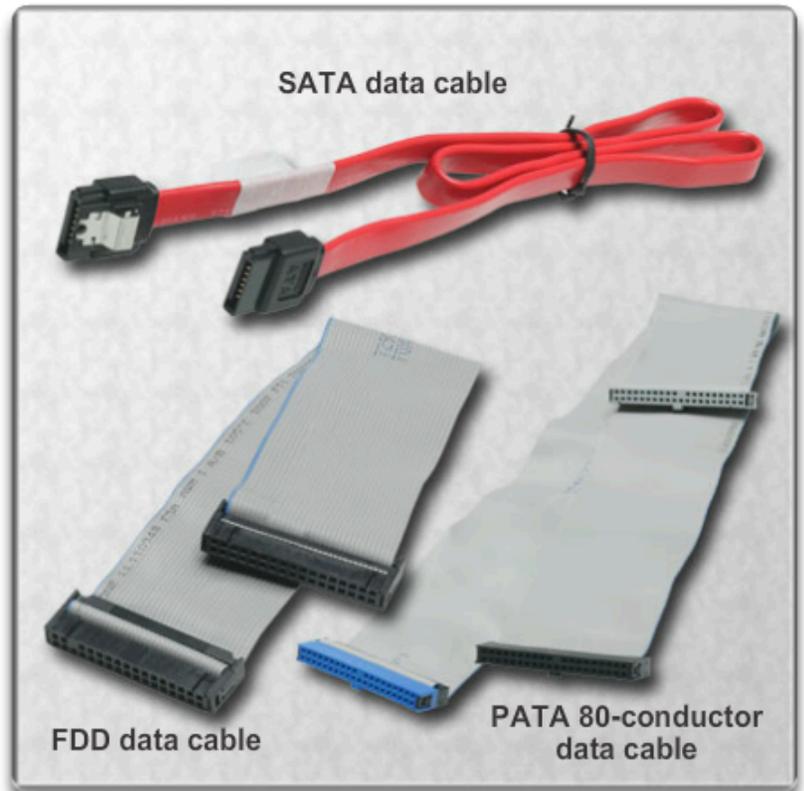
has 50 conductors, up to seven 50-pin connectors for drives, and one 50-pin connector for the drive controller, also called the host adapter. A wide SCSI data cable has 68 conductors, up to 15 68-pin connectors for drives, and one 68-pin connector for the host adapter. An Alt-4 SCSI data cable has 80 conductors, up to 15 80-pin connectors for drives, and one 80-pin connector for the host adapter.

NOTE: A colored stripe on a floppy or PATA cable identifies Pin 1 on the cable. When installing a data cable, always ensure that Pin 1 on the cable aligns with Pin 1 on the drive or drive controller. Keyed cables can be connected only one way to the drive and drive controller.