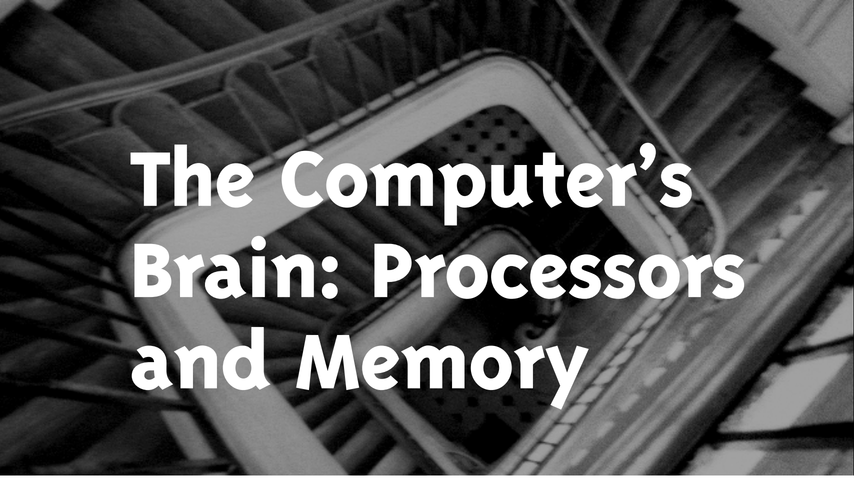


# The Computer's Brain: Processors and Memory

# 1

**pro•cess** *v* : to complete a series of actions

Every computer consists of a microprocessor and memory. Without the two, the computer would not function. The microprocessor, commonly referred to as the Central Processing Unit (CPU), is the brain of the computer. Like the human brain, the CPU is responsible for managing the timing of each operation and carrying out the instructions or commands from an application or the operating system.

The CPU uses memory as a place to store or retrieve information. Memory comes in several forms, such as random access memory (RAM) and read-only memory (ROM). Memory provides a temporary location for storing information and contains more permanent system configuration information. This chapter provides an overview of these topics related to microprocessors and memory:

- Processor performance
- Processor types
- History and evolution of Intel processors
- Intel's competition—AMD, Cyrix, PowerPC, and Alpha
- Multiprocessor computers
- Physical memory
- Bus architecture and bus types

# Processor Performance

The most central component to the computer is the processor. It is responsible for executing the instructions that are given to the computer. The processor determines the operating systems you can use, the software applications you can run on the computer, and the computer's stability and performance. It is also typically one of the major factors in computer cost. Computers that contain newer and powerful processors are more expensive than computers with less complex processors. This has led processor manufacturers to offer several different lines of processors for the home user, business workstation, and server markets.

The goal of processor performance is to make applications run faster. Performance is commonly defined by how long it takes for a specific task to be executed. Traditionally, processor performance has been defined as how many instructions can be completed in each clock cycle, or instructions per clock (IPC) times the number of clock cycles. Thus, performance is measured as:

IPC × Frequency

**single-edge cartridge (SEC)**
An advanced packaging scheme that the Intel Pentium II and later models use. The processor is encased in a cartridge module with a single edge that plugs into a 242-pin slot on the system board, much as an expansion card plugs into the system board.

**motherboard**
The main board in a computer that manages communication between devices internally and externally.

**Central Processing Unit (CPU)**
The microprocessor, or brain, of the computer. It uses logic to perform mathematical operations that are used in the manipulation of data.

# Processor Types: A First Look

So many types of computer processors, also referred to as microprocessors, are on the market today that it can be quite confusing to wade through them all. All processors are not created equal, and each processor has its own characteristics that make it unique. For instance, a processor that is built around an architecture common to other processors of the same time period may actually operate at double or triple the speed. Fierce competition among the various chip makers lays the groundwork for new technological innovations and constant improvements.

The most obvious difference among processors is the physical appearance of the chips, meaning that many processors differ noticeably from one another in size and shape. The first processor that Intel released was packaged in a small chip that contained two rows of 20 pins each. As processor technology improved, the shape and packaging scheme of the processor also changed. Modern processors, such as the Intel Pentium 4 class processors, use an advanced packaging scheme in which the processor is encased in a **single-edge cartridge (SEC)** module that plugs into a slot on the **motherboard**. Much like an expansion card that easily plugs into the motherboard, the SEC module can easily be removed and upgraded. This design also reduces the cost involved in producing the **CPU**.

Another noticeable difference among processors is the type of instruction set they use. The instruction sets that are most common to processors are either **Complex Instruction Set Computing (CISC)** or **Reduced Instruction Set Computing (RISC)**.

CISC has been a common method of processing operations, especially in Intel CPUs. CISC uses a set of commands, which include subcommands that require additional CPU memory and time to process. Each command must go through a decode unit, located inside the CPU, to be broken down into **microcode**. The microcode is then processed one microcode at a time, which slows computing.

RISC, on the other hand, uses smaller commands that enable it to operate at higher speeds. The smaller commands work directly with microcode, so there is no need for a decode unit. This factor—along with a RISC chip's capability to execute multiple commands simultaneously—dramatically increases the processing power.

Finally, different manufacturers design processors to varying specifications. You should be sure that the processor type and model you choose are compatible with the operating system that you want to use. If the processor is not 100 percent compatible with the operating system, the computer will not operate at its best or might not work at all.

**NOTE**

The terms processor, microprocessor, chip, and CPU are used interchangeably.

## Deciphering Processor Terminology

For most computer novices, terms such as *microcode efficiency* and *internal cache RAM* can sound like part of a foreign language. To help you keep things straight, here are some common terms and their definitions:

**Clock cycles** The internal speed of a computer or processor expressed in **megahertz (MHz)** or **gigahertz (GHz)**. The faster the clock speed, the faster the computer performs a specific operation.

**CPU speed** The number of operations that are processed in one second.

**Data path** The number of **bits** that can be transported into the processor chip during one operation.

**Floating Point Unit (FPU), or math coprocessor** A secondary processor that speeds operations by taking over math calculations of decimal numbers. Also called a numeric processor.

**Complex Instruction Set Computing (CISC)**
A full complement of instructions used by a processor to complete tasks such as mathematical calculations. Used in the most common type of processors produced; Intel processors are currently based on this standard.

**Reduced Instruction Set Computing (RISC)**
A reduced set of instructions used by a processor. PowerPC and Alpha processors are manufactured using this standard. The reduced instruction set enables a microprocessor to operate at higher speeds.

**microcode**
The smallest form of an instruction in a CPU.

**megahertz (MHz)**
One million cycles per second. The internal clock speed of a microprocessor is expressed in MHz.

**gigahertz (GHz)**
One billion cycles per second. The internal clock speed of a microprocessor is expressed in GHz.

**bit**
A binary digit. The digit is the smallest unit of information and represents either an off state (zero) or an on state (one).

**Level 1 (L1), or internal, cache** Memory in the CPU that is used to temporarily store instructions and data while they are waiting to be processed. One of the distinguishing features of different processors is the amount of internal cache that is supported.

**Level 2 (L2), or backside, cache** Memory that is used by the CPU to temporarily store data that is waiting to be processed. Originally located on the motherboard, CPU architectures such as the Pentium II, III, and 4 have incorporated L2 cache directly on the same board as the CPU. The CPU can access the on-board L2 cache two to four times faster than it can access the L2 cache on the motherboard.

**Microcode efficiency** The capability of a CPU to process microcode in a manner that uses the least amount of time and completes the greatest number of operations.

**Word size** The largest number in bits that can be processed during one operation.

**NOTE**

All the computer's components, including the processor, are installed on the motherboard. This fiberglass sheet is designed for a specific type of CPU. When purchasing a motherboard, you should check with the motherboard manufacturer to determine which types of CPUs are supported.

# The Intel Processor Lineup

Over time, Intel has introduced several generations of microprocessors. Each processor type is referred to as a generation; each is based on the new technological enhancements of the day. With each product release come new software and hardware products to take advantage of the new technology.

Several generations of Intel processors are available today. Since the arrival of the first Intel chip in the IBM PC, Intel has dominated the market. It seems that every time you turn around, a new chip promises greater performance and processing capabilities than the previous one.

What makes Intel the market leader is its ability to bring the newest innovations in chip technology to the public, usually before its competitors, who are not far behind. Competition is fierce, and each manufacturer attempts to improve on the designs of the others, releasing similar chips that promise better performance.

The following table shows the specifications for the Intel processors issued to date. You should read the specifications and reviews of each processor to understand its capabilities and reliability.

| Model | Year Introduced | Maximum Internal Clock Frequency | Data Path (in Bits) |
|---|---|---|---|
| 4004 | 1971 | .108MHz | 4 |
| 8008 | 1972 | .2MHz | 8 |
| 8080 | 1974 | 2MHz | 8 |
| 8086 | 1978 | 8MHz | 16 |
| 8088 | 1979 | 4.77MHz | 8 |
| 80286 | 1982 | 20MHz | 16 |
| 80386 | 1985 | 40MHz | 32 |
| 80486 | 1989 | 100MHz | 32 |
| Pentium | 1993 | 200MHz | 32 |
| Pentium Pro | 1995 | 200MHz | 32 |
| Pentium MMX | 1997 | 233MHz | 32 |
| Pentium II | 1997 | 450MHz | 64 |
| Pentium II Xeon | 1998 | 450MHz | 64 |
| Celeron | 1998 | 500MHz | 64 |
| Pentium III | 1999 | 733MHz | 64 |
| Pentium III Xeon | 1999 | 550MHz | 64 |
| Itanium | 2000 | 800MHz | 64 |
| Tualatin | 2001 | 1.2GHz | 64 |
| Pentium 4 | 2000 | 2.2GHz | 64 |

## Factors Affecting Performance

Many factors come together to determine the performance of any computer. All other factors being equal, faster components will give better performance, but any computer will be limited by its "weakest links." As an analogy, consider that putting a larger engine in a standard automobile will make it faster, but only if the automobile is going in a straight line. As soon as you try to make the car follow a twisting road, other components such as the drivetrain and the tires can limit the performance of the larger engine.

Within a processor family, faster processors will outperform slower processors. But when we're comparing processors from different families, that rule does not apply. For example, the rating of 400MHz for a processor from one family does not indicate that it will run significantly faster than a 333MHz processor from a more advanced processor family.

As you learned earlier, clock cycles and data path are two factors that can influence the performance of your computer. Other factors are:

**Cache memory** Very fast memory that sits between the CPU and the main RAM. Cache memory can be as fast as 5 to 10 nanoseconds, whereas main RAM is usually not faster than 60 to 70 nanoseconds. (Yes, a lower number is better here because it indicates that the memory takes less time to move data.)

**Bus speed** The rate at which data can be transferred between the CPU and the rest of the motherboard. Typical bus speeds are 733MHz and higher with the current standard for motherboards entering the market.

**NOTE**

The type of peripherals on your computer can affect system performance. If your application spends a lot of time accessing your hard disk, selecting a better-performing disk system would improve CPU efficiency. For example, Small Computer System Interface (SCSI) hard disks place a much smaller overhead burden on your CPU than Integrated Device Electronics (IDE) storage devices. Storage systems are covered in detail in Chapter 2, "Storing Your Files: Data Storage."

## History of Intel Chips

Intel released the world's first microprocessor, the Intel 4004, in 1971. It was a 4-bit microprocessor containing a programmable controller chip that could process 45 instructions. The 4 bits meant that the chip had four lines for data to travel on, much like a four-lane highway. Because of its limitations, it was implemented only in a few early video games and some other devices. The following year, Intel released the 8008, an 8-bit microprocessor with enhanced memory storage and the capability to process 48 instructions.

Intel then began to research and develop faster, more capable processors. From that research emerged the 8080, which could process instructions 10 times faster than its predecessors. Although the speed had dramatically improved, it was still limited by the number of instructions it could process. Finally, in 1978, Intel broke many barriers by releasing the first of many computer-ready microprocessors, the 8086. The 8086 was a breakthrough technology with a bus speed of 16 bits and the capability to support and use 1MB of RAM. Unfortunately, the cost of manufacturing such a chip and compatible 16-bit components made the chip unaffordable. Intel responded the following year with the production of an 8-bit chip, the 8088.

Intel continued to break new ground as the release of each new generation of processor offered improved functions and processing capabilities. The most dramatic improvement was the number of instructions, based on a scale of millions, that the processor could process in one second. This rate, referred to as **millions of instructions per second (MIPS)**, ranges from 0.75MIPS for the 8088 to over 450MIPS for Pentium 4 processors.

**millions of instructions per second (MIPS)**
A measurement of the number of microcode instructions that a CPU or microprocessor can complete in one second, or cycle.

The second most dramatic improvement was the speed of the internal clock, measured in megahertz. All processors are driven by an internal clock mechanism that keeps the rhythm of the chip, much like the rhythm of a heartbeat. The faster the speed of the internal clock, the faster the processor can process instructions. Intel continued to increase the speed of the internal clock from 4.77MHz for the original 8088 to more than 2.2GHz for the newest generation of Intel microprocessors.

## The First Generation: 8086 and 8088

The first major processor release from Intel was the 8086 microprocessor. The processor debuted as the first evolutionary step in a multitude of processors, each improving on the design of the original 8086. The lineage is referred to as the *x*86 family of microprocessors. Although this first release was crude compared to today's standards, it paved the way for the others to follow.

The 8088 was released a short time after the 8086 but was not as powerful as its predecessor. The 8086, a true 16-bit processor, contained 16-bit registers and a 16-bit data path. Motherboard technology had not quite reached the 16-bit level and was still costly in 1981. IBM decided to use a version of the 8088 chip, with the same design but with an 8-bit data path to accommodate the widely used 8-bit technology of the time.

## The Second Generation: 80286

Intel forged a new milestone in PC processor technology with the release of the 80286, more commonly called the 286. The 286 offered a significant performance increase over the 8086 and 8088 with the unique capability to operate in a **protected mode**. The protected mode enabled the processor to **multitask** and still included its normal, or real, mode of operation.

**protected mode**
A mode available in Intel 80286 and 80386 processors. Added the capability for the processor to allocate each application its own separate memory space. In the event that an application crashed, the rest of the system was protected.

**multitask**
To perform several operations concurrently.

Real mode required memory to be accessed in a linear format. This means that data being sent to RAM had to be placed in the order it was received—one application after another. With this limitation, instructions were usually processed one at a time.

Protected mode enabled multitasking to occur by allocating a specific range within memory for each task. Applications could therefore be accessed simultaneously, greatly improving performance.

**transistor**
A microscopic electronic device that uses positive electrons to create the binary value of one, or "on," and negative electrons to create the binary value of zero, or "off." Modern CPUs have millions of transistors.

**conventional memory**
The first 640KB of memory, which is required by DOS to run. Memory above 640KB was used by operating systems such as Windows 3.1.

**DOS**
An operating system developed by Microsoft. DOS predominantly uses command lines to manage the operating system, applications, and files.

**Windows operating system**
An operating system developed by Microsoft that provides a graphical user interface (GUI) for DOS.

**NOTE**

Some companies produce upgrades for 286, 386, and 486 computers. The processor upgrades are relatively inexpensive and can greatly improve the overall CPU speed. Although 286 upgrades are nearly impossible to find, upgrades for 486-based computers are available. The processor upgrade can convert your aging 486 into a speedy computer, comparable to a Pentium.

## The Third Generation: 80386

Intel's introduction of the 80386 processor reached yet a new milestone, condensing more than 250,000 **transistors** onto a single 32-bit processor chip. (The number of transistors on a processor is an indicator of the complexity of the processor and of its ability to perform complex calculations.) This new generation of processors incorporated true, fully functioning multitasking capabilities. Protected mode was now commonly referred to as the 386 Enhanced Mode, because the 80386 was able to overcome the multitasking limitations of the 80286.

The 80386 included a new operating mode called Virtual Real Mode. This new mode created **conventional memory** space required by **DOS** programs to run within the **Windows operating system**. Virtual Real Mode, or Virtual DOS Mode as it is commonly called, is still used for running DOS-based games and applications within Windows 95 and 98.

**NOTE**

You will learn more about DOS and Windows operating systems in Chapter 5, "Desktop Operating Systems: A Comparison," and Chapter 6, "DOS 101: DOS Basics Every MCSA and MCSE Should Know."

Several types of 80386 chips were issued, each with a unique combination of features. Intel offered two options: the 80386DX and the 80386SX CPUs. Both were 32-bit processors, but the 80386DX used a 32-bit data path and the 80386SX used a 16-bit data path. Although the SX chip had smaller data paths, it was more competitively priced.

## The Fourth Generation: 80486

Like the 80386, the next family of processors was released in 80486SX and 80486DX versions. Both included a 32-bit internal and external data path and an original internal clock frequency of 33MHz. The SX version was released with the numeric processor, or FPU, disabled and the internal clock speed slowed to 20MHz to offer a lower-cost processor to the consumer. Later this became a limitation with the emergence of more powerful software applications. A numeric processor was issued to complement the SX, turning it into a fully functioning DX.

A dramatic improvement was engineered into later deployments of the processor. A mechanism called a clock doubler enabled the internal system clock to run at twice the normal bus speed. Soon the 486DX-33 became the 486DX2-66, with the *2* signifying the clock-doubling technology. Eventually the idea of increasing the clock speed led to a clock tripler.

## The Next Generations: The Pentium Family

Intel released the Pentium chip to take advantage of the newly released **Peripheral Component Interconnect (PCI) bus architecture**. The new processor also consisted of 3.1 million transistors and a new 64-bit data path. The chip was originally designed to operate at 66MHz but was scaled down to 60MHz to support the new transistor design, which was experiencing heat and power problems. The first chips deployed also suffered from a bug in the microcode that hampered the processor's capability to calculate complex mathematical equations with precision. This problem was immediately fixed through a new batch of chips.

The most significant development in the Pentium was the use of two parallel 32-bit **pipeline**s that enabled it to execute twice the number of instructions as previous Intel processors—a technological advancement that Intel named superscalar technology. Almost all processors today use this technology.

**Peripheral Component Interconnect (PCI)**
A bus standard for the transfer of data between the CPU, expansion cards, and RAM. PCI communicates at 33MHz.

**bus architecture**
Any linear pathway on which electrical signals travel and carry data from a source to a destination.

**pipeline**
A place in the processor where operations occur in a series of stages. The operation is not complete until it has passed through all stages.

Released with the Pentium family of processors was **Multimedia Extension (MMX)** technology. MMX technology is often referred to as multimedia-enhanced technology, but this is not completely accurate. MMX-equipped processors contained additional instruction code sets that increased the processing speed for audio, video, and graphical data by up to 60 percent as compared to traditional Pentium processors. The MMX chips dramatically improved the response time of games and multimedia-based applications.

**Multimedia Extension (MMX)**
A processor technology that dramatically improves the response time of games and multimedia-based applications. The technology was introduced through the MMX-equipped line of Intel Pentium chips.

The types of Pentium processors include:

- Pentium
- Pentium MMX
- Pentium Pro
- Pentium II (PII)
- Celeron
- Pentium II Xeon
- Pentium III (PIII)
- Pentium III Xeon
- Itanium/Itanium 2
- Pentium 4
- Tualatin

## Pentium

The Pentium chip introduced the world to the first parallel 32-bit data path, which enabled the Pentium to process 64 bits—twice as much data as before. The Pentium was the first microprocessor chip designed to work with the PCI bus specification and had internal clock speeds ranging from 60MHz to 200MHz.

## Pentium MMX

The Pentium with MMX technology included an expanded instruction code set with 57 new MMX microcode instructions. MMX enabled the microprocessor to increase the processing speed of audio, video, and graphics by up to 60 percent.

## Pentium Pro

The Pentium Pro was the successor to Intel's Pentium processor. One of the unique features of this microprocessor was its internal RISC architecture with CISC-RISC translator service. The translator service was able to use the CISC set of instructions, common to all Intel chips, convert them to the RISC set, the faster of the two, and then complete the tasks as necessary using RISC.

The architectural enhancement that really distinguished the Pro from the original Pentium would influence how most microprocessors would later be developed. The Pro was two chips in one: On the bottom of the Pentium was the actual processor. Connected directly overhead of the processor was an L2 cache. By placing the L2 cache close to the processor, Intel was able to greatly increase the performance of the Pentium Pro.

## Pentium II (PII)

The Intel Pentium II, or PII, processor is essentially an enhanced Pentium Pro processor with MMX extensions, cache memory, and a new interface design. The PII was designed to fit into an SEC that plugs into a 242-pin slot.

## Celeron

The only noticeable difference between the Celeron and regular Pentium II processors is the lack of cache memory within its cartridge. Later models of the Celeron include cache memory on the same chip as the processor.

## Pentium II Xeon

One of the major enhancements in the Pentium II Xeon is larger on-board cache. This processor is available with either 1MB or 2MB of L2 cache and a clock rate of 450MHz.

## Pentium III (PIII)

With its faster clock rates (up to 733MHz), the Pentium III supports demanding applications such as full-screen, full-motion video and realistic graphics. Seventy new instructions have also been added to make technologies such as 3-D graphics, video, speech, and imaging faster and more affordable for mainstream users. Each Pentium III also contains a unique processor serial number. Intel's intent behind this feature was to enhance system security and asset tracking. However, many individuals object to the serial number as infringement on their privacy because it can be used to identify computers on the Internet.

## Pentium III Xeon

The Pentium III Xeon processor challenges RISC-based servers in both price/performance and raw performance. It is available in speeds of up to 550MHz and supports configurations that have more than one processor in the same box.

## Itanium/Itanium 2

Previously known by the code name Merced, the Itanium processor employs a 64-bit architecture and enhanced instruction handling to greatly increase the performance of computational and multimedia operations, and supports clock speeds of up to 800MHz. The Itanium 2 processor uses a 128-bit architecture and supports speeds of 900MHz and 1GHz.

## Pentium 4

The latest family of Intel processors is the Pentium 4, which have been marketed to the advanced desktop market. The architectural changes allow the processor to increase performance by processing more instructions per clock cycle. This technology is referred to as Hyper Pipeline and allows for 20 pipeline stages as opposed to 10 pipeline stages used in the Pentium III family. Other enhancements are added through NetBurst technology, which includes such features as improved L1 and L2 caches and the Rapid Execution Engine. Current Pentium 4 processors can support speeds of up to 2.53GHz.

## Tualatin

The Tualatin processor was originally designed to be a logical progression to the Pentium III family. However, as the schedule for this processor slipped, Intel shifted focus to the Pentium 4 processor family. As a result, the Tualatin processor was not released until mid-2001. The Tualatin processors support speeds of up to 1.2GHz.

**WARNING**

Even though the Tualatin processor appears to be compliant with Socket 370, the clocking, voltage, and signal levels it uses make it incompatible with existing Pentium III motherboards.

**NOTE**

Although most of us would like to get our hands on the new high-speed processors, the reality is that it will be a while before they are affordable. Also, to really reap the benefits of those high-speed CPUs, computers will need to have equivalently high-powered hardware. That is why you will see the first high-speed high CPUs only in expensive servers.

# Stacking Up the Competition

Many manufacturers are competing with Intel to produce microprocessor chips. For many years, Intel's competitors produced clone copies of its chips, often slightly altering the original design to allow for faster processing speeds. A good example of this was the release by Advanced Micro Devices (AMD) of a 40MHz version of the 386 processor to rival the 33MHz version that Intel was producing. Non-Intel, or clone, chips became popular because of the cheaper price and improved features.

**Hardware Compatibility List (HCL)**
Provided by Microsoft, the HCL lists all hardware that has been tested by Microsoft and has proved to work with a particular operating system. Hardware not on the HCL might work, but is not certain to.

In addition to clone chips, other manufacturers have produced powerful processors that are not based on Intel architecture. Digital Equipment Corporation (DEC), Sun Microsystems, IBM, and Motorola have all produced powerful CPUs. Most of these chips are RISC-based CPUs designed to meet two needs: First, RISC-type chips could meet the powerful speed demands of Unix workstations; second, companies wanted to differentiate themselves from Intel to increase sales.

When Intel released the Pentium generation of processors, the clone manufacturers adopted their own unique naming conventions that steered away from the path that Intel laid with this new release. Intel at the same time was experiencing problems with the early release of its Pentium line, with the discovery of a high-level mathematical division problem. Intel's competitors took advantage of the opportunity by releasing their chips to compete with the Pentium processor.

The subsections that follow provide an overview of these processors:

- AMD
- Cyrix
- PowerPC
- Alpha

**WARNING**

Be sure to check the Microsoft Hardware Compatibility List (HCL) before attempting to buy non-Intel processors.

## Advanced Micro Devices (AMD)

In 1996, AMD introduced the K5 to combat the already released Intel Pentium processor. The K5 was released in a 64-bit version as a follow-up to the earlier K5x86, which resembled a higher-performance 486-based processor. The performance of the K5 equals the Pentium at a reduced cost to the consumer.

AMD soon followed the K5 generation with the release of the K6 processor. The K6 offers a boost by accelerating the audio, video, and 3-D capabilities of the chip in processing software, and adding MMX technology to compete with the Celeron, Pentium II, and Pentium III.

**Basic Input/Output System (BIOS)**
Software located in a ROM chip that is responsible for communicating directly between the computer hardware and the operating system.

In addition to competing with the latest PC processors equipped with MMX technology, the AMD K6 offers a bigger "bang for the buck." The AMD K6 processors still plug into standard motherboards by using current technology with chipset and **Basic Input/Output System (BIOS)** support, without the need for special motherboards required by processors such as the Intel Pentium Pro and Pentium II models.

AMD's latest processor versions are the Athlon (formerly the K7) and the Duron. Unlike earlier AMD processors, these processors cannot be used with standard motherboards. Instead, these processors require a special Athlon- or Duron-compatible motherboard. One factor that sets these chips apart from their Intel and Cyrix counterparts is that they use RISC technology. By using the reduced instruction set, they are able to process instructions at a more rapid rate. This capability and other improved implementations in design enable these chips to often outperform their Intel counterparts.

**NOTE**

The Athlon family of processors is geared toward workstations and servers, while the Duron family of processors is geared toward lower-end business and home users.

## Cyrix

Cyrix introduced a rival to the Intel Pentium processor in 1995. The first generation of its non-clone processor was named the MI 6x86 series. Although early releases of the MI encountered heat-related issues, Cyrix resolved the issues and produced a model that did not suffer from the initial design problem. The improved chip offered lower power consumption requirements that enabled the chip to operate at cooler temperatures.

Although the chip was originally designed to rival the Pentium, it included additional features found in the Intel Pentium Pro. One of the important features of the MI processor was the capability to predict the next instruction to process before encountering it, thereby considerably boosting processor performance.

A follow-up to the MI series of processors was the MII series, a direct competitor with the Celeron and Pentium II CPUs. The improved design included additional optimization, enabling instructions to be processed faster than by other processors. The MII processors' improved capabilities were overshadowed by incompatibilities with software that made them unable to take full advantage of the improved timing. Cyrix has since released software utilities and patches to address the timing issues. The MII features a set of 57 new instructions that are fully compatible with industry-standard MMX software.

**Silicon-on-Insulator (SOI)**
The microchip manufacturing innovation that IBM invented. It is based on the capability to enhance silicon technology by reducing the time it takes to move electricity through a conductor.

## PowerPC

Apple, IBM, and Motorola developed the PowerPC as a new microprocessor technology. The PowerPC microprocessor uses RISC technology to produce a high processing rate. The innovative design of the PowerPC chip enables it to deliver high-performance computing power with lower power consumption than its counterparts.

The PowerPC chip is used in the IBM RS/6000 Unix-based workstation and in Apple Macintosh computers. Its design is much different from the traditional design of the Intel microprocessors. The term *PowerPC* refers to more than just a type of processor; it is also an architecture standard that outlines specifications by which manufacturers can design processors. The resulting designs that follow the specifications offer performance advantages and innovative manufacturing techniques such as those IBM created.

IBM developed one of the most significant changes in processor manufacturing, which it called **Silicon-on-Insulator (SOI)** technology. The PowerPC 750, marketed by Apple Computer as the G3, was the first chip released that used this new manufacturing method. SOI technology provided increased processor performance while using low power consumption. Low power consumption is the key to producing products such as handheld devices, which operate for long periods of time powered by a battery. Since the PowerPC 750, Motorola has released the PowerPC MPC 7400, which is more commonly known in Apple circles as the G4.

## Alpha

The Alpha is a high-speed microprocessor that DEC developed. The Alpha processor is typically found in workstations and servers that need more processing power than that found in Intel-based servers. Compaq, which has acquired DEC, has continued to enhance the speed and capabilities of the Alpha processor.

**WARNING**

Do not confuse the Alpha processor with the first line of DEC processors referred to as the Alpha, or **Virtual Address Extension (VAX)**. The Alpha processor is unique and is much more advanced than the VAX.

**Virtual Address Extension (VAX)**
The technology built by DEC to run the VMS platform computers.

One of the Alpha chip's selling points is that it is the only other chip besides the Intel *x*86 generations of processors that can run the Microsoft Windows NT operating system. Alpha-equipped workstations are often characterized as the fastest NT workstations on the planet. NT takes advantage of the Alpha's capability to produce or generate graphics up to eight times faster than Intel Pentium-based systems. Alpha chips are also commonly found in Unix workstations.

**Asymmetrical Multiprocessing (ASMP)**
A computer architecture that uses multiple CPUs to improve the performance of the computer. In the ASMP model, one CPU is dedicated to managing tasks (which usually involves managing the other CPUs) for the computer system. The remaining CPUs process user tasks.

**NOTE**

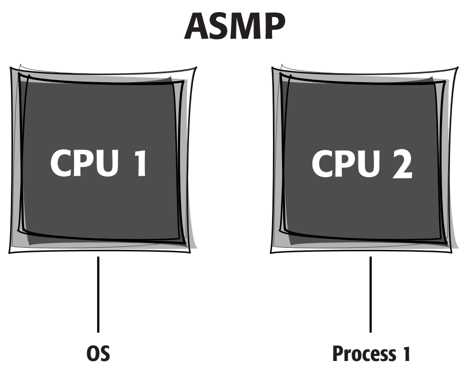
Although Microsoft and Compaq do not support Windows 2000, Windows XP, or Windows Server 2003 on the Alpha platform, other operating systems, including Compaq's version of Unix and Linux, are supported. Other manufacturers, such as Samsung, will also be producing servers and workstations running on the latest Alpha processors.

# Using Multiprocessor Computers

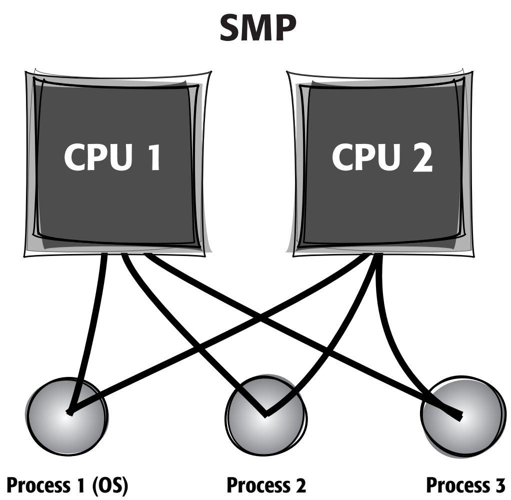
Multiprocessor computers can have more than one processor installed in them. Computers that contain more than one processor can scale to meet the needs of more demanding application programs. Microsoft Windows 2000, Windows XP Professional, and Windows Server 2003 are examples of operating systems that can use multiple processors.

There are two multiprocessing methods: **Asymmetrical Multiprocessing (ASMP)** and **Symmetrical Multiprocessing (SMP)**.

In ASMP, one processor is reserved to run the operating system and the **input/output (I/O)** devices. The second ASMP processor runs the application, including the other miscellaneous tasks that the first processor does not handle. This method is often inefficient, because one processor can become busier than the other.




In SMP, all tasks are shared equally. The tasks are split among each processor. The Microsoft Windows 2000, Windows XP Professional, and Windows Server 2003 operating systems support this multiprocessing method.




**Symmetrical Multiprocessing (SMP)**
A computer architecture that uses multiple CPUs to improve a computer's performance. As performance demands increase on an SMP-capable computer, additional CPUs can be added to boost performance. During operation, if one CPU is idle, it can be given any task to perform.

**input/output (I/O)**
Refers to any device or operation that enters data into or extracts data from a computer.

# Physical Memory

Memory is an important part of any computer's system. Memory is used in every function of a computer, and it can have a major effect on computer performance. If you are going to get the most out of your computer, you must understand the types of physical memory and how to select the type that is best suited to your computing needs.

**NOTE**

In Windows XP and Windows Server 2003, memory is more important than ever. The minimum requirement for Windows XP Professional is 64MB, and 128MB is recommended. Windows Server 2003 has a minimum requirement of 128MB, and 256MB recommended.

**random access memory (RAM)**
A temporary memory location that stores the operating system, applications, and files that are currently in use. The content in this type of memory is constantly changing. When you shut down the computer, all information in this type of memory is lost.

**read-only memory (ROM)**
A type of memory that has data pre-copied onto it. The data can only be read from and cannot be overwritten. ROM is used to store the BIOS software.

**power-on self-test (POST)**
A set of diagnostic tests that are used to determine the state of hardware installed in the computer. Some components that fail the POST, such as bad RAM or a disconnected keyboard, will prevent the computer from booting up properly.

Memory is basically a series of cells with an address. Each memory cell stores a small piece of information. And each memory cell is identified by a unique address so the processor knows where the cell resides and can easily access it. Computers use several types of memory, each serving a different purpose.

## Random Access Memory (RAM)

**Random access memory (RAM)**, often referred to as main memory, is a temporary type of memory that the computer uses as a work area. This type of memory is dynamic, meaning that it is constantly changing because of the activity of the processor. When you shut off the power to the computer, RAM loses everything stored in it. RAM stores program instructions and related data for the CPU to quickly access without having to extract data from a slower type of memory, such as the hard disk.

The hard disk and floppy disk are more permanent forms of data storage. Programs and their output data are stored on disks for future use. When you shut off the power to the computer, the data on the storage media is intact. Accessing data and program instructions from storage media can take over a hundred times longer than from RAM.

## Read-Only Memory (ROM)

**Read-only memory (ROM)** is a special type of memory in which data is written onto a chip during manufacturing. Information stored in ROM is permanent and cannot be changed. ROM stores the BIOS, the set of instructions a computer uses during the first stages of initialization. Without the BIOS, the computer would not have a mechanism to verify that the main hardware components are installed and functioning properly.

## RAM Types

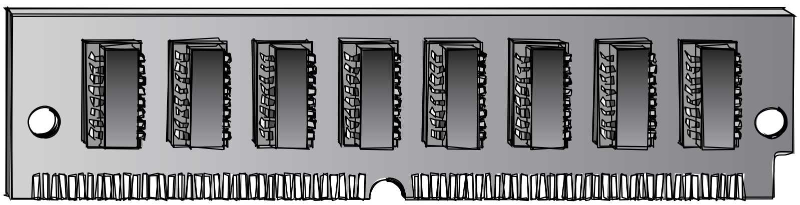
Every computer needs RAM, but which type? Not all types of RAM will work in a computer. Some physically won't fit in the RAM socket, and others will fit but won't work, preventing the computer from passing the **power-on self-test (POST)**.

Selecting the right type of RAM requires you to know your CPU type and motherboard. Some CPUs, such as the Pentium II, work only with motherboards designed for that chip. The motherboard is typically designed to meet the highest performance levels of a particular CPU and, therefore, determines which types of physical RAM can be used. RAM comes in one of two types: Single Inline Memory Modules (SIMMs) and Dual Inline Memory Modules (DIMMs).

**parity**
An extra bit found on some memory modules. Non-parity memory has 8 bits. Parity adds an extra bit that is used to keep track of the other 8 bits. This can help prevent memory errors and is recommended for use in servers.

## SIMMs

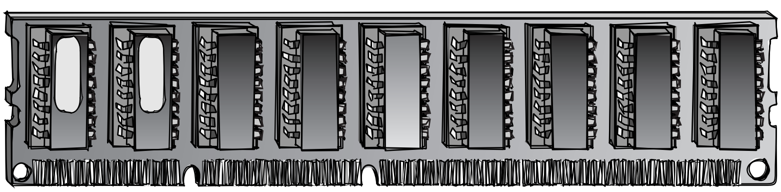
SIMMs are physically different from DIMMs. Older SIMMs were designed with 30 pins that connected to a slot in the motherboard. These modules were slow and typically had to be added in groups of two or four identical SIMMs to be recognized by the BIOS. The current model is a 72-pin SIMM. On motherboards designed for the Pentium processor, the SIMMs must be added in pairs.



72-pin SIMM

## DIMMs

DIMMs have 168 pins with a data path of either 64 bits for non-parity memory or 72 bits for **parity** memory. DIMMs have the largest data path of any memory module. The wider data path makes the chip as fast as the data path on the CPU. This means that the DIMMs can be added one at a time and in varying sizes. It is because of this improved performance and flexibility that DIMMs have become popular in today's personal computers.



168-pin DIMM

# RAM Speed

Identifying the type of RAM that will physically fit into your computer is only one part of the selection process. You also should consider the performance of the RAM you select. Two types of RAM to choose from include Extended Data Out (EDO) and Synchronous Dynamic RAM (SDRAM). Each offers improved performance over older models. Check with your computer manufacturer to see which type of RAM is supported on your computer.

## EDO RAM

EDO RAM uses dual-pipeline architecture that enables the unit to store data (write) at the same time it sends it out (reads). EDO RAM is limited to a bus speed of 66MHz, due to its non-parity design. EDO RAM can be purchased in 72-pin SIMMs or 168-pin DIMMs.

## SDRAM

SDRAM is similar in design to EDO RAM in that it writes at the same time that it reads, vastly accelerating data along. SDRAM is a popular choice over EDO RAM due to its high bus speed of 100MHz and its low cost.

# Other ROM Types

Besides the basic ROM chip discussed earlier, other ROM chips are used in computers and small computing devices. The ROM chips described next are programmable, meaning that information can be recorded onto them. These types of chips are important because they enable software that is critical to the computer start-up process to be updated.

## PROM

Programmable Read-Only Memory (PROM) is a special type of chip that is manufactured without any configuration. Manufacturers can then *burn in*, or program, the chip to contain whatever configuration is needed.

## EPROM

Erasable Programmable Read-Only Memory (EPROM) maintains its contents without the use of electrical power. The stored contents of an EPROM chip are erased and reprogrammed by removing the protective cover and using special equipment to reprogram the chip.

### EEPROM

Electrically Erasable Programmable ROM (EEPROM) typically maintains the BIOS code, which can be updated with a disk that the BIOS manufacturer supplies.

# Bus Architecture

When configuring the hardware for a new computer, you have to consider the CPU and motherboard, as discussed earlier in this chapter. In addition, you need to decide which **expansion cards** to install. Expansion cards include sound cards, video adapters, and **network interface cards**.

The expansion cards fit into expansion slots built into the motherboard. The most common exceptions are special types of computers such as laptop computers. Expansion cards and the slots they fit into can have several different connector types. The connector types are physically different from one another and have varying performance characteristics.

Some reasons why expansion slots are useful are:

- The earliest motherboards didn't have room for all the necessary components.
- The expansion slots add flexibility in the event that you need to replace a failed expansion card without having to buy a complete new motherboard.
- Most motherboards have several types of expansion slots. The older type of expansion slots, described in the next section, are available to support older expansion cards, protecting consumers' original investment in their hardware.

In most modern computers, you insert a new add-in, or expansion, card as follows:

**WARNING**

Before opening any electronic device, make sure that the power is turned off and that you are grounded. To ground yourself, use a special tool called an electrostatic discharge wrist strap. One end of the wrist strap attaches to you, and the other end clips to the metal case of the computer. Using the strap prevents you from shocking the computer and possibly causing irreversible damage.

1. Turn the power off and disconnect the power cord from the case.
2. Open the case.

**expansion card**
An add-on device, such as a sound or video card, that is installed directly into an expansion slot built into a motherboard. The card must be of the same bus architecture as the slot on the motherboard.

**network interface card**
A device that connects a computer to the physical cable media and produces signals for transferring data.

3. Make sure that the card that you are trying to install is the proper type for an open expansion slot.
4. Insert the card and fasten it down.
5. Close the case.
6. Turn the power back on.

# Bus Types

Many types of buses have been introduced since the creation of the personal computer. Some, such as Industry Standard Architecture (ISA), have had long histories. Others, such as IBM's MicroChannel, were never widely adopted for one reason or another. The most widely used bus today is PCI (described earlier in the section, "The Next Generations: The Pentium Family"). Not long ago, PCI was seen as adding better performance to emerging high-speed computers. Now, even the once-sought-after PCI is considered sluggish. Accelerated Graphics Port (AGP) is one bus technology that may hold some solutions.

## IBM PC

The original IBM PC supported 8-bit expansion cards that ran at the same speed as its Intel 8088 processor, 4.77MHz.

## IBM PC-AT, or Industry Standard Architecture (ISA)

The IBM PC-AT introduced two major enhancements: The data path was increased (by use of a second connector) to 16 bits, and the speed of the expansion cards, usually fixed at 8.33MHz, was made independent of the processor speed.

## IBM MicroChannel Architecture (MCA)

IBM's third version of a motherboard expansion bus increased the width of the bus (to 32 bits) and increased the speed. However, unlike with the two original bus designs, IBM didn't freely allow all the other hardware vendors to build cards that were compatible with the MCA specifications.

## Enhanced Industry Standard Architecture (EISA)

In response to IBM's proprietary MCA bus, the other major hardware vendors (led primarily by Compaq) developed this enhanced bus design.

## Video Electronics Standards Association (VESA) Local Bus (VL-Bus)

The VESA Local Bus is not a replacement for the other bus types, but is instead usually used as an auxiliary bus. The primary devices that support the VL-Bus are, as might be expected by its name, video cards. However, some high-performance disk controllers were released that use this standard. Using VL-Bus technology, especially over the long term, has limitations. Major limitations of the VL-Bus include a restriction in the number of VL-Bus devices, a maximum 32-bit data path (preventing expansion to the new Intel Pentium 64-bit systems), and a clock-speed limit of only 33MHz.

**megabytes per second (MBps)**
A measurement of the transfer speed of a device in terms of millions of bytes per second.

## Peripheral Component Interconnect (PCI)

The PCI architecture is a 32-bit wide local bus design running at 33MHz. As a local bus design, PCI devices have direct access to the CPU local bus. The PCI local bus is connected to the CPU local bus and system memory bus via a PCI-Host bridge. This is a caching device providing the interface between the CPU, memory, and PCI local bus. The cache enables the CPU to hand off executions to the PCI bus to finish freeing valuable CPU resources. The CPU can continue to fetch information from the caching bridge while the cache controller provides an expansion device with access to system memory.

More than one communication on more than one bus can occur at the same time. This concurrent bus operation could not happen with previous architectures (such as VESA). Additionally, PCI expansion devices are fully independent of the CPU local bus; there is no CPU dependency at all. This design enables the CPU to be upgraded without requiring new designs for devices on the CPU or expansion buses.

## Accelerated Graphics Port (AGP)

AGP was developed as a replacement for PCI. AGP uses the Intel two-chip 440LX AGP set. This set of chips sits directly on the motherboard and provides similar functionality to PCI. The new chips are responsible for handling the transfer of data between memory, the processor, and the ISA cards all at the same time. Transfer of data to and from PCI cards still occurs at 132 **megabytes per second (MBps)** at 33MHz. The significant change from PCI is in the speed of transfers to RAM and to the accelerated graphics port. Both have transfer speeds of 528MBps each. This fourfold performance increase provides a significant boost, speeding data along to high-speed CPUs and RAM.

# Review Questions

**Terms to Know**

- ❑ ASMP
- ❑ BIOS
- ❑ bit
- ❑ bus architecture
- ❑ CISC
- ❑ conventional memory
- ❑ CPU
- ❑ DOS
- ❑ expansion card
- ❑ GHz
- ❑ HCL
- ❑ I/O
- ❑ MBps
- ❑ MHz
- ❑ microcode
- ❑ MIPS
- ❑ MMX

1. Which processor was released in the first IBM PC?

   ______________________________

2. How did the 8086 differ from the 8088?

   ______________________________

3. What does *CPU speed* refer to?

   ______________________________

4. How does SDRAM differ from EDO RAM?

   ______________________________

5. How does real mode differ from protected mode?

   ______________________________

6. What does *clock cycles* refer to?

   ______________________________

7. What is Virtual Real Mode?

   ______________________________

8. What does PROM stand for, and what is it?

   ______________________________

9. What does the term *clock doubling* refer to?

   ______________________________

**10.** How many transistors make up the original Pentium processor?

______________________________________________

**11.** How does asymmetrical multiprocessing differ from symmetrical?

______________________________________________

**12.** What is a math coprocessor?

______________________________________________

**13.** What is the recommended amount of RAM for Windows Server 2003?

______________________________________________

**14.** What is the primary difference between RAM and ROM?

______________________________________________

**15.** What performance gains does PCI have over the EISA bus architecture?

______________________________________________

**Terms to Know**

- ❑ motherboard
- ❑ multitask
- ❑ network interface card
- ❑ parity
- ❑ PCI
- ❑ pipeline
- ❑ POST
- ❑ protected mode
- ❑ RAM
- ❑ RISC
- ❑ ROM
- ❑ SEC
- ❑ SMP
- ❑ SOI
- ❑ transistor
- ❑ VAX
- ❑ Windows operating system