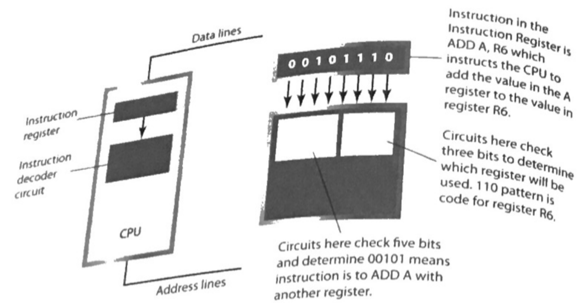
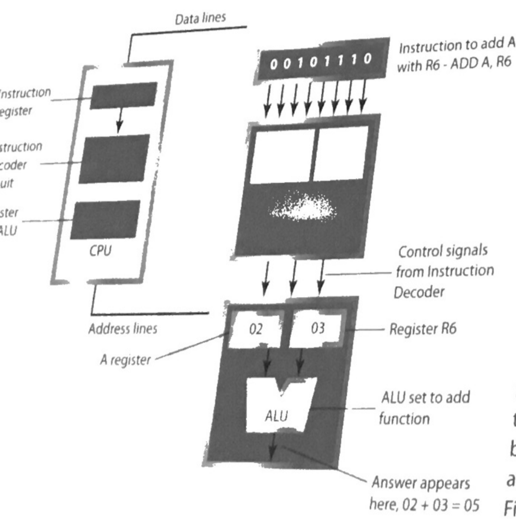


Figure 10.34 | **Instructions are placed into the Instruction Register so that the CPU circuitry can determine what to do.**

the memory chip holding the instruction. The CPU does this by first generating the address where the instruction is located and then placing the address on the memory chip's address lines. The CPU then activates signals necessary to carry out a read operation. During this fetch phase, the CPU is merely locating and acquiring the instruction.

The fetched instruction from memory enters the CPU on eight wires called the data bus. Bus is a word used to identify a common group of wires. The CPU captures the instruction's bit pattern and stores each bit in a special set of flip-flops called the Instruction Register (see Figure 10.34). Once the instruction is transferred from memory to the CPU, the instruction fetch is complete.

Remember that, in our example, the CPU could have fetched any of 256 unique instructions. A good part of the CPU's logic circuitry is devoted to decoding the various instruction bit patterns in order to determine which instruction it has received. The circuitry designed to decode the instruction bit patterns is called the Instruction Decoder. Its function is to examine the levels of the instruction pattern and then activate the specific parts of the CPU that carry out the command.



This picture shows how the various parts of the CPU work to execute instruction.

Assume that we want to move a data byte from one part of the CPU to another. The command is fetched and then held in the Instruction Register. Some of the instruction bits signify that data is to be moved. Other bits tell where the data is located, and still others identify where the data will go. Just eight instruction bits encode all this information. Once the instruction decoder examines these bits, additional control logic circuits are activated to move the data (see Figure 10.35 for an example of this process). After instruction execution is complete, the CPU will automatically *begin fetching the next instruction stored in memory. The fetch-execute cycle occurs repeatedly in a computer and governs the basic timing of all computer operations.*

Every instruction in a processor chip exists by deliberate design. Computer *engineers* determine that an instruction, such as moving data, is a process they *want the* CPU to carry out, and they purposely design the CPU circuitry to do this *task. The* specific design of a computer's architecture evolves from the instructions *the computer* engineer wants the chip to execute.

Registers

CPUs are equipped with places that temporarily store data. The most common locations are the general purpose registers, which are groups of flip-flops built for this purpose. A byte of data, for instance, can easily be placed in a general purpose register to be used later by the CPU. Many microprocessors also use specific addresses in SRAM as general-purpose registers.

A general purpose register common to most machines is the accumulator, or A-register. In a simple CPU, the A-register is eight bits wide. If we were to specify moving data to the A-register from the B-register (another common register name), we would need a specific binary pattern of instruction to do so. After decoding the instructions, the CPU would carry them out. As a result, the 8-bit data contained in the B-register would be copied to the A-Register. This seemingly simple task is the kind of process carried out by machine-level instructions.

ALU

The CPU also contains ALU circuitry, which typically supports add, subtract, multiply, and divide operations. The ALU also makes possible instructions that compare the magnitudes of two numbers, and it supports logical operations, such as ANDing and ORing. The computations supported by arithmetic circuits vary greatly from microprocessor model to model, and because arithmetic circuitry is complex, mathematically powerful chips cost more.

There is also microprocessor circuitry designed for electronic communication with external devices (such as connecting your computer to a printer). Serial ports, found on many computers, are common examples of communication circuitry. Additional hardware and instructions are usually necessary to use the communications features.

Every microprocessor includes circuits that control the timing requirements of all CPU processes, such as fetch and execute. In a microprocessor, nothing happens randomly. Every operation is synchronized to a master clock.

Interrupts

Another important feature of microprocessors is the interrupt logic, which permits the processor to shift its attention from one program to another. Interrupts make it possible for many external devices to work with one microprocessor. The effect is that many devices seem to work simultaneously, but only one device has the processor's attention at any moment. An external device (one not on the microprocessor chip) needing attention interrupts the CPU only when action is necessary. For example, each key struck on a keyboard generates an interrupt, and the CPU responds to each by executing an interrupt program that accepts the character code of the key. Once the interrupt program completes, the CPU returns to whatever program was previously running. Since CPUs are faster than typing, the interrupt system permits the slow keyboard device to communicate with the CPU only when necessary. This is an efficient way to use computer-processing resources.

TECHNOLOGY AND PEOPLE: Master of the Electromagnetic Wave

Joseph Iannotti (Figure 10.36) is a senior engineer in the RF (radio frequency) and photonics lab at General Electric Research and Development Center. He designs systems that make use of electromagnetic waves, from medical equipment to airport security devices. They are not usually products you would buy at a store, but high-value systems that companies are willing to pay a lot of money for. "Some of the stuff I work on costs billions of dollars," Iannotti says.

The first step for a new project is talking to the customers to see what they need. "They want to know how they can get their product to be better than anybody else's," Iannotti says. "I try to figure out what technology we can use to differentiate their system."

Iannotti got interested in engineering when he helped his dad build their house. "I thought it was pretty cool the way home wiring worked," he says. He was also drawn to the many gadgets that appeared in the early 1980s, like computers and videocassette recorders.

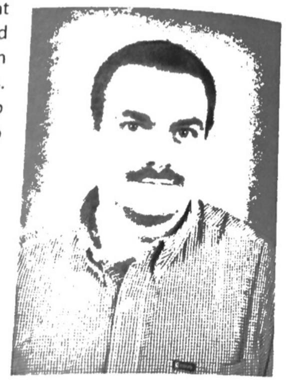
Iannotti earned an associate degree in Electrical Technology from Fulton-Montgomery Community College. He continued his studies at the Rochester Institute of Technology, graduating with a degree in electrical engineering technology. He got his first job as a design engineer.

"I screwed up on the first project they gave me, but I finally did it right," he says. "Failures happen, but the main thing is to learn from them."

Since then, Iannotti has participated in many different projects. He helped modernize aging military systems and worked on ways for satellites to communicate with one another.

"I never get bored because I'm doing different things all the time," he says.

According to Iannotti, the two things that make a great engineer are a love of math and a love of solving problems. "The problems can be as abstract or as real as you like," he says. "There are a lot of people at my company who never leave the lab. There are other people who never leave their office—they just think a lot."



Education A.A.S.—Electrical Technology, Fulton-Montgomery Community College, Johnstown, NY
B.S.—Electrical Engineering Technology, Rochester Institute of Technology, Rochester, NY

Job Description Design Engineer at a research and development lab developing and inventing products, which use radio frequency and photonics to communicate and sense.

Advice to Students "Understand the basics, enjoy what you do, and try to work with the best people you can!"

.36 Mr. Joseph Iannotti is an electrical engineer working in a research and development lab.

SECTION THREE FEEDBACK >

1. **Sketch a diagram showing how memory and a microprocessor communicate.**
2. **What is an instruction set?**
3. **What is the purpose of the instruction decoder logic in a CPU?**
4. **Where are the instructions for a computer program stored prior to execution?**

SECTION 4: Components of a Computer System

KEY IDEAS >

- Complete computer systems consist of many elements including a microprocessor, memory, and I/O.
- In a home computer system, the main PCB is the motherboard, which holds many key components, including memory, the microprocessor, and a chip set.
- The purpose of the chip set is twofold. It improves performance and reduces the number of parts needed.
- Computer owners can add to their systems by plugging small, printed circuit cards into the expansion slots.
- Interrupts are key structural features in computer architecture that ensure efficient operation.

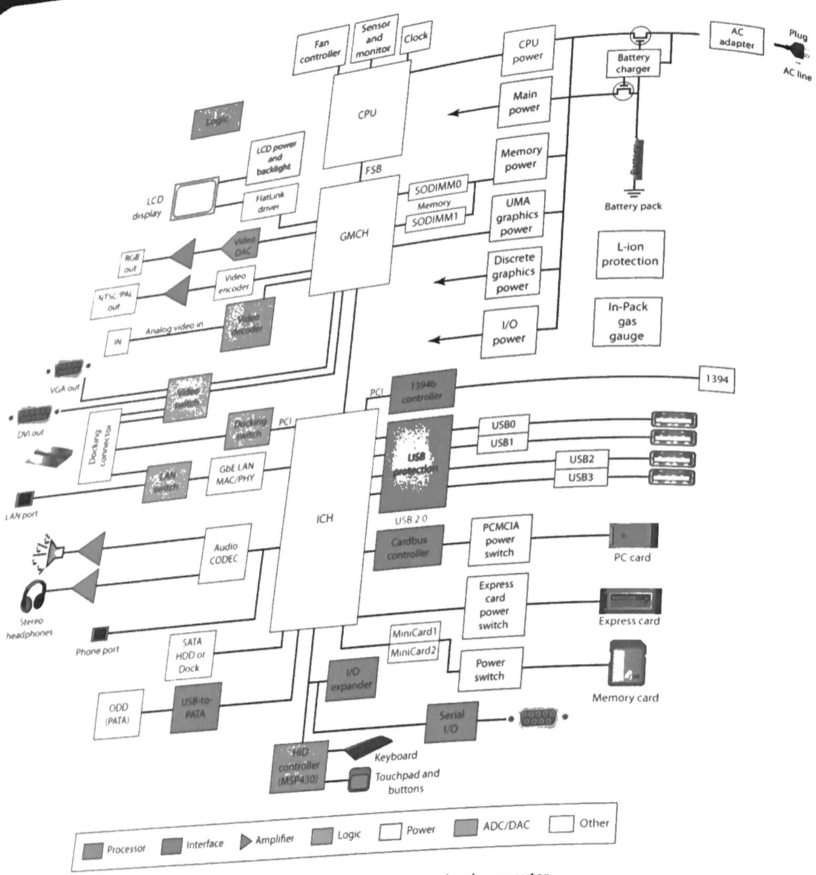
In most cases, a microprocessor chip is not a complete computer system. A complete, functional computer needs additional parts and assemblies. If you were to remove the cover from a home computer, you would recognize this immediately. You would see many integrated circuits, several circuit cards, and a few metal boxes connected by wire cables and printed circuit wiring. In order for the entire system to work, all these devices must communicate with each other. Complete computer systems consist of many elements, including a microprocessor, memory, and I/O.

Computer Subsystems

Figure 10.37 illustrates several of the critical subsystems found in a typical home computer. The CPU, part of the microprocessor chip, coordinates most computer activity. As previously discussed, the CPU processes instructions received from memory. Figure 10.37 shows many forms of memory in a typical system. The memory technology used depends on the memory application, the memory speed required, and the volatility of the memory.

As a computer operates, the microprocessor interacts with external devices such as keyboards, monitors, disk drives, DVD writers, USB drives, and network interface cards. These external devices are known as peripheral devices, or, more specifically, I/O devices. I/O stands for input/output and describes components sending information to the CPU (input) or receiving information from the CPU (output).

You see from Figure 10.38 that both I/O devices and memory share a common set of wires with the CPU. The number of wires varies depending on the complexity of the system, but it typically ranges from eight to sixty-four wires. Notice a number of the wires labeled with the word "bus." A bus is several wires used for a similar purpose. For example, the data bus shown is eight bits wide. This means eight wires carry the data information between the CPU and memory or between the CPU and I/O. Each wire carries one of the eight data bits. Instead of referring to each individual wire, it is easier to refer to the data bus in general. The size or width of the data bus is an important factor in determining how fast a computer will operate. The more wires there are in the data bus, the more information



37 | *This block diagram shows the many important subsystems necessary in a notebook computer.*

each computer operation can process. For systems using bus structures, as most do, it is important to ensure that only one device actually uses the bus at any one time. Otherwise, severe electrical and timing problems will result. For this reason, computer engineers carefully design their systems and use components specifically created for bus structures.

If you could view the signals on a data bus, you would find either binary instructions or binary data passing back and forth between the components attached to the bus. Since systems operate at electronic speeds, any particular piece of information exists on the bus for only a few nanoseconds. You can appreciate just how important timing is when devices operate so quickly.

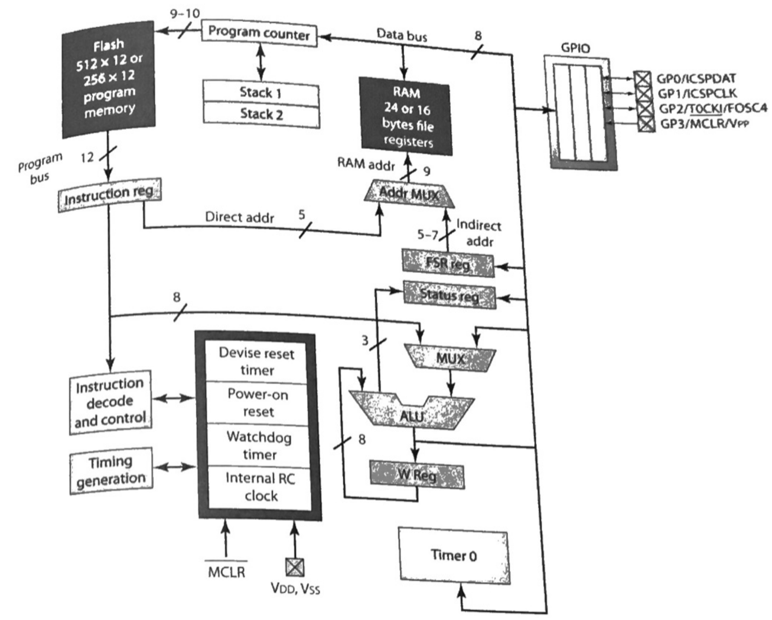


Figure 10.38 | **Common groups of wires, called busses, are used in computer systems on computer chips so that data can be shared by many devices.**

The other important bus shown in Figure 10.38 is the address bus. This bus consists of many wires, commonly between sixteen and thirty-six. On these wires, the CPU provides the addressing information necessary to access any specific piece of information.

Computer systems also have many dedicated signals controlling the timing and sequencing of operations in the system. For example, a signal is necessary to inform memory and I/O devices whether they are needed at any particular moment. Since both devices connect to the same bus, but only one at a time may use the bus, selection control is essential.

Motherboard

When you look closely at pictures of integrated circuits, you will see many small pins. In order for a computer system to work, the pins of many ICs and electrical components must be interconnected to form the necessary circuits. These wiring interconnections are made on a printed circuit board (PCB) that connects components efficiently and provides beneficial electrical properties. For instance, PCBs keep wiring as short as possible and help reduce signal interference.

The PCB is constructed of nonconductive materials coated with copper metal. Some PCBs are several layers thick. Copper is removed in selected areas of the board by an etching process. After etching, thin copper lines or wires called traces remain on the board. You can easily see the traces on a PCB running from one component to another.

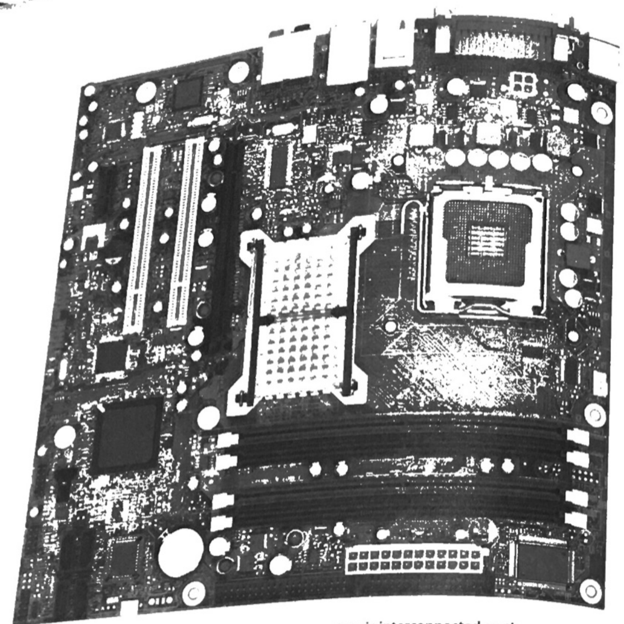


Figure 10.39 The majority of circuitry in a computer system is interconnected on the system motherboard.

Holes drilled through the copper traces permit insertion of integrated circuits and other components, interconnecting the small pins of individual parts and holding them in place with solder. On some PCBs, very small surface-mount components are soldered directly to the traces without the need to drill holes.

In a home computer system, the main PCB is the motherboard, which holds many key components (see Figure 10.39), including memory, the microprocessor, and a chip set. The chip set is often two ICs, one called Northbridge, and the other called Southbridge. The Northbridge chip handles the microprocessor's connections to system memory and graphics memory; the Southbridge chip controls the I/O devices supporting serial communications, USB, and other I/O operations. Figure 10.40 illustrates this with a simplified block diagram.

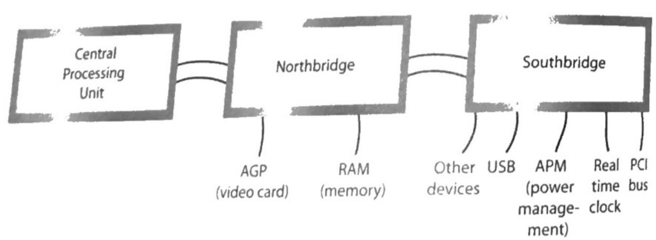


Figure 10.40 | A computer chip set simplifies the construction and assembly of computer systems.

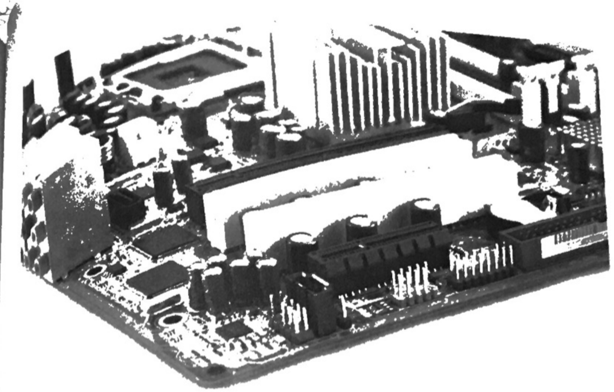


Figure 10.41 | Motherboard expansion slots make it possible for additional equipment to be added to a computer system.

The purpose of the chip set is twofold. It improves performance and reduces the number of parts needed, which means increased reliability. Computer speeds also increase when circuitry connections are on as few chips as possible.

Of course, computer technology is always changing as designers strive to make systems faster and more useful. An example is a new series of chip sets from Intel called the Intel Hub Architecture, which will make systems even faster.

The motherboard also holds special electrical and mechanical connectors called expansion slots. Computer owners can add to their systems by plugging small printed circuit cards into the expansion slots (see Figure 10.41). For example, a gaming system requires superior video capabilities, and, in order to keep up with game action, a gamer might want to add a high performance video card to his system.

The peripheral components interface (PCI) bus is an example of a common expansion slot that is standard in home systems. This 47-pin bus interface connects devices such as sound cards and disk drives to the motherboard hardware.

TECHNOLOGY IN THE REAL WORLD: USB Connections

Do you download pictures from digital cameras to personal computers? You could be using a USB connection to do this. Figure 10.42 shows the symbol for USB. You might see this logo near some of your computer connections. The thumb drive you use for file storage (also known as a memory stick, flash drive, or jump drive) uses USB to store files.

USB stands for Universal Serial Bus. The word serial means to send or receive many bits, one bit at a time. The word "bus" in USB tells how many devices share a wire. The idea behind a bus in a digital system is to have many devices attached together via a common wire (or groups of common wires). This saves a lot of wiring and works well as long as only one device uses the bus at a time. The USB does require specific wiring and connectors, defined voltages on specific pins, and distinct signaling specifications that are agreed upon by the sender and receiver.

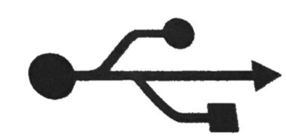


Figure 10.42 | The trident symbol indicates a USB connection.

Figure 10.43 | A USB Type A connector is usually plugged into a computer.

Figure 10.44 | A USB Type B connector is usually plugged into devices.

Therefore, USB is actually the bus system permitting devices to connect with a computer. Almost any device connected to a computer can be made to work using a USB connection.

You don't need to be a computer expert to make such connections. USB is known for its easy plug-and-play characteristics. Plug-and-play means that devices can connect or disconnect from a computer while the machine is running. The computer is designed to support USB and has the necessary USB software on it (Windows, for example), so the instant a USB-capable device is plugged into a socket, it is recognized by the computer and able to work. USB is also fast and transmits information up to 480 Mbits (million bits) per second.

USB has several kinds of connectors. Figure 10.43 shows a type A connector, and Figure 10.44 shows a type B connector. The computer end of a USB connection, often called the host controller, uses the type A connector. The devices that attach to the computer use the type B connector. As USB has become more popular, designers have created mini-versions of these connectors so that smaller devices, like digital cameras, can use USB.

A USB connector holds only four wires. Two wires are for power: one is a +5 volt wire and the other a ground wire. The other two wires, labeled D− and D+, work together to carry a single bit of information. The latter two wires implement a kind of signaling called differential signaling. This method helps reduce electrical noise and makes the connection more reliable.

When a USB device is connected to a computer, a process known as device enumeration begins, which permits the computer and USB device to communicate. USB is available in several speed versions—the computer determines the speed needed. The computer also reads device information to determine the kinds of drivers required for the device. A GPS unit needs different support than does a keyboard, for example. USB allows that multiple devices be connected, and since the computer assigns a 7-bit address to the device, up to 128 devices may be connected at one time (2^7 equals 128). Hubs are used to interconnect the extra devices.

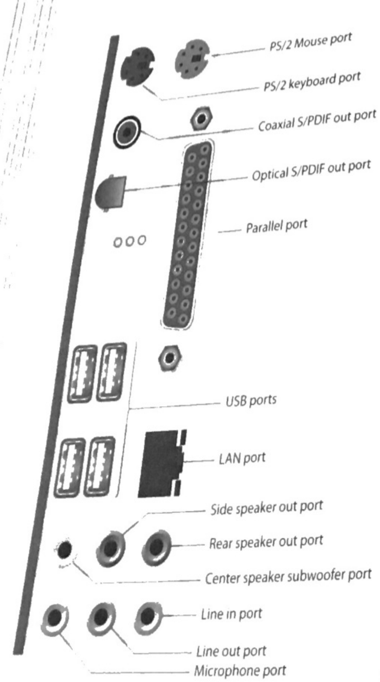


Figure 10.45 | I/O connectors found on home computers make it easy for the user to plug in equipment.

I/O

The CPU is constantly obtaining instructions from memory to determine which processes to carry out. Many of these instructions command the CPU to communicate with external devices through the Input/Output (I/O) circuitry. Like memory, I/O devices are addressable and may receive or send data to the CPU. Because there are many I/O devices in a computer system, they need addresses as identifiers. When information is sent to a computer monitor screen for display, the CPU sends the display data to the monitor electronics via the monitor's I/O circuits. The monitor has a specific I/O address, and only when the CPU addresses the monitor does the exchange of data begin.

A keyboard illustrates another basic I/O action. A binary code is transferred to the computer system each time a key is pressed. The I/O keyboard address selects the keyboard for service, enabling the CPU to read the keyboard data. Think of any piece of equipment you might attach to a computer system, and you will most likely have identified gear using the computer's I/O system (see Figure 10.45).

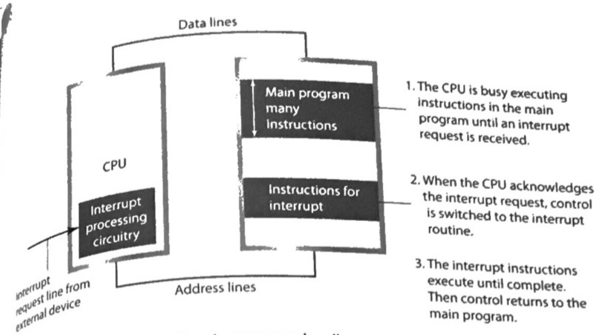


Figure 10.46 | Interrupts help the microprocessor handle many different tasks.

Interrupts

The microprocessor is a busy chip. The CPU is always executing instructions for the main system programs, but also has to keep track of externally attached devices. Because CPU time is a precious resource, methods have been developed to free the CPU from dealing with external devices until a specific need arises.

Assume you are typing an e-mail message on your computer keyboard. Every time you press a key, binary information representing that key's letter transfers from the keyboard to computer memory, so that your e-mail program can use it. The CPU controls this data transfer, but it is a waste of CPU time to constantly check the keyboard for each typed character. It is more efficient for the CPU to respond to the keyboard only when you actually press a key. Computer designers engineer this response by designing the keyboard so that every keystroke sends a special signal to the CPU. This signal starts a process known as an interrupt.

Interrupts are key structural features in computer architecture that ensure efficient operation. Even if you type quickly, say one character every 0.2 seconds, a reasonably fast CPU can execute over 2 million instructions between keystrokes. It does not make sense to waste this computing power looking for keyboard activity, so instead the keyboard circuitry generates an interrupt request signal each time a key is pressed. The CPU notices the request, suspends its current work, acknowledges the inter-rupt, and, through the I/O system, receives keyboard data. Once finished with that key, the CPU picks up exactly where it left off prior to the interrupt. Many other devices also use the interrupt system.

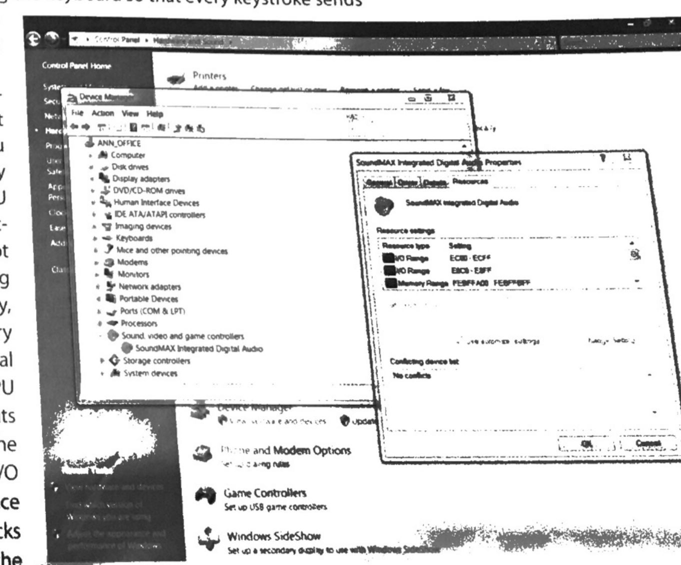


Figure 10.47 | Computer users can configure and troubleshoot system hardware using features in their computer's operating system.

Other Devices in a Computer System

If you have ever purchased a computer, you are aware that you may customize your system with devices such as mice, sound cards, network interface cards, wireless adapters, and speakers. Software is usually necessary to operate these hardware devices, and a device driver is the software program that specifically controls the hardware, allowing it to communicate properly with the CPU through the interrupt and I/O circuits. Device drivers are supplied when hardware is purchased and can be updated through a download from the manufacturer's Web site.

Every system device requires electrical power. The system power supply produces the necessary voltages and currents for the system. Computer power supplies plug into household outlets and convert AC into the regulated DC power needed by the machine's electronic devices. It is important to make sure the power rating, given in watts, is sufficiently large to supply all the electrical needs of the computer.

SECTION FOUR FEEDBACK >

1. ***What are the key differences between the microprocessor chip used in a home computer system and the processor used in an embedded system?***
2. ***What memory technology will you find in the main memory of a computer?***
3. ***How would you attach a writing tablet to a computer? Besides the tablet, what else would you need to make the tablet operate?***

CAREERS IN TECHNOLOGY

Matching Your Interests and Abilities with Career Opportunities: Computer, Electrical, and Electronic Engineers

Overall job opportunities in engineering are expected to be good, but will vary by specialty. A bachelor's degree is required for most entry-level jobs. Starting salaries are among the highest of all college graduates. Continuing education is critical for engineers who want to enhance their value to employers as technology evolves.

Nature of the Work

Engineers apply the principles of science and mathematics to develop economical solutions to technical problems. Their work is the link between perceived social needs and commercial applications.

In addition to design and development, many engineers work in testing, production, or maintenance. These engineers supervise production in factories, determine the causes of component failure, and test manufactured products to maintain quality. They also estimate the time and cost to complete projects. Some move into engineering management or into sales. In sales, their engineering backgrounds enable them to discuss technical aspects and assist in product planning, installation, and use. Supervisory engineers are responsible for major components or entire projects.

* Computer hardware engineers research, design, develop, test, and oversee the installation of computer hardware and supervise its manufacture and installation.
* Electrical engineers design, develop, test, and supervise the manufacture of electrical equipment. Electrical engineers specialize in areas such as power systems engineering or electrical equipment manufacturing.
* Electronics engineers are responsible for a wide range of technologies, from portable music players to the global positioning system (GPS). Electronics engineers design, develop, test, and supervise the manufacture of electronic equipment, such as broadcast and communications systems.

Working Conditions

Most engineers work in office buildings, laboratories, or industrial plants. Some engineers travel extensively to plants or worksites. Many engineers work a standard 40-hour week. At times, deadlines or design standards may bring extra pressure to a job, requiring engineers to work longer hours.

Training and Advancement

A bachelor's degree in engineering is required for almost all entry-level engineering jobs.

Most engineering programs involve a concentration of study in an engineering specialty, along with courses in both mathematics and the physical and life sciences.

In addition to the standard engineering degree, many colleges offer 2- or 4-year degree programs in engineering technology. These programs, which usually include various hands-on laboratory classes that focus on current issues in the application of engineering principles, prepare students for practical design and production work, rather than for jobs that require more theoretical and scientific knowledge.

Engineers should be creative, inquisitive, analytical, and detail oriented. They should be able to work as part of a team and to communicate well, both orally and in writing. Communication abilities are important because engineers often interact with specialists in a wide range of fields outside engineering.

Beginning engineering graduates usually work under the supervision of experienced engineers and, in large companies, also may receive formal classroom or seminar-type training. As new engineers gain knowledge and experience, they are assigned more difficult projects with greater independence to develop designs, solve problems, and make decisions. Engineers may advance to become technical specialists or to supervise a staff or team of engineers and technicians. Some may eventually become engineering managers or enter other managerial or sales jobs.

Outlook

Overall engineering employment is expected to grow by 11 percent over the 2006–16 decade, about as fast as the average for all occupations. Engineers have traditionally been concentrated in slow-growing manufacturing industries, in which they will continue to be needed to design, build, test, and improve manufactured products. Overall job opportunities in engineering are expected to be favorable because the number of engineering graduates should be in rough balance with the number of job openings over this period.

Earnings

Earnings for engineers vary significantly by specialty, industry, and education. Even so, as a group, engineers earn some of the highest average starting salaries among those holding bachelor's degrees.

The following tabulation shows average starting-salary offers for engineers, according to a 2007 survey by the National Association of Colleges and Employers.

CURRICULUM	BACHELOR'S	MASTER'S	PH.D
Aerospace/aeronautical/astronautical	$53,408	$62,459	$73,814
Agricultural	49,764	—	—
Architectural	48,664		
Bioengineering and biomedical	51,356	59,240	—
Chemical	59,361	68,561	73,667
Civil	48,509	48,280	62,275
Computer	56,201	60,000	92,500
Electrical/electronics and communications	55,292	66,309	75,982
Environmental/environmental health	47,960		
Industrial/manufacturing	55,067	64,759	77,364
Materials	56,233		
Mechanical	54,128	62,798	72,763
Mining and mineral	54,381	—	—
Nuclear	56,587	59,167	—
Petroleum	60,718	57,000	—

[Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2008–09 Edition, visited May 12, 2008, http://www.bls.gov/oco/]

Summary >

Computers are manufactured using electronic components, such as resistors and transistors. Computer design is accomplished at the logic level, using logic devices grouped in families with similar electrical characteristics.

The binary number system provides a mathematical foundation for logic circuits that use binary levels as inputs and outputs. Binary values called "bits" simplify computer design, as only one of two possible values can exist on any logic device input or output. The two values representing on and off are referred to as high and low levels.

Logic devices include AND, OR, NAND, NOR, invert, and flip-flop. These fundamental logic devices combine to create complex digital circuitry. Computer engineers interconnect basic logic devices into combinatorial and sequential circuits; this circuitry is the heart of digital computers. Common digital circuits include the adder, ALU, and counter.

Modern computing systems require memory chips to store data and programming instructions. No memory technology is the perfect combination of speed, density, and nonvolatility, so computer systems use several memory technologies.

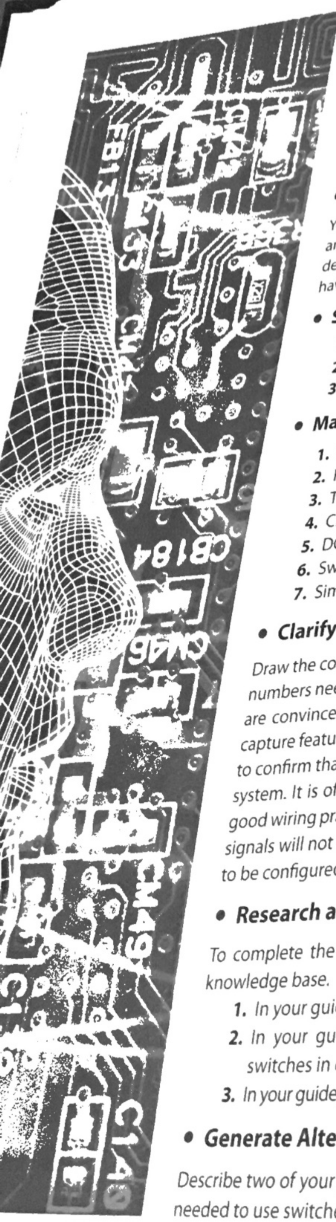
Microprocessor chips contain the computation circuitry for computers. The term microprocessor includes embedded processors used in simple products, microcontrollers used in complex systems, and advanced microprocessors used in desktop computers. All microprocessor-type chips contain common features such as the CPU, I/O, and interrupts. Many microprocessor chips have on-chip memory as well.

The microprocessor internal architecture determines the level of performance. The faster instructions reach the CPU, the better the overall performance will be. Instructions received by the CPU go into the Instruction Register for decoding. Since machine level instructions are just unique binary patterns, they are easily decoded. Once decoded, the CPU carries out the task signified by the instruction. CPUs undergo a constant fetch-execute process in the course of running a computer program.

Microprocessor chips are only one component in a typical desktop or laptop computer system. These systems require support chips to interconnect memory and I/O. The chips in a computer system communicate on a motherboard. Computer systems also have many peripheral devices attached, such as mice, keyboards, and video cards. The I/O and interrupt circuitry coordinate how peripheral devices share the CPU resources.

FEEDBACK

1. An AND gate logic device has six input lines. How many combinations of ones and zeros produce a one level output? How many combinations will produce a zero output from the device?
2. Find Web sites pertaining to building your own computer. Identify three important factors to keep in mind when buying a motherboard.
3. AGP, DIMM and PCI are connector slots found on motherboards. Find information on these slots, including the technical specifications of each.
4. Look at the memory modules in your own computer. How many memory chips are on the module? Can you determine how the chips interconnect on the module in order to expand the overall memory size?
5. Research online to find out what differentiates PC100 memory modules from PC133 memory modules.
6. Design a burglar alarm system using logic devices, so that if any one of three doors opens, a binary signal will trigger an alarm. Assume the doors are equipped with magnetic switches, such that a closed door switch provides a zero signal to your circuit, and an open door switch provides a one signal to your circuit. Also, assume the alarm activates with a one-level signal.
7. Look up the term K-map online to see if you can find an explanation for designing logic circuits with the K-map. Also, search for a K-map program to download. You should find free programs readily available. Use the program to design the circuit discussed in Figure 10.12.
8. Do you have a digital camera? What kind of memory device does your camera use to store pictures? What is the size of the memory device?
9. Using the Internet, find a data sheet for a DRAM chip. Can you figure out the relationship between the number of address lines and the number of addresses?
10. Look up information on the ASCII code. If you were to design a memory system to store ASCII codes, what word size would you want the memory system to have?
11. Look on the Internet for the instruction set of the 8051 microcontroller. What kinds of instructions are possible with this popular 8-bit machine?
12. Go to a computer manufacturer's Web site, and design your own computer system. Explain the reasons for your selections of memory, power supply, microprocessor, and peripheral devices.
13. Look up information on video-graphics cards. Determine what kind of memory technology these cards use. Are there any other significant features of these cards related to microprocessors?



DESIGN CHALLENGE 1:
Digital Adder Design

- ***Problem Situation***

You and your classmates decide to start a digital design business. You must be able to prove to potential clients that your team can design and build digital circuitry. The group decides that demonstrating the operation of a 12-bit adder will show off the design skills of your company.

- ***Your Challenge***

Your challenge is to design a working adder capable of adding two 12-bit numbers and to display the result of the addition on LEDs. You will need to simulate the design, as well as determine how to drive the LEDs with digital signals. You will also have to generate the two 12-bit binary numbers for addition.

- ***Safety Considerations***

1. *Always exercise caution when working with electricity.*
2. *Assume circuits are energized.*
3. *Follow your instructor's safety guidelines for your lab.*

- ***Materials Needed***

1. *LEDs*
2. *Resistor assortment*
3. *TTL or CMOS ICs*
4. *Circuit Breadboard*
5. *DC Voltage source*
6. *Switches*
7. *Simulation software (such as DigitalWorks)*

- ***Clarify the Design Specifications and Constraints***

Draw the complete adder schematic on paper. Identify the individual digital IC part numbers needed for the circuit as well as the total number of ICs needed. Once you are convinced of the design's correctness, create the circuit using the schematic capture feature of the circuit simulation software you are using. Simulate the adder to confirm that your design adds properly, and then gather the parts and build the system. It is often advantageous to "bring up" the circuit in small sections. Follow good wiring practices. Short wires are best. Caution: LEDs are analog devices. Digital signals will not necessarily light an LED. Switches are also analog devices and need to be configured to produce digital levels.

- ***Research and Investigate***

To complete the design challenge, first gather information to help you build a knowledge base.

1. *In your guide, complete the Knowledge and Skill Builder I: Digital gates.*
2. *In your guide, complete the Knowledge and Skill Builder II: LEDs and switches in digital applications.*
3. *In your guide, complete the Knowledge and Skill Builder III: Half and full adders.*

- ***Generate Alternative Designs***

Describe two of your possible alternatives to the adder design. Discuss the factors needed to use switches and LEDs as digital devices.

- ***Choose and Justify the Optimal Solution***

Explain why the solution you selected is better.

- ***Display Your Prototypes***

Construct your chosen design. Use the working model and simulation results to show how the adder operates.

- ***Test and Evaluate***

Explain how your design met the specifications and constraints. What simulated and actual tests did you conduct to verify this?

- ***Redesign the Solution***

Explain how you would redesign your circuit based on the knowledge and information that you gained during this design challenge. What additional features would you add to the design if you had more time?

- ***Communicate Your Achievements***

Describe the plan you will use to present your solution to your class. Include a media-based presentation.