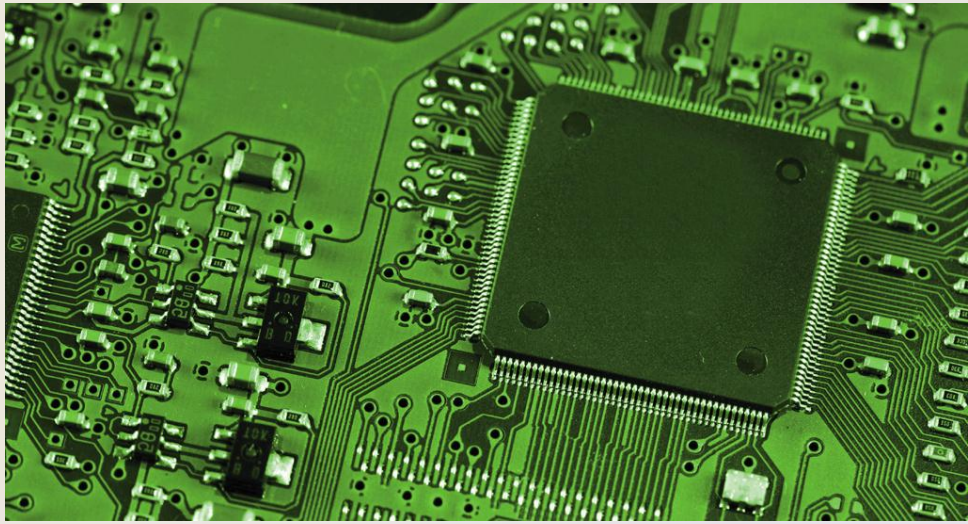
Discovering Computers 2016

Tools, Apps, Devices, and the Impact of Technology

Chapter 6

Computing Components



Objectives Overview

Describe the various computer and mobile device cases and the contents they protect

Describe multi-core processors, the components of a processor, and the four steps in a machine cycle

Identify characteristics of various personal computer processors on the market today, and describe the ways processors are cooled

Explain the advantages and services of cloud computing

Define a bit, and describe how a series of bits represents data

Explain how program and application instructions transfer in and out of memory

See Page 276
for Detailed Objectives

Objectives Overview

- Differentiate among the various types of memory
- Describe the purpose of adapter cards and USB adapters
- Explain the function of a bus
- Explain the purpose of a power supply and batteries
- Describe how to care for computers and mobile devices

See Page 276
for Detailed Objectives

Chapter 5
Computer Systems Organization

INVITATION TO
Computer Science

6TH EDITION

Objectives

After studying this chapter, students will be able to:

- Enumerate the characteristics of the Von Neumann architecture
- Describe the components of a RAM system, including how fetch and store operations work, and the use of cache memory to speed up access time
- Explain why mass storage devices are important, and how DASDs like hard drives or DVDs work
- Diagram the components of a typical ALU and illustrate how the ALU data path operates

Objectives (continued)

After studying this chapter, students will be able to:

- Describe the control unit's Von Neumann cycle, and explain how it implements a stored program
- List and explain the types of instructions and how they are encoded
- Diagram the components of a typical Von Neumann machine
- Show the sequence of steps in the fetch, decode, and execute cycle to perform a typical instruction
- Describe non-Von Neumann parallel processing systems

15th Edition

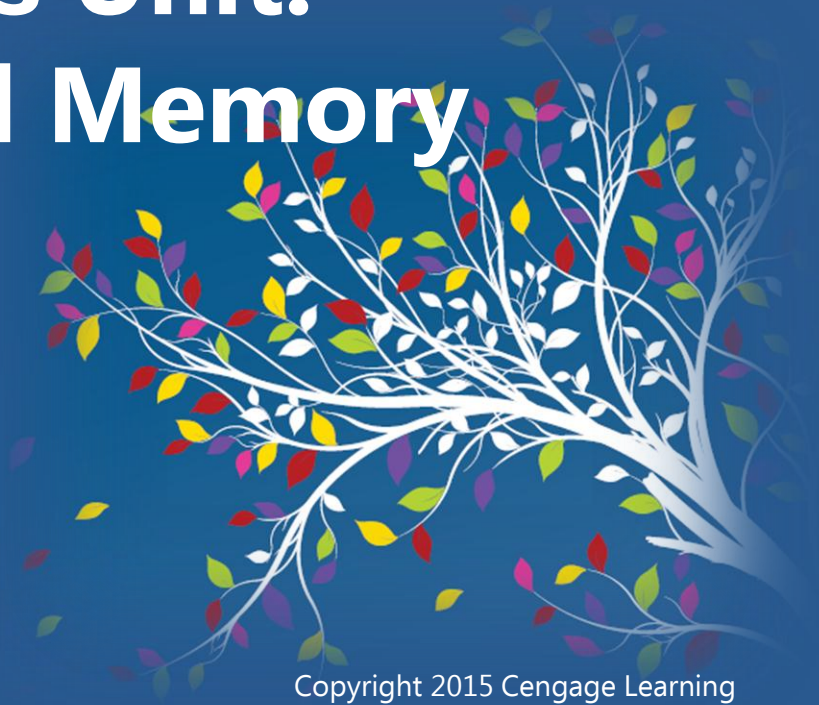
Understanding Computers

Today and Tomorrow

Comprehensive

Chapter 2

The Systems Unit: Processing and Memory



Deborah Morley
Charles S. Parker

Learning Objectives

1. Understand how data and programs are represented to a computer and be able to identify a few of the coding systems used to accomplish this.
2. Explain the functions of the hardware components commonly found inside the system unit, such as the CPU, GPU, memory, buses, and expansion cards.
3. Describe how peripheral devices or other hardware can be added to a computer.
4. Understand how a computer's CPU and memory components process program instructions and data.
5. Name and evaluate several strategies that can be used today for speeding up the operations of a computer.
6. List some processing technologies that may be used in future computers.

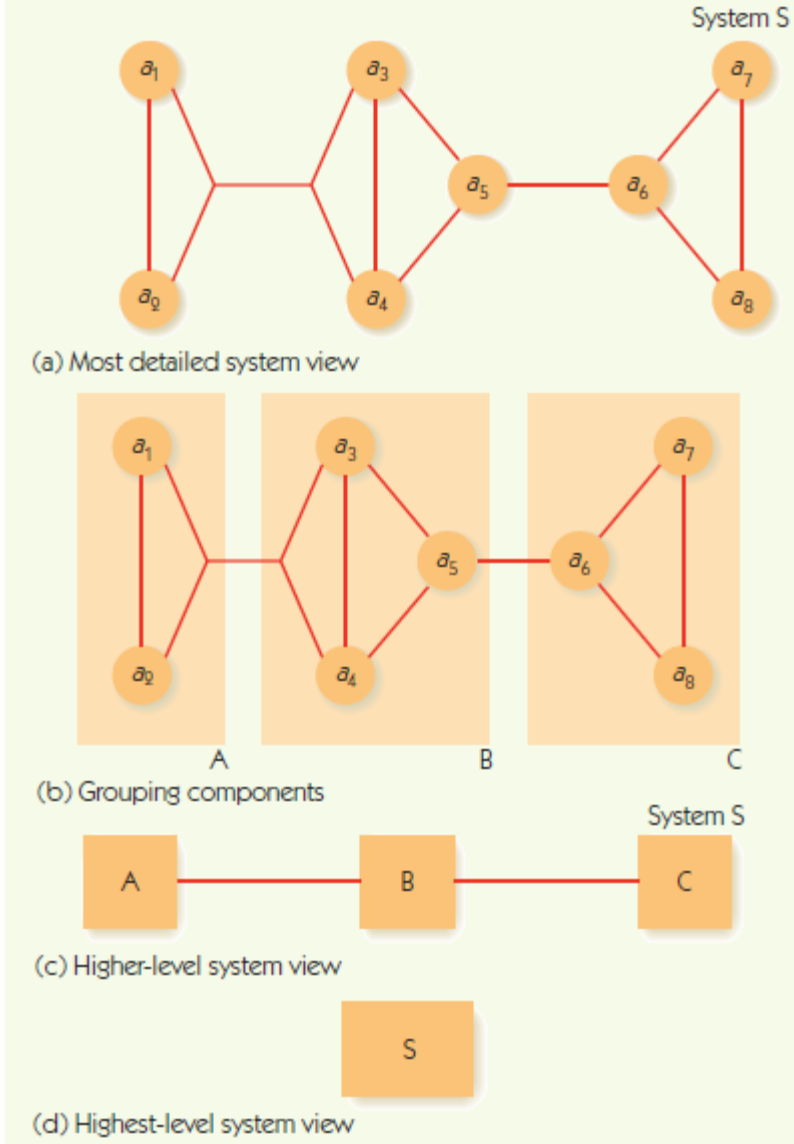
Introduction

- This chapter changes the **level of abstraction**
- Focus on **functional units** and **computer organization**
- A **hierarchy of abstractions** hides unneeded details
- Change focus from transistors, to gates, to circuits as the basic unit

Overview

- Explain how computers represent data and program instructions.
- Explain how the CPU and memory are arranged with other components inside the system unit.
- Explain how a CPU performs processing tasks.
- Identify strategies that can be used today to create faster and better computers in the future.

FIGURE 5.1



(a) Most detailed system view

(b) Grouping components

(c) Higher-level system view

(d) Highest-level system view

The concept of abstraction

Data Representation

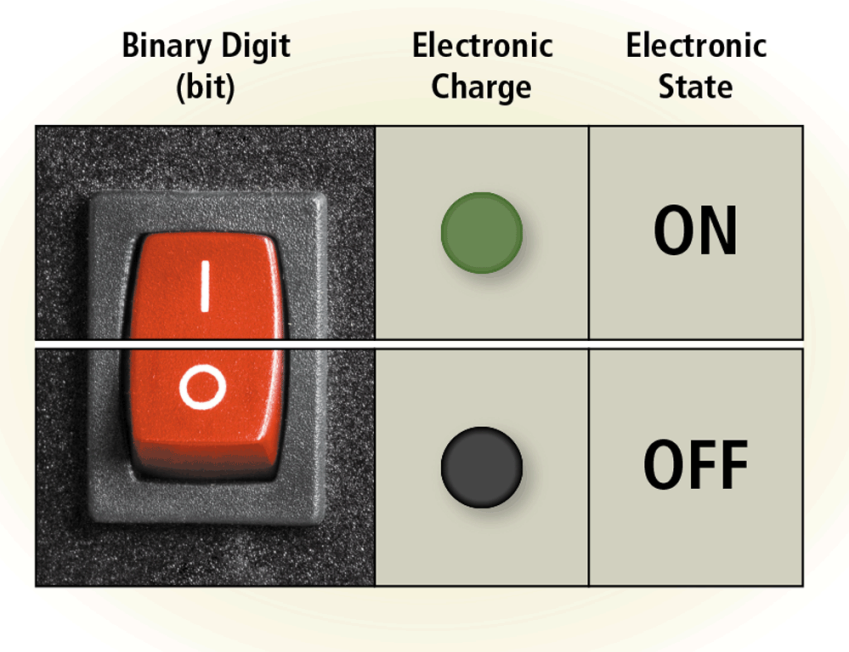
Analog signals are continuous and vary in strength and quality

Digital signals are in one of two states: on or off

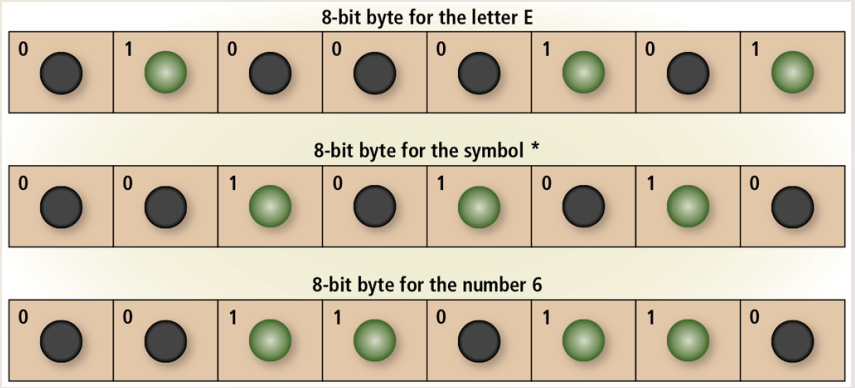
- Most computers are digital
- The **binary system** uses two unique digits (0 and 1)
  - **Bits** and **bytes**

Data Representation

The circuitry in a computer or mobile device represents the on or the off states electronically by the presence or absence of an electronic charge



Eight bits grouped together as a unit are called a byte. A byte represents a single character in the computer or mobile device



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Figures 6-8 – 6-9

Data Representation

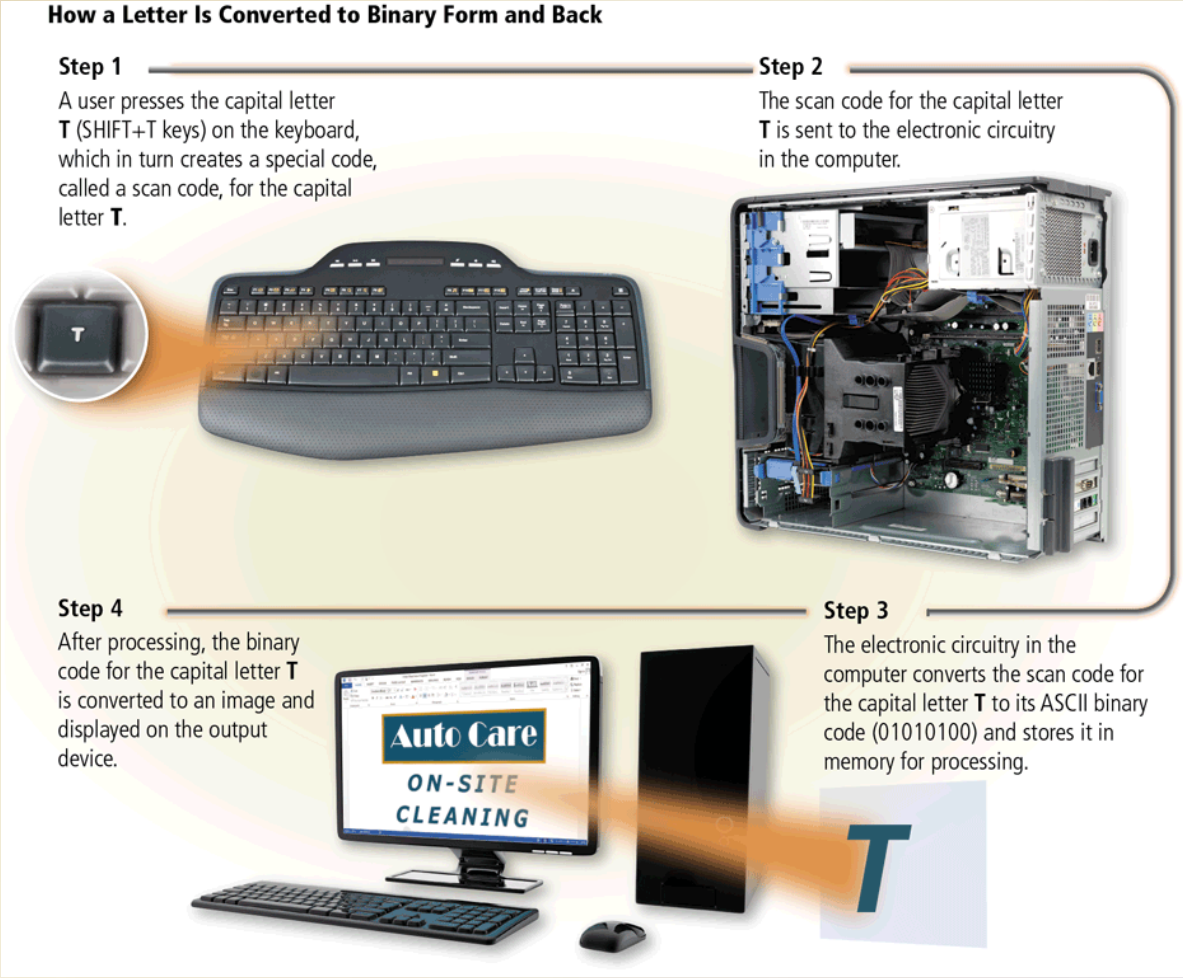

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Figure 6-10

Data and Program Representation

- Digital Data Representation
  - Coding Systems
    - Used to represent data and programs in a manner understood by the computer
  - Digital Computers
    - Can only understand two states, off and on (0 and 1)
  - Digital Data Representation
    - The process of representing data in digital form so it can be understood by a computer

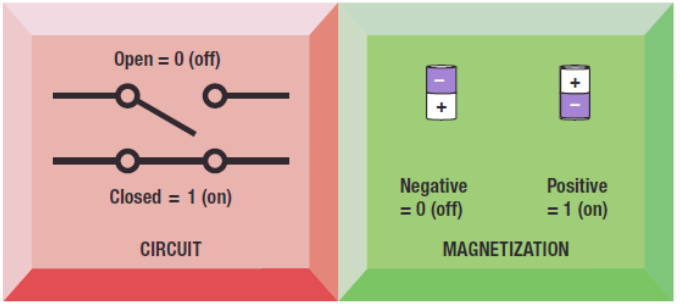
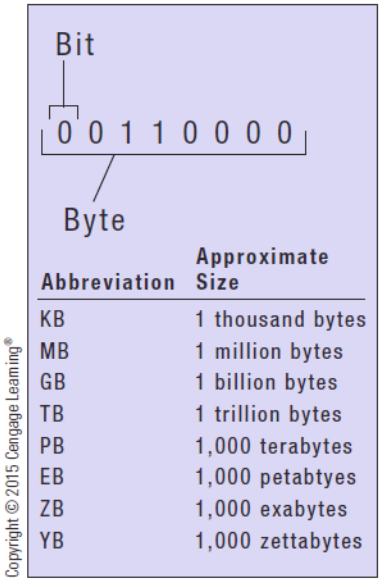


FIGURE 2-1
Ways of representing 0 and 1. Binary computers recognize only two states—off and on—usually represented by 0 and 1.

Digital Data Representation

- Bit
  - The smallest unit of data that a binary computer can recognize (a single 1 or 0)
- Byte = 8 bits
  - Byte terminology used to express the size of documents and other files, programs, etc.
- Prefixes are often used to express larger quantities of bytes: kilobyte (KB), megabyte (MB), gigabyte (GB), terabyte (TB), petabyte (PB), exabyte (EB), zettabyte (ZB), yottabyte (YB).



Abbreviation	Approximate Size
KB	1 thousand bytes
MB	1 million bytes
GB	1 billion bytes
TB	1 trillion bytes
PB	1,000 terabytes
EB	1,000 petabtyes
ZB	1,000 exabytes
YB	1,000 zettabytes

FIGURE 2-2
Bits and bytes.
Document size, storage capacity, and memory capacity are all measured in bytes.

Representing Numerical Data

- The Binary Numbering System
  - Numbering system
    - A way of representing numbers
  - Decimal numbering system
    - Uses 10 symbols (0-9)
  - Binary numbering system
    - Uses only two symbols (1 and 0) to represent all possible numbers
  - In both systems, the position of the digits determines the power to which the base number (such as 10 or 2) is raised

Representing Numerical Data

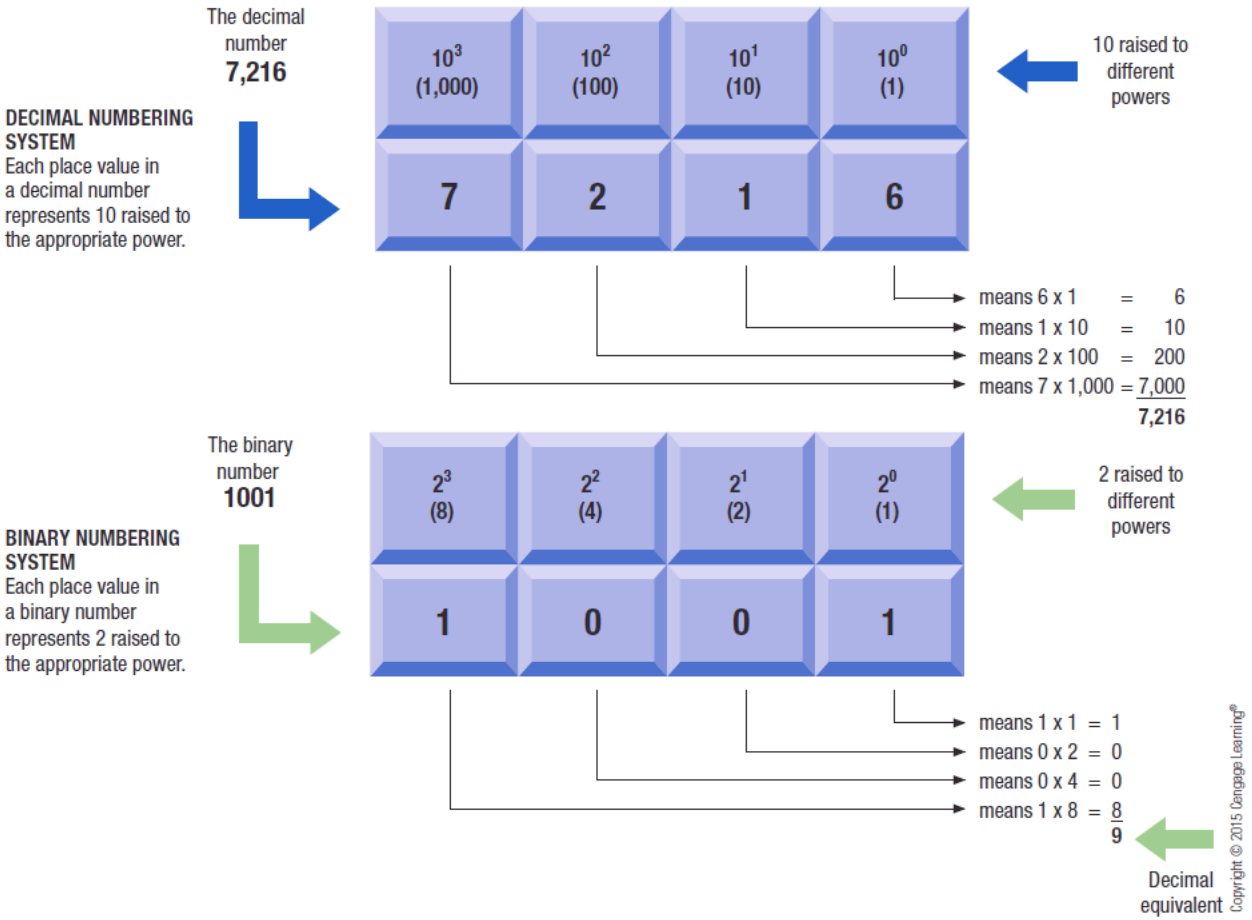


FIGURE 2-3
Examples of using the decimal and binary numbering systems.

Coding Systems for Text-Based Data

- ASCII (American Standard Code for Information Interchange)
  - Coding system traditionally used with personal computers
- EBCDIC (Extended Binary-Coded Decimal Interchange Code)
  - Developed by IBM, primarily for mainframes

CHARACTER	ASCII
0	00110000
1	00110001
2	00110010
3	00110011
4	00110100
5	00110101
A	01000001
B	01000010
C	01000011
D	01000100
E	01000101
F	01000110
+	00101011
!	00100001
#	00100011

FIGURE 2-4
Some extended ASCII code examples.

Coding Systems for Text-Based Data

- Unicode
  - Newer code (32 bits per character is common)
  - Universal coding standard designed to represent text-based data written in any ancient or modern language
  - Replacing ASCII as the primary text-coding system

FIGURE 2-5
Unicode. Many characters, such as these, can be represented by Unicode but not by ASCII or EBCDIC.

Coding Systems for Other Types of Data

- Graphics Data (still images such as photos or drawings)
  - Bitmapped images
    - Image made of up of a grid of small dots called pixels
    - Monochrome graphic can only be one of two colors
      - Requires just one bit for color storage
    - Images with more than two colors
      - Can use 4, 8, or 24 bits to store the color data for each pixel
  - More bits = more colors

Coding Systems for Other Types of Data

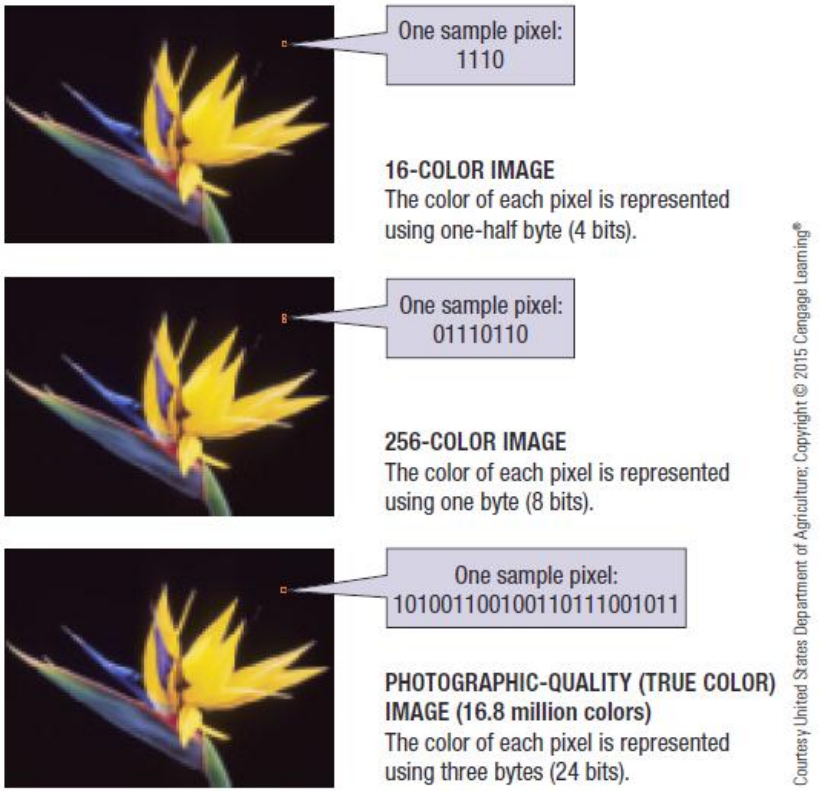


FIGURE 2-6

Representing graphics data. With bitmapped images, the color of each pixel is represented by bits; the more bits used, the better the image quality.

Coding Systems for Other Types of Data

- Audio Data
  - Must be in digital form in order to be stored on or processed by a computer
  - Often compressed when sent over the Internet
    - MP3 files are 10 times smaller than their uncompressed digital versions
    - Download more quickly and take up less storage space
- Video Data
  - Displayed using a collection of frames, each frame contains a still image
  - Amount of data can be substantial, but can be compressed

Representing Software Programs

- Machine language
  - Binary-based language for representing computer programs the computer can execute directly
  - Early programs were written in machine language
  - Today's programs still need to be translated into machine language in order to be understood by the computer

Quick Quiz

1. Another way to say “one million bytes” is
   a. one kilobyte
   b. one gigabyte
   c. one megabyte
2. True or False: MP3 files are stored using 0s and 1s.
3. The _____ numbering system is used by computers to perform mathematical computations.

Answers:
1) c; 2) True; 3) binary

Inside the System Unit

- System Unit
  - The main case of a computer
  - Houses the processing hardware for a computer
  - Also contains storage devices, the power supply, and cooling fans
  - Houses processor, memory, interfaces to connect to peripheral devices (printers, etc), and other components
  - With a desktop computer, usually looks like a rectangular box

Inside the Case

- The case contains and protects the electronics of the computer or mobile device from damage

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Figure 6-1

Inside the System Unit

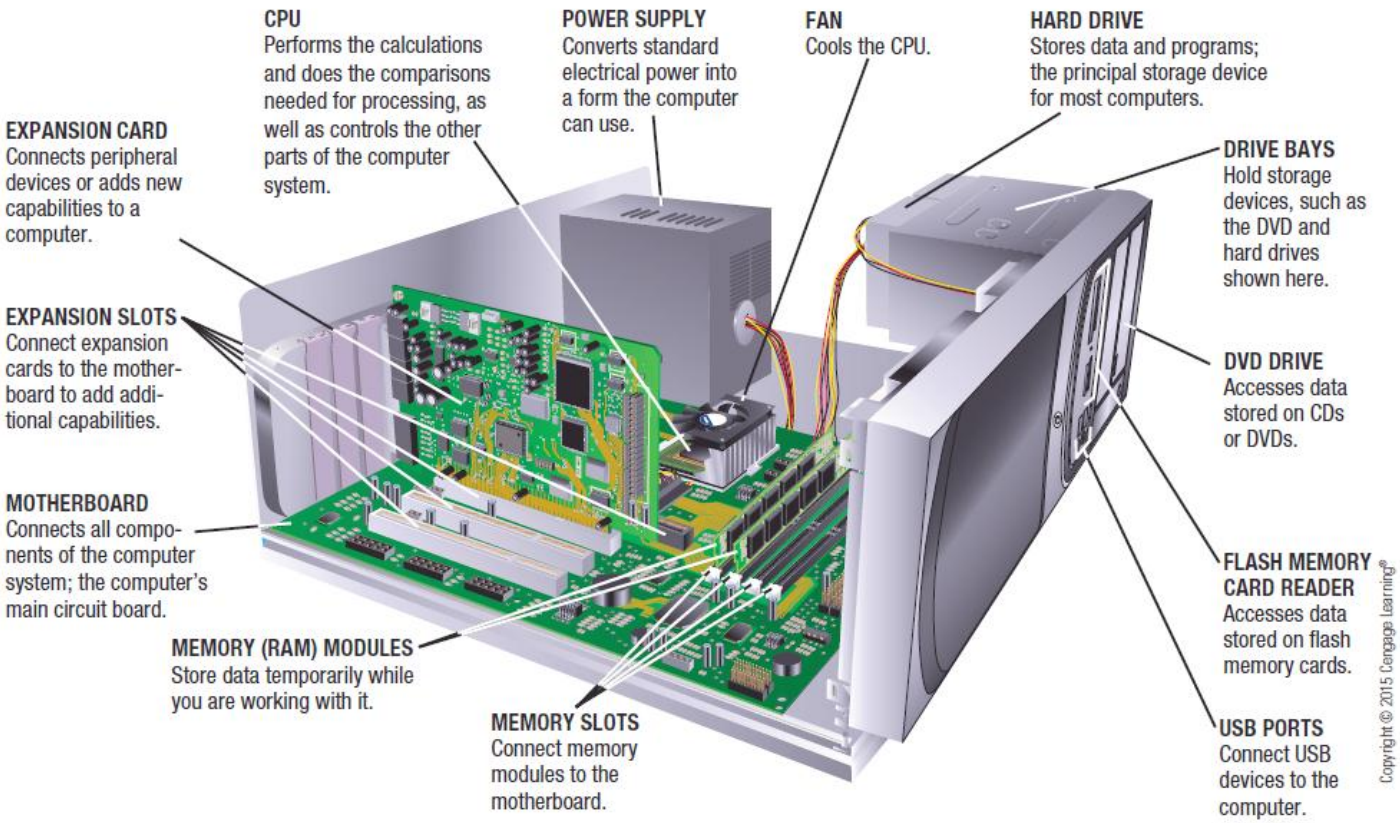

FIGURE 2-7
Inside a typical system unit. The system unit houses the CPU, memory, and other important pieces of hardware.

Inside the Case

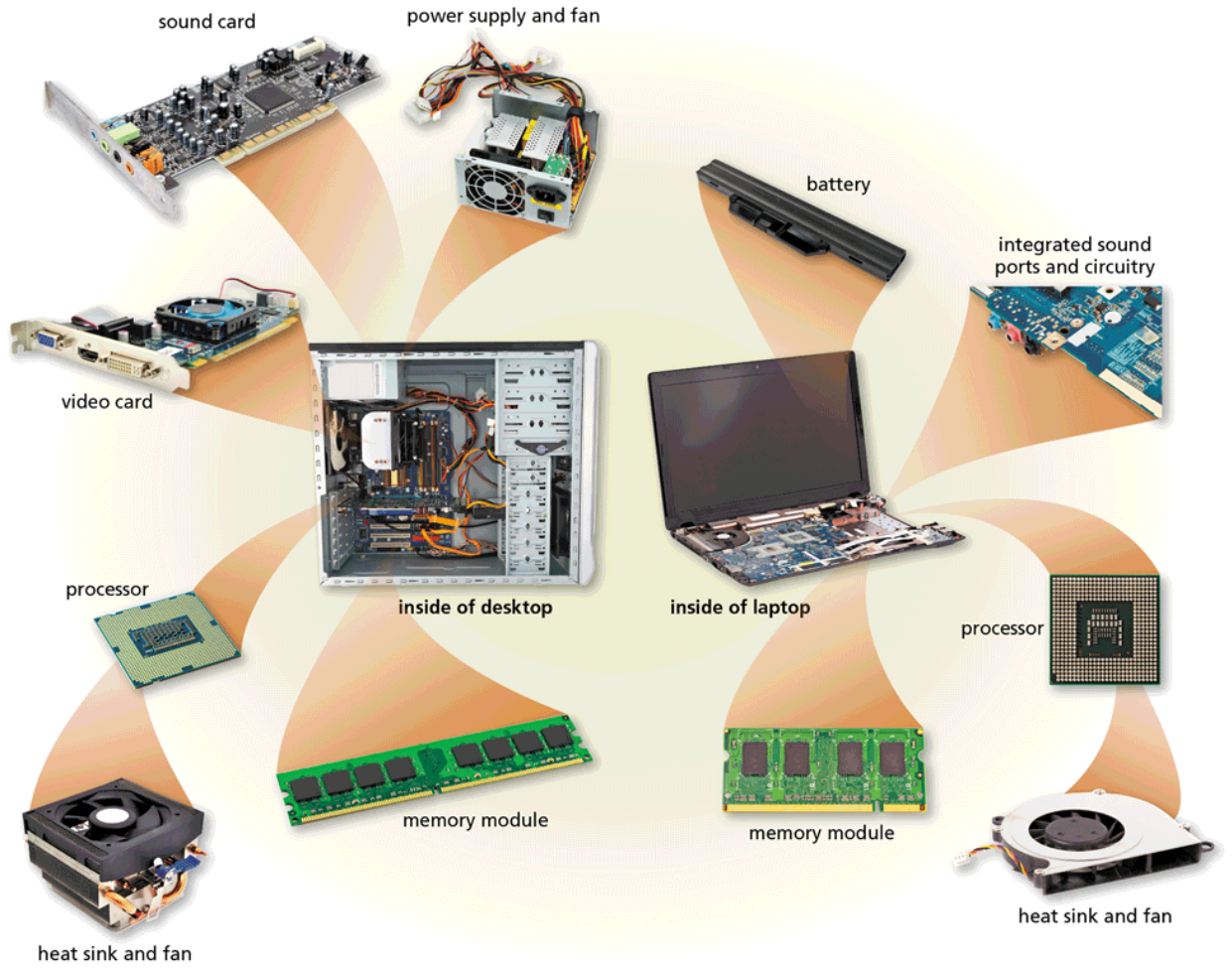

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Figure 6-2

Inside the Case

- The **motherboard** is the main circuit board of the computer
  - A computer **chip** contains integrated circuits

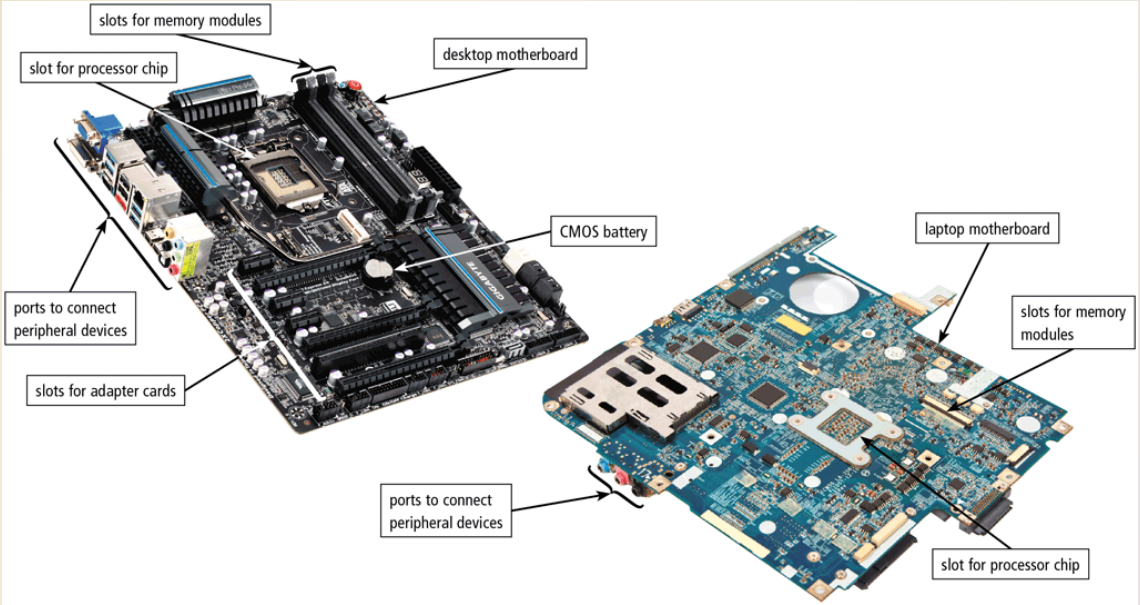

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Figure 6-3

Inside the System Unit

- The Motherboard
  - Computer Chip
    - Very small pieces of silicon or other semi-conducting material onto which integrated circuits are embedded
  - Circuit Board
    - A thin board containing computer chips and other electronic components
  - System Board
    - The main circuit board inside the system unit to which all devices must connect

Inside the System Unit

- Drive Bays
  - Rectangular metal racks inside the system unit that house storage devices
    - Hard drive, CD/DVD drive, flash memory card reader
    - Connected to the motherboard with a cable
- Processors
  - The CPU (Central Processing Unit)
    - Circuitry and components packaged together and connected directly to the motherboard
    - Does the vast majority of processing for a computer
    - Also called a processor; called a microprocessor when talking about personal computers

Inside the System Unit

- Dual-core CPU
  - Contains the processing components (cores) of two separate processors on a single CPU
- Quad-core CPU
  - Contains four cores
- Multi-core processors allow computers to work on more than one task at a time
- Typically different CPUs for desktop computers, portable computers, servers, mobile devices, consumer devices, etc.
  - Personal computer CPU often made by Intel or AMD
  - Media tablets and mobile phones use processors made by other companies such as ARM

Processors

- The **processor**, also called the **central processing unit** (**CPU**), interprets and carries out the basic instructions that operate a computer
- A **multi-core processor** is a single chip with two or more separate processor cores
- Processors contain a control unit and an arithmetic logic unit (ALU)

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Processors

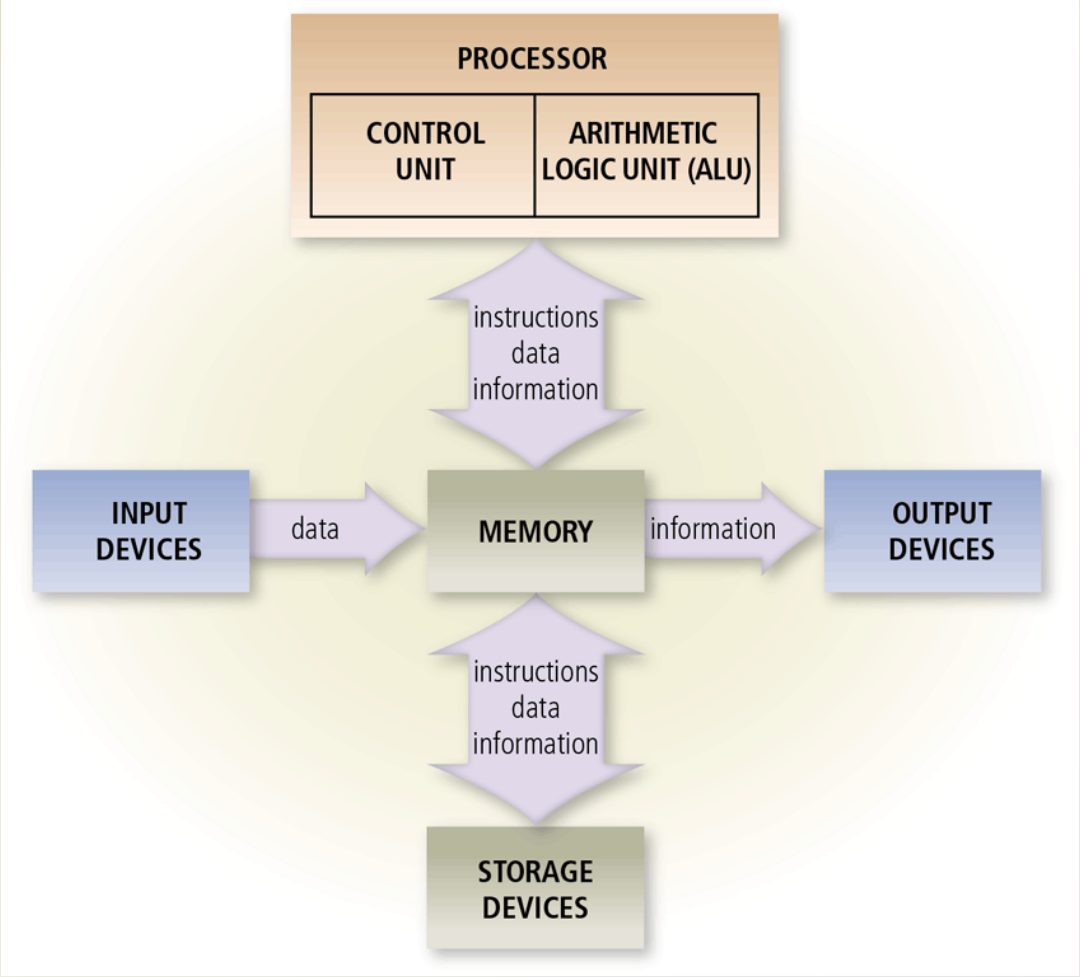

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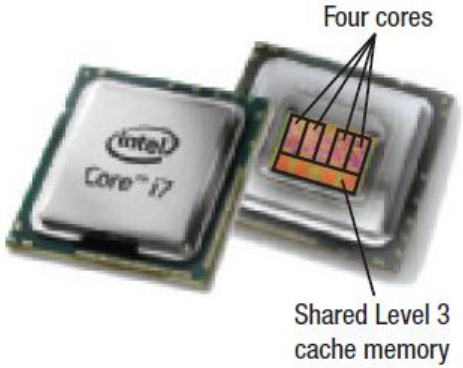
Figure 6-4

Inside the System Unit



DESKTOP PROCESSORS

MOBILE PROCESSORS

TYPE OF CPU	NAME	NUMBER OF CORES	CLOCK SPEED	TOTAL CACHE MEMORY
SERVER	Intel Xeon (E7 family)	6–10	1.73–2.66 GHz	18–30 MB
	AMD Opteron (6300 series)	4–16	1.8–3.5 GHz	20–32 MB
DESKTOP	Intel Core i7 (3rd gen)	4–6	2.5–3.6 GHz	8–12 MB
	AMD FX	4–8	3.1–4.2 GHz	8–16 MB
MOBILE (NOTEBOOKS)	Intel Core i7 Mobile (3rd gen)	2–4	1.06–3.0 GHz	4–8 MB
	AMD Athlon II Neo	1–2	1.3–1.7 GHz	1–2 MB
MOBILE (MOBILE DEVICES)	ARM Cortex-A9	1–4	800 MHz–2 GHz	up to 2 MB
	ARM Cortex-A15	1–4+	1–2 GHz	up to 4 MB
	NVIDIA Tegra 4*	4	1.9 GHz	2 MB

*Based on ARM Cortex-A15

FIGURE 2-8
CPU examples and characteristics.

Processors

- The **control unit** is the component of the processor that directs and coordinates most of the operations in the computer
- The **arithmetic logic unit** (ALU) performs arithmetic, comparison, and other operations

Processors

- For every instruction, a processor repeats a set of four basic operations, which comprise a machine cycle

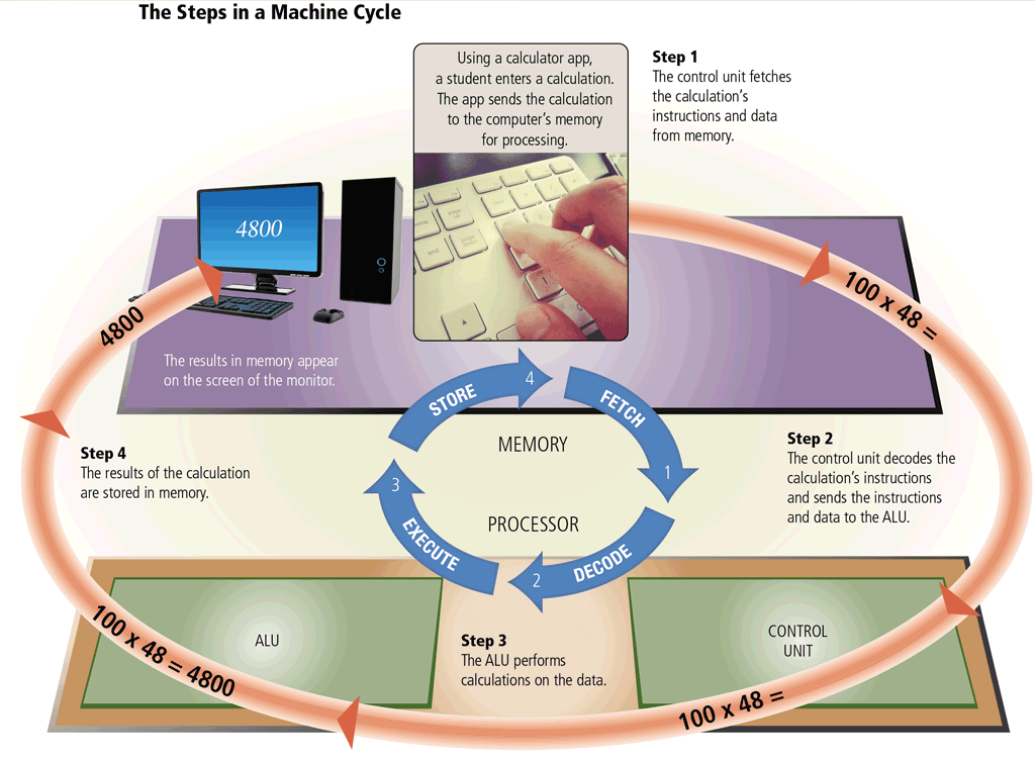


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Figure 6-5

Processors

The processor contains registers, that temporarily hold data and instructions

The **system clock** controls the timing of all computer operations

- The pace of the system clock is called the **clock speed**, and is usually measured in **gigahertz** (**GHz**)

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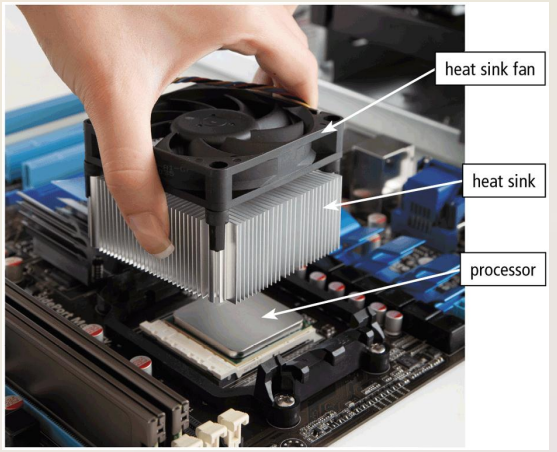
Processors

- The leading manufacturers of personal computer processor chips are Intel and AMD

Processors

- A processor chip generates heat that could cause the chip to malfunction or fail
- Require additional cooling
  - Heat sinks
  - Liquid cooling technology
  - Cooling pads



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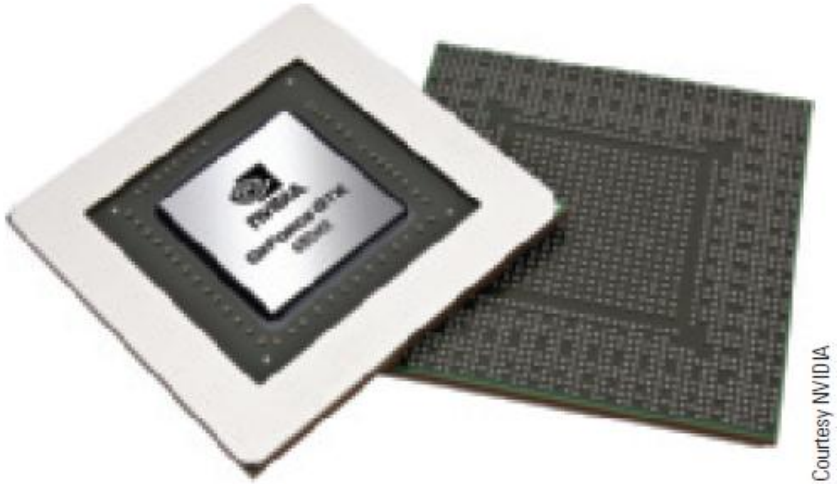
Figures 6-6 – 6-7

Inside the System Unit

- The GPU (graphics processing unit)
  - Takes care of the processing needed to display images (including still images, animations) on the screen
  - Can be located on the motherboard, on a video graphics board, on in the CPU package



Courtesy NVIDIA

FIGURE 2-9
A GPU.

How It Works Box

GPUs and *Transformers: The Ride 3D* at Universal Studios

- Uses a 2,000 foot-long track, 14 huge screens, and 34 projectors
- Motion is synchronized with the action
- Images are 3D, 4K
- Used GPUs to see 3D animations in real time as they were being developed

Inside the System Unit

- Processing Speed
  - CPU clock speed is one measurement of processing speed
  - Rated in megahertz (MHz) or gigahertz (GHz)
  - Higher CPU clock speed = more instructions processed per second
  - Alternate measure of processing speed is the number of instructions a CPU can process per second
    - Megaflops (millions), gigaflops (billions), teraflops (trillions)
  - Benchmark tests can be used to evaluate overall processing speed

Inside the System Unit

- Word Size
  - The amount of data that a CPU can manipulate at one time
  - Typically 32 or 64 bits
- Cache Memory
  - Special group of very fast memory chips located on or close to the CPU
  - Level 1 is fastest, then Level 2, then Level 3
  - More cache memory typically means faster processing
  - Usually internal cache (built into the CPU)

Inside the System Unit

- Bus Width, Bus Speed, and Bandwidth
  - A bus is an electronic path over which data can travel
  - Found inside the CPU and on the motherboard
  - Bus width is the number of wires in the bus over which data can travel
    - A wider bus allows more data to be transferred at one time

Inside the System Unit

- Bus width and speed determine the throughput or bandwidth of the bus
  - The amount of data that can be transferred by the bus in a given time period

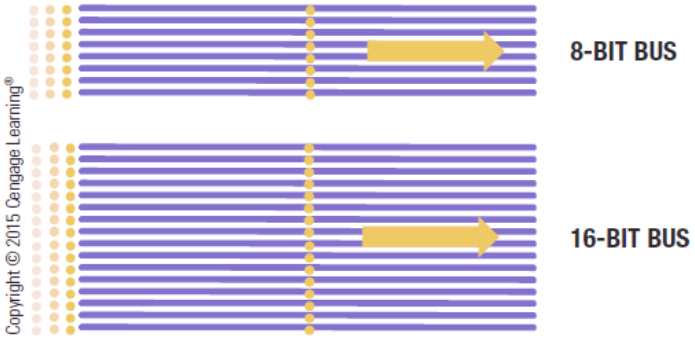


FIGURE 2-10
Bus width. A wider bus can transfer more data at one time than a narrower bus.

Memory

- Memory
  - Refers to chip-based storage located inside the system unit
  - Storage refers to the amount of long-term storage available to a computer
  - Random Access Memory (RAM)
    - Computer's main memory
    - Consists of chips arranged on a circuit board called a memory module which are plugged into the motherboard
    - Stores essential parts of operating system, programs, and data the computer is currently using

Memory

- **Memory** consists of electronic components that store instructions waiting to be executed by the processor, data needed by those instructions, and the results of processing the data
- Stores three basic categories of items:

The operating system and other programs	Applications	Data being processed and the resulting information

Memory

- Computers and mobile devices contain two types of memory:

Volatile memory

- Loses its contents when power is turned off
- Example includes **RAM**

Nonvolatile memory

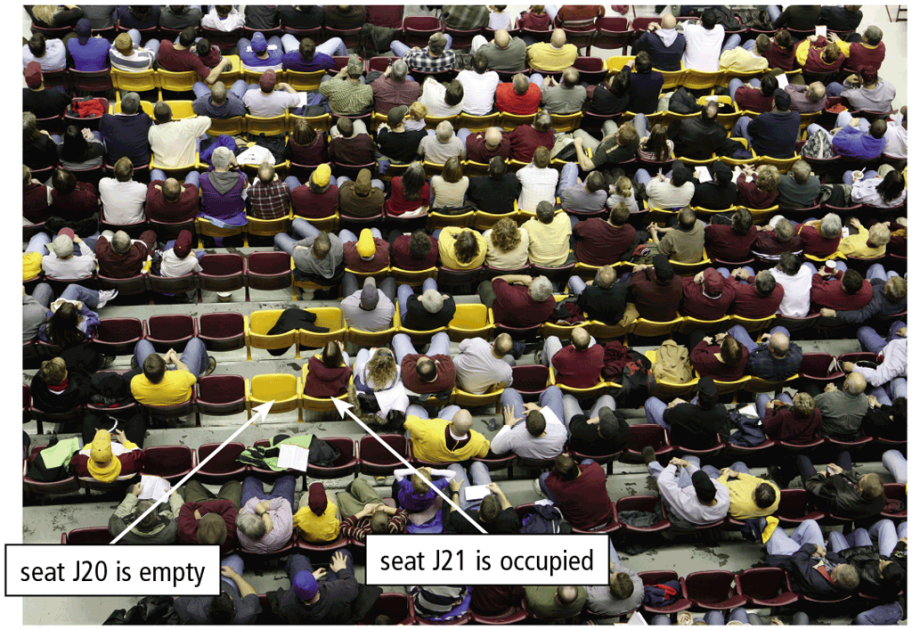
- Does not lose contents when power is removed
- Examples include ROM, flash memory, and CMOS

Memory

- Volatile
  - RAM content lost when the computer is shut off
  - ROM and flash memory are non-volatile
- Measured in bytes
  - Amount installed depends on the CPU and operating system being used
- Most personal computers use SD-RAM
- MRAM and PRAM - non-volatile RAM under development

Memory

- Each location in memory has an address
- Memory size commonly is measured in gigabytes (GB) or terabytes (TB)

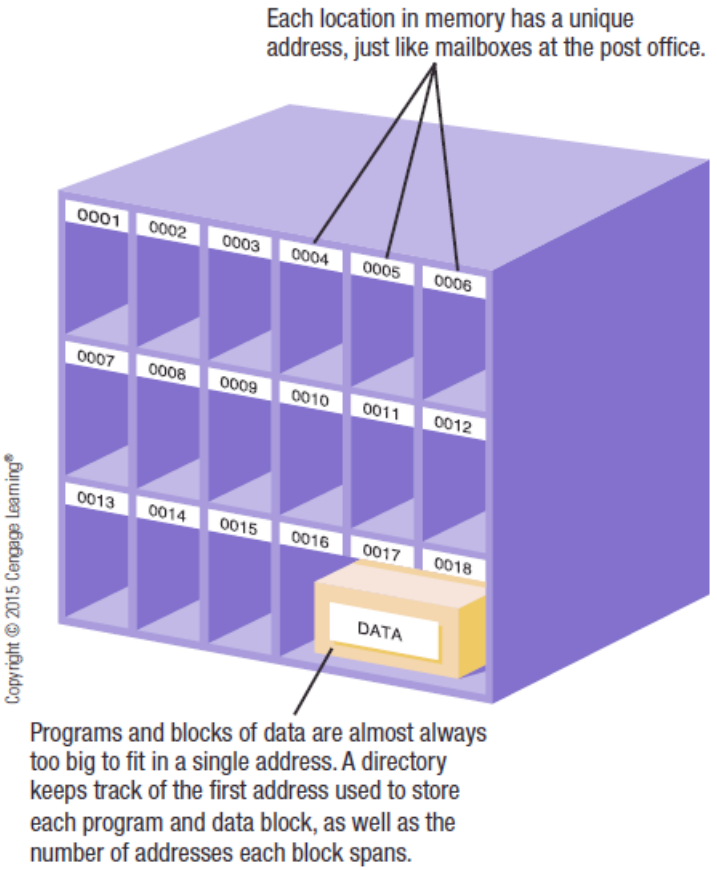


Page 290
Figure 6-11

Memory

- Each location in memory has an address
  - Each location typically holds one byte
  - Computer system sets up and maintains directory tables to facilitate retrieval of the data

FIGURE 2-12
Memory addressing.



Memory

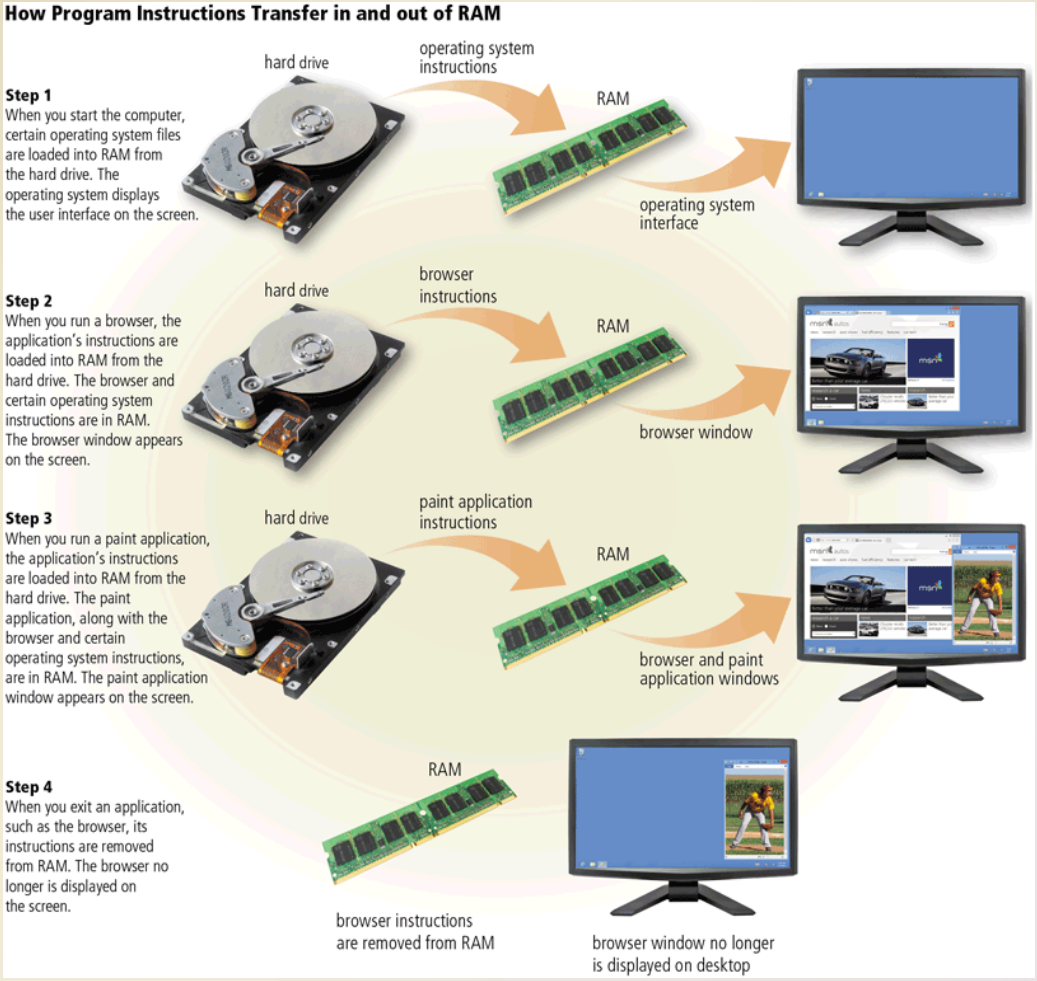


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Figure 6-12

Memory

- Two common types of RAM exist:

Dynamic RAM (DRAM)

Static RAM (SRAM)

Table 6-1 Common DRAM Variations

Name	Comments
SDRAM (Synchronous DRAM)	• Synchronized to the system clock • Much faster than DRAM
DDR SDRAM (Double Data Rate SDRAM)	• Transfers data twice, instead of once, for each clock cycle • Faster than SDRAM
DDR2	• Second generation of DDR • Faster than DDR
DDR3	• Third generation of DDR • Designed for computers with multi-core processors • Faster than DDR2
DDR4	• Fourth generation of DDR • Faster than DDR3
RDRAM (Rambus DRAM)	• Much faster than SDRAM

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Table 6-1

Memory

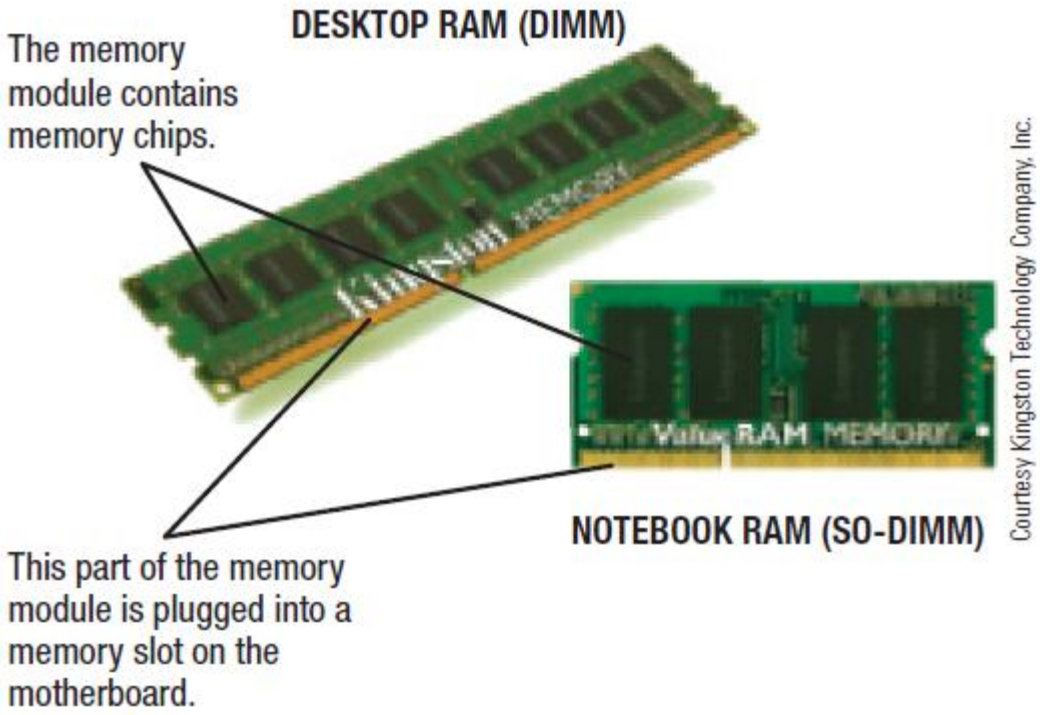

FIGURE 2-11
RAM memory modules.

Memory

- RAM chips usually reside on a memory module and are inserted into memory slots

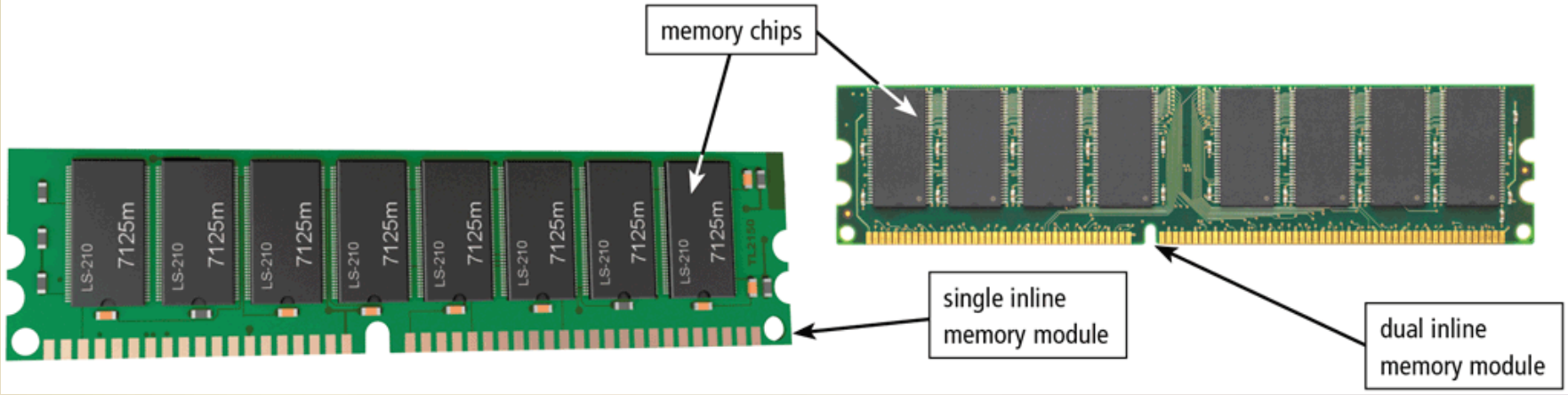

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Figure 6-13

Memory

- Registers
  - High-speed memory built into the CPU
  - Used to store data and intermediary results during processing
  - Fastest type of memory
- ROM (read-only memory)
  - Non-volatile chips located on the motherboard into which data or programs have been permanently stored
  - Retrieved by the computer when needed
  - Being replaced with flash memory

Memory

- Flash Memory
  - Nonvolatile memory chips that can be used for storage
  - Have begun to replace ROM for storing system information
  - Now stores firmware for personal computers and other devices
  - Built into many types of devices (media tablets, mobile phones, and digital cameras) for user storage

Memory

- **Memory cache** speeds the processes of the computer because it stores frequently used instructions and data

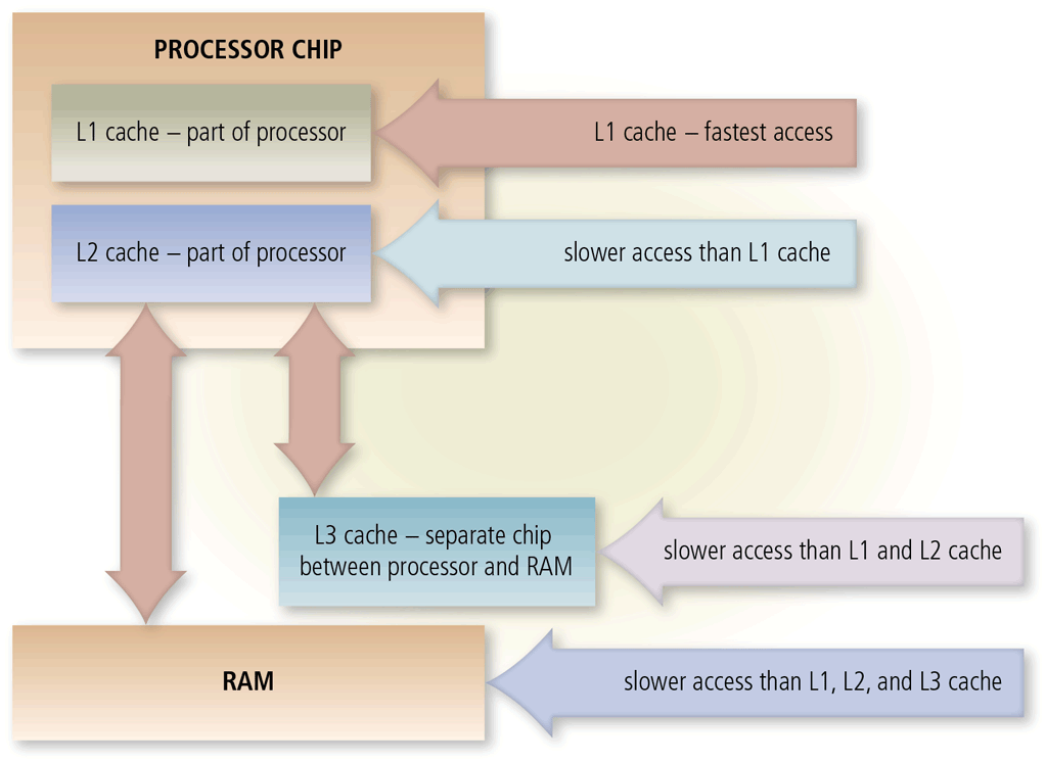

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Figure 6-14

Memory

Read-only memory (**ROM**) refers to memory chips storing permanent data and instructions

- **Firmware**

Page 294

Memory

- **Flash memory** can be erased electronically and rewritten
  - CMOS technology uses battery power to retain information when when the power to the computer is off

Pages 295- 296

Memory

- **Access time** is the amount of time it takes the processor to read from memory
  - Measured in nanoseconds

Table 6-2 Access Time Terminology

Term	Abbreviation	Speed
Millisecond	ms	One-thousandth of a second
Microsecond	µs	One-millionth of a second
Nanosecond	ns	One-billionth of a second
Picosecond	ps	One-trillionth of a second

Page 296
Table 6-2 and Figure 6-15

Adapters

- An **adapter card** enhances functions of a component of a desktop or server system unit and/or provides connections to peripherals
  - Sound card and video card
- An **expansion slot** is a socket on a desktop or server motherboard that can hold an adapter card

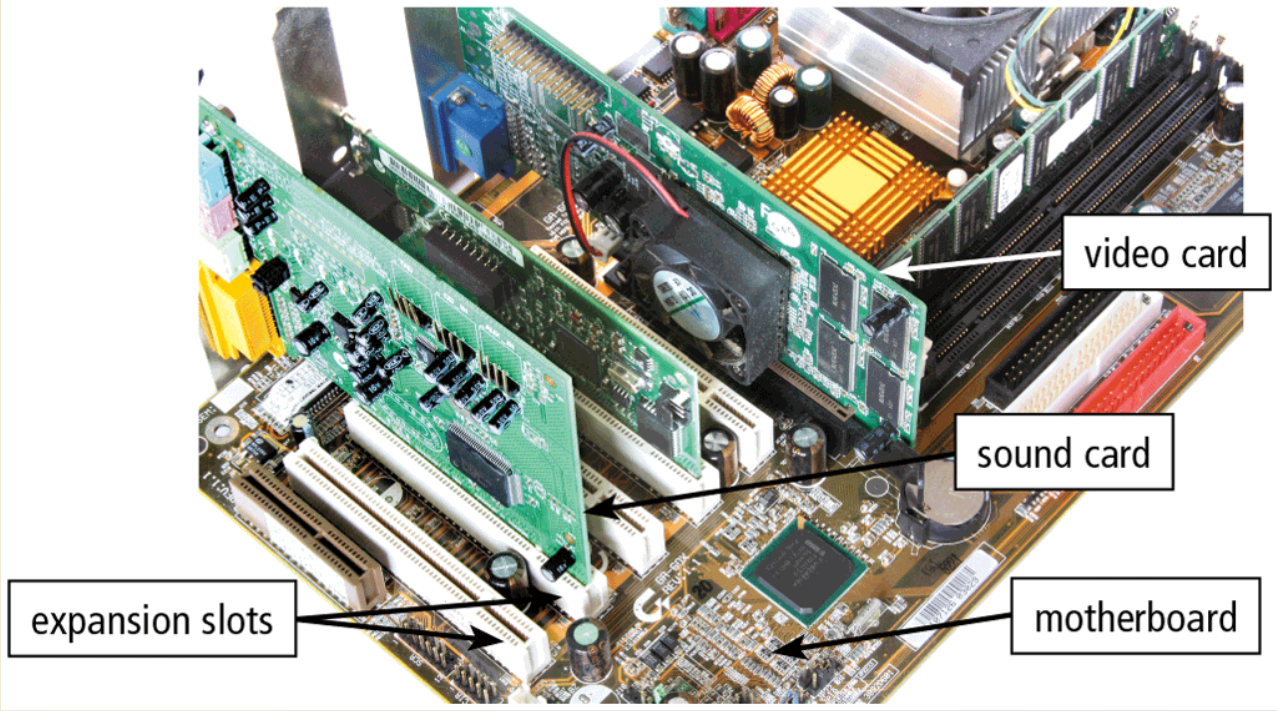
Table 6-3 Adapter Cards

Type	Purpose
Bluetooth	Enables Bluetooth connectivity
MIDI	Connects to musical instruments
Modem	Connects to transmission media, such as cable television lines or phone lines
Network	Provides network connections, such as to an Ethernet port
Sound	Connects to speakers or a microphone
TV tuner	Allows viewing of digital television broadcasts on a monitor
USB	Connects to high-speed USB ports
Video	Provides enhanced graphics capabilities, such as accelerated processing or the ability to connect a second monitor
Video capture	Connects to a video camera

Pages 297 - 298
Table 6-3

Adapters

- With **Plug and Play**, the computer automatically can recognize peripheral devices as you install them



Pages 297 - 298
Figure 6-16

Adapters

- A USB adapter enhances functions of a mobile computer and/or provides connections to peripheral devices

Pages 298 - 299
Figure 6-17

Inside the System Unit

- External devices (monitors, keyboards, mice, printers)
- Wireless devices (e.g., Bluetooth)
- Power Supply
  - Connects to the motherboard to deliver electricity (personal computer)
  - Portable computers use rechargeable battery pack
    - Nonremovable batteries more difficult and expensive to replace

Power Supply and Batteries

- The **power supply** or laptop AC adapter converts the wall outlet AC power into DC power

Page 301
Figure 6-19

Power Supply and Battery

- Mobile computers and devices can run using either a power supply or batteries
- Batteries typically are rechargeable lithium-ion batteries

Pages 301 – 302
Figure 6-20

Cooling Components

- Fans
  - Fans used on most personal computers to help cool the CPU and system unit
  - Heat is an ongoing problem for CPU and computer manufacturers
    - Can damage components
    - Cooler chips run faster
- Heat Sinks
  - Small components typically made out of aluminum with fins that help to dissipate heat

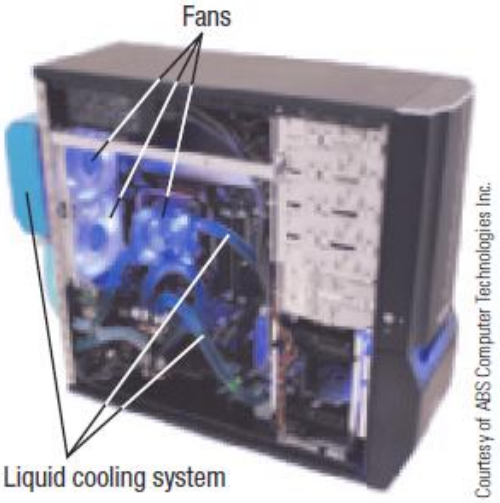
Cooling Components

- Cooling Systems
  - Liquid cooling systems
    - Cool the computer with liquid-filled tubes
  - Immersion cooling
    - Hardware is actually submerged into units filled with a liquid cooling solution
  - Notebook cooling stand
    - Cools the underside of a notebook computer
  - Other cooling methods, such as ion pump cooling systems, are under development

Cooling Components

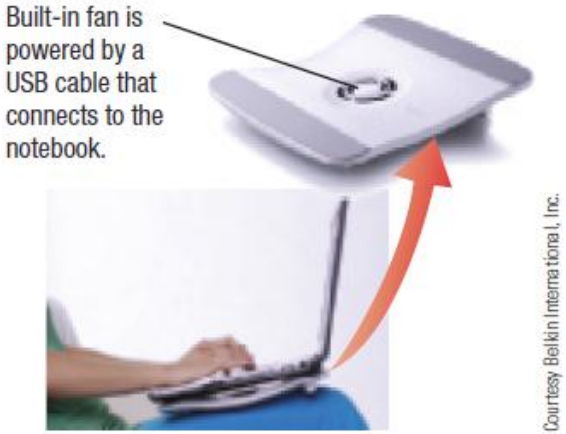
Courtesy Green Revolution Cooling

SERVERS
Often use liquid cooling systems; an immersion cooling system is shown here.



Courtesy of ABS Computer Technologies Inc.

DESKTOP COMPUTERS
Can use fans, heat sinks, and liquid cooling systems to cool the inside of the computer.



Courtesy Belkin International, Inc.

NOTEBOOK COMPUTERS
Typically have at least one internal fan; notebook cooling stands can be used to cool the underside of the computer.

FIGURE 2-13
Computer cooling methods.

Expansion

- Expansion Slots, Expansion Cards, and ExpressCard Modules
  - Expansion Slot
    - A location on the motherboard into which expansion cards are inserted
  - Expansion Card
    - A circuit board inserted into an expansion slot
    - Used to add additional functionality or to attach a peripheral device
  - ExpressCard Modules
    - Designed to add additional functionality to notebooks

Expansion

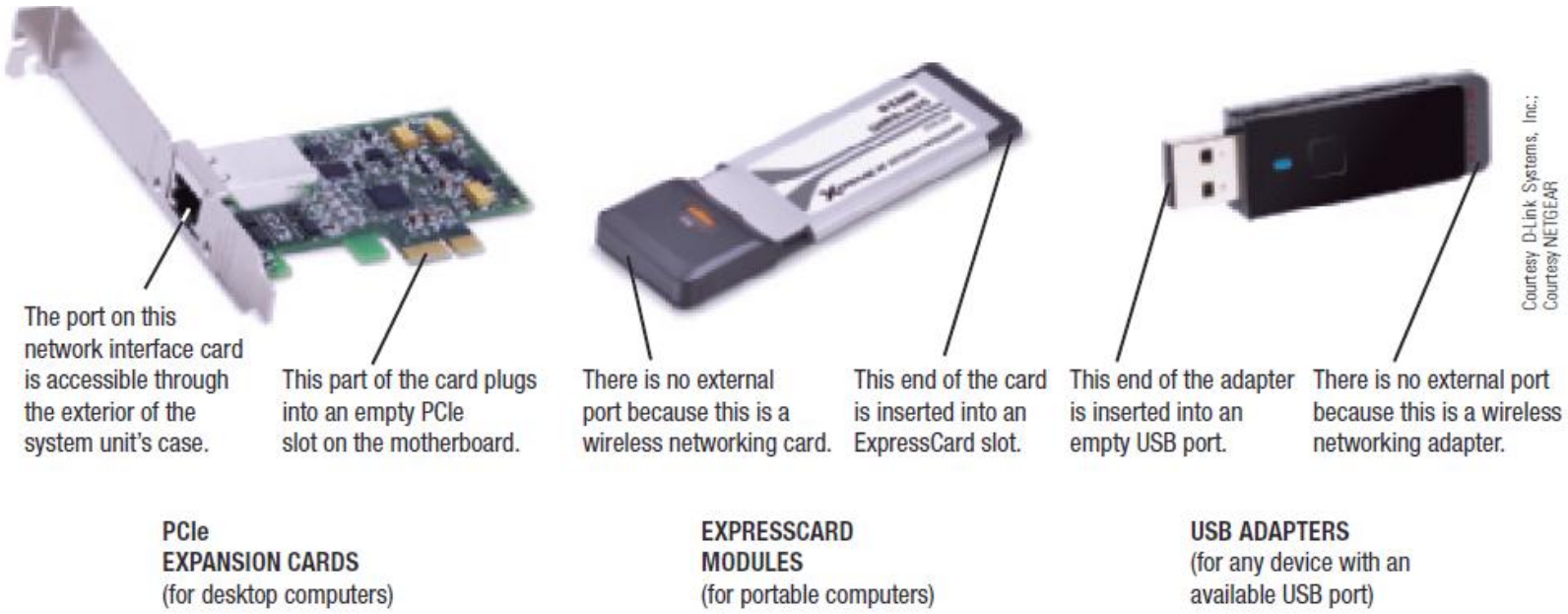
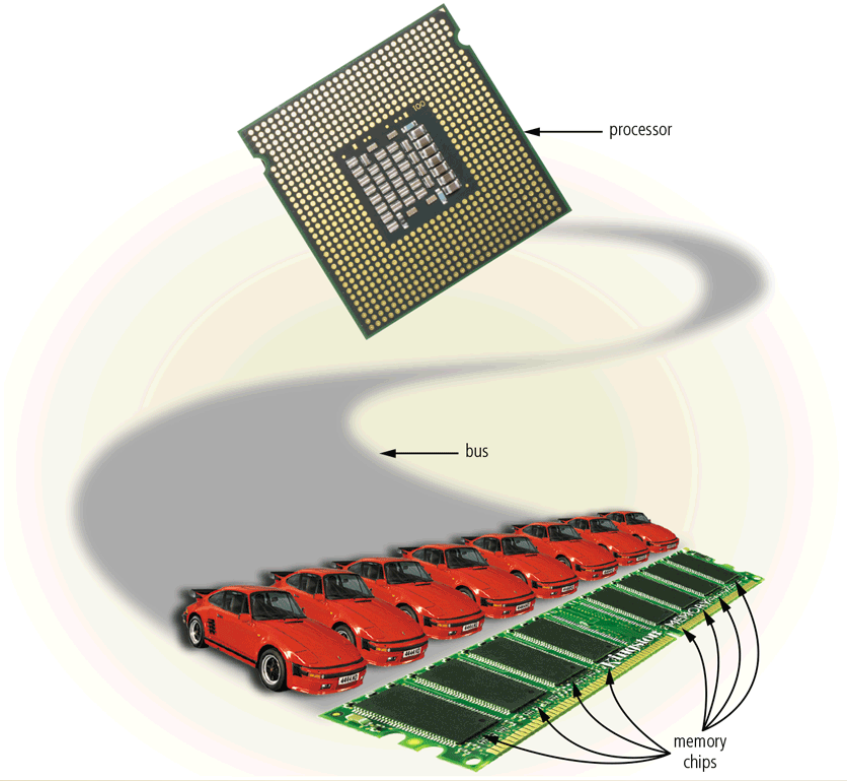


FIGURE 2-14
Types of expansion.

Buses

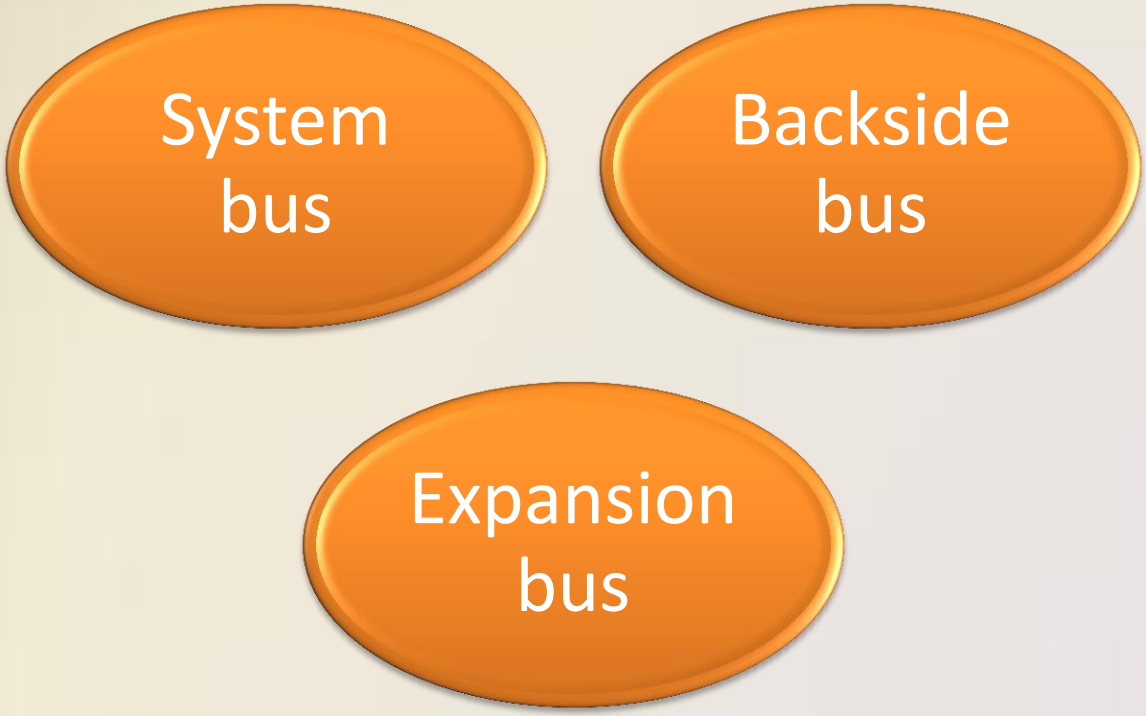


- A **bus** allows the various devices both inside and attached to the system unit to communicate with one another
  - Data bus
  - Address bus
- **Word size** is the number of bits the processor can interpret and execute at a given time

Pages 299 - 300
Figure 6-18

Buses

- A computer might have these three types of buses:



Buses

- Bus
  - An electronic path within a computer over which data travels
    - Located within the CPU and etched onto the motherboard
  - Expansion Bus
    - Connects the CPU to peripheral (typically input and output) devices
  - Memory Bus
    - Connects CPU directly to RAM
  - Frontside Bus (FSB)
    - Connects CPU to the chipset that connects the CPU to the rest of the bus architecture

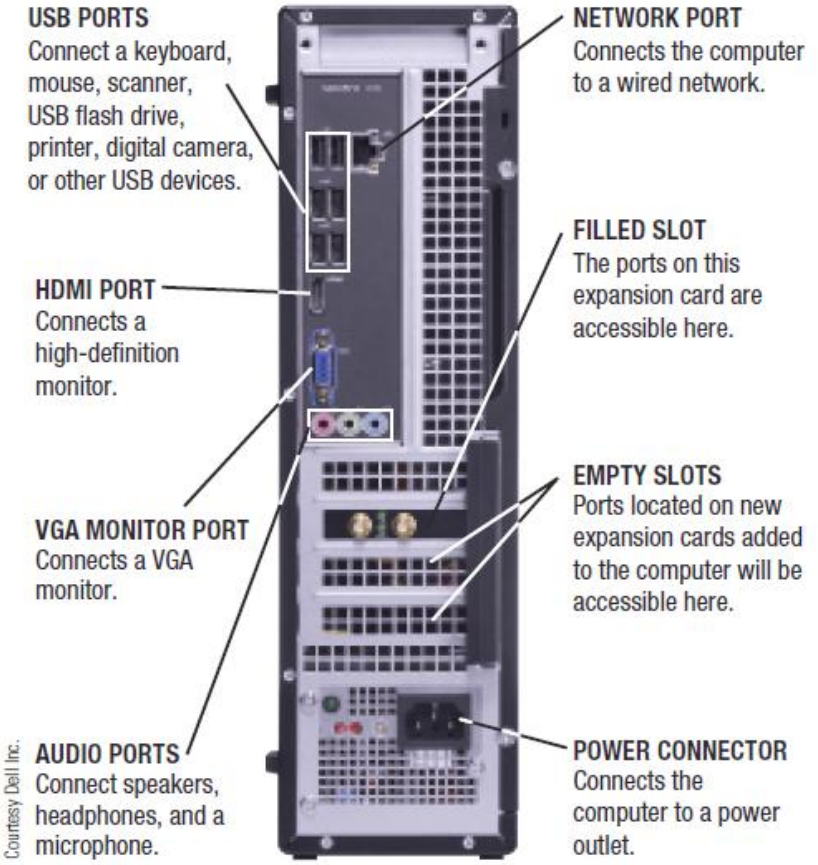
Buses

- PCI and PCI Express (PCIe) Bus
  - PCI has been one of the most common types
  - Today, PCI Express bus, which is extremely fast, has replaced the PCI bus
- Universal Serial Bus (USB)
  - Extremely versatile
  - Allows 127 different devices to connect to a computer via a single USB port
- FireWire Bus
  - Developed by Apple to connect multimedia devices to a computer

Ports and Connectors

- Port
  - A connector on the exterior of a computer's system unit to which a device may be attached
  - Typical desktop computer ports include:
    - Power connector, Firewire, VGA monitor, Network, USB, Audio, and HDMI
  - Others include IrDA and Bluetooth ports, eSATA ports, Thunderbolt ports (Apple devices)
  - Most computers support the Plug and Play standard

Ports and Connectors



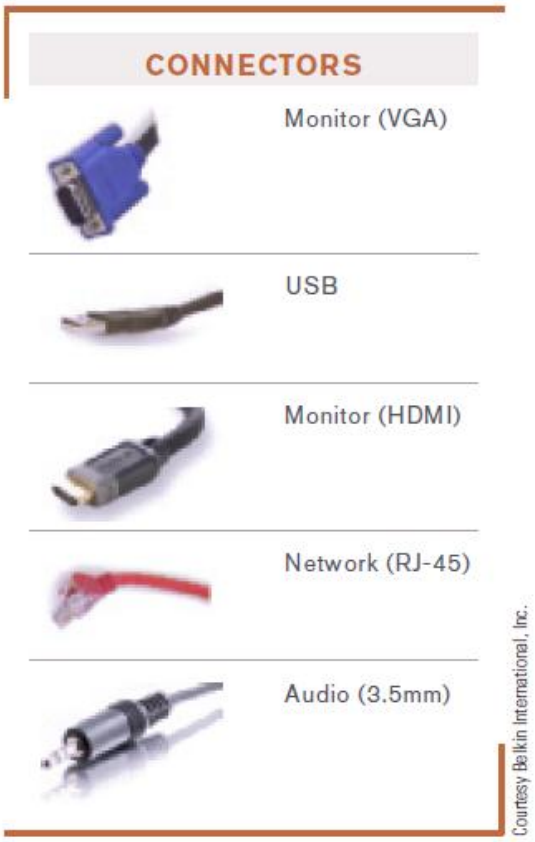


FIGURE 2-16
Typical ports for desktop computers and examples of connectors.

Ports and Connectors

- Portable computers have ports similar to desktop computers, but often not as many
- Smartphones and mobile devices have more limited expansion capabilities
  - Usually have a USB port, HDMI port, and/or flash memory card slot
  - Flash memory cards often use the Secure Digital (SD) format
  - MiniSD and microSD cars are smaller than regular SD cards

Ports and Connectors

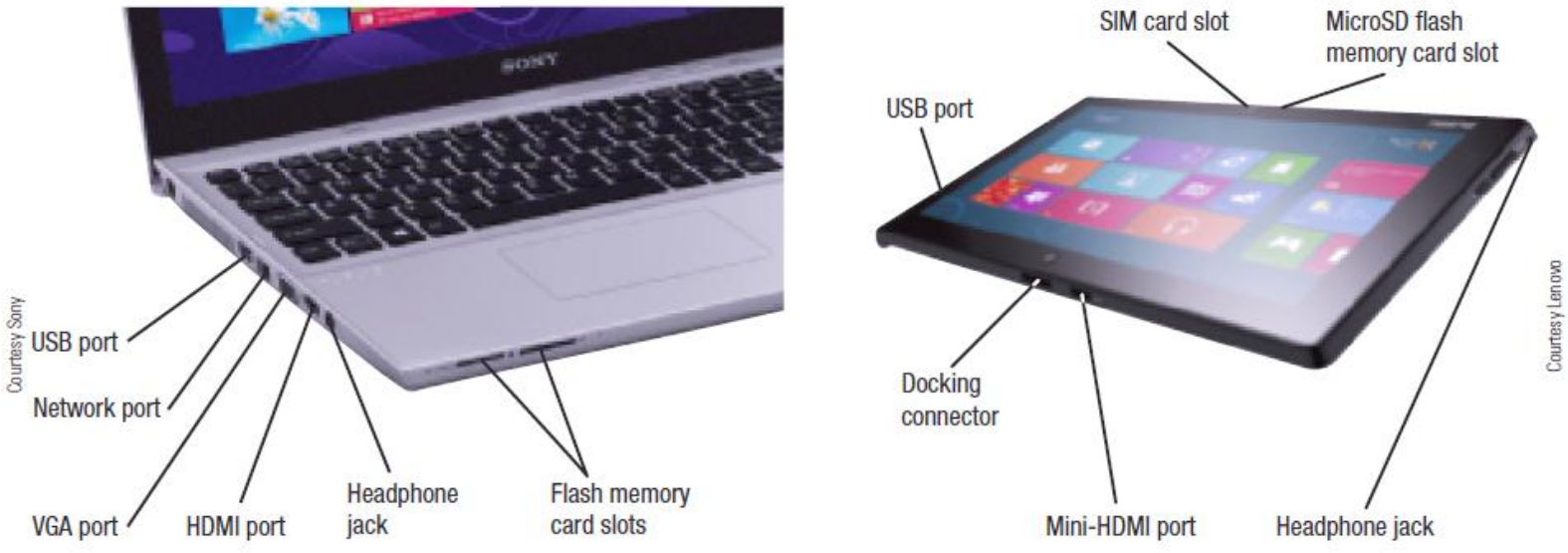


FIGURE 2-18
Typical ports for portable computers.

Trend Box

Tablet Docks

- Used to help with tablet productivity
- Some are just a stand
- Many include a keyboard
- Some include ports (USB, monitor, etc.) to connect peripherals
- Some contain a battery

Quick Quiz

1. Which type of memory is erased when the power goes out?
    a. ROM
    b. RAM
    c. flash memory
2. True or False: The CPU can also be called the motherboard.
3. A(n) electronic path within a computer over which data travels is called a(n) _____.

Answers:

1) b; 2) False; 3) bus

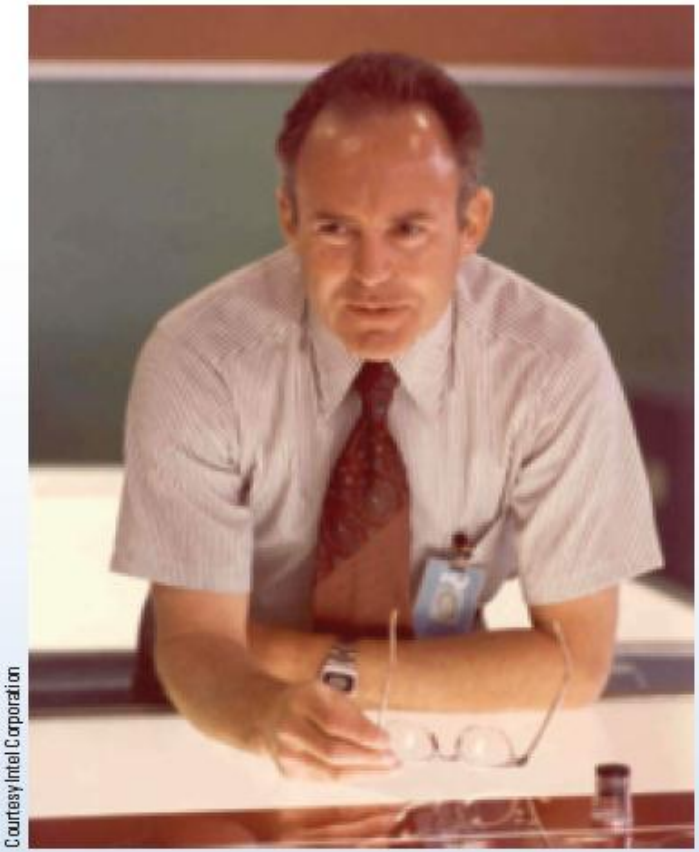
How the CPU Works

- CPU (Central Processing Unit)
  - Consists of a variety of circuitry and components packaged together
  - Transistor: Key element of the microprocessor
    - Made of semi-conductor material that acts like a switch controlling the flow of electrons inside a chip
  - Today's CPUs contain hundreds of millions of transistors; the number doubles about every 18 months (Moore's Law)

Inside the Industry Box

Moore's Law

- In 1965, Gordon Moore predicted that the number of transistors per square inch on chips had doubled every two years and that trend would continue
- Moore's Law is still relevant today for processors as well as other computer components



Gordon Moore (1970).

How the CPU Works

- Typical CPU Components
  - Arithmetic/Logic Unit (ALU)
    - Performs arithmetic involving integers and logical operations
  - Floating Point Unit (FPU)
    - Performs decimal arithmetic
  - Control Unit
    - Coordinates and controls activities within a CPU core
  - Prefetch Unit
    - Attempts to retrieve data and instructions before they are needed for processing in order to avoid delays

How the CPU Works

- Decode Unit
  - Translates instructions from the prefetch unit so they are understood by the control unit, ALU, and FPU
- Registers and Internal Cache Memory
  - Store data and instructions needed by the CPU
- Bus Interface Unit
  - Allows the core to communicate with other CPU components

How the CPU Works

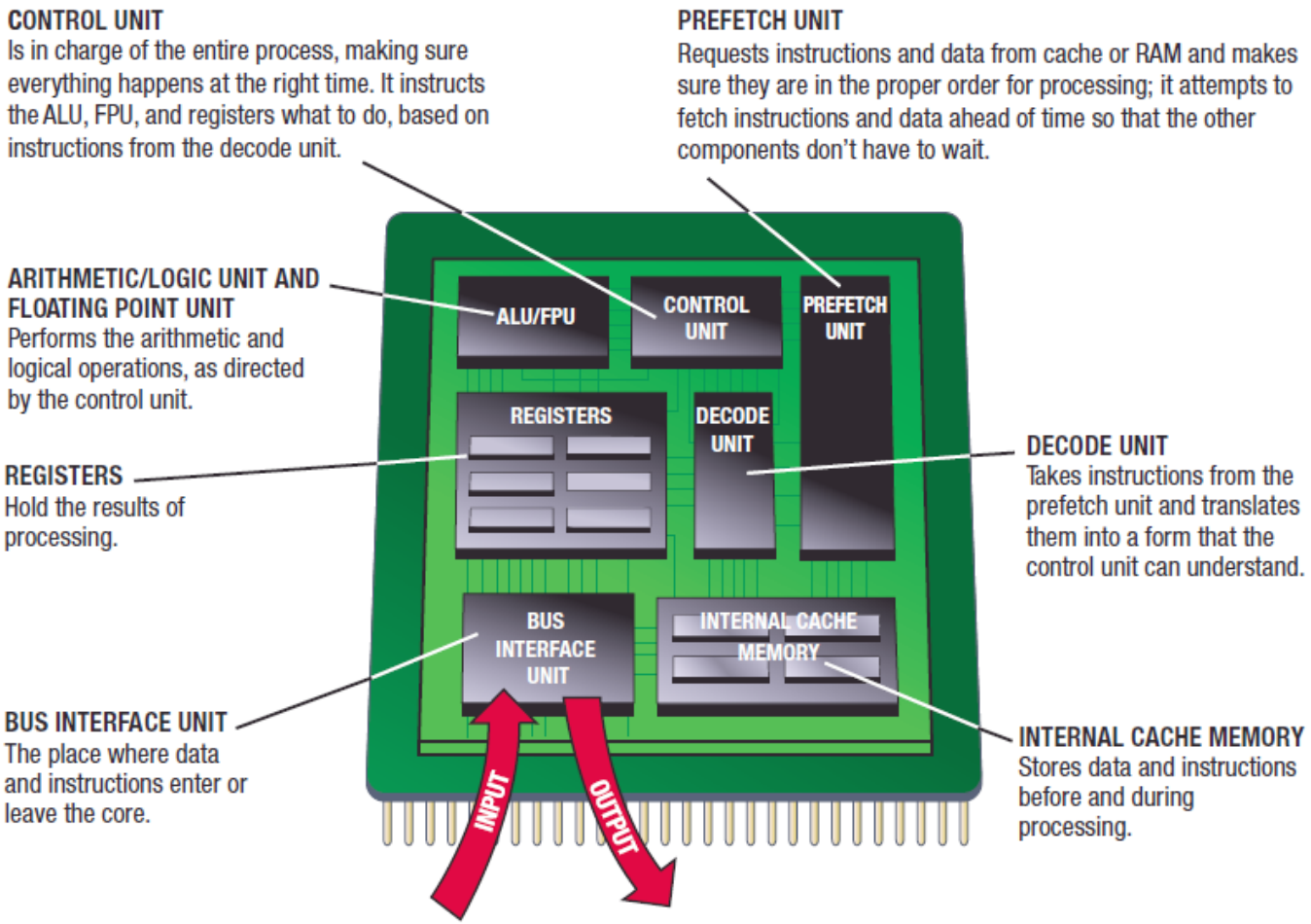


FIGURE 2-19
Inside a CPU core.

The System Clock and the Machine Cycle

- System Clock
  - Small quartz crystal on the motherboard
  - Timing mechanism within the computer system that synchronizes the computer's operations
    - Sends out a signal on a regular basis to all computer components
    - Each signal is a cycle
    - Number of cycles per second is measured in hertz (Hz)
    - One megahertz = one million ticks of the system clock

The System Clock and the Machine Cycle

- Many PC system clocks run at 200 MHz
- Computers can run at a multiple or fraction of the system clock speed
- A CPU clock speed of 2 GHz means the CPU clock "ticks" 10 times during each system clock tick
- During each CPU clock tick, one or more pieces of microcode are processed
- A CPU with a higher clock speed processes more instructions per second than the same CPU with a lower CPU clock speed

The System Clock and the Machine Cycle

- Machine Cycle
  - The series of operations involved in the execution of a single machine level instructi

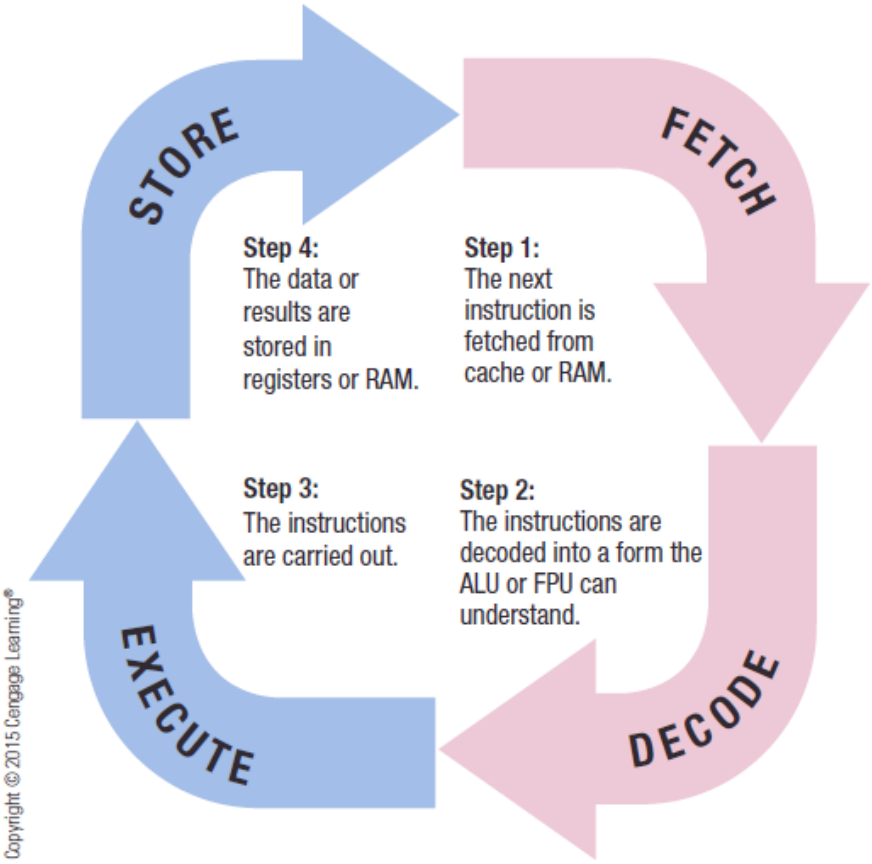
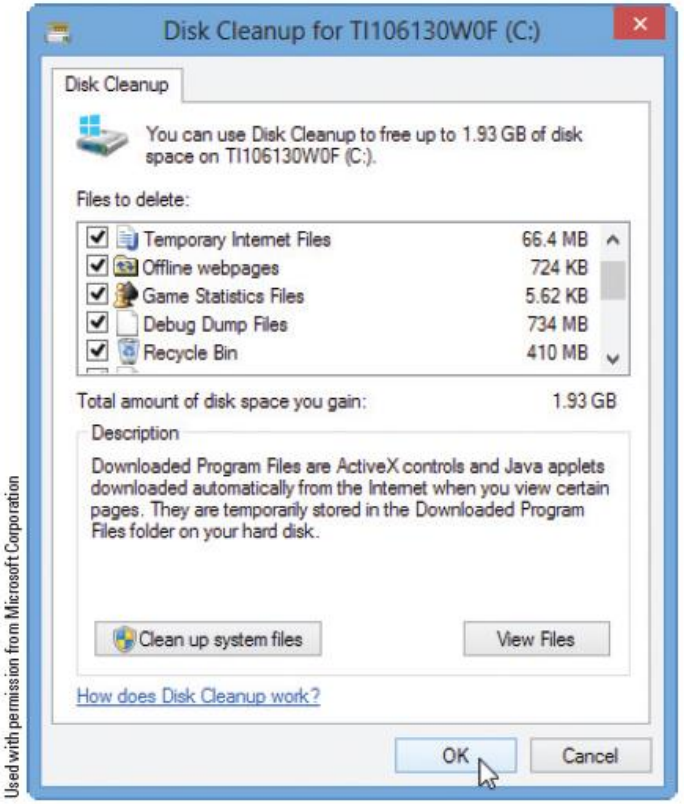


FIGURE 2-20
A machine cycle.
A machine cycle is typically accomplished in four steps.

Making Computers Faster and Better Now and in the Future

- Improving the Performance of Your System Today
  - Add more memory
  - Perform system maintenance
    - Uninstall programs properly
    - Remove unnecessary programs from the Startup list
    - Consider placing large files not needed on a regular basis on external storage
    - Delete temporary files



Used with permission from Microsoft Corporation

FIGURE 2-22
Windows Disk Cleanup. Running the Disk Cleanup program can help free up room on your hard drive.

Making Computers Faster and Better Now and in the Future

- Error check and defrag the hard drive periodically
- Scan for viruses and spyware continually
- Clean out dust once or twice a year

– Buy a larger or second hard drive
– Upgrade your Internet connection
– Upgrade your video graphics card

Making Computers Faster and Better Now and in the Future

- Strategies for Making Faster and Better Computers
  - Improved Architecture
    - Smaller components, faster bus speeds, multiple CPU cores, support for virtualization
  - Improved Materials
    - Flexible electronic components
      - Copper, high-k, graphene chip

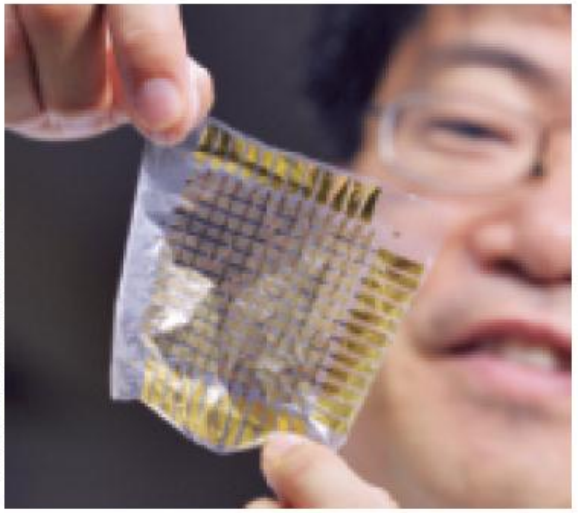


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FIGURE 2-23
Flexible electronics.

Making Computers Faster and Better Now and in the Future

- Pipelining
  - Allows multiple instructions to be processed at one time
- Multiprocessing and Parallel Processing
  - Use multiple processors to speed up processing

Making Computers Faster and Better Now and in the Future

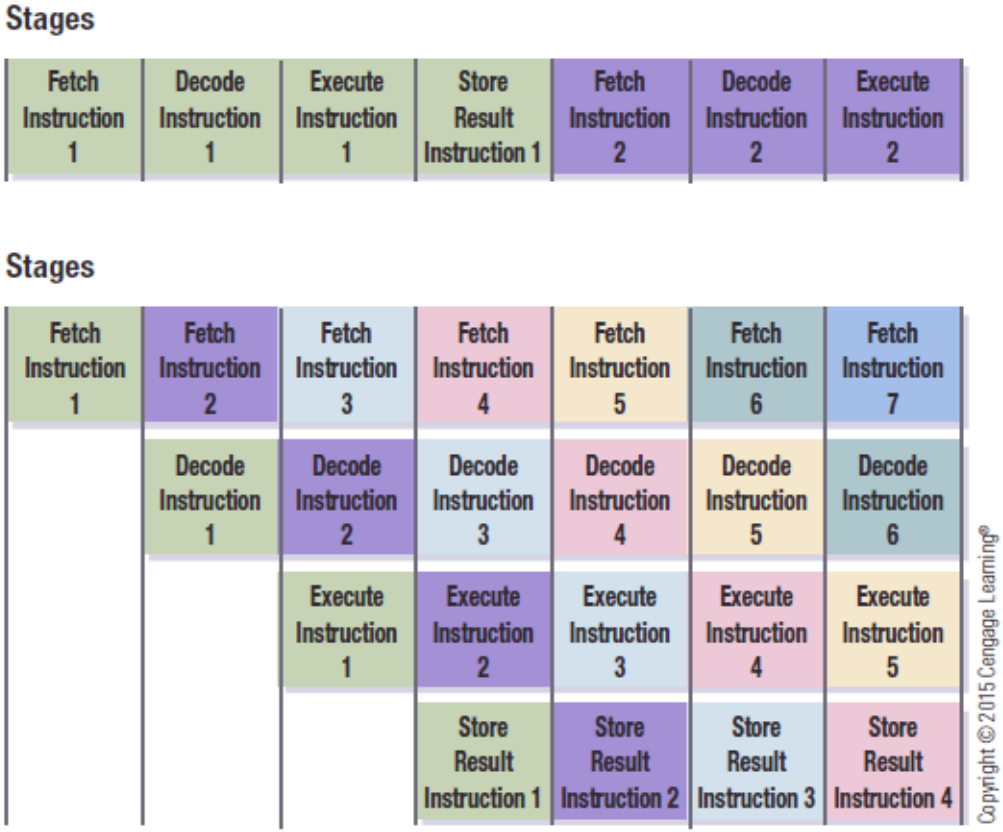

FIGURE 2-24

Pipelining. Pipelining streamlines the machine cycle by executing different stages of multiple instructions at the same time so that the different parts of the CPU are idle less often.