

Introduction to Information Technology

Lecture 2

IT 111

The System Unit: Processing and Memory

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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, memory, buses, and expansion cards.
3. Describe how new peripheral devices or other hardware can be added to a computer.

Learning Objectives

4. Understand how the computer system'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 technologies that may be used in the future computers.

- This lecture covers:
 - How computers represent data and program instructions.
 - How the CPU, memory, and other components located inside the system unit are arranged, as well as the characteristics of the components.
 - How the CPU performs processing tasks.

Data and Program Representation

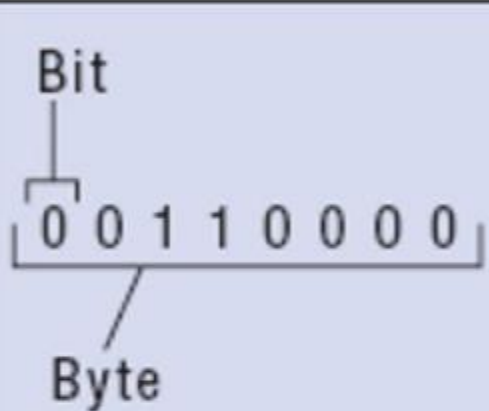
- In order to be understood by a computer, data and programs need to be represented appropriately.
- Coding systems: Used to represent data and programs in a manner understood by the computer.
- Digital computers: Can only understand two states, off and on (0 and 1).
- Digital data representation: The process of representing data in digital form so it can be understood by a computer.

What is Binary



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), etc.



Abbreviation	Approximate Size
KB	1 thousand bytes
MB	1 million bytes
GB	1 billion bytes
TB	1 trillion bytes
PB	1,000 terabytes

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.

The Binary Numbering System

DECIMAL NUMBERING SYSTEM
Each place value in a decimal number represents 10 raised to the appropriate power.

The decimal number
7216



10^3 (1000)	10^2 (100)	10^1 (10)	10^0 (1)
7	2	1	6

10 raised to different powers

means $6 \times 1 = 6$
means $1 \times 10 = 10$
means $2 \times 100 = 200$
means $7 \times 1,000 = 7,000$
7,216

BINARY NUMBERING SYSTEM
Each place value in a binary number represents 2 raised to the appropriate power.

The binary number
1001



2^3 (8)	2^2 (4)	2^1 (2)	2^0 (1)
1	0	0	1

2 raised to different powers

means $1 \times 1 = 1$
means $0 \times 2 = 0$
means $0 \times 4 = 0$
means $1 \times 8 = 8$
9

Decimal equivalent

Coding Systems for Text-Based Data

- ASCII and EBCDIC
 - 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 mainframe use.

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

Coding Systems for Text-Based Data

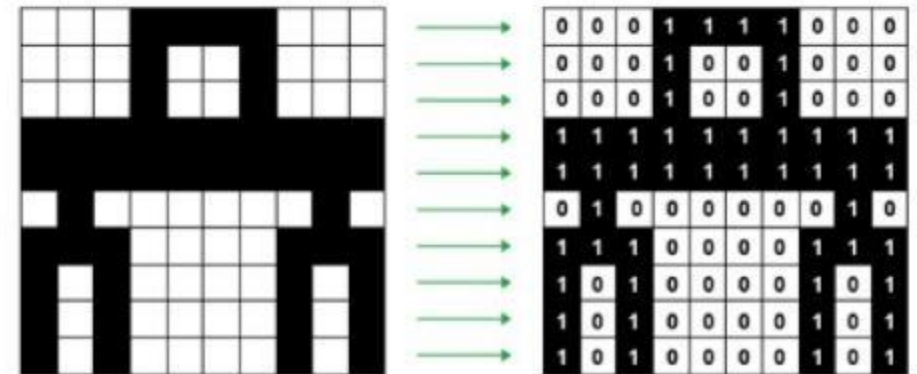
- Unicode: newer code (32 bits per character is common); universal coding standard designed to represent text-based data written in any ancient or modern language.
- Replacing ASCII as the primary text-coding system.



Coding Systems for images

- Images also need to be converted into **binary** in order for a computer to process them so that they can be seen on our screen. Digital images are made up of **pixels**. Each pixel in an image is made up of binary numbers.
- If we say that 1 is black (or on) and 0 is white (or off), then a simple black and white picture can be created using binary.
- To create the picture, a grid can be set out and the squares colored (1 – black and 0 – white). But before the grid can be created, the size of the grid needs to be known. This data is called **metadata** and computers need metadata to know the size of an image. If the metadata for the image to be created is 10x10, this means the picture will be 10 pixels across and 10 pixels down.

- This example shows an image created in this way:
- 0001111000 0001001000 0001001000 1111111111 1111111111 0100000010



Coding Systems for images

Adding color

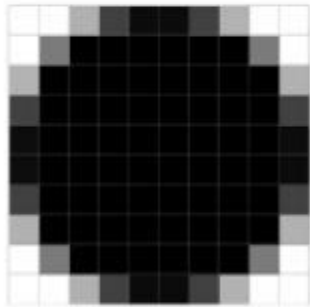
- The system described so far is fine for black and white images, but most images need to use colors as well. Instead of using just 0 and 1, using four possible numbers will allow an image to use four colors. In binary this can be represented using two **bits** per pixel:
- 00 – white.
- 01 – blue.
- 10 – green.
- 11 – red.

Coding Systems for images

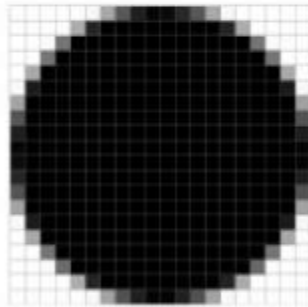
While this is still not a very large range of colors, adding another binary digit will double the number of colors that are available:

- 1 bit per pixel (0 or 1): two possible colours.
- 2 bits per pixel (00 to 11): four possible colours.
- 3 bits per pixel (000 to 111): eight possible colours.
- 4 bits per pixel (0000 – 1111): 16 possible colours.
- 16 bits per pixel (0000 0000 0000 0000 – 1111 1111 1111 1111): over 65 000 possible colors.

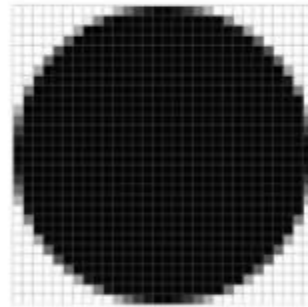
Coding Systems for images



1x
(10 x 10 px)



2x
(20 x 20 px)



3x
(30 x 30 px)

0000	Color1
0001	Color2
0010	Color3
0011	Color4
0100	Color5
0101	Color6
0110	Color7
0111	Color8
1000	Color9
1001	Color10
1010	Color11
1011	Color12
1100	Color13
1101	Color14
1110	Color15
1111	Color16



One sample pixel:
1110

16-COLOR IMAGE
The color of each pixel is represented using one half byte (4 bits).



One sample pixel:
01110110

256-COLOR IMAGE
The color of each pixel is represented using one byte (8 bits).

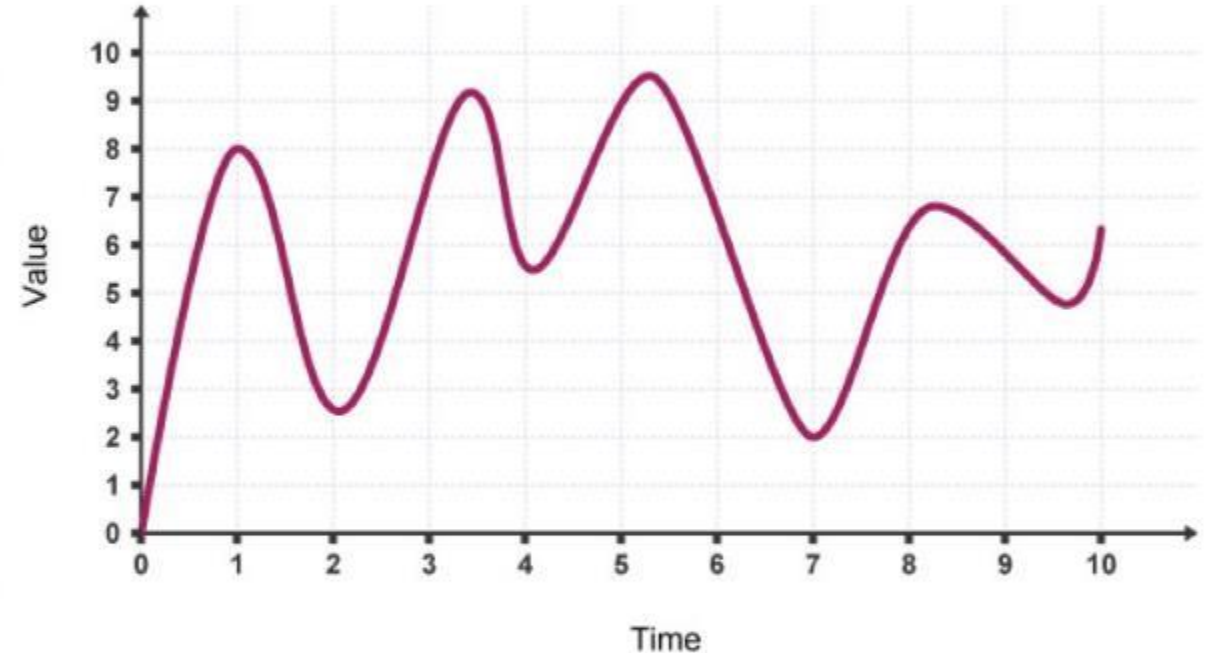


One sample pixel:
10100110010011011001011

PHOTOGRAPHIC-QUALITY (TRUE COLOR) IMAGE (16.8 million colors)
The color of each pixel is represented using three bytes (24 bits).

Coding Systems for Audio data

- Sound needs to be converted into **binary** for computers to be able to process it. To do this, sound is captured - usually by a microphone - and then converted into a **digital** signal.
- An **analogue** to digital converter will sample a sound wave at regular time intervals. For example, a sound wave like this can be sampled at each time sample point.
- The samples can then be converted to binary. They will be recorded to the nearest whole number.

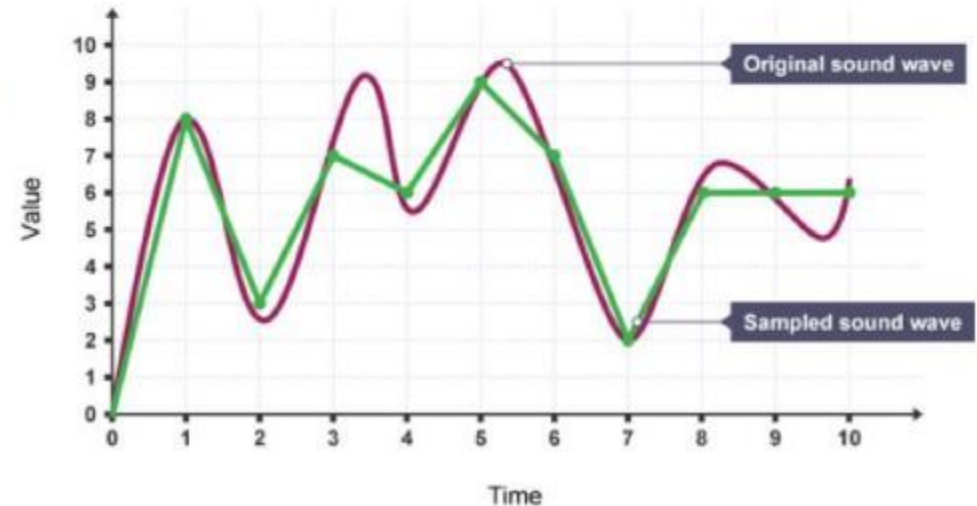


Time sample	1	2	3	4	5	6	7	8	9	10
Denary	8	3	7	6	9	7	2	6	6	6
Binary	1000	0011	0111	0110	1001	0111	0010	0100	0110	0110

Coding Systems for Audio data

- If the time samples are then plotted back onto the same graph, it can be seen that the sound wave now looks different. This is because sampling does not take into account what the sound wave is doing in between each time sample.
- This means that the sound loses quality as data has been lost between the time samples. The way to increase the quality and store the sound at a quality closer to the original, is to have more time samples that are closer together. This way, more detail about the sound can be collected, so when it's converted to digital and back to analogue again it does not lose as much quality.
- The frequency at which samples are taken is called the **sample rate**, and is measured in Hertz (Hz). 1 Hz is one sample per second.

Most CD-quality audio is sampled at 44 100 or 48 000 KHz.



Representing Programs: Machine Language

PROGRAMMING LANGUAGES

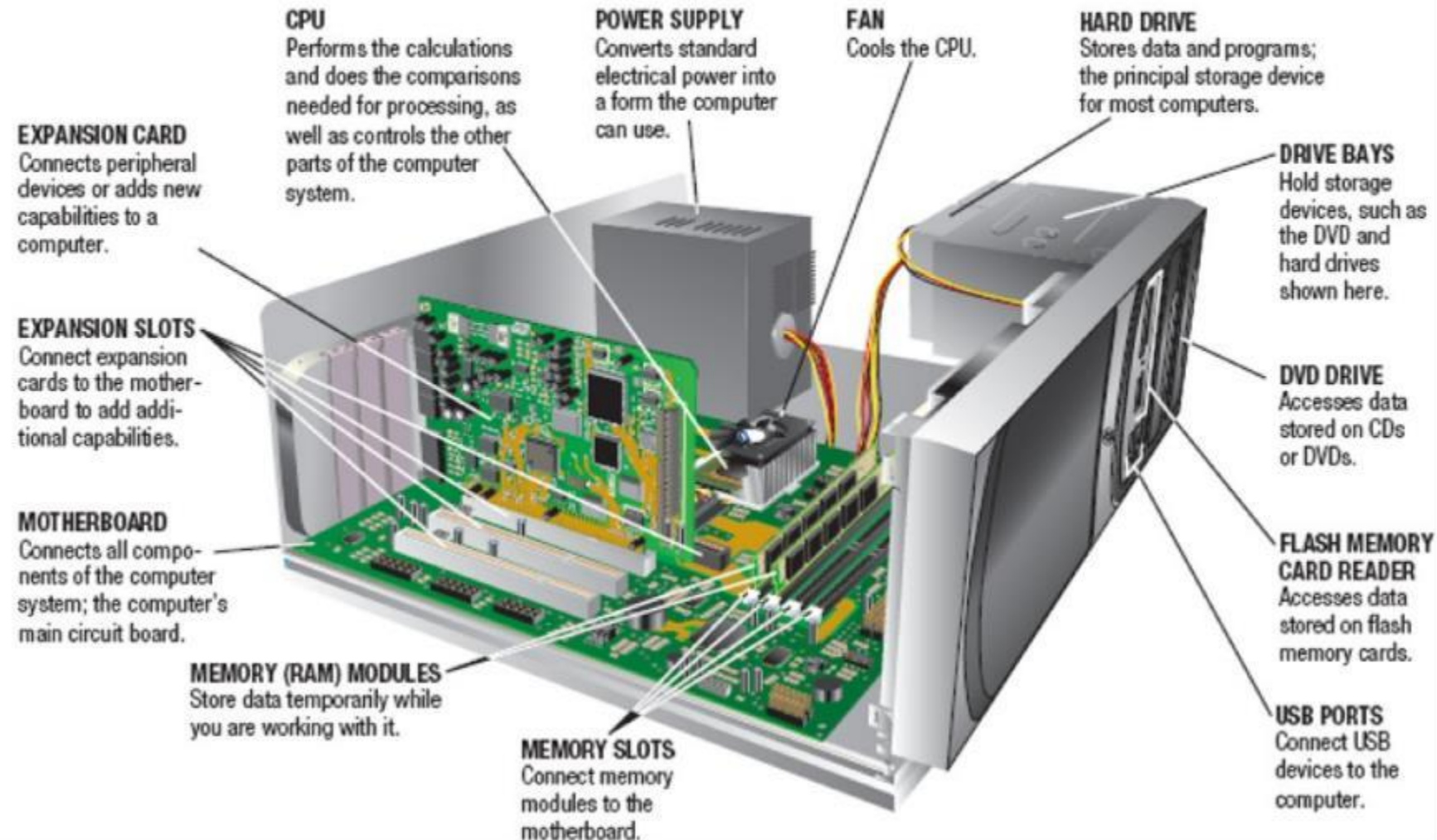
Representing Programs: Machine Language

- 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.
- Most programs are written in other programming languages .
 - Language translators are used to translate the programs into machine language.

Inside the System Unit

- System unit: The main case of a computer
 - A computer case, also known as a computer chassis is the enclosure that contains most of the components of a personal computer (usually excluding the display, keyboard, and mouse).
 - Cases are usually constructed from steel, aluminum and plastic. Other materials such as glass and wood .
 - Houses the processing hardware for a computer.
 - Also contains storage devices, the power supply, and cooling fans.
 - Houses the CPU, memory, interfaces to connect to peripheral devices (printers, etc), and other components such as CD/DVD drives.
 - With a desktop computer, usually looks like a rectangular box.

Inside the System Unit



The Motherboard

WHAT IS A MOTHERBOARD?

**Central Processing Unit
(CPU)**

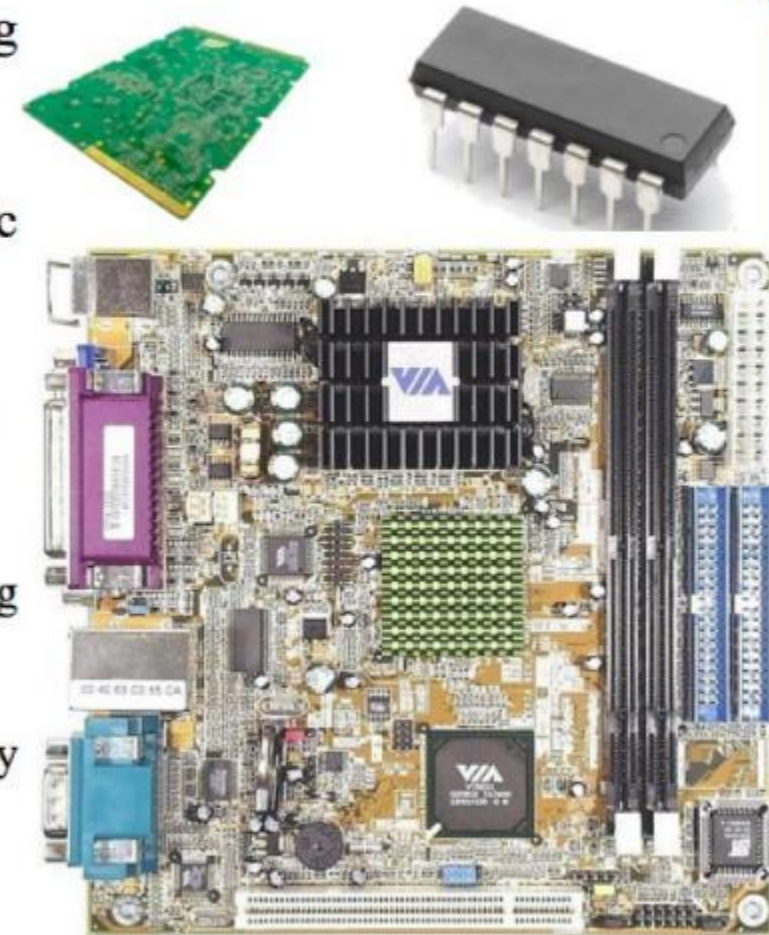


The Motherboard



The Motherboard

- Computer chip: A 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.
- Motherboard or system board: The main circuit board inside the system unit.
 - All devices must connect to the motherboard.
 - External devices (monitors, keyboards, mice, printers) typically connect by plugging into a port exposed through the exterior of the system unit.
 - Wireless devices connect through a transceiver or wireless networking technology (like Bluetooth).



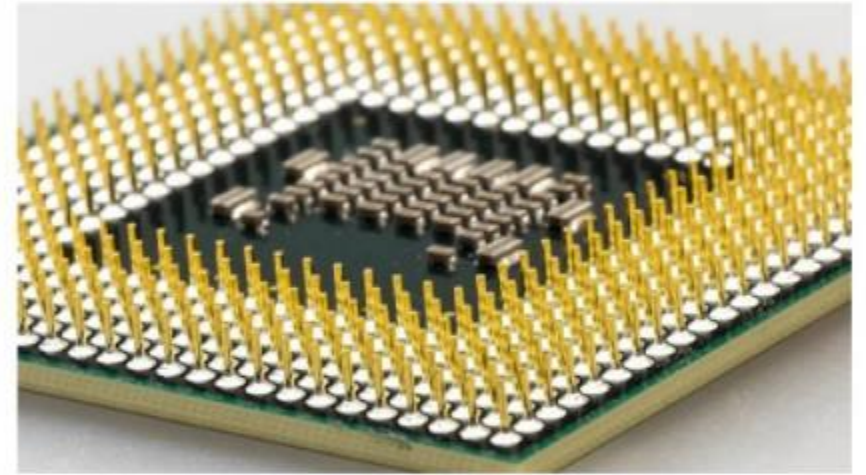
The CPU

- The CPU is the core component that defines a computing device, and while it is of critical importance, the CPU can only function alongside other hardware. The silicon chip sits in a special socket located on the main circuit board inside the device.
- CPUs are built by placing billions of microscopic transistors onto a single computer chip. Those transistors allow it to make the calculations it needs to run programs that are stored on your system's memory. They're gates that switch on or off, thereby conveying the ones or zeros that translate into everything you do with the device, be it watching videos or writing an email.

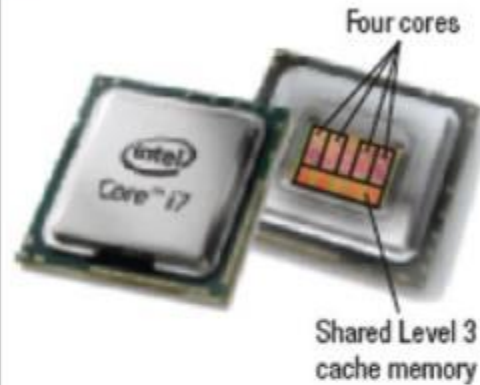
The CPU

- Dual-core CPU: Contains the processing components (cores) of two separate processors on a single CPU.
- Quad-core CPU: Contains 4 cores.
- Typically different CPUs for desktop computers, portable computers, servers, mobile devices, etc.
- Often made by Intel or AMD

The CPU

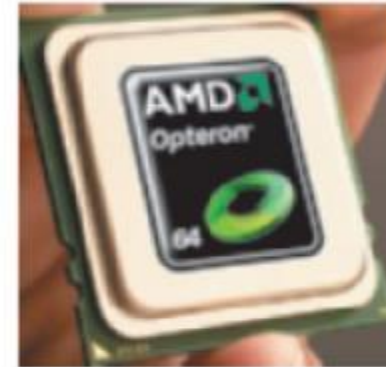


The CPU



DESKTOP PROCESSORS

Typically have 2 to 4 cores and are designed for performance.



SERVER AND WORKSTATION PROCESSORS

Typically have at least 4 cores and are designed for very high performance.



NOTEBOOK PROCESSORS

Typically have 2 to 4 cores and are designed for performance and increased battery life.



NETBOOK PROCESSORS

Typically have 1 to 2 cores, are small in size, and are designed for extended battery life.

Processing Speed

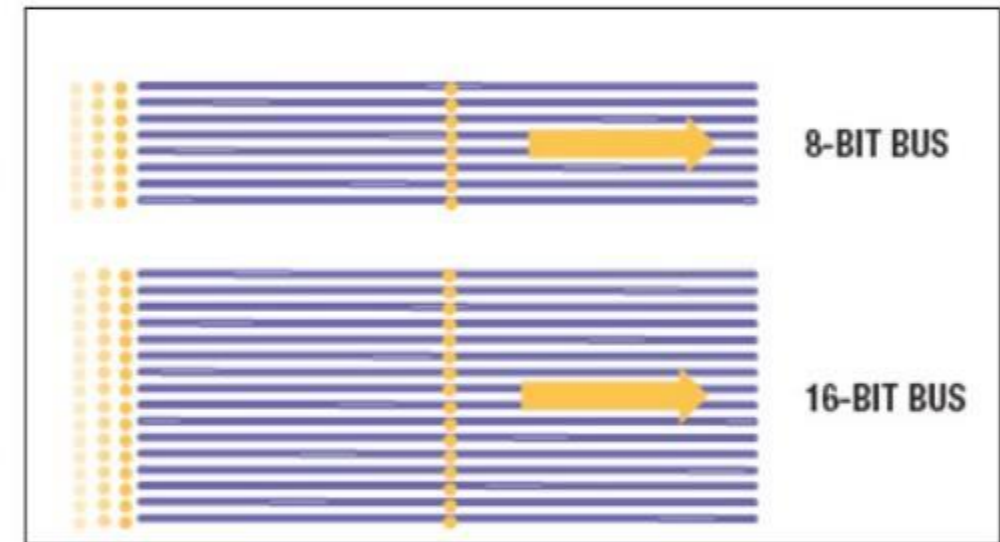
- CPU clock speed: One measurement of processing speed.
 - Measured in megahertz (MHz) or gigahertz (GHz).
 - Higher CPU clock speed = more instructions processed per second.
- Alternate measure of processing speed is the number of instructions a CPU can process per second.
 - Megaflops, gigaflops, teraflops.
- Other factors (CPU architecture, memory, bus speed, amount of RAM, etc.) also affect the overall processing speed of a computer.
- Benchmark tests: Can be used to evaluate overall processing speed.

Word Size and Cache Memory

- 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).
 - Often some cache dedicated to each core; may also have some shared cache accessible by any core.

Bus Width, Bus Speed, and Bandwidth

- Bus: An electronic path over which data can travel.
- Bus width: The number of wires in the bus over which data can travel.
- 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.



- Memory refers to chip based storage.
- RAM (random access memory): Computer's main memory.
 - Consists of chips arranged on a circuit board called a memory module plugged into the motherboard.
 - Stores essential parts of operating system, programs, and data the computer is currently using.
 - Volatile: Contents of RAM is lost when the computer is shut off.

- 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.
- Flash memory: Type of nonvolatile memory that can be erased and reprogrammed.
 - Some flash memory chips are used by the computer.
 - Flash memory chips are also used in flash memory storage media (sticks, cards, and drives).

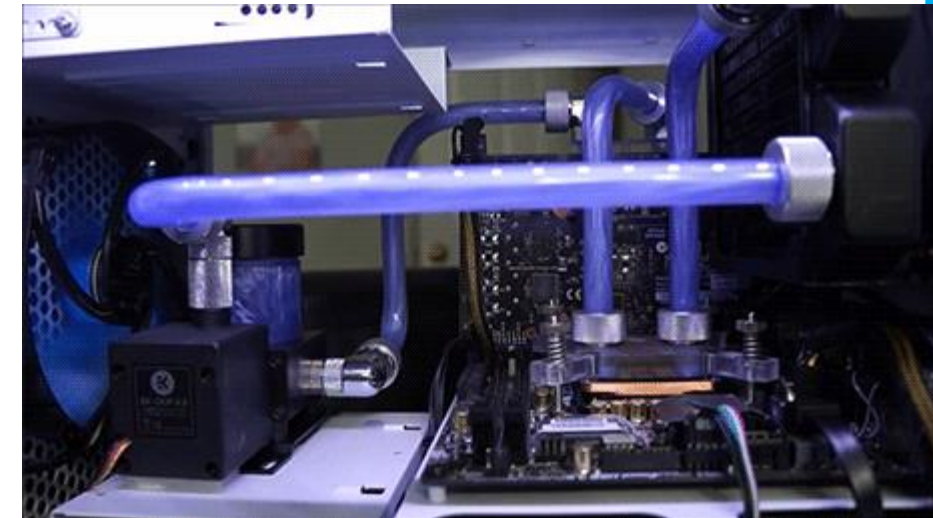
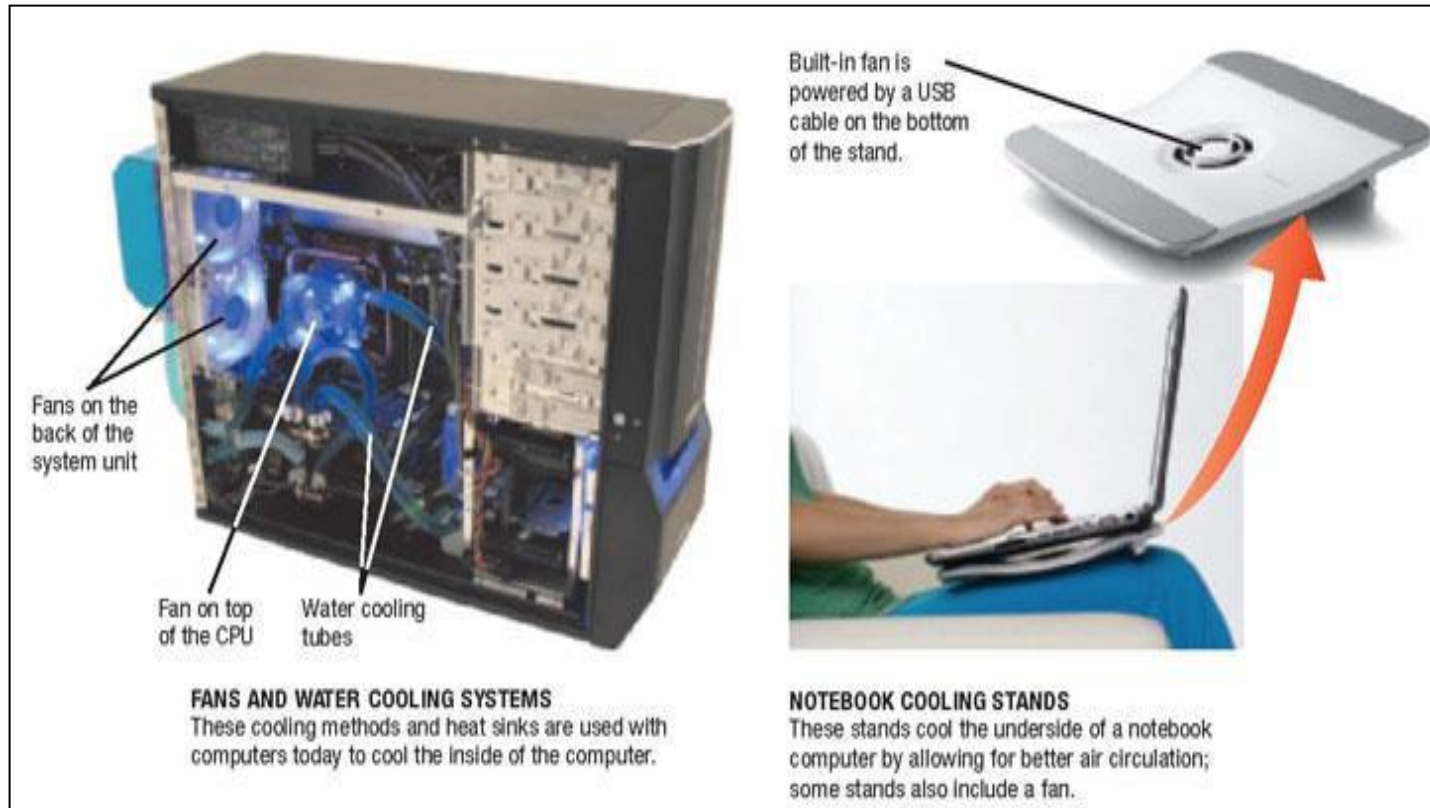
Fans, Heat Sinks, and Other Cooling Components



Fans, Heat Sinks, and Other Cooling Components

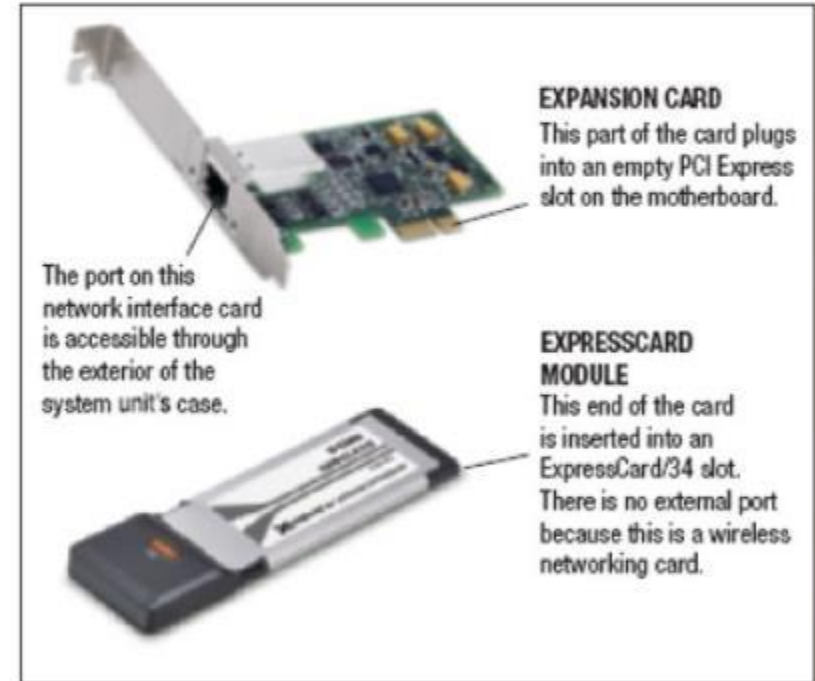
- Heat: A continuing problem for CPU and computer manufacturers.
- Fans: Used on most personal computers.
- Heat sinks: Small components typically made out of aluminum with fins that help to dissipate heat.
- Water cooling systems: Cool the computer with liquid-filled tubes.
- Notebook cooling stands.
- Other cooling methods (such as ion pump cooling systems) are under development.

Fans, Heat Sinks, and Other Cooling Components



Expansion Slots, Expansion Cards, and Express Cards

- Expansion slot: A location on the motherboard into which expansion cards are inserted.
- Expansion card: A circuit board used to add additional functionality or to attach a peripheral device.
- Express Card modules: Designed for notebook computer expansion.



How the CPU Works

- CPU: 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).

Typical CPU Components

- Arithmetic/Logic Unit (ALU): Performs integer arithmetic and logical operations.
- Floating Point Unit (FPU): Performs decimal arithmetic.
- Control unit: Coordinates and controls activities.
- Prefetch unit: Tries to fetch data and instructions before they are needed from cache or RAM.
- Decode unit: Translates instructions so they are understood by the control unit, ALU, and FPU.
- Internal cache : Store data and instructions needed by the CPU.
- Bus interface unit: Allows the core to communicate with other CPU components.

Making Computers Faster and Better

- Perform system maintenance:
 - Uninstall programs properly.
 - Consider placing large files on external storage devices.
 - Delete temporary files.
 - Error check and defragment.
 - Scan for viruses and spyware.
 - Clean out dust once or twice a year.
- Add more memory.
- Buy a larger or second hard drive.
- Upgrade your Internet connection.
- Upgrade your video graphics card.

Review: Representing data

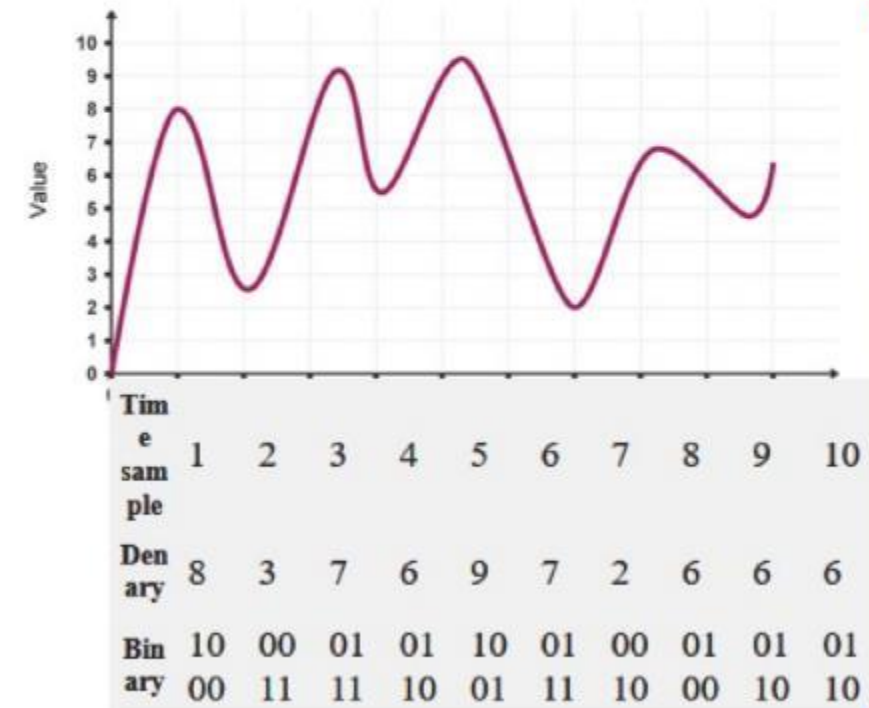
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- The samples can then be converted to binary. They will be recorded to the nearest whole number.
- More time samples that are closer together more detail about the sound can be collected, so does not lose as much quality.
- The frequency at which samples are taken is called the **sample rate**.



Review: Motherboard

- CPU, power supply, fan, hard drive, DVD drive, ports, memory slots, expansion slots, expansion cards.
- CPU is the core component that defines a computing device.
- Billions of microscopic transistors.
- Processing speed measurements (CPU clock speed, IPC, number of cores, architecture, memory speed, bus speed, ram size).
- Memory hierarchy (HD, RAM, Cache, registers).
- Bus width and speed determine the throughput of the bus.
- Fans, Heat sinks, Water cooling systems.

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