

Internet and Information Technology

Lecture 2

ITC202

The System Unit: Processing and Memory

Prepared by
Dr. Eng. Youssef Ntefeh

Chapter 2:
**The System
Unit:
Processing and
Memory**

Data and Program Representation

Digital Data Representation

The Binary Numbering System

Coding Systems for Text-Based Data

Coding Systems for Images

Coding Systems for Audio

Representing Programs: Machine Language

The Motherboard

The CPU

Memory

Fans, Heat Sinks, and Other Components

Expansion Slots and Expansion Cards

Typical CPU Components

Inside the System Unit

How the CPU Works

Making Computers Faster and Better

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.

Overview

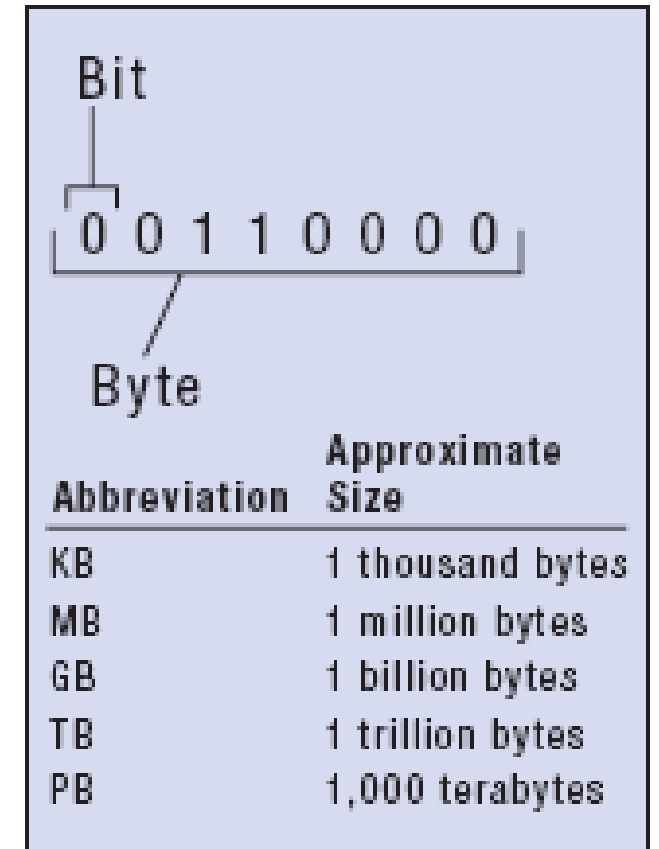
- This lecture covers:
 - How computers represent data and program instructions.
 - How the CPU, memory, and other components located inside the system unit are arranged, as well as the characteristics of the components.
 - How the CPU performs processing tasks.

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.

Digital Data Representation

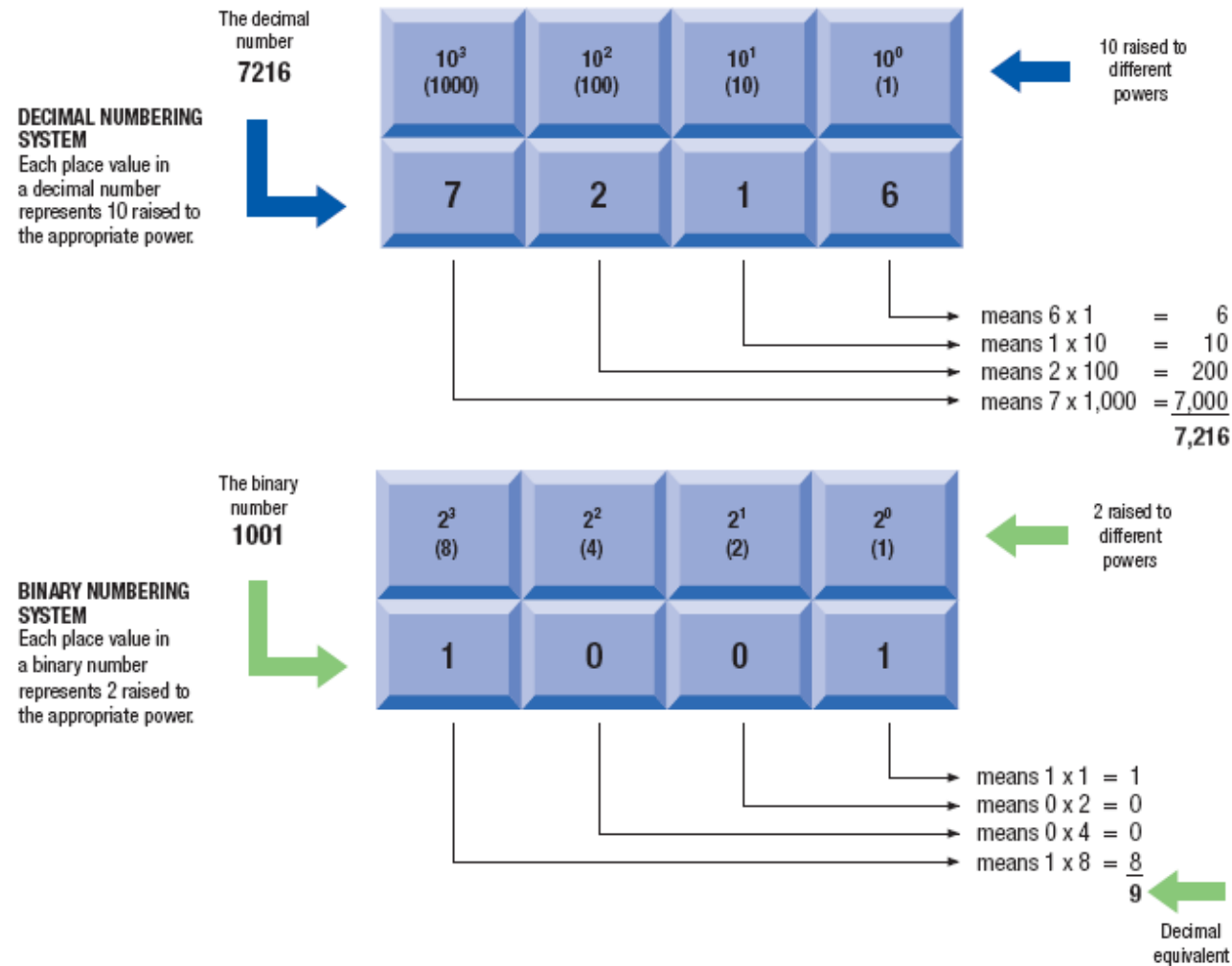
- Bit: The smallest unit of data that a binary computer can recognize (a single 1 or 0).
- Byte = 8 bits.
- Byte terminology used to express the size of documents and other files, programs, etc.
- Prefixes are often used to express larger quantities of bytes: kilobyte (KB), megabyte (MB), gigabyte (GB),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



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



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.

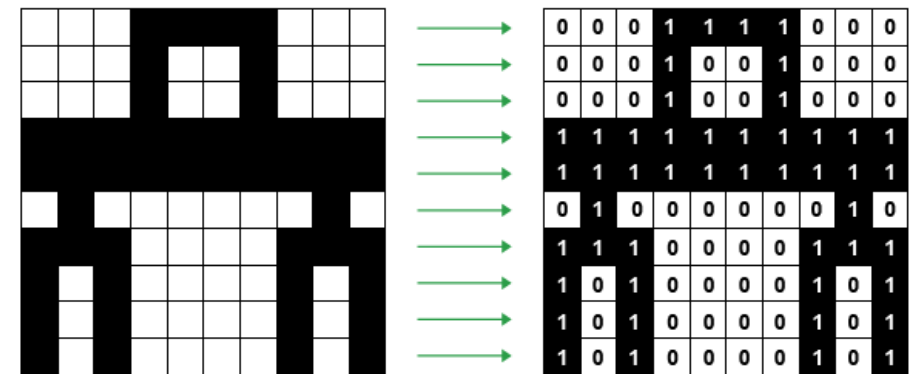
0	0	0	1	1	1	1	0	0	0
0	0	0	1	0	0	1	0	0	0
0	0	0	1	0	0	1	0	0	0
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
0	1	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	1	1	1
1	0	1	0	0	0	0	1	0	1
1	0	1	0	0	0	0	1	0	1
1	0	1	0	0	0	0	1	0	1

Coding Systems for images

- 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 1



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.

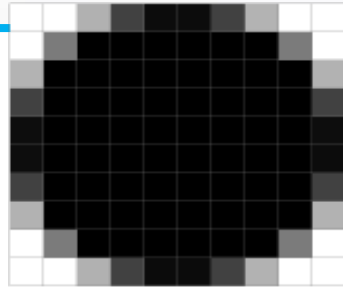
❖ 11 – red.

Coding Systems for images

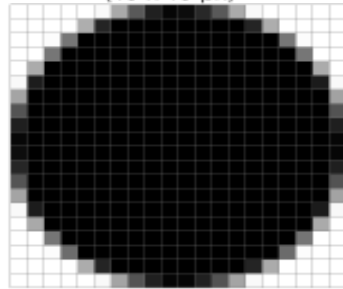
While this is still not a very large range of colors, adding **another** binary digit will double the number of colors that are available:

- **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.

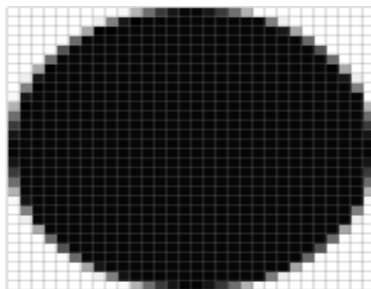
Coding Systems for images



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).



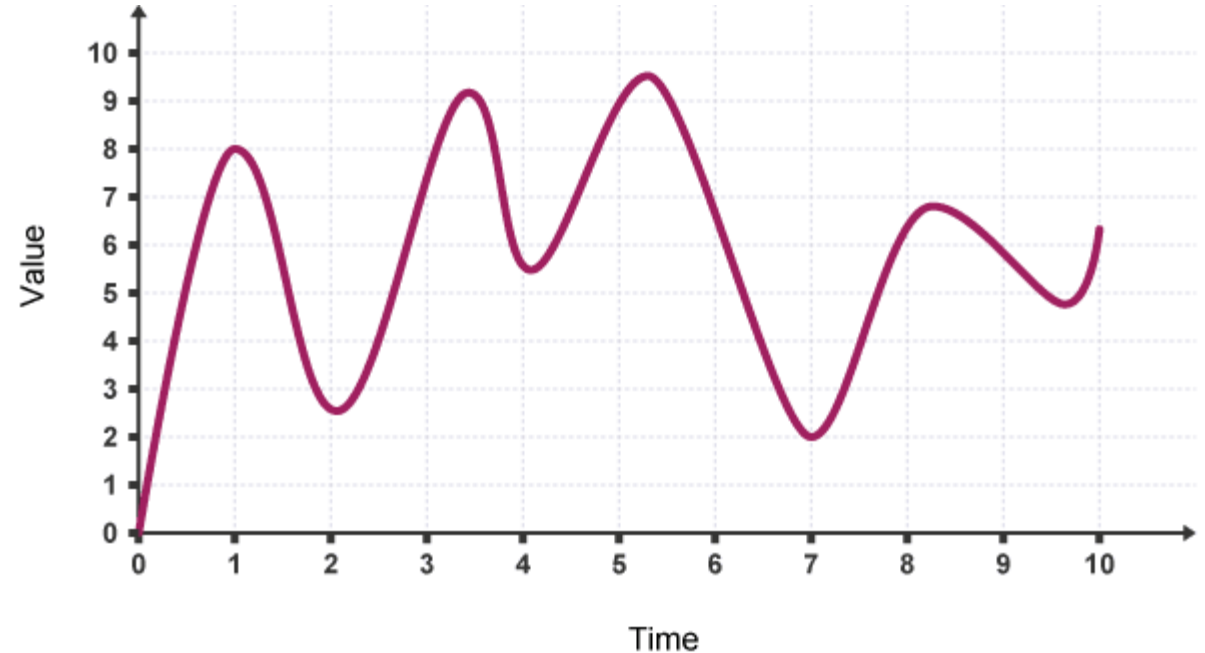
One sample pixel:
101001100100110111001011

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

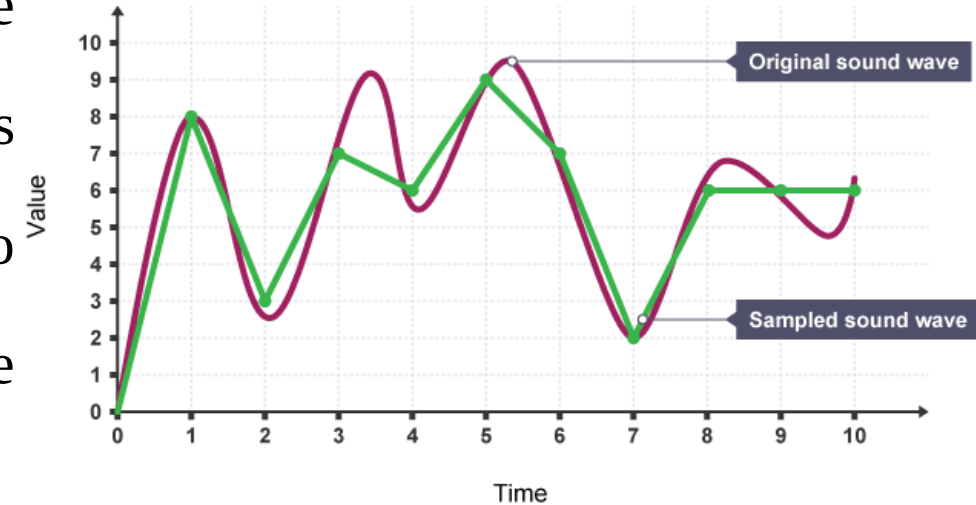
- Sound needs to be converted into **binary** for computers to be able to process it. To do this, sound is captured - usually by a microphone - and then converted into a **digital** signal.
- An **analogue** to digital converter will sample a sound wave at regular time intervals. For example, a sound 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.

Coding Systems for Audio data

- 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.

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The Motherboard

The CPU

Memory

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Expansion Slots and Expansion Cards

Typical CPU Components

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.

EXPANSION CARD

Connects peripheral devices or adds new capabilities to a computer.

EXPANSION SLOTS

Connect expansion cards to the motherboard to add additional capabilities.

MOTHERBOARD

Connects all components of the computer system; the computer's main circuit board.

MEMORY (RAM) MODULES

Store data temporarily while you are working with it.

MEMORY SLOTS

Connect memory modules to the motherboard.

CPU

Performs the calculations and does the comparisons needed for processing, as well as controls the other parts of the computer system.

POWER SUPPLY

Converts standard electrical power into a form the computer can use.

FAN

Cools the CPU.

HARD DRIVE

Stores data and programs; the principal storage device for most computers.

DRIVE BAYS

Hold storage devices, such as the DVD and hard drives shown here.

DVD DRIVE

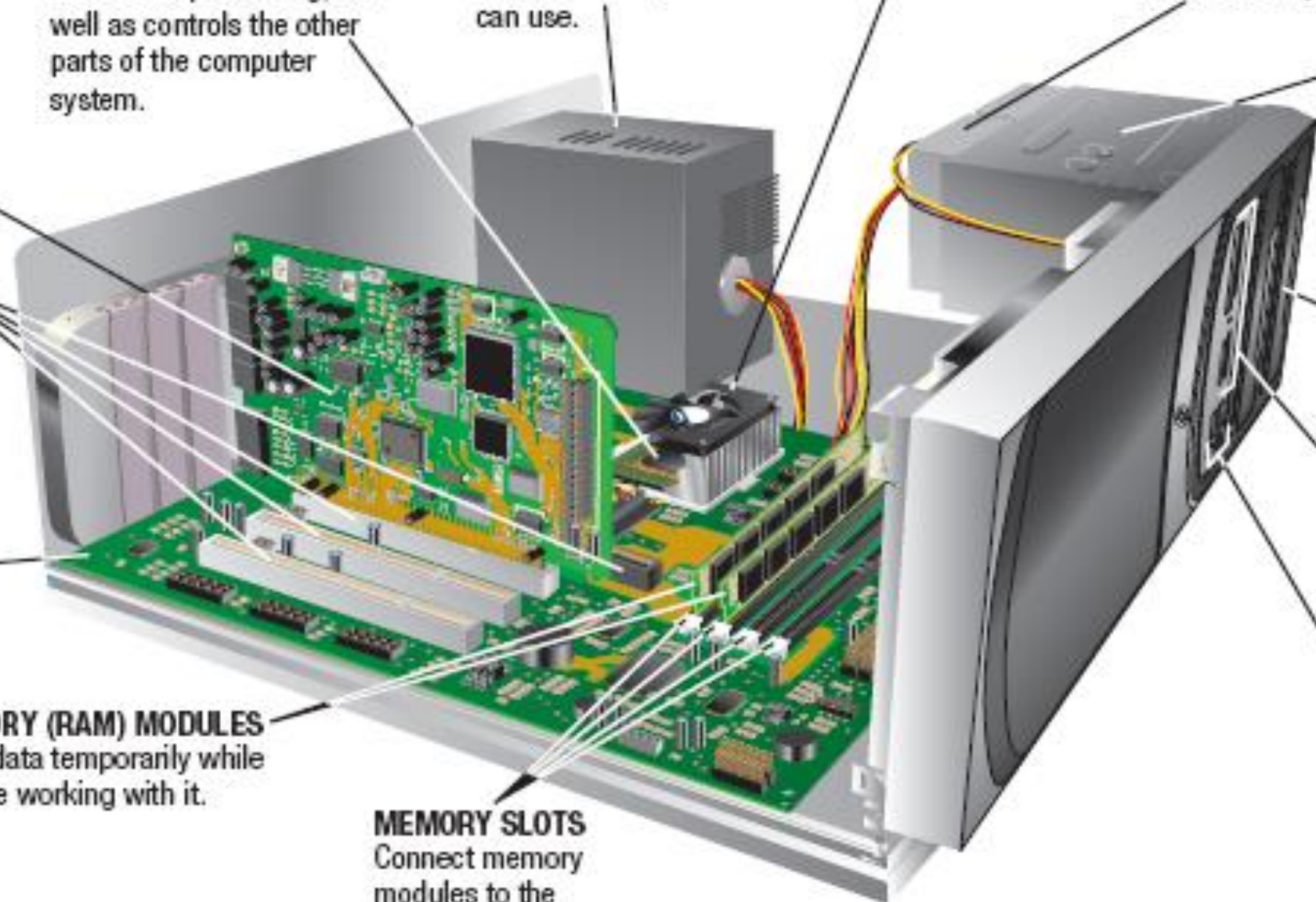
Accesses data stored on CDs or DVDs.

FLASH MEMORY CARD READER

Accesses data stored on flash memory cards.

USB PORTS

Connect USB devices to the computer.

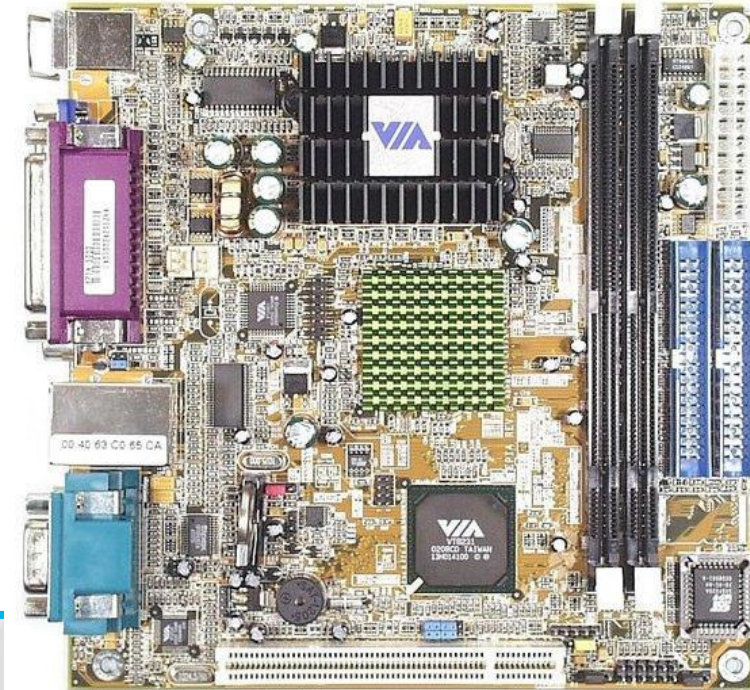
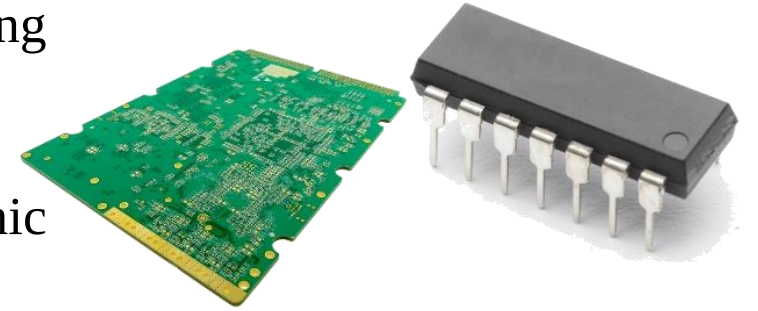


The Motherboard



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).



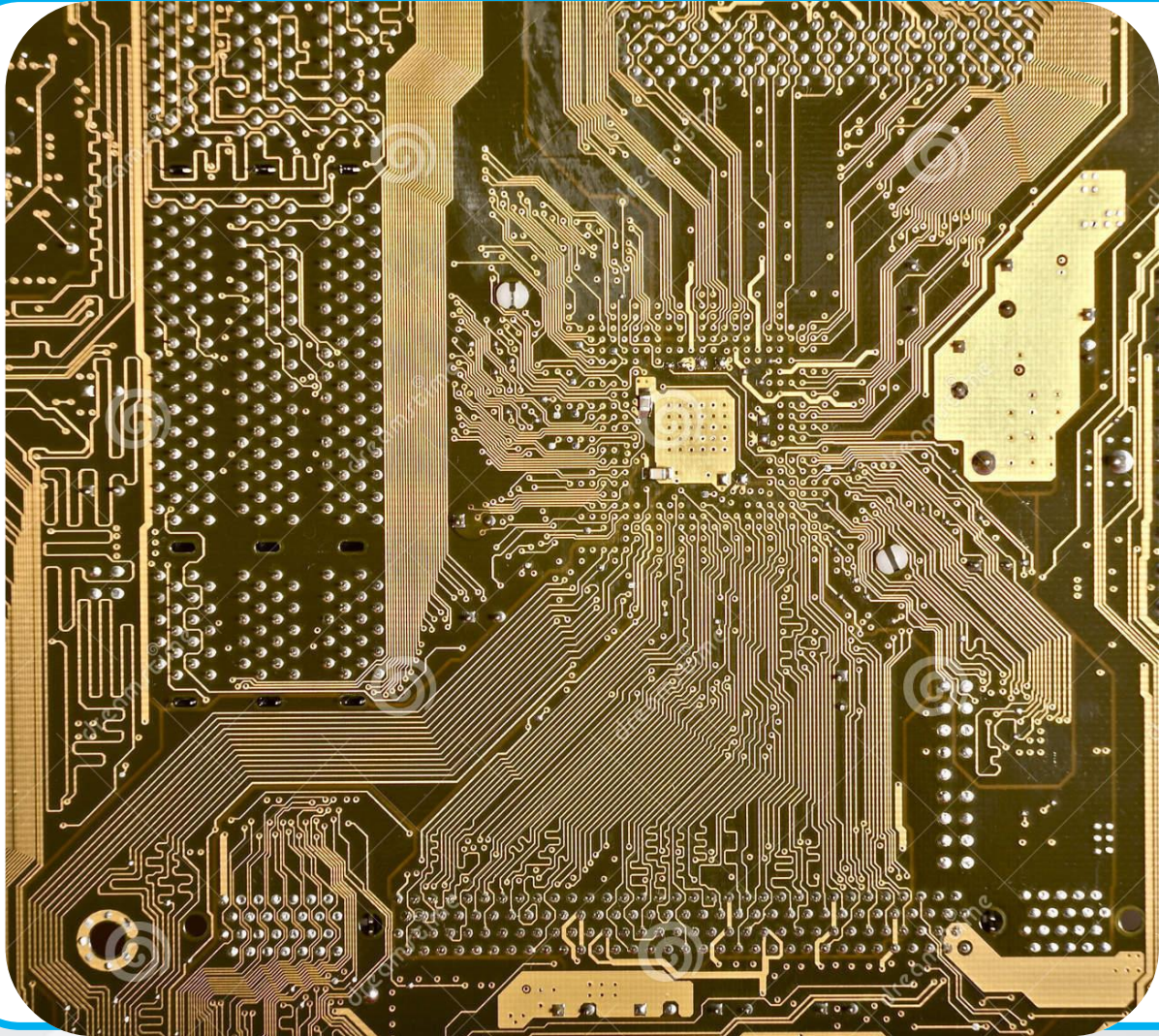
The CPU

- 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.

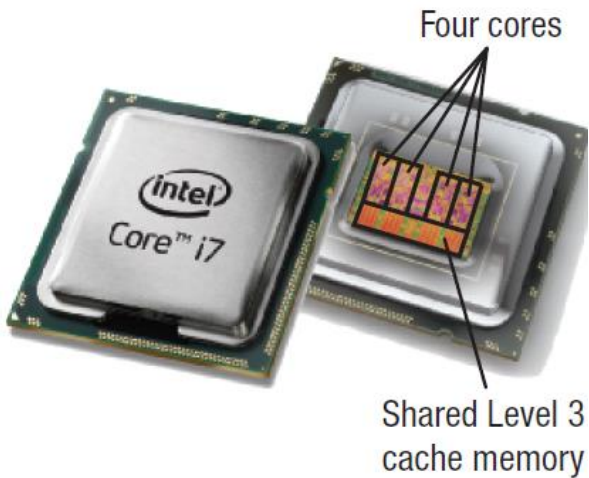
The CPU

- 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.
- **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.

The CPU



The CPU



DESKTOP PROCESSORS

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



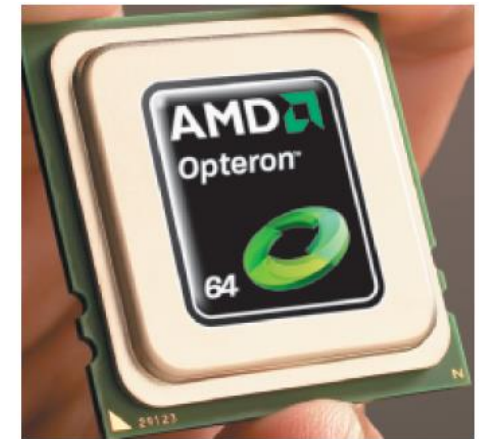
NOTEBOOK PROCESSORS

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.



SERVER AND WORKSTATION PROCESSORS

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

Clock Cycle and Frequency

Processing Speed

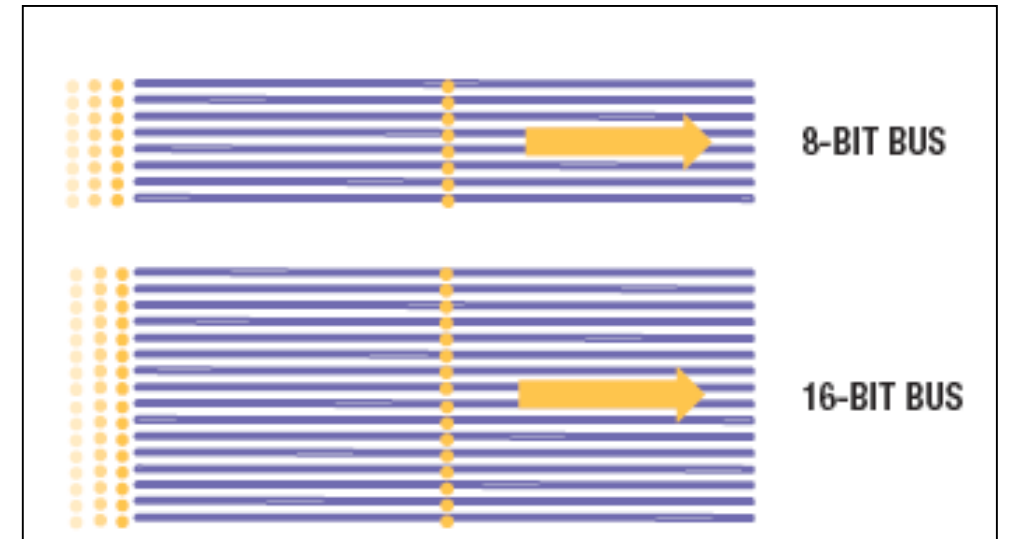
- CPU clock speed: One measurement of processing speed.
 - Measured in megahertz (MHz) or gigahertz (GHz).
 - Higher CPU clock speed = more instructions processed per second.
- Alternate measure of processing speed is the number of instructions a CPU can process per second.
 - Megaflops, gigaflops, teraflops.
- 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

- 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.

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.
- 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).

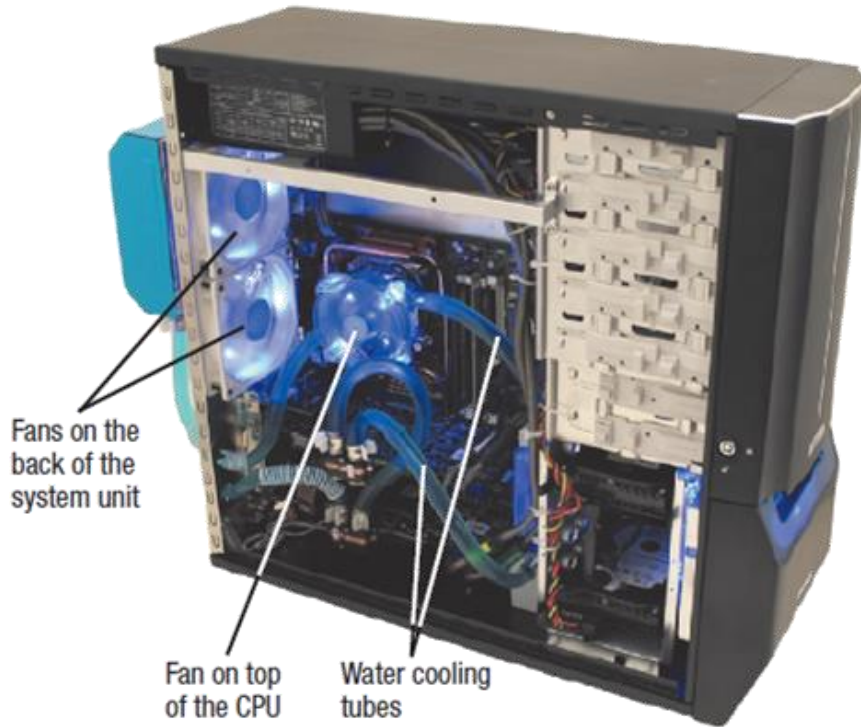
Fans, Heat Sinks, and Other Cooling Components



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



FANS AND WATER COOLING SYSTEMS

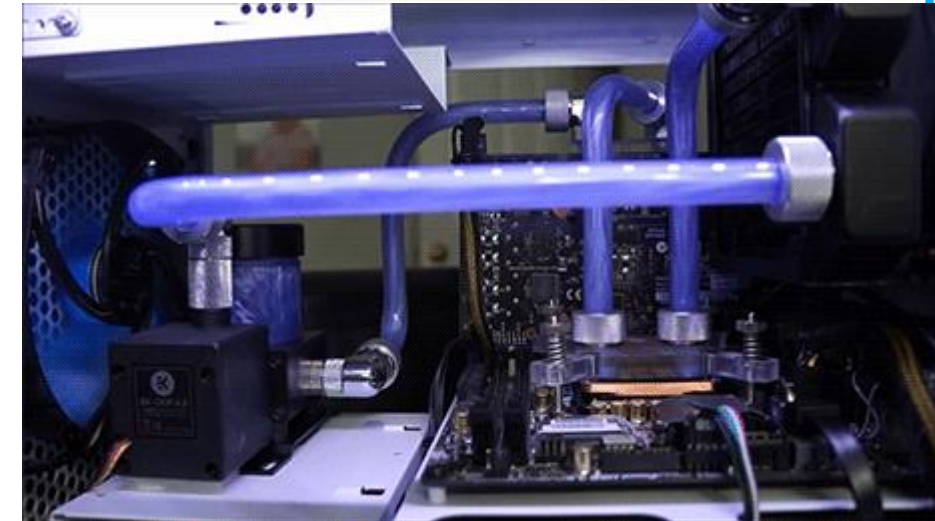
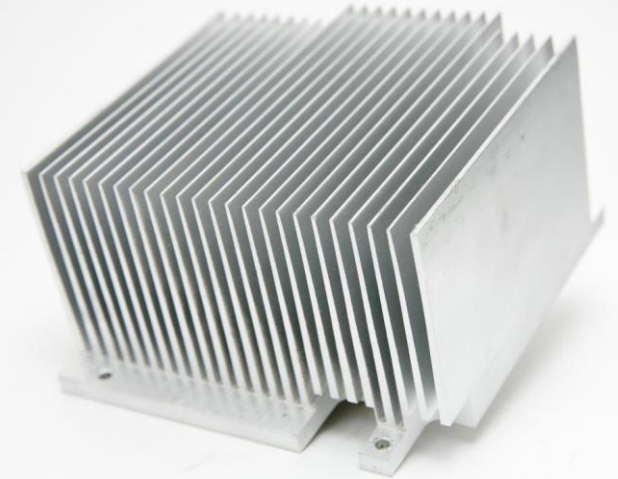
These cooling methods and heat sinks are used with computers today to cool the inside of the computer.

Built-in fan is powered by a USB cable on the bottom of the stand.



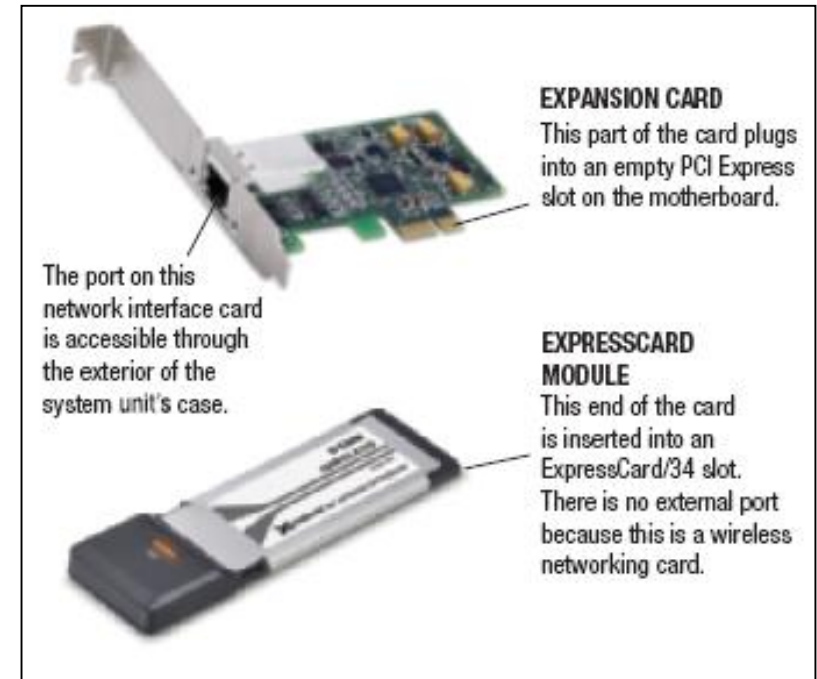
NOTEBOOK COOLING STANDS

These stands cool the underside of a notebook computer by allowing for better air circulation; some stands also include a fan.



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.



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Making Computers Faster and Better

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

Bit: The smallest unit of data that a binary computer can recognize (a single 1 or 0). Byte = 8 bits.

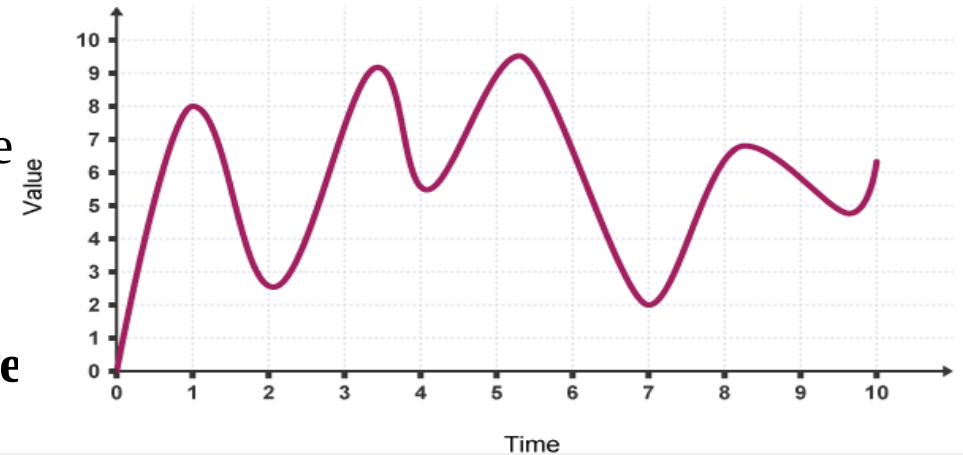
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- Binary numbering system.
 - Uses only two symbols (1 and 0) to represent all possible numbers.
- In both systems, the position of the digits determines the power to which the base number (such as 10 or 2) is raised.

Review: Representing images

- Images also need to be converted into **binary**.
- Need metadata to know the size of an image.
- Adding binary digit will double the number of colours 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.

Review: Representing audio

- An **analogue** to digital converter will sample a sound wave at regular time intervals.
- 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 can be collected, so does not lose as much quality.
- The frequency at which samples are taken is called the **sample rate**



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

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.

Reference

15th Edition

Understanding Computers

Today and Tomorrow

Comprehensive



Deborah Morley