General Informatics - Main Contents

5.1. Computer System

Chapter 5. The Architecture and Functionality of Personal Computers

5.1 Computer System

A computer system is composed by two fundamental elements (figure 5.1):

- **hardware**, that refers to the physical parts of the computer as processors, internal memory, clock, terminals, disks, network interfaces, and other input/output devices;

- **software** that make the computer able to store, process and retrieve information, to find out spelling errors in documents, to play games etc.

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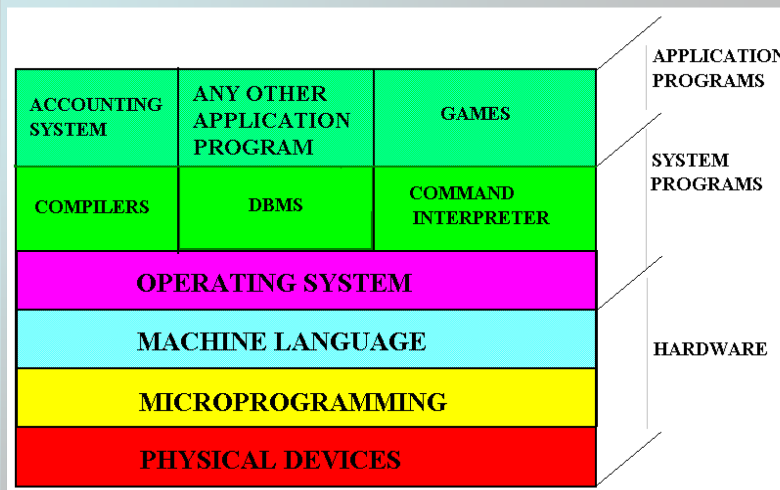

Figure 5.1. The computer system - hardware, system programs and application programs

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The Software can be classified in two types:

- **system software (or programs)** that manages and control the functionality of the computer itself;

- **application programs (or user software)** that solves problems for users.

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The most fundamental of all the system programs is the **operating system**, which controls all the computer's resources and provides the base upon the application programs can be written.

A modern computer consists of one or more processors, some main memory, clocks, terminals, disks, network interfaces, and other input/output devices.

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The operating system must hide to the user (application programmer, application user a.s.o.) the complexity of the hardware and give the programmer a more convenient set of instructions to work with.

The operating system can be defined as a collection of generalized service programs designated to control the computer and his peripheral devices.

The hardware together with the operating system form a **virtual computer** (figure 5.2).

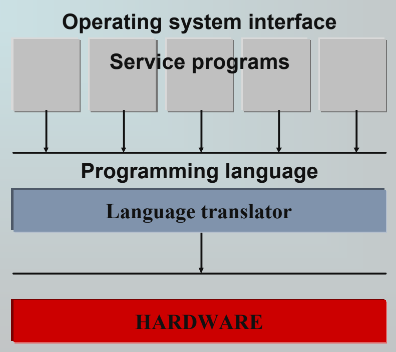
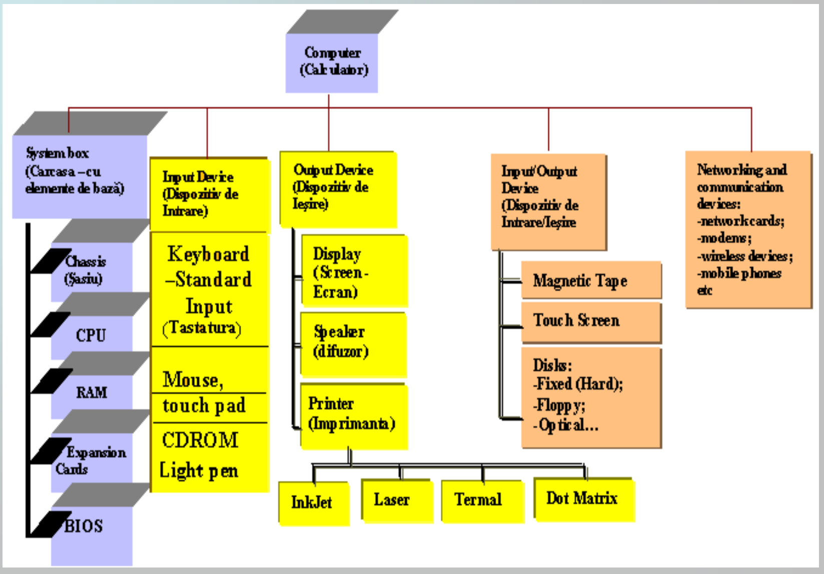


Figure 5.2. The principle of a virtual computer architecture



Some hardware components of a computer system

A computer is a digital electronic machine capable of storing data and/or information and acting instructions.
Functionally the machine has three main hardware components:
A) - **memory** (e.g. the high speed memory that is capable of storing data and instructions) ;
B) - **processor** (it is capable of interpreting instructions taken from the memory) ;
C) - **peripherals** (or I/O devices take information from agent external to the machine and provide information to those agents.

The peripherals can be:

- *input units* that allow us to send information to the computer;
- *output units* that allow us to receive information from the computer;
- *input/output* units.

Computer Systems

The PC family of computers links all internal control circuitry (figure 5.3) together by a circuitry design known as bus. A bus is simply a shared path on the main circuit board (called motherboard) all the controlling parts of the computer are attached. When data is passed from one component to another it travels along the common path to reach its destination.

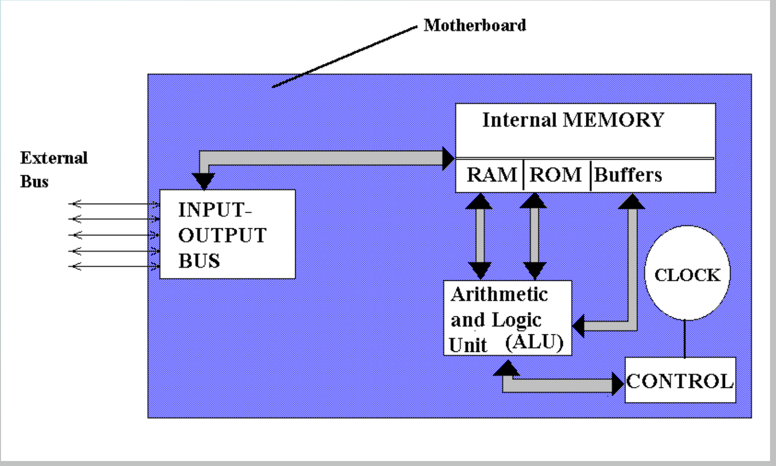


Figure 5.3. A simple CPU

Computer Systems

The data provided by the external agents is converted into a specific combination of electrical signals in a binary format. After data are converted into a binary form, they are available for processing. The central processing unit (CPU) perform this activity in conjunction with the memory and storage (figure 5.3).

The **CPU** (figure 5.4), the "brain" of the computer system, consists of a control unit and an arithmetic and logic unit (ALU):

- the **CONTROL** unit manages the computer system, acting like a traffic cop directing the flow of data throughout the system;

- the **ALU** performs all mathematical and logical functions.

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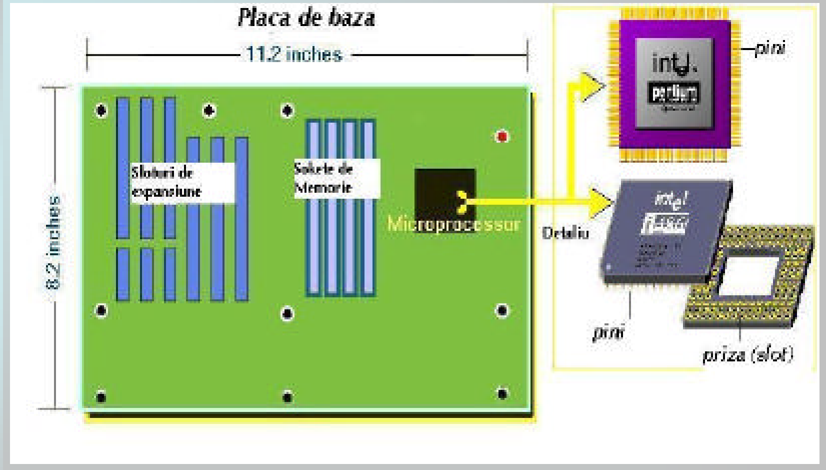

Figure 5.4. An example of CPU (external view)

A. The memory is the computer's work area that allow it to "remember" numbers, words and paragraphs as well as a list of commands we wish the computer to perform. Memory comes in two forms:

- **RAM** - random access memory (figure 5.5) - that temporarily stores data needed for the current processing task. When the power is down his content is lost and the memory is said to be volatile;

- **ROM** - read only memory - is permanent memory that provides the basic set of instructions for starting the computer.

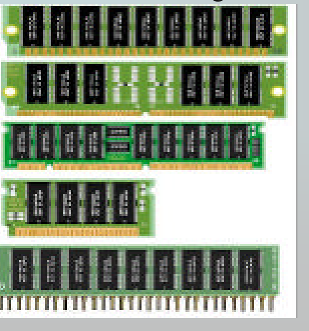

Figure 5.5. RAM memory chips

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♦**PROM - *Programmable Read Only Memory* is a ROM chip that is programmed with a device called PROM burner or programmer. This special purpose chips can be used to store application software, graphics and games.**

♦ **EPROM - (*Erasable PROM*) can be erased and reprogrammed for many times. Erasing means exposing the chip to ultraviolet light (by opening the cover of the hole).**

♦ **EEPROM - *Electrically EPROM* is a non-volatile RAM that can be deleted by using a high voltage. The EEPROM chips can be deleted and reprogrammed without removing them from the slots in which plugged.**

♦ **Flash ROM is a new version of EEPROM that can be read and erased by using the normal voltage inside of computer (5 volts for reading and 12 volts for erasing).**

B. The central processing unit has three components

- a **control unit** for controlling the computer;

- an **arithmetic and logic unit** for performing arithmetic and logical operations;

- a set of general purpose or dedicated **registers** (figure 5.6) used for storing data immediately prior to or following an operation.

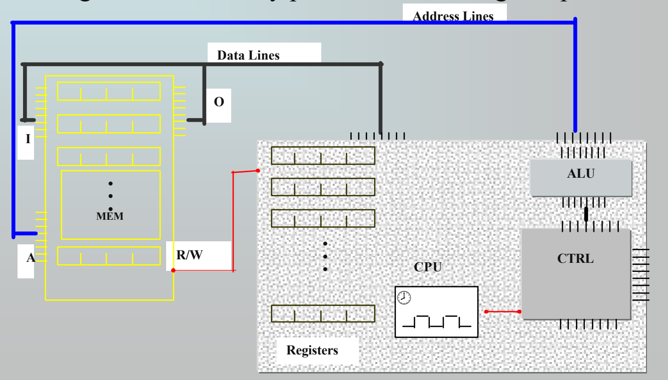

Figure 5.6. The general architecture of a computer (von Neumann)

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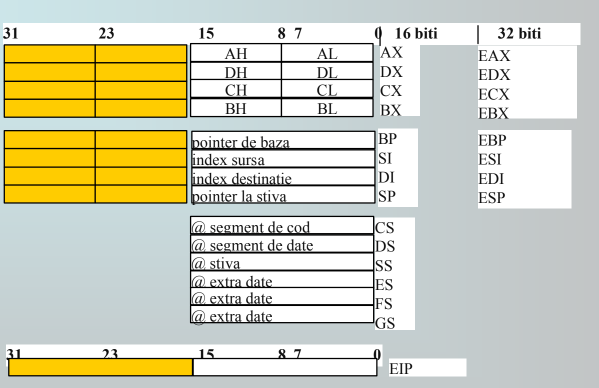

Figure 5.7. The register set for Pentium microprocessor

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The computing cycle consisting of input, processing, output and storage involves several steps in the flow of data. Data typically flow through the system in the following manner:

1. The control unit of the CPU directs the transfer of data from an input device to memory or storage. For example the text data that appears on the screen as you type goes into the random access memory (RAM);

2. Data in storage remain in storage until needed for next processing task. Then the control unit transfers data from storage to memory. For example, when you select a spreadsheet program and a balance-sheet report they are loaded from storage into memory;

3. The control unit sends the required data from memory to the arithmetic and logic unit. For example, the formula and data you need to calculate the Profit & Loss are placed in the ALU;

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4. The ALU makes the necessary mathematical and logical computations as you enter data and formula;

5. When all calculations are completed, the control unit sends the result to memory (RAM);

6. The control unit sends the output from memory (RAM) to a monitor and/or printer;

7. The control unit can also send all or part of the contents of memory to storage (disk) for future use. The control unit can also erase data from memory when instructed to do or when power to the computer is turned off.

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The control unit manages the computer in a four-step process (called Fetch, Decode, Execute and Storage):

1. **Fetch** an instruction from memory and store it in an register;

2. **Decode** the instruction into a form usable by the ALU;

3. Send a command to the ALU to **Execute** the decoded instruction;

4. [**Storage**]

    4.1 Send the result of the executed command into a register;

    4.2 Move the result to memory;

    4.3 Repeat the process for the next instruction.

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The basic instruction set that the microprocessor can perform is called machine language. From that basic set we can enumerate the four basic arithmetic operations, a variety of logic operations (tests, conditional branches, loops).

Generally this machine language is accessible for the programmers by intermediate of assembly languages. The general format of an instruction in that language take the form

instruction_code *operand*$_1$*, operand*$_2$ *[,result]*

In order to build applications we need a variety of instructions to:
- load data in general purpose registers (LOAD);
- add binary numbers (ADD);
- logical operations on bitstrings (AND, OR, NOT, XOR, NOR, NAND, …);
- store data etc.

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A computer instruction is represented generally on one memory word and to instruction component certain bits are reserved.\
To each instruction is associated an unique code (or number) code tat will be later used to be interpreted and executed by the microprocessor. If the code of an instruction is misspelled then the operation will be rejected and followed by an error message of the type "*illegal instruction*".
The next table shows examples of assembly instructions for the 8086 microprocessors family.

Instruction	**Efect**
Mov *dest, src*	Moves/Copies data from/in register to/from memory *dest ? src*
in *port8*	Loads register AL (or AX) from the I/O port byte: AL ? [port] word: AL ? [port]; AH ? [port + 1]
out *port8*	Transfers from AL in I/O port byte: [port] ? AL word: [port] ? AL; [port +1] ? AH
Pop *dest*	Transfers from stack in dest (reg16, r/m16 or segreg)
Push *src*	Transfers reg16 or r/m16 in stack
Add *dest,src*	Add two operands and places the result in dest dest ? (src + dest)
inc *dest*	aduna 1 la dest (reg or r/m) dest ? (dest+1)

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The next sequence is the source code of a bug in Word'97:

```
3080ECB6   mov        eax,dword ptr [ebp-4]
3080ECB9   and        eax,0B9000000h
3080ECBE   cmp        eax,10000000h
3080ECC3   je         3080EC15
3080ECC9   lea        eax,[ebp-0Ch]
3080ECCC   push       eax
3080ECCD   push       180h
3080ECD2   mov        ecx,esi
3080ECD4   call       30821842
3080ECD9   lea        eax,[ebp+0Ch]
3080ECDC   push       eax
3080ECDD   mov        edi,19Ch
3080ECE2   push       edi
3080ECE3   mov        ecx,esi
```

Computer Systems

How microprocessor interacts with other components

The microprocessor interacts with the circuitry world around it in three ways:

1st. Via **direct** (DMA) and **indirect** (registers) memory access;

2nd. Via **Ports** that are used by the microprocessor to communicate with and controls of all other parts of the computer (except HDD). The I/O ports are doorways to which information passes as it travels to or from an I/O device. Each port is identified by a 16-bit port number;

3rd. By using **interrupts**. The interrupts are the means by which the circuitry outside of the microprocessor reports that something has happened and requests that some action to be taken;

Computer Systems

How microprocessor interacts with other components

Interrupts are managed by interrupt handler and can be grouped in the following categories:
- interrupts generated by the computer circuitry as response to some event;
- interrupts generated by the CPU as a result of some unusual program result;
- interrupts deliberately generated by programs as a way of invoking distant subroutines stored in either RAM or ROM. (NMI - nonmascable interrupt).

The Design Philosophy

Part of the design philosophy of the IBM compatible personal computer family centers around a set of **BIOS** (Basic Input/Output System) service routines that provide essentially all the control functions and operations that IBM considers necessary.

The basic philosophy of the PC family is: let the BIOS do it; don't mess with direct control.

Using the BIOS routines encourages good programming practices and it avoids some of the tricks that have been the curse of many other computers. It also increases the chances of our programs working on every member of the PC family. In addition, it gives IBM more flexibility in making improvements and additions to the line of PC computers.

The Design Philosophy

Beginning with 286 microprocessor model two important concepts are introduced in the design:

- the ability to allow **multitasking**;
- the **virtual memory** storage.

These two concepts are inherited by all other microprocessors above 286 (386, 486, PENTIUM etc).

Multitasking is the ability of a CPU to perform several tasks at time, such as printing a document or calculating a spreadsheet, by quickly switching its attention among the controlling programs.

Virtual Memory allows a computer to act as if it has much more memory than is physically present. Through an extremely sophisticated software and hardware design, a program may be led to believe that it has more than some gigabytes (one Gigabyte is one million bytes) of memory at its disposal, even though the hardware memory chips count for only a fraction of that size.

The Motherboard

All PCs one common feature: they are built with a single, large, printed circuit board as their foundation. In many cases, the big board - usually called the *motherboard* - essentially is the entire computer (figure 5.8).

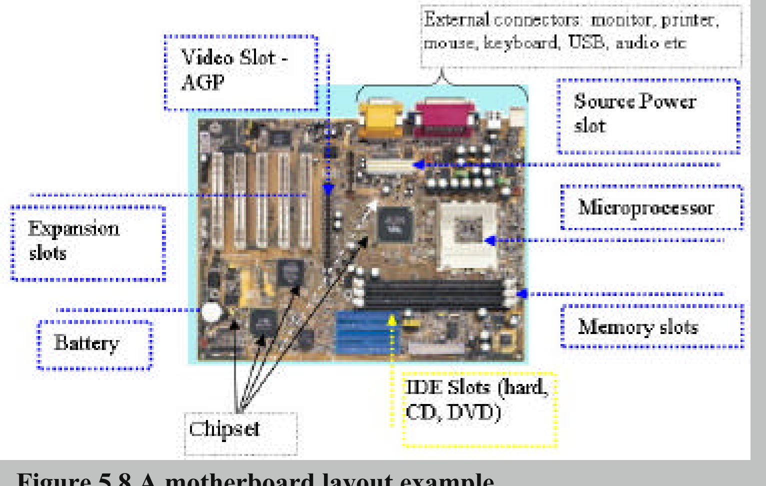

Figure 5.8 A motherboard layout example

The ROM-BIOS

The ROM-BIOS is the part of ROM (Read Only Memory) that is in active use all the time the computer is at work. The role of the ROM-BIOS is to provide the fun-damental services that are needed for the operation of the computer. For the most part, the BIOS control the computer's peripheral devices, such as the display screen, keyboard, and disk drives.
The BIOS is special program code—in a word, software—that's permanently (or nearly so) encapsulated in ROM chips or, as is most often the case with newer PCs, flash memory – in a word, hardware.
Conceptually, the BIOS programs lie between our programs (including DOS) and the hardware.

The ROM-BIOS

The BIOS code of most PCs has a number of separate and distinct functions represented in a typical PC by:
- routines that test the computer;
- blocks of data (setup values) that give the machine its personality;
- special program routines that allow software to take control of the PC's hardware so that it can more smoothly mesh with the electronics of the system;
- a complete system (in some PCs) for determining which expansion boards and peripherals you have installed and ensuring that they do not conflict in their requests for input/output ports and memory assignments;
- a rudimentary programming language that allows you to use the machine without any other software (in IBM's older machine).

The Support Chips

The microprocessor cannot control the entire computer without some help-nor should it. By delegating certain control functions to other chips, the CPU is free to attend to its own work. These support chips (called **chipset**) may be responsible for such processes as controlling the flow of information throughout the internal circuitry, as the interrupt controller and the DMA controller are, or for controlling the flow of information to or from a particular device attached to the computer, such as a video display or disk drive.

The Support Chips

The chipset in a modern PC has three chief functions:

- *System controller* - that holds together the entire PC, giving all the support the microprocessor needs to be a true computer system.
- *Peripheral controller* – it operates input/output ports, expansion buses, and disk interfaces.
- *Memory controller* - it links the microprocessor to the memory system, establishes the main memory and cache architectures, and assures the reliability of the data stashed away in RAM chips.

The Bus

The PC family of computers links all internal control circuitry together by a circuit design known as a bus. A bus is simply a shared path on the main circuit board to which all the controlling parts of the computer are attached. When data is passed from one component to another it travels along this common path to reach its destination. Every control chip and every byte of memory in the PC is connected directly or indirectly to the bus. When a new component is plugged into one of the expansion slots, it is actually plugged directly into the bus, making it an equal partner in the operation of the entire unit. Any information that enters or leaves a computer system is temporarily stored in at least one of several locations along the bus.

The bus is divided into four parts: the *power lines*, the *control bus*, the *address bus*, and the *data bus*.

Disk Drivers

In conjunction with diskettes, hard disks and disk drivers are used the following terms (figure 5.9 and 5.10)

- **tracks** – the circular area on a disk, they are concentric rings and can be compared to the grooves on a record;
- **sectors** – are pie - shaped segments that divide tracks; each sector contains data fields and address fields which store the users' programs and tells the computer the location of this information;
- **cylinder** (for hard disk drives with platter stack) – tracks on the same generator;
- read-write **head** – the magnetic head corresponding to a disk face (side). The read-write heads are moved by a head actuator to scan the hard disk for information in order to take advantage of all the recordable area in the hard disk;
- **cluster** – a defined fix number of adjacent sectors; they are used to perform the transfers between the internal memory and disks in some file systems such as those designated by FAT xx (File Allocation Table).

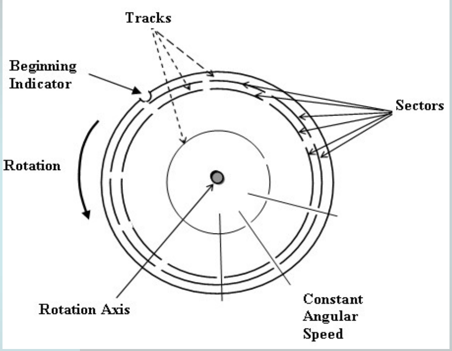

Figure 5.9 The structure of a disk platter

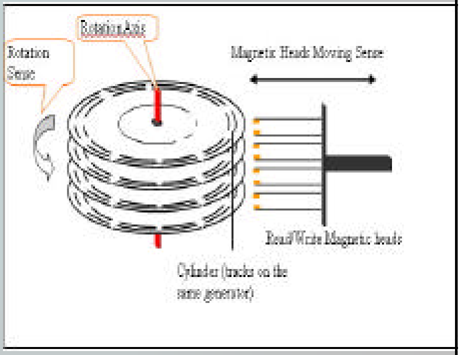

Figure 5.10 A stack of platters and magnetic heads