Unit 2: The Computer System Hardware (3 Hrs.)

Introduction

All the physical component of Computer system required for its function is called as the Hardware of Computer System. It includes everything from motherboard, Central Processing Unit, Storage devices, I/O devices and so on. Without hardware it is impossible to run software system that makes the use of computer system.
Computer hardware can be classified as internal or external hardware components.

1. **Internal hardware component**
    - Motherboard
    - CPU
    - RAM
    - Hard drive
    - Solid state drive
    - Optical drive
    - Expansion Cards (Graphic Card, Video Cards, Sound Cards, Network Adapters)
2. **External hardware component**
    - Input hardware component
        - Keyboard
        - Mouse
        - Microphone
        - Camera
    - Output hardware component
        - Monitor
        - Speakers
        - Printer

Central Processing Unit

CPU and its function:

The central processing unit is the part of a computer that does most of the data processing. The CPU is the brain of the computer. It consists of three basic units:
1. Control Unit (CU)
2. Arithmetic logical Unit (ALU)

3. Memory Unit (MU)

Control Unit:
Control unit controls communication with ALU and MU; decides which circuit is to be activated for reading instruction. It uses fetch-execution mechanism. Control unit gets instruction from memory and decides what to do with that instruction and transfer it to the ALU.

Arithmetic Logical Unit:
ALU performs various arithmetic operations like addition; subtraction, multiplication, division and logical operations like AND, OR, NAND etc on that instruction.

Memory Unit:
Memory Unit store instructions, data and intermediate results of processing. This units also supplies information to the other unit of computer when needed. It is also known as internal storage, main memory or primary memory.

#Mechanism-

An instruction is fetched from primary storage by the control unit.

The control unit decodes the instruction.

The ALU receives the data and the instruction and performs the calculation and comparison.

The result is stored in primary storage which is sent to proper output device.

Registers:
Registers are the high-speed temporary storage locations in the CPU made from electronic devices such as transistors, flip-flops etc. These are high speed storage areas withing the CPU, but have the least storage capacity. Registers are primarily used to store data temporarily during the execution of program and are accessible to the user through instructions. Registers are not referenced by their address, but are directly accessed and manipulated by the CPU during instruction execution. Registers store data, instructions, addresses and and intermediate results of processing. Registers are often referred to as the CPU's working memory. These are the part of Control unit and ALU rather than of memory. Hence their contents can be handled much faster than the contents of memory.

Some of the important registers in CPU are as follows:

- Accumulator (ACC) contains the result of arithmetic and logic operations.
- Instruction Register (IR) stores the current instruction most recently fetched.
- Memory Address Register (MAR) stores the address of next location in the memory to be accessed.
- Program Counter (PC) stores the address of next instruction to be processed.
- Data Register (DR) stores the operands and any other data.

Memory Buffer Register (MBR) temporarily stores data from memory or the data to be sent to memory.

Memory Unit

Memory is a part of the computer that holds data for processing, instructions for processing the data and information (processed data). Memory may store data temporarily or permanently depending on the types of data and the storage device. There are two kinds of computers memory: - Primary memory and secondary memory.

Primary Memory:

Primary memory is accessible directly by the processing unit. RAM is an example of primary memory. As soon as the computer is switched off the contents of the primary memory is lost. You can store and retrieve data much faster with primary memory compared to secondary memory. Primary memory is more expensive than secondary memory. Because of this the size of primary memory is less than that of secondary memory. Computer memory is used to store two things: i) instructions to execute a program and ii) data. When the computer is doing any job, the data that have to be processed are stored in the primary memory. This data may come from an input device like keyboard or from a secondary storage device

Secondary Memory:

Secondary memory is where programs and data are kept on a long-term basis. Common secondary storage devices are the hard disk and optical disks. This type of memory is also known as external memory or non-volatile. It is slower than main memory. These are used for storing data/Information permanently. CPU directly does not access these memories instead they are accessed via input-output routines. Contents of secondary memories are first transferred to main memory, and then CPU can access it.

Secondary memory is also known as secondary storage or auxiliary storage. The most common type of auxiliary storage devices are magnetic tapes, magnetic disks, floppy disks, hard disks, etc.

Cache Memory:

Cache memory is a very high speed supplementary primary memory placed in between RAM and CPU to store frequently used data and instructions needed by CPU. Cache memory increases the speed of processing.

Cash memory is a special high-speed storage mechanism. It can be either a reserved section of main memory or an independent high-speed storage device. A memory cache, sometimes called a cache store or RAM cache, is a portion of memory made of high-speed static RAM (SRAM) instead of the slower and cheaper dynamic RAM (DRAM) used in main memory. Memory caching is effective because most programs access the same data or instructions over and over. By keeping as much of this information as possible in SRAM, the computer avoids accessing the slower DRAM. The more the cache we have on our computer the more will be the processing speed.

Instruction Format

When the assembler processes an Instruction, it converts the instruction from its mnemonics form to standard machine language format called the "Instruction format". In the process of conversion the assembler must determine the type of instruction, convert symbolic labels and explicit notation to a base/displacement format, determine the lengths of certain operands and parse any literal and constants.

An instruction format defines layout of bits of an instruction, in terms of its constituent parts.

An instruction format must include an opcode and implicitly or explicitly, zero or more operands.

Each explicit operand is referenced using one of addressing modes.

Format must, implicitly or explicitly, indicate addressing mode for each operand.

For most instruction sets, more than on instruction format is used.

Concept of operation code and operand code:

The CPU understands only the binary language. The machine code is the binary format of an instruction to be executed by the CPU. It has two parts: Operand and Opcode.

Operand Code

Operand Code is the part of instruction that specifies the data or the memory location of the data on which the operation will be performed.

Types:

- Immediate
- Register
- Memory address
- Implied

Opcode

Also known as the operation code, Opcode is part of instruction that specifies the operation to be performed by the instruction. n bit opcode is used to represent 2^n instructions.

Instruction Set

The job of all the processor is to execute instructions, which are the commands that make up the machine language that the processor understands. Most software programs are written in higher-level languages, but they must be translated into the processor's machine language for the computer to run them. This is called compiling the program to machine language.

All the various instructions that the processor can execute are called ***instruction set****.* The instruction set determines what sorts of software can run on the processor; in order for two processors to be compatible, they must be able to execute the same instructions. The number and type of instructions supported by the processor dictates the requirements for all software that uses it, and has a significant impact on performance as well.

To increase performance, you can either have the processor execute instructions in less time, or make each instruction it executes do more work. The basic instruction set design philosophy is reflected in the two main labels: CISC and RISC. One of the principal characteristics that separate RISC from CISC microprocessors is the size of the instruction set- RISC microprocessor have relatively small instruction set whereas CISC microprocessors have relatively large instruction sets.

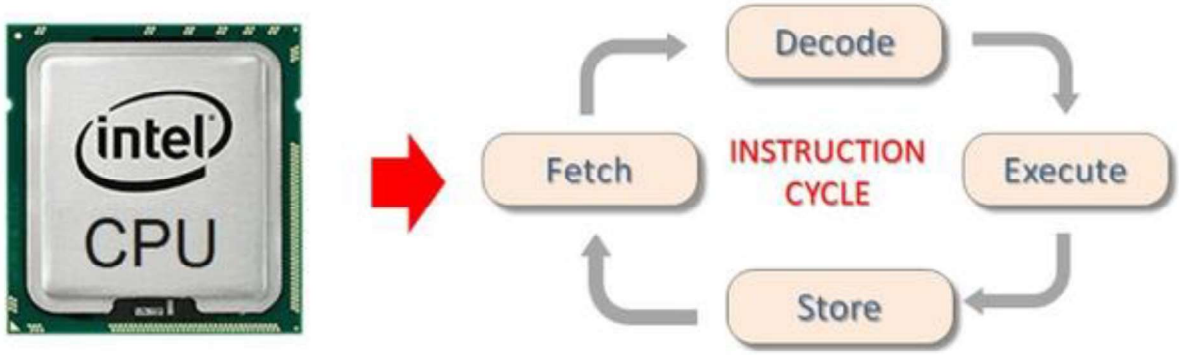
Examples of instruction set

- **ADD** - Add two numbers together.
- **COMPARE** - Compare numbers.
- **IN** - Input information from a device, e.g., keyboard.
- **JUMP** - Jump to designated RAM address.
- **JUMP IF** - Conditional statement that jumps to a designated RAM address.
- **LOAD** - Load information from RAM to the CPU.
- **OUT** - Output information to device, e.g., monitor.
- **STORE** - Store information to RAM.

Instruction Cycle

Every time the CPU executes an instruction, it takes a series of steps called the machine cycle. The machine cycle consists of two sub-cycles- the instruction cycle and the execution cycle. The machine cycle consists of four steps-fetching, decoding, executing and storing.

1. **Fetching -** Before the CPU can execute an instruction, the control unit must retrieve or fetch the command or data from the computer's memory. The fetching process fetches the instruction from memory. This step brings the instruction into the instruction register, a circuit that hold the instruction so that it can be decoded and executed.
2. **Decoding -** Before the command can be executed, the control unit must breakdown or decode the command into instructions that corresponds to those in the CPU's instruction set.
3. **Executing -** When the command is executed, the CPU carries out the instructions in order by converting them into microcode.
4. **Storing -** The CPU may be required to store the results of an instruction in memory.



Microprocessor

A Microprocessor is a multipurpose programmable, clock driven, register based electronic device that reads binary instructions from a storage device called memory, accepts binary data as input, processes data according to those instructions and provide result s as output. The microprocessor operates in binary 0 and 1 known as bits are represented in terms of electrical voltages in the machine that means 0 represents low voltage level and 1 represents high voltage level. Each microprocessor recognizes and processes a group of bits called the word and microprocessors are classified according to their word length such as 8 bits microprocessor with 8 bit word and 32 bit microprocessor with 32 bit word etc.

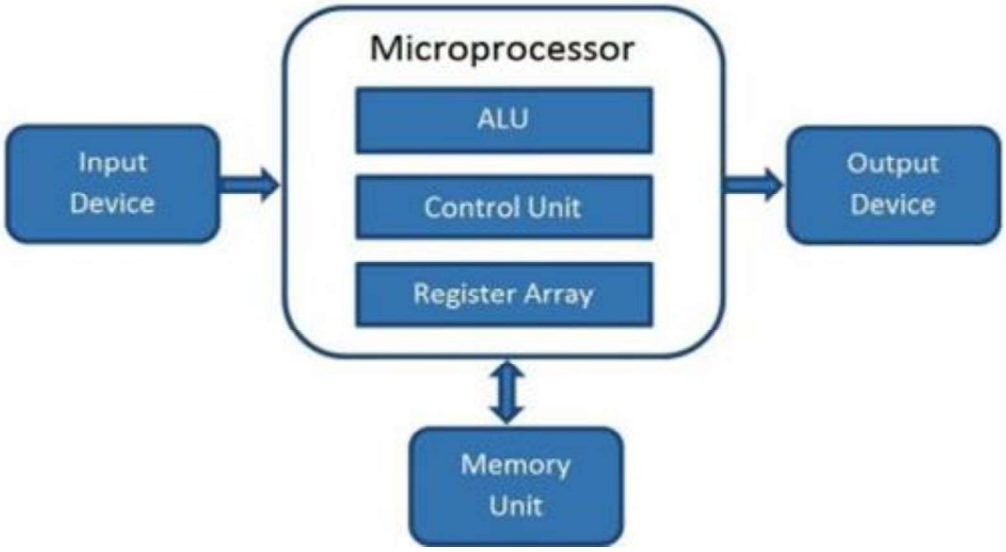


Figure 1: Block Diagram of Microprocessor Based Computer System

On the basis of instruction set, microprocessors are classified as RISC and CISC. The x86 instruction set of the original Intel 8086 processor is of the CISC type.

RISC and CISC Architecture

Reduced Instruction Set Computer (RISC)

RISC stands for Reduced Instruction Set Computer. RISC processors are designed for speeding up the processing power of the computer making the chip as simple as possible so that it uses less space and shorter design cycle. It is possible to use the technique of pipelining using RISC processors which gives the immense processing power.

The advantages of RISC processors are as follows:

i. Speed: Due to simplified instruction set RISC processors are 2 to 4 times faster.

ii. Simpler hardware- Because of simpler instruction set the RISC processor uses much less chip space, as a result extra function are also placed in the same chip.

iii. Shorter design cycle- Because of simple hardware and less instructions per task, the RISC processor uses very short machine cycles

The disadvantages of RISC processors are as follows:

i. Code quality

- Poor code- process can spend more time waiting

- Needs proper job scheduling so needs a good compiler.

ii. Debugging
    - Instruction scheduling makes debugging difficult
    - Intermingling of machine language instruction makes hard to read.

iii. Code expansion
    - It refers to the increase in size that you get when you take a program that had been compiled for a CISC machine and re-compile it for a RISC machine

iv. System Design
    - RISC machine requires very fast memory systems to feed instructions.
    - Requires large memory caches.

Complex Instruction Set Computer (CISC)

CISC stands for Complex Instruction Set Computer. Typically, CISC chips have a larger set of complex instructions. The philosophy behind it is that hardware is always faster than software, therefore one should make a powerful instruction-set, which provides programmers with assembly instructions to do a lot with short programs. In early generation CISC Machine have utilized this process, still they are less pipelined. Pipelining is the process of fetching more than one instruction from memory at a time and when the earlier fetched instructions are under process of execution. In CISC machine because of large number of complex instructions pipelining cannot be heavily used. For general purpose applications where speed of processors is not of prime importance, CISC machine are preferable because of their low cost. The processor like 8085, 8086, 80286, 80386, 80486, 80586 etc are CISC processor.

Advantages of CISC:

i. Microprogramming is as easy as assembly language to implement, and much less expensive than hardwiring a control unit.
ii. The ease of micro coding new instructions allowed the designers to make CISC machines upwardly compatible, i.e. a new computer could run the same programs as earlier computers.
iii. As each instruction became more capable, fewer instructions could be used to implement a given task.
iv. Because microprogram instruction sets can be written to match the constructs of high-level languages, the compiler does not have to be complicated.

The disadvantages of CISC:

v. The instruction set and chip hardware became more complex with each generation of computers.

vi. The instruction set were lengthy and took more time to execute, slowing down the overall performance of the machine.

vii. Many specialized instructions aren't used frequently enough to justify their existence.

Interconnecting the Units of a Computer

In Computer System, the different components such as CPU, I/O units and memory units are connected to each other by a communication system called Bus. ***Bus*** is a set of electronic signal pathways that allows information and signals to travel between components inside or outside of a computer. The different components of computer, i.e., CPU, I/O unit, and memory unit are connected with each other by a bus. The data, instructions and the signals are carried between the different components via a bus. The features and functionality of a bus are as follows:

- A bus is a set of wires used for interconnection, where each wire can carry one bit of data.
- A bus width is defined by the number of wires in the bus.
- A computer bus can be divided into two types—Internal Bus and External Bus.
- The Internal Bus connects components inside the motherboard like, CPU and system memory. It is also called the *System Bus*. shows interaction between processor and memory.

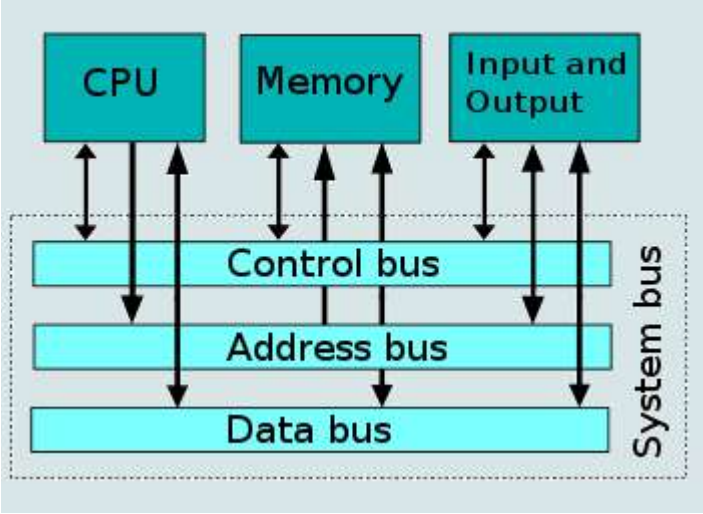


Figure 2: Interaction between CPU and memory

- The External Bus connects the different external devices, peripherals, expansion slots, I/O ports and drive connections to the rest of computer. The external bus allows

various devices to be attached to the computer. It allows for the expansion of computer's capabilities. It is generally slower than the system bus. It is also referred to as the *Expansion Bus*.

- A system bus or expansion bus comprise of three kinds of buses - data bus, address bus and control bus. The interaction of CPU with memory and I/O devices involves all the three buses.
    - The command to access the memory or the I/O device is carried by the **control bus**. It consists of 4 to 10 parallel signal lines that report the status of various devices and carries control information between the CPU and other devices within the computer. Typically control bus signals are: Memory Read/Write and I/O Read/Write.

    - **Address bus** is a channel which transmits addresses of data (not the data) from the CPU to memory. The address bus consists of 16, 20, 24, or 32 parallel signal lines. The number of lines (wires) in the address bus determines the amount of memory that can be directly addressed as each line carries one bit of the address. If the CPU has N address lines, then it can directly address 2^N address lines. For example, a computer with a 32-bit address bus can directly address 4GB of physical memory, while one with 36 bits can address 64GB.

    - **Data bus** is a channel across which actual data are transferred between the CPU, memory, and I/O devices. The data bus consists of 8, 16, 32, or 64 parallel signal lines. Because each wire can transfer 1 bit of data at a time, an 8-wire bus can move 8 bits at a time, which is a full byte. A 16-bit bus can transfer 2 bytes, and a 32-bit bus can transfer 4 bytes at a time. The number of wires in the bus affects the speed at which data can travel between hardware components. The data bus is bidirectional, this means that the CPU can read data in from memory or it can send data out to memory

Inside a Computer Cabinet

The computer cabinet is nothing but an enclosure that allows other computer parts to be installed inside them; such parts are motherboard, power supply, memory chips, Processor, cables, storage device, etc.

The computer cabinets are also called "Chassis", "Computer case", "Computer Box", "Tower", and so on.

These computer cabinets are made up of fiber, plastic and iron-like materials. The cabinet's primary purpose is to attach all the parts of the computer system inside the chassis and protect the sensitive parts.

The cabinet also possesses connecting ports and buttons. They are used to connect peripheral devices such as keyboard, mouse and printers to the motherboard.
Parts that are attached and installed inside Computer Cabinet are as follows:

Motherboard

The motherboard is the central nervous system of the computer. It is a large Printed Circuit Board (PCB), having many chips, connectors and other electronics mounted inside the computer cabinet, responsible for connecting and facilitating communication between all the other components. Think of it as a central hub that allows everything else to work together seamlessly. The Basic Input Output System (BIOS) and Complementary Metal-Oxide Semiconductor (CMOS) are present on the motherboard.
Functions:

- Connects everything: Provides sockets and slots for the CPU, RAM, storage drives, graphics card, and other peripherals.
- Facilitates communication: Acts as a central pathway for data to flow between different components.
- Distributes power: Receives power from the power supply unit and distributes it to all connected components.
- Houses essential components: Often integrates features like audio and network controllers, eliminating the need for separate cards.

BIOS is the basic program used as an interface between the operating system and the motherboard. It acts as the first program that the CPU executes after the computer system is turned on. The BIOS is stored in the ROM and cannot be rewritten.

The four functions of BIOS:
⇒ BIOS Identifies, configures, tests, and connects computer hardware to the OS immediately after a computer is turned on. The combination of these steps is called the boot process.

These tasks are each carried out by BIOS's four main functions:

1. Power-On-Self-Test (POST)
   This tests the hardware before loading the OS.

2. Bootstrap Loader

   This locates the OS.

3. Software/Driver

   This locates the software and drivers that interface with the OS once running.

4. CMOS setup (Complementary Metal Oxide Semiconductor)

CMOS is the name of BIOS non-volatile memory. It enables users to alter hardware and system settings. This may include things like system date and time. First boot device, boot password, voltage power settings of RAM, etc. The CMOS chip is working even when the computer power is switched off. The CMOS chip saves some system information, such as time, system date and essential system settings. Information of the hardware installed in the computer (such as the number of tracks or sectors on each hard drive) is stored in the CMOS chip.

In computing, BIOS is also known as system BIOS, ROM BIOS, BIOS ROM or PC BIOS.

Memory Chips

Memory chips stores program operations and data while a program is being executed. There are several types of memory, including registers, cache, RAM, and virtual memory. Registers are a number of small, high speed memory units built-in within the CPU itself that hold data and instructions temporarily during processing.

Storage Devices

Storage device stores programs and files to a long-term, even when they are not in use. Devices such as hard drives and optical drives are examples.

- Hard Disk Drive | SSD (Solid State Drive).
- Optical Drives (DVDs).

CPU (Central Processing Unit) | Processor.

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Expansion Cards (Graphic Card, Video Cards, Sound Cards, Network Adapters).

The expansion cards are inserted in the expansion slots on the motherboard. Expansion slots is used to hold expansion cards to expand the computer's functionality, like a video card, network card, or sound card. There are several types of slots including:

- ISA (Industry Standard Architecture) slot: to connect modem and input devices,
- PCI (Peripheral Component Inter Connect) slot: to connect audio, video and graphics,
- AGP (Accelerated Graphic Port) slot: A fast port for a graphics card,
- PCI (Peripheral Component Inter Connect) Express slot: Faster bus architecture than AGP and PCI buses,
- PC Card: used in laptop computers. It includes Wi-Fi card, network card and external modem.

Expansion cards are becoming less common in modern laptops due to space constraints and integrated components. Newer technologies like USB and Thunderbolt offer external alternatives for some functionalities.

Ports and Interface

Motherboard has a certain number of I/O sockets that are connected to the ports and interfaces found on the rear side of a computer. Ports are the physical connectors on your computer that allow you to connect various devices and peripherals. They act as gateways for both **input** (data entering your computer) and **output** (data exiting your computer). Think of them as handshake points for information to flow between your digital world and the physical world.

Interface are the communication protocols and standards that govern how data flows between devices through ports. Examples: USB, HDMI, Ethernet and Wireless interfaces