

Unit I: Basic Structure of Computers

Computer Architecture in general covers three aspects of computer design namely: Computer Hardware, Instruction set Architecture and Computer Organization.

Computer hardware consists of electronic circuits, displays, magnetic and optical storage media and communication facilities.

Instruction set Architecture is programmer visible machine interface such as instruction set, registers, memory organization and exception handling. Two main approaches are mainly CISC (Complex Instruction Set Computer) and RISC (Reduced Instruction Set Computer)

Computer Organization includes the high level aspects of a design, such as memory system, the bus structure and the design of the internal CPU.

Computer Types

Computer is a fast electronic calculating machine which accepts digital input, processes it according to the internally stored instructions (Programs) and produces the result on the output device. The internal operation of the computer can be as depicted in the figure below:

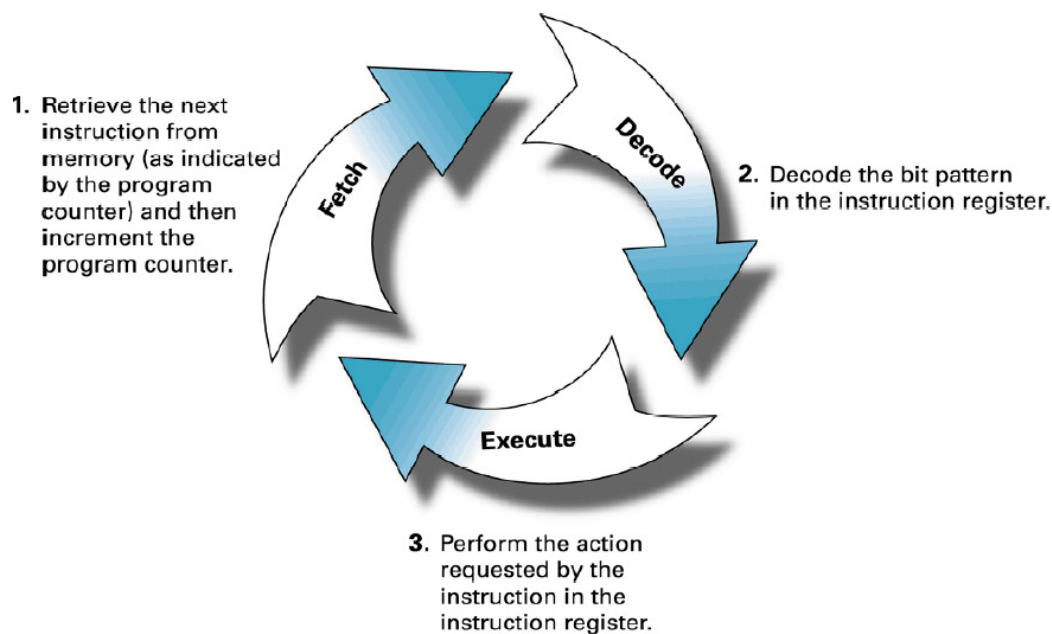


Figure 1: Fetch, Decode and Execute steps in a Computer System

The computers can be classified into various categories as given below:

- Micro Computer
- Laptop Computer
- Work Station
- Super Computer
- Main Frame
- Hand Held
- Multi core

Micro Computer: A personal computer; designed to meet the computer needs of an individual. Provides access to a wide variety of computing applications, such as word processing, photo editing, e-mail, and internet.

Laptop Computer: A portable, compact computer that can run on power supply or a battery unit. All components are integrated as one compact unit. It is generally more expensive than a comparable desktop. It is also called a Notebook.

Work Station: Powerful desktop computer designed for specialized tasks. Generally used for tasks that requires a lot of processing speed. Can also be an ordinary personal computer attached to a LAN (local area network).

Super Computer: A computer that is considered to be fastest in the world. Used to execute tasks that would take lot of time for other computers. For Ex: Modeling weather systems, genome sequence, etc (Refer site: <http://www.top500.org/>)

Main Frame: Large expensive computer capable of simultaneously processing data for hundreds or thousands of users. Used to store, manage, and process large amounts of data that need to be reliable, secure, and centralized.

Hand Held: It is also called a PDA (Personal Digital Assistant). A computer that fits into a pocket, runs on batteries, and is used while holding the unit in your hand. Typically used as an appointment book, address book, calculator and notepad.

Multi Core: Have Multiple Cores – parallel computing platforms. Many Cores or computing elements in a single chip. Typical Examples: Sony Play station, Core 2 Duo, i3, i7 etc.

Functional Unit

A computer in its simplest form comprises five functional units namely input unit, output unit, memory unit, arithmetic & logic unit and control unit. Figure 2 depicts the functional units of a computer system.

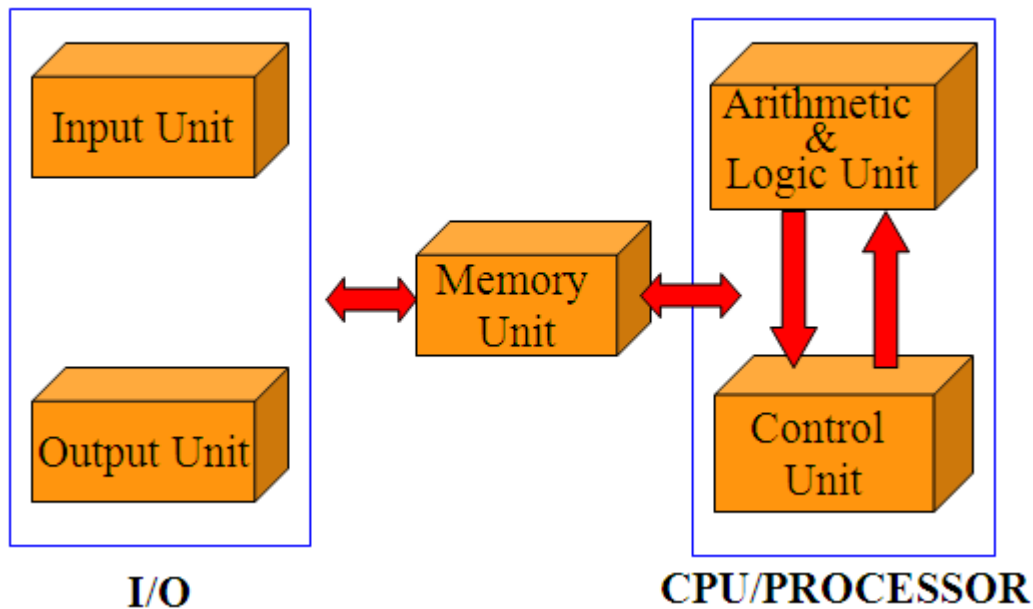


Figure 2: Basic functional units of a computer

Let us discuss about each of them in brief:

1. **Input Unit:** Computer accepts encoded information through input unit. The standard input device is a keyboard. Whenever a key is pressed, keyboard controller sends the code to CPU/Memory.

Examples include Mouse, Joystick, Tracker ball, Light pen, Digitizer, Scanner etc.

2. **Memory Unit:** Memory unit stores the program instructions (Code), data and results of computations etc. Memory unit is classified as:

- Primary /Main Memory
- Secondary /Auxiliary Memory

Primary memory is a semiconductor memory that provides access at high speed. Run time program instructions and operands are stored in the main memory. Main memory is classified again as ROM and RAM. ROM holds system programs and firmware routines such as BIOS, POST, I/O Drivers that are essential to manage the hardware of a computer. RAM is termed as Read/Write memory or user memory that holds run time program instruction and data. While primary storage is essential, it is volatile in nature and expensive. Additional requirement of memory could be supplied as auxiliary memory at cheaper cost. **Secondary memories** are non volatile in nature.

3. **Arithmetic and logic unit:** ALU consist of necessary logic circuits like adder, comparator etc., to perform operations of addition, multiplication, comparison of two numbers etc.
4. **Output Unit:** Computer after computation returns the computed results, error messages, etc. via output unit. The standard output device is a video monitor, LCD/TFT monitor. Other output devices are printers, plotters etc.
5. **Control Unit:** Control unit co-ordinates activities of all units by issuing control signals. Control signals issued by control unit govern the data transfers and then appropriate operations take place. Control unit interprets or decides the operation/action to be performed.

The operations of a computer can be summarized as follows:

1. A set of instructions called a program reside in the main memory of computer.
2. The CPU fetches those instructions sequentially one-by-one from the main memory, decodes them and performs the specified operation on associated data operands in ALU.
3. Processed data and results will be displayed on an output unit.
4. All activities pertaining to processing and data movement inside the computer machine are governed by control unit.

Basic Operational Concepts

An Instruction consists of two parts, an Operation code and operand/s as shown below:

OPCODE	OPERAND/s
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Let us see a typical instruction

ADD LOCA, R0

This instruction is an addition operation. The following are the steps to execute the instruction:

Step 1: Fetch the instruction from main memory into the processor

Step 2: Fetch the operand at location LOCA from main memory into the processor

Step 3: Add the memory operand (i.e. fetched contents of LOCA) to the contents of register R0

Step 4: Store the result (sum) in R0.

The same instruction can be realized using two instructions as

Load LOCA, R1
Add R1, R0

The steps to execute the instructions can be enumerated as below:

Step 1: Fetch the instruction from main memory into the processor

Step 2: Fetch the operand at location LOCA from main memory into
the processor Register R1

Step 3: Add the content of Register R1 and the contents of register R0

Step 4: Store the result (sum) in R0.

Figure 3 below shows how the memory and the processor are connected. As shown in the diagram, in addition to the ALU and the control circuitry, the processor contains a number of registers used for several different purposes. The instruction register holds the instruction that is currently being executed. The program counter keeps track of the execution of the program. It contains the memory address of the next instruction to be fetched and executed. There are n general purpose registers $R0$ to R_{n-1} which can be used by the programmers during writing programs.

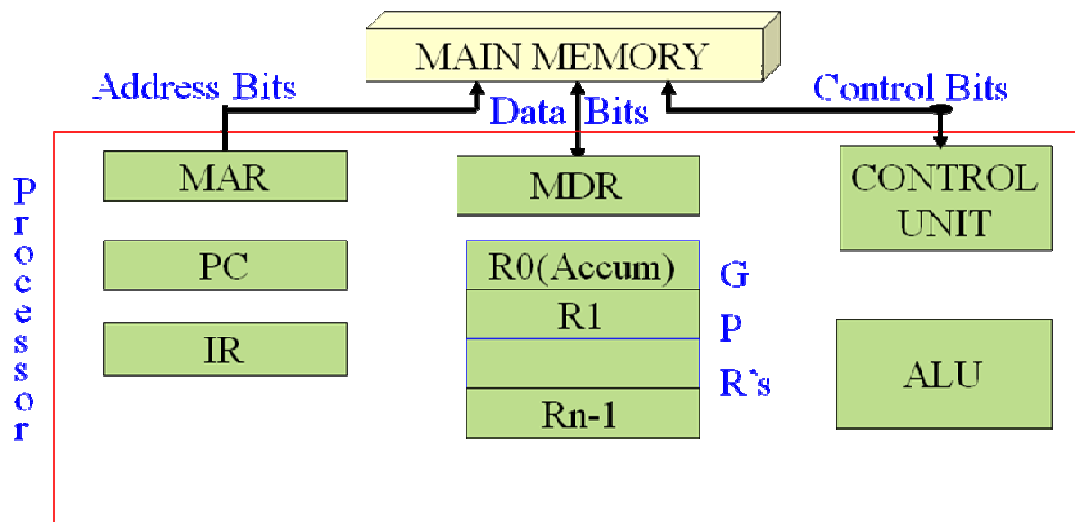


Figure 3: Connections between the processor and the memory

The interaction between the processor and the memory and the direction of flow of information is as shown in the diagram below:

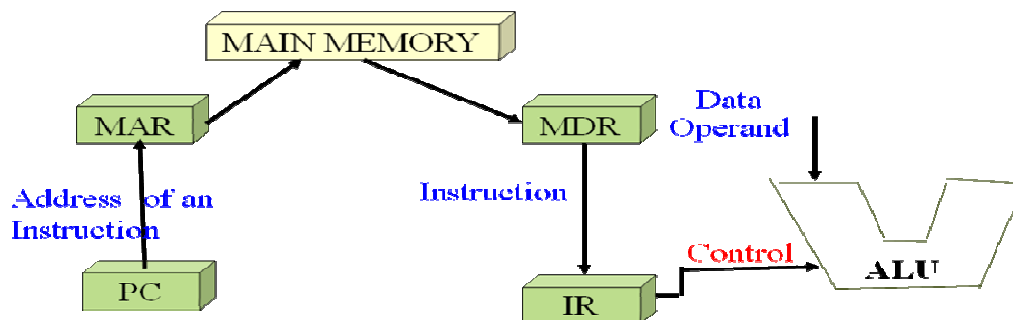


Figure 4: Interaction between the memory and the ALU

BUS STRUCTURES

Group of lines that serve as connecting path for several devices is called a bus (one bit per line). Individual parts must communicate over a communication line or path for exchanging data, address and control information as shown in the diagram below. Printer example – processor to printer. A common approach is to use the concept of buffer registers to hold the content during the transfer.

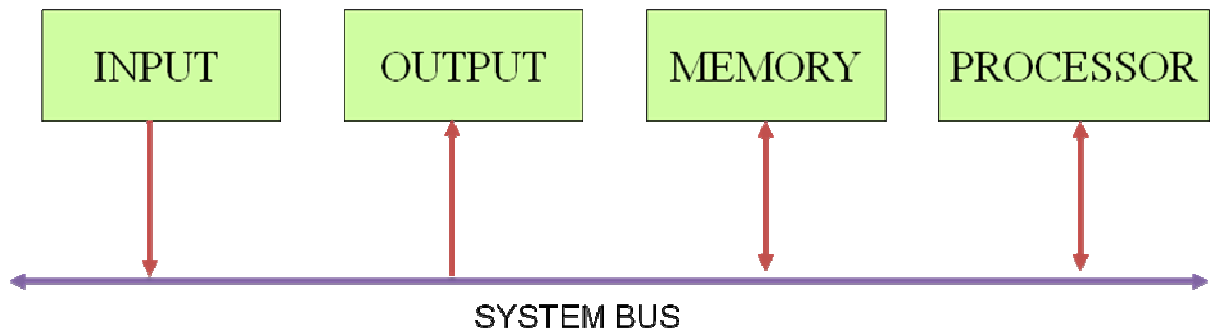


Figure 5: Single bus structure

SOFTWARE

If a user wants to enter and run an application program, he/she needs a System Software. System Software is a collection of programs that are executed as needed to perform functions such as:

- Receiving and interpreting user commands
- Entering and editing application programs and storing them as files in secondary storage devices
- Running standard application programs such as word processors, spread sheets, games etc...

Operating system - is key system software component which helps the user to exploit the below underlying hardware with the programs.

USER PROGRAM and OS ROUTINE INTERACTION

Let's assume computer with 1 processor, 1 disk and 1 printer and application program is in machine code on disk. The various tasks are performed in a coordinated fashion, which is called multitasking. $t_0, t_1 \dots t_5$ are the instances of time and the interaction during various instances as given below:

- t_0 : the OS loads the program from the disk to memory
- t_1 : program executes
- t_2 : program accesses disk
- t_3 : program executes some more
- t_4 : program accesses printer
- t_5 : program terminates

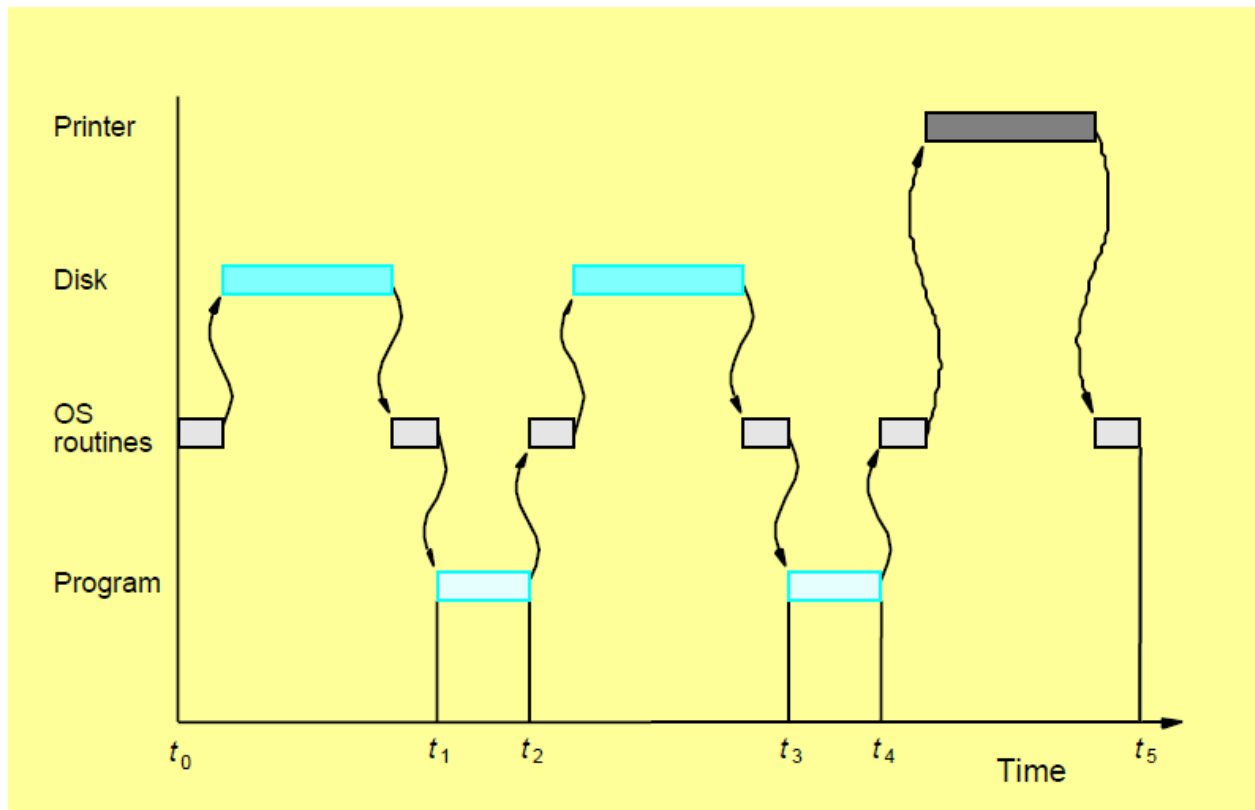


Figure 6 :User program and OS routine sharing of the processor

PERFORMANCE

The total time required to execute a program is the most important measure of performance for a computer. (t_0 - t_5 of earlier example). Compiler, instruction set and hardware architecture, program all have impact on performance.

Basic Performance Equation: The basic performance equation is given by

$$T = (N * S) / R$$

where T =execution time, N =number of instructions, S =average cycles per instruction, R =clock rate in cycles per second

CACHING

Commonly used data are copied to on-processor memory (cache) to reduce access time. Small memories can be made with higher speed than large ones. In a computer, we need both.

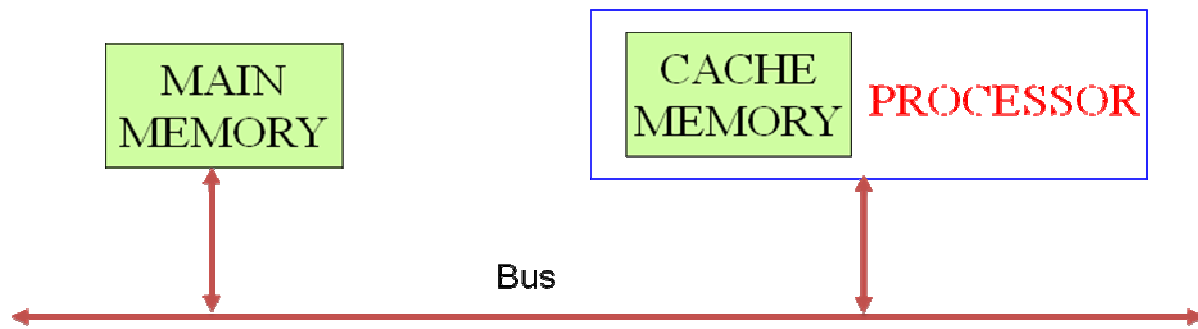


Figure 7: The processor cache

PIPELINING and SUPERSCALAR OPERATION

Pipelining: Like a production line, instruction execution overlapped so greater parallelism is achieved.

Superscalar operation: Execute several instructions simultaneously using multiple ALU's.

CISC vs RISC

Reduced instruction set computer

- Large N, small S

Complex instruction set computer

- Small N, large S

COMPILER

Translates high level language such as C, C++ and Java to machine instructions. Aims to reduce N×S

PERFORMANCE MEASUREMENT

Benchmark refers to standard task used to measure how well a processor operates. To evaluate the performance of Computers, a non-profit organization known as SPEC-System Performance Evaluation Corporation employs agreed-upon application programs of real world for benchmarks. Accordingly, it gives performance measure for a computer as the time required to execute a given benchmark program. The SPEC rating is computed as follows

$$\text{SPEC Rating} = \frac{\text{Running time on a Reference Computer}}{\text{Running time on a test Computer}}$$

GENERATION OF COMPUTERS

Development of technologies used to fabricate the processors, memories and I/O units of the computers has been divided into various generations as given below:

- First generation
- Second generation
- Third generation
- Fourth generation
- Beyond the fourth generation

First generation:

1946 to 1955: Computers of this generation used Vacuum Tubes. The computers were built using stored program concept. Ex: ENIAC, EDSAC, IBM 701.

Computers of this age typically used about ten thousand vacuum tubes. They were bulky in size had slow operating speed, short life time and limited programming facilities.

Second generation:

1955 to 1965: Computers of this generation used the germanium transistors as the active switching electronic device. Ex: IBM 7000, B5000, IBM 1401. Comparatively smaller in size About ten times faster operating speed as compared to first generation vacuum tube based computers. Consumed less power, had fairly good reliability. Availability of large memory was an added advantage.

Third generation:

1965 to 1975: The computers of this generation used the Integrated Circuits as the active electronic components. Ex: IBM system 360, PDP minicomputer etc. They were still smaller in size. They had powerful CPUs with the capacity of executing 1 million instructions per second (MIPS). Used to consume very less power consumption.

Fourth generation:

1976 to 1990: The computers of this generation used the LSI chips like microprocessor as their active electronic element. HCL horizon III, and WIPRO'S Uniplus+ HCL's Busybee PC etc. They used high speed microprocessor as CPU. They were more user friendly and highly reliable systems. They had large storage capacity disk memories.

Beyond Fourth Generation:

1990 onwards: Specialized and dedicated VLSI chips are used to control specific functions of these computers. Modern Desktop PC's, Laptops or Notebook Computers.