ELECTRICAL ENGINEERING

COMPUTER FUNDAMENTALS

Comprehensive Theory
with Solved Examples *and* Practice Questions

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Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016 | **Ph. :** 9021300500

Email : infomep@madeeasy.in | **Web :** www.madeeasypublications.org

Computer Fundamentals

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Computer Fundamentals

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Computer Fundamentals

Goal of the Subject

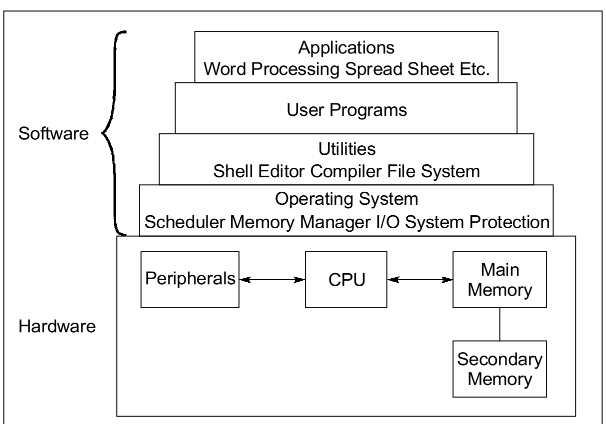
Basic understanding of Computer Fundamentals includes, the study about the basic architecture of computer, its Central Processing Unit (CPU), how the memory organization is done, I/O organization, data representation, basics of operating systems, file systems, basics of networking and elements of programming languages.

CHAPTER 1

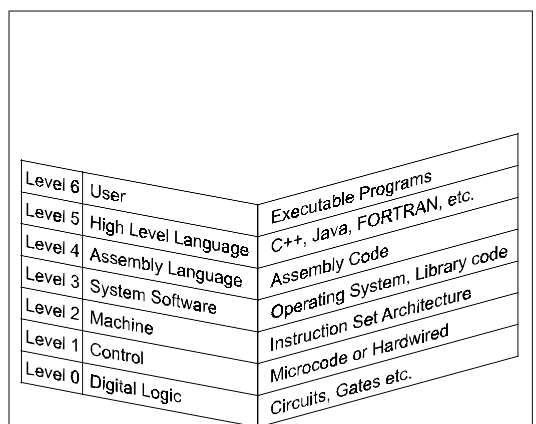
Basic Architecture

1.1 Computer System

Computer system is divided into two functional entities: Hardware and Software.



Computer System Block Diagram



Computer System Level Hierarchy

- **Hardware:** Lowest level in a computer are all the electronic circuits and physical devices from which it is built.

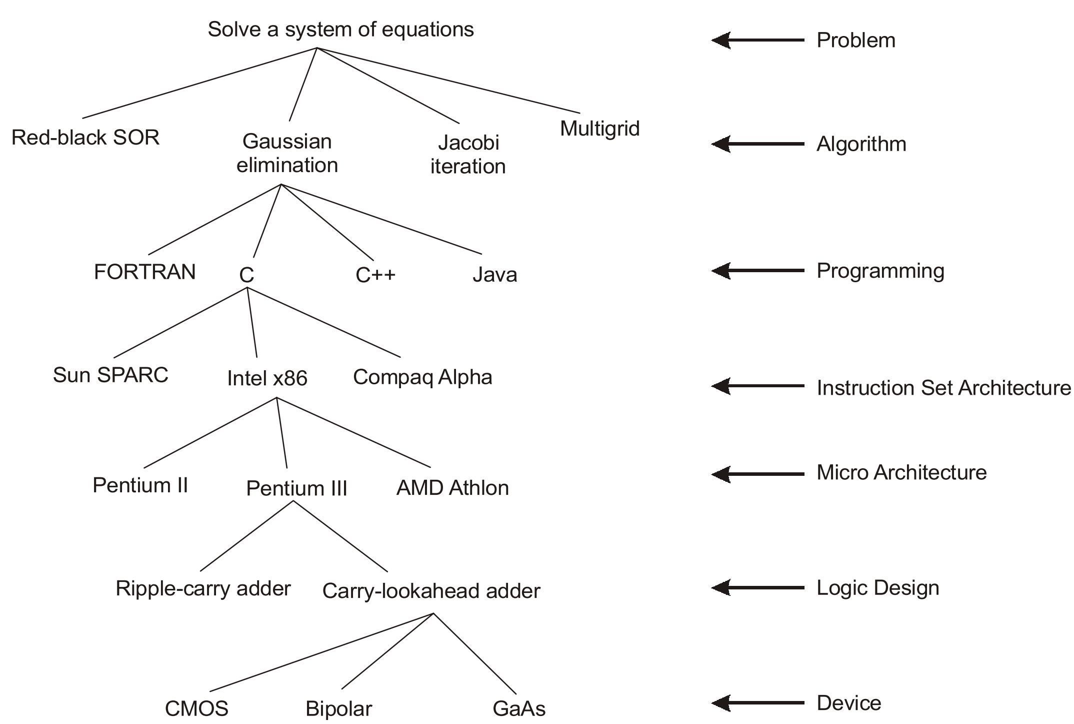
  Hardware consisting of its physical devices (CPU, memory, bus, storage devices, ...)
- **Software:** Sequences of instructions and data that make computers do useful work.

  Software, consisting of the programs it has (Operating system, applications, utilities, ...)

  Program is a sequence of instructions for a particular task.
- Operating system is set of programs included in system software package and Link between hardware and user needs.

1.2 Layers of Abstraction

- **Problem Statement:** stated using "natural language". It may be ambiguous are imprecise.
- **Algorithm:** step-by-step procedure, guaranteed to finish. It is definiteness, effective computability, and finiteness.
- **Program:** Express the algorithm using a computer language such as high-level language and low-level language.
- **Instruction Set Architecture (ISA):** It specifies the set of instructions the computer can perform using data types and addressing modes.
- **Micro-architecture:** It is detailed organization of a processor implementation.
- **Logic Circuits:** Combine basic operations to realize micro-architecture.
- **Devices:** Which is properties of materials and manufacturability.



Layers of Abstraction

1.3 Computer Organization and Computer Architecture

Computer design: The determination of how to interconnect the components and which components to used based upon some specifications.

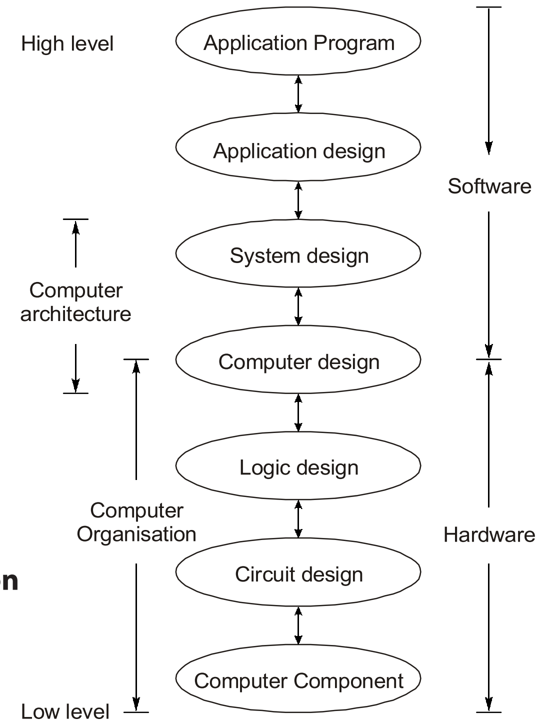
1.3.1 Computer Architecture (CA)

- Computer architecture is the conceptual design and fundamental operational structure of a computer system. It is a functional description of requirements and design implementations for the various parts of a computer.
- It is the science and art of selecting and interconnecting hardware components to create computers that meet functional, performance and cost goals.

- It deals with the architectural attributes like physical address memory, CPU and how they should be designed and made to coordinate with each other keeping the goals in mind.

1.3.2 Computer Organization (CO)

- Computer architecture comes before computer organization.
- Computer organization is how operational attributes are linked together and contribute to realise the architectural specifications.
- It encompasses all physical aspects of computer systems. e.g. Circuit design, control signals, memory types.



Computer System

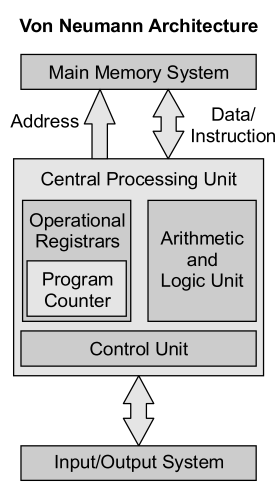
1.3.3 Computer Architecture Vs Computer Organization

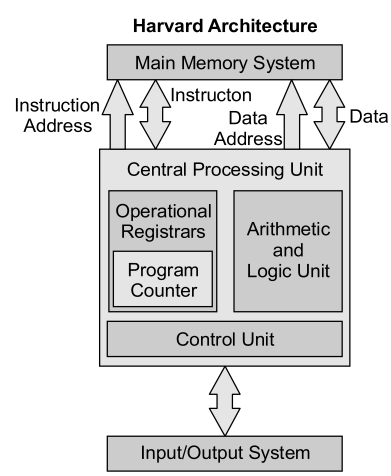
Architecture and organization are independent, you can change the organization of a computer without changing its architecture.

1. The architecture indicates its hardware whereas the organization reveals its performance.
2. For designing a computer, its architecture is fixed first and then its organization is decided.

Computer Organization	Computer Architecture
• Computer organization deals with structural relationships that are not visible to the programmer (like clock frequency or the size of the physical memory).	• Computer architecture deals with the functional behavior of a computer system as viewed by a programmer (like the size of a data type – 32 bits to an integer).
• A computer's organization expresses the realization of the architecture.	• A computer's architecture is its abstract model and is the programmer's view in terms of instructions, addressing modes and registers.
• Organization describes how it does it.	• Architecture describes what the computer does.

Von Neumann Architecture Vs Harvard Architecture





1.4 Evolution of Digital Computers

First generation: Vacuum tube computers (1945~1953)

- Program and data reside in the same memory (stored program concepts: John von Neumann)
- Vacuum tubes were used to implement the functions (ALU & CU design)
- Magnetic core and magnetic tape storage devices are used.
- Using electronic vacuum tubes, as the switching components.
- Assembly level language is used

Second generation: Transistorized computers (1954~1965)

- Transistor were used to design ALU & CU
- High Level Language is used (FORTRAN)
- To convert HLL to MLL compiler were used
- Separate I/O processor were developed to operate in parallel with CPU, thus improving the performance
- Invention of the transistor which was faster, smaller and required considerably less power to operate

Third generation: Integrated circuit computers (1965~1980)

- IC technology improved
- Improved IC technology helped in designing low cost, high speed processor and memory modules
- Multiprogramming, pipelining concepts were incorporated
- DOS allowed efficient and coordinate operation of computer system with multiple users
- Cache and virtual memory concepts were developed
- More than one circuit on a single silicon chip became available.

Fourth generation: Very large scale integrated (VLSI) computers (1980~2000)

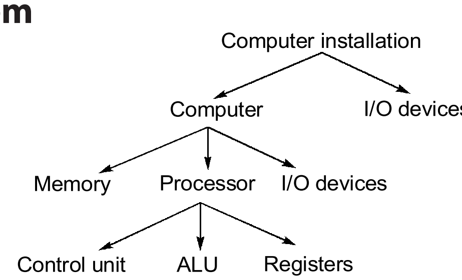
- CPU termed as microprocessor
- INTEL, MOTOROLA, TEXAS, NATIONAL semiconductors started developing microprocessor
- Workstations, microprocessor (PC) & Notebook computers were developed
- Interconnection of different computer for better communication LAN, MAN and WAN
- Computational speed increased by 1000 times
- Specialized processors like Digital Signal Processor were also developed.

Fifth generation: System-on-chip (SOC) computers (2000~)

- E-Commerce, E- banking, home office
- ARM, AMD, INTEL, MOTOROLA
- High speed processor - GHz speed
- Because of submicron IC technology lot of added features in small size.

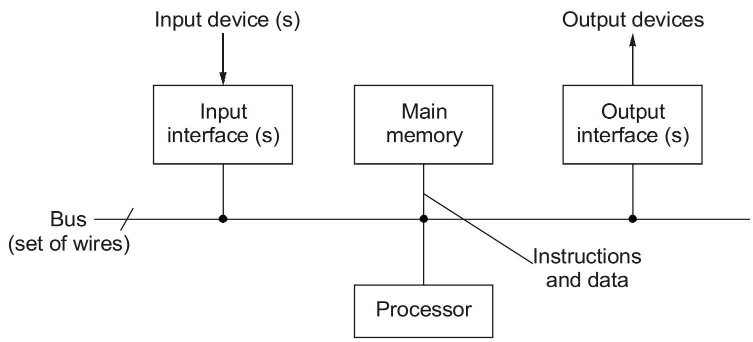
1.5 Structure and Function of a Computer System

The designer need only deal with a particular level of the system at a time. At each level, the system consists of a set of *components and their interrelationships*.



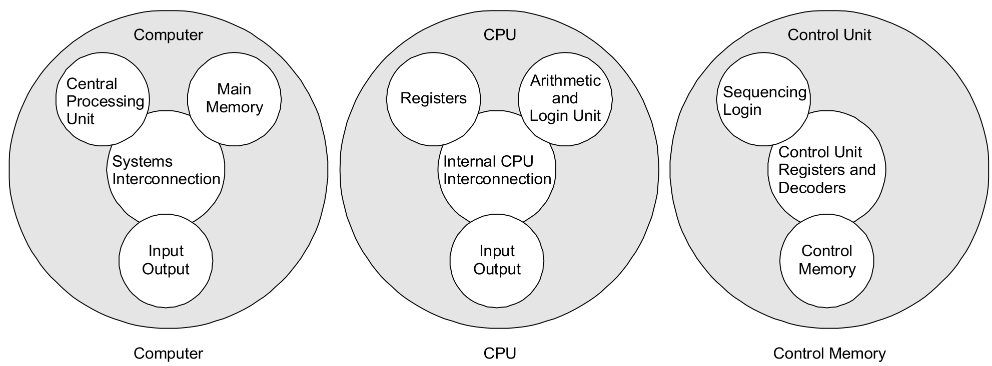
The behavior at each level depends only on a simplified, abstracted characterization of the system at the next lower level. At each level, the designer is concerned with structure and function. Important relationships are explained in the figure.

Structure is the way in which components relate to each other (shown in the following figure). Function is the operation of individual components as part of the structure. Functions are Data processing, Data storage, Data movement and Control.



Internal Structure of Computer

1.6 Components of Computer Structure



Computer Structure vs CPU Structure vs Control Unit

1. **Input Unit:** Computers can understand only machine language. Therefore, for converting data from human language to machine language we use some special peripheral devices which are called input device.
   Examples: Keyboard, Mouse, Joystick, etc.
2. **Output Unit:** After passing instructions for solving particular problem, the results came out from computer comes in machine language and this is very difficult to convert that results into human language. There are several such peripheral devices which help us to convert the machine language data into human acceptable data. These devices are called output devices.
   Examples: Monitor, Printer, LCD, LED etc.
3. **Memory Unit:** Which is used to store data in computer.
   Memory unit performs the following actions
   (a) Stores data and instructions required for processing.
   (b) Stores the intermediate results obtain during processing.
   (c) Stores final results before sending it to output unit.

   Two class of storage units: (i) Primary Memory (ii) Secondary Memory
   Two types of primary memory are RAM (Random Access Memory) and ROM (Read Only Memory). RAM is used to store data temporarily during the program execution. ROM is used to store data and program which is not going to change.
   Secondary Memory is used for bulk storage or mass storage to store data permanently.

4. **CPU:** It is main unit of the computer system. It is responsible for carrying out computational task. The major structural components of a CPU are:
(a) *Control Unit (CU):* Controls the operation of the CPU and hence the computer.
(b) *Arithmetic and Logic Unit (ALU):* Performs computer's data processing functions.
(c) *Register:* Provides storage internal to the CPU.
(d) *CPU Interconnection:* communication among the control unit, ALU, and register.

1.7 Bus Structure

Bus: It is a group of wires (lines or signals) which carries information form CPU to peripherals or peripherals to CPU. The CPU and Memory are connected by Data Bus, Address Bus and Control Bus.

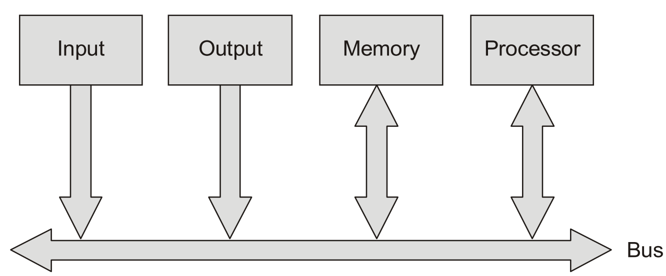
Address Bus: It is unidirectional bus which carries address information bits form processor to peripherals.

Data Bus: It is bidirectional bus which carries data information bit form processor to peripherals and vice-versa.

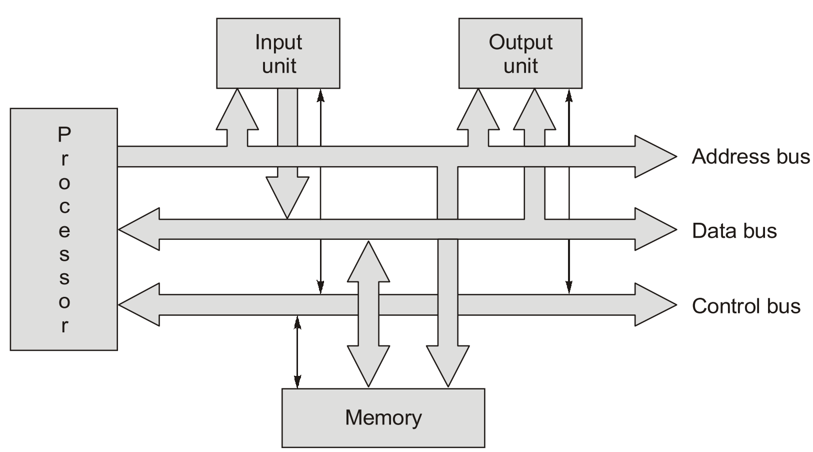
Control Bus: It is bidirectional bus which carries control signals form processor to peripherals and vice-versa.

1.7.1 Types of Bus Structure

- **Single bus structure:** Common bus used (shown in the following figure) to communicate between peripherals and microprocessor.



Single Bus Structure



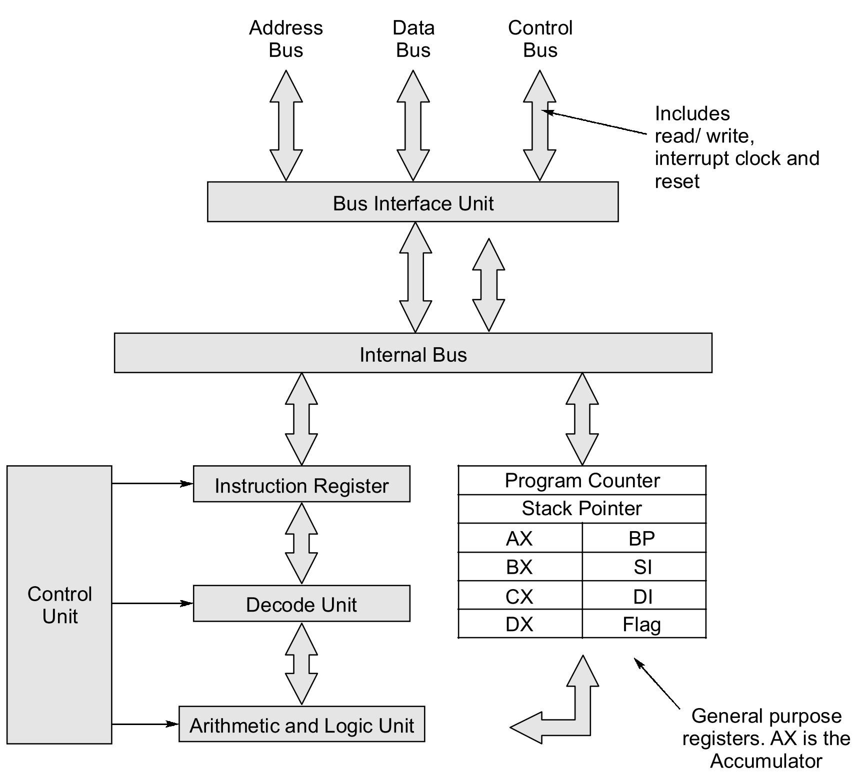
Internal view of Single Bus Structure

- **Two Bus Structure:** One bus can be used to fetch instruction other can be used to fetch data, required for execution. It improves the performance, but cost increases.

1.7.2 CISC and RISC Architectures

CISC (Complex Instruction Set Computers)	RISC (Reduced Instruction Set Computers)
• Large instruction set	• Compact instruction set
• Instruction formats are of different lengths	• Instruction formats are all of the same length
• Instructions perform both elementary and complex operations	• Instructions perform elementary operations
• Control unit is micro-programmed	• Control unit is simple and hardwired
• Not pipelined or less pipelined	• Pipelined
• Single register set	• Multiple register set
• Numerous memory addressing options for operands	• Compiler and IC developed simultaneously
• Emphasis on hardware	• Emphasis on software
• Includes multi-clock complex instructions	• Single-clock, reduced instruction only
• Memory-to-memory: "LOAD" and "STORE" incorporated in instructions	• Register to register: "LOAD" and "STORE" are independent instructions
• Small code sizes, high cycles per second	• Low cycles per second, large code sizes
• Transistors used for storing complex instructions	• Spends more transistors on memory registers
Examples of CISC processors: • VAX • PDP?11 • Motorola 68000 family • Intel x86 architecture based processors.	**Examples** of RISC processors • Apple iPods (custom ARM7TDMI SoC) • Apple iPhone (Samsung ARM1176JZF) • Nintendo Game Boy Advance (ARM7) • Sony Network Walkman (Sony in?house ARM based chip)

1.7.3 General CPU Architecture (8086 Microprocessor)



1.7.4 Issues of Computer Design

- Cannot assume infinite speed and memory.
- Speed mismatch between memory and processor
- Handle bugs and errors
- Multiple processors, processes, threads
- Shared memory
- Disk access
- Better performance with reduced power

Summary

- **Computer:** A device that accepts input, processes data, stores data, and produces output, all according to a series of stored instructions.
- **Hardware:** Includes the electronic and mechanical devices that process the data; refers to the computer as well as peripheral devices.
- **Software:** A computer program that tells the computer how to perform particular tasks.
- **Computer organization:** Interconnection of hardware to form the computer system
- **Computer architecture:** the structure and behaviour of the computer perceived by the user.
- **Input:** Whatever is put into a computer system.
- **Data:** Refers to the symbols that represent facts, objects, or ideas.
- **Information:** The results of the computer storing data as bits and bytes; the words, numbers, sounds, and graphics.
- **Output:** Consists of the processing results produced by a computer.
- **Main Memory:** Area of the computer that temporarily holds data waiting to be processed, stored, or output. *Example:* Cache and Main memory
- **Secondary Storage:** Area of the computer that holds data on a permanent basis when it is not immediately needed for processing. Example: Disk, Floppy, etc.

Student's Assignments

Q.1 A 32-bit address bus allows access to a memory of capacity
(a) 64 MB (b) 16 MB
(c) 1 GB (d) 4 GB

Q.2 The system bus is made up of
(a) data bus
(b) data bus and address bus
(c) data bus and control bus
(d) data bus, control bus and address bus

Q.3 Which of the following is not involved in a memory write operation?
(a) MAR (b) PC
(c) MDR (d) data bus

Q.4 The read/write line
(a) belongs to the data bus
(b) belongs to the control bus
(c) belongs to the address bus
(d) CPU bus

Q.5 ________ is a piece of hardware that executes a set of machine-language instructions.
(a) controller (b) bus
(c) processor (d) motherboard

Q.6 Given below are some statements associated with the registers of a CPU. Identify the false statement.

(a) The program counter holds the memory address of the instruction in execution.
(b) Only opcode is transferred to the control unit.
(c) An instruction in the instruction register consists of the opcode and the operand.
(d) The value of the program counter is incremented by 1 once its value has been read to the memory address register.

Q.7 The following are four statements regarding what a CPU with only a set of 32-bit registers can perform?
1. Hold and operate on 32-bit integers
2. Hold and operate on 16-bit integers
3. Hold and operate on 64-bit floating point arithmetic
4. Hold and operate on 16-bit UNICODE characters

Which of the following is true about such a CPU?
(a) all are true (b) 1,2 and 3 only
(c) 1,2 and 4 only (d) 1,3 and 4 only

Q.8 The following are four statements about Reduced Instruction Set Computer (RISC) architectures.
1. The typical RISC machine instruction set is small, and is usually a subset of a CISC instruction set.
2. No arithmetic or logical instruction can refer to the memory directly.
3. A comparatively large number of user registers are available.
4. Instructions can be easily decoded through hard-wired control units.

Which of the above statements is true?
(a) 1 and 3 only
(b) 1,3 and 4 only
(c) 1, 2 and 3 only
(d) All of these

Q.9 The word length of a CPU is defined as
(a) the maximum addressable memory size.
(b) the width of a CPU register (integer or float point).
(c) the width of the address bus.
(d) the number of general purpose CPU registers.

Q.10 Which of the following statements is false about CISC architectures?
(a) CISC machine instructions may include complex addressing modes, which require many clock cycles to carry out.
(b) CISC control units are typically micro-programmed, allowing the instruction set to be more flexible.
(c) In the CISC instruction set, all arithmetic/logic instructions must be register based.
(d) CISC architectures may perform better in network centric applications than RISC.

Q.11 Which one is required while establishing the communication link between CPU and peripherals?
(a) Synchronization mechanism
(b) Conversion of signal values
(c) Operating modes
(d) All of the above

Student's Assignments — Answer Key

1. (d) **2.** (d) **3.** (b) **4.** (b) **5.** (c)
6. (a) **7.** (c) **8.** (d) **9.** (b) **10.** (c)
11. (d)

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