Study Material -1

COMPUTER ORGANISATION AND ARCHITECTURE

(PCC-CSM301)

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1. WHAT IS COMPUTER ARCHITECTURE AND ORGANIZATION?

- In general terms, the architecture of a computer system can be considered as a catalogue of tools or attributes that are visible to the user such as instruction sets, number of bits used for data, addressing techniques, etc.

- The organization of a computer system defines the way system is structured so that all those catalogued tools can be used. The significant components of Computer organization are ALU, CPU, memory, and memory organization

2. COMPUTER ARCHITECTURE VS COMPUTER ORGANIZATION

S. NO.	COMPUTER ARCHITECTURE	COMPUTER ORGANIZATION
1.	Architecture describes what the computer does.	The Organization describes how it does it.
2.	Computer Architecture deals with the functional behavior of computer systems.	Computer Organization deals with a structural relationship.
3.	it's clear that it deals with high-level design issues.	it's also clear that it deals with low-level design issues.
4.	Architecture indicates its hardware.	Organization indicates its performance.
5.	As a programmer, you can view architecture as a series of instructions, addressing modes, and registers.	The implementation of the architecture is called organization.
6.	For designing a computer, its architecture is fixed first.	For designing a computer, an organization is decided after its architecture.

S. NO.	COMPUTER ARCHITECTURE	COMPUTER ORGANIZATION
7.	Computer Architecture is also called Instruction Set Architecture (ISA).	Computer Organization is frequently called microarchitecture.
8.	Computer Architecture comprises logical functions such as instruction sets, registers, data types, and addressing modes.	Computer Organization consists of physical units like circuit designs, peripherals, and adders.
9.	The different architectural categories found in our computer systems are as follows: 1. Von-Neumann Architecture 2. Harvard Architecture 3. Instruction Set Architecture 4. Micro-architecture 5. System Design	CPU organization is classified into three categories based on the number of address fields: 1. Organization of a single Accumulator. 2. Organization of general registers 3. Stack organization
10.	It makes the computer's hardware visible.	It offers details on how well the computer performs.
11.	Architecture coordinates the hardware and software of the system.	Computer Organization handles the segments of the network in a system.
12.	The software developer is aware of it.	It escapes the software programmer's detection.
13.	Examples- Intel and AMD created the x86 processor. Sun Microsystems and others created the SPARC processor. Apple, IBM, and Motorola created the PowerPC.	Organizational qualities include hardware elements that are invisible to the programmer, such as interfacing of computer and peripherals, memory technologies, and control signals.

4. EVOLUTION OF COMPUTING DEVICES

- **ENIAC (Electronic Numerical Integrator and Computer)** was the first computing system designed in the early 1940s. It consisted of 18,000 buzzing electronic switches called vacuum tubes, 42 panels each 9'x 2'x1'.
- It was organized in U-Shaped around the perimeter of a room with forced air cooling.
  - **Atanasoff-Berry Computer (ABC)** design was known as the first digital electronic computer (though not programmable). It was designed and built by **John Vincent Atanasoff and his assistant, Clifford E. Berry in 1937**.
  - **In 1941, Z3** was invented by **German inventor Konrad Zuse**. It was the first working programmable, fully automatic computing machine.
  - **Transistors** were invented in **1947 at Bell Laboratories** which were a fraction the size of the vacuum tubes and consumed less power, but still, the complex circuits were not easy to handle.
  - **Jack Kilby and Robert Noyce** invented the **Integrated Circuit** at the same time. in July1959 Noyce filed a patent for this.
  - **In 1968, Robert Noyce co-founded Intel Electronics company** which is still the global market leader in IC manufacturing, research, and development.
  - **In 1983, Lisa was launched as the first personal computer** with a graphical user interface (GUI) that was sold commercially; it ran on the Motorola 68000, dual floppy disk drives, a **5 MB hard drive and had 1MB of RAM**.
  - In 1990, Apple released the Macintosh Portable; it was heavy weighing 7.3 kg (16 lb) and extremely expensive. It was not met with great success and was discontinued only two years later.
  - In 1990, Intel introduced the Touchstone Delta supercomputer, which had 512 microprocessors. This technological advancement was very significant as it was used as a model for some of the fastest multi-processor's systems in the world.

5. FUNCTIONAL UNITS OF COMPUTER SYSTEM

- A computer organization describes the functions and design of the various units of a digital system.
- A general-purpose computer system is the best-known example of a digital system.
- Other examples include telephone switching exchanges, digital voltmeters, digital counters, electronic calculators and digital displays.
- Computer architecture deals with the specification of the instruction set and the hardware units that implement the instructions.
- Computer hardware consists of electronic circuits, displays, magnetic and optic storage media and also the communication facilities.
- Functional units are a part of a CPU that performs the operations and calculations called for by the computer program.
- Functional units of a computer system are parts of the CPU (Central Processing Unit) that performs the operations and calculations called for by the computer program.
- A computer consists of five main components namely, Input unit, Central Processing Unit, Memory
  unit Arithmetic & logical unit, Control unit and an Output unit.

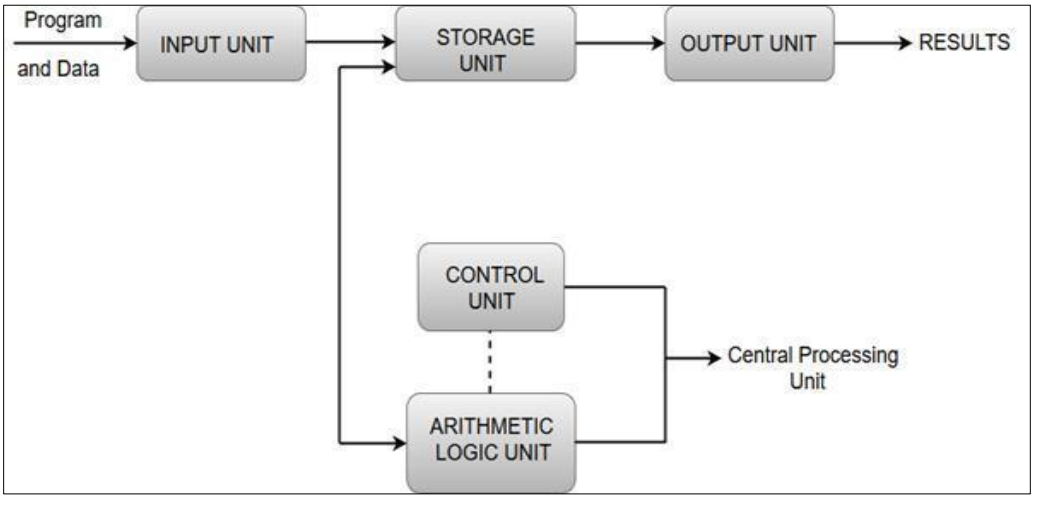

Figure 1: functional units of a computer system

I. INPUT UNIT:

- Input units are used by the computer to read the data. The most commonly used input devices are keyboards, mouse, joysticks, trackballs, microphones, etc.
- However, the most well-known input device is a keyboard. Whenever a key is pressed, The corresponding letter or digit is automatically translated into its corresponding binary code and transmitted over a cable to either the memory or the processor.

II. CENTRAL PROCESSING UNIT:

- Central processing unit commonly known as CPU can be referred to as an electronic circuitry within a computer that carries out the instructions given by a computer program by performing the basic arithmetic, logical, control and input/output (I/O) operations specified by the instructions.

III. MEMORY UNIT:

- The Memory unit can be referred to as the storage area in which programs are kept which are running, and that contains data needed by the running programs.
- The Memory unit can be categorized in two ways namely, primary memory and secondary memory.
- It enables a processor to access running execution applications and services that are temporarily stored in a specific memory location.
- Primary storage is the fastest memory that operates at electronic speeds. Primary memory contains a large number of semiconductor storage cells, capable of storing a bit of information. The word length of a computer is between 16-64 bits.
- It is also known as the volatile form of memory, means when the computer is shut down, anything contained in RAM is lost.
- Cache memory is also a kind of memory which is used to fetch the data very soon. They are highly coupled with the processor.
- The most common examples of primary memory are RAM and ROM.
- Secondary memory is used when a large amount of data and programs have to be stored
- for a long-term basis.
- It is also known as the Non-volatile memory form of memory, means the data is stored permanently irrespective of shut down.

- The most common examples of secondary memory are magnetic disks, magnetic tapes, and optical disks.

IV. MAIN MEMORY UNIT (REGISTERS) :

- **Accumulator:** Stores the results of calculations made by ALU.
- **Program Counter (PC):** Keeps track of the memory location of the next instructions to be dealt with. The PC then passes this next address to Memory Address Register (MAR).
- **Memory Address Register (MAR):** It stores the memory locations of instructions that need to be fetched from memory or stored into memory.
- **Memory Data Register (MDR):** It stores instructions fetched from memory or any data that is to be transferred to, and stored in, memory.
- **Current Instruction Register (CIR):** It stores the most recently fetched instructions while it is waiting to be coded and executed.
- **Instruction Buffer Register (IBR):** The instruction that is not to be executed immediately is placed in the instruction buffer register IBR.

V. ARITHMETIC & LOGICAL UNIT:

- Most of all the arithmetic and logical operations of a computer are executed in the ALU (Arithmetic and Logical Unit) of the processor.
- It performs arithmetic operations like addition, subtraction, multiplication, division and also the logical operations like AND, OR, NOT operations.

VI. CONTROL UNIT:

- The control unit is a component of a computer's central processing unit that coordinates the operation of the processor. It tells the computer's memory, arithmetic/logic unit and input and output devices how to respond to a program's instructions.
- The control unit is also known as the nerve center of a computer system.
- A control unit (CU) handles all processor control signals. It directs all input and output flow, fetches the code for instructions and controlling how data moves around the system.

VII. OUTPUT UNIT:

- The primary function of the output unit is to send the processed results to the user. Output devices display information in a way that the user can understand.

- Output devices are pieces of equipment that are used to generate information or any other response processed by the computer.
- These devices display information that has been held or generated within a computer.
- The most common example of an output device is a monitor.

VIII. BASIC OPERATIONAL CONCEPTS

- The primary function of a computer system is to execute a program, sequence of instructions. These instructions are stored in computer memory.
- These instructions are executed to process data which are already loaded in the computer memory through some input devices.
- After processing the data, the result is either stored in the memory for further reference, or it is sent to the outside world through some output port.
- To perform the execution of an instruction, in addition to the arithmetic logic unit, and control unit, the processor contains a number of registers used for temporary storage of data and some special function registers.
- The special function registers include program counters (PC), instruction registers (IR), memory address registers (MAR) and memory and memory data registers (MDR).
- **Program counter(PC)** :is one of the most critical registers in CPU.
    - The Program counter monitors the execution of instructions. It keeps track on which instruction is being executed and what the next instruction will be.
- **Instruction register (IR):** is used to hold the instruction that is currently being executed.
    - The contents of IR are available to the control unit, which generate the timing signals that control, the various processing elements involved in executing the instruction.
- The two registers MAR and MDR are used to handle the data transfer between the main memory and the processor.
    - **MAR:** holds the address of the main memory to or from which data is to be transferred.
    - **MDR:** contains the data to be written into or read from the addressed word of the main memory.

- Whenever the processor is asked to communicate with devices, we say that the processor is servicing the devices. The processor can service these devices in ***one of the two ways:***
    1. polling routine
    2. to use an interrupt.

a) **Polling:** enables the processor software to check each of the input and output devices frequently. During this check, the processor tests to see if any devices need servicing or not.

b) **Interrupt method:** provides an external asynchronous input that informs the processor that it should complete whatever instruction that is currently being executed and fetch a new routine that will service the requesting device.

6. COMPUTER INSTRUCTIONS

- Computer instructions are a set of machine language instructions that a particular processor understands and executes. A computer performs tasks on the basis of the instruction provided. An instruction comprises groups called ***fields***.
- These fields include:
    1. **Operation code (Opcode)** field which specifies the operation to be performed.
    2. **Address field** which contains the location of the operand, i.e., register or memory location.
    3. **Mode** field which specifies how the operand will be located.

Figure 2: Fields of an Instruction

- A basic computer has three instruction code formats which are:
    - Memory - reference instruction
    - Register - reference instruction
    - Input-Output instruction

I. MEMORY - REFERENCE INSTRUCTION:

Figure 3: Memory-reference instruction

- In Memory-reference instruction, 12 bits of memory is used to specify an address and one bit to specify the addressing mode 'I'.

II. REGISTER - REFERENCE INSTRUCTION:

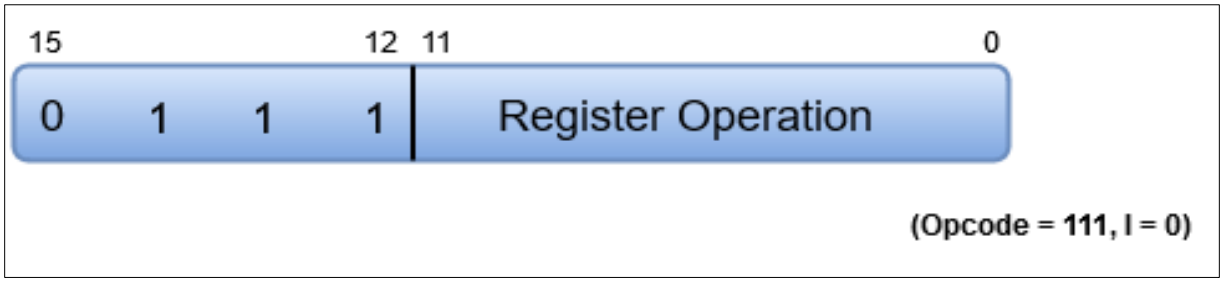

Figure 4: Register-reference instruction

- The Register-reference instructions are represented by the Opcode 111 with a 0 in the leftmost bit (bit 15) of the instruction.
- ***The Operation code (Opcode) of an instruction refers to a group of bits that define arithmetic and logic operations such as add, subtract, multiply, shift, and complement.***
- A Register-reference instruction specifies an operation on or a test of the AC (Accumulator) register.

III. INPUT-OUTPUT INSTRUCTION:

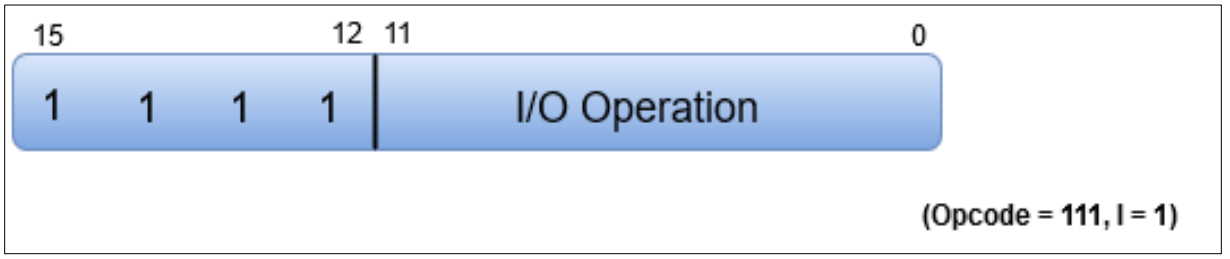

Figure 5: Input/Output-reference instruction

- Just like the Register-reference instruction, an Input-Output instruction does not need a reference to memory and is recognized by the operation code 111 with a 1 in the leftmost bit of the instruction.
- The remaining 12 bits are used to specify the type of the input-output operation or test performed.

***Note:**

a. *The three operation code bits in positions 12 through 14 should be equal to 111. Otherwise, the instruction is a memory-reference type, and the bit in position 15 is taken as the addressing mode I.*

b. *When the three operation code bits are equal to 111, control unit inspects the bit in position 15. If the bit is 0, the instruction is a register-reference type. Otherwise, the instruction is an input-output type having bit 1 at position 15.*

7. INSTRUCTION SET COMPLETENESS

- A set of instructions is said to be complete if the computer includes a sufficient number of instructions in each of the following categories:
    a. Arithmetic, logical and shift instructions
    b. A set of instructions for moving information to and from memory and processor registers.
    c. Instructions which control the program together with instructions that check status conditions.
    d. Input and Output instructions

  Arithmetic, logic and shift instructions provide computational capabilities for processing the type of data the user may wish to employ.

8. BASIC COMPUTER DIAGRAM

- A computer can process data, pictures, sound and graphics.
- They can solve highly complicated problems quickly and accurately.
- A computer as shown in figure performs basically five major computer operations or functions irrespective of their size and make.

These are:

1) it accepts data or instructions by way of input,
2) it stores data,
3) it can process data as required by the user,
4) it gives results in the form of output, and
5) it controls all operations inside a computer

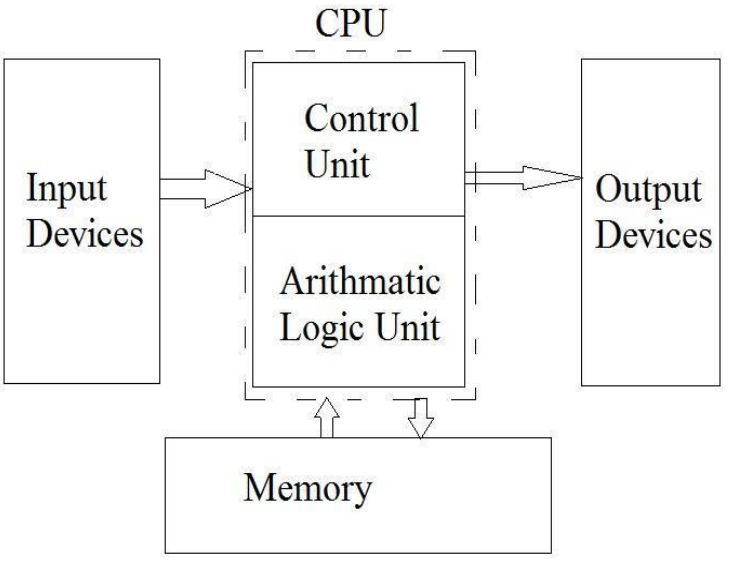

Figure 6: Basic computer diagram

1. **Input:** This is the process of entering data and programs in to the computer system. You should know that computer is an electronic machine like any other machine which takes as inputs raw data and performs some processing giving out processed data. Therefore, the input unit takes data from us to the computer in an organized manner for processing.
2. **Memory:** The process of saving data and instructions permanently is known as storage. Data has to be fed into the system before the actual processing starts. It is because the processing speed of Central Processing Unit (CPU) is so fast that the data has to be provided to CPU with the same speed. Therefore the data is first stored in the storage unit for faster access and processing. This storage unit or the primary storage of the computer system is designed to do the above functionality. It provides space for storing data and instructions.

   The storage unit performs the following major functions:

   - All data and instructions are stored here before and after processing.
   - Intermediate results of processing are also stored here.

3. **Arithmetic Logic Unit:** The task of performing operations like arithmetic and logical operations is called processing. The Central Processing Unit (CPU) takes data and instructions from the storage unit and makes all sorts of calculations based on the instructions given and the type of data provided. It is then sent back to the storage unit.

4. **Output:** This is the process of producing results from the data for getting useful information. Similarly, the output produced by the computer after processing must also be kept somewhere inside the computer before being given to you in human readable form. Again, the output is also stored inside the computer for further processing.

5. **Control Unit:** The manner how instructions are executed and the above operations are performed. Controlling of all operations like input, processing and output are performed by control unit. It takes care of step-by-step processing of all operations inside the computer.

9. FUNCTIONAL UNITS

In order to carry out the operations mentioned in the previous section the computer allocates the task between its various functional units. The computer system is divided into three separate units for its operation. They are:

1. ARITHMETIC LOGICAL UNIT (ALU)

Logical Unit: After you enter data through the input device it is stored in the primary storage unit. The actual processing of the data and instruction are performed by Arithmetic Logical Unit. The major operations performed by the ALU are addition, subtraction, multiplication, division, logic and comparison. Data is transferred to ALU from storage unit when required. After processing the output is returned back to storage unit for further processing or getting stored.

2. CONTROL UNIT (CU)

The next component of computer is the Control Unit, which acts like the supervisor seeing that things are done in proper fashion. Control Unit is responsible for coordinating various operations using time signal. The control unit determines the sequence in which computer programs and instructions are executed. Things like processing of programs stored in the main memory, interpretation of the instructions and issuing of signals for other units of the computer to execute them. It also acts as a switch board operator when several users access the computer simultaneously. Thereby it coordinates the activities of computer's peripheral equipment as they perform the input and output.

3. CENTRAL PROCESSING UNIT (CPU)

The ALU and the CU of a computer system are jointly known as the central processing unit. You may call CPU as the brain of any computer system. It is just like brain that takes all major decisions, makes all sorts of calculations and directs different parts of the computer functions by activating and controlling the operations.

10.VON-NEUMANN COMPUTER (ISA COMPUTER)

Historically there have been 2 types of Computers:

1. **Fixed Program Computers –** Their function is very specific and they couldn't be programmed, e.g. Calculators.
2. **Stored Program Computers –** These can be programmed to carry out many different tasks, applications are stored on them, hence the name.

The modern computers are based on a stored-program concept introduced by John Von Neumann. In this stored-program concept, programs and data are stored in a separate storage unit called memories and are treated the same. This novel idea meant that a computer built with this architecture would be much easier to reprogram.

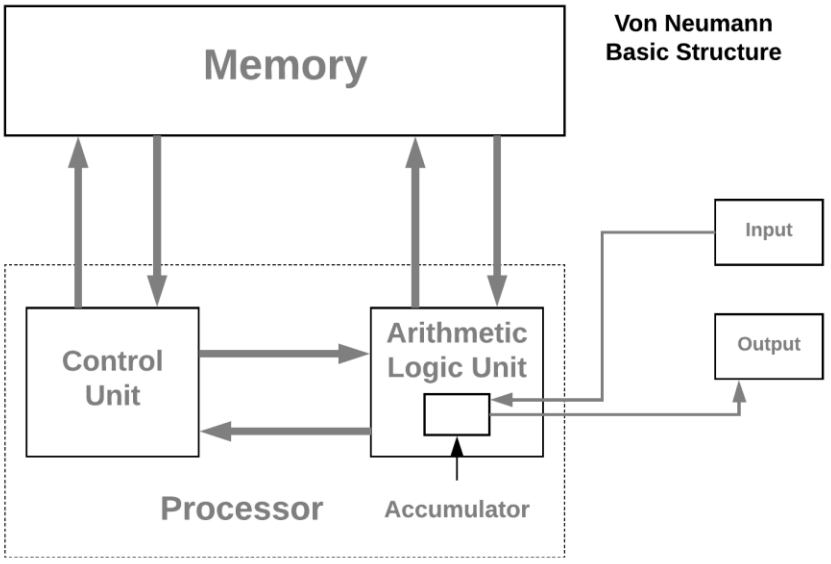

Figure 7: Von Neuman Basic structure

It is also known as **ISA (Instruction Set Architecture)** computer and is having three basic units:

1. The Central Processing Unit (CPU)
2. The Main Memory Unit
3. The Input/Output Device

1. **<u>CONTROL UNIT –</u>**

A control unit (CU) handles all processor control signals. It directs all input and output flow, fetches code for instructions and controlling how data moves around the system.

2. **ARITHMETIC AND LOGIC UNIT (ALU) –**
   The arithmetic logic unit is that part of the CPU that handles all the calculations the CPU may need, e.g., Addition, Subtraction, Comparisons. It performs Logical Operations, Bit Shifting Operations, and Arithmetic Operation.

3. **MAIN MEMORY UNIT (REGISTERS) –**
   1. **Accumulator:** Stores the results of calculations made by ALU.
   2. **Program Counter (PC):** Keeps track of the memory location of the next instructions to be dealt with. The PC then passes this next address to Memory Address Register (MAR).
   3. **Memory Address Register (MAR):** It stores the memory locations of instructions that need to be fetched from memory or stored into memory.
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   5. **Instruction Register (IR):** It stores the most recently fetched instructions while it is waiting to be coded and executed.
   6. **Instruction Buffer Register (IBR):** The instruction that is not to be executed immediately is placed in the instruction buffer register IBR.

4. **INPUT/OUTPUT DEVICES –** Program or data is read into main memory from the *input device* or secondary storage under the control of CPU input instruction. *Output devices* are used to output the information from a computer. If some results are evaluated by computer and it is stored in the computer, then with the help of output devices, we can present it to the user.

5. **BUSES –** Data is transmitted from one part of a computer to another, connecting all major internal components to the CPU and memory, by the means of Buses.
   Types:
   1. **Data Bus:** It carries data among the memory unit, the I/O devices, and the processor.
   2. **Address Bus:** It carries the address of data (not the actual data) between memory and processor.
   3. **Control Bus:** It carries control commands from the CPU (and status signals from other devices) in order to control and coordinate all the activities within the computer.

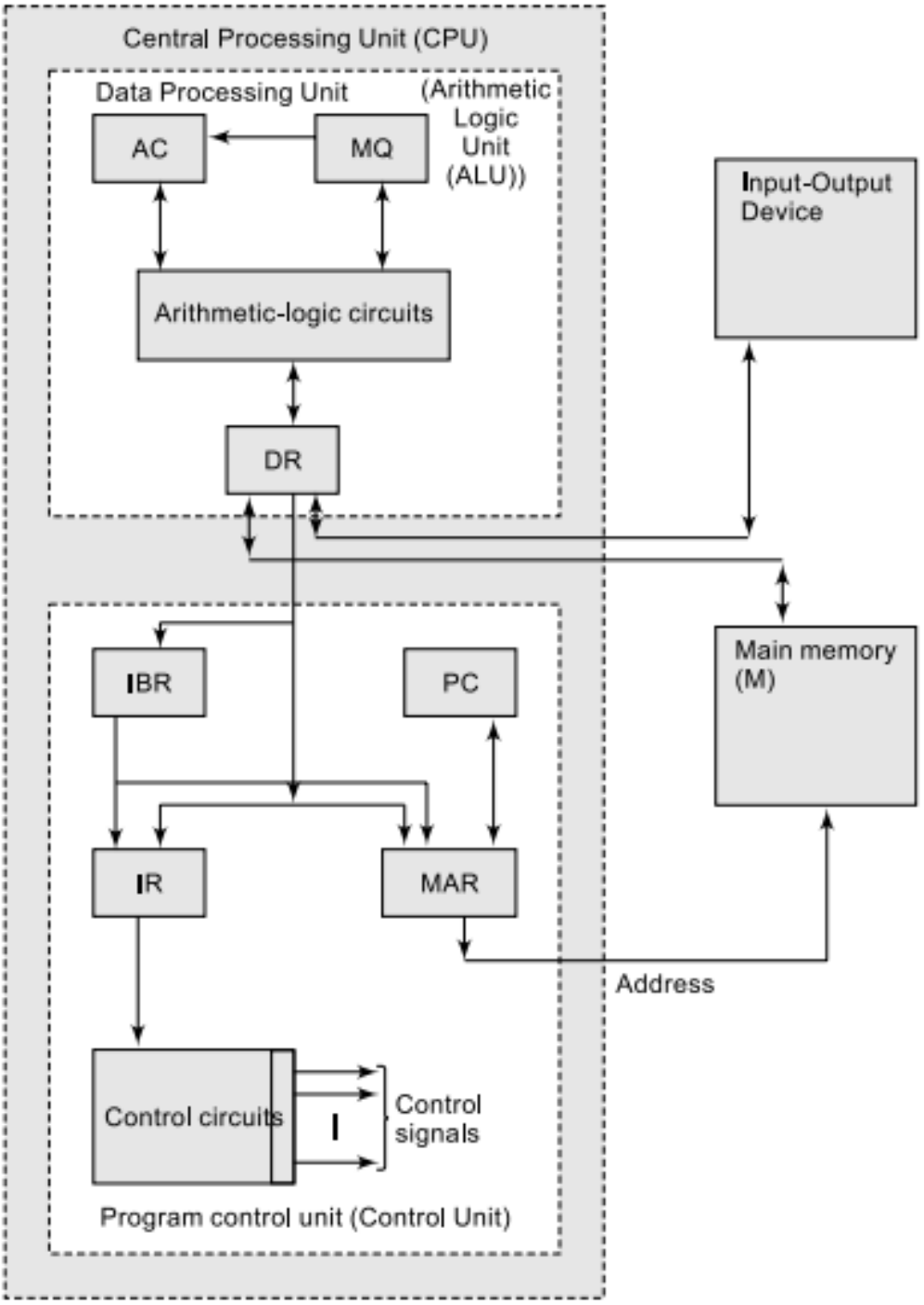

Figure 8: ISA computer's structure

VON NEUMANN BOTTLENECK –

- Whatever we do to enhance performance, we cannot get away from the fact that instructions can only be done one at a time and can only be carried out sequentially. These factors hold back the competence of the CPU. This is commonly referred to as the '***Von Neumann bottleneck'.***
- We can provide a Von Neumann processor with more cache, more RAM, or faster components but if original gains are to be made in CPU performance, then an influential inspection needs to take place of CPU configuration.
- This architecture is very important and is used in our PCs and even in supercomputers.

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