SECTION 8

CENTRAL PROCESSING UNIT (CPU)

Introduction

What is a CPU?

The Central Processing Unit (CPU) carries out instructions from programs by performing basic arithmetic, logical, control, and input/output operations. It is responsible for executing all tasks that keep a computer running.

Instruction Cycle

The instruction cycle is the process by which a CPU fetches, decodes, and executes instructions from memory, and, if necessary, stores the result. This cycle repeats billions of times per second in modern CPUs.

- Fetch – Retrieves instructions from memory.
- Decode – Interprets the instructions.
- Execute – Performs the operation.
- Writeback – Stores the result in memory or registers.

Main Components of a CPU

Arithmetic Logic Unit (ALU)

The Arithmetic Logic Unit (ALU) is a component of the CPU that performs arithmetic operations (addition, subtraction, multiplication, division) and logical operations (AND, OR, NOT, XOR).

Control Unit (CU)

The Control Unit (CU) directs the operation of the CPU by fetching, decoding, and coordinating instructions. It tells the ALU, memory, and input/output devices how to respond to program instructions.

Registers

Registers are small, high-speed storage locations inside the CPU. They store data temporarily for quick access.

Examples:

- Program Counter (PC) – Holds the address of the next instruction.
- Instruction Register (IR) – Stores the currently executed instruction.
- Accumulator (ACC) – Holds intermediate results.

Cache Memory

Cache memory is a small, fast memory located inside or close to the CPU. It stores frequently used data to speed up processing.

Typically, cache memory has three levels (L1, L2, and L3), but in some high-performance CPUs, there is also an L4 cache.

- L1 Cache – The smallest and fastest, located inside each CPU core.
- L2 Cache – Larger than L1 but slightly slower, still within or near the core.
- L3 Cache – Shared among multiple cores, larger but slower than L2.
- L4 Cache – Found in some high-end processors, usually located on a separate chip or embedded in DRAM.

Buses

Buses are data highways that transfer information within the CPU and to/from memory and peripherals.

Peripherals are external devices that are connected to a computer system to extend its functionality. Peripherals can be categorized into two main types: input and output devices and storage devices. Examples of input and output devices include the mouse, keyboard, and monitor, while storage devices include flash drives and external HDDs/SSDs.

The CPU is equipped with three distinct types of buses.

- Data Bus – Transfers actual data.
- Address Bus – Specifies memory locations.
- Control Bus – Carries control signals (e.g., read/write commands).

Clock

A CPU has a clock signal generator, often called the system clock, which synchronizes operations by producing a regular clock signal. This clock signal controls the pace at which instructions are executed, ensuring that all components of the CPU work in harmony.

The clock's speed is typically measured in Hertz (Hz), with modern CPUs operating at GHz (Gigahertz). It affects how many instructions a CPU can process per second.

Execution Units & Cores

- Cores – Modern CPUs have multiple cores (dual-core, quad-core, etc.), allowing them to handle multiple tasks simultaneously.
- Execution Units – Specialized units like floating-point units (FPU) for faster mathematical calculations.

Overclocking

Overclocking refers to the process of increasing the clock speed of a CPU (or other components like the GPU or RAM) beyond its manufacturer's specifications (specs). By doing this, the processor performs tasks faster, improving overall system performance.

To support higher clock speeds, the CPU may require an increase in voltage, which can improve stability but also generate more heat.

Risks of Overclocking

- Heat Generation: Higher clock speeds lead to increased heat output, which can cause damage if not properly managed. Overclocking may require better cooling, such as a larger heatsink, to handle the extra heat.
- Stability Issues: Overclocking can make a system unstable, leading to crashes or errors if pushed beyond safe limits.
- Reduced Lifespan: Running a CPU at higher speeds and voltages for extended periods may reduce its lifespan.