Computer System Architecture & OS Performance – Part I

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Lesson Plan

- Introduction
- Computer System Architecture
- Central Processing Unit
- Components of the CPU
- Fetch-Decode-Execute Cycle
- Types of CPU
- CPU Manufacturers
- Factors Affecting CPU Performance
- Q&A
- Additional Links
- Activity

Introduction

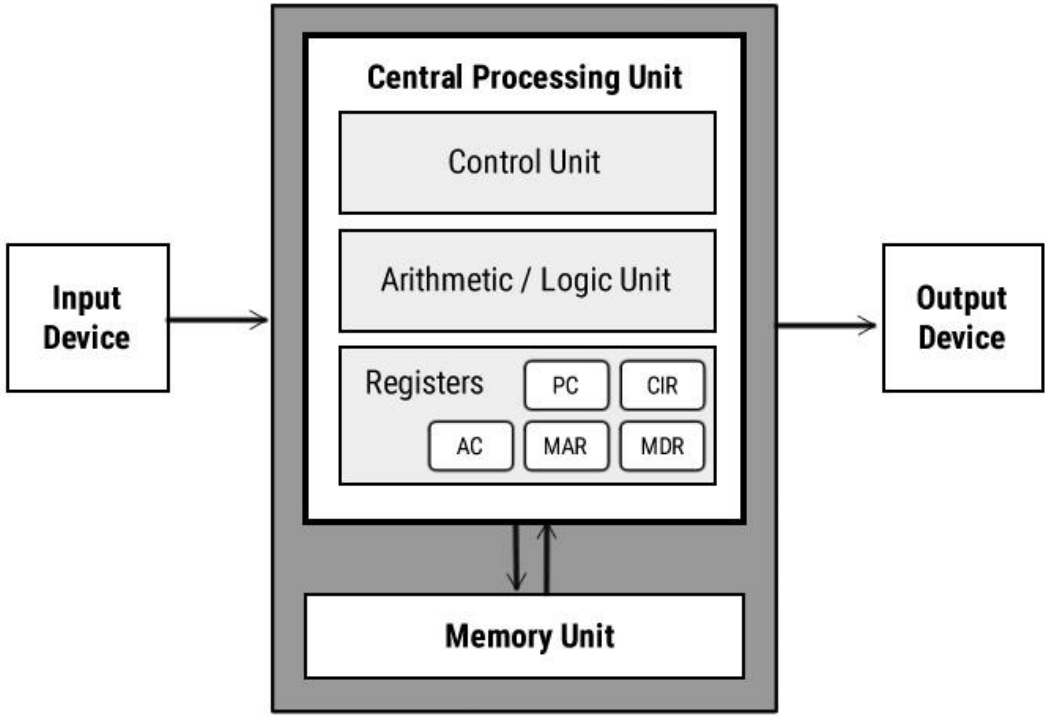
- Modern computer systems are changing rapidly.
- Computer system users expect the operating system to manage system resources and provide useful services with minimal overhead.
- In reality, modern operating systems are large and more complex programs with memory and CPU requirements than many other application programs.
- So, it is important to consider the functionality and features of the main components of the computer system architecture.

Computer System Architecture

- This refers to the structure of the internal components of a computer system.
- It shows the components that make up a computer system and describes how they are interconnected, interact with each other, and how they are managed.
- Modern computers often follow the **Von Neumann Architecture**, which includes...
  - A processor
  - A memory unit - which stores both instructions and data
  - Connections for I/O devices
  - Secondary storage for data

Computer System Architecture Cont.

Von Neumann Architecture



John Von Neumann developed the stored program concept in the 1940s. The Von Neumann architecture used the idea of storing program instructions and data in the main memory and moving them between memory and the processor.

Central Processing Unit

- CPU is the most crucial logic circuit (integrated circuit) that responds to and processes the basic instructions that drive a computer.
- CPU interprets most computer commands, performs most arithmetic, logic, and I/O operations, and allocates commands for other chips and components running in a computer.
- Processors can be found in PCs, smartphones, tablets, and other computers.
- Core is on a CPU's processor. Earlier every processor had just one core that could focus on one task at a time.
- Most of the modern processors are multi-core. That means CPUs have two or more cores, each of which can work on different tasks.

Central Processing Unit Cont.

- Multi core concept enhances performance, reduce power consumption and processing become more efficient due to the simultaneous processing of multiple tasks.
- In a "single core" CPU, the processor chip has one core. And a dual-core processor has two cores, a quad-core has four, a hexa-core has six, an octa-core has eight, and so on.
- Some processors use multi-threading, which uses virtualised processor cores. Virtualised processor cores are called vCPUs. These are not as powerful as physical cores but can be used to improve performance in Virtual Machines (VMs). However, adding unnecessary vCPUs can hurt consolidation ratios, so there should be about four to six vCPUs per physical core.

Components of the CPU

Arithmetic & Logical Unit (ALU)

- The ALU is responsible for performing arithmetic calculations and logical operations such as…
  - Addition, subtraction, multiplication, division
  - Logical bitwise operations, such as AND, OR, NOT, and XOR
  - Comparisons between values, such as greater than, less than, equal to
  - Shifting binary patterns to the left or right

Components of the CPU Cont.

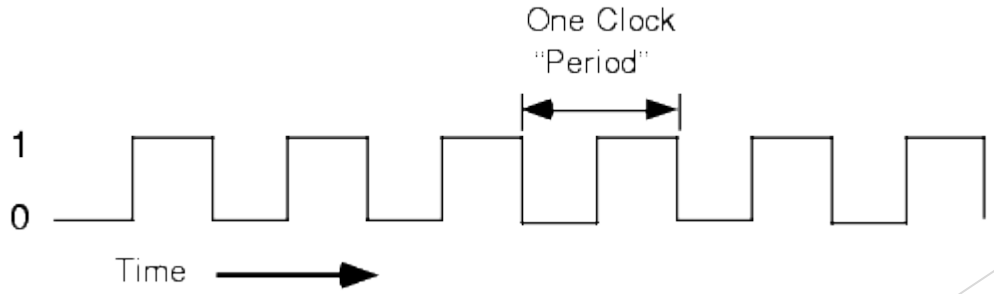
Control Unit (CU)

- The control unit organises the execution of instructions and manages the other components in the processor. It is responsible for…
  - Ensuring the execution of instructions in the correct sequence
  - Decoding every instruction that the processor will execute
  - Sending and receiving control signals to and from other components
  - Checking that signals have been delivered successfully
  - Making sure that data goes to the correct place at the correct time
- The control unit also contains the clock. This is a tiny component that controls the rate at which instructions are executed in the processor.

Components of the CPU Cont.

Clock

- The clock signal is used to synchronise the operations of the processor components. The system clock generates regular clock pulses by emitting a signal that continuously switches between a low (or '0') and a high (or '1') state.
- The time taken between two sequential rising edges is called a **clock cycle** or a **clock period**. The **clock speed** is measured by the number of clock cycles in one second.



Components of the CPU Cont.

Clock Cont.

- Every operation of the processor requires a number of clock cycles to complete. The number of cycles is specific to each type of processor.
- 1 clock cycle per second is 1Hz.

1 million Hz (10^6 Hz)	1 megahertz
1000 MHz (10^9 Hz)	1 gigahertz

- When the clock speed is increased, the execution time for instructions decreases. Therefore, more cycles per second increase the performance.
- But there is a limit on clock speed. If the heat generated by higher clock speeds cannot be removed fast enough, that can be led to overheating.

Components of the CPU Cont.

Registers

- Registers are locations of computer memory within the processor that provide extremely fast access. There are two types of registers.
- **General-purpose Registers** - Accessing the main memory can slow down the execution of instructions. Therefore, the processor uses general-purpose registers to temporarily store the results of the intermediate calculations that are part of larger computations.
- **Dedicated or Special-purpose Registers** - Used for a specific purpose. Involves in the fetch-decode-execute cycle. Each one of them has a specific role to play in each phase.

Components of the CPU Cont.

Dedicated or Special-purpose Registers Cont.

- ***Program Counter (PC)*** - Holds the address of the next instruction to be executed by the processor.
- ***Current Instruction Register (CIR)*** - Holds the current instruction that the processor is executing.
- ***Memory Address Register (MAR)*** - Temporarily stores the memory addresses used when searching for data in RAM
- ***Memory Data Register (MDR) / Memory Buffer Register (MBR)*** - Temporarily holds the data (data values or instructions) that are read from or written to the main memory
- ***Accumulator*** - Stores the result of any calculation

Components of the CPU Cont.

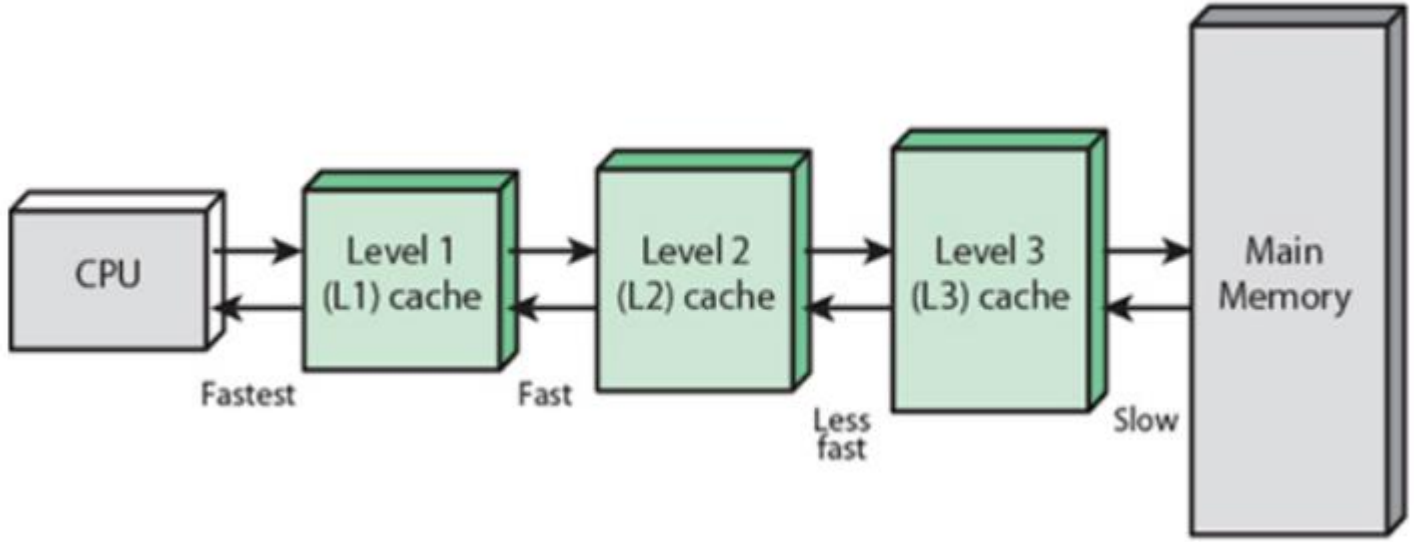
Buses

- A bus transfers data and signals between components inside the computer.
- There are three types of buses.
  - ***Address Bus*** - Carries address locations of stored data from the processor to memory and input/output devices.
  - ***Data Bus*** – Sends the data to and from the processor, memory, and input and output devices.
  - ***Control Bus*** - Carries signals that coordinate the operation of the components.
- The **address**, **data**, and **control bus** together is known as the **system bus**.

Components of the CPU Cont.

Cache Memory

- Cache Memory is a high-speed memory, which is small in size but faster than the main memory (RAM).
- The CPU can access it more quickly than the primary memory. So, it is used to synchronise with high-speed CPU and to improve its performance.



Components of the CPU Cont.

Cache Memory Cont.

- There are many levels of cache memory…
- L1 Cache – This is a cache memory that is directly built into the microprocessor, which is used for storing recently accessed information. It is also called the primary cache. Each and every core of the CPU has its own L1 cache memory.
- L2 Cache – This memory is built into the CPU chip or outside the CPU on the motherboard. The L2 cache feeds the L1 cache, which feeds the processor. L2 cache memory is slower than L1 cache memory.

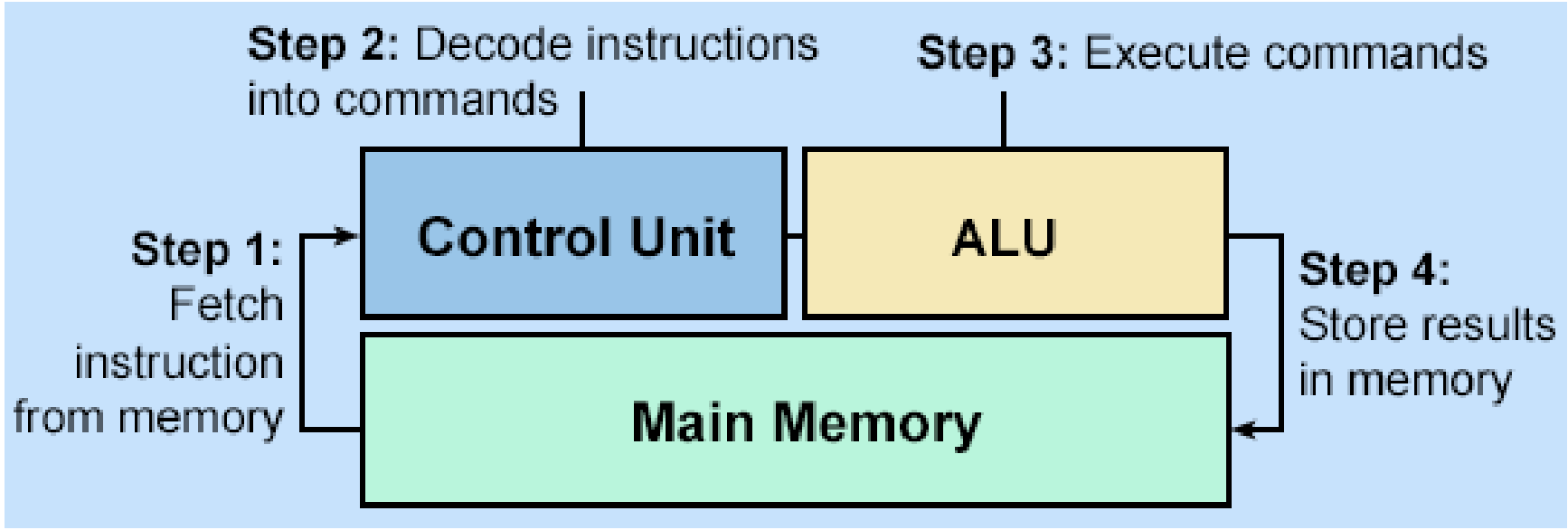
Components of the CPU Cont.

Cache Memory Cont.

- L3 Cache – This is a specialised memory developed to improve the performance of L1 and L2. L1 and L2 is faster than L3, but L3 is usually faster than the RAM. With multicore processors, each core can have a dedicated L1 and L2 cache, but they can share an L3 cache.
- L4 Cache – This is an extra layer of cache located outside the processor cores but inside the CPU package. This cache is not present in all the processors. Some high-end processors may have this type of cache.

Fetch-Decode-Execute Cycle

- This describes the basic operation of the central processing unit.



Fetch-Decode-Execute Cycle Cont.

Fetch

- Fetch involves retrieving an instruction from the main memory.
- The instruction's location (address) in main memory is determined by the program counter, which stores a number that identifies the address of the next instruction to be fetched.
- After an instruction is fetched, the PC is incremented by the length of the instruction so that it will contain the address of the next instruction in the sequence.
- https://www.youtube.com/watch?v=m6vkJV4UeI4&t=100s

Fetch-Decode-Execute Cycle Cont.

Decode

- Once an instruction is fetched and stored in the CIR, the CPU passes the instruction to a circuit called the instruction decoder.
- This converts the instruction into signals to be passed through to other parts of the CPU for action.
- https://www.youtube.com/watch?v=akUFlECCErk

Fetch-Decode-Execute Cycle Cont.

Execute

- In the final step, the decoded instructions are sent to the relevant parts of the CPU to be completed.
- The results are usually written to a CPU register.
- https://www.youtube.com/watch?v=Z3cvYfkAyOI

- Watch full cycle:
- https://www.youtube.com/watch?v=5L1QQM1i3-8

Types of CPU

RISC (Reduced Instruction Set Computer)

- This is a microprocessor architecture with a simple collection and a highly customised set of instructions.
- RISC processors are used in modern smartphones and tablets. This type of processor can carry out simple instructions quickly.
- It is built to minimise the instruction execution time by optimising and limiting the number of instructions.
- The RISC processor is also used to perform various complex instructions by combining them into simpler ones.
- Examples of RISC processors are SUN's SPARC, PowerPC, Microchip PIC Processors, and RISC-V.

Types of CPU Cont.

Features of RISC (Reduced Instruction Set Computer)

- **One cycle execution time** - For executing each instruction in a computer, the RISC processors require one CPI (Cycles per Instruction). And each CPI includes the fetch, decode and execute method applied in computer instruction.
- **Pipelining technique** - The pipelining technique is used in the RISC processors to execute multiple parts or stages of instructions to perform more efficiently.
- **A large number of registers** - RISC processors are optimised with multiple registers that can be used to store instruction and quickly respond to the computer and minimise interaction with computer memory.

Types of CPU Cont.

CISC (Complex Instruction Set Computer)

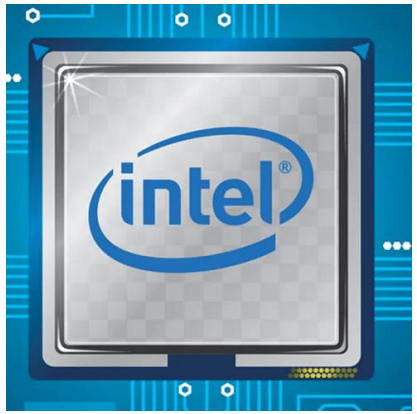
- The CISC was developed by Intel. CISC processors are used in desktop and laptop computers. It has a large collection of complex instructions that range from simple to very complex and specialised in the assembly language level, which takes a long time to execute the instructions.
- CISC approaches reducing the number of instructions on each program and ignoring the number of cycles per instruction.
- It emphasises building complex instructions directly in the hardware because the hardware is always faster than the software. But CISC chips are relatively slower as compared to RISC chips but use little instruction than CISC.
- Examples of CISC processors are VAX, AMD, Intel x86, and the System/360.

Types of CPU Cont.

Features of CISC (Complex Instruction Set Computer)

- The length of the code is short, so it requires less RAM capacity.
- Less instruction is needed to write an application.
- Complex instructions may take longer than a single clock cycle to execute the code.
- It provides easier programming in assembly language.
- Support for complex data structure and easy compilation of high-level languages.
- It emphasises the building of instruction on hardware because it is faster to create than the software.

CPU Manufacturers



Intel Core Processors

- The Intel series of processors include the Core i3, i5, i7, and also the recently introduced i9.
- i5 and i7 are significantly stronger than i3. The strongest of the bunch is the i9 series introduced in 2017. The i9 series has an incredible number of threads and cores. The i9-7980X boasts 18 cores clocked at 2.6GHz with 32 threads.
- The Intel processors generally have a higher clock speed than an AMD processors. This means they perform better in office jobs or running your games.
- In addition, almost all Intel processors have a built-in video chip. So, no need for a separate video card.

CPU Manufacturers Cont.

Intel Core Processors Cont.

- Basic Intel processors are more expensive, but they're relatively more affordable in the high-end.

Intel® Core™ i9 Processors	Delivering up to 24 cores for seamless 4K Ultra HD and 360-degree video, robust gameplay, and multitasking performance.
Intel® Core™ i7 Processors	This CPU packs the power of up to 20 cores for accelerated computing supporting high-end gaming, connectivity, and security.
Intel® Core™ i5 Processors	Experience exceptional performance for home and business PCs with up to 14 cores for gaming, creativity, and multitasking.
Intel® Core™ i3 Processors	These value-packed processors deliver outstanding performance for everyday tasks.
Intel® Core™ X-series Processors	Unlocked CPUs that deliver up to 18 cores for the most extreme gaming, creative production, and multi-tasking.

CPU Manufacturers Cont.

AMD Ryzen Processors

- The first generation of Ryzen processors was released in 2017 and reached enormous popularity.
- There are three categories-Ryzen 3, 5, and 7. The 7 series had the most powerful CPUs.
- In 2018, AMD introduced the super-powerful Threadripper series as the answer to the Intel i9.
- It has processors with 32 cores and 64 threads. Video rendering and editing are better on the Ryzen processors.

Factors Affecting CPU Performance

- A computer's processor performance is affected by a range of features.
  - ***Cache***
  - ***Number of Cores***
  - ***Clock Speed***
  - ***Data Bus Width*** - The number of bits that can be transferred to or from in one operation.
  - ***Address Bus Width*** - The number of bits that can be used to form an address of a memory location.
  - ***Word Length*** – The amount of data that can be handled at one time by the processor.

Q&A

- Time for your questions and queries ...

Activity

- Find out about other computer architectures.
- Discuss how the learned factors affect the CPU performance.
- Find out other factors that can increase CPU performance.

Thank you!