PROCESSORS

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What is a processor?

A microprocessor is the central processing unit (CPU) of a computer, responsible for executing instructions and performing arithmetic/logic operations. A microprocessor it is known as the brain of a computer, responsible for executing instructions and performing arithmetic and logic operations.

A microprocessor may also be called a processor or central processing unit, but it is actually more advanced in terms of architectural design and is built over a silicon microchip. It is the most important unit within a computer system and is responsible for processing the unique set of instructions and processes.

A microprocessor is designed to execute logical and computational tasks with typical operations such as addition/subtraction, interprocess and device communication, input/output management, etc. Also, it's composed of integrated circuits that hold thousands of transistors.

Microprocessors are generally classified according to the number of instructions they can process within a given time, their clock speed measured in megahertz and the number of bits used per instruction.

Evolution of microprocessor

I. First Generation (4 - bit Microprocessors)

The first generation microprocessors were introduced in the year 1971-1972 by Intel Corporation. It was named **Intel 4004** since it was a 4-bit processor.

It was a processor on a single chip. It could perform simple arithmetic and logical operations such as addition, subtraction, Boolean OR and Boolean AND.

A 4-bit processor refers to a type of microprocessor architecture where the width of the data bus and the size of the registers are designed to handle 4 bits of binary information at a time. The "bit" is the smallest unit of data in computing and can have a value of 0 or 1. Here's what this means;

Evolution of microprocessor Cont..

Data Width: The term "4-bit" indicates that the processor can process and handle data in chunks of 4 bits at a time. This includes operations like arithmetic, logic, and data movement.

Register Size: The registers in the processor, which are small, fast storage locations for holding data temporarily during processing, typically have a size of 4 bits.

Address Bus: In addition to the data bus, processors have an address bus that determines the range of memory addresses the processor can access. The size of the address bus is also relevant to the total amount of memory the processor can address. However, the term "4-bit processor" usually refers more to the data bus size.

Data Bus: refers to a subsystem within a computer or electronic system that is responsible for transferring data between various components. It is a communication pathway used to transmit binary-coded information (0s and 1s) between different parts of a computer, such as the central processing unit (CPU), memory,

Evolution of microprocessor Cont..

Address Bus: refers to a subsystem within a computer or electronic system that is responsible for carrying memory addresses. In a computer architecture, the address bus is used by the central processing unit (CPU) to specify the memory location it wants to read from or write to. It's one of the three main buses in a computer system, alongside the data bus and control bus.

Control Bus: refers to a subsystem within a computer or electronic system that is responsible for transmitting control signals between different components. In a computer architecture, the control bus is one of the three primary buses, alongside the data bus and address bus. It facilitates communication and coordination between the central processing unit (CPU), memory, and other peripherals.

Historical Significance: While 4-bit processors were used in early computing devices, they are quite limited compared to modern processors. Most contemporary processors have larger data bus sizes, such as 64-bit or 32-bit, allowing them to handle much larger chunks of data and address more memory.

Evolution of microprocessor Cont..

II. Second Generation (8 - bit Microprocessor)

The second generation microprocessors were introduced in 1973 again by Intel. It was a first 8 - bit microprocessor which could perform arithmetic and logic operations on 8-bit words. It was Intel 8008, and another improved version was Intel 8088.

An 8-bit processor is a type of microprocessor architecture where the width of the data bus, the size of the registers, and the processing capabilities are designed to handle 8 bits of binary information at a time. Each "bit" represents a binary digit, which can have a value of 0 or 1. Here's what this means;

Evolution of microprocessor Cont..

Data Width: The term "8-bit" indicates that the processor can process and handle data in chunks of 8 bits at a time. This includes operations like arithmetic, logic, and data movement.

Register Size: The registers in the processor, which are small, fast storage locations for holding data temporarily during processing, typically have a size of 8 bits.

Address Bus: While the term "8-bit processor" specifically refers to the data bus size, processors also have an address bus that determines the range of memory addresses the processor can access.

Data Size: The width of the data bus determines the maximum amount of data that can be transferred in a single operation. An 8-bit data bus can transfer 8 bits of data at once.

Evolution of microprocessor Cont..

Memory Addressing: The processor's architecture allows it to address memory locations up to 2^8 (256) different addresses. This means it can directly access or manipulate data stored in up to 256 memory locations.

Historical Significance: 8-bit processors were prevalent in the early days of computing and were used in various home computers and early personal computers. Examples include processors like the Intel 8080, Zilog Z80, and MOS Technology 6502.

Limited Range: The limited width of the data bus and address bus in an 8-bit processor imposes limitations on the amount of data that can be processed and the memory that can be addressed compared to more modern architectures with wider buses.

Evolution of microprocessor Cont..

III. Third Generation (16 - bit Microprocessor)

The third generation microprocessors, introduced in 1978 were represented by **Intel's 8086, Zilog Z800 and 80286**, which were 16 - bit processors with a performance like minicomputers.

A 16-bit processor is a type of microprocessor architecture in which the data bus, arithmetic/logic unit (ALU), and registers are designed to handle 16 bits of data at a time. Here's what this means;

Evolution of microprocessor Cont..

Data Width: The term "16-bit" specifically refers to the size of the data bus. The data bus is a communication pathway that allows data to be transferred between different components of the processor and the computer system. A 16-bit processor can process data in 16-bit chunks.

Registers: The registers in a 16-bit processor typically have a width of 16 bits. Registers are small, fast storage locations within the CPU that are used for temporary storage and manipulation of data during processing.

Arithmetic/Logic Unit (ALU): The ALU is the part of the processor responsible for performing arithmetic and logical operations. In a 16-bit processor, the ALU is designed to operate on 16-bit binary data.

Address Bus: While the term "16-bit processor" primarily refers to the data bus, processors also have an address bus that determines the range of memory addresses the processor can access. The address bus width influences the maximum amount of memory the processor

Evolution of microprocessor Cont..

Memory Addressing: A 16-bit processor can directly address 2^16 (65,536) different memory locations. This means it can access or manipulate data stored in up to 65,536 memory locations.

Historical Significance: 16-bit processors were widely used in the late 1970s and 1980s in personal computers and gaming consoles. Examples include the Intel 8086 and Motorola 68000 processors.

Performance: 16-bit processors offered improved performance and capabilities compared to earlier 8-bit processors. They were able to handle more extensive data sets and perform more complex computations.

Transition to 32-bit: Over time, as computing demands increased, processors with wider data buses, such as 32-bit and 64-bit, became more prevalent for enhanced performance and

Evolution of microprocessor Cont..

IV. Fourth Generation (32 - bit Microprocessors)

Several different companies introduced the 32-bit microprocessors, but the most popular one is the **Intel 80386**.

A 32-bit processor is a type of microprocessor architecture in which the data bus, arithmetic/logic unit (ALU), and registers are designed to handle 32 bits of data at a time. Here's what this means;

Data Width: The term "32-bit" specifically refers to the size of the data bus. The data bus is a communication pathway that allows data to be transferred between different components of the processor and the computer system. A 32-bit processor can process data in 32-bit chunks.

Registers: The registers in a 32-bit processor typically have a width of 32 bits. Registers are small, fast storage locations within the CPU that are used for temporary storage and manipulation of data during processing.

Arithmetic/Logic Unit (ALU): The ALU is the part of the processor responsible for performing arithmetic and logical operations. In a 32-bit processor, the ALU is designed to operate on 32-bit binary data

Evolution of microprocessor Cont..

Address Bus: While the term "32-bit processor" primarily refers to the data bus, processors also have an address bus that determines the range of memory addresses the processor can access. The address bus width influences the maximum amount of memory the processor can address.

Memory Addressing: A 32-bit processor can directly address 2^32 (4 gigabytes) of different memory locations. This means it can access or manipulate data stored in up to 4 gigabytes of memory.

Performance: 32-bit processors offer increased performance and capabilities compared to earlier 16-bit processors. They can handle larger data sets and perform more complex computations, which is crucial for modern applications and operating systems.

Transition to 64-bit: As computing demands continued to increase, processors with wider data buses, such as 64-bit processors, became more common. The transition to 64-bit architectures allowed for even larger memory addressing and further increased processing capabilities.

Common in Modern Systems: While 64-bit processors are prevalent in contemporary computing, 32-bit processors are still encountered in some older systems, embedded applications, and lightweight devices where the demand for processing power and memory addressing is

Evolution of microprocessor Cont..

V. Fifth Generation (64 - bit Microprocessors)

From 1995 to now we are in the fifth generation. After 80856, Intel came out with a new processor namely Pentium processor followed by **Pentium Pro CPU**, which allows multiple CPUs in a single system to achieve multiprocessing. Other improved 64-bit processors are **Celeron, Dual, Quad, Octa Core processors**. A 64-bit processor is a type of microprocessor architecture in which the data bus, arithmetic/logic unit (ALU), and registers are designed to handle 64 bits of data at a time. Here's what this means;

Data Width: The term "64-bit" specifically refers to the size of the data bus. The data bus is a communication pathway that allows data to be transferred between different components of the processor and the computer system. A 64-bit processor can process data in 64-bit chunks.

Registers: The registers in a 64-bit processor typically have a width of 64 bits. Registers are small, fast storage locations within the CPU that are used for temporary storage and manipulation of data during processing.

Arithmetic/Logic Unit (ALU): The ALU is the part of the processor responsible for performing arithmetic and logical operations. In a 64-bit

Evolution of microprocessor Cont..

Address Bus: While the term "64-bit processor" primarily refers to the data bus, processors also have an address bus that determines the range of memory addresses the processor can access. The address bus width influences the maximum amount of memory the processor can address.

Memory Addressing: A 64-bit processor can directly address 2^64 (approximately 18.4 exabytes) of different memory locations. This vast addressing range allows for the handling of very large amounts of system memory.

Performance: 64-bit processors offer increased performance and capabilities compared to earlier 32-bit processors. They can handle larger data sets, perform more complex computations, and support more extensive memory addressing, which is crucial for modern applications and operating systems.

Transition from 32-bit: As computing demands increased, the industry transitioned from 32-bit to 64-bit architectures to address the need for larger memory capacities and improved processing power.

Common in Modern Systems: Most modern computers, servers, and operating systems use 64-bit processors due to their ability to handle more significant amounts of memory and provide improved performance for resource-intensive tasks

Basic Terms used in Microprocessor

Instruction Set - The group of commands that the microprocessor can understand is called Instruction set. It is an interface between hardware and software.

Bus - Set of conductors intended to transmit data, address or control information to different elements in a microprocessor. A microprocessor will have three types of buses, i.e., data bus, address bus, and control bus.

IPC (Instructions Per Cycle) - It is a measure of how many instructions a CPU is capable of executing in a single clock.

Clock Speed - It is the number of operations per second the processor can perform. It can be expressed in megahertz (MHz) or gigahertz (GHz). It is also called the Clock Rate.

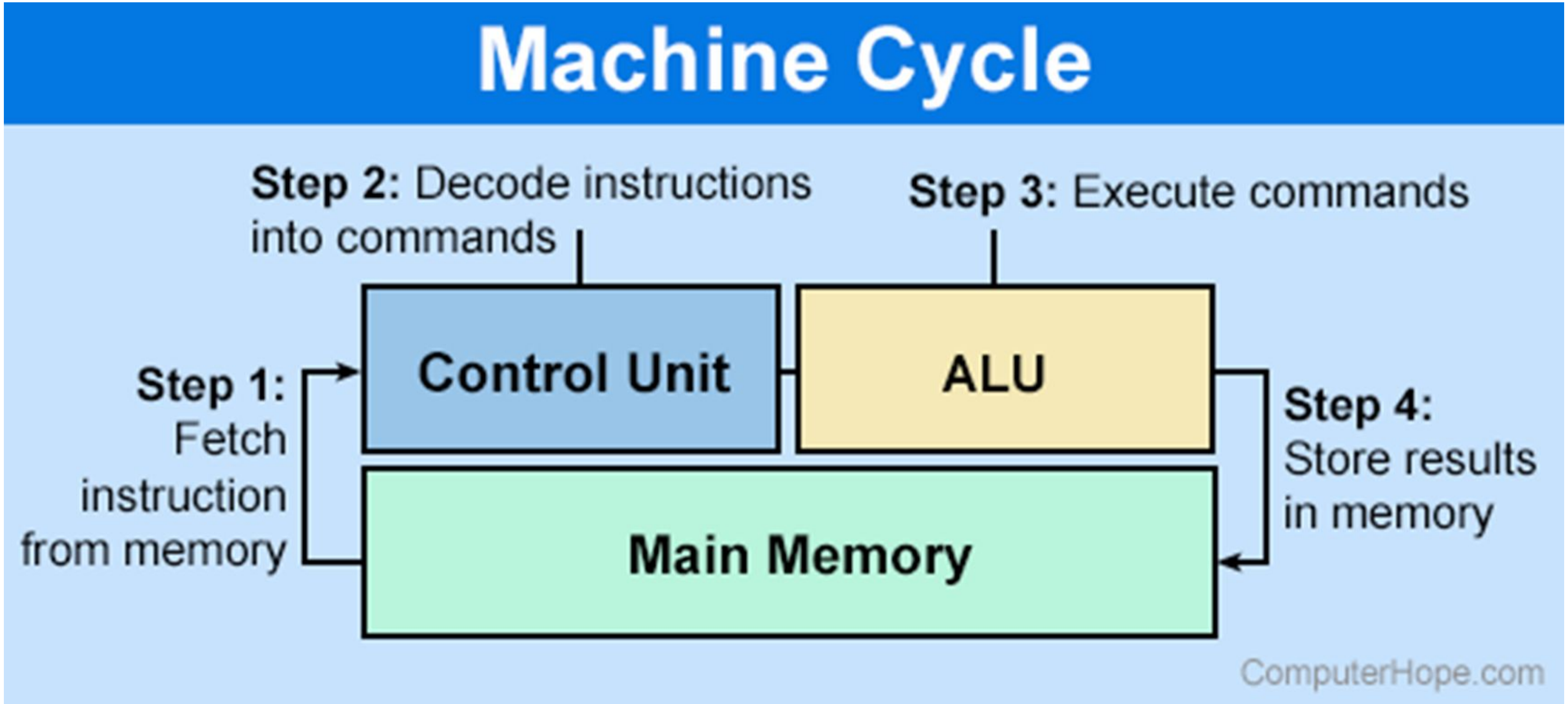
Word Length - The number of bits the processor can process at a time is called the word length of the processor. 8-bit Microprocessor may process 8 -bit data at a time. The range of word length is from 4 bits to 64 bits depending upon the type of the microcomputer.

Architecture of Microprocessors

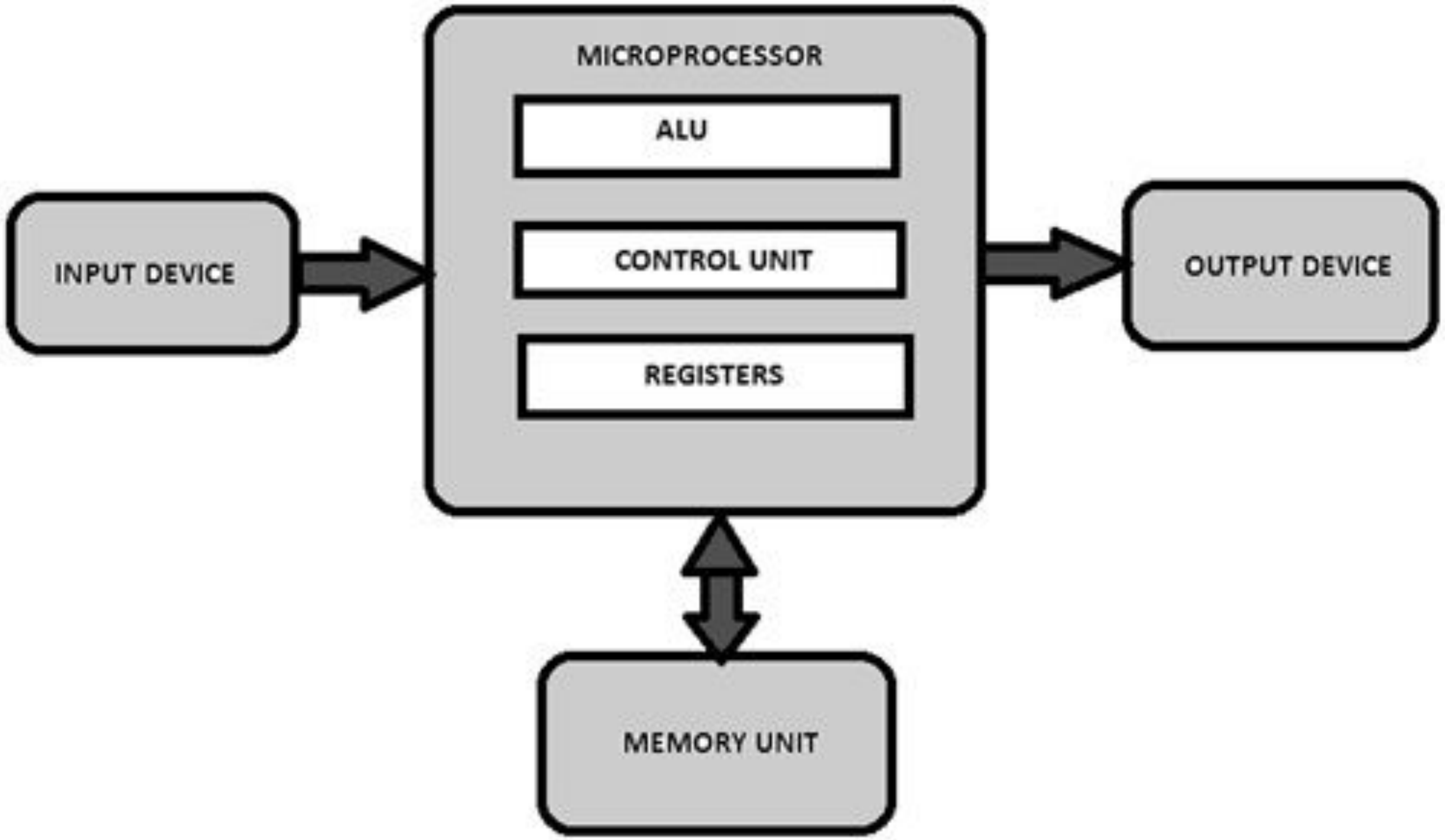
A microprocessor is built using three basic circuit blocks:

I. Main memory
II. Arithmetic Logic Unit (ALU)
III. Control unit (CU)

Architecture of Microprocessors Cont….



Architecture of Microprocessors Cont....



Architecture of Microprocessors Cont....

I. Components of Microprocessors

- **Control Unit (CU):**
  - Oversees the execution of instructions, coordinating the flow of data within the processor and between other system components.
  - Responsible for fetching instructions from memory, decoding them, and controlling the execution of operations.
- **Arithmetic Logic Unit (ALU):**
  - Performs arithmetic (addition, subtraction, multiplication, division) and logical (AND, OR, NOT) operations on data.
  - Executes the actual computations based on the instructions provided.
- **Registers:**
  - Small, high-speed storage units located within the processor.
  - Temporarily holds data, instructions, and addresses during processing.
- **Memory Unit:**
  - Stores data and instructions that the processor accesses during operation.
  - Consists of various types of memory, including cache, RAM, and ROM.

Architecture of Microprocessors Cont.…

II. Bus System

- **Data Bus:**
  - Transfers data between the processor, memory, and other peripheral devices.
- **Address Bus:**
  - Carries the address of the memory location or peripheral device being accessed.
  - Determines the source or destination of data on the data bus.
- **Control Bus:**
  - Controls the operation of various components within the processor, including data transfer, interrupts, and clock signals.
  - Coordinates communication between different parts of the processor and external devices.

Architecture of Microprocessors Cont.…

III. Fetch-Decode-Execute Cycle:

- **Fetch:**
  - The control unit fetches the next instruction from memory, transferring it to the instruction register.
- **Decode:**
  - The control unit interprets the instruction, determining the operation to be performed and the data involved.
- **Execute:**
  - The ALU executes the instruction, performing the specified operation on the data.
  - Results may be stored in registers, memory, or transferred to output devices.

Key Components

Control Unit (CU):

- **Function:**
  - Manages the operation of the microprocessor by fetching instructions, decoding them, and controlling the execution of operations.
  - Coordinates the flow of data within the processor and between other system components.
- **Importance:**
  - Acts as the "brain" of the microprocessor, orchestrating the execution of instructions and ensuring proper operation.
  - Determines the sequence of operations and controls the timing of each step in the instruction execution process.

Key Components Cont.…

Arithmetic Logic Unit (ALU):

- **Function:**
  - Performs arithmetic (addition, subtraction, multiplication, division) and logical (AND, OR, NOT) operations on data.
  - Executes the actual computations specified by the instructions fetched from memory.
- **Importance:**
  - Handles mathematical and logical operations required for data processing and manipulation.
  - Forms the core computational engine of the microprocessor, driving its ability to perform various tasks.

Key Components Cont.…

Registers:

- **Function:**
  - Small, high-speed storage units within the processor used to store temporary data, instructions, and addresses during processing.
  - Includes various types such as the instruction register (IR), program counter (PC), and general-purpose registers.
- **Importance:**
  - Facilitates efficient data access and manipulation, enabling quick retrieval and storage of information.
  - Stores intermediate results and memory addresses required for executing instructions and accessing data.

Key Components Cont.…

Memory Unit:

- **Function:**
  - Stores data and instructions that the microprocessor accesses during operation.
  - Consists of various types of memory, including cache, RAM, and ROM.
- **Importance:**
  - Provides the data and instructions necessary for the microprocessor to execute programs and perform tasks.
  - Supports the storage and retrieval of information required for processing and executing instructions.

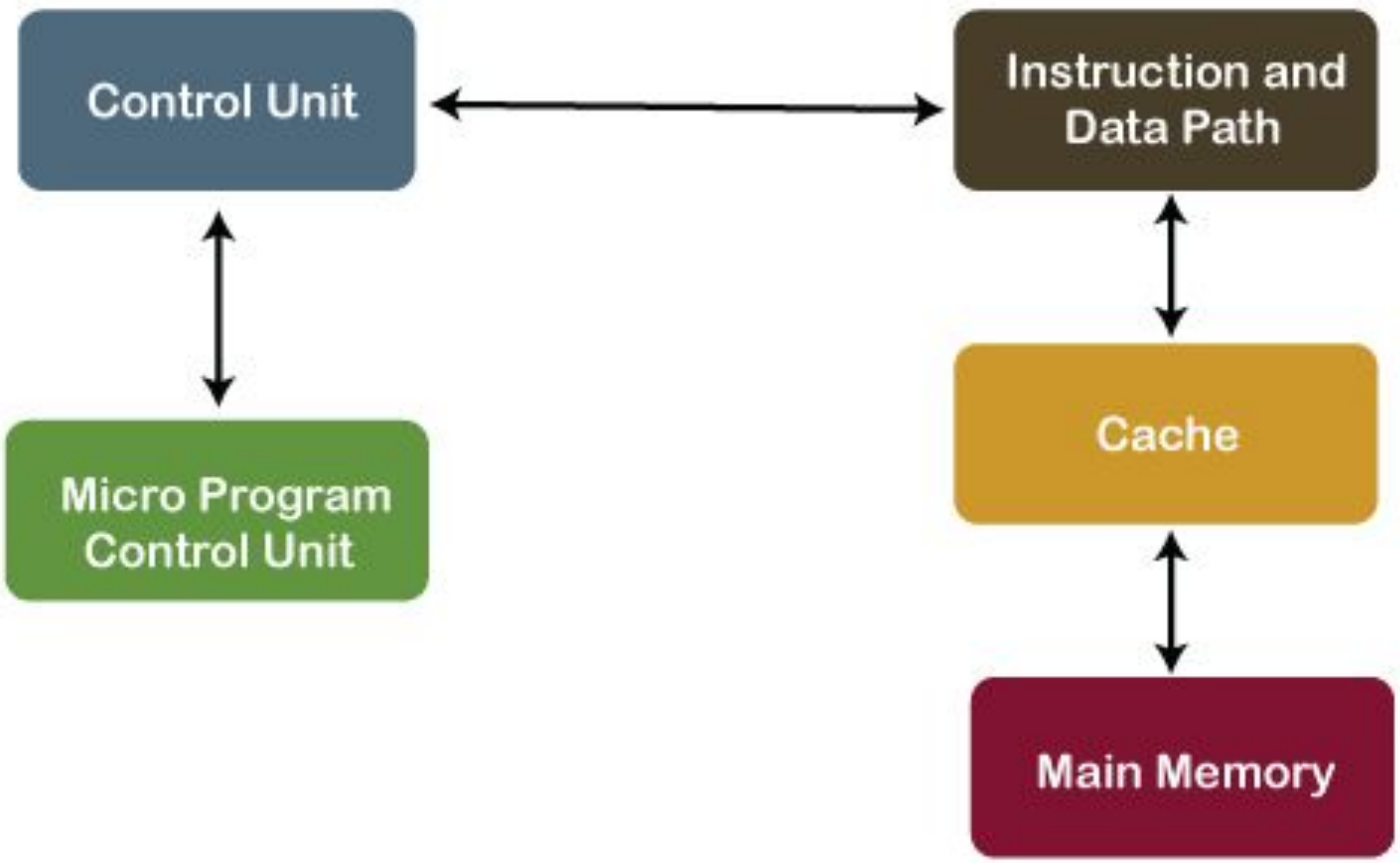
Types of Microprocessors

I. Complex Instruction Set Computing (CISC)

Complex Instruction Set Computing (CISC) is a computer architecture that emphasizes a large and complex instruction set. CISC processors have many instructions that can perform multiple operations in a single instruction. The goal of CISC architecture is to reduce the number of instructions a program needs to execute, which can lead to faster program execution

CISC processors typically have more extensive hardware support for performing complex instructions. This allows for more sophisticated operations to be performed in a single instruction, which can lead to faster program execution. However, the increased complexity can also lead to slower processing times.

Types of Microprocessors Cont....



CISC Architecture

Types of Microprocessors Cont....

Example: CISC processors include the x86 architecture used in most desktop and laptop computers today. The x86 architecture includes instructions that can perform complex tasks such as string manipulation, as well as instructions that can access and modify system memory directly.

Advantages of CISC:

- Ability to perform complex instructions
- Programs require fewer instructions to execute
- Greater hardware support for performing complex instructions

Disadvantages of CISC:

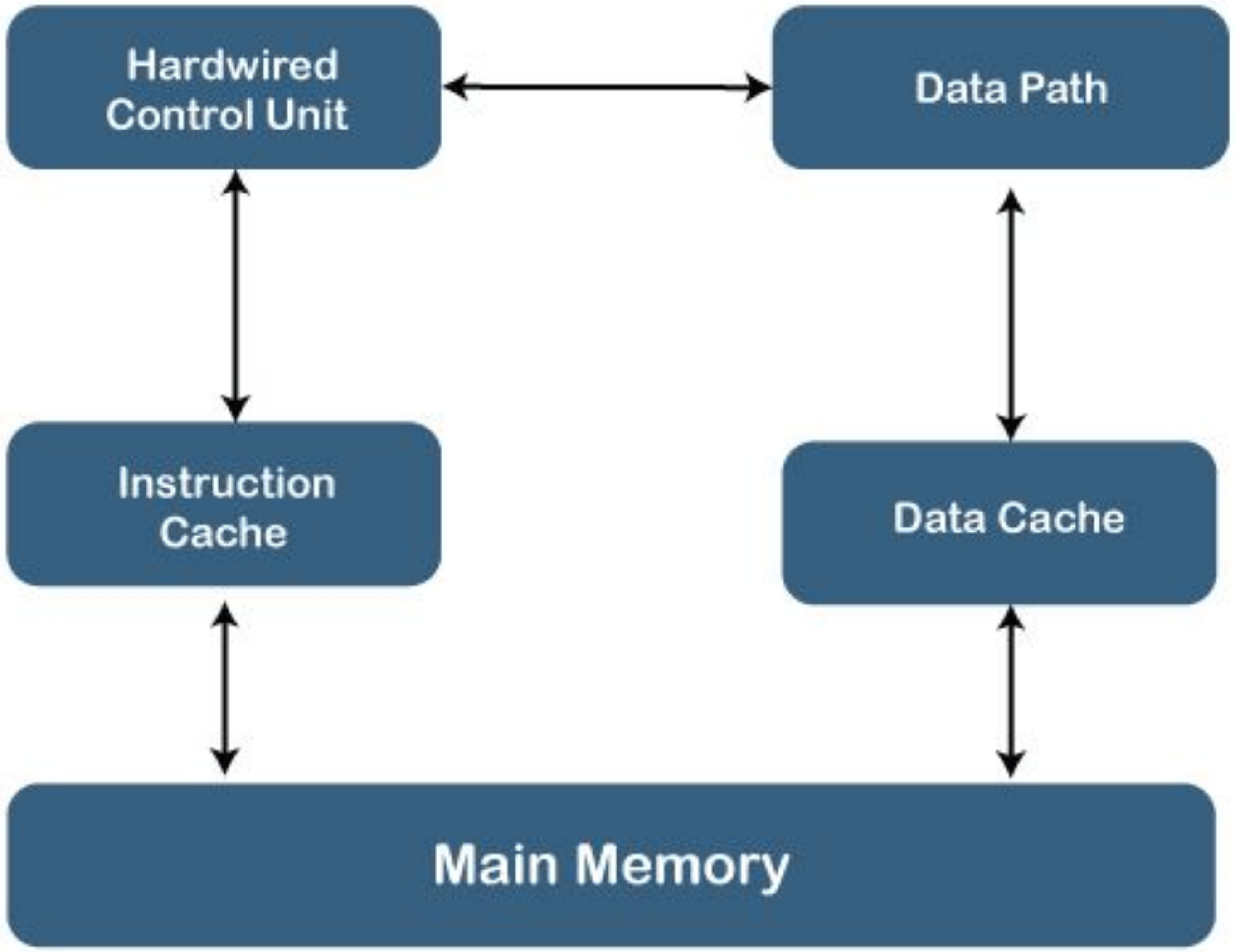
- Increased complexity can lead to slower processing times
- Larger chip size can lead to increased costs

Types of Microprocessors Cont....

Reduced Instruction Set Computing (RISC) is a computer architecture that emphasizes a simple and efficient instruction set. RISC processors have a smaller instruction set than CISC processors, with each instruction performing a single operation. The goal of RISC architecture is to reduce the amount of work the processor needs to do for each instruction, which leads to faster and more efficient processing.

RISC processors often use pipe-lining to achieve greater performance. Pipe-lining involves breaking down the execution of an instruction into smaller stages, so multiple instructions can be executed simultaneously. This reduces the overall execution time for a program, as each stage of the pipeline can be devoted to a different instruction.

Types of Microprocessors Cont....



RISC Architecture

Types of Microprocessors Cont….

Example: RISC processors include the ARM, MIPS, and PowerPC architectures. The ARM architecture is used in many smartphones and tablets, while the MIPS architecture is commonly used in embedded systems such as routers and set-top boxes. The PowerPC architecture was used in Apple's Power Macintosh computers before they switched to Intel processors.

Advantages of RISC:

- Simplified instruction set leads to faster processing
- Pipe-lining can increase performance
- Lower power consumption
- Smaller chip size, which can lead to cost savings

Disadvantages of RISC:

- Programs may require more instructions to complete a task than with CISC
- Limited ability to perform complex instructions

Review Questions

- Discuss the significance of Moore's Law in driving the exponential growth of microprocessor capabilities and its implications for technology advancement.
- Explore the benefits and challenges associated with multicore processors and their role in meeting the demands of modern computing workloads.
- Highlight the importance of power efficiency in addressing environmental concerns, reducing operational costs, and enabling sustainable computing solutions.
- Explore the diverse applications of microprocessors across various domains, including personal computing, server infrastructure, embedded systems, mobile devices, and IoT.
- Discuss the role of microprocessors in enabling key functionalities and driving innovation in each application area.
- Highlight the significance of microprocessor performance, efficiency, and integration with other hardware components in meeting the requirements of different use cases.