



Computer Organization & Architecture

Cybersecurity Department

Course Code: CBS219

Lecture 9: Multicore Processor

Halal Abdulrahman Ahmed

Lecture Outline

- Processor Evolution
- Single-Core vs Multi-Core
- Multicore Architecture
- Parallel Processing
- Performance and Applications

Lecture Outcomes

By the end of this lecture, students will be able to:

- Define single-core, dual-core, and multicore processors.
- Explain why multicore processors were introduced.
- Describe the basic architecture of a multicore processor.
- Explain the concept of parallel processing and threads.
- Compare single-core and multicore processor performance.
- Distinguish between multicore processors and multiprocessor systems.
- Identify advantages and limitations of multicore processors.
- Recognize real-world applications of multicore processors.

Single-Core Processors

A **single-core processor** has one core, meaning it can execute one instruction at a time. Here's how it works:

- **Sequential Execution:** A single-core processor handles tasks one by one. It processes one instruction, finishes it, and then moves to the next. This is called **sequential execution**.
- **Time-Slicing:** Modern operating systems support multiple tasks on single-core processors using a method called **time-slicing**. The CPU quickly switches between tasks, giving the illusion of multitasking. However, only one task is actually being processed at any moment.
- **Performance Limitation:** The performance of single-core processors is limited by their clock speed (how fast they execute instructions) and their inability to perform true multitasking. Increasing clock speed improves performance but also increases power consumption and heat generation.

Advantages of a Single-core CPU

- **Simplicity:** Easier to design and implement in embedded devices.
- **Lower Cost:** Generally cheaper due to fewer transistors and simpler architecture.
- **Low Power Needs:** Consumes less energy compared to multi-core chips.
- **Good for Legacy Applications:** Older software that isn't optimized for multiple cores runs fine.



Disadvantages of a Single-core CPU

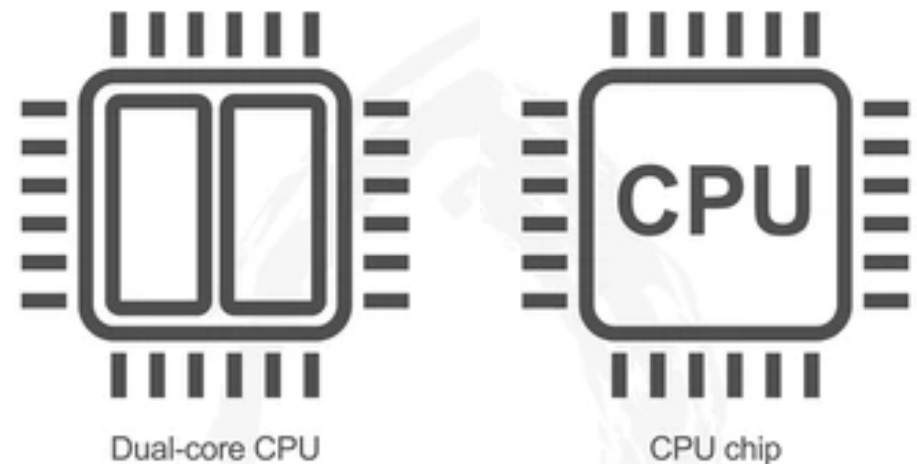
- **Poor Multitasking:** Performance drops when running multiple applications.
- **Limited Performance Growth:** Clock speeds can only be increased to a point before overheating.
- **Obsolete for Modern Needs:** Struggles with high-demand software, gaming, and media editing.
- **Not Future-Proof:** Most new applications require multi-core optimization.

Dual-Core Processors

- A dual-core processor is a CPU with two processors or "execution cores" in the same integrated circuit. Each processor has its own cache and controller, which enables it to function as efficiently as a single processor. However, because the two processors are linked together, they can perform operations up to twice as fast as a single processor can.
- The Intel Core Duo, the AMD X2, and the dual-core PowerPC G5 are all examples of CPUs that use dual-core technologies. These CPUs each combine two processor cores on a single silicon chip. This is different than a "dual processor" configuration, in which two physically separate CPUs work together. However, some high-end machines, such as the PowerPC G5 Quad, use two separate dual-core processors together, providing up to four times the performance of a single processor.

Dual-Core Processors

While a dual-core system has twice the processing power of a single-processor machine, it does not always perform twice as fast. This is because the software running on the machine may not be able to take full advantage of both processors. Some operating systems and programs are optimized for multiprocessing, while others are not. Though programs that have been optimized for multiple processors will run especially fast on dual-core systems, most programs will see at least some benefit from multiple processors as well



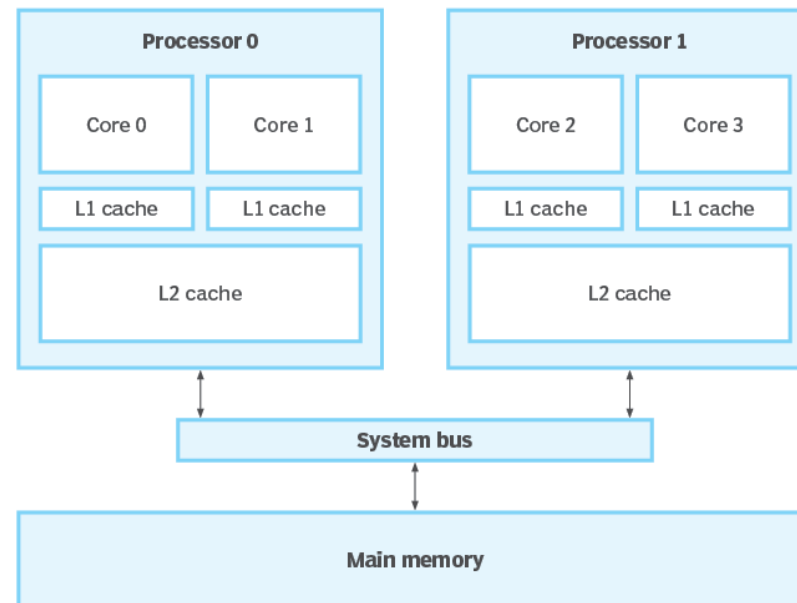
Multi-core Processor

- A multi-core processor is a type of computer central processing unit (CPU) that contains two or more independent processing units, or cores, within a single chip. Together, these cores are capable of executing multiple instructions simultaneously, leading to improved performance and efficiency compared to single-core processors.
- Multi-core processors are widely used in a variety of devices, from smartphones and laptops to servers and supercomputers. They have become the standard for modern computing, offering improved speed, energy efficiency, and reliability.

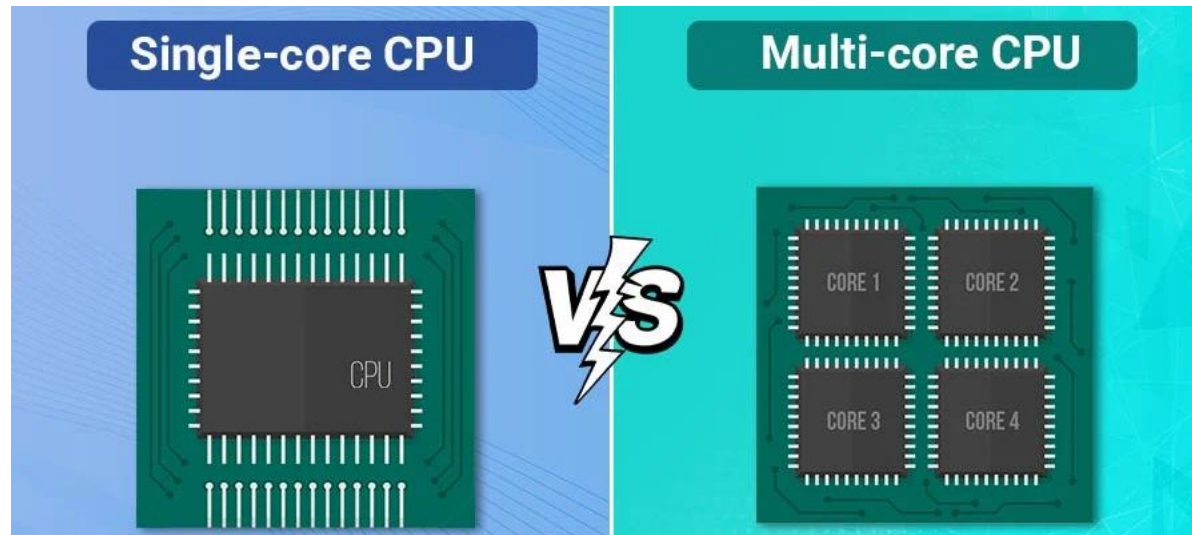
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- Processors, or CPUs (Central Processing Units), are the brains of computers, running instructions from software. The main difference between single-core and multi-core processors is the number of independent cores they have, which impacts their performance and task handling.
 - The rise of multi-core processors is due to the limitations of single-core processors in keeping up with increasing demand for computing power. Multi-core processors allow parallel processing, meaning that tasks can be divided into smaller parts that can be executed simultaneously by different cores, resulting in faster processing times. Additionally, multi-core processors make more efficient use of available resources, as each core can be assigned tasks based on its availability and processing capabilities.

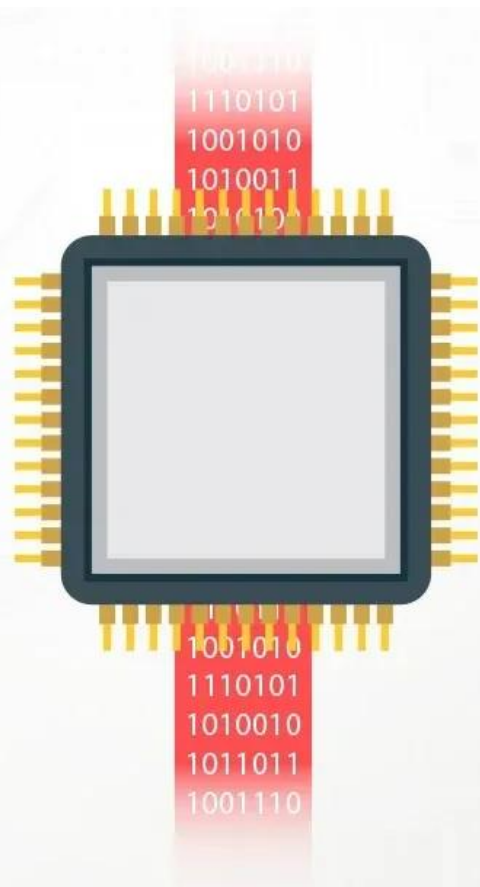
Architecture of Multicore Processor

A multi-core processor's design enables communication between all existing cores, and they divide and assign all processing duties appropriately. Each core's processed data is sent back to the Motherboard by a single common gateway once all of the operations have been finished. In terms of total performance this technique beats a single core CPU.

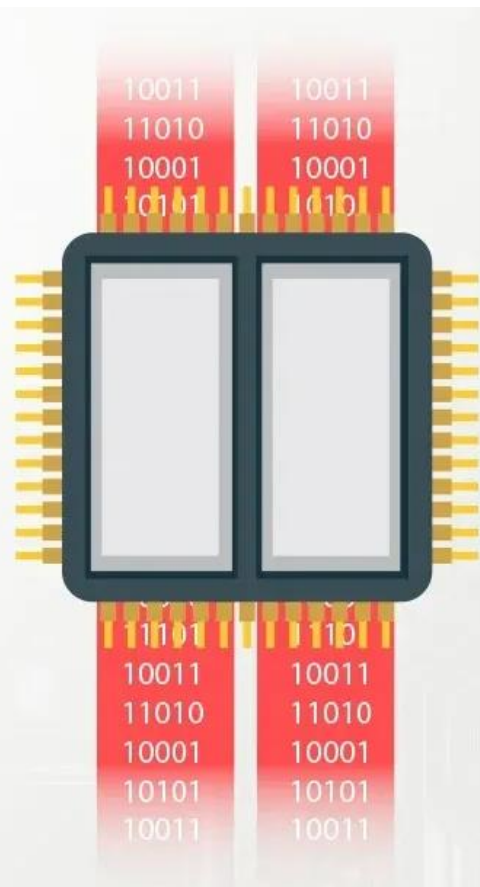


The companies who created the chip based processors could only put one CPU on one chip. Chipmakers were able to create chip with more circuits as chip making technology also chipmakers were able to generate multi core chip with more than one processor. The **first multicore CPU** was invented by **Kunle Olukotun in 1998** who was a professor of electrical engineering at Stanford. **Multicore chips were first accessible in 2005** from Advanced Mi.

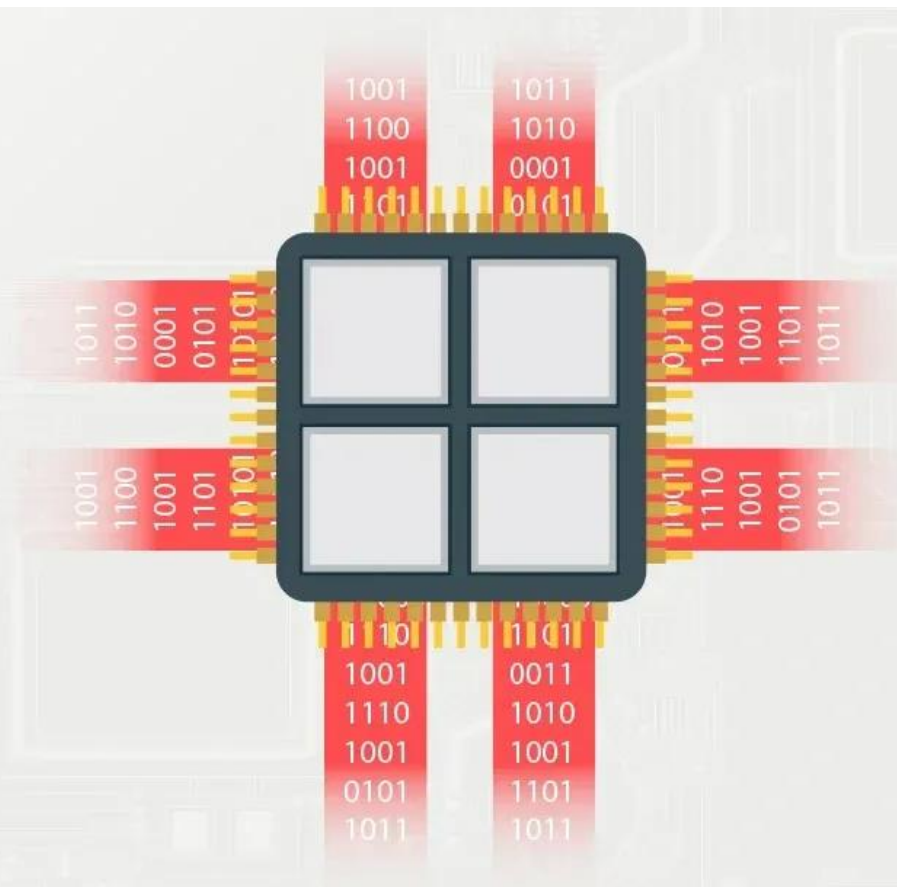




Single-core



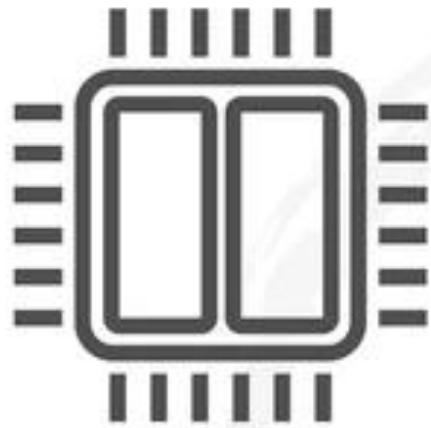
Dual Core



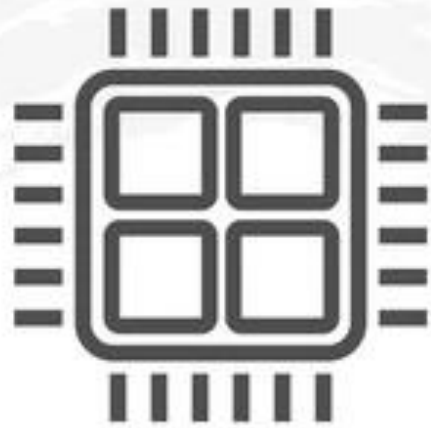
Quad Core

Modern processors are designed to balance multi-core scaling with single-core performance. Innovations like boost clocks, branch prediction, and cache optimizations ensure that single-core performance remains competitive:

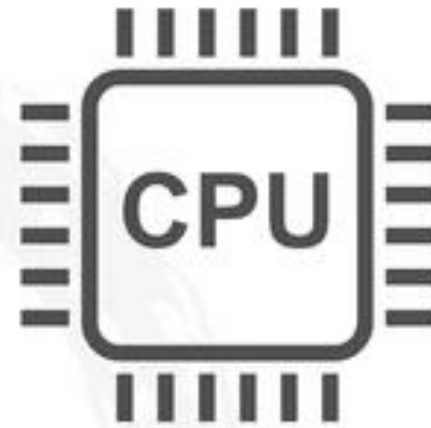
- **Boost Clock Speeds:** Temporarily increasing the clock speed of a single core for demanding tasks.
- **Improved Cache Mechanisms:** Features like AMD's Smart Data Cache Injection (SDCI) reduce memory latency and enhance single-threaded workloads.
- **Enhanced Instruction Pipelines:** Optimized pipelines ensure faster execution of sequential instructions.



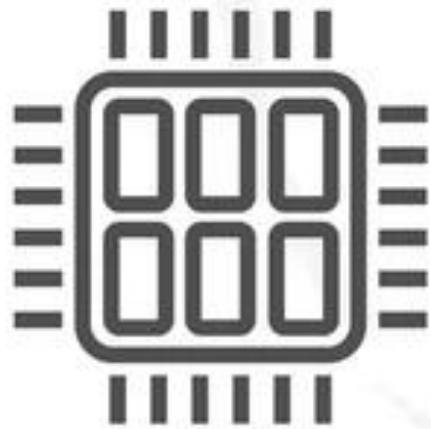
Dual-core CPU



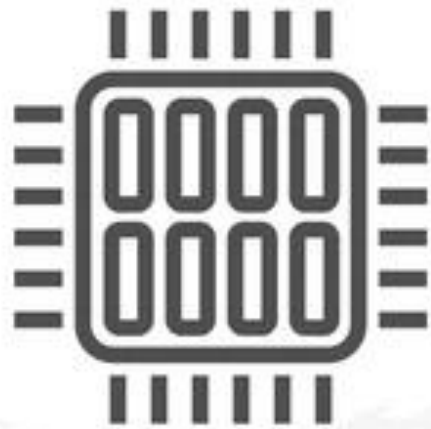
Quad-core CPU



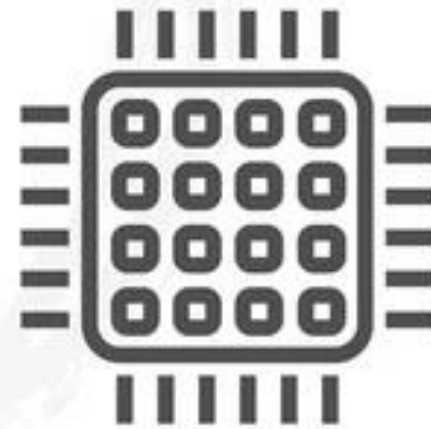
CPU chip



Six-core CPU

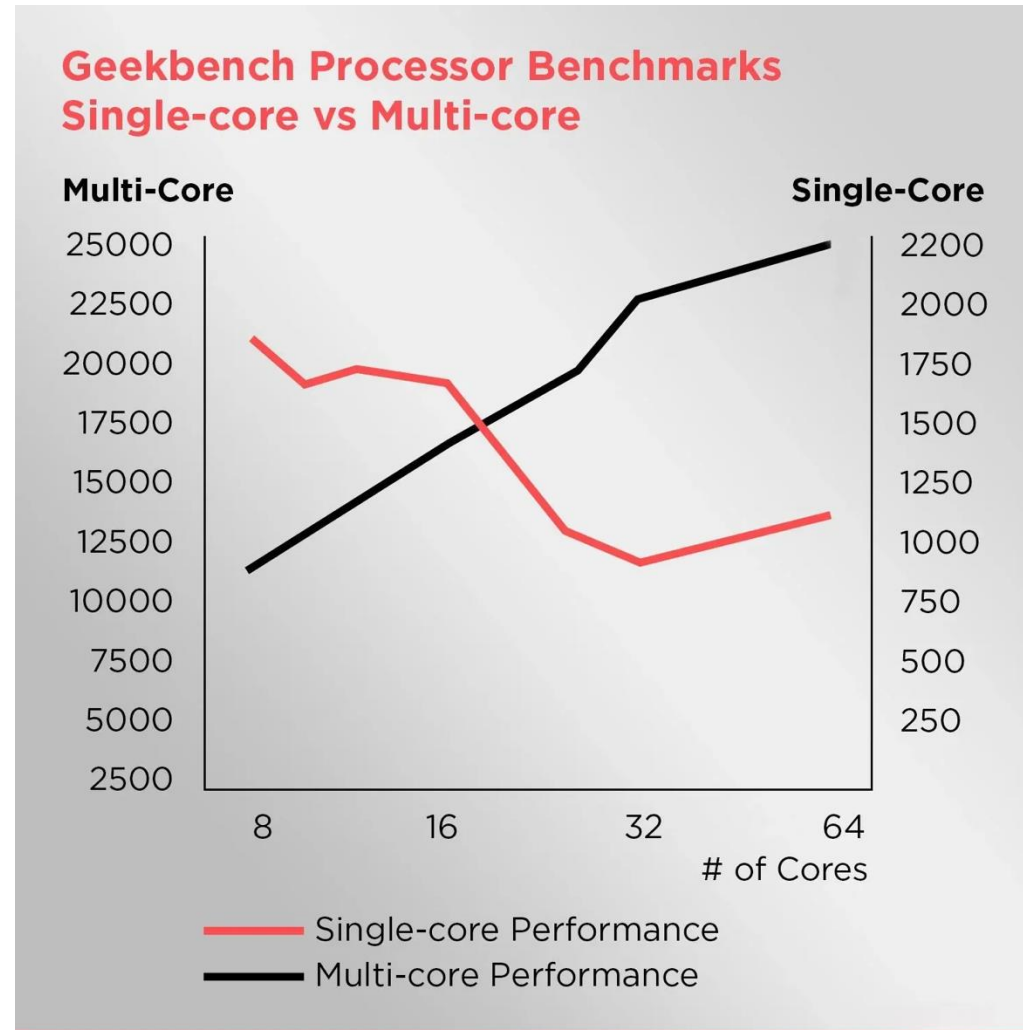


Octa-core CPU



Multiple-core CPU

Single-core vs Multi-core Processors performance



When to Use a Multi-Core Processor?

A multi-core processor is useful when:

- **High performance is needed:** Tasks like video rendering, data analysis, and simulations can be divided into parts and processed in parallel, making them much faster.
- **Energy efficiency is important:** Multi-core processors can share the workload between cores, saving power and extending battery life in laptops and smartphones.
- **High reliability is required:** In servers and data centers, if one core fails, others can continue working, reducing system downtime.

- most modern games utilize at least 4–8 cores for smooth performance, though clock speed also matters.



Uses of Multicore Processor

- Multicore processors are used in many devices like desktop, laptop, smartphone, and gaming systems. Some applications which use multicore processor are as below.
- Multicore Processor is used in high graphics games like Overwatch and Star Wars Battlefront, and other 3D games.
- The multicore processor is more appropriate used in video editing software like Adobe Photoshop, and iMovie.
- Multicore Processor is used solidworks with computer-aided design (CAD).
- Database servers also handled by multicore CPU.
- Multicore CPU is used in high network traffic.
- Embedded systems can handle by multicore processor.

Advantages of Multicore Processor

- **Performance:** A multi-core CPU can perform more work as compared to a one-core processor. so multi core processor performance is better.
- **Reliability:** The software is always assigned to different cores in multi core processor. If one piece of software fails others remain unaffected.
- **Software Interactions:** If a software is running on many cores. it will communicate with each other.
- **Multitasking:** Multi core CPU can perform multiple tasks at a same time even if many applications may be run at the same time.
- **Power Consumption:** A multi-core processor consumes less power. Only a part of the CPU that produces heat will be used. Due to low battery utilization the power consumption is automatically reduced.

Disadvantages of Multicore Processors

- **Higher Cost:** More expensive than single-core processors.
- **Heat Generation:** Multiple cores produce more heat, requiring advanced cooling.
- **Software Dependency:** Performance gains depend on whether the software is optimized for multi-core use.
- **Complex Design:** Increases chances of inefficiency if not utilized properly.

Why Does Single-Core Performance Still Matter?

Even with the rise of multi-core processors, there are scenarios where single-core performance is indispensable:

1. Latency-Sensitive Applications

Tasks like UI rendering, real-time analytics, and financial computations often prioritize responsiveness over throughput. These workloads benefit from the fastest possible execution on a single core.

How They Work in Practice

Single-Core Processor in Action:

- **Task Handling:** Imagine you're using a word processor, a web browser, and a music player on a single-core CPU. The CPU will quickly switch between these tasks, making it seem like all three are running at the same time, but in reality, only one task is being processed at any moment.
- **Limitations:** If one task is very demanding, it can slow down the performance of the other tasks because the CPU can only handle one task at a time.

How They Work in Practice

Multi-Core Processor in Action:

- **Task Handling:** In the same scenario, a multi-core processor might assign the word processor to Core 1, the web browser to Core 2, and the music player to Core 3. All three tasks run at the same time, making everything faster and more responsive.
- **Parallel Processing:** For tasks that can be split into smaller parts (like video rendering or scientific simulations), each core can work on a different part at the same time, greatly reducing the time needed to finish the task.

Operating System Role

The operating system is crucial in deciding how tasks are assigned to the CPU cores:

- **Task Scheduling:** The OS scheduler decides which tasks run on which cores, balancing the load so no single core is overloaded and ensuring efficiency.
- **Thread Management:** The OS can break tasks into threads that run in parallel on different cores in a multi-core processor, boosting performance.
- **Affinity and Priority:** The OS can set certain tasks to always run on specific cores (affinity) or prioritize some tasks over others based on system needs.

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- **Single-Core Processors:** Can handle only one task at a time, quickly switching between tasks. Performance is limited by clock speed and handling tasks one after another.
 - **Multi-Core Processors:** Can handle multiple tasks at once, with each core working on a different task or part of a task. This results in better performance, energy efficiency, and real multitasking abilities.

Multi-core Processors vs. Multiprocessors

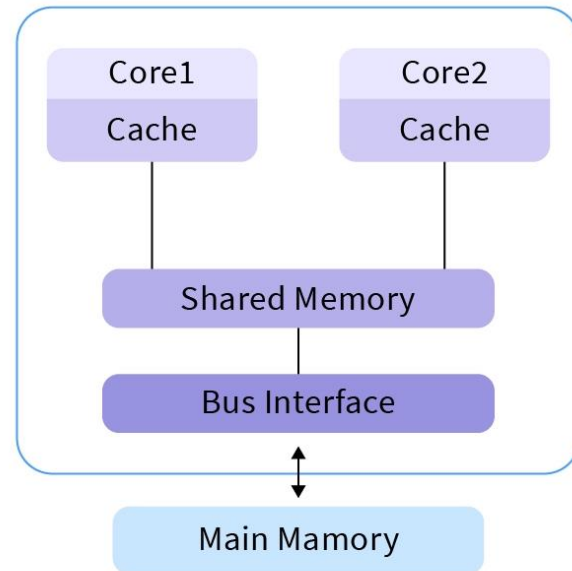
- A **multi-core processor** is a **single CPU chip** that contains **multiple cores**. These cores run tasks in parallel to improve performance and efficiency.
- A **multiprocessor system** is a **computer with two or more separate processors** working together to increase total processing power.

Key Differences

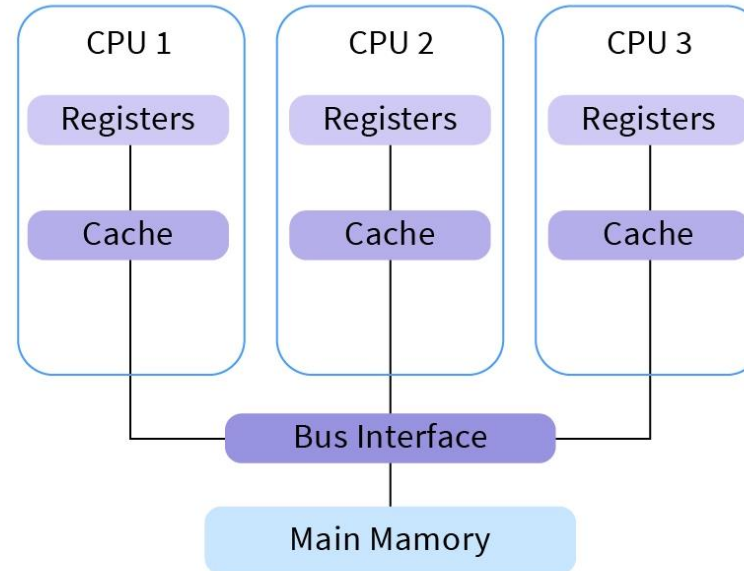
- **Multi-core:** One processor, many cores, simpler design
- **Multiprocessor:** Many processors, more complex system
- **Multi-core:** Tasks split between cores inside one chip
- **Multiprocessor:** Tasks split between separate processors

Choosing Between Them

- Use a **multi-core processor** for most everyday and moderate workloads.
- Use a **multiprocessor system** for very **high-performance tasks** like large servers and supercomputers.



Multicore processor



Multiprocessor

2. Software Bottlenecks

Some software, especially legacy applications, cannot effectively utilize multiple cores. In such cases, single-core performance dictates the overall speed of execution.

3. Gaming and Creative Workloads

For gaming, tasks like rendering, AI, and physics simulations often run on a single thread. Similarly, creative software like Photoshop relies on single-core performance for tasks such as applying filters.

4. Compiler and Kernel Dependencies

Low-level tasks, including compiling code or handling kernel operations, are often single-threaded. This makes single-core performance crucial for developers and system administrators.

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Any

Question

