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Issue Article

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THE IMPACT OF PARALLEL ARCHITECTURES ON PROCESSOR PERFORMANCE

Abstract*: In the context of modern technologies, a further significant increase in processor performance is possible only due to new architectural solutions. In this regard, the implementation of parallelism in modern processors is especially becomes particularly relevant.*

The article analyzes the characteristics of the Intel Core i5-8400H and Intel Core i5-8400 processors. The corresponding benchmarks are provided, and a comparative analysis of their performance is carried out. The influence of hyper-threating and multi-core on processor performance in single-threaded tasks and at maximum processor load is analyzed. The advantages of multi-core architectures over hyper-threating are noted, as well as the problems associated with their use.

Key words*: processor, processor performance, parallel processor architectures, multi-core architecture.*
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Introduction

Although the speed of processors is constantly increasing, the requirements for software are also growing. No matter how powerful the processor is, its capabilities are still insufficient to solve many non-trivial (especially scientific, technical and industrial) problems. Currently, artificial intelligence systems are developing at a rapid pace, which places particularly high demands on computer hardware.

Main part

The need to increase processor performance is determined by several main factors:

- Growing software requirements. Modern software (operating systems, games, graphic editors, artificial intelligence systems, etc.) requires more and more resources.
- Ensuring user comfort. A fast processor ensures quick application launch, lower delays when working in games, graphic programs and multiprogram environments.
- The areas of big data processing, machine learning and artificial intelligence require enormous computation resources. Without high-performance processors, the implementation of such technologies would be impossible in personal computers.
- Efficiency and reduced energy consumption. When quickly performing tasks, the processor switches to power-saving mode earlier. A high-performance processor is often more energy efficient than a low-performance one when performing tasks of the same volume.
- Support for modern standards and technologies. For comfortable work in real time, technologies such as PCI Express 6.0-7.0, USB 4.0, 5G, 8K video require high-performance processors.

Over the years, processor performance has increased due to the increase in clock frequency. However, heat generation and power consumption have also increased. The clock frequency of modern processors is 3–5 GHz. While maintaining processor performance, the only way to reduce heat generation is to improve the technology for producing microcircuits, which leads to the need to reduce the size of transistors. Over the years, the number of transistors in a processor has been growing in accordance with Moore's law. However, it should be noted that Moore's law cannot continue indefinitely. Transistor sizes are gradually decreasing and are already approaching the critical limit. Currently, processors are already being manufactured using 7, 5, and 3 nm process technology. However, the implementation of low-nanometer process technology is quite expensive. Currently, problems such as energy dissipation, current leakage, etc. are already obvious.

Therefore, a further significant increase in processor performance within the framework of existing technologies is possible only with the help of new architectural solutions.

For this purpose, developers have turned to parallel architectures. Parallel architecture involves breaking down a computational task into simpler subtasks and executing them in parallel.

One of the first examples of parallel architecture implementation is the Numeric Processor Unit (NPU), or Floating Point Processor Unit (FPU). The coprocessor is integrated into the processor crystal and specializes in performing floating point operations that require large computational resources.

The central processor can also perform floating point arithmetic operations independently, but using a coprocessor reduces the execution time of multiplication, division, and exponentiation operations by 80%.

Parallelism in the processor is implemented through pipelineization and superscalar architecture. In this case, the processor has several functional blocks, and parallel execution of instructions occurs based on parallel processing of several threads. If a regular (scalar) processor executes one instruction per cycle, then in superscalar processors, this number is multiplied by the number of blocks (if the instructions are independent of each other).

To improve the efficiency of the processor's computing units, hyper-threading technology is also used, according to which one processor is represented by two virtual processors. In conventional processors, no more than 40% of the computing units are loaded at the same time. According to hyper-threading technology, the first logical processor uses the main resources of the processor, and the second uses the remaining unloaded resources. However, hyper-threading technology also has negative properties. The "second processor", despite using the "empty" resources of the first processor, sometimes still slows down its operation, which often leads to a decrease in processor performance. Therefore, it is impossible to increase performance by 100%. Typically, this figure fluctuates within 20-30%. Hyper-threading technology does not have any effect in single-threaded tasks and is not implemented at all under high processor load. In addition, the power consumption and heat generation of the processor increase slightly. Therefore, in comparison with hyper-threading technology, preference is given to increasing the number of cores in the processor.

To improve the performance of processors, various hardware and software tools are also used, namely: an increase in the number of pipeline stages; improved dynamic execution, due to which the processor recognizes and prepares instructions in advance; improved caching, which allows avoiding waiting for the processor; Out-of-order execution technology, according to which instructions are executed not necessarily sequentially, but depending on the availability of resources; integration of special units, such as: a graphics core (iGPU), a neural processor/artificial intelligence accelerator (NPU/AI Engine), encryption tools, video codecs, a digital signal processor (DSP); code optimization for specific instructions (AVX, SSE), etc.

However, the performance of single-core processors can only increase to a certain level. Therefore, the next level of parallelism is implemented based on a multi-core architecture. In this case, several processor cores are integrated into one crystal, which perform operations in parallel. Currently, two-, four-, six-, eight-, sixteen-, etc. multi-core processors are produced for computers. The implementation of a large number of cores is effective in the parallel execution of complex tasks.

Two processors were selected for comparative analysis: Intel Core i5-8400H and Intel Core i5-8400. The Intel Core i5-8400H processor is a quad-core processor and supports hyper-threating technology, which allows eight threads to be executed simultaneously, while the Intel Core i5-8400 processor is a six-core processor and does not support hyper-threating technology. Thus, the advantage of the Intel Core i5-8400H processor over the Intel Core-i5-8500B processor is the ability to potentially execute two more threads, although the Intel Core i5-8400H processor has two more cores. The remaining main characteristics of the processors are almost identical (Table 1).

Table 1. Processor characteristics

Specifications	Intel Core i5-8400H	Intel Core i5-8400
Number of Cores	4	6
Number of Threads	8	6
Base Frequency	2,5 GHz	2,8 GHz
L1 cache	64 KB (per core)	64 KB (per core)
L2 cache	256 KB (per core)	256 KB (per core)
L3 cache	8 MB	9 MB

The testing was carried out using the Passmark program. Figures 1 and 2 show the results of testing the processors in single-threaded tasks and at full processor load, respectively. The maximum performance was obtained by averaging the results of several standard tests. It is worth noting that the test results in single-threaded tasks are almost identical, and the small difference is due to a slightly higher frequency of the Intel Core i5-8400 processor compared to the Intel Core i5-8400H processor (2.8 GHz versus 2.5 GHz). As for the maximum performance when executing multi-threaded tasks, the additional two cores of the Intel Core i5-8400 processor compared to the Intel Core i5-8400H processor significantly increase performance, despite the fact that support for hyper-threading technology allows the Intel Core i5-8400H processor to potentially execute two more threads simultaneously.

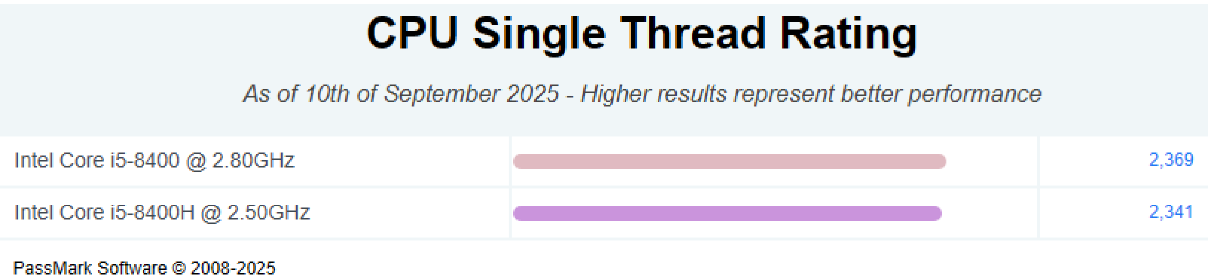

Fig. 1. Test results in single-threaded tasks

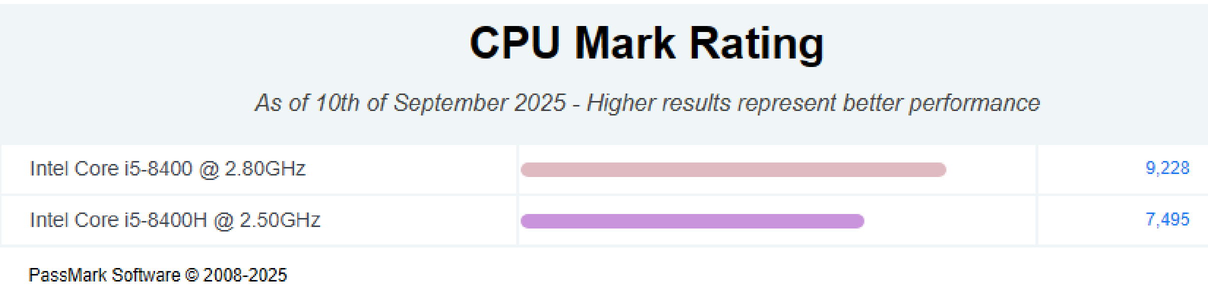

Fig. 2. Maximum processor performance

Multi-core architecture also has other positive properties:

- Scalability. Multi-core architecture allows for the implementation of processors with an increased number of cores, as well as the combination of several multi-core processors into one system. Depending on the load, the power of computing resources can be adjusted.
- Multi-core processors can reserve computational resources. In the event of a failure or breakdown of one of the cores, the remaining cores continue to operate, which increases the fault tolerance and reliability of the system.

However, increasing the number of cores does not lead to a directly proportional increase in processor performance, since the multi-core architecture is also characterized by certain problems:

- When sequentially executing threads, the multi-core architecture does not provide an advantage over the single-core one.
- According to Amdahl's law, the speed of a parallel system is determined by its slowest component. Accordingly, increasing the number of cores does not necessarily lead to the same increase in program execution speed.
- As the number of cores increases, their coordinated operation and communication with memory become more difficult.

Conclusion

The article analyzes the impact of parallel architectures on processor performance. Test results show that in single-threaded tasks, both hyper-threating technology and multi-core architecture have virtually no impact on processor performance. Thus, it is possible to use relatively low-performance processors without any losses. However, when processors are fully loaded, parallel architectures have a significant, although indirect, impact on processor performance. At the same time, multi-core architecture is significantly more effective than hyper-threating technology in terms of increasing processor performance.

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