



Multi-Core Processor Architecture Explained

by Andrew Binstock

Introduction

Intel has announced that the future generations of its Itanium®, Pentium® processors, and Intel® Xeon® processors would rely on multi-core architecture. By announcing this new design Intel revealed how it will improve platform performance and capabilities while facing the increasing challenge of power consumption. This article explains what multi-core is, how it works, and why it's important to the software industry as well as to buyers of PCs and servers.

What is Multi-Core?

At its simplest, multi-core is a design in which a single physical processor contains the core logic of more than one processor. It is as if an Intel Xeon processor were opened up and inside were packaged all circuitry and logic for two (or more) Intel Xeon processors. The multi-core design puts several such processor “cores” and packages them as a single physical processor. The goal of this new design is to enable a system to run more tasks simultaneously and thereby achieve greater overall system performance.

The Intel® Pentium® 4 and Intel Xeon processors today already use Hyper-Threading Technology (HT) to execute multiple programs simultaneously. But HT Technology and multi-core designs differ significantly and deliver different performance characteristics. The key differentiator lies in how instructions are executed. To get at this difference, we need to review how multiple threads are run on today's servers and desktops.

Multithreading, Hyper-Threading, or Multi-Core?

Programs are made up of execution threads. These threads are sequences of related instructions. In the early days of the PC, most programs consisted of a single thread. The operating systems in those days were capable of running only one such program at a time. The result was—as some of us painfully recall—that your PC would freeze while it printed a document or a spreadsheet.

The system was incapable of doing two things simultaneously. Innovations in the operating system introduced multitasking in which one program could be briefly suspended and another one run. By quickly swapping programs in and out in this manner, the system gave the appearance of running the programs simultaneously. However, the processor was in fact at all times running just a single thread.

In recent years, processor design had gained additional execution resources (such as logic dedicated to floating-point and integer maths) for the parallel execution of instructions. Intel saw an opportunity in these extra facilities. The company reasoned it could make better use of these resources by employing them to execute two separate threads simultaneously on the same processor core. Intel named this simultaneous processing Hyper-Threading Technology and released it on the Intel Xeon processors in 2003.

According to Intel benchmarks, programs using multiple threads could see improvements of up to 30% by running on processors with HT Technology. More important, however, two programs could now run simultaneously on a processor without having to be swapped in and out (See [Figure 1](#).) To induce the operating system to recognize one processor as two possible execution pipelines, the new chips were made to appear as two logical processors to the operating system.

The performance boost of HT Technology was limited by the availability of shared resources to the two executing threads. As a result, HT Technology cannot approach the processing throughput of two distinct processors because of the underlying contention for these shared resources. To achieve greater performance gains on a single chip, a processor would require two separate cores, such that each thread would have its own complete set of execution resources. Enter multi-core.

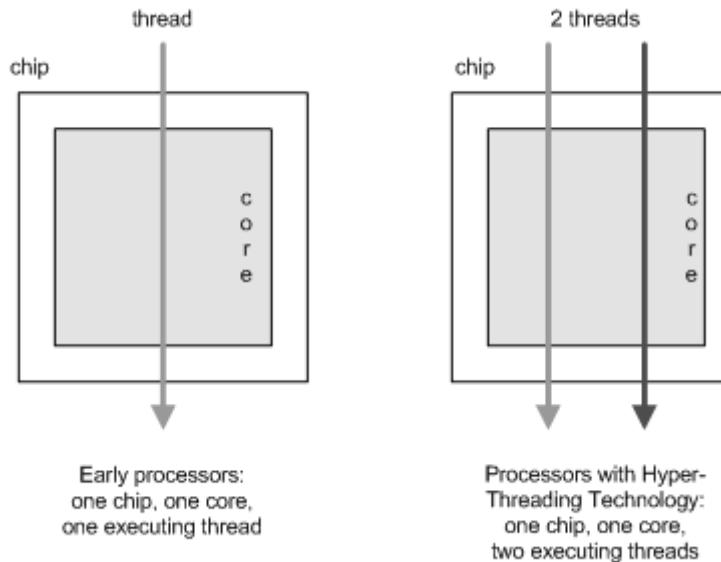


Figure 1. HT enables two threads to execute simultaneously on a single processor core.

Multi-Core Processors

Multi-core processors, as the name implies, contain two or more distinct cores in the same physical package. [Figure 2](#) shows how this appears in relation to previous technologies.

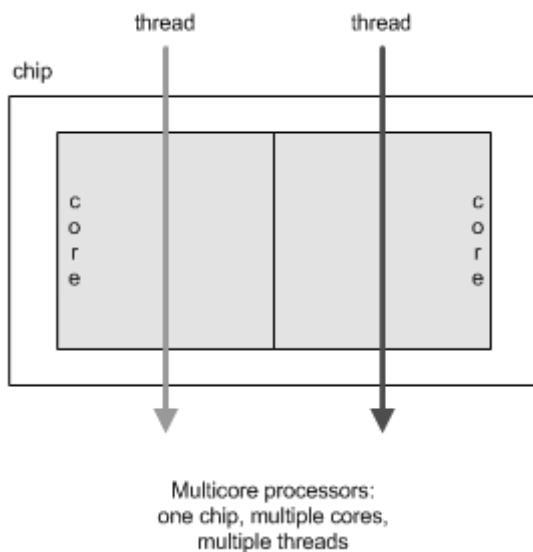


Figure 2. Multi-Core processors have multiple execution cores on a single chip.

In this design, each core has its own execution pipeline. And each core has the resources required to run without blocking resources needed by the other software threads. While the example in [Figure 2](#) shows a two-core design, there is no inherent limitation in the number of cores that can be placed on a single chip. Mainframe processors today use more than two cores, so there is precedent for this kind of development. The design enables two or more cores to run at somewhat slower speeds and at much lower temperatures. The combined throughput of these cores delivers processing power greater than the maximum available today on single-core processors and at a much lower level of power consumption. In this way, Intel increases the capabilities of server platforms as predicted by Moore's Law while the technology no longer pushes the outer limits of physical constraints.

Software Implications

Multi-core systems deliver benefits to all software, but especially multi-threaded programs. All code that supports HT Technology or multiple processors, for example, will benefit automatically from multi-core processors without need for modification. Most server-side enterprise packages and many desktop productivity tools fall into this category; as do most of today's operating systems. Single-threaded applications still benefit from multi-core (although they do not gain the full advantages offered by the technology), because while they are executing, the operating system can execute tasks on the other cores without interrupting the running program for access to the processor.

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