

Intel® Multi-Core Processors: Making the Move to Quad-Core and Beyond

By R.M. Ramanathan

Overview: Intel® Quad-Core Processors Represent Future of Computing

One constant in computing is that the world's hunger for faster performance is never satisfied. Every new performance advance in processors leads to another level of greater performance demands from businesses and consumers. Today these performance demands are not just for speed, but also for smaller, more powerful mobile devices, longer battery life, and—in the enterprise—better price/performance per watt and lower cooling costs.

Through advances in silicon technology, microarchitecture, software, and platform technologies, Intel is on a fast-paced trajectory to continuously deliver new generations of multi-core processors with the superior performance and energy-efficiency necessary to meet these demands for years to come. In mid-2006, new levels of energy-efficient performance were reached with Intel® Core™2 Duo processors and Dual-Core Intel® Xeon® processor 5100 series processors, both produced with the latest 65-nanometer (nm) silicon technology and Intel® Core™ microarchitecture. Now we are ready to top that with the world's first mainstream quad-core processors for both desktop and volume servers.

A Fundamental Theorem of Multi-Core Processors

Overcoming the resultant heat from increasing power densities, multi-core processors take advantage of a fundamental relationship between power and frequency to dramatically increase a computer's capabilities and computing resources. This provides better responsiveness, improves multithreaded throughput, and delivers the advantages of parallel computing to properly threaded mainstream applications.

By incorporating multiple cores, each core is able to run at a lower frequency, dividing among them the power normally given to a single core. The result is a significant performance increase over that of a single-core processor.

This fundamental relationship between power and frequency can be effectively used to multiply the number of cores from two to four, and then eight and more, to deliver continuous increases in performance without increasing power usage. Steps taken by Intel to accelerate the introduction of additional cores include:

- **Continuously advancing silicon process technology** from 65 nm to 45 nm to 32 nm to increase transistor density. In addition, Intel is committed to continuing to deliver superior energy-efficient performance transistors.
- **Enhancing and optimizing multi-core performance** through the introduction of new advanced microarchitectures about every two years.
- **Improving the memory subsystem and optimizing data access** in ways that ensure data can be used as fast as possible among all cores. This minimizes latency and improves efficiency and speed.
- **Optimizing interconnect fabrics** to improve performance between cores and memory units.
- **Optimizing and expanding the instruction set** to enhance the capabilities of Intel® architecture and enable the industry to deliver advanced applications with greater performance and lower power requirements. Some of these instructions can effectively dedicate a core to deliver specific capabilities.
- **Continuing to grow Intel's commitment to developing multi-core software tools and programs** by working closely with developers, independent software vendors (ISVs), operating system vendors (OSVs), and academia. Through these efforts, Intel enables the industry to develop software that runs faster and better on our energy-efficient performance multi-core platforms.

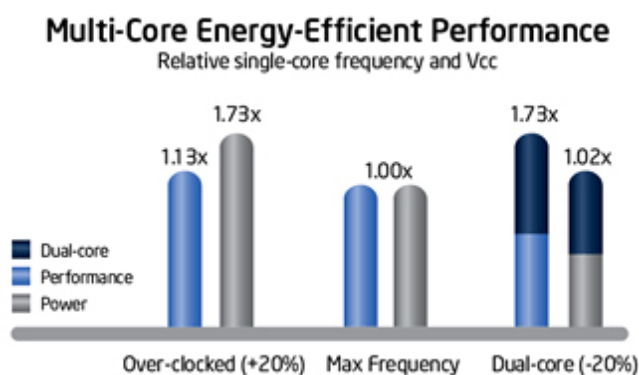


Figure 1. An underclocked dual-core processor effectively delivers more performance while using approximately the same power as a single-core processor at maximum frequency.

Introducing Intel® Quad-Core Processors

Intel's unveiling of the industry's first quad-core processors for desktops, workstations, and volume servers represents the next milestone in multi-core processor design and performance. Intel's rapid implementation of quad-core takes advantage of our rich history of engineering expertise, along with our industry-leading manufacturing technologies and capabilities. This translates into excellent volume pricing and consistent supply. The industry will be able to make a fast transition as well—these quad-core processors are designed to plug into current motherboards meeting the proper thermal and electrical specifications.¹

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First up are the Intel® Core™2 Extreme quad-core processor QX6700 for performance desktops and the new Quad-Core Intel® Xeon® 5300 processor for servers. These 65 nm quad-core processors feature four complete execution cores within a single processor and are based upon the revolutionary and proven Intel Core microarchitecture.

Enhanced Multitasking from the World's First Quad-Core for the Desktop

Intel Core 2 Extreme quad-core processors power next-generation gaming machines and act as multimedia processing engines for today's growing list of threaded applications. Gamers can expect a smoother, more exciting gaming experience through the distribution of artificial intelligence, physics, and rendering across four hardware threads. Ideal for processor-intensive, highly threaded applications, the Intel Core 2 Extreme quad-core processor is the top choice for multimedia enthusiasts, gamers, and workers in demanding multi-tasking environments. It features a core speed of 2.66 GHz and front side bus speed of 1066 MHz.

A New Cadence for Technological Advancement

Building on the foundation of Intel® Core™ microarchitecture, Intel is establishing a new cadence that will speed up the delivery of products featuring superior performance and energy-efficiency for years to come. Intel plans to deliver a new, optimized energy-efficient performance microarchitecture approximately every two years that supports all its process technology advancements. For more information, read "Intel® Architecture and Silicon Cadence: The Catalyst for Industry Innovation," in *Technology@Intel* magazine.

Breakthrough Performance from the Industry's First Quad-Core High-Volume Processor

The Quad-Core Intel Xeon 5300 processor will enable server customers to boost their general purpose servers with breakthrough energy-efficient performance, greater density, and fewer cooling challenges. The Quad-Core Intel Xeon 5300 processor provides up to 50 percent better performance² (SPECintRate*) than two-way dual-core Intel Xeon processors on certain applications. The additional threads from quad-core technology and key Intel® platform-level innovations deliver the most headroom for running simultaneous multiple applications and virtualized environments on a two-way server.

The Quad-Core Intel Xeon processor 5300 series features core speeds from 2.66 GHz to 1.60 GHz, bus speeds from 1333 to 1066 MHz, and mainstream 80-watt TDP roadmap with performance SKU at 120-watt TDP. A low-power version (L5310) with a 50-watt TDP is planned for the first quarter of 2007. Another version will be available for single-processor servers and workstations in the same time frame.

Quad-Core Intel Xeon 5300 processor platforms include several advanced capabilities:

- **Intel® Virtualization Technology.** Intel Virtualization Technology is the industry's first hardware-assisted technology supporting today's industry-leading virtualization software.
- **Fully-Buffered DIMM Technology.** The latest in memory technology, fully-buffered DIMM technology provides significantly greater performance and capacity while improving memory reliability.
- **Intel® I/O Acceleration Technology.** This unique Intel technology moves network data more efficiently through Intel Xeon processor-based servers for fast, scaleable, and reliable networking.

Multi-core processors will empower the development of new usage models that will enable wide-ranging advances in everything from medicine to IT, as well as revolutionize the digital office, digital home, computing on the go, and computer gaming.

Beyond Quad-Core: Tera-Scale Computing

Spurred by increasing globalization, growing device intelligence, and the explosion of digital data, Intel believes that the applications of the next decade will be much more computationally intensive than anything seen to date. This will be the "tera era"—an age when people need teraflops (a trillion floating point operations per second) of computing power, terabits (a trillion bits per second of communications bandwidth) of bandwidth, and terabytes (1,024 gigabytes) of data storage to handle the information all around them.

With this in mind, Intel researchers are working to shape future Intel® microprocessors through the Intel® Tera-Scale Computing Research Program. Intel has over 100 R&D projects worldwide addressing the hardware and software challenges of building and programming systems with dozens (and even

hundreds) of energy-efficient cores with sophisticated memory hierarchies—systems powerful enough to accommodate the next decade of computing.

Preparing Software for Multi-Core Processing

The throughput, energy efficiency, and multitasking performance of multi-core processors will all be more fully realized when application code is threaded and multi-core ready. Intel provides extensive partner programs with software developers, OSVs, ISVs, and academia to accelerate the delivery of dual-core and quad-core products. Intel has recently updated the Intel® Threading Building Blocks, Intel® Thread Profiler, and Intel® Thread Checker development tools to support quad-core processing.

Intel's leadership in the industry, our commitment to investment in research and development, our understanding of all segments of the market, and our long history of collaboration with other industry leaders put us in a unique position to lead the charge for multi-core processor-based platforms.

Intel's software products and programs include:

- **Intel® Software Development Products.** These products and tools embrace multi-core programming best practices, facilitate threading applications, and help developers shorten the time to market. [For more information, visit the Intel Web site.](#)
- **Software Programs and Services.** Beyond software products, Intel works with leading software vendors to provide tools, resources, expertise, and relationships to drive thread optimization across a wide range of applications. Intel also works with industry groups like ODSL and Eclipse to shape the direction of the open source community. In addition, Intel works with thousands of ISVs to help them prepare and optimize their solutions for new platform technologies and with academia to develop multi-core curriculum.

The Race is On

Intel plans to ship millions of multi-core processors in 2006 and expects to exit the year shipping dual-core and quad-core processors at a rate of more than 75 percent for its performance and main-stream desktop, 90 percent for its performance mobile processor families, and 85 percent for its servers. Intel expects to exit 2007 shipping multi-core processors at a rate of 90 percent for its performance desktop and mobile families and close to 100 percent for its servers.

Progress has been fast. Software such as Microsoft Windows XP*, Windows Server*, Microsoft Vista*, some applications in Microsoft Office* 2007, various Linux* vendor offerings, and others is already threaded for better performance with Intel multi-core processors.

No one is in a better position to spearhead platform development than Intel. Intel's leadership in the industry, our commitment to investment in research and development, our understanding of all segments of the market, and our long history of collaboration with other industry leaders put us in a unique position to lead the charge for multi-core processor-based platforms.

Summary

Multi-core processors represent the future of computing. As the wealth and complexity of the data around us grows, multi-core processors will become increasingly important for helping run businesses, governments, our homes, and our entertainment. Multi-core processors will empower the development of new usage models that will enable wide-ranging advances in everything from medicine to IT, as well as revolutionize the digital office, digital home, computing on the go, and computer gaming.

In a decade or so when the full power of high-performance computing and parallel processing is available to computer users everywhere, it might be possible to hold the power of a computer with hundreds of execution cores in the palm of your hand. Intel® quad-core processors are the next step in this evolution.

More Info

[Intel® Quad-Core](#)
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[New Instructions](#)
[Intel® Architecture](#)
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[Tera-Scale Computing](#)
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[Technology and Research at Intel](#)

Author Bio

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R. M. Ramanathan has been a technology evangelist at Intel for the past three years, most recently in the Sales and Marketing Group. In his 11 years with Intel, he has held various positions, from engineering to management.

Before coming to Intel, Ramanathan was director of engineering for a multinational company in India. He has received 4 patents and has 10 patents pending in the areas of networking and security. Ramanathan holds a master's degree in mathematics from Madurai Kamaraj University in India.

¹ Contact your motherboard vendor for more information.

² Performance may vary. Please refer to www.intel.com/performance for more details.