White Paper
Intel® Xeon® Processor- and Intel Atom™ Processor-Based Servers
Server-Side Java* Applications

Accelerating Performance for Server-Side Java* Applications

Servers and microservers running an optimized Java Virtual Machine (JVM) and powered by Intel® Xeon® processors and Intel® Atom™ processors provide significant performance advantages for Java applications

Executive Summary

From nearly the beginning of Java and through collaboration with JVM developers, Intel has been a part of optimizing JVM performance on Intel® processor-based servers. These collaborative efforts have resulted in a 32X[1] performance improvement since 2007 for Java applications running on servers powered by Intel® Xeon® processors.

Intel continues its collaboration as it enhances processors with new technologies and introduces advanced processors for microservers, such as the new Intel® Atom™ processor C2000 family and Intel® Xeon® processor E3 v3 family. These processors help boost software performance with very low power consumption in data centers, such as those of cloud service providers (CSPs), where power and performance are key factors.

This paper describes the key architectural advancements of the latest Intel Xeon processors and Intel Atom processor C2000s that are beneficial to Java applications. It also describes some of the techniques and strategies used to optimize JVM software and the benefits those optimizations bring to Java applications.

This paper will be useful to anyone looking for fast, cost-effective ways to maximize the performance of their Java applications.

Intel and Oracle: Building a Better Java Foundation

Java is one of the most deployed software platforms in existence; it is now used in over three billion devices, according to Oracle. Java powers a massive array of usages from enterprise applications, to games and personal productivity software.

Intel's Java-Enabling History

Since 1996, Intel engineers have worked on Java optimization through close collaboration with the industry's key JVM vendors:

- BEA JRockit* JVM—Intel began work with BEA in 2002 and continued after Oracle acquired BEA in 2008.
- Sun Microsystems Hotspot* JVM—Intel began work with Sun Microsystems in 2007 and continued after Oracle acquired Sun in 2009.
- Intel continues a close collaboration with Oracle on the combined Hotspot and JRockit teams.
- Intel software engineers work directly with Oracle Java engineers to identify and provide specific optimizations that take advantage of the latest Intel® microarchitecture enhancements.

Because of this ongoing collaboration, organizations can realize significant performance gains using the latest Oracle Java Virtual Machine (JVM) running on servers powered by Intel® server processors.

Intel and Oracle Continue to Enhance Java Performance

Each new generation of Intel microarchitecture introduces features that increase both hardware execution efficiency and software performance. Older versions of Java will benefit simply from running on newer Intel® platforms.

To push performance even further, Intel and Oracle software engineers optimize Java to take advantage of microarchitecture enhancements being introduced in new Intel processor generations. As Intel releases new features, Intel and Oracle collaborate to identify specific areas within the JVM to take advantage of these hardware advances. These optimizations can deliver the highest performance possible across a broad range of applications, including enterprise, web, cloud, and Big Data.

From 2007 to 2013, this collaboration produced benchmark scores with significant performance gains, as shown in Figures 1 and 2[1].

Intel processor-based servers continue to boost the performance of Java-based applications in the enterprise, thanks to the joint efforts of Intel and Oracle. Together, their work has enabled a 2X performance improvement[2] on enterprise applications in just two years (Figure 3) over three generations of Intel Xeon processors.

New Processor Features Benefit Java Performance

The continuing evolution of the Intel Xeon processor E5 and Intel Xeon processor E3 families brings more cores, higher performance, larger cache, improved energy efficiency, and greater capability for server-side Java applications. Additionally, with the latest generation of the Intel Atom processor C2000 family for microservers, Intel offers leading performance/watt server capabilities for data centers in a very energy-efficient SOC design. These capabilities are critical where energy consumption is a driving factor, such as with Cloud Service Providers (CSPs).

Better Memory and I/O Performance—Intel Xeon processors include Intel® QuickPath Interconnect Technology (Intel® QPI) and integrated memory controllers, which deliver fast core-to-core and core-to-memory communications. These processors also include larger shared, on-die cache than previous generations, keeping more data closer to the processor cores for fast access. The shared cache architecture, along with improved cache coherency algorithms, help to reduce cache misses.

Altogether, these features can improve data flow to and from the processor cores, so the processing cores spend less time waiting for data and more time actively processing it. This can significantly improve performance for Java applications that are memory-bound. It also helps to accelerate garbage collection (GC) processes, which are used to free up memory space in Java applications by eliminating software objects that are no longer needed. Many Java applications are GC-intensive, and speeding-up these processes can substantially improve overall performance.

Intel® Hyper-Threading Technology[3]—Each Intel Xeon processor core can simultaneously execute two software threads. When one thread is waiting for data or instructions, the other can remain active to further increase processor utilization and overall throughput. Except for a few niche workloads, Intel software engineers have observed that Intel Hyper-Threading technology typically improves performance by 5-35 percent[4] for threaded applications. It also helps servers to support more users, while providing balanced performance across the consolidated workloads.

Performance Boosts at Peak Workloads—With Intel® Turbo Boost Technology,[5] Intel Xeon processors and Intel Atom processors can automatically operate cores above rated frequency during heavy workloads. This enables the processor to respond intelligently to demands, so it can deliver maximum performance when needed. The processors automatically and dynamically apply a frequency boost to each core, so performance can be tailored to match specific workloads. Intel Turbo Boost Technology can improve overall throughput for demanding Java applications. It can also improve response times for time-sensitive Java applications.

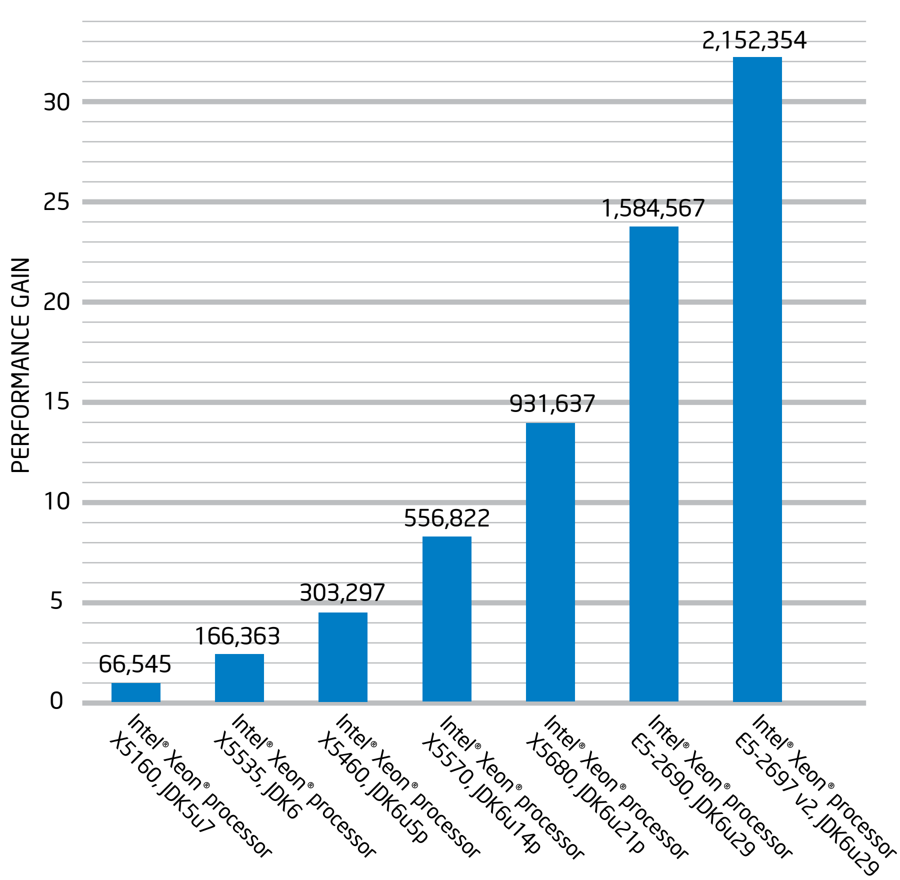

Figure 1. SPECjbb2005* performance gains across multiple generations of Intel® hardware and Java* Development Kit Software[1].

Automated Energy Efficiency—Intel® Intelligent Power Technology in Intel Xeon processors enables fine-grained, policy-based control of server energy states to optimize performance and power consumption across all workloads. It allows the operating system to put processor power and memory into the lowest available energy states needed to support current workloads without compromising performance. The processor independently manages individual cores, including putting one or more cores into low-power idle states as needed. These configurable capabilities help reduce power consumption, while reducing server idle power by up to 50 percent.[6] Most Java applications have a wide range of utilization patterns in production environments, so dynamically tailoring power consumption to the workload can often deliver significant power savings, with little or no impact on performance or response times. Intel Atom processors deliver very high energy efficiency through their system-on-chip (SOC) design with built-in power management. This makes them ideal for microservers where power efficiency is critical, while still meeting required service level agreements (SLAs).

Accelerated Array and String Operations—Intel® Advanced Vector Extensions (Intel® AVX) expands Streaming SIMD Extensions (SSE) instructions with wider vectors to improve floating-point operation performance. Java is used in a large number of math-intensive applications, including the management and analysis of Big Data. But, with the increasing width of Single Instruction, Multiple Data (SIMD) data and the richness of instructions not directly accessible to the Java programmer, Java has seen limited use where advanced floating-point intensive operations are common, such as high-performance computing and media processing. These areas can now benefit from the JVM's support for Intel AVX. Intel AVX also accelerates character encoding, string and array operations, and other mathematical functions.

Accelerated Encryption—Banking, healthcare, and other institutions often deploy Java applications that protect sensitive data during transit. But software-based encryption is a compute-intensive operation, so some organizations forego secure data transit in-house because of the performance degradation. To solve that problem, Intel® Advanced Encryption Standard – New Instructions (Intel® AES-NI) enables on-chip encryption and decryption in Intel server processors. Intel AES-NI speeds these operations as much 4X,[7] enabling wider use of data encryption and decryption without a performance penalty. Java applications can now benefit from much faster encryption and decryption based on hardware-enhanced Intel AES-NI in Intel processors.

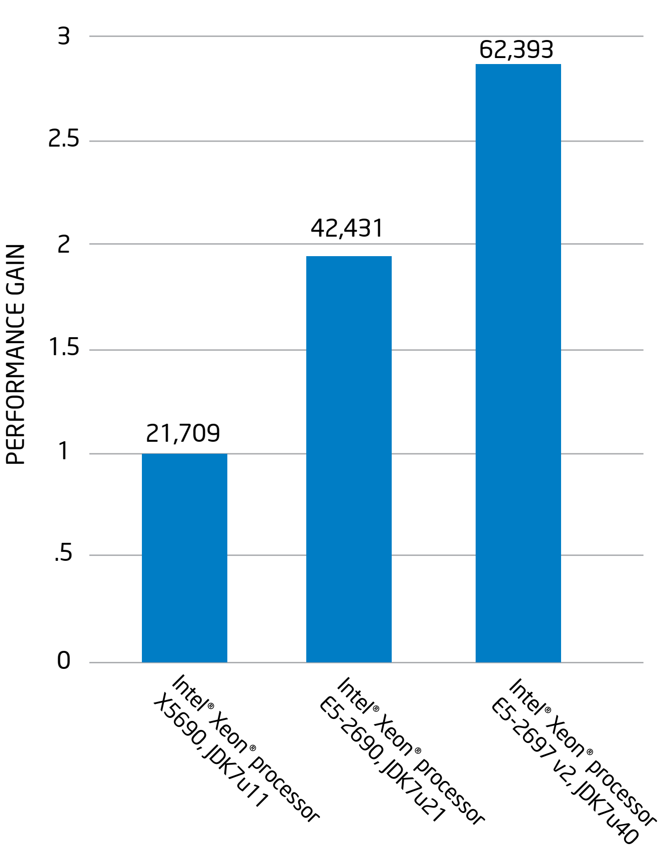

Figure 2. SPECjbb2013* performance gains across multiple generations of Intel® hardware and Java* Development Kit Software[1].

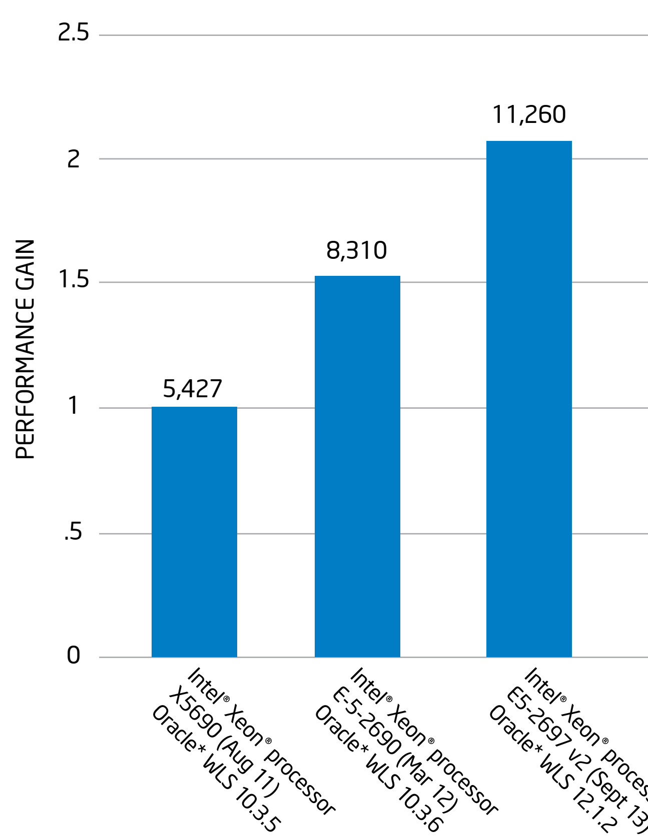

Figure 3. SPECjEnterprise2010* performance (EjOPS)[2] gains across multiple generations of Intel® hardware and Oracle* WebLogic Server* software[2].

Fast Cyclic Redundancy Check (CRC) Generation—With the explosion of high-speed networking—10 gigabit/second Ethernet (10GbE) networks are becoming commonplace—and the dramatic increase in storage demands over the past decade, CRC residue generation has become a problem. For file systems like the Hadoop Distributed File System (HDFS), where the processor must generate a CRC32 checksum at network speeds for every 512 bytes of data, a new PCLMULQDQ instruction accelerates CRC computations in Intel processors. Taking advantage of this new instruction in Java applications can improve Java performance for Big Data and other environments.

Optimizing the JVM to Maximize Performance Gains

Every major transition in processor microarchitecture and platform capability requires JVM developers to rethink their performance and optimization techniques to maximize the performance gains delivered by the new generation of servers. Enhancements in Intel Xeon processors and Intel Atom processors created many opportunities for Intel software engineers and Oracle JVM engineers to tune and optimize their code (Table 1).

OPTIMIZATION	DESCRIPTION	PERFORMANCE BENEFIT
LATEST-GENERATION INTEL® MICROARCHITECTURE OPTIMIZATIONS		
Intel® AES-NI	Silicon-based encryption/decryption acceleration	Increases data encryption performance for storage and network transactions, enabling wide use of encrypted data in transit
Intel® AVX	New 256-bit instruction set extensions to Intel® Streaming SIMD Extensions (Intel® SSE)	Improves the performance of floating-point operations and operations containing array and string manipulation
ISO 8859-1 encoding	Uses Intel AVX/Intel AVX2 to increase character encoding to 16 or 32 characters at a time, instead of character by character	Improves the performance of applications that use international string encoding
Fast CRC computation	New CRC generation algorithm using carry-less multiplication instruction and CRC32 instruction	Increases file checksum and compression/decompression checksum performance, which increases network and filesystem performance
OTHER MICROARCHITECTURE-SPECIFIC OPTIMIZATIONS		
Instruction decoding optimization	Removes length-changing prefixes and aligning branch targets	Allows the JVM to take advantage of new Intel microarchitecture performance features
Out-of-order execution optimization	Eliminates partial flag and partial register stalls	Allows the JVM to take advantage of new Intel microarchitecture performance features
Intrinsic function optimization	Optimizes the most common code paths	Reduces instruction count and cycles per instruction (CPI), which increases overall performance
GENERAL OPTIMIZATIONS		
Allocation pre-fetch	Caches additional memory ahead of the object being allocated	Increases critical code path performance
Large-page usage	Uses large memory pages for both code and data memory	Increases performance of large analytics jobs
Vectorization	Loads, operates on, and stores multiple array elements within a single machine instruction	Increases execution performance of widely used operations, which improves overall performance
Compressed references	Stores 32-bit compressed references for 64-bit pointers	Reduces memory footprint and cache misses while improving CPI
Lock optimization	Multi-tiered lock deferrals to avoid or delay inflation to fat locks for coincidental lock contention	Increases scalability through reduction of fat locks
CLASS LIBRARY OPTIMIZATIONS		
HashMap, TreeMap, BigDecimal	Optimizes commonly used functions	Improves performance by using caching and other optimizations to reduce path length and object allocation
String optimizations	Optimizes code generation for methods that are frequently used	Reduces intermediate object allocation for common operations, such as string comparisons

Table 1. JVM optimizations that help boost Java performance.

Developer Tools to Enhance Java Code Optimization

In addition to collaboration with Oracle on JVM development, Intel works with the entire ecosystem to help support developer implementations for maximum benefit on Intel processors. The Intel software packages discussed below are available for download at the Intel Developer Zone.

Network Security Services (NSS) Libraries

Intel has worked with the open source community to support new Network Security Services (NSS) libraries available for Linux*. These libraries now support Intel AES-NI in Java applications running on Linux-based browsers, like Mozilla Firefox*. These updated libraries help improve encryption/decryption performance. Updated libraries to support Intel AES-NI for Windows are expected in NSS 3.14.4 in the future.

Intel® vTune™ Amplifier Support for Oracle Java

Intel® vTune™ Amplifier helps developers optimize their code with code profiling and analysis tools for serial and parallel performance analysis. Intel vTune Amplifier now supports Oracle Java. Using Intel vTune Amplifier, Java developers can collect a rich set of data for their application to tune the CPU performance, multi-core scalability, bandwidth, and more. It provides tools to sort, filter, and visualize collected data for quick insight into performance bottlenecks in any Java application. Learn more at http://software.intel.com/en-us/intel-vtune-amplifier-xe/.

Intel Math Kernel Library Support for Java

Intel® Math Kernel Library (Intel® MKL) includes highly vectorized and threaded Linear Algebra, Fast Fourier Transforms (FFT), Vector Math, and Statistics functions. Through a single C or Fortran API call, these functions automatically scale across previous, current, and future processor architectures, by selecting the best code path for each. Using Java native interface, a Java application can also bind with Intel MKL and utilize its rich features. Intel MKL includes a set of Java examples to demonstrate the usage of MKL functions from Java.

Intel® Distribution for Apache Hadoop* Software

With the Intel® Distribution for Apache Hadoop* software (Intel® Distribution), Intel contributes to the application frameworks written in Java. The Intel Distribution is built from the silicon up to enable the widest range of data analysis on Apache Hadoop. It includes hardware-enhanced performance and security capabilities and enables a platform on which the entire ecosystem can build next-generation analytics solutions. Also the user can see increased performance using the latest Intel Xeon processors, Intel® Solid-State Drives (Intel® SSDs), and 10 Gigabit Intel® Ethernet Converged Network Adapters. You can learn more the Intel Big Data web site.

Summary

Java continues to be a strong force in all sectors and markets. Intel will continue enabling and optimizing Java by introducing enhancements to Intel processors and helping optimize Java performance on those technologies through collaboration with Oracle and the Java community.

Intel offers a wide range of servers and microservers based on Intel Xeon processors and Intel Atom processors that help deliver high performance for Java applications. By combining the right choice of server with an optimized JVM, enterprise IT departments and Cloud Service Providers can reap the following benefits:

- Improved user-response times with less infrastructure investment.
- Improved power/heat management, leading to lower utility costs.
- Improved information security capabilities.
- Ability to handle heavier workloads and more users with fewer servers.

For more information about Java and Intel's enabling efforts with Java, please visit the **Intel Java Resource Center.**

1 Benchmark performed using Specjbb2005 and SPECjbb2013. See http://www.spec.org for more details.
Configurations:
http://www.spec.org/jbb2005/results/res2013q4/jbb2005-20130911-01180.html
http://www.spec.org/osg/jbb2005/results/res2012q1/jbb2005-20120306-01056.html
http://www.spec.org/osg/jbb2005/results/res2010q3/jbb2005-20100629-00874.html
http://www.spec.org/osg/jbb2005/results/res2009q2/jbb2005-20090330-00702.html
http://www.spec.org/osg/jbb2005/results/res2008q1/jbb2005-20080208-00452.html
http://www.spec.org/jbb2013/results/res2013q4/jbb2013-20130917-00039.html
http://www.spec.org/jbb2013/results/res2013q3/jbb2013-20130723-00035.html
http://www.spec.org/jbb2013/results/res2013q1/jbb2013-20130205-00003.html

2 Based on SPECjEnterprise2010 published result."The SPECjEnterprise2010 benchmark is a full system benchmark which allows performance measurement and characterization of Java EE 5.0 servers and supporting infrastructure such as JVM, Database, CPU, disk and servers." -- http://www.spec.org/jEnterprise2010/
Configurations:
http://www.spec.org/jEnterprise2010/results/res2011q3/jEnterprise2010-20110727-00023.html
http://www.spec.org/jEnterprise2010/results/res2012q1/jEnterprise2010-20120208-00028.html
http://www.spec.org/jEnterprise2010/results/res2013q3/jEnterprise2010-20130904-00046.html

3 Available on select Intel® processors. Requires an Intel® HT Technology-enabled system. Consult your PC manufacturer. Performance will vary depending on the specific hardware and software used. For more information including details on which processors support HT Technology, visit http://www.intel.com/info/hyperthreading.

4 The 5-35 percent performance increase with Intel® Hyper-Threading Technology is based on internal Intel measurements using a wide variety of Java workloads and benchmarks.

5 Requires a system with Intel® Turbo Boost Technology. Intel Turbo Boost Technology and Intel Turbo Boost Technology 2.0 are only available on select Intel® processors. Consult your system manufacturer. Performance varies depending on hardware, software, and system configuration. For more information, visit http://www.intel.com/go/turbo.

6 Up to 50% lower platform idle power based on Intel internal measurement (Feb 2009). Configuration details: Intel internal measurements of 221W at idle with Supermicro 2xE5450 (3.0GHz 80W) processors, 8x2GB 667MHz FBDIMMs, 1x700W PSU, 1x320GB SATA hard drive vs. 111W at idle with Supermicro software development platform with 2xE5540 (2.53GHz Nehalem 80W) processors, 6x2GB DDR3-1066 RDIMMs, 1x800W PSU, 1x150GB 10k SATA hard drive. Both systems were running Windows 2008 with USB suspend select enabled and maximum power savings mode for PCIe link state power management.

7 Cross-client claim based on lowest performance data number when comparing desktop and mobile benchmarks. Configurations and performance test as follows:

Mobile - Comparing pre-production Intel® Core™ i5-2410M Processor (2C4T, 2.3GHz, 3MB cache), Intel Emerald Lake CRB, 4GB (2x2GB) PC3-10700 (DDR3-1333)-CL9, Hitachi* Travelstar 320GB hard-disk drive, Intel® HD Graphics 3000, Driver: 2185 (BIOS:v.34, Intel v.9.2.0.1009) , Microsoft* Windows* 7 Ultimate 64-bit RTM Intel® Core™2 Duo Processor T7250 (2M Cache, 2.00 GHz, 800 MHz FSB), Intel Silver Cascade Fab2 CRB, Micron* 4 GB (2x2GB) PC3-8500F (DDR3-1066)-400, Hitachi* 320GB hard-disk drive, Mobile Intel 4 Series Express Chipset Family w/ 8.15.10.2182 (BIOS: American Megatrends AM-VACRB1.86C.0104.B00.0907270557, 9.1.2.1008).

Desktop - Pre-production Intel® Core™ i5-2400 Processor (4C4T, 3.1GHz, 6MB cache), Intel Los Lunas CRB, Micron* 4GB (2x2GB) PC3-10700 (DDR3-1333)-CL9, Seagate* 1 TB, Intel® HD Graphics 2000, Driver: 2185 (BIOS:v.35, Intel v.9.2.0.1009), Microsoft* Windows* 7 Ultimate 64-bit RTM Intel® Core™ 2 Duo E6550 (2C2T, 2.33GHz, 4MB cache), Intel DG945GCL Motherboard, Micron 2GB (2x1GB) DDR2 667MHz, Seagate320 GB hard-disk drive, Intel® GMA 950, Driver: 7.14.10.1329, (BIOS:CL94510J.86A.0034, INF: 9.0.0.1011), Microsoft* Windows* 7 Ultimate 64-bit RTM.

Business productivity claims based on SYSmark* 2007, which is the latest version of the mainstream office productivity and Internet content creation benchmark tool used to characterize the performance of the business client. SYS-mark 2007 preview features user-driven workloads and usage models developed by application experts. Multitasking claims based on PCMark Vantage, a hardware performance benchmark for PCs running Windows 7 or Windows Vista, includes a collection of various single and multi-threaded CPU, Graphics, and HDD test sets with a focus on Windows* application tests. Security workload consists of Si Software Sandra* 2010 -AES256 CPU Cryptographic subtest measures CPU performance while executing AES (Advanced Encryption Standard) encryption and decryption algorithm. For more information go to http://www.intel.com/performance.

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance.

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