Maximize Performance and Scalability of RADIOSS* Structural Analysis Software on Intel® Xeon® Processor E7 v2 Family-Based Platforms

Executive Summary

Complex simulations of structural and systems performance, such as car crash simulations, require a massive number of computations. Today's simulation software relies on highly parallelized codes to take advantage of the large number of cores in high-performance computing (HPC) clusters to increase processing speed for such complex simulations.

Altair RADIOSS* software, optimized for Intel® Xeon® processors, uses Hybrid Massively Parallel Processing to deliver outstanding performance on a wide range of computing configurations, from smaller single-node workstations to more powerful clusters with thousands of cores.

To evaluate the performance and scalability of Altair RADIOSS on Intel® Xeon® processor E7-4890 v2, Altair benchmarked RADIOSS using a modified publicly available crash simulation model of a Chrysler Neon* passenger car on a single-node platform with 4 sockets/60 cores/120 threads and 256 GB of memory. RADIOSS was able to easily take advantage of all 60 cores, running the workload 2.75X faster than on a comparable 24-core platform based on Intel® Xeon® processor E5-2695 v2.

This paper summarizes the findings of the benchmark.

KEY BENCHMARK RESULTS:[1]

- 2.75x faster on single 60-core node
- 10x performance evolution from Intel® Xeon® processor 5100 series to Intel® Xeon® processor E5 v2 family
- Message Passing Interface (MPI) delivers excellent performance for single-node systems
- Hybrid Massively Parallel Processing supports massive scalability for large systems

Altair – Driving HPC and Engineering Innovation

Altair knows HPC. The company not only provides product design services, but also develops, uses, and markets their own HPC engineering simulation software, 3D industrial design suites, enterprise analytics solutions, and HPC management tools. Altair understands the needs and demands of companies who rely on computing clusters and compute-intensive applications to develop products and solve problems. The company's 30 year track record for high-end software and consulting services enables Altair to consistently deliver high-value software solutions for their 5000+ customers.

Intel and Altair – Optimizing HPC Solutions Together

Intel and Altair have a long history of collaboration, resulting in Altair software solutions designed and optimized for high-performance computing on Intel® architecture. Altair and Intel software developers continue to work closely to tune and optimize Altair codes using Intel® Parallel Studio XE suite, including Intel® MPI Library, Intel® Fortran and C/C++ compilers, Intel® Math Kernel Library, and Intel® VTune™ Amplifier, as well as other Intel products like Intel® Trace Analyzer.

Altair has worked closely with Intel to optimize message passing interface (MPI) codes in Altair PBS Works* and to certify PBS Professional* and RADIOSS*, OptiStruct*, and AcuSolve* solvers as Intel® Cluster Ready applications. PBS Professional supports the Intel® Xeon Phi™ coprocessor for accelerated problem solving on Intel architecture-based clusters.

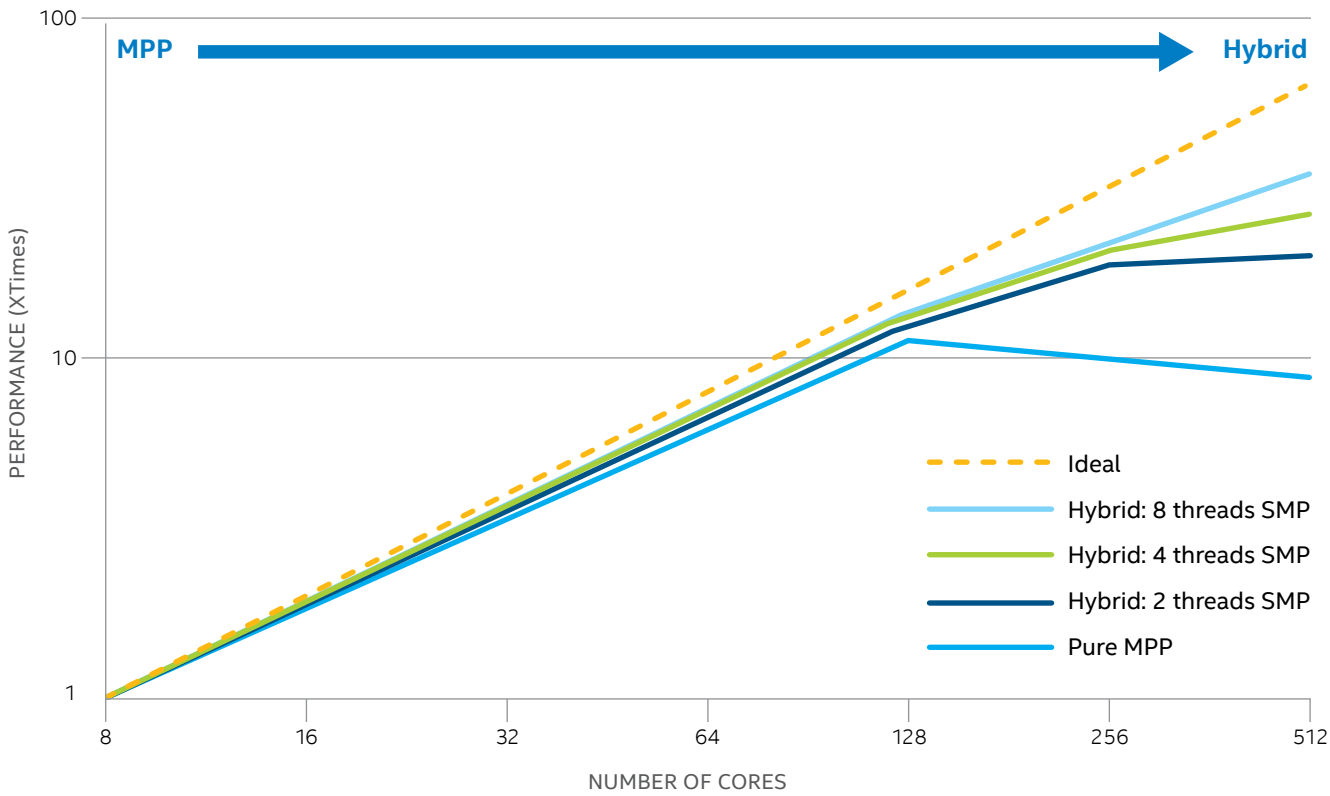

Figure 1. Hybrid Massively Parellel Processing (HMPP) enables scalability on large clusters.

About RADIOSS

Altair RADIOSS is a leading structural analysis solver for highly non-linear problems under dynamic loads. For over 25 years, RADIOSS has established itself as a leader and industry standard for automotive crash and impact analysis. Companies around the world and across all industries use RADIOSS to improve the crashworthiness, safety, and manufacturability of their structural designs.

The software is known for scalability, quality, and robustness, as well as for providing multi-physics simulation capabilities and supporting advanced materials, such as composites.

Optimized for Parallelism

Altair has optimized RADIOSS to take advantage of multi-core Intel® processors in systems ranging from single-node platforms to large clusters. Using Hybrid Massively Parallel Processing (HMPP), Altair engineers combined MPI with OpenMP coding to create a multi-level parallelism model, which enables high scalability and allows users to fine tune RADIOSS to the workload and hardware the software runs on (Figure 1).

The result is superior performance and flexibility for a wide range of structural analysis problems on RADIOSS running on systems of any size.

RADIOSS Performance on Intel® Xeon® Processors

Working with Intel engineers over the years to achieve key hardware and software optimizations, Altair developers have continually improved RADIOSS performance on Intel architecture, resulting in a 10X performance increase from Intel® Xeon® processor 5100 series to Intel Xeon processor E5 v2 family (Figure 2). These expanding core counts on Intel® processor-based platforms continue to deliver unmatched RADIOSS scalability. Indeed, a single node today can deliver the performance of large clusters from just a few years ago.

Benchmarking RADIOSS on Intel® Xeon® Processor E7-4890 v2

Altair has benchmarked RADIOSS performance in numerous scenarios using a modified version of a publicly available model of the Chrysler Neon (see Figure 7). This freely available model has been used in previous benchmarks in the automotive industry; the modified version has 1 Million elements versus the public version's only 270,000 elements. By today's standards this is a moderately-sized model. Note that a car crash is a short term event lasting only 80 milliseconds (ms) in the present case.

The model was run with RADIOSS on a 60-core, single-node platform based on the Intel Xeon processor E7-4890 v2. RADIOSS performed beyond expectations during these benchmarks, revealing the benefits possible for accelerating time to solution of complex crash simulations for smaller systems, in addition to large HPC clusters.

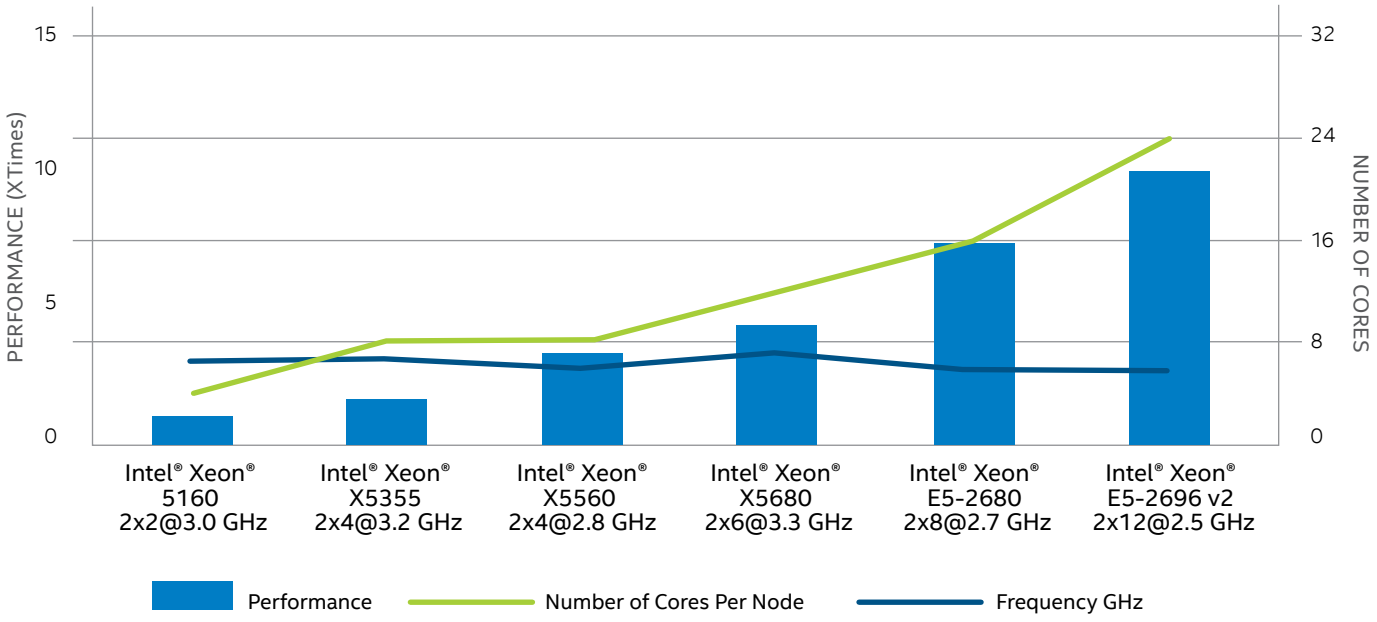

Figure 2. RADIOSS single-node performance evolution for Intel® processor-based platforms.

Intel Xeon Processor E7-4890 v2

The Intel Xeon processor E7-4890 v2 integrates 15 cores with Intel® Hyper-Threading technology[2] (30 simultaneous threads), 37.5 MB of cache, three 8 gigatransfer-per-second (GT/s) Intel® QuickPath Interconnect (Intel® QPI) links, and Intel® Advanced Vector Extensions[3]/(Intel® AVX) onto a single 22nm-process die. Built into a 4-socket platform with 256 GB of memory, this configuration offers highly scalable performance for complex simulations using RADIOSS.

With 60 cores and 120 threads, Altair was able to analyze the capabilities of HMPP and the response from a large number of cores on a node. At low node counts, pure MPI generally outperforms HMPP, while at high core counts, it is advised to use only one MPI per socket with a number of OpenMP threads that matches the number of cores per socket.

Test Platforms

The systems used for testing are listed in Table 1.

Key Findings

The benchmarks showed outstanding performance, revealing the efficiency of RADIOSS on Intel Xeon processor E7-4890 v2-based platform for systems with just a few nodes.

Pure MPI Parallelism Benchmarking

Using only MPI parallelism, RADIOSS processed the benchmark simulation 2.75X faster on the 4-socket Intel Xeon processor E7-4890 v2-based platform than on the 2-socket platform based on Intel Xeon processor E5-2695 v2 with a total of 24 cores (Figure 3).

HMPP Benchmarking

Hybrid MPP parallelization makes it possible to maintain scalability when pure MPI efficiency drops (when the number of MPI domains and associated inter-MPI communication cost increase) – i.e., for systems with higher core counts. Using HMPP, RADIOSS has shown to be highly scalable and incredibly efficient on large HPC clusters up to thousands of cores (Figure 4). Depending on the hardware platform, users can adjust decomposition of their problems across MPI domains, while maximizing performance across cores with multi-threading based on OpenMP.

At a high number of cores, a configuration that runs one MPI process per socket and executes as many OpenMP threads as the number of cores per socket has shown to deliver optimal scalability. As illustrated in Figure 4,

	Intel® Xeon® processor E5-2695 v2 product family-based platform	Intel® Xeon® processor E7-4890 v2 product family-based platform
CPU	Intel Xeon processor E5-2695 v2	Intel Xeon processor E7-4890 v2
# sockets	2	4
# cores/thread	12/24	15/30
Total cores/threads	24/48	60/120
Cache	30 MB	37.5 MB
Memory	128 GB; 1600 DDR3	256 GB; 1600 DDR3
Frequency	2.5 GHz	2.8 GHz

Table 1. Benchmarking Test Platforms.

scalability with pure MPI drops after 16 nodes, while for HMPP with 8 OpenMP threads per MPI, RADIOSS continues to scale up to 64 nodes. Thus, with HMPP, it is possible to scale up to 1,024 cores even when running a moderately sized model of 1 million elements.

For smaller systems, Altair believes that because of Altair's optimized codes and high efficiency communications of the Intel Xeon processor E7-4890 v2-based platform, single-domain decomposition under MPI delivers the best computational performance (best data locality). By using the Intel MPI Library, which is optimized to take advantage of the virtual shared memory of the Intel Xeon processor E7 family, the communication cost on the 4-socket platform stays extremely low.

Hyper-Threading

Intel® Hyper-Threading technology provides an additional approximate 5 percent performance boost when activated, by taking advantage of all 120 threads. Hyper-Threading is particularly well suited on single node systems. As shown in Figure 5, Altair used HMPP with 2 OpenMP threads per MPI to take advantage of the 2 threads per cores available with Hyper-Threading.

Single-Versus Double-Precision Floating-Point Benchmark

Comparisons between single-precision (SP) and double-precision (DP) floating-point showed that RADIOSS performed up to 1.5X better overall with single precision on a single-node system. Here, too, Intel Hyper-Threading technology offers a 5 percent gain in performance.

Note: The standard version of RADIOSS uses double-precision FP. Altair has developed a single-precision FP version which enables users to improve performance by a ratio of around 1.5X. This is an extended single-precision version, which continues to use double-precision at certain critical places, keeping very good accuracy, while maximizing performance.

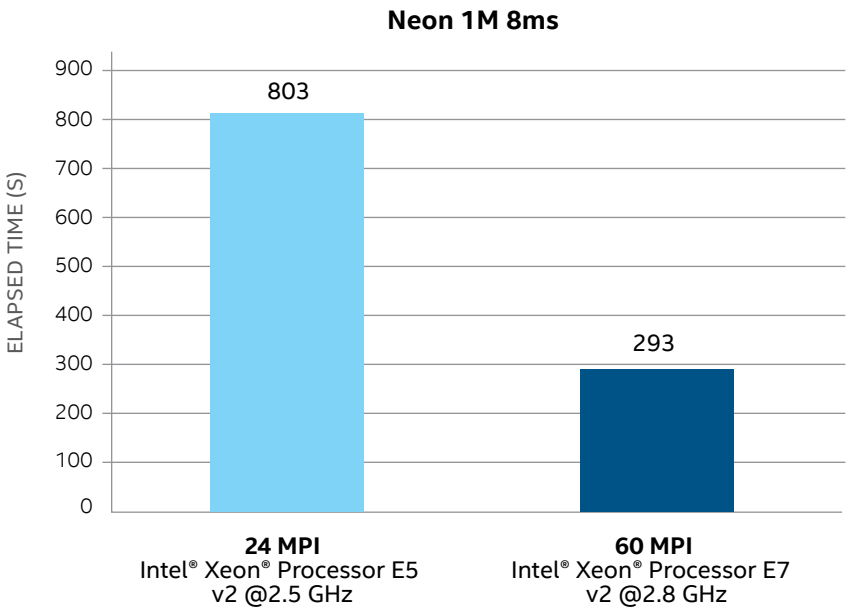

Figure 3. Scalability improvement on Intel Xeon processor E7-4890 v2.

RADIOSS DIFFERENTIATORS:

- Optimization-enabled crash simulation, including advanced materials such as composites.
- High scalability due to advanced multi-processor solution—Hybrid Massively Parallel Processing (HMPP).
- High quality formulation and complete material and rupture library.
- Fully repeatable results, regardless of number of cores, nodes, or threads used in parallel computation.
- Full integration with Altair's PBS Professional* for HPC workload management.

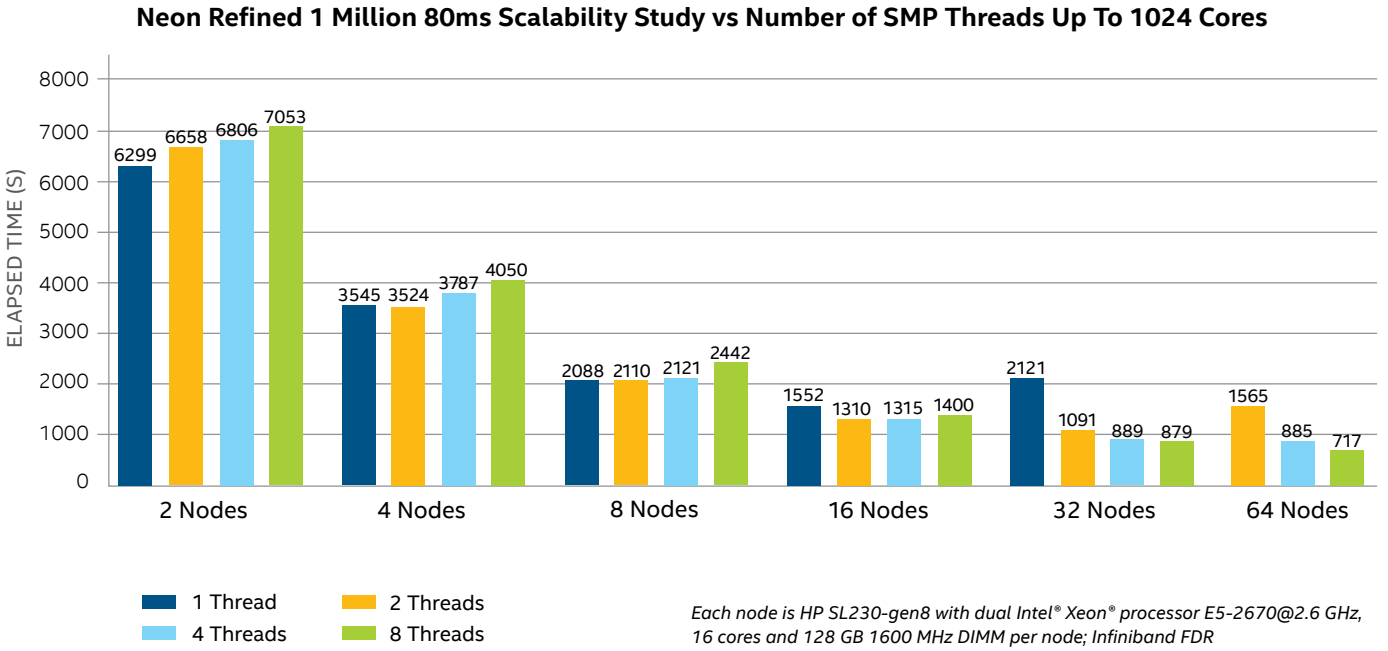

Figure 4. Tuning HMPP performance for RADIOSS across clusters.

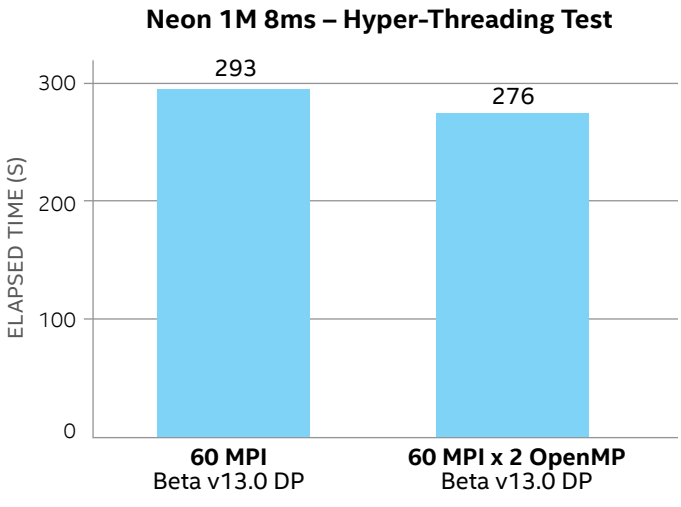

Figure 5. Tuning HMPP performance with Hyper-Threading.

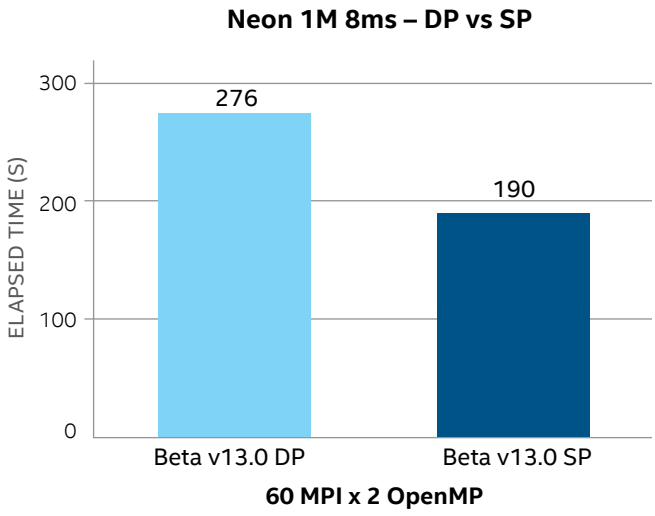

Figure 6. Double Precision (DP) versus Single Precision (SP) Performance comparison (with Hyper-Threading enabled).

Conclusion

Optimized for massively parallel processing on Intel Xeon processors, Altair RADIOSS software delivers highly scalable performance by taking advantage of all the system's cores. RADIOSS performs well on both small and large systems, making it an ideal solution for businesses stepping up from a workstation to something more powerful to run compute-intensive simulations.

Benchmarks using the modified crash model of a Neon car with 1 Million elements in an 80ms crash show that, when run on an Intel Xeon processor E7-4890 v2 product family-based platform with 60 cores and 120 threads, the software scales well due to the high efficiency of the hardware and optimization of the code for the Intel architecture.

For companies looking to refresh their technical computing for running RADIOSS, whether on a single workstation or a large cluster, now is the time to consider an Intel Xeon processor-based platform or cluster to take advantage of the scalability and optimizations for performance of RADIOSS on Intel architecture.

For more information on the Intel Xeon processor family, visit www.intel.com/content/www/us/en/servers/server-products.html.

For more information about Altair's collaboration with Intel, visit www.altair.com/partner-intel.

Figure 7. Modified Chrysler Neon* model (1 million elements) used in RADIOSS* crash simulation benchmark testing.

[1] 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. For more complete information about performance and benchmark results, visit Performance Test Disclosure.

[2] 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.

[3] Intel® Advance Vector Extensions (Intel® AVX) and Intel® Advance Vector Extensions 2 (Intel® AVX 2) are designed to achieve higher throughput in certain integer and floating point operations. Intel® AVX and Intel® AVX 2 instructions may run at lower frequency to maintain reliable operation. Consult your system manufacturer. Performance may vary depending on hardware, software, and system configuration. For more information see product specification update.

INFORMATION IN THIS DOCUMENT IS PROVIDED IN CONNECTION WITH INTEL® PRODUCTS. NO LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT. EXCEPT AS PROVIDED IN INTEL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, INTEL ASSUMES NO LIABILITY WHATSOEVER, AND INTEL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY, RELATING TO SALE AND/OR USE OF INTEL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT. UNLESS OTHERWISE AGREED IN WRITING BY INTEL, THE INTEL PRODUCTS ARE NOT DESIGNED NOR INTENDED FOR ANY APPLICATION IN WHICH THE FAILURE OF THE INTEL PRODUCT COULD CREATE A SITUATION WHERE PERSONAL INJURY OR DEATH MAY OCCUR.

Intel may make changes to specifications and product descriptions at any time, without notice. Designers must not rely on the absence or characteristics of any features or instructions marked "reserved" or "undefined." Intel reserves these for future definition and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them. The information here is subject to change without notice. Do not finalize a design with this information.

The products described in this document may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request. Contact your local Intel sales office or your distributor to obtain the latest specifications and before placing your product order. Copies of documents which have an order number and are referenced in this document, or other Intel literature, may be obtained by calling 1-800-548-4725, or by visiting Intel's Web site at www.intel.com.

Copyright © 2014 Intel Corporation. All rights reserved. Intel, the Intel logo, VTune, Xeon, and Intel Xeon Phi are trademarks of Intel Corporation in the U.S. and/or other countries.

*Other names and brands may be claimed as the property of others. Printed in USA 0414/DW/HBD/PDF ♻ Please Recycle 330525-001US