

Oracle Database and Analytics on Intel® Architecture

Collaboration between Intel and Oracle empowers analytics workloads with cost savings, security, and efficiency—leading to innovation and optimization

This solution brief describes how to solve business challenges through investment in innovative technologies.

If you are responsible for...

- **Business strategy:** You will better understand how Oracle Database and analytics on Intel® architecture will enable you to successfully meet your business outcomes.
- **Technology decisions:** You will learn how Oracle Database and analytics on Intel® architecture work to deliver IT and business value.

Executive Summary

Faster analytics. More efficient operations. Enhanced security. Lower costs. These are some of the characteristics enterprises are looking for in a next-generation database for their real-time online analytics processing (OLAP) and online transaction processing (OLTP) workloads. Oracle is the leader in database management systems^{1,2,3} and Oracle Database 18c* is the newest and most advanced database innovation from Oracle. It is also the latest example of the jointly engineered solutions that Intel and Oracle have been developing for the past 20 years. Oracle Database 18c is the foundation for Oracle's vision of a fully automated database platform that supports diverse on-premises and cloud workloads.

Oracle Database 18c is a next-generation database designed for the cloud, with a new multitenant architecture that runs on a fast, scalable, and security-enabled database platform. Whether plugging into the cloud or their own data center, customers using Oracle Database 18c can improve the quality and performance of both new and existing applications, save time with optimal availability architecture and storage management, and simplify their database consolidation efforts by managing several hundreds or thousands of databases as one.



FASTER COMPLETION OF DATABASE TRANSACTIONS

with Intel® Xeon® Scalable processor compared to prior generation Intel Xeon processor.⁴



MORE SECURE AND MORE COMPLEX ANALYSES

of large datasets across mission-critical online transaction processing, data storage, mixed database, and emerging analytics/artificial intelligence workloads.



SIMPLIFY AND OPTIMIZE INFRASTRUCTURE

across hardware, storage, software, and application layers, delivering greater consolidation, performance, and scale from hybrid cloud to your data center.

Author

Ashis Chatterjee

Enterprise Analytics/AI Scale Manager
Intel Data Center Group

Figure 1. Oracle Database 18c* and analytics with Intel® Xeon® Scalable processors and Intel® storage technologies are engineered to work together.

Solution Benefits

- **Cost savings and efficiency** result from multitenant database architecture, where a single instance of Oracle Database 18c* software can run hundreds of individual databases.
- **Reliability, availability, and serviceability (RAS)** features are empowered by Intel® Xeon® Scalable processor-based technologies.
- **Virtually unlimited scalability** can be achieved for large research and governmental projects.
- **Long-term collaboration** between Intel and Oracle yields a highly optimized system that can boost the performance of virtually any real-time analytics workload.

The database features in-memory capabilities and is powered by advanced analytics and machine learning to deliver self-driving, self-securing, and self-repairing administration that result in significant reduction in database downtime. The goal is to minimize human labor, human error, and manual tuning to deliver high availability, high performance, and enhanced security while lowering costs.

Oracle and Intel have worked closely throughout the development of Oracle Database 18c and customers can depend on optimal performance when Oracle Database 18c runs on Intel® technology. Customers can use customized servers from a variety of partners or Oracle engineered systems such as Oracle Exadata and Oracle Database Appliance. Together, Oracle and Intel work to provide optimal performance, security, scalability, and energy efficiency.

Business Challenge: Increasing the Pace and Efficiency of Analytics

With data streaming into the data center and the cloud from the Internet of Things (IoT), social media, clickstreams, and more, enterprises find themselves needing faster techniques for online transaction processing (OLTP) and online analytics processing (OLAP) workloads that provide real-time streaming analytics capabilities. Traditional databases can't meet the current streaming analytics needs of most enterprises.

Also, many organizations run multiple databases on a single server to handle escalating amounts of big data. With traditional, multi-instance database architecture, each of those databases requires separate memory and processes—resulting in escalating costs, high memory usage, time-consuming management and backup, inflexibility, and a variety of additional operational challenges.

Increasingly, enterprises are turning to Oracle to solve these challenges. Oracle is a recognized leader in the advanced and predictive analytics field (see Figure 2). Oracle's new database, Oracle Database 18c, includes in-memory capabilities, which means analysts can access data much faster compared to traditional disk-based systems.^{6,7}

And because Oracle Database 18c is optimized for the underlying Intel® technologies, it can accelerate analytics even further. Enterprises are also attracted by Oracle Database 18c's multitenant architecture that can significantly increase operational efficiency.

Analytics with Oracle Database 18c Benefits Many Industries

Who benefits from Oracle Database 18c isn't so much defined by the industry but rather by the need for performance and scalability. Does your application demand lightning-fast data access, lots of data storage and manipulation, and vast quantities of data? If so, then Oracle Database 18c, optimized to run on Intel® architecture, can help accelerate your OLTP and OLAP workloads. Examples include many real-time applications, such as recommendation engines, banking, cloud gaming, affinity marketing, fraud detection using natural language processing and cognitive computing, medical analytics, analysis of streaming sensor data, and geospatial processing.



Oracle is a leader in database managements systems.^{1,2} Oracle is also a leader in Gartner's Magic Quadrant for Enterprise Integration Platform as a Service.⁵



Oracle has been the leader in the database management and analysis category for 20 years and counting, according to Statista.³



In 2016, Oracle led the category for advanced and predictive analytics with over 45% market share, or nearly 2x that of the next closest competitor.²

Figure 2. The close collaboration between Oracle and Intel has strengthened Oracle's leadership in database management for advanced and predictive analytics.

Solution Value: A Multitenant Database for Today's Analytic Workloads

Oracle Database 18c sets a new standard for modern databases, as described in the following sections.

Multitenancy for Operational Efficiency

Oracle Database 18c is a revolutionary departure from traditional databases—it allows multiple databases to run under a single instance of the Oracle database software. In other words, Oracle is the first database to offer multitenancy at the database—not the application—layer, which makes it an ideal foundation for cloud computing with the potential for massive cost savings and business agility. Oracle Database 18c with Intel® Xeon® Scalable processors addresses the key challenges of customers who are consolidating their databases in a private cloud model—enabling improved efficiency and lower management costs, while retaining the autonomy of separate databases. See [Solution Architecture](#) for additional details.

In-Memory Column Store for Real-Time Analytics

One of the flagship features of Oracle Database 18c is the performance benefit of in-memory column store. In-memory database support is critical for today's real-time analytics applications. In-memory applications benefit especially from the performance optimizations in the Intel Xeon Scalable processor, including Intel® Advanced Vector Extensions 512 (Intel® AVX-512). Figure 3 shows how in-memory decision

support benefits from enabling Intel AVX-512 on the Intel® Xeon® Platinum 8168 processor, with a 20 percent performance boost compared to the previous generation of vector extensions—Intel® Advanced Vector Extensions 2 (Intel® AVX2)—on the same processor.⁶ Figure 3 also shows how the in-memory decision support benefits from enabling Intel AVX-512 on the Intel Xeon Platinum 8168 processor, with a 30 percent performance boost compared to the previous generation of Intel Xeon processor.⁷ Improvements are due to higher core count, higher memory bandwidth, higher frequency, and new core technology in the latest Intel Xeon Scalable processor-based platforms. Intel is continuing to work with Oracle on in-memory databases and real-time analytics by adding new instructions and optimizing where needed.

“Oracle Database 18c innovations, optimized for Intel® architecture, let you plug into the cloud or perform on-premises maintenance for advanced analytics and online transaction processing (OLTP) with low processing and memory overhead. The performance and energy efficiency of Intel Xeon processors helps scale critical information processing at any company.”

Sujan Kamran

General Manager, Data Center Sales and Marketing Group,
Oracle Account Team, Intel Corp.

Oracle Database 18c* In-Memory Performance

Workload: Oracle Database In-Memory Decision Support (DS)

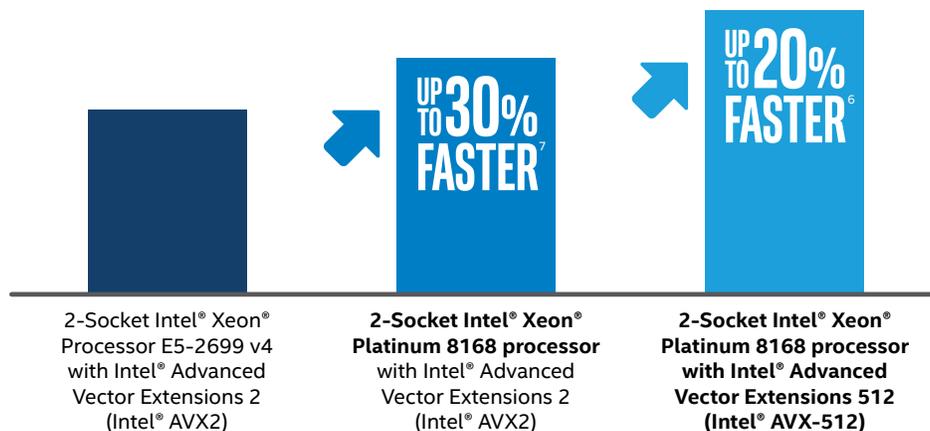


Figure 3. By upgrading to the latest generation of Intel® Xeon® processor, then enabling Intel® Advanced Vector Extensions 512 (Intel® AVX-512), the in-memory performance of Oracle Database 18c* improves significantly.^{6,7}

Additional Key Features and Benefits of Oracle Database 18c* with Intel® Xeon® Scalable Processors

In addition to the scalability and performance benefits, Oracle Database 18c with Intel Xeon Scalable processors can help organizations dramatically decrease their hardware and operational costs; increase resource utilization; and accelerate database provisioning, upgrades, patching, and cloning. Here are some additional advantages of Oracle Database 18c:

- **Faster, simpler analytics.** With up to a 1.6X performance benefit over the previous generation of Intel Xeon processor,⁴ Oracle Database 18c running on Intel Xeon Scalable processors lets customers complete more complex analyses in less time. In addition, data scientists can take advantage of new in-database predictive algorithms to enhance analysis of enterprise information and big data.
- **More uptime.** Oracle Database 18c introduces several high-availability features, as well as enhancements to existing technologies that enable continuous access to enterprise data. Routine administrative tasks are automated, minimizing human error. The Oracle Database 18c is:
 - **Self-driving**—users simply define workloads and policies, and database automation makes them happen
 - **Self-securing**—protection from both external attacks and internal users
 - **Self-repairing**—automated protection from downtime
- **Comprehensive security platform.** Oracle Database 18c features security innovations that benefit from Intel Xeon Scalable processors. Preventive, detective, and administrative protections include advanced encryption without interfering with native database security features such as auditing and redaction.
- **Efficient database management.** Seamless integration with Oracle Enterprise Manager Cloud Control* enables administrators to easily implement and manage new Oracle Database 18c functionality, including the new Oracle multitenant architecture and data redaction.
- **Simplified infrastructure.** Optimizations across all layers of the platform, from hardware to application, make it easier to scale whether it's in a private data center or in the cloud.
- **Enhanced storage efficiency.** Along with optimized compute, Oracle Database 18c features storage innovations that optimize storage compression and simplify management, including built-in database heat maps, compression algorithms, and automated data tiering and compression. With both storage and compute optimized and virtualized, Oracle Database 18c provides an ideal database-as-a-service (DBaaS) or cloud platform.
- **Compatibility.** Oracle Database 18c works with all Oracle Database features, including Real Application Clusters, Partitioning, Data Guard, Compression, Automatic Storage Management, Real Application Testing, Transparent Data Encryption, Database Vault, and more.

Advantages of Running Oracle Database 18c* on Intel® Xeon® Scalable Processors

Servers based on Intel® Xeon® processors are designed for optimal database performance. The Intel Xeon processor Scalable family, for instance, is a good choice for mission-critical operations such as back-end and in-memory databases. The four-socket configuration is ideal for virtualization, while the powerful eight-socket configuration works well for deployment and consolidation of large, monolithic databases. The extensive feature set provides support for error detection, correction, containment, and recovery in all processors, memory, and I/O data paths.

Oracle Database 18c* benefits from several Intel Xeon Scalable processor features:

- **Accelerated encryption** with Intel® Advanced Encryption Standard – New Instructions (Intel® AES-NI), which implements some sub-steps of the AES algorithm in the hardware. This enables fast and secure data encryption and decryption. **Intel® Advanced Vector Extensions 512 (Intel® AVX-512)** further optimizes and accelerates encryption and decryption of data—providing fast, affordable, and enhanced data protection compared to software-only protection.⁸ Oracle Database was one of the first enterprise applications to adopt Intel AES-NI.⁸ By deploying Intel Xeon Scalable processors with enabled software solutions such as Oracle Database 18c, enterprises can significantly reduce the historical performance penalty for data encryption and decryption, making it possible to enhance data protection throughout the enterprise and comply with regulatory requirements. Because data is automatically encrypted and decrypted as it is written to or read from disk, data at rest is protected against unauthorized access without costly changes to database applications.
- **Mesh architecture** maximizes performance between all CPU cores/threads and memory.
- **Flexibility and scalability** with up to 28 cores per socket, available in a two-, four- or eight-socket configuration.
- **Large memory capacity** with up to 12 TB of memory per server.
- **Oracle reliability, availability, and serviceability (RAS) features** such as sparing and mirroring help ensure faster and more reliable memory performance. Intel® Run Sure Technology maximizes uptime for mission-critical workloads.
- **Intel® Ultra Path Interconnect (Intel® UPI)** speeds data transfers by connecting distributed shared memory, the internal cores, the I/O hub, and other Intel® processors.

Solution Architecture: High-Performance Database Supports Real-Time Analytics

The Oracle Database 18c (see Figure 4) is the foundation for autonomous cloud databases for data warehousing, relational, OLTP, Apache Hadoop*, and NoSQL workloads. By utilizing machine-learning techniques, the Oracle Database can deliver a level of performance and reliability that manually managed databases struggle to handle.

The Oracle Database 18c is a multitenant container database (CDB), which means a single consolidated database can host many so-called “pluggable” databases (PDBs) that hold user and application data while being independent from the CDB. The multitenancy can be done without requiring changes to existing applications.

Each database consolidated or “plugged in” to a CDB appears to applications the same as for pre-multitenant Oracle databases. By consolidating multiple databases into a multitenant container, many pluggable databases share the container memory and processor resources, thereby enabling a greater level of database consolidation density. In addition, all PDBs in a CDB are all effectively “managed as one” for database backup, patching, upgrading, and standby operations. This is a fundamental feature in OLTP use cases.

With Oracle Database 18c, memory, storage, and processes are required at the CDB level only, and DBaaS cloud deployments are far more efficient because each customer's data is secured in a private PDB.

Even as it prepares the data center for the move to cloud computing, Oracle Database 18c also simplifies management, which is a significant advantage for organizations that are now managing hundreds, or even thousands, of databases on-premises. Oracle Database 18c does not require changes to applications or a steep learning curve for database administrators, so they can manage more databases in less time with fewer software installations and patches over the lifetime of applications.

The Intel team worked closely with Oracle to design and test enhancements to support Intel Xeon Scalable processors. Long before the database was released, Intel teams were working with Oracle to optimize Oracle Database 18c for exceptional performance on servers based on Intel Xeon Scalable processors and Intel® storage technologies. The optimizations in Oracle Database 18c include:

- **Performance improvements.** Intel and Oracle have been collaborating to optimize the multiple performance features in Intel Xeon Scalable processors over several years.
 - **In-memory distributed real-time analytics.** Oracle Database 18c's in-memory enhancements significantly speed up real-time analytics, delivering performance similar to having an index on every column, but without the index overhead. Intel and Oracle worked together to optimize these features in Oracle Database 18c.

Advantages of Intel® Optane™ and 3D NAND Solid State Drives

Intel and Oracle collaborate to enable utilization of Intel® Solid State Drive (Intel® SSD) capabilities and Intel® Optane™ technology. They also work together to ensure that future Intel SSD designs are optimized for performance with Oracle solutions.

Intel Optane SSDs and Intel 3D NAND SSDs provide numerous advantages over rotating storage⁹, including:

- **Lower failure rates.** Intel SSDs experience lower failure rates than traditional hard drives.
- **Faster performance.** Intel SSDs perform much faster than hard disk drives.
- **Advanced security.** Intel SSDs feature built-in encryption.
- **Greater reliability.** Like all SSDs, Intel SSDs have no moving parts, making them more durable in the event of drops or earthquakes, and are generally longer-lasting than traditional hard drives.

Oracle Database 18c* Solution Architecture

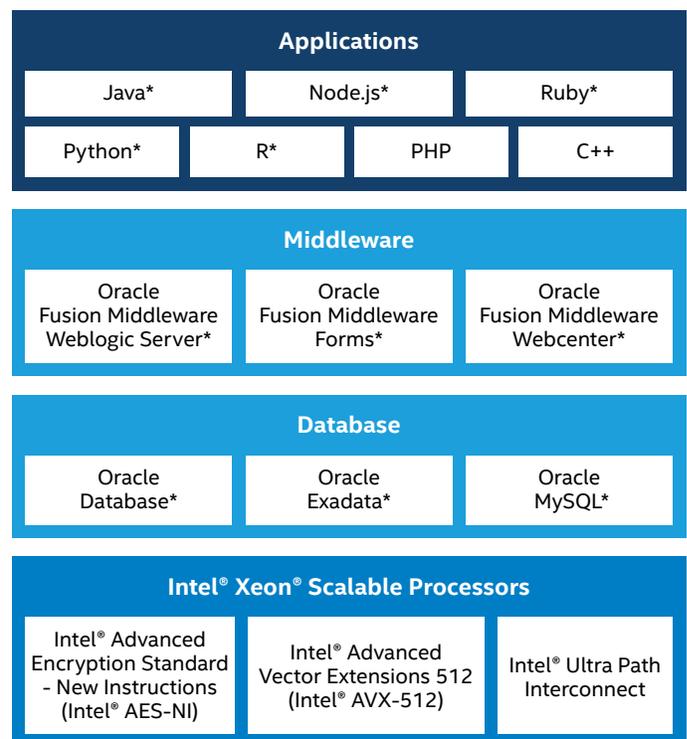


Figure 4. Oracle Database 18c*, as well as other Oracle databases, supports a wide range of applications and is optimized to run on Intel® Xeon® Scalable processors.

- **Memory-optimized performance.** Oracle Database 18c is equipped to take advantage of Intel Xeon Scalable processor mesh architecture and faster interconnects to improve performance of state-of-the-art algorithms for in-memory scans. Joins and aggregations needed for data analytics and mixed-workloads benefit from these. Close collaboration was required to optimize and take advantage of these memory-intensive features.
- **Enhanced scalability.** Oracle Database 18c benefits from reliability, availability, and serviceability (RAS) feature improvements in Intel Xeon Scalable processors, working with Oracle Database features like native database sharding. Oracle offers native database sharding for massive scalability and reliability for transactional applications. This also enables features such as Zero Data Loss Recovery Appliance, which is a standardized system for the backup and recovery process of Oracle databases throughout the enterprise.
- **Enhanced security.** Oracle Database 18c benefits from the improved security features in Intel Xeon Scalable processors. Intel and Oracle collaborated to enable and optimize Oracle Database security features like transparent data encryption (TDE), dynamic data masking, defense and auditing mechanisms, encryption, and key management. These features are enabled using Intel® Advanced Encryption Standard – New Instructions (Intel® AES-NI) instructions in Intel Xeon processors.⁸

Solution Configuration: Recommended Configuration Based on Intel® Architecture

Table 1 provides the recommended solution configuration (compute and storage) for Oracle Database 18c. The platform components shown in Table 1 take advantage of powerful Intel Xeon Scalable processors and Intel® Solid State Drives (Intel® SSDs) that can support demanding OLAP and OLTP workloads.

Table 1. Oracle Database 18c* Solution Configuration for Compute and Storage Nodes Using Intel® Xeon® Scalable Processors and Intel® Solid State Drives

Component	Compute Node(s)	Storage Node(s)
Server Configuration	Two-socket (2S), four-socket (4S), or eight-socket (8S) Note: The 4S and 8S configurations support more reliability, availability, and scalability (RAS) features.	Two-socket
Processor (CPU)	Choose from the following: <ul style="list-style-type: none"> • Intel® Xeon® Platinum 8180 processor • Intel Xeon Platinum 8170 processor • Intel Xeon Platinum 8168 processor • Intel® Xeon® Gold 6154 processor 	Choose from the following: <ul style="list-style-type: none"> • Intel® Xeon® Silver 4114 processor • Intel Xeon Silver 4116 processor
Memory	Choose from the following: <ul style="list-style-type: none"> • 192 GB • 384 GB • 878 GB • 1,536 GB 	Choose from the following: <ul style="list-style-type: none"> • 96 GB • 192 GB
Intel® Solid State Drives (Intel® SSDs)	Choose from the following: <ul style="list-style-type: none"> • Intel SSD Data Center (DC) P4500 Series • Intel SSD DC P4600 Series • SATA SSD Note: For the OS disk, use a RAID 1 configuration.	Choose from the following: <ul style="list-style-type: none"> • Intel SSD DC P4500 Series • Intel SSD DC P4600 Series • SATA SSD Notes: For the OS disk, use RAID 1. For hot data or the journal disk, use one Intel® Optane™ SSD DC P4800X Series. For warm or hot data, use 4 to 24 drives.
Network	Choose either 40 GbE, 25 GbE, or 10 GbE InfiniBand* Note: Separate the storage network and database inter-connect network.	
Storage Software	Oracle: Automatic Storage Management* (ASM*) and Logical I/O (LIO) Others: Dell EMC ScaleIO*, NetApp*, Ceph*, VMware VSAN*, or additional choices from the ecosystem	

Close Collaboration Delivers Results

Oracle Database 18c lays the foundation for autonomous databases and analytics and is a huge leap forward in database technology. Intel technology, such as Intel Xeon Scalable processors, interconnects, and storage solutions, combined with close collaboration between Intel and Oracle delivers significant enhancements in performance, efficiency, security, and scalability.

The close, long-term collaboration between Intel and Oracle also means that Oracle's latest innovations have already been tested on Intel Xeon Scalable processors and are optimized to deliver excellent performance. Customers looking for a reliable, efficient, and high-performing foundation for on-premises or cloud-based OLTP and real-time analytics don't need look any further.

Find the right solution for your organization.
Contact your Intel representative.

Learn More

You may also find the following resources useful:

- [Oracle Database 18c*](#)
- [Oracle Intel x86 Collaboration](#)
- [Intel® Data Center Products](#)
- [Intel® Xeon® Scalable Processors](#)
- [Intel® Optane™ Technology](#)
- [Intel® Solid State Drives](#)

Solution Provided By:



¹ The Forrester Wave™: Enterprise BI Platforms with Majority Cloud Deployments, Q3 2017. reprints.forrester.com/#/assets/2/132/RES137263/reports

² 2016 Commercial Database Market Share. seekingalpha.com/article/4044813-death-commercial-database-oracles-dilemma

³ "Ranking of the most popular database management systems worldwide, as of February 2018." statista.com/statistics/809750/worldwide-popularity-ranking-database-management-systems

⁴ **Baseline configuration:** 1 node, 2x Intel® Xeon® Processor E5-2699 v4, Total Memory 384 GB, 24 slots/16 GB/2133 MT/s DDR4 RDIMM, Red Hat Enterprise Linux* 7.4 Kernel: 3.10.0-693.21.1.el7.x86_64, uCode: 0x02A, Hammerdb 2.23, Oracle 12.1, Intel® SSD DC S3700 series (800 GB), 2x Intel SSD DC P3700 PCI-E for data, 2x Intel SSD DC P3700 PCI-E for REDO, Intel® Hyperthreading Technology enabled, Intel® Turbo Boost Technology enabled, Score=5.03M TPM; **Test configuration:** 1 node, 2x Intel® Xeon® Platinum 8180 Processor, Total Memory 768 GB, 24 slots/32 GB/2666 MT/s/DDR4 RDIMM, Red Hat Enterprise Linux* 7.4, Kernel: 3.10.0-693.11.6.el7.x86_64, uCode: 0x043, Hammerdb 2.23, Oracle 12.1, Intel® SSD DC S3700 Series (800 GB), 2x Intel® SSD DC P3700 PCI-E for data, 2x Intel® SSD DC P3700 PCI-E for REDO, Intel® Hyperthreading Technology enabled, Intel® Turbo Boost Technology enabled, Score=8.18M TPM (higher is better)

⁵ Oracle evaluated based on its ability to execute and completeness of vision: gartner.com/doc/reprints?id=1-4WLJS38&ct=180418&st=sb

⁶ **Baseline configuration:** Oracle Database In-Memory 12c R2 with Intel® AVX2, 1 node, 2x Intel® Xeon® Platinum 8168 processor @ 2.70 GHz (28 core parts used for test), 12x 16 GB DDR4, 2400 DIMM, 1DPC, 192 GB Total Memory on Linux* 4.11.0 x86_64, Benchmark: Star Schema Benchmark; **Test configuration:** Oracle Database In-Memory 12c R2 with Intel® AVX-512 enabled, 1 node, 2x Intel® Xeon® Platinum 8168 processor @ 2.70 GHz (28 core parts used for experiment), 12x 16 GB DDR4, 2400 DIMM, 1DPC, 192 GB Total Memory on Linux* 4.11.0 x86_64, Benchmark: Star Schema Benchmark

⁷ **Baseline configuration:** 1 node, 2x Intel® Xeon® Processor E5-2699 v4, 8x 32 GB DDR4, 2134 DIMM, 1DPC, 256 GB Total Memory on Red Hat Enterprise Linux* 6.5 kernel 2.6.32-431.e16.x86_64, Benchmark: Star Schema Benchmark, Score: 2585 (lower is better); **Test configuration:** Oracle Database In-Memory 12c R2 with Intel® AVX-512 enabled, 1 node, 2x Intel® Xeon® Platinum 8168 processor @ 2.70 GHz (28 core parts used for experiment), 12x 16 GB DDR4, 2400 DIMM, 1DPC, 192 GB Total Memory on Linux* 4.11.0 x86_64, Benchmark: Star Schema Benchmark, Score: 2082 (lower is better)

⁸ Intel, September 2010, "Securing the Enterprise with Intel® AES-NI." intel.co.uk/content/www/uk/en/enterprise-security/enterprise-security-aes-ni-white-paper

⁹ For more information about Intel® Solid State Drives, visit intel.com/ssds

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Cost reduction scenarios described are intended as examples of how a given Intel-based product, in the specified circumstances and configurations, may affect future costs and provide cost savings. Circumstances will vary. Intel does not guarantee any costs or cost reduction.

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Intel processor numbers are not a measure of performance. Processor numbers differentiate features within each processor family, not across different processor families: [Learn About Intel® Processor Numbers](#).

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