Intel® RAID Performance 12Gb/s SAS RAID Controllers

WHITE PAPER

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For more information on the Intel RAID visit: www.intel.com/go/RAID

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1 Introduction

The Intel® 12Gb/s SAS RAID controllers, featuring the LSI dual-core SAS3108 RAID-on-Chip (ROC) processor, offer significant performance enhancements for solutions architected with 12Gb/s or 6Gb/s SAS drives. The superior read/write performance ideally suits the controllers for a broad range of application workloads:

- Enterprise data center applications, such as email, transactional databases, and analytical databases
- Cloud computing, software-defined storage systems, and big data (Hadoop)
- Content applications, such as streaming video and cold storage/archival

The massive growth of cloud and big data applications require enterprise features to manage, optimize, and improve the efficiency of growing data centers and clusters. The Intel 12Gb/s SAS RAID controller StorCLI utility features extensive command line options that easily integrate into clustered environments, and include server storage management, both locally or remotely, from a single pane of glass with the RAID Web Console application.

This generation of storage, spurred by the increased adoption and trending lower costs of flash, requires more bandwidth and I/O per second (IOPs) capability then the previous generation. Additionally, balancing power and performance in environments where solid state devices and SAS and SATA spinning hard drives coexist becomes even more critical. This paper demonstrates how Intel 12Gb/s SAS RAID controllers, with premium feature offerings such as Fast Path I/O and RAID SSD Cache, have met and exceeded this challenge.

In addition to outstanding performance, the Intel 12Gb/s SAS product family supports advanced features such as multipathing, VMware ESXi virtualization, dual level advanced RAID types, and revertible hot-spare. The product family is flexible, with support for high-performance SAS hard drives, high-capacity SATA hard drives, and energy-efficient solid state drives (SSDs).

1.1 Architectural Benefits of 12Gb/s SAS Capable RAID

The Intel 12Gb/s SAS generation of RAID products offer architectural changes to provide new or enhanced benefits. The new LSI SAS3108 chip combines the processing power of a dual 1.2 GHz dedicated RAID processor, low latency DDR3-1866 RAID cache, and built-in hardware acceleration engines dedicated to processing and protecting data with the lowest latencies and highest performance. The products come in multiple form factors for easy installation in most Intel-based servers.

The faster clock speed and memory dramatically increase the RAID 5 and RAID 6 write capability of the controller, producing a 30% increase in performance over the previous generation products. The integrated 12Gb/s SAS capability of the controller allows for twice the SAS throughput of the previous generation with up to 1 GB/s per port transfer speed.

To support the increased bandwidth, the Intel 12Gb/s SAS RAID controllers include 1 GB of RAID cache memory and an 8-lane PCI Express® (PCIe®) 3.0 bus interface. These hardware features come together with a highly optimized RAID firmware stack that supports over 125% more IOPs compared to the previous generation. The added IOPs capability of Intel 12Gb/s RAID products provides a cost effective means to support an SSD environment with high performance read and write operations.

2 Performance Tests and Results

Using IOMeter 1.1, an open-source I/O workload generator, Intel designed I/O workload profiles to demonstrate how real-world applications might perform. Sequential read and write benchmarks reveal how well streaming applications perform. Real-world benchmarks simulate multiple enterprise workloads that typically include mixed and overlapping reads and writes across request sizes, such as the real-world applications in the following table.

Table 1 Real-World Applications

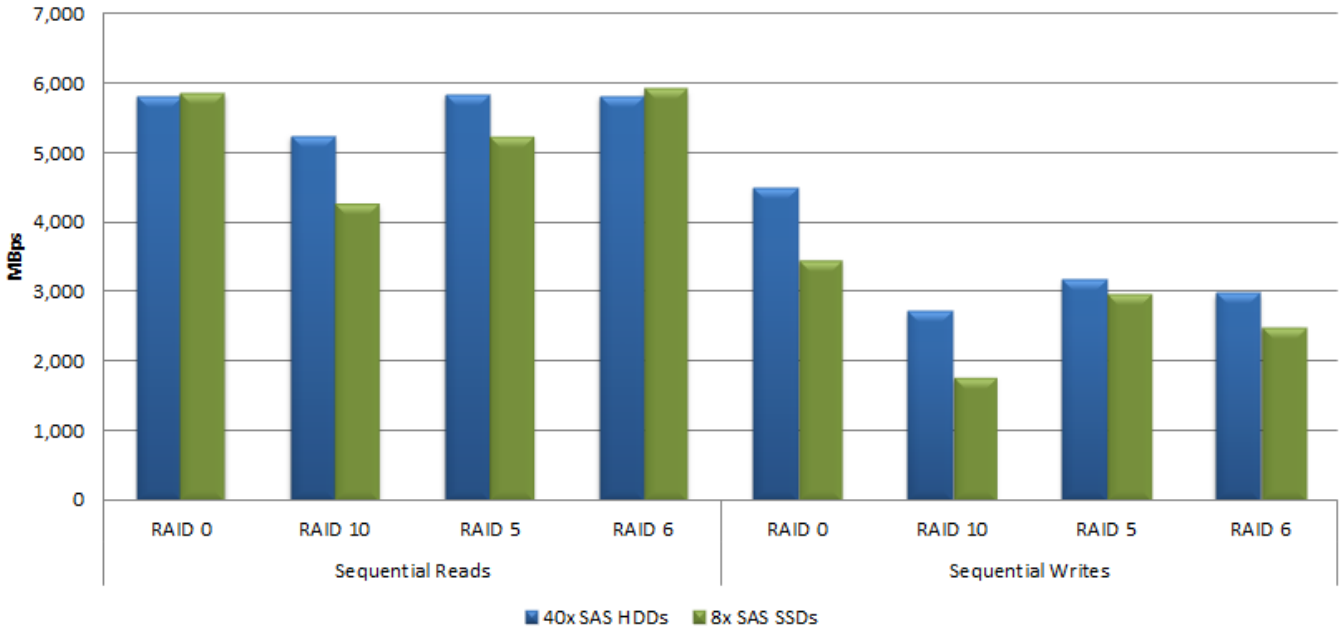
Workload	Typical Applications
Streaming reads	Online analytical processing (OLAP), data warehousing, extract-transform-load (ETL), virtual tape library
Streaming writes	Video surveillance, medical imaging, archival, backup
Workstation	Scientific and office application
Web server	Web serving applications
OS drive	Operating systems
File server	Structured file systems
Email server	Server accept, deliver, store and forward applications
Enterprise databases	Online transaction processing (OLTP), OLAP transactions, email applications
Multithreaded reads	Video on demand, Hadoop® Framework, Hadoop Distributed File System (HDFS™), cloud content
Multithreaded writes	Hadoop source ingest (Apache Sqoop™ or Flume™)
Analytics	SQL, NewSQL and NoSQL databases, MapReduce

2.1 Intensive Streaming Applications

The Intel 12Gb/s SAS RAID controllers implement eight lanes of PCIe 3.0 (8 GT/s) that provide 8,000 MBps of unidirectional bandwidth, while eight phys of third generation SAS produces 9,600 MBps of SAS bandwidth.

Streaming applications focus on efficiency, storage capacity, and throughput. As the following figure shows, all RAID types provide similar high read performance of nearly 6,000 MBps. When you require highly available and protected data, there is a penalty in write performance to either provide mirrored writes (RAID 1/10) or to compute and store parity (RAID 5/6). In terms of mean time to data loss (MTTDL), RAID 0 scores the lowest followed by RAID 5, RAID 10, and RAID 6.

Figure 1 Intel Integrated RAID Module RMS3CC080 Large Streaming Reads and Writes



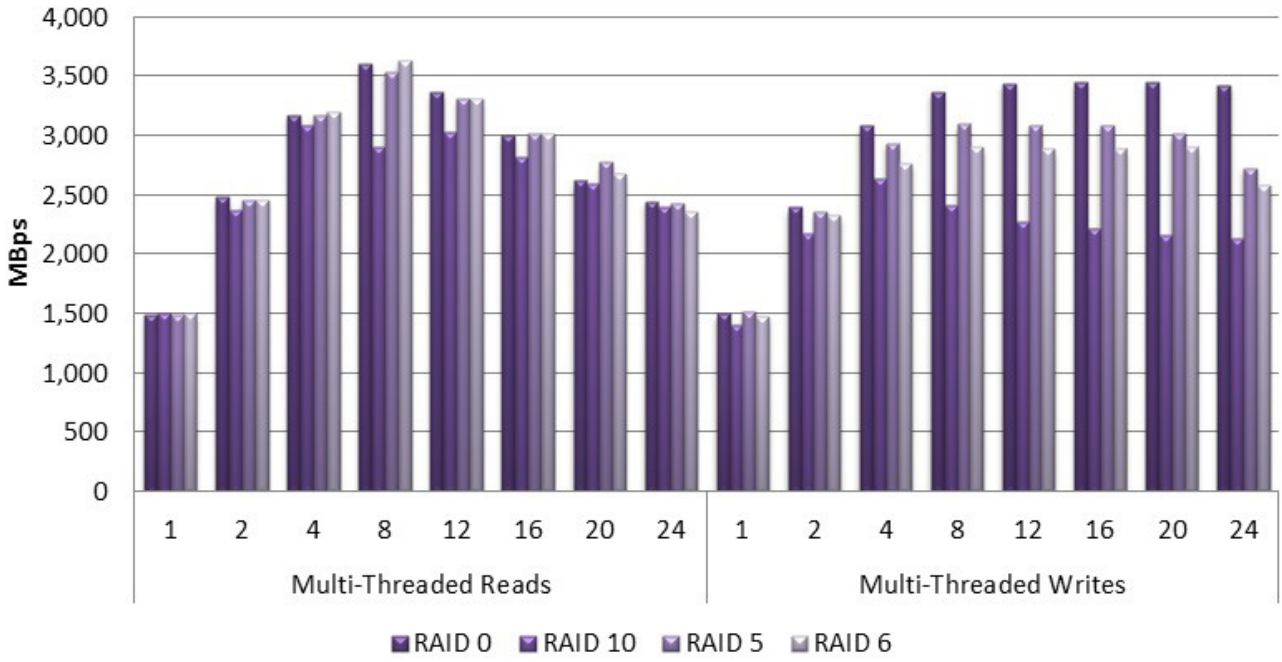
Streaming workloads represent contiguous requests made to the disk. The workloads are predominately sequential I/O. Applications such as data warehousing, ETL, and VTL backup operations experience this type of workload for reads. Applications such as media capture (video surveillance, medical imaging, and so on), archival, and backup experience this type of workload for writes. High bandwidth is crucial for these applications.

Multithreaded Workloads

For multithreaded read and write workloads, high bandwidth and the ability to identify and optimally manage multiple threads are crucial for these applications. Intel 12Gb/s SAS RAID controllers can identify multiple threads and optimize the commands to reduce missed rotations and minimize disk seeks.

Multithreaded workloads, while similar to streaming workloads, vary in that there are multiple simultaneous threads that typically do not overlap. This workload is mimicked by launching 1 through 24 threads at 64 KB (or larger) separated by 2 GB ranges, as shown in the following figure. Applications such as media servers (video-on-demand), cloud content delivery, Hadoop MapReduce, and HDFS experience this type of workload for reads. Big data applications such as Hadoop source ingest (Sqoop or Flume) and media operations (video surveillance) experience this type of workload for writes.

Figure 2 Intel Integrated RAID Module RMS3CC080 40x 15,000 RPM 6Gb/s SAS HDD, Multithreaded Reads and Writes



The previous figures highlight the streaming bandwidth of the 12Gb/s SAS infrastructure with both SAS HDDs and SAS SSDs, bypassing the previous theoretical 6Gb/s SAS limitation and now achieving nearly 6,000 MBps. Sequential writes, in write-back mode, can exceed 4,500 MBps, while write-through mode sails to 6,530 MBps (not shown in the figures). Some workloads, such as those employed in disaster recovery plans (DRPs), truly benefit from this increase in bandwidth by improving time to optimal (TTL) when implementing restore operations. Similarly, this helps reduce scheduled backup window times – an important yardstick as businesses store more and more data. Multithreaded workloads benefit too, such as allowing more simultaneous video and audio feeds, or improving Hadoop MapReduce batch job times to help customers explore their data faster.

2.2 Transaction-Oriented Applications

Applications dominated by random I/O access patterns are well-suited for both SAS hard drives and SSDs. These applications include traditional and transaction capable NewSQL or NoSQL databases.

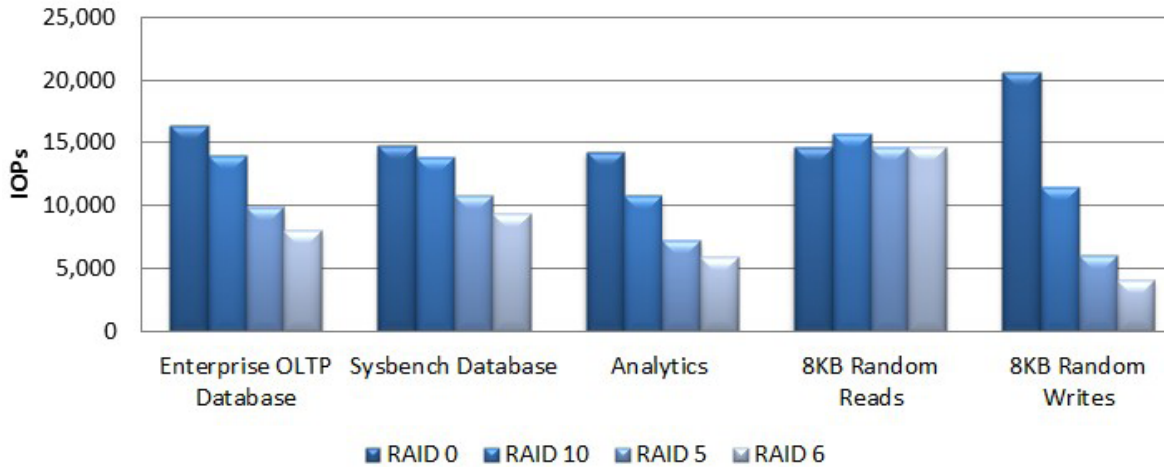
Enterprise database workloads include transaction-oriented queries such as OLTP and OLAP against structured data. OLTP databases that observe ACID-compliance require high concurrency and strict in-order processing, which includes a number of data accesses: a read of the original value, followed by an update, then write and verify operation. Because these operations must be handled in order, low latency and optimal cache strategies are necessary for enterprise database performance. OLAP style processing is characterized by relatively low volume of transactions; however the queries are often very complex and involve aggregations. An 8 KB, 2:1 ratio of random reads:writes workload simulates these types of queries.

Analytics is becoming increasingly popular due to the proliferation of NoSQL databases combined with declining disk cost, and innovative cost-effective distributed scale-out storage architectures that let businesses collect more data that analytic database management software can efficiently mine.

Besides traditional analytics, real-time analytics such as targeted ads, security intelligence, or fraud detection require the highest performance to keep up with customer transactions. Additional features beyond traditional database management software (DBMS) (such as column-oriented storage organization, automated data replication and distributed data, write-ahead logging, and hybrid storage organization) can mean data acrobats when it comes to characterizing typical I/O operations. Analytics benchmarks typically simulate database reads, inserts, and updates; with the most common benchmarks comprised of a series of data loads followed by percentages of read, write, and insert operations. Multiple clients' analytical workloads are simulated with 8 KB random 50:50 read to write ratio at high queue depths. In addition, because data access patterns can vary wildly, pure random reads and random writes are spotlighted to identify the maximum performance potential for these types of operations.

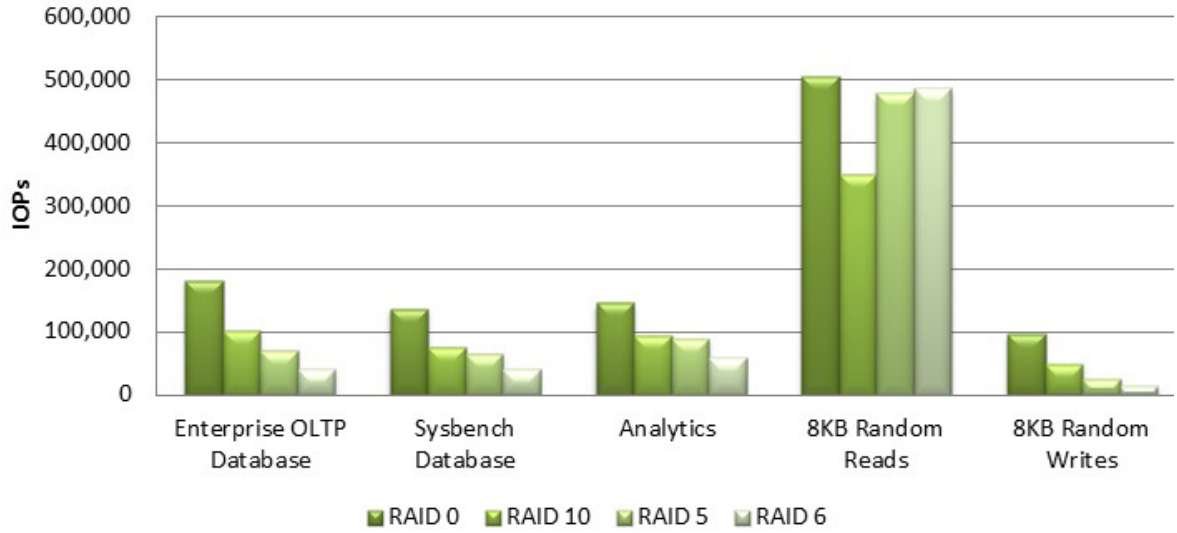
Random read performance does not vary with the RAID type, but the type of data organization influences random writes. The Intel 12Gb/s SAS RAID controller cache architecture optimizes random write operations by buffering writes and sorting them in a physical order to reduce disk seek overhead. The results show a large increase in the random write IOPs combined with lower latencies, ensuring fast application response times, as shown in the following figure.

Figure 3 Intel Integrated RAID Module RMS3CC080 15,000 RPM 6Gb/s SAS HDD, Transactional Workloads



As customers look to increase the overall performance of their storage infrastructure, SSDs continue to make inroads into the enterprise server market. SSDs are well-suited for server workloads that require very high IOPs. Applications that fit this profile include online transaction systems with small, random reads and writes such as reservation and ecommerce systems. The true performance advantage of Intel 12Gb/s SAS RAID controllers are best demonstrated with SSDs. Only with SSDs can you see the full performance capabilities of the Intel 12Gb/s SAS RAID controllers, as shown in the following figure.

Figure 4 Intel Integrated RAID Module RMS3CC080 12Gb/s SAS SSD, Transactional Workloads



The Intel 12Gb/s SAS RAID controller exhibits incredibly high performance, easily achieving more than 500,000 8-KB random reads - nearly 4,000 MBps. This translates to more than 100,000 database operations for a typical RAID 10 configuration, and even a more capacity-optimized RAID 5 configuration can still achieve upwards of 70,000 database type IOPs.

2.3 Common Enterprise Applications

Workstation workloads represent primarily single tenancy operating systems running multiple applications that predominately handle random read requests, with a mix of sequential reads and writes. Low response times and effective caching strategies are essential for workstation users.

Web server workloads typically service multiple, primarily random simultaneous requests. Text, images, video, and audio are commonly featured files served by web servers, with a high skew towards the most popular web pages. Low response times are critical to support fast page loads and ensure customer satisfaction.

Operating system drive workloads represent the I/O activity of an operating system drive. This workload is defined as a pseudo random 70:30 mix of reads and writes combined with small sequential I/Os that simulate logging. Operating systems must manage system cache, metadata and application code and effective caching of frequently accessed data, while maintaining data integrity. The ability to handle numerous outstanding requests is absolutely essential. With the extensive use of virtualization and distributed file technologies, optimal OS performance is more important than ever.

File server workloads are characterized by a large number of users requesting access to structured reference data and files. While file systems and access patterns can vary significantly, we measure 80:20 random read and write workload with the majority of request sizes ranging, bimodally balanced, around 4 KB and 64 KB.

Email server workloads typically service multiple simultaneous requests to transport or store email. Many email servers use databases or database-like structures to manage and store user data. Because of the variations in email server applications, two common types of email servers were simulated in testing:

1. 8 KB 50% mix of random reads and writes
2. 32 KB 65% mix of random reads and writes

The following figures show the common enterprise application performance testing results at 6Gb/s SAS and 12Gb/s SAS.

Figure 5 Intel Integrated RAID Module RMS3CC080 15,000 RPM 6Gb/s SAS HDD, Common Enterprise Workloads

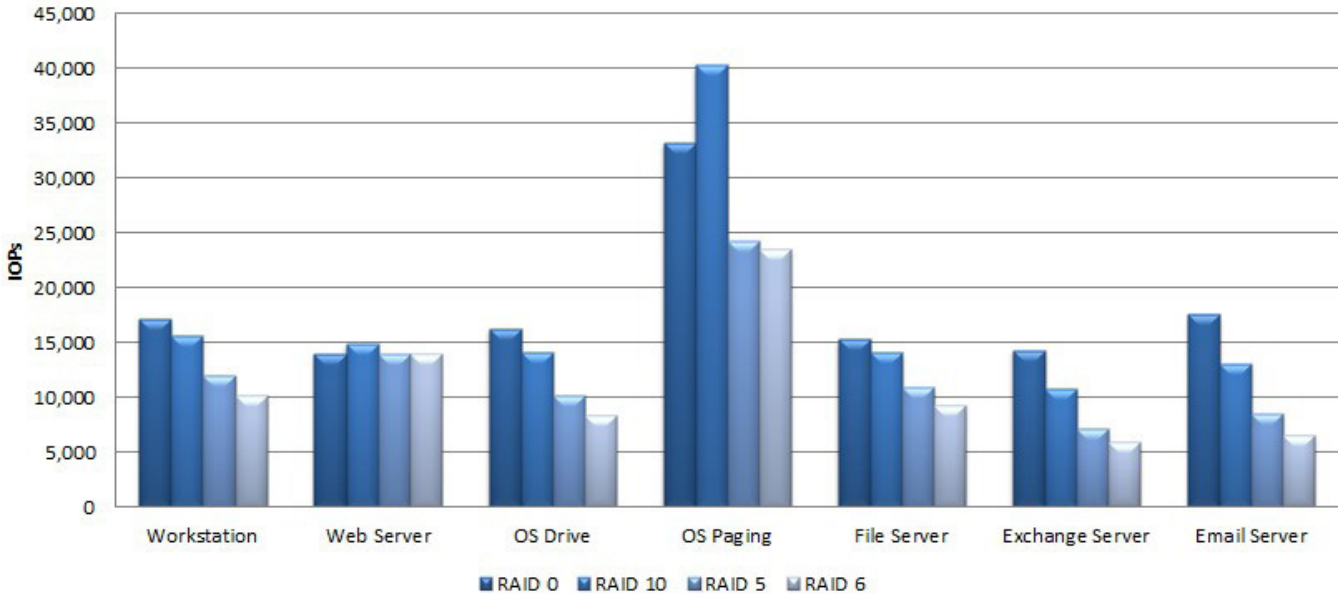
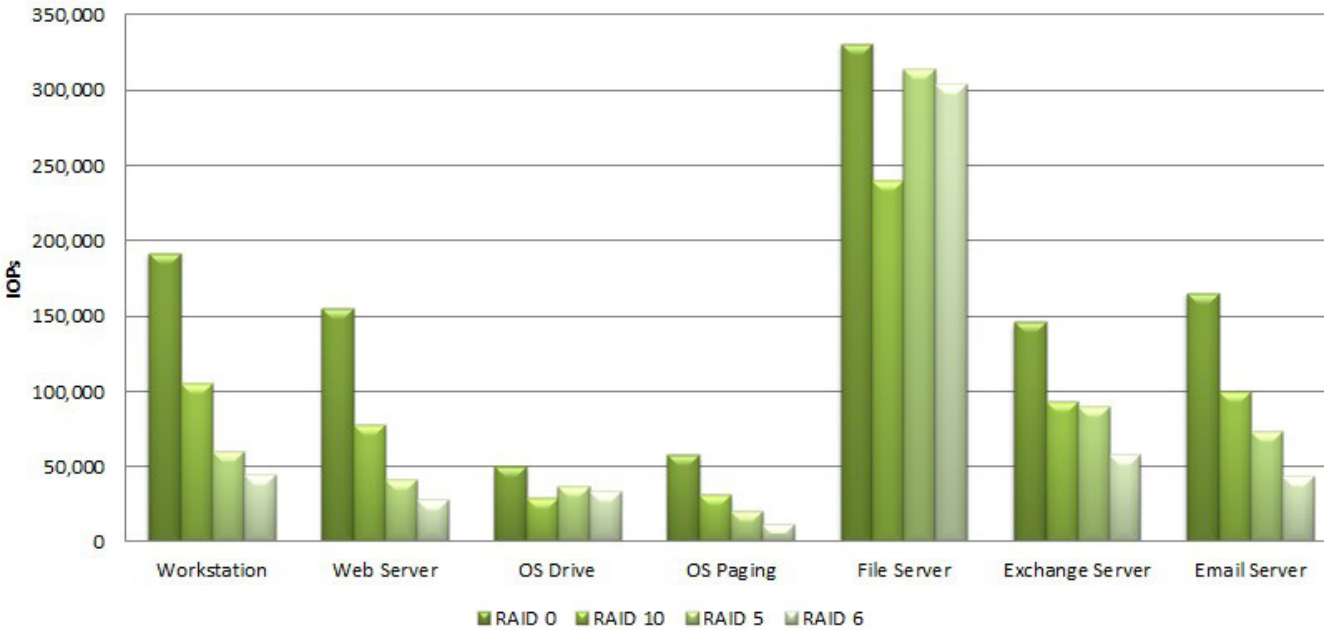


Figure 6 Intel Integrated RAID Module RMS3CC080 12Gb/s SAS SSD, Common Enterprise Workloads

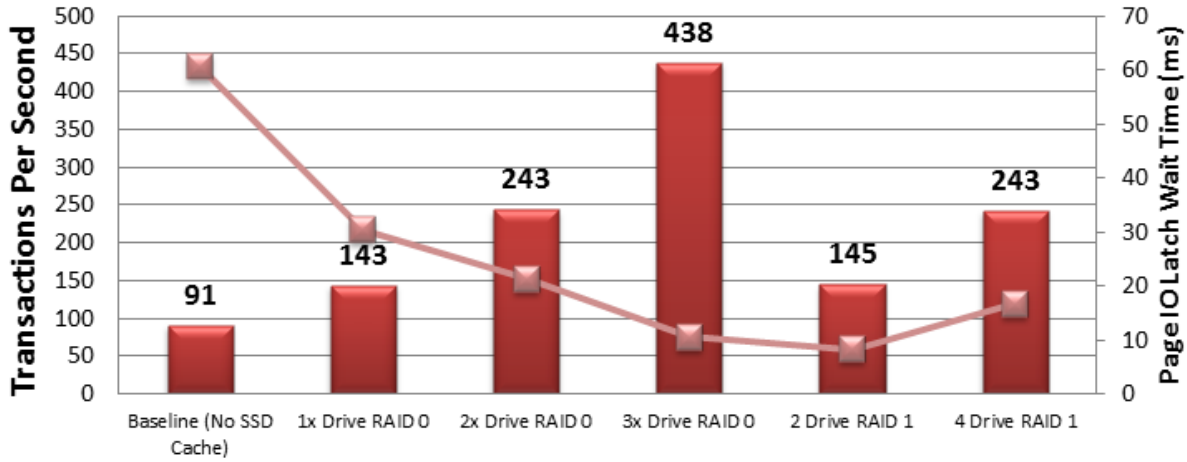


2.4 Microsoft® SQL Server 2014 OLTP Benchmarking

IOmeter simulation characterizes performance well, however real applications have multiple system interactions that are hard to capture in an artificial benchmark. To determine the true database capabilities of the Intel 12Gb/s SAS RAID controller, it was measured using a Microsoft® SQL Server 2014 database and a standard benchmark that exercises complex transactional operations modeled after a brokerage house. This benchmark allowed measurements and observations of the Intel RAID SSD cache benefits from one to four SSDs, as shown in the following steps and charts.

1. Database loaded with data for 10,000 customers.
2. Baseline measurement taken with only SAS HDDs.
3. Added SSDs 1 to 3 (for RAID 0), and 2 and 4 (for RAID 10), configured with both read and write caching and assigned to the database volume.
4. Tests ran for four hours. After each four-hour run, the average transactions per second and the SQL Server Page IO Latch Wait Time was recorded.
5. The database was restored to its original state. The results are quite astounding.

Figure 7 Intel Integrated RAID Module RMS3CC080 Microsoft SQL Server 2014 OLTP Benchmark



Three disks in a RAID 0 SSD cache volume provided the highest increase of 381%, and even a protected RAID 10 produced a very generous 167% increase in the number of achieved transactions. Using the SSD cache feature is one of the most cost effective ways to enhance application performance, especially when working with hot user data.

3 12Gb/s SAS Intel RAID: Best-in-Class Storage Portfolio

The Intel 12Gb/s SAS controller portfolio provides channel partners with best-in-class storage solution options. Intel enables channel partners to stay ahead of today's technology by offering controllers perfectly suited for database, email, and Web server environments where performance and security directly affect success.

The Intel 12Gb/s SAS mainstream product family uses an LSI SAS3108 ROC processor (1.2 GHz) to provide the following features:

- Four- (RS3DC040) or 8- (RS3DC080) internal ports
- SFF-8643 internal connectors
- RAID 0, 1, 5, 6, 10, 50, 60 support
- x8 PCI Express 3.0 (8 GT/s per lane) support
- 1-GB DDR3 at 1866 MHz support
- SAS and SATA drive type support
- Low profile board

4 Summary

When architecting a RAID solution, give careful consideration to understanding the characteristics, data availability, storage architecture, and any applications for which the storage controller will be deployed.

The Intel 12Gb/s SAS RAID controllers provide optimum performance in many different environments. Features such as intelligent write back RAID cache, adaptive read ahead, various stripe size support, multi-level RAID architectures, dedicated and global hot spare support, and SSD caching allow IT professionals to customize their storage environment to ensure the highest performance and data availability.

Intel offers a wide range of RAID products to architect a highly optimized and scalable solution specifically for your environment. By using advanced technology, world-class features, and a SAS design that allows for SAS, SATA and SSD drives, Intel RAID allows you to balance performance, reliability, and cost requirements.

5 Hardware Configurations Tested

Intel Server Board S2600WTT

- 2x Intel Xeon® E5-2695 v2 CPUs at 2.3 GHz
- 64-GB DDR3-1600 Memory
- x8 Generation 3.1 PCIe slot

Intel RAID Controller RMS3CC080

- Firmware version 4.230.20-3423
- Driver version 6.600.21.08
- 1-GB RAID cache

Drive Enclosures

- 2x Serial Cables SA-ENC12G-01A + 1x Serial Cables SA-ENC12G-024A with the LSI SAS 3x48 C1 expander (firmware version 0.05.00.00)

Drives

- 40x Seagate® ST9146853SS 146 GB 6Gb/s 15,000 SAS drive
- 8x Hitachi HUSMM8020ASS200 200 GB 12Gb/s SAS SSD
- Disk cache always disabled

Test Suite

- Windows Server 2012 R2 Standard 64-bit
- IOMeter Version 1.1.0
  - SSD data tested with 64-KB stripe size, Write Thru, Direct IO, and No Read Ahead policies
    - SSD drives preconditioned to steady state before taking measurements
  - HDD data tested with 256-KB stripe size, Write Back, Direct IO, and Adaptive Read Ahead policies
  - Run time: 30 seconds
  - Ramp time: 30 seconds
  - Queue depth sweep from 1 to 256
  - Raw disk access (no file system)
- Microsoft SQL Server 2014
  - Database: 20x drive RAID 10, 256-KB stripe size, Write Thru and No Read Ahead policies
  - Log Drive: 4x drive RAID 5, 256-KB stripe size, Write Back and No Read Ahead policies
  - 100,000 Customer database, 4 hour run time

NOTE Although testing was performed with the RMS3CC080 modular controller, expect similar performance from other Intel 12Gb/s SAS RAID models, based on the similar product architecture.

For more information on the Intel RAID visit: www.intel.com/go/RAID