IT@Intel Brief
Intel IT
Computer Manufacturing
October 2013

Advantages of Solid-State Drives for Design Computing

- SSDs used as swap space for large silicon design workloads
- 1.63x performance-normalized cost advantage due to lower cost of SSDs
- Up to 88 percent of the performance compared with running workloads entirely in RAM

In Intel IT tests with large silicon design workloads, substituting lower-cost solid-state drives (SSDs) for part of a server's physical memory resulted in a 1.63x performance-normalized cost advantage, as shown in Figure 1.

We conducted tests to evaluate the use of SSDs as application swap drives. We ran electronic design automation (EDA) workloads on servers configured with enough RAM—512 GB—to load the entire workload into physical memory. Then we configured the servers with only half as much RAM, 256 GB, forcing the applications to use swap drives based on multi-level cell (MLC) SSDs or hard disk drives (HDDs).

When swapping to a 400-GB Intel® Solid-State Drive (Intel® SSD) DC S3700 Series SATA, an enterprise-class MLC drive, the server completed the workloads 12 percent less quickly than when the workloads were entirely loaded in RAM. However, because SSDs cost much less than RAM, server cost was greatly reduced; this resulted in a substantial performance-normalized cost advantage. Performance with the Intel SSD DC S3700 swap drive was 38 percent faster than with the HDD swap drive. Our tests show that a server with an SSD swap drive is a cost-effective, high-performance server platform for EDA applications.

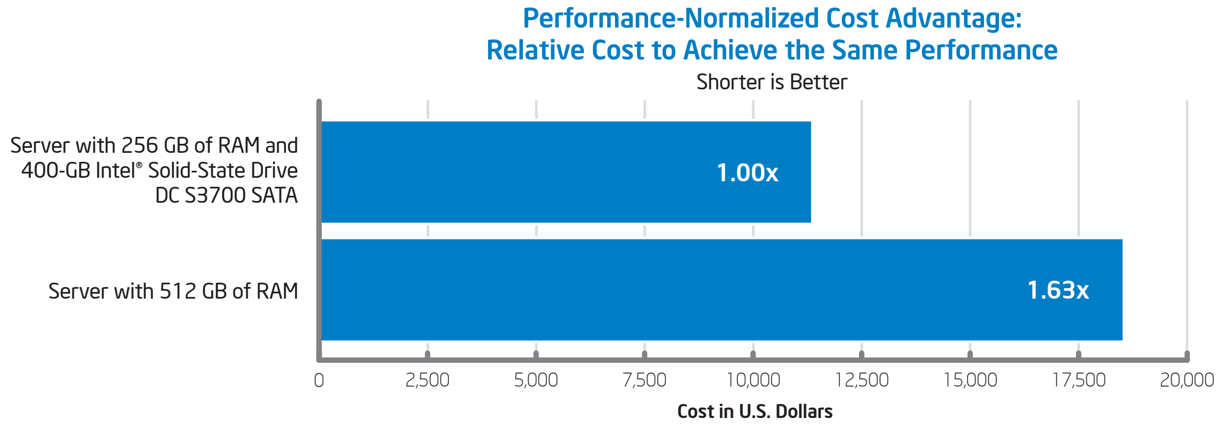

Figure 1. Performance-normalized cost advantage with solid-state drives. Using Intel® Solid-State Drive (Intel® SSD) DC S3700 SATA as swap space delivered a 1.63x performance-normalized cost advantage. Electronic Design Automation performance was only 12 percent lower than a full RAM configuration, but server cost was greatly reduced. (Intel IT internal measurements, DELL server list prices, www.dell.com, and Intel SSD list prices, www.intel.com, August 2013.)

Table 1. Comparison of Intel® Solid-State Drive (Intel® SSD) Technologies

Factor	High-Endurance Data Center SSD	Data Center SSD
	Intel SSD DC S3700	Intel SSD DC S3500
Cost	Higher	Lower
Capacity	Comparable	Comparable
Read Speed	Comparable	Comparable
Write-Erase Speed	Best	Good
Write-Erase Endurance	Best	Good

Table 2. Test System Specification

Processor	2x Intel® Xeon® processor E5-2670
Frequency	2.6 GHz
Bus	8.0 GT/s Intel® QuickPath Interconnect
Chipset	Intel® C600 Chipset
RAM Configurations	▪ 512 GB (16 x 32 GB) DDR3-1333 when entire workload loaded in RAM ▪ 256 GB (16 x 16 GB) DDR3-1600 when using swap drive
Drive Interface	SAS 6.0 Gb/s; SATA 6.0 Gb/s
OS	64-bit Linux*

Business Challenge

Silicon chip design engineers at Intel face the challenges of integrating more features into ever-shrinking silicon chips, resulting in more complex designs.

The increasing design complexity creates large design workloads that have considerable memory and compute requirements. We typically run the workloads on servers that need to be configured to meet these requirements in the most cost-effective way.

Traditionally, we have had two options for configuring servers to support these large design workloads:

- We can install a large amount of RAM, enabling the workloads to run entirely in physical memory. This maximizes performance, but is an expensive solution due to the relatively high cost of the high-density 32-GB RAM modules required.
- We can use less RAM, using low-cost 16-GB RAM modules, so that application workloads whose memory requirements exceed the physically installed RAM swap to HDDs as necessary. This reduces cost because HDDs are much less expensive than 32-GB RAM modules, but it also substantially reduces performance.

SSDs offer a promising new approach. These storage devices use solid-state memory to store persistent data; they emulate HDDs and can replace HDDs in many applications.

Because of this, we now have a third server configuration option:

- We can use SSDs as swap drives instead of HDDs. Because SSDs are faster than HDDs but much less expensive than RAM, this option has the potential to deliver good performance at relatively low cost. An additional benefit is that SSDs consume significantly less power than HDDs, reducing total system power requirements.

Both high-endurance data center and data center MLC SSDs are available, which are compared in Table 1.

To evaluate the potential of SSDs as swap drives in design computing, we conducted tests to compare performance and cost when using each of these server configuration options to support actual Intel silicon design workloads. Our tests included both high-endurance data center SSDs and data center SSDs.

Performance Tests

We conducted performance tests using Intel silicon design workloads on a current two-socket server platform based on Intel® Xeon® processor E5-2600 product family.

Depending on the test, we configured the server so that the workloads were loaded entirely in RAM or used an HDD, a high-endurance data center SSD, or a data center SSD as a swap drive. Specifications of the server and swap drives are shown in Tables 2 and 3.

Table 3. Test Swap Drives Configuration

	Intel® Solid-State Drive DC S3700	Intel® Solid-State Drive DC S3500	SAS Hard Disk Drive
Capacity	400 GB	480 GB	900 GB
Component Specification	25nm NAND	20nm NAND	10,000 RPM
Read Bandwidth	500 MB/s	500 MB/s	No Data
Write Bandwidth	460 MB/s	410 MB/s	No Data
Read Latency	50 us	50 us	Average 2.9 ms
Random 4-KB Reads	75,000 IOPS	75,000 IOPS	No Data
Random 4-KB Writes	36,000 IOPS	11,000 IOPS	No Data
Interface	SATA 6.0 Gb/s, NCQ	SATA 6.0 Gb/s, NCQ	SAS 6.0 Gb/s
Mean Time Between Failures (Millions of Hours)	2	2	1.6

EDA WORKLOADS AND SWAP CONFIGURATIONS

Each test case consisted of one or more EDA applications operating on an actual Intel silicon design workload, as shown in Table 4. Test case memory requirements ranged from 343 GB to 476 GB.

We tested the following system configurations:

- **512 GB of RAM; no swap space allocated.** We used the more expensive 32-GB RAM modules since the server had only 16 memory slots. The entire application workload was loaded into physical RAM.
- **256 GB of RAM; HDD used as swap space.** We used the less expensive 16-GB RAM modules in all 16 memory slots.
- **256 GB of RAM; MLC-based Intel SSD DC S3700 high-endurance data center SSD used as swap space.** We used 16-GB RAM modules in all 16 slots.
- **256 GB of RAM; MLC-based Intel SSD DC S3500 data center SSD used as swap space.** We used 16-GB RAM modules in all 16 slots.

RESULTS

When using the Intel SSD DC S3700 as a swap drive, average performance was 38 percent faster than with the HDD swap drives and only 12 percent slower than using the full 512-GB RAM configuration with no swap space.

With the Intel SSD DC S3500, average performance was 25 percent faster than using HDD swap drives and 20 percent slower than using the full 512-GB RAM configuration with no swap space.

The results are shown in Table 5.

Cost Comparison

Based on our performance test results and typical server list prices, we compared the cost for the two highest-performance alternative configurations:

- A server with 512 GB of RAM
- A server with 256 GB of RAM and a 400-GB MLC Intel SSD DC S3700 used as a swap drive

To do this, we calculated a performance-normalized cost by adjusting the cost of each configuration based on its relative performance in our tests, as shown in Table 6.

We then compared these performance-normalized costs. The Intel SSD DC S3700 swap disk resulted in a 1.63x performance-normalized cost advantage.

Table 4. Electronic Design Automation (EDA) Test Workloads

	Test Case 1	Test Case 2
Workload	Simulation A	Simulation B
Threads	1 thread; 32 jobs in parallel	1 thread; 20 jobs in parallel
Virtual Memory Required for Application[1]	343 GB	476 GB

[1] Virtual memory not including the system buffer and page cache

Table 5. Performance Test Results (Intel IT internal measurements, August 2013)

	Intel® Xeon® Processor E5-2670			
Test Case	512-GB RAM No Swap (hh:mm:ss)	SAS HDD Swap (hh:mm:ss)	Intel® SSD DC S3700 MLC Technology SSD Swap (hh:mm:ss)	Intel® SSD DC S3500 MLC Technology SSD Swap (hh:mm:ss)
Test Case 1: Simulation A 32 Jobs in parallel	10:19:23	12:43:33	10:54:15	12:17:14
Test Case 2: Simulation B 20 Jobs[a] in parallel	15:13:22	27:13:00	18:04:30	19:40:59
Average Run Time	12:46:22	19:58:16	14:29:22	15:59:07
Relative Performance Baseline: 512-GB RAM	1.00	0.64	0.88	0.80
Relative Performance Baseline: HDD Swap		1.00	1.38	1.25

[a] 16-job run on HDD swap because 20 jobs leads to operating system thrashing and system instability

HDD - Hard Disk Drive; **MLC** - Multi-Level Cell; **SSD** - Solid-State Drive

Table 6. Performance-Normalized Cost Comparison (Intel internal measurements, DELL server list prices, www.dell.com, and Intel® Solid-State Drive list prices, www.intel.com, August 2013.)

Server Configuration	Total Cost	Relative Electronic Design Automation Performance	Performance-Normalized Cost
512-GB DRAM Server	USD 18,512.00	100%	USD 18,512.00
256-GB DRAM Server with 400-GB Multi-Level Cell Technology Solid-State Drive	USD 9,992.56	88%	USD 11,335.55
Performance-Normalized Cost Advantage			**1.63**

Conclusion

Using SSDs as swap drives enables us to substitute lower-cost solid-state storage for higher-cost RAM, with only a small performance impact.

In our tests, servers with SSDs provided a 1.63x performance-normalized cost advantage, delivering up to 88 percent of the performance compared with running workloads entirely in RAM.

Servers with SSD swap drives are a cost-effective, high-performance server platform for EDA applications.

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AUTHORS

Shesha Krishnapura
Senior Principal Engineer, Intel IT

Vipul Lal
Senior Principal Engineer, Intel IT

Ty Tang
Senior Principal Engineer, Intel IT

Shaji Achuthan
Senior Staff Engineer, Intel IT

Murty Ayyalasomayajula
Staff Engineer, Intel IT