IT@Intel Brief

Intel Information Technology
Computer Manufacturing
September 2009

Advantages of Solid-State Drives for Design Computing

- SSDs used as swap space for large silicon design workloads
- 1.74x performance-normalized cost advantage due to lower cost of SSDs
- Up to 88% 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 1.74x performance-normalized cost advantage.

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—96 GB—to load the entire workload into physical memory. Then we configured the servers with only half as much RAM, 48 GB, forcing the applications to use swap drives based on single-level cell technology (SLC) SSDs; multi-level cell (MLC) SSDs; or hard disk drives (HDDs).

When swapping to a 64-GB Intel® X25-E Extreme SATA Solid-State Drive, an SLC 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 SLC SSD swap drive was 73 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.

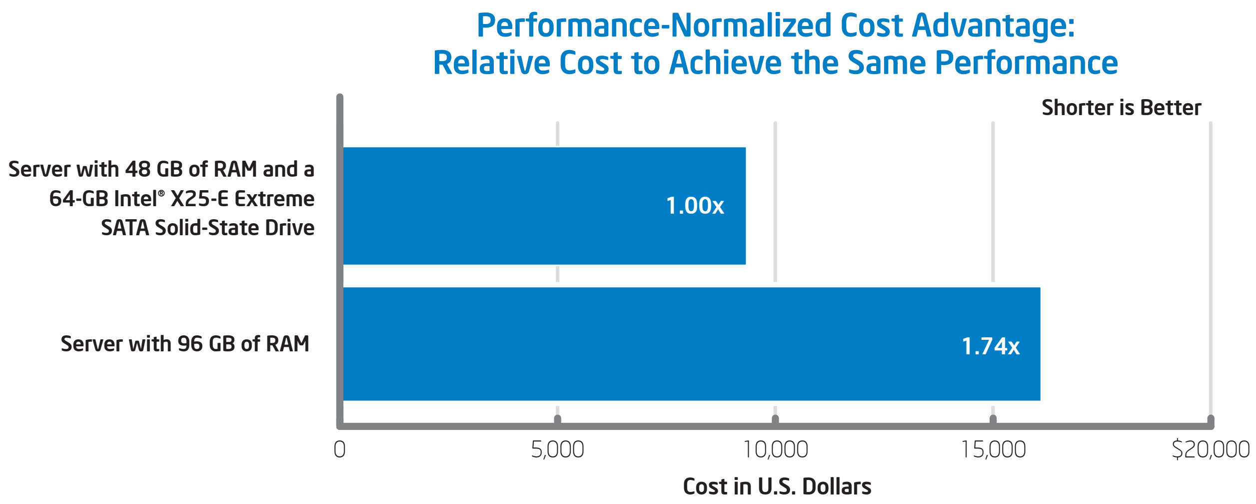

Figure 1. Performance-normalized cost advantage with solid-state drives. Using Intel® X25-E Extreme SATA Solid-State Drives (SSDs) as swap space delivered a 1.74x performance-normalized cost advantage. Electronic design automation (EDA) performance was only 12 percent lower than with a much larger RAM 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, September 2009.

Table 1. Comparison of Solid-State Drive Technologies

Factor	Single-level Cell (SLC)	Multi-level Cell (MLC)
Cost	Higher	Lower
Density	Lower	Higher
Read Speed	Best	Very Good
Write-Erase Speeds	Best	Good
Write-Erase Endurance	Best	Good

Table 2. Test System Specification

Processor	2x Intel® Xeon® processor X5570
Frequency	2.93 GHz
Bus	6.4 GT/s QPI
Chipset	Intel® 5520 Chipset
RAM Configurations	96 GB (12x 8 GB) DDR3-1066 when entire workload loaded in RAM
	48 GB (12x 4 GB) DDR3-1066 when using swap drive
Drive Interface	SAS 3.0 GB/s; SATA 3.0 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, which 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 8-GB RAM modules required.
- We can use less RAM, using low-cost 4-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 8-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.

There are two types of SSD technology available: SLC and MLC. They are compared in Table 1. SLCs have greater write-erase speed and endurance than MLCs, but MLCs are less expensive and have larger capacity.

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 real Intel silicon design workloads. Our tests included both SLC and MLC SSDs.

Performance Tests

We conducted performance tests using Intel silicon design workloads on a current two-socket server platform based on Intel® Xeon® processor 5500 series.

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

Table 3. Test Swap Drives

	Intel® X25-E Extreme SATA Solid-State Drive Single-level Cell (SLC) Technology	Intel® X25-M Mainstream SATA Solid-State Drive Multi-level Cell (MLC) Technology	300-GB 10,000-RPM SAS Hard Disk Drive
Capacity	64 GB	80 GB	2x 300-GB disks (RAID 0)
Component Specification	50nm NAND	50nm NAND	10,000 RPM, 16-MB disk cache
Read Bandwidth	Up to 250 MB/s	Up to 250 MB/s	Up to 129 MB/s
Write Bandwidth	Up to 170 MB/s	Up to 70 MB/s	No Data
Read Latency	75 us	85 us	3.0 ms
Random 4-KB Reads	>35,000 IOPS	>35,000 IOPS^	No Data
Random 4-KB Writes	>3,300 IOPS	>3,300 IOPS^	No Data
Interface	SATA 3.0 Gb/s, NCQ	SATA 3.0 Gb/s, NCQ	SAS 3.0 Gb/s
Mean Time Between Failures (Millions of Hours)	2	1.2	1.6

^Measurements are performance on an 8-GB span.

EDA WORKLOADS AND SWAP CONFIGURATIONS

Each test case consisted of one or more EDA applications operating on a real Intel silicon design workload, as shown in Table 4. Test case memory requirements ranged from 61 GB to 87 GB.

We tested the following server configurations:

- 96 GB of RAM; no swap space allocated. We used more-expensive 8-GB RAM modules since the server had only 12 memory slots. The entire application workload was loaded into physical RAM.
- 48 GB of RAM; HDD used as swap space. We used less-expensive 4-GB RAM modules in all 12 memory slots.
- 48 GB of RAM; Intel X25-E Extreme SATA Solid-State Drive—SLC—used as swap space. We used 4-GB RAM modules in all 12 slots.
- 48 GB of RAM; Intel X25-M Mainstream SATA Solid-State Drive—MLC—used as swap space. We used 4-GB RAM modules in all 12 slots.

RESULTS

When using the SLC SSD as a swap drive, average performance was 73 percent faster than with the HDD swap drives, and only 12 percent slower than using the full 96-GB RAM configuration with no swap space.

With the MLC SSD, average performance was 33 percent faster than using HDD swap drives, and 33 percent slower than using the full 96-GB RAM configuration with no swap space.

Results are shown in Table 5.

Cost Comparison

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

- A server with 96 GB of RAM
- A server with 48 GB of RAM and a 64-GB SLC SSD 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 SLC SSD swap disk resulted in a 1.74x performance-normalized cost advantage.

Table 4. Electronic Design Automation (EDA) Test Workloads

	Test Case 1	Test Case 2		Test Case 3
Workload	Simulation–A	Design Rule Check–B	Simulation–C	Design Rule Check–D
Threads	1 thread; 8 jobs in parallel	8 threads	1 thread; 2 jobs in parallel	8 threads
Virtual Memory Required for Application[1]	71 GB	61 GB		87 GB

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

Table 5. Performance Test Results

Test Case	Swap Space Required with 48-GB RAM Configuration	96 GB of RAM No Swap (hh:mm:ss)	SAS Hard Disk Drive (HDD) Swap (hh:mm:ss)	Single-level Cell (SLC) Technology Solid-State Drive (SSD) Swap (hh:mm:ss)	Multi-level Cell (MLC) Technology SSD Swap (hh:mm:ss)
Test Case 1 Simulation—A (8 Jobs)	23 GB	3:38:49	5:38:51	3:51:42	5:14:29
Test Case 2.1 Design Rule Check—B (8 Threads)	13 GB	7:46:44	9:56:31	8:09:12	8:44:05
Test Case 2.2 Simulation—C (2 Jobs)		4:13:12	5:40:31	4:42:31	5:02:56
Test Case 3 Design Rule Check—D (8 Threads)	39 GB	12:22:05	69:30:47	16:50:40	30:58:06
Geometric Mean		6:12:12	12:11:58	7:04:09	9:11:54
Relative Performance Baseline: 96 GB of RAM		1.00	0.51	0.88	0.67
Relative Performance Baseline: SAS Swap			1.00	1.73	1.33

Note: Intel internal measurements, August 2009.

Table 6. Performance-Normalized Cost Comparison

Server Configuration	Total Cost	Relative Electronic Design Automation (EDA) Performance	Performance-Normalized Cost
96-GB DRAM Server	USD 16,147.00	100.00%	USD 16,147.00
48-GB DRAM Server with 64-GB Single-level Cell (SLC) Technology Solid-State Drive (SSD)	USD 8,307.00	88.00%	USD 9,303.84
Performance-Normalized Cost Advantage			**1.74**

Intel internal measurements, DELL server list prices, www.dell.com, and Intel® SSD list prices, www.intel.com, September 2009.

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 1.74x 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.

For more straight talk on current topics from Intel's IT leaders, visit www.intel.com/it

AUTHORS

Shaji Achuthan
Systems programmer with Intel IT

Shesha Krishnapura
Senior principal engineer with Intel IT

Vipul Lal
Principal engineer with Intel IT

Ananth Sankaranarayanan
Technical program manager with Intel IT

Ty Tang
Principal engineer with Intel IT

ACRONYMS

EDA electronic design automation
HDD hard disk drive
MLC multi-level cell
SLC single-level cell
SSD solid state drive

Printed in USA
0909/KAR/KC/PDF

Please Recycle
322464-001US