Principled Technologies®

TEST REPORT
SEPTEMBER 2008

64-bit Black-Scholes financial workload performance and power consumption on multiprocessor Intel- and AMD-based servers

Executive summary

Intel® Corporation (Intel) commissioned Principled Technologies (PT) to measure the 64-bit Black-Scholes financial application-based workload performance and power consumption on servers using the following three processors:

- AMD® Opteron® processor 8360 SE
- Intel Xeon® processor X7350
- Intel Xeon processor X7460

In this section, we discuss the best results for each server. For complete details of the performance of each server with varying thread counts, see the Test results section.

Figure 1 illustrates the performance/watt of each server. In this and the other performance chart in this section, we normalized the results for each workload to the configuration with the lowest performance/watt or performance. The system with the lowest performance/watt or performance result is thus always 1.00. By normalizing, we make each data point in these charts a comparative number, with higher results indicating better performance/watt or performance (i.e., faster times to complete the workload with the specified number of threads).

KEY FINDINGS

- The Intel Xeon processor X7460-based server delivered 101 percent more performance/watt than the AMD Opteron processor 8360 SE-based server and 128 percent more performance/watt than the Intel Xeon processor X7350-based server (see Figure 1). (We calculated performance/watt using system-level power measurements.)
- The Intel Xeon processor X7460-based server performed 121 percent more Black-Scholes jobs per hour than the AMD Opteron processor 8360 SE-based server. The Intel Xeon processor X7460-based server performed 113 percent more Black-Scholes jobs per hour than the Intel Xeon processor X7350-based server (see Figure 2).

As Figure 1 illustrates, the Intel Xeon processor X7460-based server delivered 101 percent more performance/watt than the AMD Opteron processor 8360 SE-based server and 128 percent more performance/watt than the Intel Xeon processor X7350-based server.

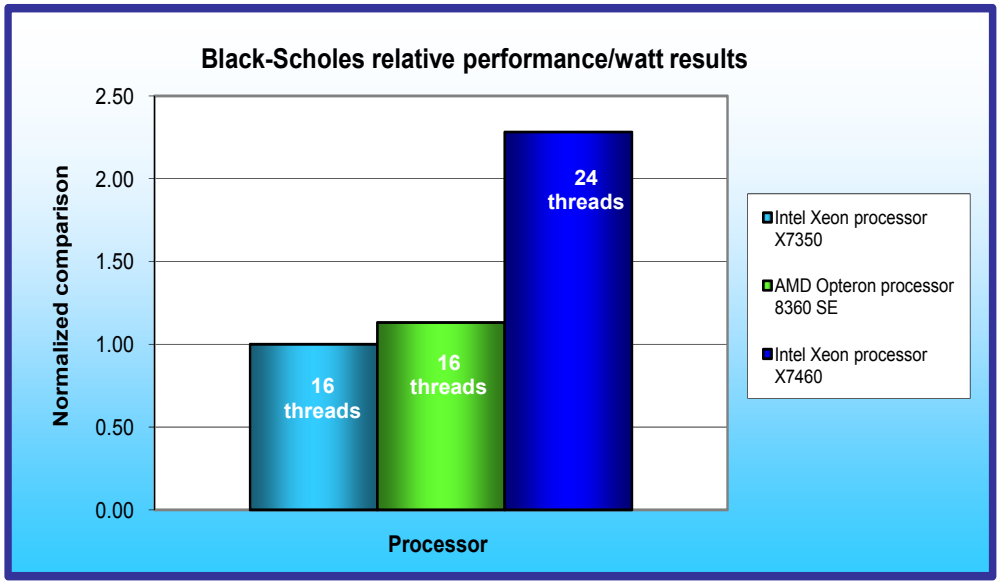

Figure 1: Normalized performance/watt results of the test servers running the Black-Scholes workload. Higher numbers indicate better performance.

To calculate the performance/watt we used the following formula:

Performance/watt = (3,600 / (the benchmark's duration in seconds)) / average power consumption in watts during the time period in which the benchmark was delivering peak performance

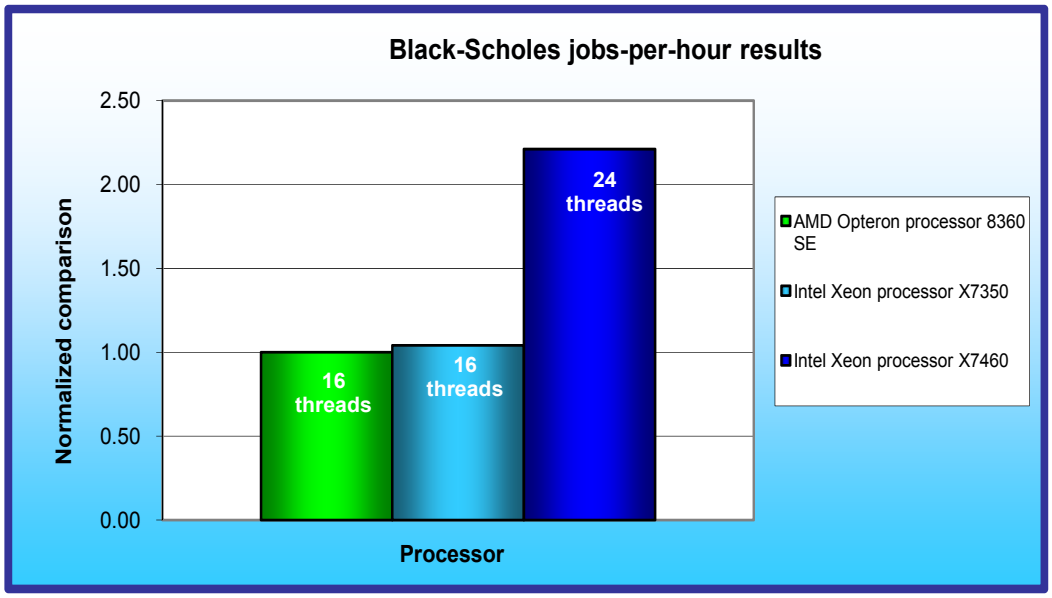

Figure 2: Normalized jobs-per-hour of the servers with the optimum thread-to-processor configurations with the Black-Scholes workload. Higher numbers are better.

Figure 2 illustrates the peak performance for each of the three servers at the optimum thread count using a jobs-per-hour metric. We took the number of seconds each system took to perform the workload and divided 3,600 (the number of seconds in an hour) by that number. We then normalized the scores to the lowest-performing system. The Intel Xeon processor X7460-based server performed 121 percent more Black-Scholes jobs per hour than the AMD Opteron processor 8360 SE-based server. The Intel Xeon processor X7460-based server performed 113 percent more Black-Scholes jobs per hour than the Intel Xeon processor X7350-based server.

Workload

The Black-Scholes kernel workload is based on a financial modeling algorithm for the pricing of European-style options. After its publication in 1973 by Fisher Black, Myron Scholes, and Robert Merton, its impact was enormous and rapid. The benchmark consists of a kernel that implements a derivative of the Black and Scholes technique. SunGard developed the code, which uses a continuous-fraction technique that is more accurate than the traditional polynomial approximation technique. Intel provided an enhanced 32-bit version of the Black-Scholes Kernel to www.2cpu.com, which created a 64-bit version. Intel then provided the www.2cpu.com 64-bit source code we used to build the executables we employed in this report.

We reviewed that source and found no changes designed to favor one processor architecture over another.

Test results

Figure 3 details the results of our tests with 2, 4, 8, 16, and 24 threads using the Black-Scholes workload. For each test, we present the median run of the three individual test runs we executed. The test produces the time, in seconds, the server took to complete the workload; lower completion times are better.

Server / # of threads	2 threads	4 threads	8 threads	16 threads	24 threads
AMD Opteron processor 8360 SE-based server	119.47	59.73	29.86	**14.94**	16.69
Intel Xeon processor X7350-based server	114.50	57.25	28.69	**14.36**	16.08
Intel Xeon processor X7460-based server	80.53	40.27	20.25	10.13	**6.75**

Figure 3: Median completion times (in seconds) of the server with varying thread counts using the Black-Scholes workload. Lower times are better. The result for the optimum thread count for each server appears in bold.

As Figure 3 shows, both the Intel Xeon processor X7350-based server and AMD Opteron processor 8360 SE-based server achieved their fastest times with 16 threads, making that the optimum thread-to-processor

configuration for these servers. In contrast, the Intel Xeon processor X7460-based server achieved the fastest time with 24 threads, making that the optimum thread-to-processor configuration for that server. Figure 4 details the average power consumption of the test servers during the median runs of our tests with 2, 4, 8, 16, and 24 threads.

Server / # of threads	2 threads	4 threads	8 threads	16 threads	24 threads
AMD Opteron processor 8360 SE-based server	457.5	487.0	549.9	655.7	630.6
Intel Xeon processor X7350-based server	579.2	615.7	677.2	772.7	756.0
Intel Xeon processor X7460-based server	539.8	569.0	601.3	652.9	720.4

Figure 4: Average power usage (in watts) of the servers with varying thread counts running the Black-Scholes workload. Lower times are better.

Figure 5 details the power consumption, in watts, of the test servers while idle and during the median peak runs at the optimum thread count of the benchmark.

Server	Idle power (watts)	Average power (watts)
AMD Opteron processor 8360 SE-based server	429.0	655.7
Intel Xeon processor X7350-based server	517.1	772.7
Intel Xeon processor X7460-based server	506.9	720.4

Figure 5: Average power usage (in watts) of the test servers while idle and during the median peak runs at optimum thread count of the Black-Scholes workload. Lower numbers are better.

Test methodology

Figure 6 summarizes some key aspects of the configurations of the three server systems; Appendix A provides detailed configuration information.

Server	AMD Opteron processor 8360 SE-based server	Intel Xeon processor X7350-based server	Intel Xeon processor X7460-based server
Processor frequency (GHz)	2.50	2.93	2.66
Front-side bus frequency (MHz)	2,000 with HyperTransport	1,066	1,066
Number of processor packages	4	4	4
Number of cores per processor package	4	4	6
Number of hardware threads per core	1	1	1
Motherboard	HP 013241-001	Intel S7000FC4UR	Intel S7000FC4UR
Chipset	NVIDIA nForce Pro 2050	Intel ID3600	Intel ID3600
RAM	Micron MT36HTF25672PY-667D1 ELPIDA EBE21AD4AJFA-6E-E	Kingston KVR667D2D4F5/2G	Kingston KVR667D2D4F5/2G
Hard drive	HP DG072BABCE	Seagate ST973401SS	Seagate ST973401SS

Figure 6: Summary of some key aspects of the server configurations.

Intel configured and provided the two Intel Xeon processor-based servers. PT purchased the AMD Opteron processor-based server.

We used the default BIOS settings on the Intel Xeon processor X7460-based server and the Intel Xeon processor X7350-based server. We used the default BIOS settings on the AMD Opteron processor 8360 SE-based server except for one change which was to change the HP Power Regulator for ProLiant setting from Dynamic Power Savings Mode to Static Performance Mode.

We began our testing by installing a fresh copy of Microsoft Windows 2003 Server, x64 Enterprise Edition Service Pack 2 on each server. We followed this process for each installation:

1. Assign a computer name of “Server”.
2. For the licensing mode, use the default setting of five concurrent connections.
3. Enter a password for the administrator log on.
4. Select Eastern Time Zone.
5. Use typical settings for the Network installation.
6. Use “Testbed” for the workgroup.

We then installed the Microsoft .NET Framework, version 3.5 with the default options; it is available at http://msdn.microsoft.com/netframework/.

Power measurement configuration

To record each server’s power consumption during each test, we used an Extech Instruments (www.extech.com) 380803 Power Analyzer / Datalogger. We connected the power cord from the server under test to the Power Analyzer’s output load power outlet. We then plugged the power cord from the Power Analyzer’s input voltage connection into a power outlet.

We used the Power Analyzer’s Data Acquisition Software (version 2.11) to capture all recordings. We installed the software on a separate Intel–processor-based PC, which we connected to the Power Analyzer via an RS-232 cable. We captured power consumption at half-second intervals.

To gauge the idle power usage, we recorded the power usage while each server was running the operating system but otherwise idle.

We then recorded the power usage (in watts) for each server during the testing at half-second intervals. To compute the average power usage, we averaged the power usage during the time the server was producing its peak performance results. We call this time the power measurement interval. See 4 (power consumption at different thread counts) and 5 (idle and average peak power) for the results of these measurements.

Installation of the Black-Scholes 64-bit version kernel workload

Intel supplied the Black-Scholes 64-bit kernel workload compressed in a zip file. We unzipped the file’s contents into a directory on a system separate from the servers under test. The folder contained C++ source code files and make files.

We used the Visual Studio project Intel provided to build the 64-bit versions of the workload with Microsoft Visual Studio 2005 as follows:

1. Double click the black_scholes_x64.vcproj file. Visual Studio automatically opens.
2. In the Solution Explorer pane, right-click black_scholes_x64, and select Properties
3. From inside the "black_scholes_x64 Property Pages" dialog, click the "Configuration Manager..." button.
4. From the "Active solution configuration:" drop-down menu, choose "Optimized_x64".
5. From the "Active solution platform:" drop-down menu, choose "x64".
6. Close the Configuration Manager.
7. While still inside the "black_scholes_x64 Property Pages" dialog, expand the C/C++ properties, and click "Command Line".

8. In the "Additional options:" text box, type "/favor:EM64T" to build the executable.
9. Click "OK" to close the "black_scholes_x64 Property Pages" dialog.
10. From the "Build" menu, select "Rebuild Solution".

We used the Microsoft Visual Studio 2005 to build 64-bit versions of the “Optimized_x64” executables. Intel provided the source code. As part of the process of building the executables, we needed to specify options for the compiler. We used the options in the project for the Optimized_x64 executable we received. (Per Intel, the staff at www.2cpu.com started with the 32-bit version of the Black-Scholes kernel workload and created this 64-bit version).

Once we built the executables, we created a folder on each server under test called BlackScholes and stored the executables in that folder.

Black-Scholes kernel workload switches/parameters

This workload provides the following switches, which we set as appropriate for each test run:

- */numThreads* or */t* This option designates the number of threads the workload should run. We set this to the number of threads we wanted in each test.
- *Number of steps* This option designates the number of steps the workload should use to calculate the option price.

By default, the workload assumes the following values:

- Number of threads: 4
- Number of steps: 100,000,000

This workload defaults to four threads regardless of the number of logical processors available on the server.

Running the Black-Scholes kernel workload

We rebooted the server before each individual test and then followed this process to run the test:

1. Open a DOS command window.
2. Navigate to the C:\BlackScholes folder.
3. Enter the following command:
   For Intel processor based systems:
   “black_scholes_intel.exe <# of threads> 2000000000 > <server name>_<# of threads>_<run no.>.txt, where
   a. <server name> is either Intel Xeon X7460 or Intel Xeon X7350 as appropriate
   b. <# of threads> is either 2, 4, 8, 16, or 24 as appropriate
   c. <run no.> is either 1, 2, or 3 (we ran each test three times)

   For AMD processor based systems:
   “black_scholes_amd.exe <# of threads> 2000000000 > <server name>_<# of threads>_<run no.>.txt, where
   a. <server name> AMD Opteron 8360 SE
   b. <# of threads> is either 2, 4, 8, 16, or 24 as appropriate
   c. <run no.> is either 1, 2, or 3 (we ran each test three times)

Each execution of the workload generates a text file that includes how long the workload took to complete. We recorded that time as the result for each run.

Appendix A – Test server configuration information

This appendix provides detailed configuration information about each of the test server systems, which we list in alphabetical order.

Servers	AMD Opteron processor 8360 SE-based server	Intel Xeon processor X7350-based server	Intel Xeon processor X7460-based server
General processor setup			
Number of processor packages	4	4	4
Number of cores per processor package	4	4	6
Number of hardware threads per core	1	1	1
System Power Management Policy	Always On	Always On	Always On
CPU			
Vendor	AMD	Intel	Intel
Name	Opteron 8360 SE	Intel Xeon X7350	Intel Xeon X7460
Stepping	3	B	1
Socket type	Socket F (1207)	Socket P (478)	Socket P (478)
Core frequency (GHz)	2.50	2.93	2.66
Front-side bus frequency (MHz)	2,000 with HyperTransport	1,066	1,066
L1 cache	64 KB x 64 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	4 x 512 KB (512 KB per core)	2 x 4 MB (each 4 MBs shared by 2 cores)	3 x 3 MB (each 3 MB shared by 2 cores)
L3 cache	2MB	N/A	16 MB
Platform			
Vendor and model number	HP DL585 G5	Intel Fox Cove	Intel Fox Cove
Motherboard model number	013241-001	S7000FC4UR	S7000FC4UR
Motherboard chipset	NVIDIA nForce Pro 2050	Intel ID3600	Intel ID3600
Motherboard revision number	0H	01	01
BIOS name and version	HP A07 (06/27/2008)	Intel SFC4UR.868.01.00.0024.061320082253 (06/13/2008)	Intel SFC4UR.868.01.00.0024.061320082253 (06/13/2008)
BIOS settings	Power Regulator for ProLiant set to Static Performance Mode	Default	Default
Chipset driver	Microsoft 5.2.3790.1830	Intel 8.4.0.1015	Intel 8.4.0.1015
Memory module(s)			
Vendor and model number	8 x Micron MT36HTF25672PY-667D1, 8 x ELPIDA EBE21AD4AJFA-6E-E	Kingston KVR667D2D4F5/2G	Kingston KVR667D2D4F5/2G
Type	PC2-5300 DDR2	PC2-5300 FB-DDR2	PC2-5300 FB-DDR2
Speed (MHz)	667 MHz	667 MHz	667 MHz
Speed in the system currently running @ (MHz)	667 MHz	667 MHz	667 MHz

Servers	AMD Opteron processor 8360 SE-based server	Intel Xeon processor X7350-based server	Intel Xeon processor X7460-based server
Timing/Latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15	5-5-5-15	5-5-5-15
Size	32 GB	32 GB	32 GB
Number of RAM modules	16 x 2 GB	16 x 2 GB	16 x 2 GB
Chip organization	Double-sided	Double-Sided	Double-Sided
Hard disk			
Vendor and model number	HP DG072BABCE	Seagate ST973401SS	Seagate ST973401SS
Number of disks in system	2	2	2
Size	72 GB	73.4 GB	73.4 GB
Buffer size	16 MB	8 MB	8 MB
RPM	10,000	10,000	10,000
Type	SAS	SAS	SAS
Controller	Smart Array P400 Controller	Integrated Intel RAID Controller SROMBSASFC	Integrated Intel RAID Controller SROMBSASFC
Driver version	HP 6.8.0.64	Intel 2.20.0.64	Intel 2.20.0.64
Operating system			
Name	Microsoft Windows Server 2003 Enterprise x64 Edition	Microsoft Windows Server 2003 Enterprise x64 Edition	Microsoft Windows Server 2003 Enterprise x64 Edition
Build number	3790	3790	3790
Service Pack	SP2	SP2	SP2
File system	NTFS	NTFS	NTFS
Kernel	ACPI	ACPI	ACPI
Language	English	English	English
Microsoft DirectX version	9.0c	9.0c	9.0c
Graphics			
Vendor and model number	ATI ES1000	ATI ES1000	ATI ES1000
Chipset	ES1000	ES1000	ES1000
BIOS version	BK-ATI VER008.005.013.000	BK-ATI VER008.005.031.000	BK-ATI VER008.005.031.000
Type	Integrated	Integrated	Integrated
Memory size	32 MB	32 MB	32 MB
Resolution	1,280 x 1,024	1,280 x 1,024	1,280 x 1,024
Network card/subsystem			
Vendor and model number	HP NC371i Multifunction Gigabit Server Adapter	Intel PRO/1000 EB	Intel PRO/1000 EB
Type	Integrated	Integrated	Integrated
Driver version	HP 4.4.15.0	Intel 9.12.18.0	Intel 9.12.18.0
Optical drive			
Vendor and model number	HL-DT-ST RW/DVD GCC-C10N	Optiarc DVD-ROM DDU810A	Optiarc DVD-ROM DDU810A
USB ports			
Number	4	5	5
Type	USB 2.0	USB 2.0	USB 2.0

Servers	AMD Opteron processor 8360 SE-based server	Intel Xeon processor X7350-based server	Intel Xeon processor X7460-based server
Power supplies			
Total number	2	2	2
Wattage of each	1300W	1570W	1570W
Cooling fans			
Total number	6	8	8
Dimensions	5” x 5”	4 x 80mm + 4 x 120mm	4 x 80mm + 4 x 120mm
Voltage	12V	12 V	12 V
Amps	3.3A	4 x 1.76 A + 4 x 3.3 A	4 x 1.76 A + 4 x 3.3 A

Figure 7: Detailed system configuration information for the three test servers.

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