Principled Technologies®

TEST REPORT
NOVEMBER 2006

64-bit Black-Scholes financial workload performance on quad-core and dual-core dual-processor servers

Executive summary

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

- dual-core AMD Opteron processor model 2220 SE
- Dual-Core Intel Xeon processor 5160
- Quad-Core Intel Xeon processor X5355

KEY FINDINGS

- The Quad-Core Intel Xeon processor X5355-based server delivered almost 46 percent higher peak performance than the dual-core AMD Opteron processor model 2220 SE-based server (see Figure 1).
- The Quad-Core Intel Xeon processor X5355-based server delivered over 43 percent higher peak performance than the Dual-Core Intel Xeon processor 5160-based server (see Figure 1).

The Black-Scholes kernel workload is multithreaded and allows users to specify the number of threads the program should run. Performance of the workload can increase as it runs with more threads, up to an optimum thread count, generally equal to the number of logical and physical processors available on the server. (We refer to this as the optimum thread-to-processor configuration.)

The optimum thread count for our testing was 4 on the dual-core AMD Opteron processor model 2220 SE-based server and Dual-Core Intel Xeon processor 5160-based server, because both servers have 2 physical processors with 2 cores per processor, or 4 available execution units. The Quad-Core Intel Xeon processor X5355-based server has 2 physical processors with 4 cores per processor, or 8 available execution units, so its optimum thread count was 8.

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.

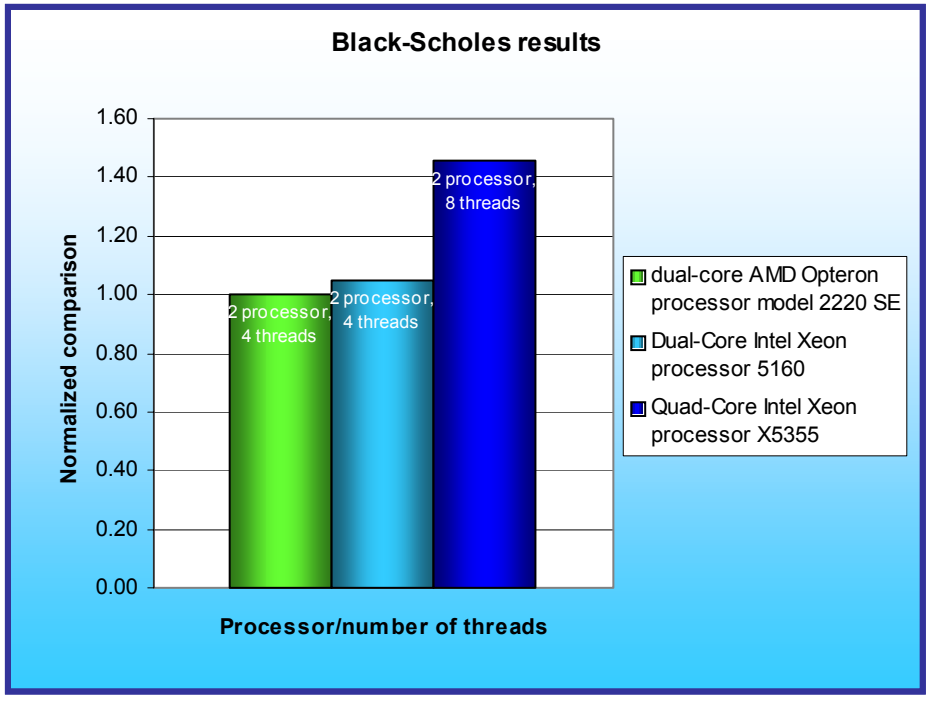

Figure 1: Normalized peak (dual-processor) performance of the servers with the optimum thread-to-processor configurations with the Black-Scholes workload. Higher numbers are better.

Figure 1 illustrates the relative peak (dual-processor) performance of each server. In this and the other performance charts in this section, we normalized the results for each workload to the time the slowest configuration took to complete that workload. The slowest system’s 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 (i.e., faster times to complete the workload with the specified number of threads).

The Quad-Core Intel Xeon processor X5355-based server finished the Black-Scholes workload in 1.8 seconds, 45.9 percent faster than the dual-core AMD Opteron processor

model 2220 SE-based server, which finished the same workload in 3.4 seconds. The Quad-Core Intel Xeon processor X5355-based server was 43.2 percent faster than the Dual-Core Intel Xeon processor 5160-based server, which took 3.2 seconds to complete the same workload.

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.

We used Microsoft Visual Studio 2005 to compile this source code. To optimize the code for the test servers, we used the compiler's "/favor:EM64T" option. In the Test methodology section, we present the details of how we compiled this source code.

Test results

Figure 2 details the results of our tests with 2, 4, 8, and 16 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	4	8	16
dual-core AMD Opteron processor model 2220 SE-based server	6.7	3.4	3.4	3.4
Dual-Core Intel Xeon processor 5160-based server	6.4	3.2	3.3	3.2
Quad-Core Intel Xeon processor X5355-based server	7.2	3.6	1.8	2.1

Figure 2: Median completion times (in seconds) of the server with varying thread counts using the Black-Scholes workload. Lower times are better.

As Figure 2 shows, the dual-core AMD Opteron processor model 2220 SE and Dual-Core Intel Xeon processor 5160-based servers achieved their fastest completion times with 4 threads, which means 4 threads is the optimum thread-to-processor configuration for these servers. The Quad-Core Intel Xeon processor X5355-based server achieved its fastest time with 8 threads, which means 8 threads is its optimum thread-to-processor configuration.

Test methodology

Figure 3 summarizes some key aspects of the configurations of the three server systems; Appendix A provides detailed configuration information.

Server	dual-core AMD Opteron processor model 2220 SE-based server	Dual-Core Intel Xeon processor 5160-based server	Quad-Core Intel Xeon processor X5355-based server
Processor frequency (GHz)	2.8 GHz	3.0 GHz	2.66 GHz
System bus	2000 MHz HyperTransport	1333 MHz	1333 MHz
Dual/Quad-Core processors	Dual	Dual	Quad
Motherboard	Tyan h2000M (S3992)	Intel Server Board S5000PSL	Intel Server Board S5000PSL
Chipset	Broadcom BCM5780 (HT2000) + BCM5785 (HT1000) chipset	Intel 5000P Chipset	Intel 5000P Chipset
RAM (8GB in each)	PC2-5300	PC2-5300 FBDIMM	PC2-5300 FBDIMM
Hard Drive	Western Digital WD1600YD	Western Digital WD1600YD	Western Digital WD1600YD
NICs	Broadcom NetXtreme Gigabit Dual Port Network Connection / Intel PRO/100 Server Adapter	Intel PRO/1000 EB Network Dual Port Network Connection	Intel PRO/1000 EB Network Dual Port Network Connection

Figure 3: Summary of some key aspects of the server configurations.

Intel configured and provided all three servers.

We began our testing by installing a fresh copy of Microsoft Windows 2003 Server Enterprise x64 Edition Service Pack 1 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 applied the following updates from the Microsoft Windows Update site:

- Security Update for Windows Server 2003 x64 Edition (KB922819)
- Security Update for Windows Server 2003 x64 Edition (KB924191)
- Security Update for Windows Server 2003 x64 Edition (KB923191)
- Security Update for Windows Server 2003 x64 Edition (KB924496)
- Security Update for Windows Server 2003 x64 Edition (KB923414)
- Security Update for Windows Server 2003 x64 Edition (KB925486)
- Security Update for Windows Server 2003 x64 Edition (KB920685)
- Security Update for Windows Server 2003 x64 Edition (KB921883)
- Update for Windows Server 2003 x64 Edition (KB922582)
- Security Update for Windows Server 2003 x64 Edition (KB921398)
- Security Update for Outlook Express for Windows Server 2003 x64 Edition (KB920214)
- Security Update for Windows Server 2003 x64 Edition (KB917422)
- Security Update for Windows Server 2003 x64 Edition (KB922616)
- Security Update for Windows Server 2003 x64 Edition (KB920683)

- Security Update for Windows Server 2003 x64 Edition (KB920670)
- Cumulative Security Update for Internet Explorer for Windows Server 2003 x64 Edition (KB918899)
- Security Update for Windows Server 2003 x64 Edition (KB914388)
- Security Update for Windows Server 2003 x64 Edition (KB911280)
- Security Update for Windows Server 2003 x64 Edition (KB917953)
- Security Update for Windows Server 2003 x64 Edition (KB918439)
- Security Update for Windows Server 2003 x64 Edition (KB917344)
- Update for Windows Server 2003 x64 Edition (KB914784)
- Security Update for Windows Server 2003 x64 Edition (KB914389)
- Security Update for Windows Server 2003 x64 Edition (KB917734)
- Security Update for Windows Server 2003 x64 Edition (KB911562)
- Cumulative Security Update for Outlook Express for Windows Server 2003 x64 Edition (KB911567)
- Security Update for Windows Media Player Plug-in (KB911564)
- Security Update for Windows Server 2003 x64 Edition (KB911927)
- Security Update for Windows Server 2003 x64 Edition (KB908519)
- Security Update for Windows Server 2003 x64 Edition (KB912919)
- Update for Windows Server 2003 x64 Edition (KB910437)
- Security Update for Windows Server 2003 x64 Edition (KB896424)
- Security Update for Windows Server 2003 x64 Edition (KB900725)
- Security Update for Windows Server 2003 x64 Edition (KB902400)
- Security Update for Windows Server 2003 x64 Edition (KB904706)
- Security Update for Windows Server 2003 x64 Edition (KB901017)
- Security Update for Windows Server 2003 x64 Edition (KB890046)
- Security Update for Windows Server 2003 x64 Edition (KB899587)
- Security Update for Windows Server 2003 x64 Edition (KB899591)
- Security Update for Windows Server 2003 x64 Edition (KB893756)
- Security Update for Windows Server 2003 x64 Edition (KB899588)
- Security Update for Windows Server 2003 x64 Edition (KB901214)
- Security Update for Windows Server 2003 x64 Edition (KB896358)
- Security Update for Windows Server 2003 x64 Edition (KB896428)
- Update for Windows Server 2003 x64 Edition (KB898715)

We then installed the Microsoft .NET Framework, version 2.0.50727 with the default options; it is available at http://msdn.microsoft.com/netframework/.

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:
   “blackscholes_x64.exe ,<# of threads> > <server name>_<# of threads>_<run no.>.txt, where
   a. <server name> is server name as appropriate
   b. <# of threads> is either 2, 4, 8, or 16 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 system configuration information

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

Processors	dual-core AMD Opteron processor model 2220 SE-based server	Dual-Core Intel Xeon processor 5160-based server	Quad-Core Intel Xeon processor X5355-based server
System configuration information			
General			
Processor and OS kernel: (physical, core, logical)	2P4C4L	2P4C4L	2P8C8L
Number of physical processors	2	2	2
Dual/Quad-Core processors	Dual	Dual	Quad
System Power Management Policy	Always On	Always On	Always On
CPU			
Vendor	AMD	Intel	Intel
Name	dual-core AMD Opteron processor model 2220 SE	Dual-Core Intel Xeon processor 5160	Quad-Core Intel Xeon processor X5355
Stepping	2	4	7
Socket type	F	LGA 771	LGA 771
Core frequency (GHz)	2.8 GHz	3.0 GHz	2.66 GHz
System bus	2000 MHz HyperTransport	1333 MHz	1333 MHz
L1 Cache	64 KB + 64 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 Cache	2 x 1MB	4 MB (shared by 2 cores)	2 x 4MB (each 4MB shared by 2 cores)
Platform			
Vendor and model number	dual-core AMD Opteron processor model 2220 SE-based server	Dual-Core Intel Xeon processor 5160-based server	Quad-Core Intel Xeon processor X5355-based server
Motherboard model number	Tyan h2000M (S3992)	Intel Server Board S5000PSL	Intel Server Board S5000PSL
Motherboard chipset	Broadcom BCM5780 (HT2000) + BCM5785 (HT1000) chipset	Intel 5000P Chipset	Intel 5000P Chipset
Motherboard revision number	G3NR	B1	B1
Motherboard serial number	TC62423A0149	QSSL63800874	QSSL63800874
BIOS name and version	American Megatrends Inc. AMIBIOS 08.00.11	Intel Corporation S5000.86B.04.00.0065 .092920061534	Intel Corporation S5000.86B.04.00.0065 .092920061534
BIOS settings	Default	Default	Default
Chipset INF driver	N/A	8.1.1.1001	8.1.1.1001

Memory module(s)			
Vendor and model number	Micron MT18HTF12872PDY	Micron MT18HTF12872FDY	Micron MT18HTF12872FDY
Type	PC2-5300	PC2-5300 FBDIMM	PC2-5300 FBDIMM
Speed (MHz)	667 MHz	667 MHz	667 MHz
Speed in the system currently running @ (MHz)	667 MHz	667 MHz	667 MHz
Timing/Latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15	5-5-5-15	5-5-5-15
Size	8192 MB	8192 MB	8192 MB
Number of RAM modules	8	8	8
Chip organization	Double-Sided	Double-Sided	Double-Sided
Hard disk			
Vendor and model number	Western Digital WD1600YD-01NVB1	Western Digital WD1600YD-01NVB1	Western Digital WD1600YD-01NVB1
Number of disks in system	1	1	1
Size	160 GB	160 GB	160 GB
Buffer Size	16 MB	16 MB	16 MB
RPM	7200	7200	7200
Type	SATA-II	SATA-II	SATA-II
Controller	Integrated IDE ATA/ATAPI	Integrated IDE ATA/ATAPI	Integrated IDE ATA/ATAPI
Controller driver	Microsoft 5.2.3790.1830	Microsoft 5.2.3790.1830	Microsoft 5.2.3790.1830
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	SP1	SP1	SP1
Microsoft Windows update date	10/13/2006	10/13/2006	10/13/2006
File system	NTFS	NTFS	NTFS
Kernel	ACPI Multiprocessor x64-based PC	ACPI Multiprocessor x64-based PC	ACPI Multiprocessor x64-based PC
Language	English	English	English
Microsoft DirectX version	DirectX 9.0c	DirectX 9.0c	DirectX 9.0c
Graphics			
Vendor and model number	ATI ES1000	ATI ES1000	ATI ES1000
Chipset	ATI ES1000 PCI	ATI ES1000 PCI	ATI ES1000 PCI
BIOS version	BK-ATI VER008.005.019.000	BK-ATI VER008.005.023.000	BK-ATI VER008.005.023.000
Type	Integrated	Integrated	Integrated
Memory size	32 MB	16 MB	16 MB
Resolution	1024 x 768	1024 x 768	1024 x 768
Driver	ATI 6.14.10.6553	ATI 8.24.3.0	ATI 8.24.3.0
Network card/subsystem			

Vendor and model number	Broadcom NetXtreme Gigabit Dual Port Network Connection / Intel PRO/100 Server Adapter	Intel PRO/1000 EB Network Dual Port Network Connection	Intel PRO/1000 EB Network Dual Port Network Connection
Type	Integrated	Integrated	Integrated
Driver	Broadcom 8.39.1.0 / Intel 8.0.27.0	Intel 9.5.12.0	Intel 9.5.12.0
Optical drive			
Vendor and model number	TSSTcorp CD/DVDW TS-H552B	Sony DVD RW DW-Q120A	Sony DVD RW DW-Q120A
Type	DVD-RW	DVD-RW	DVD-RW
Interface	Internal	Internal	Internal
Dual/Single layer	Dual	Dual	Dual
USB ports			
# of ports	4	6	6
Type of ports (USB 1.1, USB 2.0)	USB 2.0	USB 2.0	USB 2.0

Figure 4: Detailed system configuration information for the test servers.

Principled Technologies, Inc.
4813 Emperor Blvd., Suite 100
Durham, NC 27703
www.principledtechnologies.com
info@principledtechnologies.com