Principled Technologies®

TEST REPORT
MAY 2006

# 64-bit financial application-based workload performance on Intel- and AMD-processor-based server platforms

## Executive summary

Intel Corporation (Intel) commissioned Principled Technologies (PT) to measure the performance of two different 64-bit financial application-based workloads on two servers in various configurations. We compared the performance of the two servers, and we also gauged how performance scaled on the Dual-Core Intel Xeon Processor 5160-based server when upgrading from one to two processors.

### KEY FINDINGS

- The Dual-Core Intel Xeon Processor 5160-based server delivered as much as 38 percent higher peak performance than the AMD Opteron processor-based server on both the SunGard Adaptiv Credit Risk workload setup and the Black-Scholes kernel workload (see Figure 1).
- The two-processor Dual-Core Intel Xeon Processor 5160-based server completed each of the workloads up to twice as fast as the same server with one Intel processor (see Figure 2).
- On all thread counts we tested with each workload, the Dual-Core Intel Xeon Processor 5160-based server performed better than the AMD Opteron processor-based server.

The two financial workloads were the SunGard Adaptiv Credit Risk (SunGard ACR) and the Black-Scholes Kernel. Each workload is multithreaded and lets users specify the number of threads the program should run. Performance of both workloads can increase as each runs with more threads up to an optimum thread count, which is typically the number of logical and physical processors available on the server. (We refer to this as the optimum thread-to-processor configuration.) For both workloads and both of these servers, the optimum thread count is four, because each server has two physical processors, each with two cores and two logical processors per core. For details of the performance of each server with varying thread counts, see Figures 3 and 4. For more information on the two workloads, refer to the Workloads section.

Figures 1 illustrates the relative peak (dual-processor) performance of each server. One server contained two Dual-Core Intel Xeon Processor 5160 CPUs, each 3.00 GHz with 4MB of L2 Cache. The other used two AMD Opteron 280 Dual-Core 280 processors, each 2.4 GHz with 2MB of L2 cache. Each server had 4GB of RAM. In this and the other performance charts, we normalized the results to the time the slower configuration took to complete the workload. The slower 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).

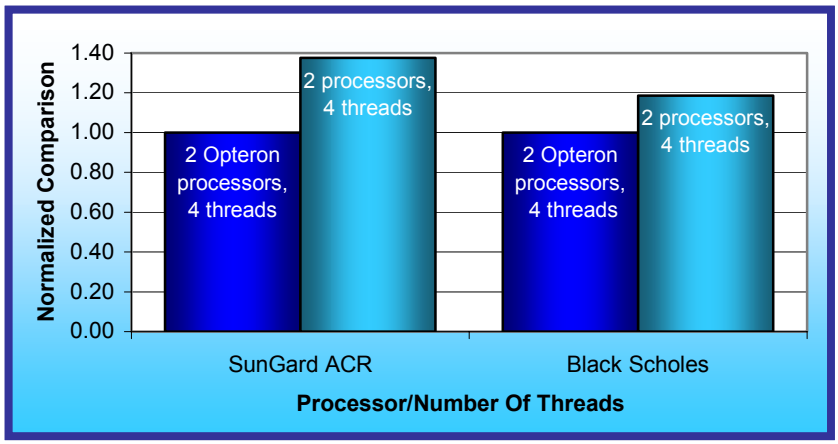


**Figure 1: Peak (dual-processor) performance of the two servers with the optimum thread-to-processor configurations on both the SunGard ACR and Black-Scholes workloads. Higher numbers are better.**

As Figure 1 shows, the peak performance of the Dual-Core Intel Xeon Processor 5160-based server was as much as 38 percent higher than that of the AMD Opteron processor-based server on the SunGard Adaptiv Credit Risk workload—a speed difference that means a user would receive a solution over one and a half minutes quicker with the Dual-Core Intel Xeon Processor 5160-based server. With the Black-Scholes workload, the peak performance of the Dual-Core Intel Xeon Processor 5160-based server was about 19 percent faster than that of the AMD Opteron processor-based server.

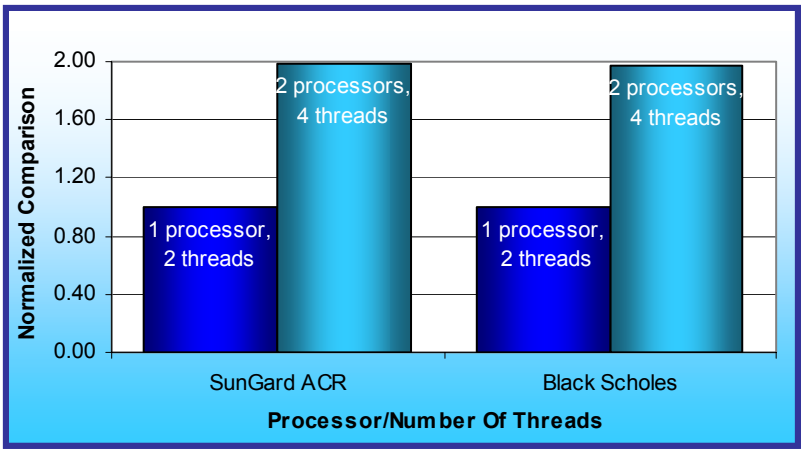


**Figure 2: One- to two-processor performance scaling on the Intel Xeon Processor 5160-based server using the optimum threads-to-processor configurations on both the SunGard ACR and Black-Scholes workloads.**

The Dual-Core Intel Xeon Processor 5160-based server demonstrated significant performance gains in both workloads from the addition of the second processor. As Figure 2 shows, performance on each workload nearly doubled with the second processor.

In addition to the tests these figures summarize, we ran numerous other tests on each server. We tested both the single-physical-processor and the dual-physical-processor configurations with 1, 2, 3, 4, 5, 6, 7, and 8 threads for each workload. We present those results in the Test results section. Intel provided the servers and workloads. We executed all tests with clean installations of Microsoft Windows 2003 Server, x64 Enterprise Edition.

# Workloads

## SunGard Adaptiv Credit Risk

Per SunGard, "SunGard Adaptiv Credit Risk provides a total, real-time credit risk solution for counterparty credit exposure aggregation, global limit management, credit risk analytics and collateral management." This workload analyzes a large portfolio of client assets and generates a credit risk evaluation. The quicker the workload completes, the quicker the user receives the evaluation; saving time and improving productivity. SunGard developed the Adaptiv Credit Risk workload and supplied the computational engine and financial data.

Per SunGard, "With annual revenue of $4 billion, SunGard is a global leader in software and processing solutions for financial services, higher education and the public sector. SunGard also helps information-dependent enterprises of all types to ensure the continuity of their business. SunGard serves more than 25,000 customers in more than 50 countries, including the world's 50 largest financial services companies. SunGard Adaptiv Credit Risk is a risk management system that supports the credit risk management on all levels by combining comprehensive credit risk related functionality, powerful real-time analytic capabilities and sophisticated user interfaces and reporting. SunGard Adaptiv Credit Risk (www.sungard.com/adaptiv) provides global scalability, real-time performance and the capacity to handle vast trading volumes." SunGard Adaptiv Credit Risk has an open architecture and uses middleware, XML-based formats, and industry standard technologies and data standards.

## Black-Scholes kernel 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 test executables.

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 Dual-Core Intel Xeon Processor 5160-based server, we used the compiler's "/favor:EM64T" option. To optimize the code for the AMD Opteron processor-based server, we selected the compiler's "/favor:AMD64" option. In the Test methodology section, we present the details of how we compiled this source code.

# Test results

Figure 3 details the results of our tests with up to eight threads using the SunGard Adaptiv Credit Risk workload. For each test, we use in our summary graphs 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 system\ # of threads | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| AMD Opteron processor-based server- 1 processor | 2397.2 | 1206.3 | 1235.5 | 1221.9 | 1204.1 | 1264.8 | 1206.8 | 1195.1 |
| AMD Opteron processor-based server - 2 processors | 2423.2 | 1220.2 | 828.6 | 605.5 | 621.6 | 638.8 | 653.5 | 602.5 |
| Dual-Core Intel Xeon Processor 5160-based server - 1 processor | 1738.6 | 877.8 | 912.3 | 886.7 | 888.0 | 883.2 | 880.4 | 879.8 |
| Dual-Core Intel Xeon Processor 5160-based server - 2 processors | 1749.0 | 875.9 | 585.4 | 440.2 | 461.5 | 461.2 | 469.3 | 447.5 |

**Figure 3: Median completion times (in seconds) of the server configurations with varying thread counts using the SunGard ACR workload. Lower times are better.**

Figure 4 details the results of our tests with up to eight threads using the Black-Scholes kernel workload that we created by compiling with Microsoft Visual Studio 2005 and then optimizing for each server platform. For each test, we use in our summary graphs 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 System\ # of threads | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| AMD Opteron processor-based server- 1 processor | 15.1 | 7.6 | 7.8 | 7.6 | 7.7 | 7.6 | 7.7 | 7.7 |
| AMD Opteron processor-based server - 2 processors | 14.6 | 7.3 | 5.0 | 3.8 | 4.4 | 3.9 | 4.2 | 4.0 |
| Dual-Core Intel Xeon Processor 5160-based server - 1 processor | 12.7 | 6.4 | 6.5 | 6.4 | 6.5 | 6.4 | 6.5 | 6.4 |
| Dual-Core Intel Xeon Processor 5160-based server - 2 processors | 12.8 | 6.4 | 4.3 | 3.2 | 3.8 | 3.3 | 3.7 | 3.3 |

**Figure 4: Median completion times (in seconds) of the server configurations with varying thread counts using the Black-Scholes kernel workload that we compiled with Microsoft Visual Studio and optimized for each platform. Lower times are better.**

# Test methodology

Figure 5 summarizes a few key aspects of the configurations of the two server systems. Appendix A provides more detailed configuration information.

| Server system | Dual-Core Intel Xeon Processor 5160-based server | Dual-Core AMD Opteron 280-based server |
|---|---|---|
| Processor frequency (GHz) | 3.00 | 2.4 |
| Motherboard | SuperMicro X7DB8+ | Uniwide Technologies, Inc. SS232-128-02 |
| Chipset | Intel Dual-Processor Server chipset codename Blackford | NVIDIA nForce4 Professional 2050/2200 |
| RAM (4096 MB in each) | 4 x 1024MB PC2-5300 DDR2-SDRAM FBDIMM | 4 x 1024MB PC-3200 DDR-SDRAM |
| Hard drive | Western Digital Caviar WD1200JS (120GB) | Western Digital Caviar RE WD1600SD (160GB) |

**Figure 5: Summary of key aspects of the server configurations.**

Intel configured and provided both servers.

The difference in RAM types reflects the capabilities of the two motherboards. The Intel motherboard offered a front-side bus speed of 1333 MHz and employed Fully-Buffered DIMM (FBDIMM) modules that used commodity DDR2 PC2-5300 667MHz memory components. The Uniwide motherboard supported 184-pin DDR memory, and the highest memory speed available for the AMD Opteron processor-based server was DDR PC3200 400MHz RAM.

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

1. Assign a computer name that reflects the processor name and vendor.
2. For the licensing mode, use the default setting of five concurrent connections.
3. Do not enter a password for the administrator log on.
4. Select Eastern Time Zone.
5. Use typical settings for the Network installation.
6. Use “WORKGROUP” for the workgroup.

We applied to each server the following updates from the Microsoft Windows Update site:

- Cumulative Security Update for Internet Explorer for Windows Server 2003 x64 Edition (KB905915)
- Microsoft Base Smart Card Cryptographic Service Provider Package: x64 (KB909520)
- 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 (KB896422)
- 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 (KB910437)
- Update for Windows Server 2003 x64 Edition (KB898715)

We then installed the Microsoft .NET Framework*, version 2.0.50727, which SunGard recommends in the documentation that accompanied the SunGard Adaptiv Credit Risk workload. SunGard developed the SunGard Adaptiv Credit Risk application in Microsoft C#. The application executes as a process within the host Microsoft .NET framework and requires a specific version of .NET, so we downloaded and installed that version (Microsoft .NET Framework x64 Version 2.0.50727, available at http://msdn.microsoft.com/netframework/).

We rebooted the server before each test run.

## Testing with one processor

When we ran the single-processor tests on each server, we physically removed the second processor. Because the AMD Opteron processor-based server assigns each CPU its own RAM, we also removed the RAM associated with that second processor, which left the server with 2GB of RAM. Though the Dual-Core Intel Xeon Processor 5160-based server does not associate RAM with specific processors, to ensure fair and consistent results, we also reduced the RAM in that system to 2GB for the single-processor tests.

### Installation of the SunGard Adaptiv Credit Risk 64-bit version workload

Intel supplied the SunGard Adaptiv Credit Risk 64-bit application and workload compressed in a zip file on CD-ROM. We unzipped the file's contents into the folder C:\Sungard on each system. The files in that folder contained both the SunGard Adaptiv Credit Risk executable (RiskAnalytics.exe) and the two data files the workload uses:

- *MarketData.dat* – sample data representing a fictional set of financial market conditions
- *Portfolio D.cpf* – sample data representing a fictional customer's investment portfolio

### SunGard Adaptiv Credit Risk workload switches/parameters

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

- */numThreads* or */t*
  Designates the number of threads the workload should run. We set this to the number of threads we wanted in each test.
- */outputFileName or /o*
  Saves the results in a text file and overwrites that file if the file already exists. We saved each test's results in a separate file.

By default, the application detects the number of logical processors and runs with one thread per logical processor. So, by default the application would run as follows:

- Dual-Core AMD Opteron processor-based server with 1 processor: 2 threads
- Dual-Core AMD Opteron processor-based server with 2 processors: 4 threads
- Dual-Core Intel Xeon Processor 5160-based server with 1 processor: 2 threads
- Dual-Core Intel Xeon Processor 5160-based server with 1 processor: 4 threads

### Running the SunGard Adaptiv Credit Risk 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:\Sungard folder.
3. Enter the following command:
   "RiskAnalytics /o <server name>_<# of CPUs>_<# of threads>_<run no.>.txt /t <# of threads>", where
   - <server name> is either Intel or AMD, as appropriate
   - <# of CPUs> is either 1 or 2, as appropriate

- <# of threads> is either 1, 2, 3, 4, 5, 6, 7, or 8 as appropriate
- <run no.> is either 1, 2, or 3 (we ran each test three times)

4. The workload then starts and opens a monitoring console like the one in Figure 6, but without the results graph (see next point for more on that graph).
5. Click on Calculate at the top left corner of the window.
6. A "Percentage Complete" progress message displays in the bottom left corner of the status bar.
7. When the workload completes, the monitoring console presents a graph of the results over the course of the test; Figure 6 shows an example graph. The text below the graph in the display describes the parameters the workload used for this run and the time (in seconds) it took to complete the test. Record this time as the primary result of each test.

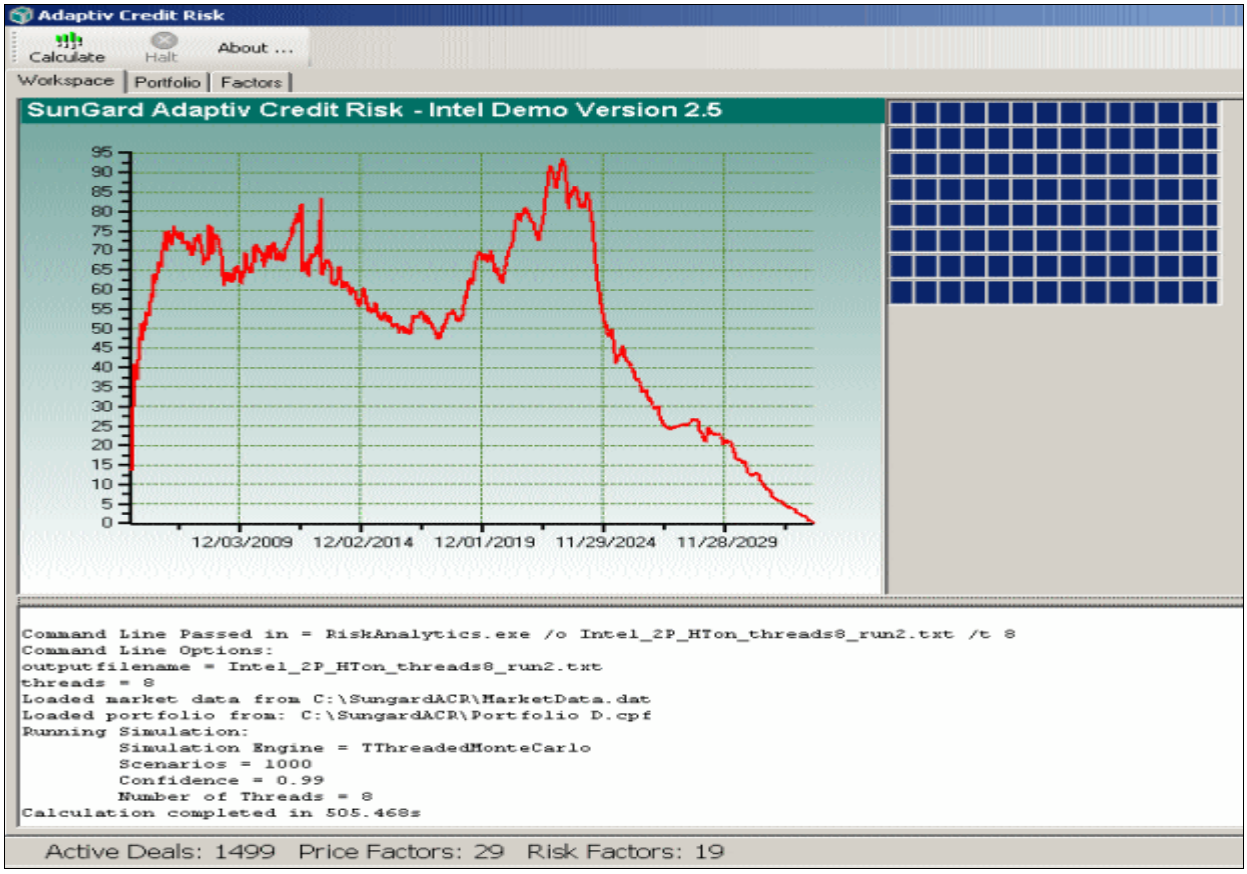


**Figure 6: An example of the monitoring console after the SunGard ACR workload completes.**

## 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 built versions of this workload with both the Microsoft and Intel compilers.

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 either "/favor:EM64T" or "/favor:AMD64" to build the executable for the Dual-Core Intel Xeon Processor 5160-based server or the Dual-Core AMD Opteron processor-based server, respectively.
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*
  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*
  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

Unlike the SunGard Adaptiv Credit Risk application, 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 CPUs>_<# of threads>_<run no.>.txt, where
   a. <server name> is either Intel or AMD, as appropriate
   b. <# of CPUs> is either 1 or 2, as appropriate
   c. <# of threads> is either 1, 2, 3, 4, 5, 6, 7, or 8 as appropriate
   d. <run no.> is either 1, 2, or 3 (we ran each test three times)

# Appendix A – Test server configuration information

This appendix provides detailed configuration information about each of the two test server systems.

| Processor type | Dual-Core Intel Xeon Processor 5160 | Dual-Core AMD Opteron 280 processor |
|---|---|---|
| **General** | | |
| Processor and OS kernel: (physical, core, logical) / (UP, MP) | 2P4C4L / MP | 2P4C4L / MP |
| Number of physical processors | 2 | 2 |
| Single/Dual-Core processors | Dual-Core | Dual-Core |
| System Power Management Policy | AC/Always On | AC/Always On |
| **CPU** | | |
| System type | Server | Server |
| Vendor | Intel | AMD |
| Name | Dual-Core Intel Xeon Processor 5160 | AMD Opteron 280 |
| Stepping | 4 | 6 |
| Socket type | LGA-771 | 940 |
| Core frequency (GHz) | 3.0 | 2.4 |
| Front-side bus frequency (MHz) | 1333 | 1000 |
| L1 Cache | 32 KB + 32 KB | 64 KB + 64 KB |
| L2 Cache | 4096 KB (2048 KB per core) | 2048 KB (1024 KB per core) |
| **Platform** | | |
| Vendor and model number | Dual-Core Intel Xeon Processor 5160 server | Uniwide UniServer 1322 1U Rack Server System |
| Motherboard model number | SuperMicro X7DB8+ | Uniwide Technologies, Inc. SS232-128-02 |
| Motherboard chipset | Intel 5000P Chipset | NVIDIA nForce4 Professional 2050/2200 |
| Motherboard revision number | 0 | 0 |
| Motherboard serial number | TM63S03434 | WTOPET0000143 |
| BIOS name and version | Phoenix Technologies, LTD., version 255.255 (05/03/2006) | American Megatrends BIOS version 64-0100-000001-00101111-111505-CK8-04, 11/15/2005 |
| BIOS settings | Default | Default |
| Chipset INF driver | Intel version 1.2.43.0, 01/19/2006 | NVIDIA version 5.1.2600.445, 7/27/2004 |
| **Memory module(s)** | | |
| Vendor and model number | Micron MT18HTF12872FDY | Viking Components VI4CR287228ETPA2 |
| Type | FBDIMM memory modules that use commodity 240-pin DDR2-SDRAM PC2-5300 ECC Registered memory components | 184-pin DDR400-SDRAM PC3200 ECC Registered memory components |
| Speed (MHz) | 667 | 400 |
| Speed in the system currently running @ (MHz) | 333 | 200 |
| Timing/Latency (tCL-tRCD-tRP-tRASmin) | 5.0-5-5-12 | 3.0-3-3-8 |
| Size | 4096 MB | 4096 MB |

| | | |
|---|---|---|
| Number of RAM modules | 4 x 1 GB | 4 x 1 GB |
| Chip organization | Double-sided | Double-sided |
| Channel | Single | Single |
| **Hard disk** | | |
| Vendor and model number | Western Digital Caviar WD1200JS | Western Digital Caviar RE WD1600SD |
| Number of disks in system | 1 | 1 |
| Size | 120 GB | 160 GB |
| Buffer Size | 8 MB | 8 MB |
| RPM | 7200 | 7200 |
| Type | SATA 300 MB/sec | SATA 150 MB/sec |
| Controller | Intel 6321ESB Serial ATA Storage Controller | nForce4 Professional 2200 SATA II |
| Driver | Intel version 7.3.0.1010, 11/18/2005 | Microsoft 5.2.3790.1830, 10/01/2002 |
| **Operating system** | | |
| Name | Microsoft Windows 2003 Server, x64 Enterprise Edition | Microsoft Windows 2003 Server, x64 Enterprise Edition |
| Build number | Build 3790 | Build 3790 |
| Service pack | N/A | N/A |
| Microsoft Windows update date | 12/12/2005 | 12/12/2005 |
| File system | NTFS | NTFS |
| Kernel | ACPI Multiprocessor x64-based PC | ACPI Multiprocessor x64-based PC |
| Language | English | English |
| Microsoft DirectX version | DirectX 9.0c | DirectX 9.0c |
| **Graphics** | | |
| Vendor and model number | ATI Rage XL PCI | ATI Rage XL Family |
| Chipset | B41 | B41 |
| BIOS version | Gr-xlints3y.09a.-4.332 | GR-xlacrs3p.003-4.328 |
| Type | Integrated | Integrated |
| Memory size | 8 MB Shared DDR | 8 MB Shared DDR |
| Resolution | 1024 x 768 x 32-bit color | 1024 x 768 x 32-bit color |
| Driver | ATI Technologies version 6.14.10.6024, 01/20/2004 | ATI Technologies version 6.14.10.6025, 12/03/2004 |
| **Network card/subsystem** | | |
| Vendor and model number | 2 x Intel PRO/1000 EB Dual-port Gigabit Ethernet Adapters | 2 x Broadcom NetXtreme Gigabit Ethernet Adapters |
| Type | Integrated | Integrated |
| Driver | Intel version 9.3.28.0, 01/23/2006 | Broadcom version 8.39.1.0, 07/21/2005 |
| Other Network Card Information | N/A | N/A |
| **Optical drive** | | |
| Vendor and model number | Lite-On Combo SOHC-5236V | N/A |
| Type | DVD-ROM/CD-RW | N/A |
| Single/Dual Layer | N/A | N/A |
| Interface | Internal | N/A |
| **USB ports** | | |
| # of ports | 4 (2 front, 2 back) | 4 (2 front, 2 back) |
| Type of ports (USB1.1, USB2.0) | 2.0 | 2.0 |

**Figure 7: System configuration information for the two test servers.**


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