



## Virtualized OLTP performance and power consumption test on multiprocessor Intel- and AMD-based servers

### Executive summary

Intel® Corporation (Intel) commissioned Principled Technologies (PT) to compare virtualized online transaction processing (OLTP) performance of three servers, all using Fibre Channel connected storage. To provide a baseline target score, we used fourth system as a representative three-year-old server. We used the following hardware platforms:

- AMD\* Opteron\* 2384-based server
- Intel® Xeon® processor X5570-based server
- Intel Xeon processor E5450-based server
- 64-bit Intel Xeon processor with 2MB L2 cache 3.6 GHz-based server (Intel Xeon processor 3.6 GHz)

The AMD Opteron 2384- and Intel Xeon processor E5450-based server both contained 64GB of RAM, while the Intel Xeon processor E5570-based server contained 72GB of RAM. These three comparison servers used an EMC CX3-40f Fibre Channel storage area network (SAN) for all virtual machine (VM) and database storage. The baseline server, the Intel Xeon processor 3.6 GHz-based server, contained 4GB of RAM and used the six onboard disks for all storage.

For this comparison, we selected the DVD Store Version 2 (DS2) test tool. DS2 is an open-source simulation of an online e-commerce DVD store, where customers log in, browse, and order products. We ran DS2 in virtual machines (VMs) with Microsoft\* Windows\* Server 2008 Hyper-V (v1.0) on a server with two quad-core processors. We ran a single instance of the DS2 client per VM. Each client VM targeted only one server VM. We used a 20GB database size for each database on each server VM. The main DS2 metric is orders per minute, or OPM. We also used Windows Performance Monitor to measure certain Hyper-V counters. We reported OPM and throughput results from a 300-second period of steady activity and heavy load during the DS2 test run.

### KEY FINDINGS

- The Intel Xeon processor X5570-based server supported 60 percent more virtual machines than the Xeon processor E5450-based server and the AMD Opteron 2384-based server and sustained 91.3 percent and 118.3 percent more orders per minute (OPMs) than the Xeon E5450- and Opteron 2384-based servers, respectively (see Figure 1).
- The Intel Xeon processor X5570-based server delivered 103.5 percent more OPM/watt than the Intel Xeon processor E5450-based server and 71.1 percent more OPM/watt than the AMD Opteron 2384-based server (see Figure 2).

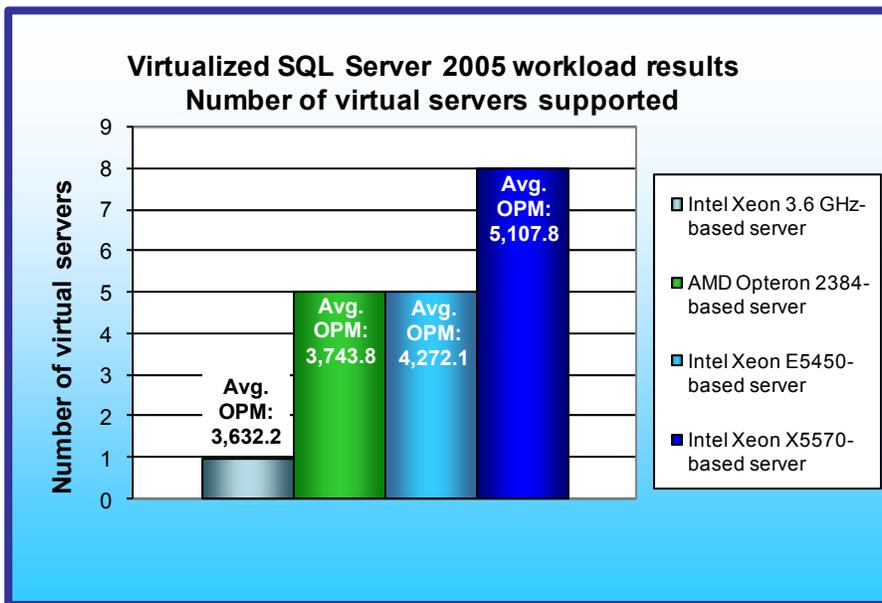


Figure 1: Microsoft SQL Server based DVD Store workload performance results for the four servers. Higher numbers are better. (The Intel Xeon 3.6 GHz-based server ran a single, non-virtual version of the database test.)

We used the Intel Xeon processor 3.6 GHz-based server, running the DS2 workload natively, as our baseline server for testing. We defined the peak number of VMs per server as the maximum number of concurrent VMs under

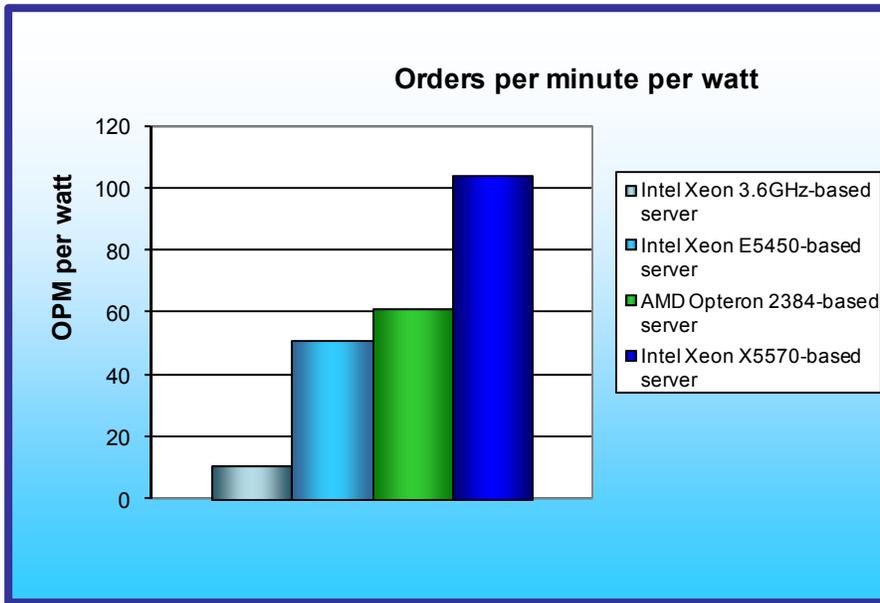


Figure 2: OPM/watt results for the four servers. Higher numbers are better.

determine the minimum score of each VM. Thus, the Intel X5570-based server was able to support 60 percent more virtual machines and sustain significantly more orders per minute than the other comparison servers. The total 40,862.1 OPM of the Intel X5570-based server was 91.3 percent more than the Intel E5450-based server (21,360.6 OPM), 118.3 percent more than the AMD 2384-based server (18,719.1 OPM) and 1,025.0 percent more than the baseline Xeon 3.6GHz-based server (3,632.2 OPM). (The Workload section explains the Microsoft SQL Server based DVD Store workload in greater detail.)

Figure 2 illustrates the orders per minute per watt each of the four servers achieved on the median run. We compute OPM/watt by dividing the total number of OPM in the median run by the average power consumption, in watts, of the server during the period the benchmark ran.

As Figure 2 shows, the Intel Xeon processor X5570-based server delivered 103.5 percent more OPM/watt than the Intel Xeon processor E5450-based server, 71.1 percent more OPM/watt than the AMD Opteron 2384-based server, and 901.4 percent more OPM/watt than the baseline Intel Xeon processor 3.6 GHz-based server.

## Workload

We conducted our testing using DVD Store Version 2, an open-source application with a back-end database component, a front-end Web application layer, and a driver layer that operates as the middle tier and actually executes the workload. Because our goal was to isolate and test database server storage, we did not use the Web application layer. Instead, we ran the driver application directly via its command-line interface.

DS2 models an online DVD store. Virtual customers log in; browse movies by actor, title, or category; and purchase movies. The workload also creates new customers. Browsing movies involves select operations, some of which use full-text search and some of which do not. The purchase, login, and new customer procedures involve updates and inserts, as well as selects. The workload's main reporting metric is orders per minute. For more details about the DS2 tool, see <http://www.delltechcenter.com/page/DVD+Store>.

Each server ran multiple SQL Server 2005 workloads, one per virtual machine. We configured all virtual machines with two virtual processors and 4 GB of virtual memory. For complete configuration details, see the test methodology section. Each VM's workload used the DVD Store test tool, which includes a data generation

load where each VM had at least the performance output in orders per minute (OPM) as the baseline server. In the case of this test's configuration, each VM had to score a minimum of 3,632 OPM.

Figure 1 compares the peak number of virtual machines running a Microsoft SQL Server 2005 database workload that each server ran with acceptable performance. The Intel X5570-based server achieved eight such simultaneous virtual machines, while the Intel E5450-based server and the AMD 2384-based server delivered only five such VMs.

We used the Intel Xeon processor 3.6 GHz-based server as the baseline score to

component, a pre-defined schema, and a lightweight command line test harness. One copy of the DS2 database was on each VM. By combining multiple virtual machines, all running a CPU, memory, and disk intensive workload, the test placed a heavy load on both the server and the storage. Thus, it measured the performance of the overall solution--server and storage, especially as it relates to an active OLTP environment.

Each client VM ran a single instance of DS2, which spawned 32 threads, and used a 15:1 search-to-order ratio. This simulated a heavily loaded environment; the load-generating client VMs ran with no think time, blasting requests as quickly as the servers could handle them.

The DS2 driver application creates an orders-per-minute performance counter on the client VM. We collected this metric on each client VM at one-second intervals. We ran this workload on all virtual machines simultaneously for 30 minutes. We considered a solution to have delivered acceptable performance if the minimum OPM score on every client VM during the 23 to 28 minute period of the test was above the baseline OPM.

## Test results

Figure 3 shows the peak number of virtual machines each solution could handle during testing before dipping below the acceptable threshold, the average OPM score, and the average total CPU utilization across all VMs. To determine the baseline score to use as a target for our VMs, we ran the database workload on the Intel Xeon processor 3.6GHz -based server to determine how many orders per minute it could achieve natively. We then ran the same workload, in a virtual Machine (VM) simultaneously in each VM, increasing the number of VMs until the OPM score decreased below the baseline threshold. We performed three runs at the peak number of VMs to verify the OPM score always remained above the score of the baseline server. Figure 3 shows the maximum number of VMs each server could support, the average OPM score of all VMs, and the average total CPU utilization across all VMs.

Server	Peak number of VMs	Average OPM score	Average total CPU utilization
AMD Opteron 2384-based server	5	3,743.8	99%
Intel Xeon processor E5450-based server	5	4,272.1	99%
Intel Xeon processor X5570-based server	8	5,107.8	100%
Intel Xeon processor 3.6 GHz-based server	N/A	3,632.2	77%

**Figure 3: The total number of virtual machines and the average OPM score for the median run for the four servers. Higher numbers of peak VMs and average OPM scores are better. The Intel Xeon processor 3.6 GHz-based server was the baseline with the workload running natively and therefore ran as a standalone server with no virtual machines.**

Figure 4 shows the average OPM per VM as well as the minimum OPM score per run for the Intel Xeon processor X5570-based server. Run 2 is the median run. Note in all three runs on the Xeon X5570-based server, one VM had a much lower score than all others. As such the average OPM per VM, and total OPM was much higher for this system than all other systems in this test.

Intel Xeon processor X5570-based server	Run 1	Run 2	Run 3
VM 1 OPM	4,978.9	5,075.1	5,354.5
VM 2 OPM	5,132.7	5,252.4	5,705.6
VM 3 OPM	4,992.6	5,454.0	5,323.1
VM 4 OPM	5,313.4	4,039.0	4,070.4
VM 5 OPM	5,141.4	5,208.4	5,484.8
VM 6 OPM	5,162.4	5,210.9	5,414.4
VM 7 OPM	5,270.3	5,410.6	5,458.5
VM 8 OPM	3,928.9	5,211.7	5,604.0
Minimum OPM	3,928.9	4,039.0	4,070.4
Average OPM	4,990.1	5,107.8	5,301.9
Total OPM	39,920.5	40,862.1	42,415.3

**Figure 4: Individual VM scores and the minimum VM score for the Intel Xeon processor X5570-based server.**

Figure 5 shows the average OPM per VM as well as the minimum OPM score per run for the Xeon processor E5450-based server. Run 1 is the median run.

Intel Xeon processor E5450-based server	Run 1	Run 2	Run 3
VM 1 OPM	4,241.5	4,407.7	4,260.0
VM 2 OPM	4,316.3	4,254.1	4,229.9
VM 3 OPM	4,276.5	4,351.5	4,307.5
VM 4 OPM	4,315.4	4,244.8	4,163.9
VM 5 OPM	4,210.9	4,322.8	4,343.2
Minimum OPM	4,210.9	4,244.8	4,163.9
Average OPM	4,272.1	4,316.2	4,260.9
Total OPM	21,360.6	21,580.9	21,304.5

Figure 5: Individual VM scores and the minimum VM score for the Intel Xeon processor E5450-based server.

Figure 6 shows the average OPM per VM as well as the minimum OPM score per run for the AMD Opteron 2384-based server. Run 2 is the median run.

AMD Opteron 2384-based server	Run 1	Run 2	Run 3
VM 1 OPM	3,690.6	3,700.2	3,901.3
VM 2 OPM	3,543.5	3,668.8	3,714.9
VM 3 OPM	3,620.0	3,695.6	3,710.4
VM 4 OPM	3,607.8	3,863.3	3,776.2
VM 5 OPM	3,655.8	3,791.2	3,804.9
Minimum OPM	3,543.5	3,668.8	3,710.4
Average OPM	3,623.6	3,743.8	3,781.5
Total OPM	18,117.8	18,719.1	18,907.7

Figure 6: Individual VM scores and the minimum VM score for the AMD Opteron 2384-based server.

Figure 7 details the power consumption, in watts, of the server-and-storage solutions while idle and during the median run of the virtualized SQL Server 2005 workload. We calculated watts/virtual server by dividing the average watts while the test was running by the number of virtual servers running on the server.

Server	Idle power (watts)	Average power (watts)	OPM/watt
AMD Opteron 2384-based server	189	307	60.95
Intel Xeon processor E5450-based server	346	417	51.23
Intel Xeon processor X5570-based server	253	392	104.27
Intel Xeon processor 3.6 GHz-based server	257	349	10.41

Figure 7: Average power usage (in watts) of the four servers while idle and during the median run of the Microsoft SQL Server database workload. Lower numbers are better. The Intel Xeon processor 3.6 GHz-based server was the baseline and therefore ran as a standalone server with no virtual machines.

Note: Microsoft Windows Server 2008 Hyper-V (v1.0) does not take advantage of the C6 power state feature in the Intel Xeon processor X5570-based server. If the next release of Windows Server 2008 Hyper-V takes advantage of this feature, as Microsoft predicts, Intel expects the idle power for this server to decrease by approximately 30 to 50 watts. (Intel bases idle power reduction estimates on power savings they have seen on other operating systems that support the X5570's C6 power state.)

## Test methodology

### Setting up and configuring EMC storage

We used an EMC CX3-40f Fibre Channel SAN in testing the AMD Opteron 2384, Intel Xeon processor X5570, and Intel Xeon processor E5450 servers. Figure 8 illustrates the configuration we used. The SAN had two storage processors, SP A and SP B. We used a dual port Fibre Channel host bus adapter (HBA) card in each server. We cabled one HBA port to each SP (A and B) on the SAN to balance the load between SPs. We used seven enclosures of disks on the SAN; with one exception, each enclosure had 15 disks. We designated RAID 0 for all RAID group configurations.

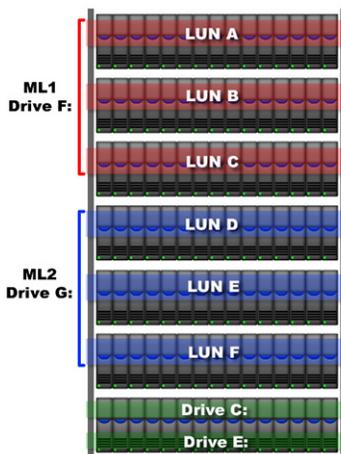


Figure 8: The EMC storage configuration we used.

We created 1 RAID group on the enclosure that had only 12 disks. We then created two logical unit numbers (LUNs) on this RAID group, one for the virtual hard drives (VHDs) that would hold SQL Server transaction logs and one for the VHDs that would hold the virtual machine system drives and operating system data.

We created six RAID groups for SQL Server data. Each of these six RAID groups was composed of 15 disks (an entire enclosure). We then created one 250GB LUN per RAID group, for a total of six LUNs dedicated to VHDs that would hold SQL Server data. We used the EMC MetaLUN feature and assigned three LUNs to MetaLUN-A and three LUNs to MetaLUN-B. To balance processing load and disk transfers, we assigned MetaLUN-A to SP A and MetaLUN-B to SP B.

After installing EMC PowerPath software, we then accessed each LUN and MetaLUN through the Disk Management utility in Windows Server 2008. We then proceeded with test setup, creation of VHDs and virtual machines, and so on.

### Adjusting BIOS settings

To maximize performance for each server, we adjusted the BIOS settings as follows:

- Intel Xeon processor X5570 system: We disabled turbo mode and enabled virtualization.
- Intel Xeon processor E5450 system: We enabled virtualization.
- Intel Xeon processor 3.6 GHz-based system: We disabled HyperThreading Technology.

We made no adjustments to the AMD Opteron 2384-based system.

### Installing and configuring Windows Server 2008, Enterprise x64 Edition

We installed a fresh copy of Windows Server 2008, Enterprise x64 Edition on the three comparison systems. (Note: For the baseline Intel Xeon processor 3.6 GHz system, we installed a fresh copy of Windows Server 2003 x86 R2 with SP2 using the steps outlined for the Master VM below.)

We followed this process for each installation:

1. Boot the server and insert the Windows Server 2008 x64 installation CD in the DVD-ROM drive.
2. At the Language Selection Screen, click Next.
3. Click Install Now.
4. Select Windows Server 2008 Enterprise (Full Installation) x64, and click Next.
5. Click the I accept the license terms check box, and click Next.
6. Click Custom.
7. Click Drive options (advanced).
8. Click New.

9. Click Apply.
10. Click Next.
11. At the warning that the user's password must be changed before logging on screen, click OK.
12. Type Password1 as the new password in both fields, and click the arrow to continue.
13. At the Your password has been changed screen, click OK.

## Setting up the Hyper-V server

Following the installing of Windows Server 2008, Enterprise x64 Edition, we proceeded to set up the host server, which included installing Hyper-V Manager and setting up the SAN.

### Setting up network configuration on the host server

1. Click Start→Control Panel→Network and Internet→Network Connections, and double-click the Local Area Connection.
2. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
3. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
4. Enter a valid static IP address, subnet mask, and default gateway.
5. Select the Use the following DNS server addresses radio button, and enter at least one valid DNS server address.
6. Click OK, and then click Close to exit.

### Installing system updates in Windows Server 2008 x64

We installed the following updates on the three comparison systems using the Microsoft Windows Update feature:

- Security Update for Windows Server 2008 x64 Edition (KB958687)
- Update for Windows Server 2008 x64 Edition (KB957388)
- Security Update for Windows Server 2008 x64-based Systems (KB938464)
- Update for Windows Server 2008 Server Manager x64 Edition (KB940518)
- Update for Windows Server 2008 x64 Edition (KB949189)
- Security Update for Windows Server 2008 x64 Edition (KB955069)
- Cumulative Security Update for ActiveX Killbits for Windows Server 2008 x64 Edition (KB956391)
- Security Update for Windows Server 2008 x64 Edition (KB954459)
- Security Update for Windows Server 2008 x64 Edition (KB957097)
- Security Update for Windows Server 2008 x64 Edition (KB958623)
- Update for Windows Server 2008 x64 Edition (KB959130)
- Cumulative Security Update for Internet Explorer 7 in Windows Server 2008 x64 Edition (KB958215)
- Update for Windows Server 2008 x64 Edition (KB957200)
- Security Update for Windows Server 2008 x64 Edition (KB953733)
- Security Update for Windows Server 2008 x64 Edition (KB950762)
- Update for Windows Server 2008 x64 Edition (KB955839)
- Security Update for Windows Server 2008 x64 Edition (KB958624)
- Security Update for Windows Server 2008 x64 Edition (KB950974)
- Update for Windows Server 2008 x64 Edition (KB951978)
- Update for Windows Server 2008 for x64-based Systems (KB955020)
- Security Update for Windows Server 2008 x64 Edition (KB954211)
- Windows Malicious Software Removal Tool x64 – January 2009 (KB890830)
- Security Update for Windows Mail for Windows Server 2008 x64 Edition (KB951066)
- Security Update for Windows Server 2008 x64 Edition (KB956841)
- Security Update for Windows Server 2008 x64 Edition (KB956802)
- Update for Windows Server 2008 x64 Edition (KB957321)
- Update for Windows Server 2008 x64 Edition (KB952287)
- Security Update for Windows Server 2008 x64 Edition (KB958644)
- Security Update for Internet Explorer 7 in Windows Server 2008 x64 Edition (KB960714)

- Security Update for Windows Server 2008 x64 Edition (KB951698)
- Update for Windows Server 2008 x64 Edition (KB950050)
- Update for Windows Server 2008 x64 Edition (KB955302)
- Windows Update Agent 7.2.6001.788
- Windows Update software 7.2.6001.788

### Installing Hyper-V in Windows Server 2008

Note: Be sure you have installed all the latest critical and recommended updates for Windows Server 2008 from Windows Update. Specifically, you must install the update that upgrades Hyper-V from beta to release software. (As of this writing, this update is KB950050 on Windows Server 2008 Enterprise Edition x64.)

1. Click Start→Administrative Tools→Server Manager.
2. Click Roles.
3. Click Add Roles.
4. Click Next.
5. Select the Hyper-V role by checking the box beside it, and click Next.
6. Check the box beside the Ethernet Card you wish to use, and click Next.
7. Click Install to begin the Hyper-V installation.
8. When the installation finishes, click Close.
9. When prompted to restart now, click Yes.
10. Follow the prompt to log on to the system.
11. Enter the password, and click the arrow to continue. The Resuming Configuration Wizard should start automatically.
12. Once the Resuming Configuration Wizard completes, the installation results should appear with a message that the installation succeeded.
13. Click Close.

### Setting up the storage area network (SAN)

1. Install the dual-port QLogic FC card in the server.
2. Connect two fibre cables from the dual-port QLogic FC card in the server to the SAN, with each cable connecting to one storage processor (SP) on the EMC.
3. Install EMC Powerpath software x64 on the server with all defaults except for the following: select the CX SAN, not the AX.
4. When prompted to reboot at the end of the Powerpath installation, do so.
5. Click Start.
6. Right-click My Computer, and select Manage.
7. Select Disk Management.
8. When the wizard prompts you to initialize new disks, click OK. Note: If you must select a partition table, select MBR.
9. Right-click the first unallocated disk partition, and select New Simple Volume...
10. Click Next.
11. Use the entire LUN storage space, and click Next.
12. Select the drive letter to assign to the new partition, and click Next.
13. Label the volume appropriately (i.e., LUN0, LUN1, etc.).
14. Confirm that Perform a quick format is checked, and click Next.
15. Click Finish.
16. Repeat steps 8 through 15 for each volume.

### Creating the master virtual machine

Note: We performed these following steps on only the first server. For subsequent servers, we used the same VHD files. We created four fixed-size virtual hard drives per VM, one on each volume in the appropriately named folders. Using Hyper-V manager, we assigned the VHD file containing the operating system to IDE Controller 0 and assigned the remaining three VHD files to the SCSI controller.

Create the virtual machines with the following VM parameters:

- Virtual processor: 2
  - Virtual memory: 4,096 MB
  - Virtual disk size: 30 GB
1. Create a folder for the Master VM on each LUN (i.e., DBServer1).
  2. Click Start→Administrative Tools→Hyper-V Manager.
  3. Click Connect to Server, and click OK.
  4. Click Action→Virtual Network Manager...
  5. Select New virtual network.
  6. Select External, and click Add.
  7. From the Actions menu, select New→Virtual Machine...
  8. Click Next.
  9. Enter a name for the virtual machine.
  10. Click Next.
  11. Specify the amount of memory to allocate to this virtual machine (4096 MB), and click Next.
  12. Select Not Connected on the Configure Networking screen, and click Next.
  13. Select the Attach a virtual hard disk later radio button, and click Next.
  14. Click Finish.
  15. Close Hyper-V Manager.

### Setting up the Master VM

After creating the Master VM through the Hyper-V interface, we proceeded to set up the Master VM, which included installing and configuring Windows Server 2003 x86 R2 with SP2.

### Configuring the Master VM

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Right-click the Master VM, and select Settings...
3. Select Processor.
4. Change the number of logical processors to 2, and click Apply.
5. Select Network Adapter.
6. Select the appropriate configuration from the drop-down menu, and click Apply.
7. Select Add Hardware.
8. Select SCSI Controller, and click Add.
9. Click Apply.
10. Select IDE Controller 0.
11. Select Disk Drive, and click Add.
12. Click New.
13. Click Next.
14. Click the Fixed size radio button, and click Next.
15. Enter a name for the VHD file.
16. Browse to DBServer1 folder on the OS LUN, and select Next.
17. Select the Create a new blank virtual hard disk radio button.
18. Enter 30 for the number of GB for the virtual hard disk, and click Next.
19. Click Finish.
20. Click Apply.
21. Select SCSI Controller.
22. Select Disk Drive, and click Add.
23. Click New.
24. Click Next.
25. Click the Fixed size radio button, and click Next.
26. Enter a name for the VHD file.
27. Browse to DBServer1 folder on the SQLData1 LUN, and select Next.
28. Select the Create a new blank virtual hard disk radio button.
29. Enter 30 for the number of GB for the virtual hard disk, and click Next.
30. Click Finish.

31. Click Apply.
32. Select SCSI Controller.
33. Select Disk Drive, and click Add.
34. Click New.
35. Click Next.
36. Click the Fixed size radio button, and click Next.
37. Enter a name for the VHD file.
38. Browse to DBServer1 folder on the SQLData2 LUN, and select Next.
39. Select the Create a new blank virtual hard disk radio button.
40. Enter 30 for the number of GB for the virtual hard disk, and click Next.
41. Click Finish.
42. Click Apply.
43. Select SCSI Controller.
44. Select Disk Drive, and click Add.
45. Click New.
46. Click Next.
47. Click the Fixed size radio button, and click Next.
48. Enter a name for the VHD file.
49. Browse to DBServer1 folder on the SQLLog LUN, and select Next.
50. Select the Create a new blank virtual hard disk radio button.
51. Enter 10 for the number of GB for the virtual hard disk, and click Next.
52. Click Finish.
53. Click Apply.
54. Click OK.

### **Installing Windows Server 2003 x86 R2 with SP2 on the Master VM**

We installed a fresh copy of Windows Server 2003 x86 R2 with SP2 on the three comparison systems using the steps below. (Note: We also installed Windows Server 2003 x86 R2 with SP2 on the baseline Intel Xeon processor 3.6 GHz server, beginning with step 12.)

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Right-click the Master VM, and select Settings...
3. Select IDE Controller 1.
4. Select DVD Drive.
5. Select the Physical CD/DVD drive: radio button, and click Apply.
6. Select BIOS and confirm that CD is at the top of the Startup order list. If this is not the case, adjust the list appropriately, and click Apply.
7. Click OK.
8. Right-click the Master VM, and select Connect...
9. Click Menu→DVD Drive→Capture appropriate DVD-ROM drive (i.e., D:).
10. Insert the Windows Server 2003 R2 installation CD in the DVD-ROM drive.
11. Click Action→Start to start the Master VM.
12. At the Welcome to Set up screen, press Enter to begin the installation.
13. At the Windows Licensing Agreement screen, press F8 to agree to the terms.
14. Press Enter to install in the default location.
15. Select Format the partition using the NTFS file system (Quick), and press Enter to continue.
16. At the Regional and Language Options screen, click Next.
17. Enter Name and Organization, and click Next. Note: Organization is an optional field, while username is required.
18. At the Your Product Key screen, enter your product key, and click Next.
19. At the Licensing Modes screen, click Next.
20. At the Computer Name and Administrator Password screen, type `Password1` as the new password in both fields, and click Next.
21. At the Date and Time Settings screen, change the Date & Time and Time Zone if appropriate, and click Next.

22. After the system restarts automatically, follow the prompt to log in to the server.
23. At the Windows Setup screen, you will be prompted to insert the second installation CD. Insert the appropriate CD, and click OK.
24. At the Windows Server 2003 R2 Setup Wizard Welcome screen, click Next.
25. At the Windows Server 2003 R2 Setup Wizard Summary screen, click Next.
26. When prompted, click Finish to end the installation.
27. Once the installation completes, on the Hyper-V Manager menu, click Action→Insert Integration Services Setup Disk.
28. At the prompt to restart, click Yes.
29. Log back in to the Master VM at the prompt.
30. Click Start.
31. Right-click My Computer and select Manage.
32. Select Disk Management.
33. If the wizard prompts you to initialize new disks, click OK. Note: If you must select a partition table, select MBR.
34. Right-click the first unallocated disk partition, and select New Simple Volume...
35. Click Next.
36. Use the entire VHD storage space, and click Next.
37. Select the drive letter to assign to the new partition, and click Next.
38. Label the volume appropriately (i.e., SQLData1, SQLLogs, etc.).
39. Confirm that Perform a quick format is checked, and click Next.
40. Click Finish.
41. Repeat steps 34 through 40 for the remaining volumes.
42. Create "SQLData" folders on the first two disks, and "SQLLog" folder on the third disk.
43. Create "ServerShare" folder on C: drive for workload scripts.
44. Browse to C:\Servershare, right-click the folder, and select Properties.
45. On the sharing tab, select the Share this folder radio button.
46. Click Permissions. For the "Everyone" user, click Full Control under Add to allow full control. Click OK.
47. On the security tab, click Add, and then type `Everyone`. Click OK.
48. Click the Full Control checkbox under Add.
49. Click OK.
50. Copy server specific script files into this folder.

### Setting up network configuration on the Master VM

1. Click Start→Control Panel→Network Connections, and Local Area Connection.
2. At the Local Area Connection Status screen, click Properties.
3. At the Local Area Connection Properties screen, select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
4. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
5. Enter a valid static IP address, subnet mask, and default gateway.
6. Select the Use the following DNS server addresses radio button, and enter at least one valid DNS server address.
7. Click OK and then click Close twice. Close the Network Connections window.

### Installing system updates in Windows Server 2003 R2 on the Master VM

We installed the following updates using the online Windows Update feature. Note: Reboot the VM as requested.

- Windows Server 2003 Security Update for Internet Explorer 7 for Windows Server 2003 (KB960714)
- Windows Server 2003 Security Update for Internet Explorer 7 for Windows Server 2003 (KB938127)
- Windows Server 2003 Windows Malicious Software Removal Tool - January 2009 (KB890830)
- Windows Server 2003 Security Update for Windows Server 2003 (KB958687)
- Windows Server 2003 Security Update for Windows Server 2003 (KB956803)
- Windows Server 2003 Security Update for Internet Explorer 6 for Windows Server 2003 (960714)

- Windows Server 2003 Security Update for Windows Server 2003 (KB925902)
- Windows Server 2003 Update for Windows Server 2003 (KB955839)
- Windows Server 2003 Cumulative Security Update for Internet Explorer 6 for Windows Server 2003 (KB958215)
- Windows Server 2003 Security Update for Windows Server 2003 (KB956802)
- Windows Server 2003 Security Update for Windows Server 2003 (KB954600)
- Windows Server 2003 Security Update for Windows Server 2003 (KB952069)
- Windows Server 2003 Security Update for Windows Server 2003 (KB957097)
- Windows Server 2003 Security Update for Windows Server 2003 (KB955069)
- Windows Server 2003 Security Update for Windows Server 2003 (KB958644)
- Windows Server 2003 Security Update for Windows Server 2003 (KB956841)
- Windows Server 2003 Cumulative Security Update for ActiveX Killbits for Windows Server 2003 (KB956391)
- Windows Server 2003 Security Update for Windows Server 2003 (KB954211)
- Windows Server 2003 Security Update for Windows Server 2003 (KB938464)
- Windows Server 2003 Security Update for Windows Server 2003 (KB944338)
- Windows Server 2003 Security Update for Windows Server 2003 (KB950974)
- Windows Server 2003 Security Update for Windows Server 2003 (KB952954)
- Windows Server 2003 Security Update for Outlook Express for Windows Server 2003 (KB951066)
- Windows Server 2003 Security Update for Windows Server 2003 (KB951748)
- Windows Server 2003 Security Update for Windows Server 2003 (KB951698)
- Windows Server 2003 Security Update for Windows Server 2003 (KB950762)
- Windows Server 2003 Security Update for Windows Server 2003 (KB945553)
- Windows Server 2003 Update for Windows Server 2003 (KB948496)
- Windows Server 2003 Security Update for Windows Server 2003 (KB943055)
- Windows Server 2003 Security Update for Windows Server 2003 (KB946026)
- Windows Server 2003 Security Update for Windows Server 2003 (KB943485)
- Windows Server 2003 Security Update for Windows Server 2003 (KB941569)
- Windows Server 2003 Security Update for Windows Server 2003 (KB944653)
- Windows Server 2003 Security Update for Windows Server 2003 (KB943460)
- Windows Server 2003 Windows Internet Explorer 7 for Windows Server 2003
- Windows Server 2003 Update for Windows Server 2003 (KB936357)
- Windows Server 2003 Security Update for Windows Server 2003 (KB933729)
- Windows Server 2003 Security Update for Microsoft .NET Framework, Version 1.1 Service Pack 1 (KB933854)
- Windows Server 2003 Security Update for Windows Server 2003 (KB938127)
- Windows Server 2003 Security Update for Windows Server 2003 (KB936782)
- Windows Server 2003 Security Update for Windows Server 2003 (KB926122)
- Windows Server 2003 Security Update for Windows Media Player 6.4 (KB925398)
- Windows Server 2003 Security Update for Windows Server 2003 (KB935839)
- Windows Server 2003 Security Update for Windows Server 2003 (KB935840)
- Windows Server 2003 Cumulative Security Update for Outlook Express for Windows Server 2003 (KB929123)
- Windows Server 2003 Security Update for Windows Server 2003 (KB924667)
- Windows Server 2003 Update for Windows Server 2003 (KB927891)
- Windows Server 2003 Security Update for Windows Server 2003 (KB932168)
- Windows Server 2003 Security Update for Windows Server 2003 (KB930178)

## Installing SQL Server 2005

### Installing SQL Server 2005 x86 on the Master VM

1. Copy the SQL Server 2005 x86 iso image file to the host machine.
2. Click Start→Administrative Tools→Hyper-V Manager.

3. Right-click the VM, and click Connect.
4. Start the VM by clicking Action→Start.
5. Click Media Menu→Insert Disk.
6. Navigate to the SQL Server 2005 Enterprise x86 ISO file, and click Open.
7. Click the Server components link under the Install section to begin the installation.
8. At the End User License Agreement, accept the licensing terms, and click Next.
9. After installing the prerequisites, click Next.
10. At the Welcome screen, click Next.
11. At the System Configuration Check, click Next. Note: This assumes that each component successfully passes the system configuration check.
12. At the Registration Screen, enter the appropriate name and company.
13. At the Components to Install screen, select SQL Server Database Services and Workstation components.
14. Click Advanced.
15. Uncheck Business Intelligent Development Studio, and uncheck Books Online & Sample Databases.
16. Click Next to start the installation.
17. At the Instance Name screen, click the Default instance radio button, and click Next.
18. At the Service Account screen, select the Use the built-in System account radio button.
19. Select Local system, and click Next.
20. At the Authentication Mode screen, select Mixed Mode.
21. Specify the sa logon password by entering a password in both fields, and click Next.
22. At the Collation Settings screen, click Next.
23. Accept the default Error and Usage Report Settings, and click Next.
24. At the Ready to Install screen, click Install to begin the installation.
25. At the end of the installation in the Setup Progress screen, click Next.
26. Click Finish to complete the installation.

### **Installing Service Pack 3 for Microsoft SQL Server 2005 on the Master VM**

Service Pack 3 is available for download from

<http://www.microsoft.com/downloads/details.aspx?FamilyID=ae7387c3-348c-4faa-8ae5-949fdbe59c4&displaylang=en>.

1. Run SQLServer2005SP3-KB955706-x86-ENU.exe.
2. At the Welcome screen, click Next.
3. At Accept the License Agreement, click Next.
4. At the Feature Selection screen, keep the defaults, and click Next.
5. At the Authentication screen, click Next.
6. At the Error and Usage Reporting Settings screen, click Next.
7. At the Running Processes screen, click Next.
8. Click Install.
9. If a compatibility error occurs during the installation, click Run program.
10. Click Next.
11. At the Installation Complete screen, click Next.
12. Click Finish.
13. Reboot the VM.

## **DVDStore setup**

### **Data generation overview**

We built the database schema using the scripts included in the DS2 distribution package, though we made a few minor modifications. The DS2 stress tool provides options to generate 10MB, 1GB, or 100GB datasets. To get the tool to generate the 20GB of user data we used in this test, we had to make a few straightforward changes to the source code and to the DVD Store application's scripts. Note: We created our test data on a Linux system to take advantage of the larger RAND MAX.

### Editing the ds2\_create\_orders.c module

The module ds2\_create\_orders.c defines constants that define the maximum values for the customer ID and the product ID. The constants for the 20GB database size did not exist. We added the constants for this size.

On the command line for the ds2\_create\_orders.c module, we specified the size. The available options were S (small), M (medium), and L (large). We added the case W for the 20GB database. In the switch statement that sets the values for the variables max\_cust\_id and max\_prod\_id, we added cases that assigned them the proper values for the 20GB database size.

We recompiled the ds2\_create\_orders.c module on Linux, following the instructions in the header comments. We used the following command line: `gcc -o ds2_create_orders ds2_create_orders.c -lm`

### Editing the ds2\_create\_cust.c module

We had to make the same changes to the ds2\_create\_cust.c module that we made to the ds2\_create\_orders.c module. On the command line for the ds2\_create\_cust.c module, we specified the size. The available options were S (small), M (medium), and L (large). We added the case W for the 20GB database. In the switch statement that sets the values for the variables max\_cust\_id and max\_prod\_id, we added cases that assigned them the proper values for the 20GB database size.

We recompiled the ds2\_create\_cust.c module on Linux, following the instructions in the header comments. We used the following command line: `gcc -o ds2_create_cust ds2_create_cust.c -lm`

### Generating the data for the 20GB database

We used shell scripts to run all four of the executables that generate the data. The distribution did not include shell scripts for the 20GB size. We wrote shell scripts based on the ds2\_create\_cust\_large.sh and ds2\_create\_orders\_large.sh scripts. The ds2\_create\_prod and ds2\_create\_inv executables did not ship with associated shell scripts, so we created shell scripts using the instructions in the readme files. We ran the shell scripts in the following order to generate the data for the 20GB database:

- ds2\_create\_orders\_20gb.sh
- ds2\_create\_inv\_20gb.sh
- ds2\_create\_prod\_20gb.sh
- ds2\_create\_cust\_20gb.sh

We waited until the processes finished before we moved onto the next step.

### Creating the database

We modified the database creation SQL Server scripts included in the DVD Store distribution package to build the database schema, which includes the file structure, tables, indices, stored procedures, triggers, and so on. We built a master copy of the 20GB database version for SQL Server 2005, and then used that master copy to restore our test database to each test server VM between each test run. The backup file was stored on the VM C: drive for quick access.

We followed these steps to create the database:

1. We created the database and file structure using database creation scripts provided with DS2. We made size modifications specific to our 20GB database and the appropriate changes to drive letters.
2. We created database tables, stored procedures, and objects.
3. We set the database recovery model to bulk-logged to prevent excess logging.
4. We loaded the generated data. For data loading, we used the import wizard in SQL Server Management Studio. Where necessary, we retained options from the original scripts, such as "Enable Identity Insert."
5. We created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
6. We updated statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
7. We created ds2user SQL Server login and user for testing using the following Transact SQL (TSQL) script.

```

USE [master]
GO
CREATE LOGIN [ds2user] WITH PASSWORD=N'',
DEFAULT_DATABASE=[master],
DEFAULT_LANGUAGE=[us_english],
CHECK_EXPIRATION=OFF,
CHECK_POLICY=OFF
GO

```

8. We set the database recovery model back to full.

We made the following several changes in the build scripts:

- Because we varied the size of the datasets, we sized the files in our scripts to reflect the database size and the number of files per filegroup. We allowed for approximately 40 percent free space in our database files to ensure that filegrowth activity did not occur during the testing.
- We followed Microsoft's recommendation of having 0.25 to 1 file per filegroup per core. We used two files per filegroup on our 2 virtual processor VMs.
- We did not use the DBCC PINTABLE command for the CATEGORIES and PRODUCTS tables, both because Microsoft recommends against this practice and because the commands do nothing in SQL Server 2005.
- We created a SQL Server login called ds2user and a database user mapped to this login. We made each such user a member of the db\_owner fixed database role.
- Using the DVD Store scripts as a reference, we created the full-text catalog and index on the PRODUCTS table manually in SQL Server Management Studio.

We then performed a full backup of the database. This backup allowed us to restore each server VM to a pristine state relatively quickly between tests.

#### Editing the workload script - ds2xdriver.cs module

To use the 20GB database we created earlier, we had to change the following constants:

- In the routine Controller(), we changed the string "sizes." We added the W option for the 20GB database size. DS2 uses the sizes string to interpret the db\_size\_str option.
- In the class Controller, we changed the arrays MAX\_CUSTOMER and MAX\_PRODUCT. To each, we added values specifying the bounds for the customer and product IDs. The Controller() routine uses these arrays.
- We added a command line parameter for the database name: -database\_name

#### Editing the workload script - ds2sqlserverfns.cs module

We changed the connection string to increase the number of available connections, to not use the default administrator ("sa") account, and to include a parameter for the database name. We raised the available connections limit from the default of 100 to 200 to allow room for experimentation. We created a user account called ds2User and used that account.

The ds2connect routine in the ds2sqlserverfns.cs module defines sConnectionString. We used the following string (the changes we made appear in bold):

```

string sConnectionString = "User ID=ds2User;Initial Catalog=+" + dbname + "";Max
Pool Size=200;Connection Timeout=120;Data Source=" + Controller.target;

```

#### Recompiling the ds2sqlserverdriver.exe executable

We recompiled the ds2xdriver.cs and ds2sqlserverfns.cs module on Windows by following the instructions in the header comments. Because the DS2 instructions were for compiling from the command line, we used the following steps:

1. Open a command prompt.

2. Use the `cd` command to change to the directory containing our sources.
3. Run the batch file `C:\Program Files\Microsoft Visual Studio 9.0\Common7\Tools\vsvars32.bat`. This sets up the environment variables for us.
4. Execute the following command:
 

```
csc /out:ds2sqlserverdriver.exe ds2xdriver.cs ds2sqlserverfns.cs
/d:USE_WIN32_TIMER /d:GEN_PERF_CTRS
```

### Creating performance monitor data collector set (DS2)

We collected system statistics at one-second intervals and logged them to a CSV file for later analysis. We created a data collector set in the Performance and Reliability Monitor tool, which included the following counters:

- Hyper-V Hypervisor Logical Processor(\_Total)\% Total Run Time
- Hyper-V Hypervisor Logical Processor(Hv LP 0)\% Total Run Time
- Hyper-V Hypervisor Logical Processor(Hv LP 1)\% Total Run Time
- Hyper-V Hypervisor Logical Processor(Hv LP 2)\% Total Run Time
- Hyper-V Hypervisor Logical Processor(Hv LP 3)\% Total Run Time
- Hyper-V Hypervisor Logical Processor(Hv LP 4)\% Total Run Time
- Hyper-V Hypervisor Logical Processor(Hv LP 5)\% Total Run Time
- Hyper-V Hypervisor Logical Processor(Hv LP 6)\% Total Run Time
- Hyper-V Hypervisor Logical Processor(Hv LP 7)\% Total Run Time
- LogicalDisk(\_Total)\% Idle Time
- LogicalDisk(C:)\% Idle Time
- LogicalDisk(E:)\% Idle Time
- LogicalDisk(F:)\% Idle Time
- LogicalDisk(G:)\% Idle Time
- LogicalDisk(H:)\% Idle Time
- LogicalDisk(\_Total)\Disk Bytes/sec
- LogicalDisk(C:)\Disk Bytes/sec
- LogicalDisk(E:)\Disk Bytes/sec
- LogicalDisk(F:)\Disk Bytes/sec
- LogicalDisk(G:)\Disk Bytes/sec
- LogicalDisk(H:)\Disk Bytes/sec
- LogicalDisk(\_Total)\Disk Transfers/sec
- LogicalDisk(C:)\Disk Transfers/sec
- LogicalDisk(E:)\Disk Transfers/sec
- LogicalDisk(F:)\Disk Transfers/sec
- LogicalDisk(G:)\Disk Transfers/sec
- LogicalDisk(H:)\Disk Transfers/sec
- Memory\Available Mbytes
- Hyper-V Virtual Network Adapter(New Virtual Network)\Bytes/sec
- Hyper-V Virtual Network Adapter(NIC1)\Bytes/sec
- Network Interface11\Bytes Total/sec

### Creating the additional VMs on the host server

After installing the system preparation tool on the Master VM, we creating the additional VMs through automated cloning scripts. Before cloning the Master VM, we used the system preparation tool to create a clean image.

#### Installing the System Preparation Tool for Windows Server 2003 x86 SP2 on the Master VM

1. Download the KB926028 file from the following location:  
<http://www.microsoft.com/downloads/details.aspx?FamilyId=93F20BB1-97AA-4356-8B43-9584B7E72556&displaylang=en>
2. Install this patch on the Master VM.
3. Click Start, and type `sysprep.exe` in the search field.

4. Extract all sysprep files from this folder location to a folder, such as C:\sysprep.
5. Browse to this folder and double-click sysprep.exe.
6. Click to select Don't reset grace period for activation and Don't regenerate security identifiers, and click Reseal.
7. The preparation tool will shut down the Master VM, which is now prepared for cloning.

### Copying the VMs

We used a Windows Powershell management library for Hyper-V we downloaded from [pshyperv.codeplex.com](http://pshyperv.codeplex.com). See the documentation provided with the download at [pshyperv.codeplex.com](http://pshyperv.codeplex.com). Specifically, we used the following functions from this library to automate the creation of new VMs:

- New-VM
- Set-VMCPUCount
- Set-VMMemory
- Add-VMDRIVE
- Add-VMDisk
- Add-VMNIC
- Start-VM
- New-VMConnectSession
- Add-VMSCSIController

Using Windows Powershell and these functions we automated the process of the following basic steps:

- Detaching the virtual hard drives from the Master VM
- Creating folders to store each VM's files
- Copying and pasting the VHD files into their respective folders
- Renaming the VHD files to match the name of the new VM
- Creating the new VM with the same virtual hardware, and reattaching the virtual hard drives

Using these automated cloning scripts both saved time and let us confirm that all VMs were similarly configured.

### Configuring the additional VMs

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Right-click the VM, and click Connect.
3. Start the VM by clicking Action→Start.
4. Proceed through the system preparation tools, and enter the appropriate license key when prompted.
5. Click Start→Control Panel→Network and Internet→Network Connections, and double-click the Local Area Connection.
6. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
7. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
8. Enter a valid static IP address, subnet mask, and default gateway.
9. Select the Use the following DNS server addresses radio button, and enter at least one valid DNS server address.
10. Click OK, and then click Close to exit.

### Creating the virtual client machines

For the DVD Store scripts, we used a number of virtual client machines to simulate a number of users putting a load on the server. We installed a fresh copy of Windows Server 2008, Enterprise x64 Edition on the server, following the procedures outlined above, with the exception of SAN storage. We followed the additional steps we outline above, installing the Windows updates listed above and installing Hyper-V Manager. We created and configured a master client as we outline above, and also installed a fresh copy of Windows Server 2003 R2 x86 with SP2 on the master client. We created a folder called C:\ClientShare to store workload scripts and output files. We used the system preparation tool described above to prepare the VM for cloning, and then used the cloning

scripts to create the additional clients. We installed the .NET 2.0 framework on each client VM, as this is required by the DVDStore test executable. We did not install SQL Server 2005 on the client machines, as this was not necessary. We created a performance counter log on each client machine to track the number of OPM each virtual database server returned.

## Testing procedure

To perform the test, we used a series of batch files. We stored batch files respective to each system on that system, either under the C:\ServerShare folder or the C:\ClientShare folder, and we used the psexec utility to coordinate the test procedures amongst the client machine, server machine, and controller. We used simple file sharing to copy files between machines as needed.

The testing procedure consisted of the following steps:

1. Execute batch files to clean up prior outputs on client virtual machines, server physical machine, and controller.
2. Drop the database on each virtual server.
3. Restore the database on each virtual server.
4. Pause for five minutes to wait for full text indexes in SQL Server 2005 to repopulate.
5. Reboot the physical machines and wait for a ping response.
6. Wait 10 additional minutes for any background tasks to complete.
7. Record idle power for two minutes.
8. Test a full text query.
9. Start performance counters on client virtual machines and server physical machine.
10. Start the workload connections (approximately 30 seconds).
11. Start the workload.
12. Stop the workload.
13. Copy all output files to controller.

## Changing servers between tests

We performed the following steps between tests on subsequent servers to minimize the amount of time required for setting up each subsequent server. Note: This eliminates the need to create and configure the master VM and clone the VM on each server.

1. Click Start→Administrative Tools→Hyper-V Manager.
2. Confirm that all VMs are in the Off State. If all VMs are in the Off State, skip to Step 5.
3. To shut down a VM that is not in the Off State, right-click the VM.
4. Select Shut down...
5. Right-click the VM, and select Settings...
6. Select Network Adapter.
7. Click Remove, and click Apply.
8. Select Disk Drive under IDE Controller 0.
9. Click Remove, and click Apply.
10. Select Disk Drive under SCSI Controller.
11. Click Remove, and click Apply.
12. Select next Disk Drive under SCSI Controller.
13. Click Remove, and click Apply.
14. Select last Disk Drive under SCSI Controller.
15. Click Remove, and click Apply.
16. Repeat Steps 5 through 15 for the remaining VMs.
17. Click OK to finish.
18. Close Hyper-V Manager.
19. Click Start→Administrative Tools→Computer Management.
20. Click Disk Management.
21. With the exception of the C: drive, right-click each volume and select offline. This cleanly unmounts the SAN drives.

22. Shut down the server.
23. Switch the QLogic FC HBA to the next server, using the steps outlined above in the section Setting up the Storage Area Network (SAN). Note: You will not need to initialize the disks, as they have already been initialized.
24. Click Start→Administrative Tools→Computer Management.
25. Click Disk Management.
26. With the exception of the C: drive, right-click each volume, and select Online.
27. Click Start→Administrative Tools→Hyper-V Manager.
28. Right-click each VM, and select Settings...
29. Select Add Hardware.
30. Select Network Adapter, and click Add.
31. Select the appropriate configuration from the drop-down menu and click Apply.
32. Select Add Hardware.
33. Select SCSI Controller, and click Add.
34. Click Apply.
35. Select IDE Controller 0.
36. Select Disk Drive, and click Add.
37. Browse to the appropriate location for the appropriate VHD file (i.e., OS LUN, DBServer1 folder), and click Apply.
38. Select SCSI Controller.
39. Select Disk Drive, and click Add.
40. Browse to the appropriate location for the appropriate VHD file (i.e., SQLData1 LUN, DBServer1 folder),
41. Click Apply.
42. Select SCSI Controller.
43. Select Disk Drive, and click Add.
44. Browse to the appropriate location for the appropriate VHD file (i.e., SQLData2 LUN, DBServer1 folder),
45. Click Apply.
46. Select SCSI Controller.
47. Select Disk Drive, and click Add.
48. Browse to the appropriate location for the appropriate VHD file (i.e., SQLLog LUN, DBServer1 folder),
49. Click Apply.
50. Repeat steps 28 through 49 for the remaining VMs.
51. Click OK to finish.

### **Power measurement procedure**

To record each server's power consumption during each test, we used an Extech Instruments ([www.extech.com](http://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 one-second intervals.

To gauge the idle power usage, we recorded the power usage for two minutes while each system was running Hyper-V and the appropriate number of VMs, but otherwise idle, meaning they were not running any test workload.

We then recorded the power usage (in watts) for each system during the testing at one-second intervals. To compute the average power usage, we averaged the power usage during the time the system was producing its peak performance results. We call this time the power measurement interval. See Figure 7 (idle and average peak power) for the results of these measurements.

## Appendix A – Server configuration information

This appendix provides detailed configuration information about the servers, which we present in alphabetical order in Figure 9.

Servers	AMD Opteron 2384-based server	Intel Xeon processor X5570-based server	Intel Xeon processor E5450-based server	64-bit Intel Xeon processor with 2MB L2 cache 3.6 GHz-based server
				
<b>General processor setup</b>				
Number of processor packages	2	2	2	2
Number of cores per processor package	4	4	4	1
Number of hardware threads per core	1	2	1	2
<b>CPU</b>				
Vendor	AMD	Intel	Intel	Intel
Name	Opteron 2384 (Shanghai)	Xeon X5570 (Nehalem)	Xeon E5450 (Harpertown)	3.6GHz Xeon with 2MB L2 cache (Irwindale)
Stepping	2	5	C0	R0
Socket type	Socket F	LGA 1366	LGA 771	Socket 604
Core frequency	2.7GHz	2.93 GHz	3.0 GHz	3.60GHz
Front-side bus frequency	2.0 GT/s HyperTransport	6.4 GT/s (QPI)	1,333 MHz	800 MHz
L1 cache	64KB + 64KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	12 KB + 16 KB
L2 cache	2 MB (4 x 512 MB)	1 MB (4 x 256 KB)	12 MB (2 x 6,144 MB)	2 MB (1 x 2,048 MB)
L3 cache	1 x 6 MB	1 x 8 MB	N/A	N/A
<b>Platform</b>				
Vendor and model number	Supermicro A+ Server 2021M-T2R+V	Supermicro SuperServer	Supermicro SuperServer 6025B-TR+	Supermicro 6024H-T
Motherboard model number	H8DME-2	X8DTN+	X7DBE+	X6DHT-G
Motherboard chipset	NVIDIA MCP55	Intel 5520	Intel 5000P	Intel E7520
Motherboard revision number	01	1.02	B1	01
BIOS name and version	AMIBIOS 08.00.14 (10/13/08)	American Megatrends v4.6.3.2 (01/13/2009)	PhoenixBios v2.1 (06/23/08)	Phoenix Technologies LTD 6.00 (08/16/2007)
BIOS settings	Default	Turbo Mode Disabled Intel Virtualization Technology Enabled	Intel Virtualization Technology Enabled	HyperThreading Technology Disabled

Servers	AMD Opteron 2384-based server	Intel Xeon processor X5570-based server	Intel Xeon processor E5450-based server	64-bit Intel Xeon processor with 2MB L2 cache 3.6 GHz-based server
<b>Memory module</b>				
Vendor and model number	Kingston KVR667D2S4P5/4G	Micron MT36JSZF51272PY-1G1D1	Kingston KVR667D2D4F5/4G I	Samsung M312L5720DZ3-CB3
Type	DDR2 PC2-5300	DDR3 PC3-8500	DDR2 PC2-5300 FB-DIMM	DDR PC2700R
Speed (MHz)	667	1,066	666	333
Speed in the system currently running @ (MHz)	533	800	666	333
Timing/Latency (tCL-tRCD-iRP-tRASmin)	4-4-4-12	6-6-6-16	5-5-5-15	2.5-3-3-10
Size	64 GB (16 x 4 GB)	72 GB (18 x 4 GB)	64 GB (16 x 4 GB)	4GB (2 x 2 GB)
Number of RAM modules	16	18	16	2
Chip organization	Double-sided	Double-sided	Double-sided	Double-sided
<b>Hard disk</b>				
Vendor and model number	Western Digital WD1601ABYS	Western Digital WD1600AAJS-00B4A0	Western Digital WD1600AAJS	Western Digital WD1600YD
Number of disks in system	1	1	1	6
Size (GB)	160	160	160	160
Buffer size (MB)	16	8	8	8
RPM	7,200	7,200	7,200	7,200
Type	SATA	SATA	SATA	SATA
Controller	NVIDIA nForce SATA controller	Intel Corporation ICH10 SATA AHCI Controller	Intel ESB2 RAID Controller	Adaptec Serial ATA HostRAID
Driver version	NVIDIA 5.10.2600.830 (04/23/2007)	Microsoft 6.0.6001.18000 (06/21/2006)	Microsoft 6.0.6001.18000 (06/21/2006)	Adaptec 1.1.5735.0 (01/13/2006)
<b>Operating system</b>				
Name	Microsoft Windows Server 2008 Enterprise Edition	Microsoft Windows Server 2008 Enterprise Edition	Microsoft Windows Server 2008 Enterprise Edition	Microsoft Windows Server 2003 R2 Enterprise Edition
Build number	6001	6001	6001	3790
Service pack	SP1	SP1	SP1	SP2
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI Multiprocessor PC
Language	English	English	English	English
<b>Graphics</b>				
Vendor and model number	ATI ES1000	ATI ES1000	ATI ES1000	ATI Rage XL SVGA PCI Video
Chipset	ES1000	ES1000	ES1000	ATI Rage XL
Type	Integrated	Integrated	Integrated	Integrated

<b>Servers</b>	<b>AMD Opteron 2384-based server</b>	<b>Intel Xeon processor X5570-based server</b>	<b>Intel Xeon processor E5450-based server</b>	<b>64-bit Intel Xeon processor with 2MB L2 cache 3.6 GHz-based server</b>
Memory size (MB)	16	32	16	8
Resolution	1,024 x 768	1,024 x 768	1,024 x 768	1,024 x 768
<b>Network card/subsystem</b>				
Vendor and model number	Intel Pro/1000	Intel 82576 Gigabit Ethernet	Intel Pro/1000 EB	Intel PRO/1000 MT
Type	Integrated	Integrated	Integrated	Integrated
Driver version	Microsoft 6.2.0.126 (6/21/2008)	Intel 10.3.49.400 (12/11/2008)	Intel 9.12.36.0 (12/04/2008)	Intel 8.10.3.0 (8/20/2008)
<b>Optical drive</b>				
Vendor and model number	Matshita DVD-ROM UJDA780	Slimtype DVD A DS8A1P	Matshita DVD-ROM SR-8178	TEAC CD-224E-N
<b>USB ports</b>				
Number	4	4	4	2
Type	USB 2.0	USB 2.0	USB 2.0	USB 2.0
<b>Power supplies</b>				
Total number	2	2	2	1
Wattage of each	700W	805W	700W	550W
<b>Cooling fans</b>				
Total number	3	3	3	4
Dimensions	3" x 3"	3" x 3"	3" x 3"	3.25" x 3.25"
Voltage	12V	12V	12V	12V
Amps	1.1A	1.1A	1.1A	1.1A

Figure 9: Detailed system configuration information for the four test servers.

## About Principled Technologies

We provide industry-leading technology assessment and fact-based marketing services. We bring to every assignment extensive experience with and expertise in all aspects of technology testing and analysis, from researching new technologies, to developing new methodologies, to testing with existing and new tools.

When the assessment is complete, we know how to present the results to a broad range of target audiences. We provide our clients with the materials they need, from market-focused data to use in their own collateral to custom sales aids, such as test reports, performance assessments, and white papers. Every document reflects the results of our trusted independent analysis.

We provide customized services that focus on our clients' individual requirements. Whether the technology involves hardware, software, Web sites, or services, we offer the experience, expertise, and tools to help you assess how it will fare against its competition, its performance, whether it's ready to go to market, and its quality and reliability.

Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.



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