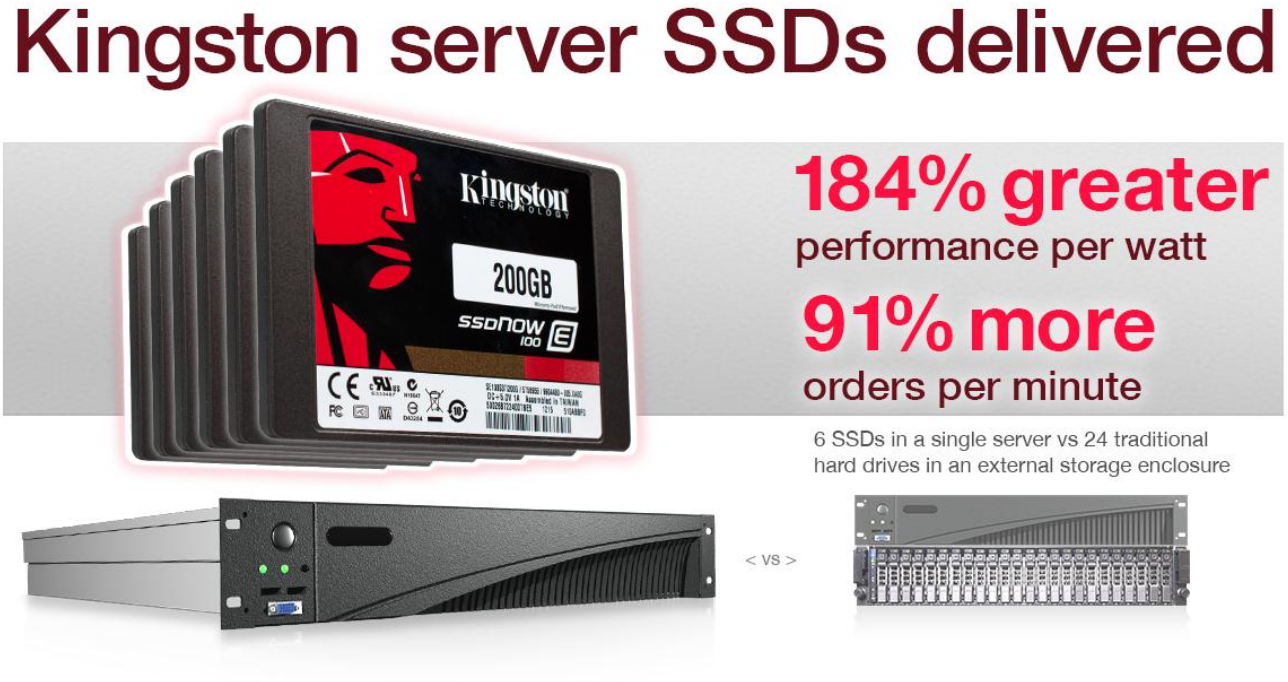
DATABASE PERFORMANCE WITH ENTERPRISE-CLASS KINGSTON SSDS



Processing power isn't the only thing that drives database performance. High performing server storage, such as enterprise-class solid-state drives (SSDs), can dramatically improve the performance of databases compared to traditional hard disk drives (HDDs).

In our labs at Principled Technologies, we put the virtualized database performance of Kingston SSDs to the test, and found that replacing a solution consisting of a server with an external chassis containing 24 HDDs with only six internal SSDs increased total database performance by up to 91.8 percent. While we performed our tests, we measured the power that the solutions consumed while idle and while running database workloads, and found that the Kingston SSD solution used up to 51.0 percent less power than the HDD solution, and increased performance per watt by a staggering 184.2 percent. Organizations that wish to increase database performance and save on power costs should consider the benefits of upgrading their HDD configurations to high-performance enterprise-class Kingston SSDs.

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A PRINCIPLED TECHNOLOGIES TEST REPORT
Commissioned by Kingston Technology Corp.

SPEED UP YOUR STORAGE WITH SSDS

Solid-state drives, or SSDs, can provide many benefits to an organization. They improve performance because they do not have moving disks and heads inside like traditional hard drives. Instead, they have integrated circuitry that works as high-speed storage memory. This design offers more bandwidth and better random performance, although typically with less storage capacity, giving an end user the ability to replace several hard drives with a single SSD providing equal or better performance depending on how many drives you are replacing.

Kingston SSDs increased performance

Figure 1 compares the total database performance of the HDD solution with that of the Kingston SSD solution. The Kingston SSD solution, using only six drives for data, increased performance by 91.8 percent over the 24 data drives in the HDD solution.

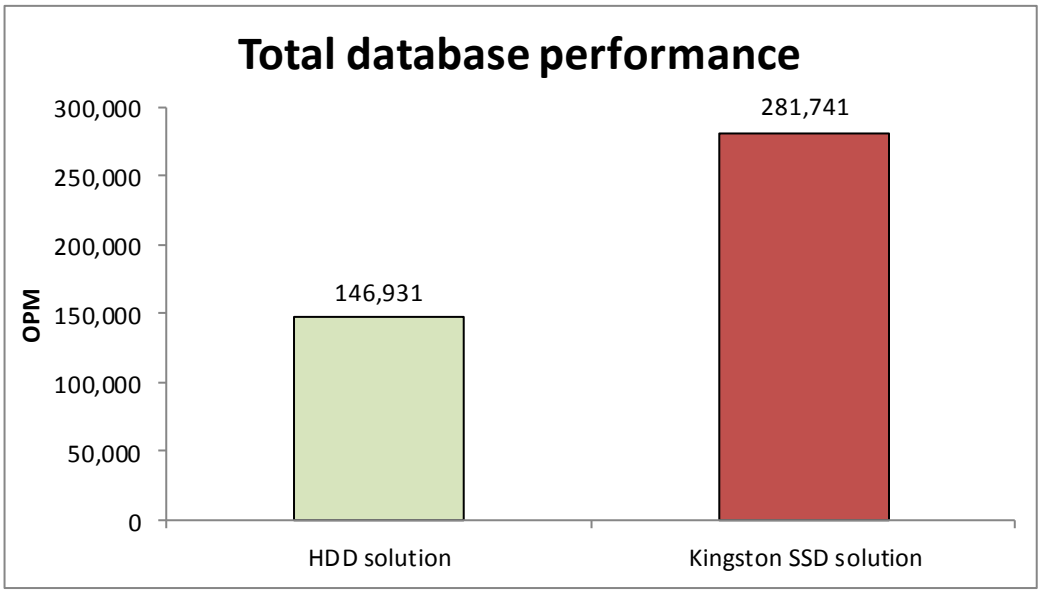

Figure 1: Using six Kingston SSDs increased performance over an all-HDD (24 drives) solution by 91.8 percent.

Increased performance isn't the only benefit of powering your servers with SSDs. The low latency and throughput of Kingston SSDs allow you to boost performance within the server itself with a relatively small number of drives, without the added rack space or power usage associated with an external chassis and the extra drives. This increased performance while using less power gives the SSD solution a greater performance per watt over the HDD solution. Figure 2 shows the performance per watt that each solution delivered. The Kingston SSD solution delivered a whopping 184.2 percent more database performance per watt than the HDD solution.

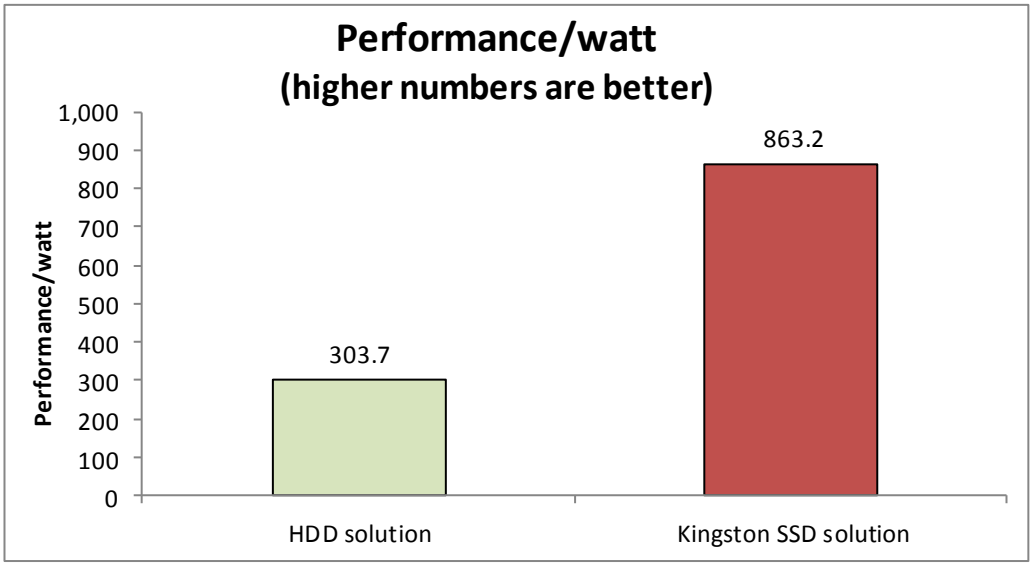

Figure 2: Performance/watt for the two solutions.

As Figure 3 shows, the Kingston SSD solution reduced power consumption while actively running workloads by 32.5 percent compared to the HDD solution. Reducing overall power consumption of your infrastructure could help you realize dramatic savings in operational costs.

While the 32.5 percent reduction in power consumption with the Kingston SSD solution is significant, it is important to note the performance/watt increase of 184.2 percent is a far better indicator of the power advantages you might expect to see in your environment. This huge increase is because the six SSDs allow the system to accomplish almost twice the work as the HDDs and use far less power to do so. The low latency and high throughput of the SSDs unleash the power of the processor. In our testing, the HDD solution could only support 39.1 percent CPU before being saturated. Meanwhile, the Kingston SSD solution supported 92.9 percent CPU utilization, all with internal drives. If we were to run a comparison where the CPU utilization and operations per minute were kept constant, we would expect the power savings of using Kingston SSDs to be far greater.

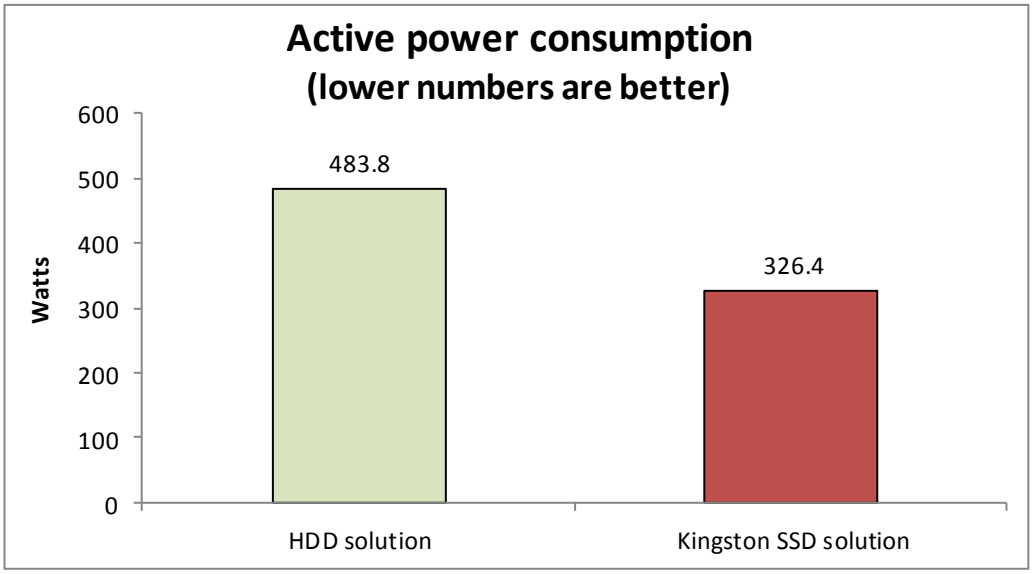

Figure 3: Power, in watts, that the solutions consumed while running database workloads.

Figure 4 shows the power, in watts, each solution consumed while idle. During this idle power measurement, the servers were not running any workloads. However, they were still supporting the powered-up VMs. While idle, the Kingston SSD solution used 51.0 percent less power than the HDD solution.

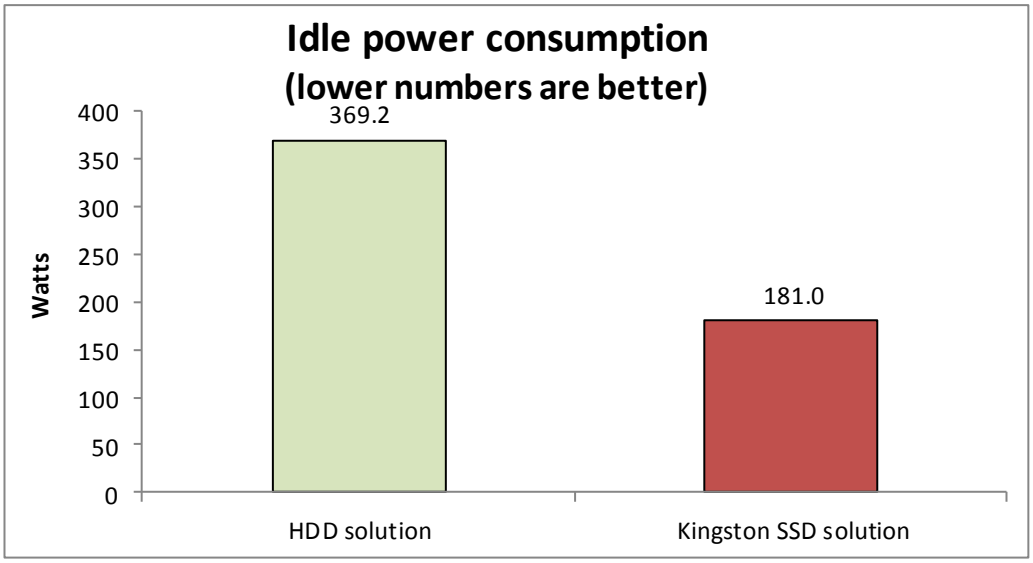

Figure 4: Power, in watts, that the solutions consumed while idle.

For more detailed test results, see Appendix D.

WHAT WE TESTED

We used a Dell™ PowerEdge™ R710 server to compare the virtualized database performance of two storage solutions: the HDD solution, which included an external drive chassis with 24 HDDs, and the Kingston SSD solution, which included six SSDs in

the server itself. Each of our eight VMs ran Microsoft® Windows Server® 2008 R2 Enterprise Edition and SQL Server® 2008 R2 with three vCPUs and 5.5 GB vRAM. We used the DVD Store benchmark to create our database workload. (We included two additional internal HDDs or SSDs on both solutions for the Windows Server 2008 R2 Enterprise Edition with Hyper-V™ operating system, but did not include them in the performance comparison, as they were mostly idle during testing.) We ran our database test three times, and report the median of the three runs.

About DVD Store Version 2.1

To create our real-world ecommerce workload, we used the DVD Store Version 2.1 (DS2) benchmarking tool. DS2 models an online DVD store, where customers log in, search for movies, and make purchases. DS2 reports these actions in orders per minute (OPM) that the system could handle, to show what kind of performance you could expect for your customers. The DS2 workload also performs other actions, such as adding new customers, to exercise the wide range of database functions you would need to run your ecommerce environment. For more information about the DS2 tool, see http://www.delltechcenter.com/page/DVD+Store.

IN CONCLUSION

Purchasing chassis with large numbers of HDDs is one way to configure your infrastructure, but such a solution can provide less than optimal performance, take up a large amount of prime data center space, and increase power and cooling costs. Configuring your servers with SSDs, on the other hand, can dramatically improve performance while simultaneously reducing the overall power consumption of your data center.

In our tests, replacing 24 HDDs in an external chassis with only six internal Kingston SSDs boosted total database performance by as much as 91.8 percent. Not only did the server with Kingston SSDs outperform the HDD solution, it also consumed 32.5 percent less power while active and 51.0 percent less power when idle. Such dramatic performance increases and reduction in power consumption can make Kingston SSDs a compelling choice for the database servers in your data center.

APPENDIX A – SERVER CONFIGURATION INFORMATION

Figure 5 provides detailed configuration information for the test servers.

System	HDD solution	Kingston SSD solution
Power supplies		
Total number	2	2
Vendor and model number	Dell N870P-S0	Dell N870P-S0
Wattage of each (W)	870	870
Cooling fans		
Total number	5	5
Vendor and model number	San Ace 60 9GV0612P1M041	San Ace 60 9GV0612P1M041
Dimensions (h x w) of each	2.5" x 2.5"	2.5" x 2.5"
Volts	12	12
Amps	1.5	1.5
General		
Number of processor packages	2	2
Number of cores per processor	6	6
Number of hardware threads per core	2	2
CPU		
Vendor	Intel®	Intel
Name	Xeon®	Xeon
Model number	X5670	X5670
Stepping	B1	B1
Socket type	LGA1366	LGA1366
Core frequency (GHz)	2.93	2.93
Bus frequency	6.4 GT/s	6.4 GT/s
L1 cache	32 + 32 (per core)	32 + 32 (per core)
L2 cache	256 (per core)	256 (per core)
L3 cache	12	12
Platform		
Vendor and model number	Dell PowerEdge R710	Dell PowerEdge R710
Motherboard model number	DP/N 0M233H	DP/N 0M233H
BIOS name and version	Dell 6.1.0	Dell 6.1.0
BIOS settings	Set power policy to Max Performance	Set power policy to Max Performance
Memory module(s)		
Total RAM in system (GB)	48	48
Vendor and model number	Samsung M393B1K70BH1-CH9	Samsung M393B1K70BH1-CH9
Type	PC3-10600R	PC3-10600R
Speed (MHz)	1,333	1,333
Speed running in the system (MHz)	1,333	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-24	9-9-9-24
Size (GB)	8	8
Number of RAM module(s)	6	6

System	HDD solution	Kingston SSD solution
Rank	Dual	Dual
Operating system		
Name	Windows Server 2008 R2 Enterprise Edition	Windows Server 2008 R2 Enterprise Edition
Build number	7601	7601
File system	NTFS	NTFS
Language	English	English
Graphics		
Vendor and model number	Matrox® G200eW	Matrox G200eW
Driver	Matrox 1.1.3.0	Matrox 1.1.3.0
RAID controller		
Internal RAID controller		
Vendor and model number	LSI® MegaRAID® SAS 9265-8i	LSI MegaRAID SAS 9265-8i
Firmware version	23.4.1-0028	23.4.1-0028
Driver version	LSI 5.2.103.0	LSI 5.2.103.0
Cache size (GB)	1	1
External RAID controller		
Vendor and model number	LSI MegaRAID SAS 9285-8e	N/A
Firmware version	23.4.1-0028	N/A
Driver version	LSI 5.2.103.0	N/A
Cache size (MB)	1	N/A
Hard drives		
Connected to internal RAID controller		
Vendor and model number	Seagate ST9146852SS	Kingston SE100S37/200G
Number of drives	2	8
Size (GB)	146	200
RPM	15,000	N/A
Type	SAS	SATA
RAID configuration	2 disks RAID 1 (OS)	2 disks RAID 1 (OS), 4 disk RAID 10 (database), 2 disks RAID 1 (logs)
Connected to external RAID controller		
Vendor and model number	Seagate ST973452SS	N/A
Number of drives	24	N/A
Size (GB)	73	N/A
RPM	15,000	N/A
Type	SAS	N/A
RAID configuration	20 disks RAID 10 (database), 4 disks RAID 10 (logs)	N/A
Ethernet adapters		
Vendor and model number	Broadcom® BCM5709C NetXtreme® II	Broadcom BCM5709C NetXtreme II
Type	Integrated	Integrated

System	HDD solution	Kingston SSD solution
Driver	Broadcom 6.2.9.0	Broadcom 6.2.9.0
Optical drive(s)		
Vendor and model number	TEAC DVD-ROM	TEAC DVD-ROM
Type	SATA	SATA
USB ports		
Number	4	4
Type	2.0	2.0

Figure 5: System configuration information for the test servers.

APPENDIX B – ABOUT DVD STORE

To build the workload, we used DVD Store Version 2.1 (DS2), an open-source simulation of an online e-commerce DVD store. DS2 has database components and Web server components, and includes driver programs that place heavy loads on these components.

The goal of this test was to show the advantage of implementing Kingston SSD drives instead of SAS drives. Therefore, we needed to ensure the test database did not become cached in memory, requiring constant reads and writes to the drives to give maximum disk activity.

The Dell PowerEdge R710 server ran eight virtual machines with a single instance of Microsoft SQL Server 2008 R2 in each. We configured each SQL Server 2008 R2 instance database with one 10GB database.

The main DS2 metric is orders per minute, which the driver program calculates and records to a text file on the client machines. The DVD Store client application outputs OPM at 10-second intervals. We ran this workload on the server for 30 minutes and report the last OPM score the benchmark reported.

A DS2 order consists of a customer login; a search for movies by title, actor, or category; and a purchase. The workload also performs other actions, such as adding new customers, to exercise a wide range of database functions.

As we note above, because our goal was to isolate and test database server performance, we did not use the front-end Web client component of DS2. Instead, we ran a compiled driver on client machines directly via its command-line interface. We used the default DS2 parameters and setup configuration, with the exceptions we note in the Setting up DVD Store version 2.1 sections in the detailed test methodology in Appendix C.

We used virtual machines for clients. Each client virtual machine ran one instance of DS2, with 32 threads to simulate a heavily loaded environment; the load-generating client machines ran with no think time, processing requests as quickly as the servers were able.

For more details about the DS2 tool, see http://www.delltechcenter.com/page/DVD+Store.

APPENDIX C – DETAILED TEST METHODOLOGY

Here, we explain the detailed steps we followed to set up our test scenario.

Setting up the server for DVD Store

Our DVD Store test bed consisted of a Dell PowerEdge R710 running Windows Server 2008 R2 with Hyper-V as the server under test and a Dell PowerEdge R900 server running Hyper-V to host the eight virtual clients. The Dell PowerEdge R710 test virtual machines had three virtual processors, 5.5 GB of memory, and a virtual network adapter. The Dell PowerEdge R900 client virtual machines had one virtual processor, 2 GB of memory, and a virtual network adapter. We connected the systems via one Gigabit network switch.

Setting up disk drives

For the HDD solution, we configured two 146 GB SAS hard drives in a RAID 1 using the Dell PowerEdge R710's internal drive bays for the operating system. We connected an external Dell PowerVault™ MD1220 with 24 73GB SAS hard drives for the VMs, database, and log volumes. We configured 20 of the external drives in a RAID 10 for the VMs and database volumes. We configured the remaining four external drives in a RAID 10 for the logs. We set both internal and external controllers policy to always write back and always read ahead for the HDD solution.

For the SSD solution we installed eight Kingston 200GB SSDs in the internal drive of the Dell PowerEdge R710. We configured two SSDs as RAID 1 for the operating system, four as RAID 10 for the VMs and database volumes, and two in a RAID 1 configuration for logs. For the SSD solution, we set the internal controller policy to write through and no read ahead. We did not have an external controller for the SSD solution testing.

Installing Windows Server 2008 R2 Enterprise Edition

1. Boot the server, and insert the Windows Server 2008 R2 installation DVD in the DVD-ROM drive.
2. At the Language Selection screen, click Next.
3. Click Install Now.
4. Select Windows Server 2008 R2 Enterprise (Full Installation), and click Next.
5. Click the I accept the license terms check box, and click Next.
6. Click Custom.
7. At the Where to Install Windows screen, click Drive options (advanced).
8. Ensure you select the proper drive, and click New.
9. Enter the partition size, and click Apply. (We used the entire disk.)
10. At the pop-up informing you Windows will create additional partitions, click OK.
11. At the Where to Install Windows screen, click Next.
12. At the User's password must be changed before logging on warning screen, click OK.
13. Enter a password as the new password in both fields, and click the arrow to continue.
14. At the Your password has been changed screen, click OK.

Setting up the network configuration on the server

1. Click Start→Control Panel→Network and Internet→Network and Sharing Center, and click Change Adapter Settings.
2. Right-click on the network adapter, and select Properties from the drop-down menu.
3. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
4. At 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. Click OK to close the window.
7. At the Local Area Connection Properties window, click Close.
8. Close the Network Connection window.

Installing system updates in Windows Server 2008 R2

We installed all critical updates on the server using the Windows Update feature.

Setting up the storage on the server

1. In the taskbar, click the Server Manager icon.
2. In the left pane, expand Storage, and click Disk Management.
3. Right-click the first volume, and choose Initialize Disk.
4. In the right pane, right-click the volume, and choose New Simple Volume…
5. At the welcome window, click Next.
6. At the Specify Volume Size window, leave the default selection, and click Next.
7. At the Assign Drive Letter or Path window, choose a drive letter, and click Next.
8. At the Format Partition window, choose NTFS and 64K allocation unit size, and click Next.
9. At the Completing the New Simple Volume Wizard window, click Finish.
10. Repeat steps 3 through 9 for the remaining volumes.

Adding the Hyper-V R2 SP1 role

1. Open Server Manager, and click Roles.
2. Click Add Roles.
3. On the Before You Begin page, check the Skip this page by default box, and click Next.
4. Select Hyper-V, and click Next.
5. On the Hyper-V Introduction page, click Next.
6. On the Create Virtual Networks page, click Next.
7. Confirm installation selections, and click Install.
8. Once the installation is complete, click Close.
9. When the system prompts a restart, click Yes.
10. Allow the system to fully reboot, and log in using the administrator credentials.
11. Once the desktop loads, the Hyper-V Installation Results window will finish the installation.
12. Click Close. The Hyper-V role will now be available in Server Manager under Roles.

Configuring Virtual Network Manager

1. At the Hyper-V Manager screen, in the right pane, click Virtual Network Manager.
2. At the Virtual Network Manager screen, select Internal, and click Add.
3. At the Virtual Network Manager screen, click Apply, and click OK.

Configuring the VMs

We provide steps below for installing the operating system, Microsoft SQL Server, and configurations of the VMs.

Installing the VM operating system on the first VM

1. Connect to the ISO image of the installation DVD for Windows Server 2008 R2 SP1 Enterprise from the VM console. If the ISO image is not stored on the host, start the VM first and then connect to the ISO image.
2. Start the VM.
3. At the Language Selection screen, click Next.

4. Click Install Now.
5. Select Windows Server 2008 R2 Enterprise (Full Installation), and click Next.
6. Click the I accept the license terms check box, and click Next.
7. Click Custom.
8. Click Next.
9. At the User's password must be changed before logging on warning screen, click OK.
10. Enter the desired password for the administrator in both fields, and click the arrow to continue.
11. At the Your password has been changed screen, click OK.
12. Connect the machine to the Internet, and install all available Windows updates. Restart as necessary.
13. Enable remote desktop access.
14. Change the hostname, and reboot when prompted.
15. Create a shared folder to store test script files. Set permissions as needed.
16. Set up networking:
    a. Click Start→Control Panel, right-click Network Connections, and choose Open.
    b. Right-click the VM traffic NIC, and choose Properties.
    c. Select TCP/IP (v4), and choose Properties.
    d. Set the IP address, subnet, gateway, and DNS server for the virtual NIC, which will handle outgoing server traffic. Click OK, and click Close.
17. In the VM, configure the VM storage:
    a. Click the Server Manager icon in the taskbar.
    b. In the left pane, expand Storage, and click Disk Management.
    c. Right-click the first volume, and choose Initialize Disk.
    d. In the right pane, right-click the volume, and choose New Simple Volume…
    e. At the welcome window, click Next.
    f. At the Specify Volume Size window, leave the default selection, and click Next.
    g. At the Assign Drive Letter or Path window, choose a drive letter, and click Next.
    h. At the Format Partition window, choose NTFS and 64K allocation unit size, and click Next.
    i. At the Completing the New Simple Volume Wizard window, click Finish.
    j. Repeat steps c through i for the remaining VM volumes.
18. Copy the pre-created DVD Store backup file to the backup virtual disk inside the first VM.

Installing SQL Server 2008 R2 on the server

1. Insert the installation DVD for SQL Server 2008 R2 into the DVD drive.
2. If Autoplay does not begin the installation, navigate to the SQL Server 2008 DVD, and double-click.
3. If prompted with a .NET installation prompt, click OK to enable the .NET Framework Core role.
4. At the SQL Server Installation Center screen, click Installation.
5. Click New installation or add features to an existing installation.
6. At the Setup Support Rules screen, click OK.
7. At the Product Key screen, specify the free Enterprise Edition evaluation, and click Next.
8. At the License Terms screen, accept the license terms, and click Next.
9. At the Setup Support Files screen, click Install.
10. At the Setup Support Rules screen, click Next.
11. At the Setup Role screen, choose SQL Server Feature Installation, and click Next.
12. At the SQL Server 2008 R2 Feature Selection screen, select the following features: Database Engine Services, Full-Text Search, Client Tools Connectivity, Client Tools Backwards Compatibility, Management Tools – Basic, Management Tools – Complete; and click Next.
13. At the Installation Rules screen, click Next.
14. At the Instance Configuration screen, leave the defaults, and click Next.

15. At the Disk Space Requirements screen, click Next.
16. At the Server Configuration screen, change SQL Server Agent and SQL Server Database Engine to NT AUTHORITY\SYSTEM, and click Next.
17. At the Database Engine Configuration screen, select Mixed Mode, fill in a password for the system administrator (sa) account, click Add Current User, and click Next.
18. At the Error Reporting screen, click Next.
19. At the Installation Configuration Rules screen, click Next.
20. At the Installation screen, click Install.
21. At the Complete screen, click Close.
22. Important: Repeat the installation process three more times to create four total instances of SQL Server 2008 R2.
23. Install SQL Server 2008 R2 Service Pack 1, and patch all instances.

Configuring SQL Server 2008 R2

After installing SQL Server 2008 R2, we enabled the SQL Server Browser and TCP/IP. We followed this process for these configurations:

1. Click Start→Administrative Tools→Services.
2. In the right pane, right-click SQL Server Browser, and select Properties from the drop-down menu.
3. At the Startup type drop-down menu, select Automatic, and click OK.
4. Close the Services window.
5. Click Start→All Programs→Microsoft SQL Server 2008 R2→Configuration Tools→SQL Server Configuration Manager.
6. Select SQL Server Services in the left pane.
7. In the right pane, right-click SQL Server Browser, and select Start from the drop-down menu.
8. In the left pane, expand SQL Server Network Configuration, and select Protocols for MSSQLSERVER (where MSSQLSERVER is the name of the first SQL Server instance).
9. In the right pane, right-click TCP/IP, and select Enable from the drop-down menu.
10. Repeat Step 9 for the remaining three SQL Server instances.
11. In the left pane, select SQL Server Services.
12. In the right pane, right-click SQL Server (MSSQLSERVER), and select Restart from the drop-down menu.
13. Repeat step 12 for the remaining three SQL Server instances.

Configuring additional VMs on Hyper-V

1. In Hyper-V, ensure VM1 is powered down.
2. Navigate to where the VHD is stored, and duplicate the file 7 times.
3. In Hyper-V, right-click the server→ New virtual machine, enter `VM2` for the name, and click Next.
4. On the Assign Memory screen, select 5632, and click Next.
5. On the Configure networking screen, select the network you set up, and click Next.
6. At the connect Virtual Hard Disk screen, select Use an Existing, and browse to where you duplicated the original VM's main VHD.
7. Repeat these steps for the remaining VMs.
8. Ensure in each VM that the necessary virtual disks are all online and the IP addressing is properly assigned.
9. Modify the hostname of each VM.

Installing and configuring the database clients

For the DS2 scripts, we used a Dell PowerEdge R900 server for virtual clients to simulate a number of users putting a load on the server. We installed Windows Server 2008 R2 with Hyper-V on the Dell PowerEdge R900 server as

outlined in the steps above. We installed Windows Server 2008 R2 Enterprise Edition inside the eight VMs we used for virtual clients. Each virtual machine had one virtual processor, 2 GB of memory, and a virtual network adapter. We installed the .NET 3.5 SP1 framework on each VM, as the DS2 test executable requires at least .NET2.0. After the installation, we created a folder on each VM to store the DS2 executable. We followed this process for each installation:

1. Install Microsoft Windows Server 2008 R2 Enterprise Edition on VM client.
2. Assign a computer name of `Clientx` for the database client, where x is the client number.
3. For the licensing mode, use the default setting of five concurrent connections.
4. Enter a password for the administrator logon.
5. Select Eastern Time Zone.
6. Use typical settings for the Network installation.
7. Type `Workgroup` for the workgroup.
8. Install Windows Updates, .NET 3.5 SP1 framework, and copy the DVD Store client executable into the folder.

Creating scripts on the database clients

To simplify testing, we created batch files named test.bat on all eight virtual clients to start the DVD Store executable with the correct parameters. We put the batch files in a folder on the clients in the following directory: c:\clientshare. The batch files contained the following text:

```
c:\clientshare\ds2sqlserverdriver.exe --target=192.168.0.100 --ramp_rate=10
--run_time=30 --n_threads=32 --db_size=10GB --think_time=0 --
database_name=ds2 --detailed_view=Y --warmup_time=1 --pct_newcustomers=20 --
output_path=c:\clientshare\opmoutds2.txt
```

Setting up DVD Store version 2.1

Data generation overview

We generated the data using the Install.pl script included with DVD Store version 2.1, providing the parameters for our 10GB database size and the database platform on which we ran - Microsoft SQL Server. We ran the Install.pl script on a utility system running Linux. The Install.pl script also generated the database schema.

After processing the data generation, we transferred the data files and schema creation files to a Windows-based system running SQL Server 2008 R2 SP1. We built the 10GB database in SQL Server 2008 R2 SP1, and then performed a full backup, storing the backup file on the C: drive for quick access. We used that backup file to restore on the server between test runs.

The only modification we made to the schema creation scripts were the specified file sizes for our database. We deliberately set the file sizes higher than necessary to ensure that no file-growth activity would affect the outputs of the test. Besides this file size modification, the database schema was created and loaded according to the DVD Store documentation. Specifically, we followed the steps below:

1. We generated the data and created the database and file structure using database creation scripts in the DS2 download. We made size modifications specific to our 10GB database and the appropriate changes to drive letters.
2. We transferred the files from our Linux data generation system to a Windows system running SQL Server.
3. We created database tables, stored procedures, and objects using the provided DVD Store scripts.
4. We set the database recovery model to bulk-logged to prevent excess logging.

5. We loaded the data we generated into the database. 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.
6. We created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
7. We updated statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
8. On the SQL Server instance, we created a ds2user SQL Server login 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
```

9. We set the database recovery model back to full.
10. We created the necessary full text index using SQL Server Management Studio.
11. We created a database user and mapped this user to the SQL Server login.
12. We then performed a full backup of the database. This backup allowed us to restore the databases to a pristine state relatively quickly between tests.

Figure 6 shows our initial file size modifications.

Logical name	Filegroup	Initial size (MB)
Database files		
primary	PRIMARY	3
cust1	DS_CUST_FG	5,632
cust2	DS_CUST_FG	5,632
ind1	DS_IND_FG	2,560
ind2	DS_IND_FG	2,560
ds_misc1	DS_MISC_FG	2,560
ds_misc2	DS_MISC_FG	2,560
orders1	DS_ORDERS	2,560
orders2	DS_ORDERS	2,560
Log files		
ds_log	Not Applicable	13,312

Figure 6. Our initial file size modifications.

Editing the workload script – ds2xdriver.cs module

A new feature of DVD Store version 2.1 is the ability to target multiple targets from one source client. We used this functionality. In order to record the orders per minute output from each specific database target, we modified the ds2xdriver to output this information to log files on each client system. To do this, we used the StreamWriter method to create a new text file on the client system, and the WriteLine and Flush methods to write the relevant outputs to the files during the tests. We also added the capabilities to target differently named databases.

After making these changes, we recompiled the ds2xdriver.cs and ds2sqlserverfns.cs module in Windows by following the instructions in the DVD Store documentation. Because the DS2 instructions were for compiling from the command line, we used the following steps on a system with Visual Studio installed:

1. Open a command prompt.
2. Use the `cd` command to change to the directory containing our sources.
3. Execute the following command:

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

Measuring power

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

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

We then recorded the power usage (in watts) for each system during the testing at 1-second intervals. To compute the average power usage, we averaged the power usage during the time the system was producing its peak performance results.

APPENDIX D – DETAILED TEST RESULTS

Figure 7 presents the results of the database performance tests we completed using the DVD Store 2.1 benchmark. We ran our database test three times, and report the median of the three runs. Run 3 is the median for the HDD solution and run 2 is median for the SSD solution.

Database performance results						
	HDD solution			Kingston SSD solution		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
VM 1	17,042	17,981	17,781	33,833	34,447	33,868
VM 2	14,484	14,849	15,379	36,885	37,396	37,274
VM 3	18,897	19,442	19,324	35,222	35,184	35,663
VM 4	20,074	19,940	19,825	34,909	34,521	34,675
VM 5	20,445	20,445	19,565	36,367	36,020	36,333
VM 6	20,143	20,528	19,566	38,198	37,679	37,865
VM 7	19,087	19,496	18,833	34,583	33,491	31,505
VM 8	16,241	16,460	16,658	33,214	33,003	33,281
Total OPM	146,413	149,141	146,931	283,211	281,741	280,464
% CPU utilization	38.5	40.0	39.1	92.8	92.9	92.8

Figure 7: Total database performance, in orders per minute, for the two solutions. Higher numbers are better.

Figure 8 presents the disks utilization counters for the database volume during testing. For the HDD solution, we configured 20 disks in the external Dell PowerVault MD1220 in a RAID 10 for the VMs and database volume. For the SSD solution, we configured four Kingston 200GB SSD internal drives in a RAID 10 for the VMs and database volume. Both systems had a two-disk RAID 1 in the internal drive bays for the operating systems. Those drives were mostly idle during testing so we do not include the disk counters for those volumes. The results are an average across the entire test.

Disk utilization (database volume)						
	HDD solution			Kingston SSD solution		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
Reads/sec	2,851.3	2,948.1	2,940.0	5,288.4	5,306.6	5,189.6
Writes/sec	3,246.0	3,022.1	2,874.5	7,275.0	7,252.1	7,233.0
Transfers/sec	6,097.3	5,970.2	5,814.5	12,563.4	12,558.7	12,422.6
% disk utilization	100.0	100.0	100.0	79.0	78.9	78.2

Figure 8: Disk utilization for database volumes for the two solutions. Higher reads, writes, or transfers/second are better. Lower percent utilization is better.

Figure 9 presents the disk utilization counters for the logs volume during testing. For the HDD solution, we configured four disks in the external Dell PowerVault MD1220 in a RAID 10 for the log volume. For the SSD solution, we configured two Kingston 200GB SSD internal drives in a RAID 1 for the log volume. The results are an average across the entire test.

Disk utilization (log volume)						
	HDD solution			Kingston SSD solution		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
Reads/sec	10.0	10.1	10.3	29.5	30.2	32.2
Writes/sec	1,795.3	1,794.4	1,793.2	2,951.5	2,962.8	2,920.4
Transfers/sec	1,805.3	1,804.5	1,803.5	2,981.0	2,993.0	2,952.6
% disk utilization	67.0	67.2	67.0	45.8	45.7	45.5

Figure 9: Disk utilization for log volumes for the two solutions. Higher reads, writes, or transfers/second are better. Lower percent utilization is better.

Figure 10 shows the power consumption in watts for both solutions when idle. Note that the statistics for the HDD solution include the power consumption of the external chassis as well as the server. The SSD solution did not use the external storage so those power numbers are for the server alone.

Power measurements while idle						
	HDD solution			Kingston SSD solution		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
Server (W)	191.3	193.1	192.6	181.1	181.0	181.3
External storage (W)	177.9	181.3	177.9	N/A	N/A	N/A
Total power (W)	369.2	374.4	370.5	181.1	181.0	181.3

Figure 10: Power consumption in watts for both solutions while idle. Lower numbers are better.

Figure 11 shows the power consumption in watts for both solutions while running database workloads. Note that the statistics for the HDD solution include the power consumption of the external chassis as well as the server. The SSD solution did not use the external storage so those power numbers are for the server alone.

Power measurements during peak performance						
	HDD solution			Kingston SSD solution		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
Server (W)	274.0	273.7	273.6	326.7	326.4	326.2
External storage (W)	209.5	209.8	210.2	N/A	N/A	N/A
Total power (W)	483.5	483.5	483.8	326.7	326.4	326.2

Figure 11: Power consumption in watts for both solutions during peak performance. Lower numbers are better.

ABOUT PRINCIPLED TECHNOLOGIES

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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.

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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.