

# SERVER POWER MANAGEMENT COMPARISON: DELL OPENMANAGE POWER CENTER AND IBM SYSTEMS DIRECTOR ACTIVE ENERGY MANAGER

## Dell™ OpenManage™ Power Center



Provided precise power limiting



Simplified power management

on the Dell PowerEdge™ R720

More efficient and accurate than IBM Systems Director Active Energy Manager, so you can better allocate resources and reduce data center costs.



In your data center, you need both strong and continuous performance to handle the needs of your employees and customers, and advanced management technologies to keep operational expenses down. High among these operational expenses are the power costs related to running and cooling your servers.

We tested two applications—Dell OpenManage Power Center managing a Dell PowerEdge R720 server and IBM® Systems Director Active Energy Manager, an IBM Systems Director plug-in, managing an IBM System x3650 M4 server—with the goal of understanding the ways that their respective power management tools affect performance and power usage in the data center. We focused on the tools' approaches to setting power limits, also known as power capping.

In our tests, the Dell OpenManage Power Center provided more precise power limiting than IBM Active Energy Manager. The difference between the actual power used by the Dell solution and the power limit we set was 2 percent or less, versus a difference of 4 to 8 percent with the IBM solution. The smaller gap lets administrators maximize the number of servers that can fit within the data center's total power capacity. Increasing data center density in this way saves money. Dell OpenManage Power Center also offered greater management flexibility out of the box, including the ability to easily set priorities among servers and to initiate an emergency power response.

The Dell PowerEdge R720 also offered greater performance per watt and supports a much higher working temperature, through the Dell Fresh Air initiative, than the IBM System x3650 M4. These energy-saving features can lead to significant data center energy cost savings for your enterprise.



A PRINCIPLED TECHNOLOGIES TEST REPORT

Commissioned by Dell Inc.; October 2012

## THE POWER OF POWER LIMITS

One of the biggest sources of return from an investment in the latest equipment and management software is being able to take advantage of new power-saving technologies. In the typical server, power utilization increases as the server load increases. Being able to limit or cap the amount of power a server or group of servers consumes offers great flexibility, often without decreasing performance.

Power management tools let you as the administrator set power limits at the data center, room, aisle, rack, or server level. You can also set different power limits for different times. For example, you can give a server a lower power limit in the evenings, when less work is taking place, and a higher limit during the day, when greater performance is needed. Being able to set these limits can dramatically boost data center rack density as you can now safely add extra servers to the same circuit without fear of tripping the breaker.

### Two approaches to power management: Dell OpenManage Power Center and IBM Active Energy Manager

Dell OpenManage Power Center, using Intel Node Manager Technology, lets IT administrators look at the data center power usage. Power Center is an open, standards-based power management application that can read power usage information from Dell PowerEdge servers, power distribution units, uninterruptable power supplies, or Dell PowerEdge blade server chassis.

As an IT administrator, you know that you can only manage power utilization if you can collect data related to it. OpenManage Power Center offers many advanced features for monitoring your data center power utilization. You can view instantaneous power usage or temperature and examine power usage over specific time increments (15 minutes, 1 hour, 1 day, 1 week, 1 month, 3 months, or 1 year). OpenManage Power Center shows peak, average, and minimum power across the data center, room, aisle, rack, or server. Understanding your power utilization opens a wide range of opportunities for server density, power savings, and uptime improvements.

To learn more about Dell OpenManage Power Center, visit <http://www.dell.com/us/enterprise/p/dell-openmanage-power-center/pd>, or see an additional report from Principled Technologies, at: [http://www.principledtechnologies.com/clients/reports/Dell/R720\\_power\\_0312.pdf](http://www.principledtechnologies.com/clients/reports/Dell/R720_power_0312.pdf)

According to the IBM Web site, "IBM Systems Director Active Energy Manager is an IBM Systems Director plug-in. Use Active Energy Manager to monitor and manage the power and cooling needs of IBM servers and BladeCenter® systems. Non-IBM systems can also be monitored using metering products, such as power distribution units (PDU), sensors, and integration with facility software.

“The tasks you can perform on Active Energy Manager resources include the following: monitoring and collecting power consumption data; managing power, which includes setting power savings options and power caps and automating power-related tasks; configuring metering devices, such as PDUs and sensors; exporting data; viewing events; calculating energy cost; setting thresholds; creating and setting power policies; and monitoring power and cooling equipment that affect IT resources.”

For more detailed information on Active Energy Manager, visit

[http://pic.dhe.ibm.com/infocenter/director/v6r1x/index.jsp?topic=/aem\\_420/frb0\\_main.html](http://pic.dhe.ibm.com/infocenter/director/v6r1x/index.jsp?topic=/aem_420/frb0_main.html).

For testing, we applied the power caps on the input power. This worked fine on the Dell PowerEdge R720 out of the box. However, the IBM System x3650 M4 did not cap the input power correctly. We worked with IBM support and applied a patch to get this feature working correctly. A Technote showing this patch is available at

[http://www-01.ibm.com/support/docview.wss?rs=0&q1=eServerOnDemandKBRCH&q2=649755169&uid=nas7d686520ea29f65dc86257aa00031f774&loc=en\\_US&cs=utf-8&lang=](http://www-01.ibm.com/support/docview.wss?rs=0&q1=eServerOnDemandKBRCH&q2=649755169&uid=nas7d686520ea29f65dc86257aa00031f774&loc=en_US&cs=utf-8&lang=)

## WHAT WE FOUND

When looking at a power management solution, it is important to understand how the application lets you set power limits for optimum data center and system management. Dell OpenManage Power Center and IBM Active Energy Manager handle power limiting differently, with the main difference being the size of the gap between the intended power limit and the actual power usage.

To understand this difference and its importance, you must first understand what these two numbers mean. The intended power limit is the setting you enter in the management software as a level not to be exceeded. For example, an intended limit of 80 percent means the server should never use more than 80 percent of its maximum capacity at any time. The actual power limit is the amount of power the server actually uses. Note that the actual power limit average should always be below the intended limit.

To illustrate the difference between these two levels, we present graphs of both systems' actual power usage under two conditions: when we set the intended power limit to 80 percent of their total power and when we set no power limit. We used a Dell PowerEdge R720 with Dell OpenManage Power Center and an IBM System x3650 M4 with the IBM Active Energy Manager for this evaluation. Because the two servers have different power draws, the intended limits of the two servers differ accordingly. We chose this approach to avoid unfairly penalizing either of the servers by setting an identical limit on both systems.

Figure 1 shows the power usage at 1-second intervals over a 2-minute period for the Dell PowerEdge R720 with an 80 percent power limit of 304 watts and with no power limit. (Note: To magnify the power variations during the run, we do not start the vertical axis of the chart at zero.) As Figure 1 shows, with the 304-watt intended limit, actual power usage of the Dell PowerEdge R720 averaged slightly over 302 watts. While it did reach the 304-watt limit, it never went over. The maximum difference between the intended 80 percent of faceplate power (304 watts) and the actual power limit was 2 percent.

Figure 1: Actual power usage of the Dell PowerEdge R720 with an 80 percent power limit stayed within 2 percent of the limit. (To magnify the power variations during the run, we do not start the vertical axis at zero.)

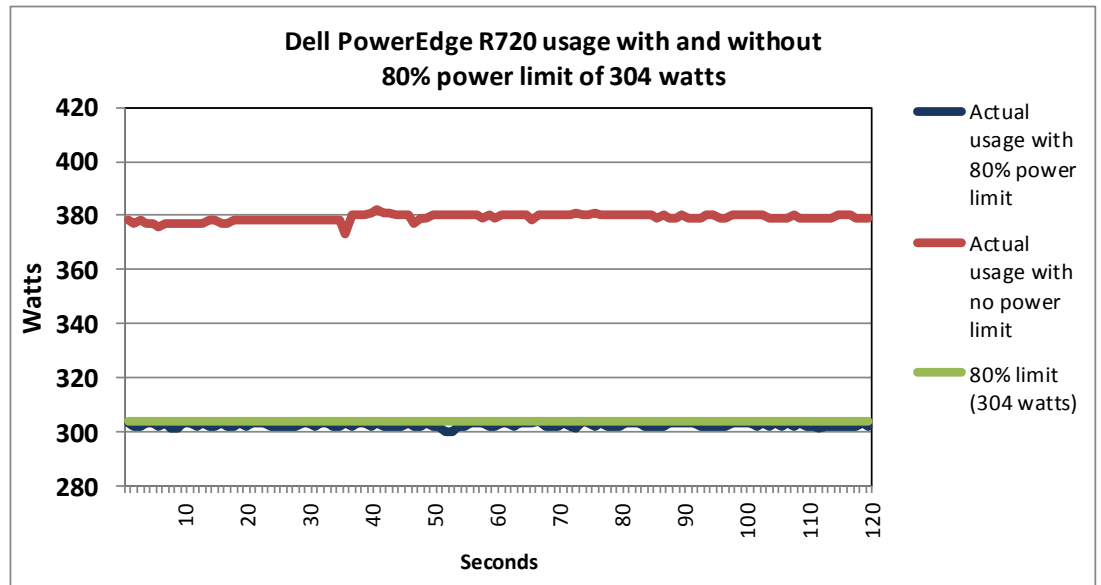
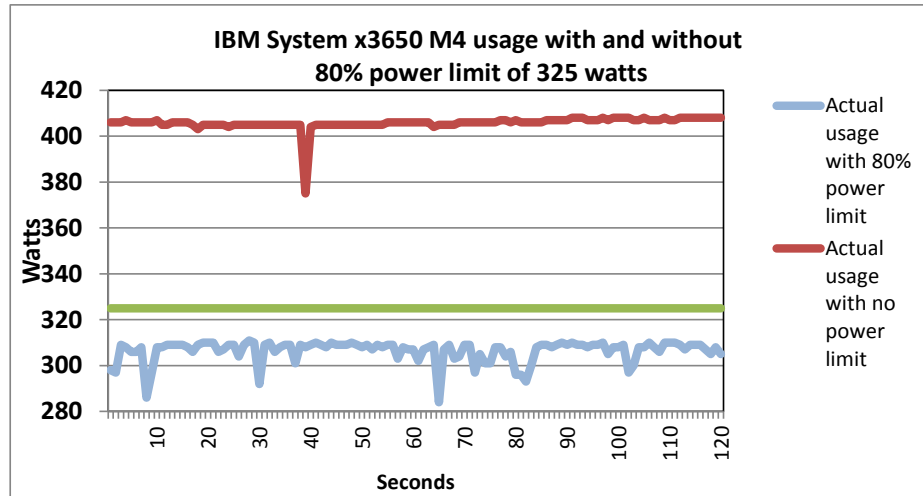


Figure 2 shows the power usage at 1-second intervals over a 2-minute period for the IBM System x3650 M4 with a 325-watt power limit and with no power limit. (As in Figure 1, to magnify the power variations during the run, we do not start the vertical axis of the chart at zero.) As Figure 2 shows, with the 325-watt intended limit, actual power usage averaged around 310 watts, roughly 5 percent lower than intended power limit.

While a larger difference between the intended and actual power limit does guarantee that the power will not exceed the set limit, it also means that you cannot configure a server rack as densely. For example, 20 servers with a 325-watt power limit would be a total of 6,500 watts, while the actual power used would be 6,200 watts. This means that 300 watts are allocated but unused. In this example, if the percentage difference between the intended limit and actual power were closer, as with the Dell PowerEdge R720, you could essentially put another server in the rack using the same total power limit.

Figure 2: Actual power usage of the IBM System x3650 M4 with an 80 percent power limit was roughly 5 percent lower than the limit. (To magnify the power variations during the run, we do not start the vertical axis at zero.)



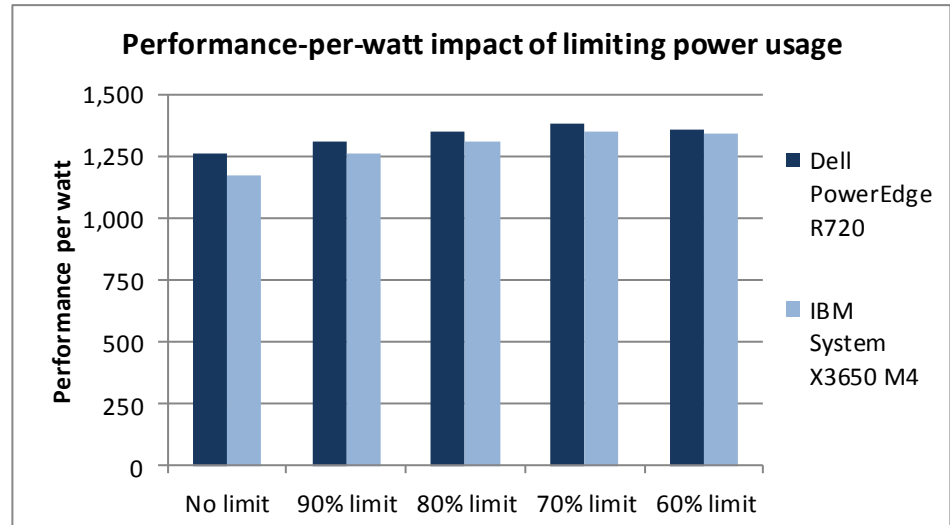
## The impact of power limiting

In addition to evaluating how both applications handle power limiting, we also looked at the performance-per-watt advantages of the new Dell PowerEdge R720 server at different power levels compared to the IBM System x3650 M4 server.

To test the performance per watt, we used DVD Store 2.1 (DS2), which reports performance in orders per minute (OPM), running Microsoft SQL Server 2008 R2 with 6GB databases on both servers. For this workload testing, we used four SQL database instances with two DVD Store databases. We used one client for each database for a total of eight clients. (For details about that workload, see [Appendix C](#).) Figure 3 shows the results from our test.

As Figure 3 shows, running the PowerEdge R720 at as much as a 40 percent power reduction provides performance-per-watt advantages over the IBM System x3650 M4. In fact, running the PowerEdge R720 with a 30 percent power reduction provides the highest performance-per-watt advantage. One practical application of the data is with CPU-intensive nightly batch jobs, where it does not matter if the job takes a few more minutes. Our findings show that you could run most efficiently if you limited the power at 70 percent.

Figure 3: The Dell PowerEdge R720 was able to provide better performance per watt at each power limit when compared to the IBM System x3650 M4.



To test the limit feature, we used DVD Store 2.1 running eight Microsoft SQL Server 2008 R2 6GB databases on both servers. To find the maximum performance per watt, we ran each system as close to 100 percent processor utilization as possible.

Figure 4 shows the results from our test.

	Total OPM	CPU %	Power set point (W)	Power utilization (W)		Perf/watt
				Peak	No activity	
<b>Dell PowerEdge R720</b>						
No power limit	473,737	99.0	NA	377	108.9	1,256.6
90% power limit	443,318	99.0	342	338	109.1	1,311.6
80% power limit	406,205	99.0	304	302	109.1	1,345.0
70% power limit	363,644	99.0	266	264	109.2	1,377.4
60% power limit	307,349	98.8	228	226	109.3	1,360.0
<b>IBM System x3650 M4</b>						
No power limit	474,443	99.1	NA	406	113.3	1,168.6
90% power limit	423,058	99.1	366	335	112.4	1,262.9
80% power limit	406,644	99.1	325	310	113.3	1,311.8
70% power limit	367,696	99.0	285	273	112.8	1,346.9
60% power limit	311,597	99.0	244	233	110.9	1,337.3

Figure 4: DVD Store results with CPU and power utilization. Higher OPM and performance/watt are better. Lower power utilization is better.

## DELL OPENMANAGE KEY FEATURES

Dell OpenManage offers several key features to help manage your data center to ensure server uptime and utilize power in the best way possible. We explain these features in the section below.

### Reliability during a power outage

Data center servers must stay up and available for users. Dell OpenManage Power Center offers a feature to reduce power in the event of an emergency such as drop in data center power or cooling.

Dell OpenManage has an option called Emergency Power Reduction (EPR). The administrator can initiate EPR by simply clicking a button in the management console to initiate the power reduction. This feature is available at all levels from the data center down to an individual server, which enables administrators to be extremely precise in selecting what to slow down.

To test the EPR feature, we ran a database workload using 100 percent processor utilization on the Dell PowerEdge R720 while running on battery backup. First, we ran the server with no power limits. We then repeated the test after selecting the EPR option.

As Figure 5 shows, the Dell PowerEdge R720 ran longer with the emergency power reduction feature enabled. While in EPR mode, the PowerEdge R720 is able to run nearly four times as long, maximizing up time during a power outage.

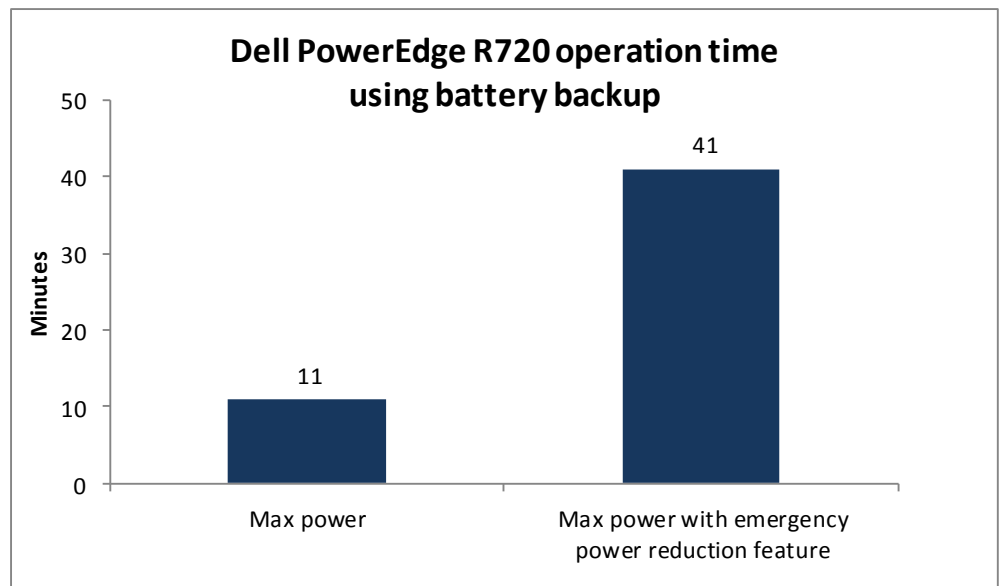


Figure 5: Running on battery backup with the emergency power reduction feature enabled let the Dell PowerEdge R720 run much longer.

IBM Active Energy Manager provides options for an administrator to set up a group policy with power capping in the event of a power change, but the setup requires many more steps. In addition, administrators must set the static power caps in advance

of an emergency power event. We did not test the IBM emergency feature as a comparison since there is no predefined emergency power feature on the IBM as with Dell OpenManage. We found Dell OpenManage's EPR simpler to initiate in the event of a power failure.

## Power limit response time

Because Dell OpenManage Power Center offers a low percentage difference between the intended and actual limit, it is important for the software to react quickly in the event that the power demand exceeds the intended limit. This fast reaction time allows administrators to increase the server density on circuits without fear of overloading. To test this feature, we implemented a power limit of 225 watts on the server and then began the database workload. As the workload ran, the server power increased up to the 225-watt limit. Figure 6 shows that within 300 milliseconds of going over the power limit, the power came back down and stayed within 1 percent of the power limit. (Note: To magnify the power variations during the run, we do not start the vertical axis of the chart at zero.)

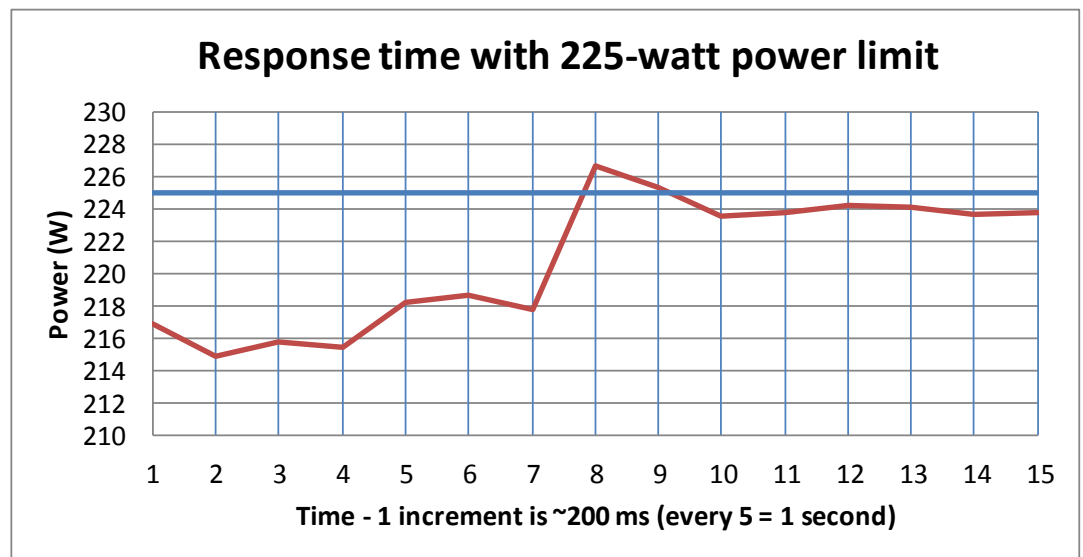


Figure 6: When power usage on the Dell PowerEdge R720 exceeded the limit, it came back down in less than half a second. (To magnify the power variations during the run, we do not start the vertical axis at zero.)

## Thermal balancing

Another major advantage of the Dell PowerEdge R720 server over the IBM System x3650 M4 server is its ability to operate at much higher temperatures. Through the Dell Fresh Air initiative, Dell servers are now rated to operate at up to 113 degrees Fahrenheit, allowing data centers to save substantially on cooling costs.<sup>1</sup> Published

<sup>1</sup> <http://en.community.dell.com/dell-blogs/direct2dell/b/direct2dell/archive/2012/03/06/12-things-you-need-to-know-about-dell-poweredge-12th-generation-servers-and-solutions-part-iii.aspx>



specifications for the IBM System x3650 M4<sup>2</sup> indicate that it supports operation at up to 104 degrees.

For most data center managers, the best approach will be to examine temperature and usage patterns to determine the “sweet spot” where the data center is providing the highest possible energy savings. For more information on the Dell Fresh Air initiative, see [www.dell.com/freshair](http://www.dell.com/freshair).

## Implementing server priority on the Dell PowerEdge R720

When using power limiting, it is important to provide proper server performance to your applications. OpenManage Power Center offers the ability to set a dynamic limit and to set priorities at the room, aisle, or server rack levels. When applying the dynamic limit, you specify a priority of high, medium, or low for each group based on its performance and power needs. For example, if applying a dynamic limit on a server rack, you specify which servers are higher or lower priority.

To test this feature, we used the SPECjbb<sup>®</sup>2005 benchmark<sup>3</sup> to apply a constant workload on three servers in a rack. We ran each server at 100 percent CPU utilization. The three Dell PowerEdge R720 servers consumed approximately 1,150 total watts. We set a dynamic limit of 850 watts and gave each server a different priority—one high, one medium, and one low. As Figure 7 shows, total power usage dropped precipitously when the limit was applied, and the usage of the three servers varied according to their priority.

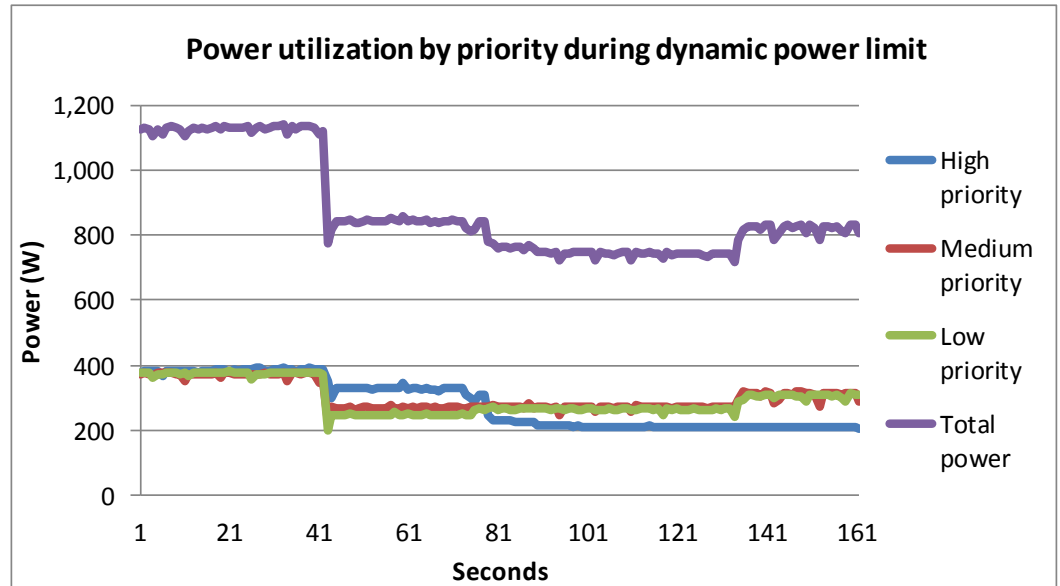
We then stopped the workload on the high-priority server. Once OpenManage Power Center identified available watts for the medium- and low-priority servers, they were allowed to consume more power up to the limit of 850 total watts.

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<sup>2</sup> <http://www.redbooks.ibm.com/abstracts/tips0850.html> (Note: See “Supported environment” in the “Physical and electrical specifications” section for operating temperature.)

<sup>3</sup> SPECjbb2005 is an industry-standard benchmark created by the Standard Performance Evaluation Corp. (SPEC) to measure a server’s Java performance. (Note: SPEC and SPECjbb2005 are trademarks of the Standard Performance Evaluation Corporation.)

Figure 7: With Dell PowerEdge R720 servers, you can implement a total power limit for the group, saving power on lower-priority servers and maintaining availability for higher-priority servers.



The server priority feature is included with Dell OpenManage Power Center and works automatically with your existing power distribution units (PDU), so other than the purchase of the Dell PowerEdge servers, no special hardware is required.

While IBM Active Energy Manager provides the option to set group power capping it does not have the ability to set priorities, but rather divides the allotted power by the number of systems. This approach leaves power unutilized. For example, in our testing we applied a 500-watt power cap on a group of two servers. When running equal workloads, both servers used 250 watts of power. However, when we stopped the workload on one server, the power draw dropped to the 110-watt idle power level, while the other server continued to use only 250 watts of power. This left 140 watts of power unused. In the Dell OpenManage approach, the 140 watts of power would be made available to the other server.

## CONCLUSION

As data centers grow, their power needs increase and space becomes more and more of a premium. These rising costs make it essential to manage your data center as effectively as possible.

Using Dell OpenManage Power Center with Intel Node Manager Technology in conjunction with the latest Dell PowerEdge servers offers a completely new approach to data center power usage. Dell OpenManage Power Center allows managers to collect, observe, and optimize power utilization to increase uptime and make better power-usage decisions.

In our testing, we saw a gap of only 2 percent between actual usage and the intended power limit; this small difference can let you fit more servers into your data center without exceeding your total available power. While implementing power limits,

the Dell PowerEdge R720 maintained consistent performance and delivered up to 7.5 percent more performance per watt than the IBM System x3650 M4 managed by IBM Active Energy Manager.

Dell OpenManage Power Center features extended operation time by almost four times using battery backup with their Emergency Power Reduction feature and permitted us to implement server prioritizing.

In addition, through the Dell Fresh Air initiative the latest Dell PowerEdge R720 servers allow you to run at higher temperatures—up to 113 degrees—which can lead to significant data center cost savings.

Overall, the Dell OpenManage Power Center gives data center managers greater confidence and control over server power usage, which leads to an efficient, optimized data center with significant cost savings.

## APPENDIX A – SERVER AND STORAGE CONFIGURATION INFORMATION

Figure 8 provides configuration information for the two servers we tested.

System	Dell PowerEdge R720	IBM System x3650 M4
<b>Power supplies</b>		
Total number	2	2
Vendor and model number	Dell D750E-S1	Emerson™ 7001605-J000
Wattage of each (W)	750	750
<b>Cooling fans</b>		
Total number	6	8
Vendor and model number	AVC® DBTC0638B2V	Delta Electronics® GFC0812DS
Dimensions (h x w) of each	2.5" x 2.5"	3" x 3"
Volts	12	12
Amps	1.2	1.8
<b>General</b>		
Number of processor packages	2	2
Number of cores per processor	8	8
Number of hardware threads per core	2	2
System power management policy	Balanced	Balanced
<b>CPU</b>		
Vendor	Intel®	Intel
Name	Xeon®	Xeon
Model number	E5-2680	E5-2680
Stepping	C1	C1
Socket type	LGA2011	LGA2011
Core frequency (GHz)	2.70	2.70
Bus frequency (GT/s)	8.0	8.0
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	256 KB (per core)	256 KB (per core)
L3 cache	20 MB	20 MB
<b>Platform</b>		
Vendor and model number	Dell PowerEdge R720	IBM System X3650 M4
Motherboard model number	00W9X3	00D2887
BIOS name and version	Dell 0.3.38	IBM VVE120CUS-1.20
BIOS settings	Default	Default
<b>Memory module(s)</b>		
Total RAM in system (GB)	64	64
Vendor and model number	Hynix® HMT31GR7BFR4A-H9	Samsung® M393B1K70CH0-YH9
Type	PC3L-10600R	PC3L-10600R
Speed (MHz)	1,333	1,333
Speed running in the system (MHz)	1,333	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-36	9-9-9-27
Size (GB)	8	8
Number of RAM modules	8	8

<b>System</b>	<b>Dell PowerEdge R720</b>	<b>IBM System x3650 M4</b>
Chip organization	Double-sided	Double-sided
Rank	Dual	Dual
<b>Operating system</b>		
Name	Microsoft® Windows® Server 2008 R2	Microsoft Windows Server 2008 R2
Build number	7601	7601
File system	NTFS	NTFS
Language	English	English
<b>Graphics</b>		
Vendor and model number	Matrox® G200e	Matrox G200eR2
Driver	Matrox 2.4.1.0	Matrox 2.4.1.0
<b>RAID controller</b>		
Vendor and model number	PERC H710P Mini	IBM ServeRAID M5110e
Firmware version	3.130.05-1311	23.7.0-0029
Driver version	Dell 5.1.90.64	LSI 5.2.127.64
Cache size	1 GB	1 GB
<b>Hard drive # 1</b>		
Vendor and model number	Seagate® ST9300605SS	IBM System X MBF2300RC
Number of disks in system	2	2
Size (GB)	300	300
Buffer size (MB)	64	16
RPM	10,000	10,000
Type	SAS	SAS
<b>Hard drive # 2</b>		
Vendor and model number	Pliant® LB 150S	Pliant LB 150S
Number of disks in system	2	2
Size (GB)	150	150
Buffer size (MB)	N/A	N/A
RPM	N/A	N/A
Type	SAS	SAS
<b>Ethernet adapters</b>		
Vendor and model number	Intel I350 Gigabit Controller	Intel I350 Gigabit Controller
Type	Integrated	Integrated
Driver	Intel 11.14.42.0	Intel 11.14.48.0
<b>Optical drive(s)</b>		
Vendor and model number	TEAC DV-28SW	TEAC DV-28SW
Type	DVD-ROM	DVD-ROM
<b>USB ports</b>		
Number	4 external, 1 internal	6 external, 2 internal
Type	2.0	2.0

Figure 8: System configuration information for the test servers.

## APPENDIX B – CONFIGURING POWER-LIMITING SOFTWARE

For testing, we used Dell OpenManage Power Center version 1.0.2.7253 to control the Dell PowerEdge R720 server. OpenManage communicated with the PowerEdge R720 through the onboard iDRAC 7 Enterprise variant, running software version 1.20.20. We used the isolated management port for iDRAC communication.

### Installing Dell OpenManage Power Center

We installed OpenManage on a Dell PowerEdge 2950 III with dual Intel Xeon processors E5405 and 16 GB of system memory. We used the default options for the OpenManage installation as the installation document outlined. After installation, we used the Discovery option to locate and configure our test servers.

### Setting the power limit for Dell OpenManage Power Center

1. Select the server or rack as needed for testing.
2. Click the Policies tab.
3. Click the Create New Policy button to create a power limit.
4. Enter the desired limit in the Power Cap Value box.
5. Click Next through the remaining wizard windows.
6. After creating the limit, use the Enable/Disable button on the Policies tab to enable or disable the power limit.
7. Click the Emergency Power Reduction button on the same page to enable EPR for testing.

### Installing IBM System Director and Active Energy Manager

For the IBM System Director and Active Energy Manager installation, we installed IBM System Director 6.3.1.1 on an IBM System x3850 M2 with dual Intel Xeon processors E7210 and 32 GB of system memory. This system acted as the management server for all System Director and Active Energy Manager tasks and the installed version of System Director includes IBM Active Energy Manager 4.4.1. We installed IBM System Director with default installation options, as the installation documentation outlined. We followed the Pre-installation Worksheet prior to the main installation to ensure proper configuration.

IBM Active Energy Manager communicated with the IBM System x3650 M4 through the Integrated Management Module (IMM) 2 management port. Our test systems used an IMM2 Advanced license and firmware version 1.65. We used the Discovery Manager option from the Home menu in IBM System Director to discover the IBM System x3650 M4 system.

### Setting the power limit for IBM Active Energy Manager

1. From the Home menu, select Discovery Manager and collect inventory for the target system.
2. From the Home menu, select Active Energy Manager. This brings up the Active Energy Manager menu.
3. Under Manage, select Work with power policies. This brings up the Power Policies menu.
4. Under Target Resources select Browse, then Active Energy Managed Resources, and then select the target system.
5. Click Add, and click OK.
6. Click Create policy, name the policy, and click Next.
7. Select System power capping, and click Next.
8. Select Activate Power Capping, Input Power Cap, Absolute value, input the value of the cap in watts, and click Next twice to complete policy creation.
9. To apply the power cap, check the box next to the desired power policy, and click Apply.
10. Select Run Now, and click OK.
11. To remove this cap, click the cap name from the Power Policies page, select Targets, check the box next to the target system, and click Remove.

## APPENDIX C – DATABASE WORKLOAD

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. A new feature of DVD Store Version 2.1 uses the ability to target multiple databases from one source client. We used this functionality to record the orders per minute output from each specific database target.

The Dell PowerEdge R720 and IBM System x3650 M4 ran four Microsoft SQL Server 2008 R2 instances, with two 6GB databases per instance for the 100 percent processor utilization testing.

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 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 below.

We used eight client machines with one client connecting to each of the eight databases. Each client machine ran a single instance of DS2, with 16 threads to simulate a heavily loaded environment; the load-generating client machines used a 5 percent new customer setting and 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>.

### Setting up the servers for DVD Store

Our DVD Store test bed consisted of a Dell PowerEdge R720 or IBM System x3650 M4 as the server under test and eight Intel-based clients. Each client had an Intel Pentium 4 3.00GHz processor, 1 GB of system memory, and a Gigabit network card in default configurations. We connected the systems via one Gigabit network switch. We installed a fresh copy of Windows Server 2008 R2 Enterprise Edition on the server.

### 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.

### 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. In the left pane, select SQL Server Services.
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.

## Installing and configuring the database clients

For the DS2 scripts, we used eight clients to simulate a number of users putting a load on the server. Each client server had a single drive on which we installed a fresh copy of Windows Server 2003 R2 Enterprise Edition. We installed the .NET 3.5 SP1 framework on each client, as the DS2 test executable requires at least .NET2.0. After the installation, we created two folders on the server, one for each client instance, to store the DS2 executable. We followed this process for each installation:

1. Install Microsoft Windows Server 2003 R2 Enterprise Edition with Service Pack 2 on the 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 each of the two folders.

## Creating scripts on the database clients

To simplify testing, we created batch files named `test.bat` on all eight clients to start the DVD Store executable with the correct parameters. We put the batch files on the clients: `c:\clientshare`. The batch files in `c:\clientshare` on four of the clients contained the text below. The batch files on the other four clients contained the same text, but the driver pointed to the different database with `-database_name=ds2-1`.

```
c:\clientshare\ds2sqlserverdriver.exe --target=192.168.2.120 --ramp_rate=10 --run_time=30 --n_threads=16 --db_size=6GB --think_time=0 --database_name=ds2 --detailed_view=Y --warmup_time=1 --pct_newcustomers=5 --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 6GB 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 6GB 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 6GB 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 9 shows our initial file size modifications.

Logical name	Filegroup	Initial size (MB)
<b>Database files</b>		
Primary	PRIMARY	8
cust1	DS_CUST_FG	675
cust2	DS_CUST_FG	675
cust3	DS_CUST_FG	675
cust4	DS_CUST_FG	675
cust5	DS_CUST_FG	675
cust6	DS_CUST_FG	675
cust7	DS_CUST_FG	675
cust8	DS_CUST_FG	675
ind1	DS_IND_FG	418
ind2	DS_IND_FG	418
ind3	DS_IND_FG	418
ind4	DS_IND_FG	418
ind5	DS_IND_FG	418
ind6	DS_IND_FG	418
ind7	DS_IND_FG	418
ind8	DS_IND_FG	418
ds_misc1	DS_MISC_FG	200
ds_misc2	DS_MISC_FG	200
ds_misc3	DS_MISC_FG	200
ds_misc4	DS_MISC_FG	200
ds_misc5	DS_MISC_FG	200
ds_misc6	DS_MISC_FG	200
ds_misc7	DS_MISC_FG	200
ds_misc8	DS_MISC_FG	200
orders1	DS_ORDERS	370
orders2	DS_ORDERS	370
orders3	DS_ORDERS	370
orders4	DS_ORDERS	370
orders5	DS_ORDERS	370
orders6	DS_ORDERS	370
orders7	DS_ORDERS	370
orders8	DS_ORDERS	370
<b>Log files</b>		
ds_log	Not Applicable	15,360

Figure 9: 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
```

## Setting up disk drives for the database

We installed two Pliant LB 150S SSD drives in both servers for the database and log files. We configured the drives as two individual disks and named them volume1 (E:) and volume2 (F:). We put the database and logs on different volumes. For example, the database 1 files were on volume1 and the log files were on volume2. We reversed this for the next database, so database 2 files were on volume2 and the log files were on volume1. We repeated these steps for the remaining database instances. This setup ensured equal disk activity on both RAID volumes.

## APPENDIX D – JAVA WORKLOAD

### SPECjbb2005 configuration

We used SPECjbb2005 version 1.07, dated March 15, 2006. We followed SPEC's run rules. (For more information about SPECjbb2005 and its run rules, see <http://www.spec.org/jbb2005/docs/RunRules.html>.) We installed SPECjbb2005 by copying the contents of the SPECjbb2005 CD to the directory C:\SPECjbb2005v1.07 on the server's hard disk.

SPECjbb2005 requires a Java Virtual Machine on the system under test. We used Java HotSpot 64-bit Server VM (build 20.6-b01 for this testing and left the default installation settings.

For an official SPECjbb2005 run, as per the run rules, the end user should edit the SPECjbb\_config.props file in the root SPECjbb2005 directory to include disclosure information about the server and our license information. We did not do this step, as our goal was to create a server load and not produce actual SPECjbb2005 results. We modified the SPECjbb.props file to change the number of JVM instances to two. This change allows a server to run two JVM instances during testing.

We created a batch file, which we placed in the root SPECjbb2005 directory, to issue the Java run command to launch the benchmark. During testing, we used the command prompt window within Microsoft Windows Server 2008 R2 Enterprise Edition to run this batch file. The contents of this file are shown below.

```
@echo off
set path="C:\Java\bin";%path%

set JVM=2
:: Set JAVA_HOME to Java.exe path.
set JAVA_HOME="C:\Java\bin"

:stage1
set PROFILE=SPECjbb.props
set JAVAOPTIONS= -Xms512m -Xmx512m
rem set JBBJARS=.\jbb.jar;.\check.jar
set JBBJARS=.\jbb.jar;.\jbb_no_precompile.jar;.\check.jar;.\reporter.jar
set CLASSPATH=%JBBJARS%;%CLASSPATH%

:stage2
echo Using CLASSPATH entries:
for %%c in ( %CLASSPATH% ) do echo %%c
@echo on
start /b C:\Java\bin\java.exe %JAVAOPTIONS% spec.jbb.Controller -profile
%PROFILE%
@echo off
set I=0
:LOOP
set /a I=%I + 1
echo.
echo Starting JVM Number %I% with Affinity to CPU %J%
echo.

@echo on
start /B C:\Java\bin\java.exe -Xmx18g -Xms18g -Xmn16g -XX:SurvivorRatio=60 -
XX:TargetSurvivorRatio=90 -XX:ParallelGCThreads=8 -
```

```
XX:AllocatePrefetchDistance=192 -XX:AllocatePrefetchLines=4 -  
XX:LoopUnrollLimit=45 -XX:InitialTenuringThreshold=12 -XX:MaxTenuringThreshold=15  
-XX:InlineSmallCode=5500 -XX:MaxInlineSize=220 -XX:FreqInlineSize=2500 -  
XX:+UseLargePages -XX:+UseParallelOldGC -XX:+UseCompressedStrings -verbose:class  
-XX:+AggressiveOpts spec.jbb.JBBmain -propfile %PROFFILE% -id %I% > multi.%I%  
    @echo off  
    IF %I% == %JVM% GOTO END  
    GOTO LOOP  
:END
```

## APPENDIX E – MEASURING POWER

### Measuring workload power

To record each server's power consumption during the workload 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 120-volt 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 power usage with no OS activity, we recorded the power usage for 2 minutes while each server was running the operating system but no applications running.

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

### Measuring response time power

To record the power limit response time, we used a Yokogawa® WT210 with WTVIEWER 8.11 software. We connected a power strip to the Yokogawa WT210 and recorded the Dell PowerEdge R720 server using a 120-volt supply voltage. We connected the WT210 to a desktop via an RS-232 cable. We set the recording time intervals to 100ms inside WTVIEWER. Note: WTVIEWER records data at a minimum interval of 200ms due to the RS-232 interface.

## ABOUT PRINCIPLED TECHNOLOGIES



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