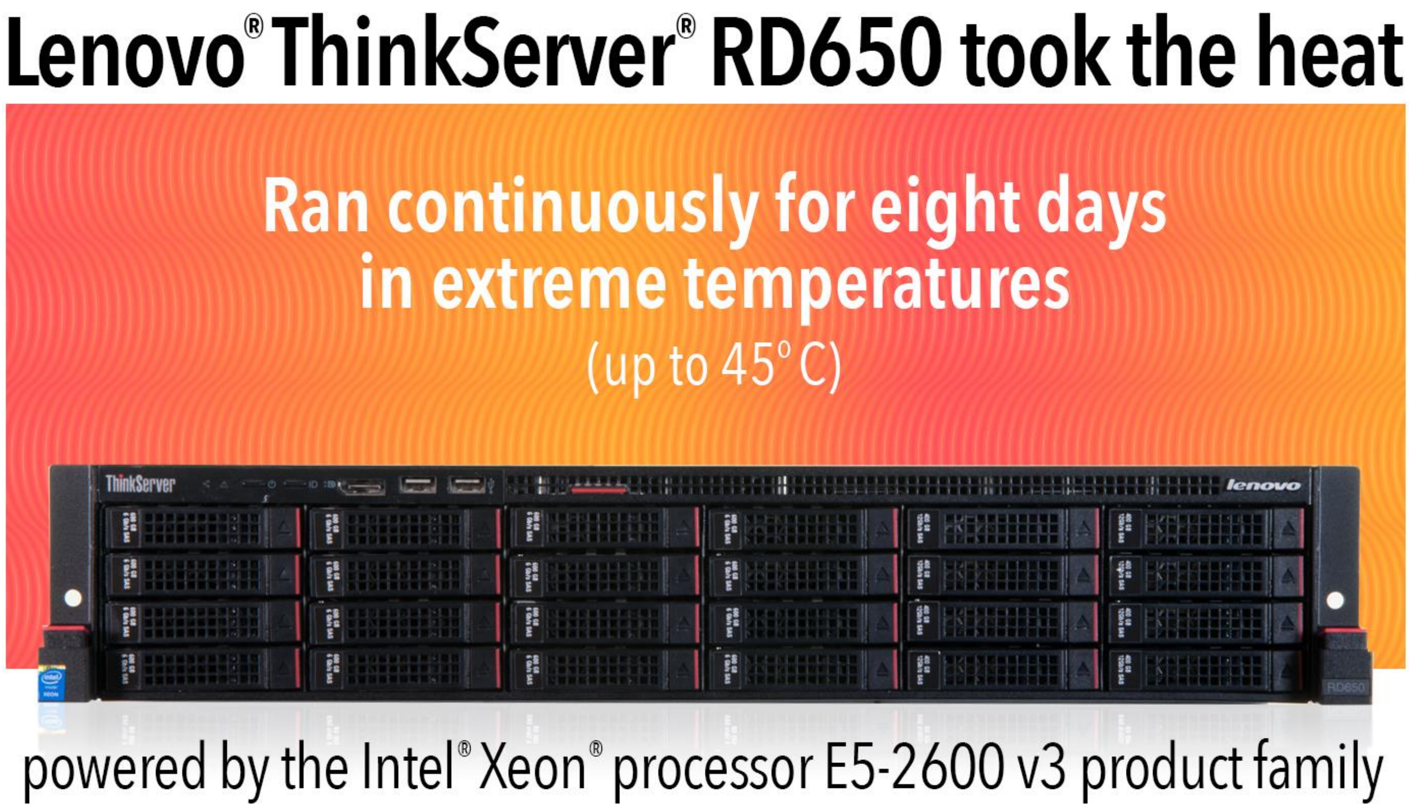
LENOVO THINKSERVER RD650: CONTINUOUS PERFORMANCE IN EXTREME TEMPERATURES



Those who run data centers in businesses of all sizes are aware that cooling costs typically account for 40 to 60 percent of their electricity costs,[1] making these costs an extremely important factor in the overall infrastructure and data center management picture. Some organizations find that for each degree that the data center temperature can be raised, savings can amount to 4 percent to 5 percent of energy costs.[2] Given this potentially enormous monetary incentive, it is critical to take advantage of hardware that is certified to withstand higher temperatures in order to control ongoing operational expenditures (OPEX) related to cooling.

To tackle this problem, Lenovo has designed the next generation Intel processor-powered ThinkServer RD650 rack server, certified to run continuously at up to 45° Celsius. To put this claim to the test, Principled Technologies placed the Lenovo ThinkServer RD650 in a high-temperature environment and performed a series of performance-intensive workloads over eight days. During this period, temperatures ranged from 40° C to 45° C, with the temperature staying at or above 43° C for more than half the time, and performance remained even, with less than 4 percent variance.

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[1] www.gartner.com/doc/2570617/hype-cycle-server-technologies-

[2] www.computerworld.com/article/2483971/data-center/it-s-getting-warmer-in-some-data-centers.html

NOVEMBER 2014

A PRINCIPLED TECHNOLOGIES TEST REPORT

Commissioned by Lenovo

The fact that the Lenovo ThinkServer RD650 can operate continuously at 45° C allows for enormous flexibility and significant economic benefits for your company. This proof of reliability makes the Lenovo ThinkServer RD650 attractive not only to those with large data centers; companies who deploy their servers in tight areas lacking ventilation can also benefit. By giving you the option to increase your server input temperature, the Lenovo ThinkServer RD650 can directly affect your overall cost picture.

SERVER OPERATING TEMPERATURE—WHY IT MATTERS

The growth of data center infrastructure and cloud environments has ballooned in recent years, with data center electricity costs contributing to between 1 percent and 3 percent of the total regional electricity use, depending on the region.[3] This huge energy impact shows no signs of slowing down, and pressure is constant on all data centers to reduce costs, particularly in the area of energy usage. In fact, between 50 percent and 71 percent of respondents to a recent industry survey answered that it was "very important" to reduce their overall data center energy consumption.[4]

Given that cooling the IT infrastructure accounts for approximately half of the energy costs of a data center, the ability of an organization to drive down cooling costs is vital. To do so, either the cost of energy must go down, which is unlikely, or the threshold to which servers must be cooled has to go up. This threshold is referred to as the inlet temperature. In the same industry survey, 64 percent of respondents in the 5,000 server+ category responded that raising the server inlet temperature was key in their roadmap for lowering cooling costs. In the 1,000 servers or less category, 39 percent responded similarly. One final piece of evidence that customers are looking to raise inlet temperature was the year-over-year percentage increase of respondents who used an inlet temperature of greater than 75° F (24° C). In this particular survey, the percentage increased from 3 percent in 2012 to 7 percent in 2013.

In 2011, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) set forth guidelines recommending that data center operators maintain temperatures between 18° C and 27° C. Server manufacturers have taken some steps to ensure their equipment can handle temperatures above this extreme, some up to 35° C, well above the ASHRAE recommendations. Some vendors then go so far as to suggest that data centers stay within the ASHRAE range at all times, while others allow brief periods of operation at temperatures as high as 45° C. In response to these conflicting messages, cautious data center managers have generally kept temperatures below 27° C, resulting in unnecessarily high energy costs for cooling.

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[3] www.analyticspress.com/datacenters.html

[4] uptimeinstitute.com/images/stories/DataCenterSurvey_assets/uptime-institute-2013-data-center-survey.pdf

One area of innovation in data center cooling has been in alternative supporting infrastructure approaches such as fresh-air and chiller-less technologies. These approaches, while beneficial, can require an expensive retrofit of your current environment, or even a new data center build out altogether, both of which are likely cost prohibitive. One alternative to redesigning the cooling mechanisms of your environment is finding a way to let the temperatures safely rise to a new higher baseline.

Some data center managers have been reluctant to do so, however, for fear of hardware failure. But this fear may be unproven. In a recent study, Intel measured the impact of using only outside air to cool a data center, and found that 450 high-density servers operating at temperatures as high as 33° C failed no more frequently than those operating at cooler temperatures.[5] Lenovo has brought this concept to the next level by building high-temperature resiliency directly into the ThinkServer RD650 architecture.

THE LENOVO THINKSERVER RD650—DESIGNED TO TAKE THE HEAT

Lenovo has designed the ThinkServer RD650 specifically to operate continuously at extremely high temperatures. Their approach includes the following:

- Stringent component temperature and voltage de-rating requirements insure reliable operation across all supported environments.
- Positioning of components in the system optimizes airflow.
- Advanced thermal controls allow the temperature of critical components to often be lower at higher ambient temperatures than in normal environments.
- The system design was thoroughly tested across the entire A4 temperature range.

In addition to the extra reliability that comes from its ability to operate continuously at very high temperatures, the Lenovo ThinkServer RD650 also boasts outstanding storage density and a highly flexible design. It has up to 26 drive bays and 74.4 TB of internal storage capacity, making it well suited for applications with large storage needs, such as databases, data analytics clusters, and video streaming. With the latest Intel Xeon processors, large memory capacity, multiple chassis types, RAID choices, and I/O options, you can easily create the right RD650 configuration for your specific business needs. Learn more at shop.lenovo.com/us/en/servers/thinkserver/racks/rd650/.

[5] www.intel.com/content/www/us/en/data-center-efficiency/data-center-efficiency-xeon-reducing-data-center-cost-with-air-economizer-brief.html

TEST APPROACH AND RESULTS

For testing, we used two concurrent performance-intensive workloads to stress the server continuously over the eight-day period. We used SPECjbb2005, an industry-standard benchmark designed to simulate middleware software, to maintain approximately 50 percent CPU utilization. This simulates a real-world workload of constant processor and memory activity. We also used Iometer, a standard IO benchmarking tool, to exercise the disk subsystem for the duration of the test. We did not design the workload for maximum IO performance, but rather to ensure constant disk activity. For full details on each of the workload parameters, see Appendix B.

To control the server inlet temperature, we installed the Lenovo ThinkServer RD650 into a temperature-controlled server rack assembly. The test fixture was designed to run the server at as close to the maximum 45° C without going over. The assembly temperature ranged from 40° C to 45° C throughout the duration of testing, staying at or above 43° C for more than half the time.

The results showed the ThinkServer RD650 handled the heat, operated without interruption, and maintained consistent performance in our two workloads across the eight-day period. In Figure 1, we show the BOPS (SPECjbb2005) and IOPS (Iometer) outputs across the test window. The important thing to note is that variance was very small, less than 4 percent, showing that the high temperature conditions had no impact on performance. Given the large amount of data, we selected approximately five data points per day, for a total of 40 data points, for this depiction.

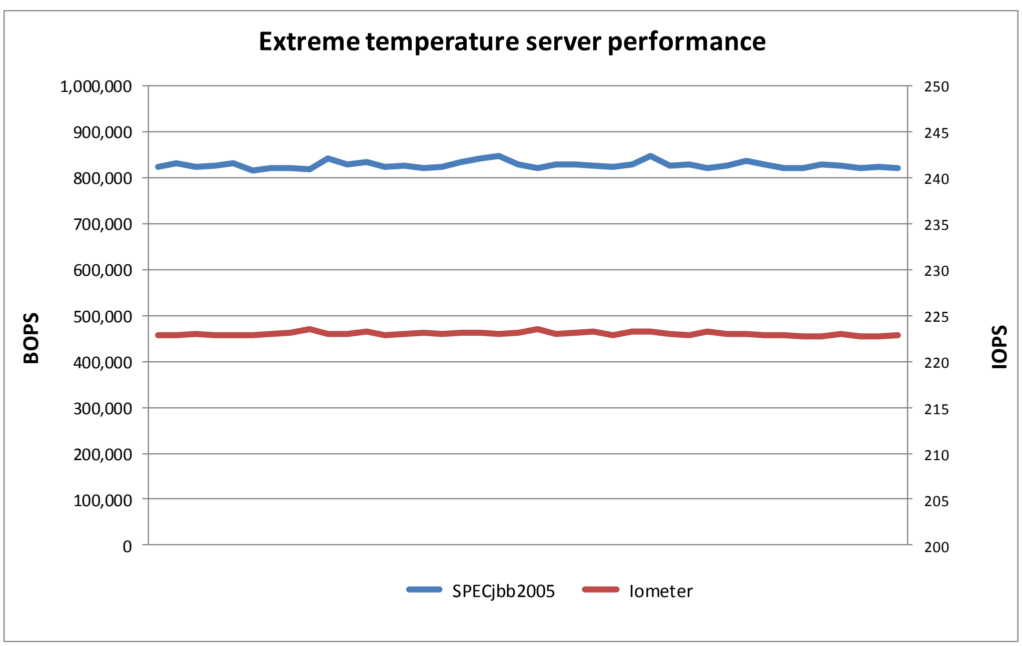

Figure 1: Performance of the Lenovo ThinkServer RD650 over eight days, measured with SPECjbb2005 and Iometer workloads.

About the Intel Xeon processor E5-2600 v3 product family

According to Intel, the Intel Xeon processor E5-2600 v3 product family "helps IT address the growing demands placed on infrastructure, from supporting business growth to enabling new services faster, delivering new applications in the enterprise, technical computing, communications, storage, and cloud." It also delivers benefits in performance, power efficiency, virtualization, and security.

The E5-2600 v3 product family has up to 50 percent more cores and cache than processors from the previous generation. Other features include the following:

- Intel Advanced Vector Extensions 2 (AVX2)
- Intel Quick Path Interconnect link
- Up to 18 cores and 36 threads per socket
- Up to 45MB of last level cache
- Next-generation DDR4 memory support
- Intel Integrated I/O providing up to 80 PCIe lanes per two-socket server
- Intel AES-NI data encryption/decryption

The Intel Xeon processor E5-2600 v3 product family also uses Intel Intelligent Power technology and Per-core P states to maximize energy efficiency. Learn more at www.intel.com/content/www/us/en/processors/xeon/xeon-e5-brief.html.

Middleware workload

SPECjbb2005 is an industry-standard benchmark created by the Standard Performance Evaluation Corp. (SPEC®) to measure a server's Java performance. (Note: SPEC and the SPECjbb2005 are trademarks of the Standard Performance Evaluation Corporation.) SPEC modeled SPECjbb2005 on the three-tier client/server architecture, with the middle layer as the primary focus. According to SPEC, "Random input selection represents the first (user) tier. SPECjbb2005 fully implements the middle-tier business logic. The third tier is represented by tables of objects, implemented by Java Collections, rather than a separate database."[6]

SPECjbb2005 utilizes multiple special data groups and multiple threads as it runs. Each data unit is a "warehouse," a roughly 25MB collection of data objects. Each thread represents an active user posting transaction requests within a warehouse. The benchmark run begins with one warehouse and then increases the number of warehouses; its goal is to saturate the server's processor capacity. As the number of warehouses increases, so does the number of threads. The benchmark's metric portrays the server's throughput in business operations per second or SPECjbb2005 BOPS. A higher number of SPECjbb2005 BOPS is better. Note that our tests were not for the

[6] www.spec.org/jbb2005

purposes of high scores but rather constant performance. For more information on SPECjbb2005, go to www.spec.org.

Disk workload

To exercise the disk subsystem, we used the Iometer tool, which measures IOPS and throughput on both single and clustered systems. Iometer performs I/O operations to stress a system, and then records the performance of these I/O operations and the system stress they create. We used Iometer 1.1.0 to exercise the disk subsystem. For more details about Iometer, see www.iometer.org.

CONCLUSION

Servers that are designed to operate at higher inlet temperatures allow for significant energy reductions in your data center. The Lenovo ThinkServer RD650, with its dynamic environmental design, lets you take advantage of these cost reductions. Lenovo has specifically enhanced the ThinkServer RD650 architecture to plan for higher temperatures and maximize data center efficiency. In our labs, this server ran two concurrent workloads, exercising CPU, disk, and memory subsystems, continuously at temperatures ranging from 40 to 45° C, with the temperature staying at or above 43° C for more than half the time for eight days—and did so without significantly varying in performance levels during the test period.

APPENDIX A – SYSTEM CONFIGURATION INFORMATION

Figure 2 provides detailed configuration information for the test server.

System	Lenovo ThinkServer RD650
Power supplies	
Total number	2
Vendor and model number	Delta DPS-1100EB
Wattage of each (W)	1,100
Cooling fans	
Total number	6
Vendor and model number	PFR0612UHE
Volts	12
Amps	1.50
General	
Number of processor packages	2
Number of cores per processor	12
Number of hardware threads per core	2
System power management policy	Balanced
CPU	
Vendor	Intel
Name	Xeon
Model number	E5-2680 v3
Socket type	LGA-2011-3
Core frequency (GHz)	2.50
Bus frequency	9.6 GT/s
L1 cache	32 KB + 32 KB (per core)
L2 cache	256 KB (per core)
L3 cache	30 MB
Platform	
Vendor and model number	Lenovo ThinkServer RD650
BIOS name and version	1.10.0
BIOS settings	Default
Memory module(s)	
Total RAM in system (GB)	256
Vendor and model number	Hynix HMA84GL7MMR4N
Type	PC4-2133
Speed (MHz)	2,133
Speed running in the system (MHz)	2,133
Timing/Latency (tCL-tRCD-tRP-tRASmin)	11-11-11-33
Size (GB)	32
Number of RAM module(s)	8
Chip organization	Dual sided
Rank	Quad

System	Lenovo ThinkServer RD650
Operating system	
Name	Windows Server® 2012 R2 Datacenter
Build number	9200
File system	NTFS
Language	English
RAID controller	
Vendor and model number	Lenovo ThinkServer RAID 720i AnyRAID
Driver version	6.703.3.0
Hard drives	
First hard drive type	
Vendor and model number	Lenovo ST9500620NS
Number of drives	2
Size (GB)	500
RPM	7,200
Type	SATA
Second hard drive type	
Vendor and model number	Lenovo ST3300657SS
Number of drives	8
Size (GB)	300
RPM	15,000
Type	SAS
Ethernet adapters	
Vendor and model number	Intel I350-T2 Server Adapter
Type	Integrated
Driver	1211.97.0

Figure 2: Configuration information for the test server.

APPENDIX B – HOW WE TESTED

To stress the server, we ran SPECjbb2005 and Iometer at the same time on the ThinkServer RD650. The RD650 had two 500GB hard drives that we configured in a RIAD 1 for the OS. We configured eight 300GB hard drives in a RAID 10 which we used for Iometer testing. We configured SPECjbb2005 so it maintained a 50 percent processor utilization.

We used batch files to run the test. We created a main batch file that executed a SPECjbb2005 and Iometer batch file. The main batch file was a loop, so it would start the test over as soon as both SPECjbb2005 and Iometer finished their runs. Each run was one hour long.

SPECjbb2005

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

SPECjbb2005 requires a Java Virtual Machine (JVM) on the system under test. We used Oracle Java SE Runtime Environment (build 1.7.0_67-b01). We installed the JVM into directory C:\java using the default installation settings.

After the installation we modified the SPECjbb.props file in the root SPECjbb2005 directory by changing the number of JVMs to four. We also changed the input.starting_number_warehouses to 14 and input.ending_number_warehouses to 28. This allowed us to keep a constant load on the server. We used the affinity switch in the batch file to set which processor cores to use for testing. We used half of the available threads so we had a sustained 50 percent processor utilization.

The following are the contents of the SPECjbb2005 batch file we use for testing.

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

 set JVM=4
 :: Set JAVA_HOME to Java.exe path.
 set JAVA_HOME="C:\java\bin"

 :stage1
 set PROPFILE=SPECjbb.props
 set JAVAOPTIONS= -Xms256m -Xmx256m
 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 -propfile %PROPFILE%
 @echo off

 @echo on
 start /AFFINITY 555 /B C:\java\bin\java.exe -Xmx60g -Xms60g -Xmn40g -
XX:+UseParallelOldGC -XX:-UseBiasedLocking spec.jbb.JBBmain -propfile %PROPFILE% -id 1 >
multi.1
 @echo off
```

```
 @echo on
 start /AFFINITY 555000 /B C:\java\bin\java.exe -Xmx60g -Xms60g -Xmn40g -
XX:+UseParallelOldGC -XX:-UseBiasedLocking spec.jbb.JBBmain -propfile %PROPFILE% -id 2 >
multi.2
 @echo off

 @echo on
 start /AFFINITY 555000000 /B C:\java\bin\java.exe -Xmx60g -Xms60g -Xmn40g -
XX:+UseParallelOldGC -XX:-UseBiasedLocking spec.jbb.JBBmain -propfile %PROPFILE% -id 3 >
multi.3
 @echo off

 @echo on
 start /AFFINITY 555000000000 /B C:\java\bin\java.exe -Xmx60g -Xms60g -Xmn40g -
XX:+UseParallelOldGC -XX:-UseBiasedLocking spec.jbb.JBBmain -propfile %PROPFILE% -id 4 >
multi.4
 @echo off

 :END

 Exit
```

Iometer

Iometer performs I/O operations to stress a system and then records the results in number of IOPS. Iometer can create and measure workloads on a single system's internal drives or on remote storage. We used Iometer version 1.1.0 for testing. More information about Iometer can be found at www.iometer.org/.

We installed Iometer with the default installation options in the C:\Iometer directory. We started Iometer using the following batch file we use for testing. The file.icf file stored our test settings.

```
iometer /c File.icf /r results.csv

 exit
```

Figure 3 details the Iometer access specifications we used for testing.

Block size	% of size	% reads	% random	delay	Burst	Align	Reply
512	10	80	100	0	1	4,096	0
1,024	5	80	100	0	1	4,096	0
2,048	5	80	100	0	1	4,096	0
4,096	60	80	100	0	1	4,096	0
8,192	2	80	100	0	1	4,096	0
16,384	4	80	100	0	1	4,096	0
32,768	4	80	100	0	1	4,096	0
65,536	10	80	100	0	1	4,096	0

Figure 3: Iometer access specifications.

ABOUT PRINCIPLED TECHNOLOGIES

Principled Technologies, Inc.
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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.

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 our clients assess how it will fare against its competition, its performance, its market readiness, 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.