

# Lenovo® ThinkServer® RD650 scaled to fit

*Flexible drive options for the database performance you need*



When equipped with six 800GB SSDs,  
delivered the work of two legacy server workloads

When equipped with four 1.6TB PCIe SSDs,  
delivered the work of four legacy server workloads

Many of today's enterprise data centers are using any number of older servers to run their database infrastructure. Those who manage data centers also are contending with a steadily growing volume of data and ever-increasing user expectations for application performance—while also working within budget constraints and getting the greatest return on their investment. Expanding storage needs along with demanding heterogeneous applications require flexible storage options to offer optimal performance for diverse workloads. Consolidating these older servers onto a powerful new server with flexible storage solutions can be an excellent investment.

In the Principled Technologies labs, we show how the new Lenovo ThinkServer RD650 with AnyBay high-density storage and Intel processor-powered solid-state drive (SSD) technology is a great option to answer the flexibility and performance growth issues data centers face. We conducted baseline testing on a hard disk drive-based Lenovo ThinkServer RD630 server running a TPC-H-like database workload. We ran the same workload in virtual machines on the ThinkServer RD650 in two different configurations. Using Intel solid-state drives, the ThinkServer RD650 was able to

perform the work of two RD630 servers. After we upgraded it with Intel PCIe SSDs in the AnyBay slots, it performed the work of four RD630 servers. What's more, the time to complete the queries decreased with each drive upgrade. While it took 55 minutes for a user to complete a single query set on the legacy server, it only took an average of 38 minutes on the ThinkServer RD650 with Intel SSDs, and an average of 28 minutes, on the ThinkServer RD650 with Intel PCIe SSDs. Faster queries means a faster response time for end users. In both configurations, the new server delivered stronger performance than the older server did while handling up to four times the workload. Upgrading to ThinkServer RD650 servers will provide the flexibility and performance your database workloads require while also replacing several older servers, freeing up valuable space and administration time.

The flexibility that the ThinkServer RD650 with AnyBay high-density storage capacity offers your company is also a great advantage. Compared to other servers that offer more limited storage choices, AnyBay allows you to optimize your configuration to balance performance and capacity, tailoring your storage configuration precisely to your specific needs.

## THE IMPORTANCE OF STORAGE AND FLEXIBLE STORAGE DESIGN

Server storage has traditionally focused on spinning disk technologies. As CPU performance and processor core counts have increased over the past several years, the performance of the storage subsystem has remained relatively unchanged. This widening gap created an I/O bottleneck for applications, where CPUs must wait for storage to retrieve data.

In response, alternative storage media emerged—most notably solid-state drives using flash, a chip technology with no moving parts that greatly sped up data retrieval. These drives came with better performance, but also a higher price tag and less capacity than hard disk drives (HDDs). In addition, the drive interface technologies, which were originally designed for HDDs, limited the SSD transfer rate. For instance, SATA III, the most common interface for current SSDs, has a maximum data transfer rate of 600 MB/s, and SATA development has ceased; there will be no SATA IV.

Today, the future of storage lies with a direct connection to the CPU's host bus, also known as PCIe. The new PCIe SSD, based on open standards non-volatile memory (NVMe), was designed for Flash and new storage memory technologies, unlike SAS and SATA. (Learn more in the [About NVMe and NVM Express](#) section of this report.)

These new drives offer significant performance improvements and come in sizes (up to several TB) to support large data center workloads. The PCIe 3.0 x4 SSDs used in our testing have a transfer speed of 4 GB/s, which helps virtualization workload mixes because it transfers IO to the CPU in the fastest way possible.

Another limitation of traditional servers is their standard drive slots and backplanes that support only one specific type of drive at a time. A hybrid server such as the ThinkServer RD650 can leverage several different types of drives and interfaces—SATA SSD, PCIe SSDs, and SAS HDDs—in the same drive slot, using a technology Lenovo calls AnyBay. Application designers and database administrators can then use this drive flexibility to their advantage by selectively placing certain files on specific media, or adding or removing drives to benefit the performance profile of the server. You can use high-performance block caching software to take advantage of the varied features and IO performance of both HDDs with SSDs. You now have maximum flexibility.

In addition to the database workloads we focus on in this paper, the RD650 can be used for other applications, such as a file or Exchange mail server, which can utilize large-capacity HDDs. The configuration in this report has a large amount of extra space for backups, staging, or other usages.

Because of the advantages, limitations, and cost factors of the many different types of storage and related technologies available today, no single approach is “best.” Identifying the storage solution that suits your specific business needs—the volume of data your company has and the service levels you must provide, along with your financial resources—is a complicated endeavor. Lenovo has designed the RD650 with this question in mind, offering several different configurations with drives ranging from high-capacity HDDs to high-performance PCIe SSDs—whatever matches your business goals.

According to Lenovo, while other servers allow you to put PCIe drives in only specific bays, ThinkServer AnyBay technology gives you the flexibility to use the bay for ANY drive technology—SATA, SAS, or PCIe. You can configure some of the bays with PCIe SSDs, use the remaining bays for high capacity, low-cost HDDs, and retain the option of upgrading to more PCIe SSDs in the future. The configuration we tested offered four 2.5” front-load AnyBay drive bays, where all new NVMe-based Intel SSDs were used.

Lenovo also designed the ThinkServer RD650 with the data center in mind. Unlike traditional servers with PCIe slots in the rear, the Lenovo server places these drives in the front of the server, making the drives easier to access for servicing and replacement. In addition, the front facing drives help alleviate temperature management issues that arise when the PCIe drives are behind the main processor in the server.

## TEST APPROACH AND RESULTS

We began our testing by running a HammerDB TPC-H-like database benchmark scenario on a ThinkServer RD630 server with Sandy Bridge Intel processors and hard disk drives to represent the performance of many servers that companies are looking to upgrade.

We then used virtualization to create VMs that represented the legacy server to show how many servers one ThinkServer RD650 with Intel SSDs could replace. Each VM on the ThinkServer RD650 had 12 vCPUs and 64 GB of RAM while the legacy system had two Intel Xeon processors E5-2640 and 128 GB of RAM.

Finally, we repeated the second scenario with the databases stored on the faster PCIe SSDs. We stored one VM's database VHDs on each PCIe SSD. Our configuration did not use hardware RAID, and we assumed a SQL AlwaysOn Configuration (database replication technology). Such a failover environment with a hot, identical backup server can hold the standby database replicas giving you a complete failover scenario, in case of any failed hardware component. In fact, up to five replica servers are supported by SQL Server AlwaysOn. Our test configuration did not include SQL AlwaysOn failover testing, or a hot standby system configuration.

The TPC-H-like workload consists of two parts, a power test and a throughput test. The power test measures how quickly a single user can complete a full query set on the database. The throughput test measures how quickly five users can complete the test while running simultaneously. HammerDB supplies an Excel calculator that uses the power and throughput results to calculate the composite query-per-hour performance (QphH@size) result that allows runs to be compared to each other based on the scale size of the database. The scale size is a HammerDB TPC-H parameter that determines the database schema size. We chose a scale of 100 for this test.

We configured the VMs to best represent the hardware found on the legacy servers while also fitting the available hardware resources on the RD650. Configured thus, the ThinkServer RD650 with SSDs was able to consolidate two of the legacy servers. When we replaced the SSDs with PCIe SSDs, the ThinkServer RD650 could consolidate four legacy servers (see Figure 1). In both cases, the ThinkServer RD650 surpassed the legacy server's performance.

**Figure 1: The Lenovo ThinkServer RD650 could replace two legacy servers when configured with SSDs and four legacy servers when configured with PCIe SSDs.**

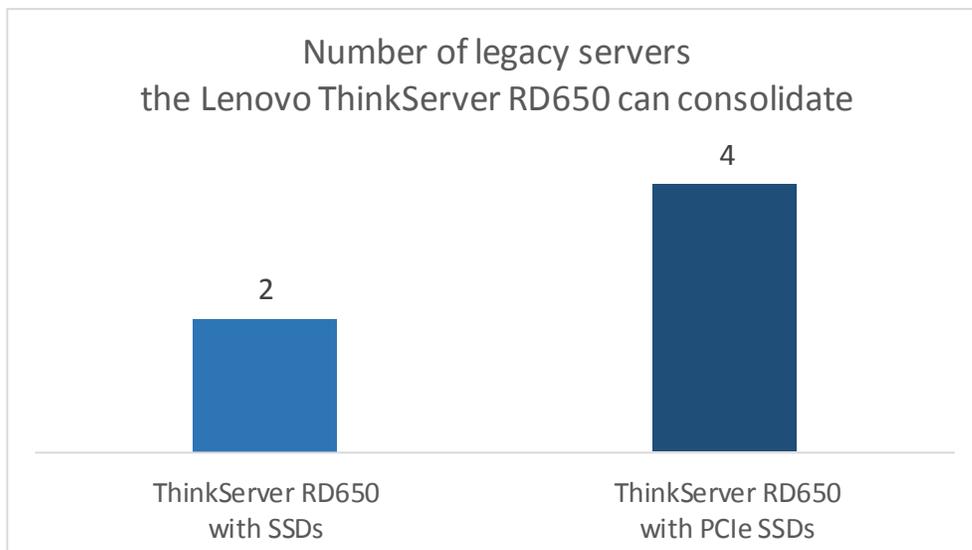


Figure 2 shows the total database performance in the calculated QphH@size score that the single HammerDB instance on the legacy server and the combined instances on the two configurations of the ThinkServer RD650 delivered.

**Figure 2: The Lenovo ThinkServer RD650 delivered 2.7 times the performance of the legacy server when configured with SSDs and 7.0 times when configured with PCIe SSDs.**

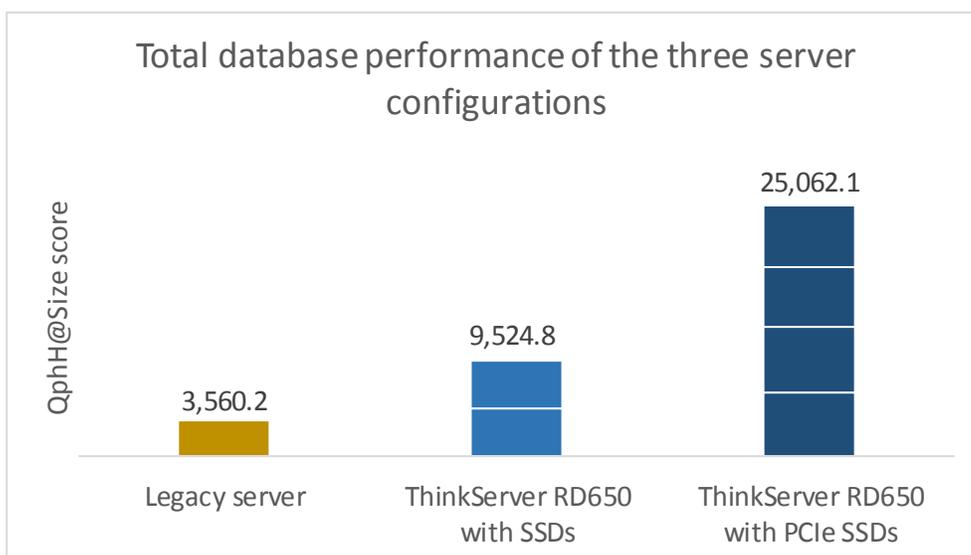
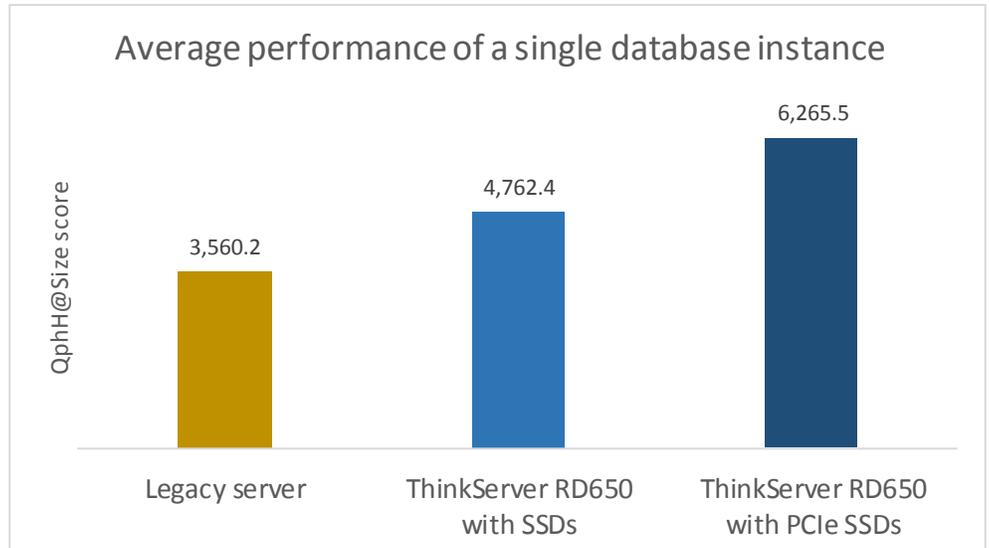


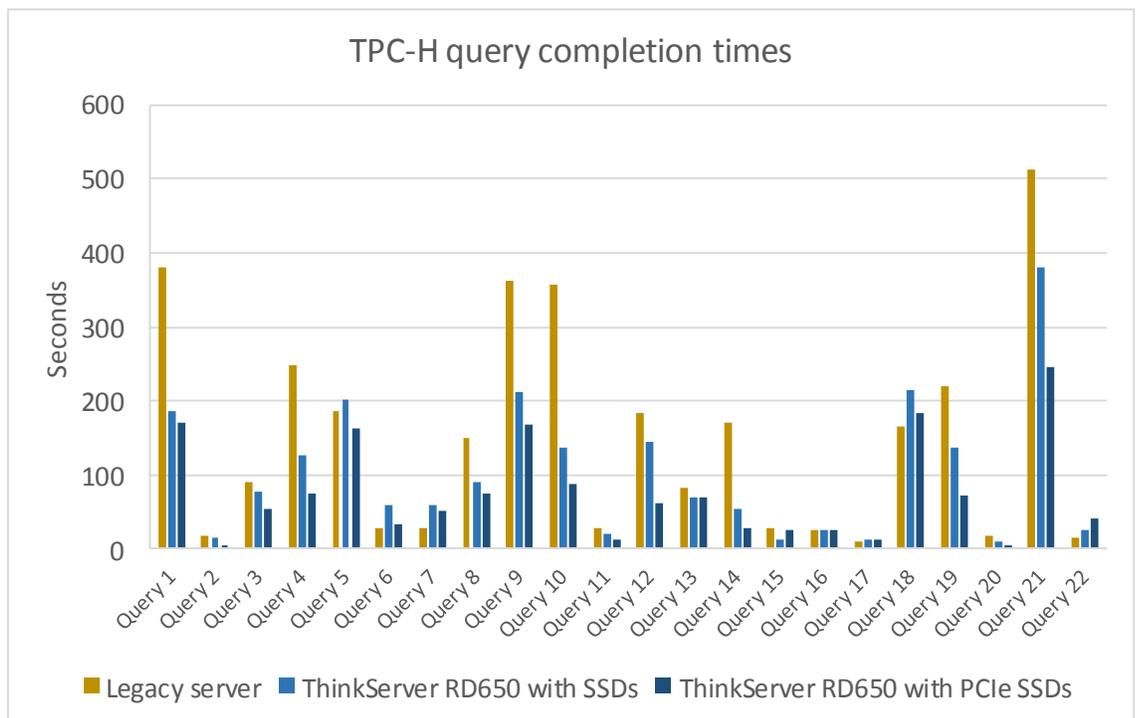
Figure 3 shows the average, per-instance database QphH@size score on each configuration, showing that not only was the RD650 able to support more instances, but that each instance was able to outperform the legacy server database instance.

**Figure 3: On average, each database instance on the Lenovo ThinkServer RD650 delivered 34 percent better performance than the legacy server instance when configured with SSDs and 76 percent better performance with PCIe SSDs.**



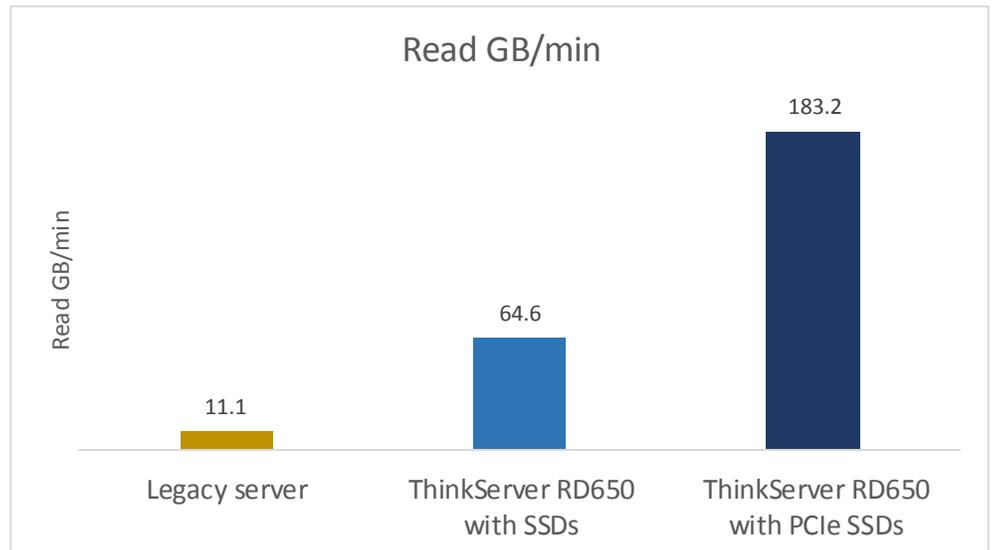
The ThinkServer RD650 also completed the 22 TPC-H workload queries up to 98 percent more quickly with PCIe SSDs during the power test than the legacy server did. The full set of 22 queries finished in 55.3 minutes on the legacy server, an average of 38.0 minutes on the ThinkServer RD650 with Intel SSDs, and in an average of 27.9 minutes on the ThinkServer RD650 with AnyBay PCIe drives. Figure 4 shows the individual query times in the TPC-H workload for each configuration. For this figure, we averaged the query completion times across the VMs in the RD650 configuration runs to more easily compare to the single workload run on the legacy system.

**Figure 4: The individual query completion times for each scenario show that the Lenovo ThinkServer RD650 completed the workload faster than the legacy server, and had the fastest times with the AnyBay PCIe SSDs. Lower values are better.**



At the disk level, we can see a large increase in the data scanned per minute as we progress from the legacy system to the ThinkServer RD650 with PCIe SSDs. Figure 5 shows the total GB/min each drive configuration processed during the throughput test, as recorded by Windows Performance Monitor. For the PCIe drives, we totaled the four drives' counters to provide the performance of the configuration as a whole.

**Figure 5: The Lenovo ThinkServer RD650 had 5.8x the read performance of the legacy server when configured with SSDs and 16.6x when configured with PCIe SSDs.**



In addition to being able to consolidate multiple older servers while delivering improved performance, the ThinkServer RD650 has another advantage over the legacy server: it retains the availability of the high-capacity HDDs, offering space for other applications and storage.

## ABOUT THE TEST COMPONENTS

### About the Lenovo ThinkServer RD650

The ThinkServer RD650 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. Its use of ThinkServer AnyBay technology gives users great flexibility in storage options. The latest Intel Xeon processors, large memory capacity, multiple chassis types, RAID choices, and I/O options make it easy for you to create the right RD650 configuration for your specific business needs. Learn more at [shop.lenovo.com/us/en/servers/thinkserver/racks/rd650/](http://shop.lenovo.com/us/en/servers/thinkserver/racks/rd650/).

### 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](http://www.intel.com/content/www/us/en/processors/xeon/xeon-e5-brief.html).

## About Intel Solid State Drive Data Center Family for PCIe

The Intel® Solid-State Drive Data Center Family for PCIe\* brings extreme data throughput directly to Intel® Xeon® processors with up to six times faster data transfer speed than 6 Gbps SAS/SATA SSDs. The performance of a single drive from the Intel SSD Data Center Family for PCIe, specifically the Intel® Solid-State Drive Data Center P3700 Series (460K IOPS), can replace the performance of seven SATA SSDs aggregated through a host bus adapter (HBA) (approximately 500K IOPS). The Intel SSD Data Center Family for PCIe outperform HDDs by a magnitude of 2300:1, uses up to 16x less energy and generate up to 3x less heat than HDDs. Intel SSDs have a guaranteed failure rate of less than 0.44 percent.

The Intel SSD Data Center Family for PCIe undergoes 5000 unique test to ensure quality. Learn more at [www.intel.com/content/www/us/en/solid-state-drives/why-choose-intel-ssd-vs-hdd-infographic.html](http://www.intel.com/content/www/us/en/solid-state-drives/why-choose-intel-ssd-vs-hdd-infographic.html).

## About the benchmark testing tool, HammerDB

HammerDB is an open-source benchmark tool that tests the database performance of many leading databases, including Oracle Database, Microsoft® SQL Server®, PostgreSQL®, MySQL™, and more. The benchmark includes two built-in workloads derived from industry-standard benchmarks: a transactional (TPC-C-like) workload and a data warehouse (TPC-H-like) workload. For this study, we used the analytics or data warehouse workload. Our tests were not official TPC results and are not comparable in any manner to the official TPC audited results. For more information about HammerDB, visit [hammerora.sourceforge.net](http://hammerora.sourceforge.net)

## About NVMe and NVM Express

NVMe relates to NVM Express, an industry standard for using non-volatile memory (e.g., NAND memory) in a solid-state drive. NVMe standardizes the interface from the storage driver to the SSD, including command set and features (e.g., power management). The standard enables native OS drivers in Windows, Linux, and VMware to provide a seamless user experience. The standard was defined from the ground up for NVM, so it is capable of much higher IOPs and lower latency than legacy storage standards (SATA, SAS) that were designed for hard drives. The benefits of the NVMe driver's efficiency with respect to the SSDs used in this report are best described at <https://communities.intel.com/community/itpeernetwork/blog/2014/06/16/intel-ssd-p3700-series-nvme-efficiency>. The starting point for the standards specification, and resources on the standardization effort for NVMe is at [www.nvmexpress.org](http://www.nvmexpress.org). The specification can be found at [nvmexpress.org/specifications/](http://nvmexpress.org/specifications/).

## CONCLUSION

The new Lenovo ThinkServer RD650 with AnyBay high-density storage and Intel processor-powered SSD technology is an extremely flexible option for data centers facing performance and growth issues. In our testing, this server equipped with Intel solid-state drives performed a database workload equal to that of two legacy servers with hard disk drives. When we upgraded the AnyBay slots in the ThinkServer RD650 with Intel PCIe SSDs, it performed the workload of four legacy servers. The time to complete database queries also decreased with each drive upgrade.

Your company's database needs are likely to grow and change as your company does. The ThinkServer RD650 with AnyBay high-density storage and Intel processor-powered SSD technology give you both performance and flexibility to meet these needs both today and in the future.

## APPENDIX A—DETAILED SERVER CONFIGURATION

Figure 6 provides detailed configuration information for the test systems.

System	Lenovo ThinkServer RD630	Lenovo ThinkServer RD650
<b>General</b>		
Number of processor packages	2	2
Number of cores per processor	6	12
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	E5-2640 0	E5-2680 v3
Stepping	7	2
Socket type	2011 LGA	FCLGA2011-3
Core frequency (GHz)	2.5	2.5
Bus frequency	7.2 GT/s	9.6 GT/s
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	15 MB (shared)	30 MB (shared)
<b>Platform</b>		
Vendor and model number	Lenovo ThinkServer RD630	Lenovo ThinkServer RD650
Motherboard model number	PBT-SX52600	70D4000EUX
BIOS name and version	Lenovo 9.30	1.25.0
BIOS settings	Default	Default
<b>Memory modules</b>		
Total RAM in system (GB)	128 GB	256 GB
Vendor and model number	Micron® MT36KSF2G72PZ-1G6EHF	Hynix® HMA84GL7MMR4N-TF
Type	PC3L-12800R	PC4-2133P
Speed (MHz)	1333	2133
Speed running in the system (MHz)	1333	2133
Size (GB)	16	32
Number of RAM module(s)	8	8
Chip organization	Double-sided	Double-sided
Rank	Dual	Quad
<b>Hypervisor</b>		
Name	N/A	Microsoft® Hyper-V®
Build number	N/A	6.3.9600.16384
Language	N/A	English
<b>RAID controller</b>		
Vendor and model number	LSI Mr9260-8i	Lenovo ThinkServer RAID 720ix AnyRAID Adapter
Firmware version	2.130.403-3303	4.230.00-3860
Firmware Package version	12.15.0-0190	24.3.0-0074

System	Lenovo ThinkServer RD630	Lenovo ThinkServer RD650
<b>Drive type 1</b>		
Vendor and model number	Hitachi® HUS156060VLS600	Seagate® ST3300657SS
Number of drives	8	2
Size (GB)	600 GB	300 GB
RPM	15k	15k
Type	3.5" HDD	2.5" HDD
<b>Drive type 2</b>		
Vendor and model number	N/A	Seagate ST4000NM0023
Number of drives	N/A	9
Size (GB)	N/A	4 TB
RPM	N/A	7.2k
Type	N/A	3.5" HDD
<b>Drive type 3</b>		
Vendor and model number	N/A	Intel SSDSC2BB800G4
Number of drives	N/A	6
Size (GB)	N/A	800 GB
RPM	N/A	N/A
Type	N/A	2.5" SATA SSD
<b>Drive type 4</b>		
Vendor and model number	N/A	Intel SSDPE2MD016T4
Number of drives	N/A	4
Size (GB)	N/A	1.6 TB
RPM	N/A	N/A
Type	N/A	2.5" NVMe/PCIe
<b>Virtual machine operating system</b>		
Name	N/A	Windows Server 2012 R2
Language	N/A	English
<b>Database software &amp; benchmarks</b>		
Benchmark	HammerDB TPC-H	HammerDB TPC-H
Software	Microsoft SQL Server® 2014	Microsoft SQL Server 2014

Figure 6: Configuration information for the systems used in our tests.

## APPENDIX B—DETAILED TEST METHODOLOGY

We ran HammerDB's TPC-H test bare-metal on the Lenovo ThinkServer RD630, and virtualized on the Lenovo ThinkServer RD650. In accordance with HammerDB documentation, we did not use client machines to host the HammerDB software as doing so has negligible impact on the hardware or performance. We created a two-disk RAID 1 on the Lenovo ThinkServer RD630 for the OS, and created a RAID 10 with the remaining disks to hold the database files. We created a RAID 1 of the two back drives on the Lenovo ThinkServer RD650 for the OS. We then created a RAID 10 with our six SSDs, a RAID 5 with our nine HDDs, and presented each PCIe SSD to Windows separately. For the SSD scenario, we stored the data and log VHDs on the SSD volume, with the OS and backup VHDs on the HDD volume. For the PCIe scenario, we stored each VM's data and log VHDs on a single PCIe drive (one VM per drive), the OS and backup VHDs remained on the HDD volume.

### Installing Microsoft Windows Server 2012 R2 Datacenter Edition

1. Insert the installation media into the CD/DVD drive, and restart the server.
2. When the option appears, press F11 to enter the Boot Manager.
3. Select BIOS Boot Menu.
4. Select SATA Optical Drive, and press Enter.
5. When prompted to boot from DVD, press any key.
6. When the installation screen appears, click My language is English (United States).
7. Leave language, time/currency format, and input method as default, and click Next.
8. Click Install now.
9. When the installation prompts you, enter the product key.
10. Select Windows Server 2012 Datacenter (Server with a GUI), and click Next.
11. Check I accept the license terms, and click Next.
12. Click Custom: Install Windows only (advanced).
13. Select Drive 0 Unallocated Space, and click Next, at which point Windows begins automatically, and restarts automatically after completing.
14. When the Settings page appears, fill in the Password and Reenter Password fields with the same password.
15. Log in with the password you set up previously.

### Configuring Windows Update

1. In the left pane of the Server Manager window, click Local Server.
2. In the main frame, next to Windows Update, click Not configured.
3. In the Windows Update window, in the main pane, click Let me choose my settings.
4. Under Important updates, select Never check for updates (not recommended), and click OK.
5. In the left pane, click Check for updates, and install all available updates.
6. Close the Windows Update window.

### Installing SQL Server 2014

1. Mount the installation DVD for SQL Server 2014.
2. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2014 DVD, and double-click it.

3. In the left pane, click Installation.
4. Click New SQL Server stand-alone installation or add features to an existing installation.
5. Select the Enter the product key radio button, and enter the product key. Click Next.
6. Click the checkbox to accept the license terms, and click Next.
7. Click Use Microsoft Update to check for updates, and click Next.
8. Click Install to install the setup support files.
9. If there are no failures displayed, click Next.
10. At the Setup Role screen, choose SQL Server Feature Installation, and click Next.
11. At the Feature Selection screen, select Database Engine Services, Full-Text and Semantic Extractions for Search, Client Tools Connectivity, Client Tools Backwards Compatibility, Management Tools –Basic, and Management Tools – Complete. Click Next.
12. At the Installation Rules screen, after the check completes, click Next.
13. At the Instance configuration screen, leave the default selection of default instance, and click Next.
14. At the Server Configuration screen, choose NT Service\SQLSERVERAGENT for SQL Server Agent, and choose NT Service\MSSQLSERVER for SQL Server Database Engine. Change the Startup Type to Automatic. Click Next.
15. At the Database Engine Configuration screen, select the authentication method you prefer. For our testing purposes, we selected Mixed Mode.
16. Enter and confirm a password for the system administrator account.
17. Click Add Current user. This may take several seconds.
18. Click Next.
19. At the Error and usage reporting screen, click Next.
20. At the Installation Configuration Rules screen, check that there are no failures or relevant warnings, and click Next.
21. At the Ready to Install screen, click Install.
22. After installation completes, click Close.
23. Close the installation window.
24. Open SQL Server 2014 Configuration Manager, and expand Protocols for MSSQLSERVER.
25. Right-click Named Pipes, and choose Enabled.
26. Click OK, and restart the SQL service.

### Enabling Lock Pages in Memory

1. Click Start, and type `gpedit.msc`, and hit Enter.
2. In the Local Group Policy Editor, expand Computer Configuration→Windows Settings→Security Settings→Local Policies
3. Select User Rights Assignment, and scroll down to Lock pages in memory in the right pane.
4. Right-click Lock pages in memory, and click Properties.
5. Click Add User or Group, and add your SQL user account (NT SERVICE\MSSQLSERVER).
6. Click OK.

## Installing HammerDB

1. Download the latest version of HammerDB from [www.hammerdb.com/download.html](http://www.hammerdb.com/download.html)
2. Double-click the exe file, chose English, and click OK.
3. Click Yes.
4. Click Next.
5. Choose a destination location, and click Next.
6. Click Next.
7. Click Finish.

## Moving and expanding tempdb

1. Open SQL Management Studio.
2. Run the following query with the appropriate destinations:

```
SELECT name, physical_name AS CurrentLocation
FROM sys.master_files
WHERE database_id = DB_ID(N'tempdb');
GO
```

```
USE master;
GO
ALTER DATABASE tempdb
MODIFY FILE (NAME = tempdev, FILENAME = 'D:\Data\tempdb.mdf');
GO
ALTER DATABASE tempdb
MODIFY FILE (NAME = templog, FILENAME = 'D:\Logs\templog.ldf');
GO
```

3. Stop and restart the SQL server instance.
  4. Verify that the files are in the new destinations.
  5. Run the following query to verify that SQL recognizes the new destination:
- ```
SELECT name, physical_name AS CurrentLocation, state_desc
FROM sys.master_files
WHERE database_id = DB_ID(N'tempdb');
```
6. Delete the original tempdb files.
  7. Expand Databases→System Databases
  8. Right-click tempdb, and choose Properties.
  9. Click Files, and enter a new Initial Size (MB) for both files. The size required will depend on the scale of your TPC-H database. We set tempdev to 40GB and templog to 4GB to ensure more than enough space.
  10. When the files are finished expanding, click OK.

## Creating the Database and database backup file

1. Open HammerDB, and click Options→Benchmark.
2. Choose MSSQL Server and TPC-H.
3. Expand SQL Server→TPC-H→Schema Build.
4. Double-click on Options.
5. Choose 100 scale, and 12 virtual users, and click OK.
6. Double-click Build. This build could take several hours.

7. Once the database has been created, open SQL Server Manager.
8. Right-click the TPCH database, and click Tasks→Back up...
9. Choose a location to store the backup, and click OK.

#### Installing the Hyper-V role on the Lenovo RD650 server

1. Open the Server Manager.
2. Click Manage→Add Roles and Features.
3. Click Next on the Before You Begin screen.
4. Choose Role-based or feature-based installation, and click Next.
5. Choose the local server, and click Next.
6. Choose Hyper-V, and click Add Features when prompted. Click Next.
7. Click Next on the Hyper-V Things to note screen.
8. Choose a port for the virtual switch, and click Next.
9. Choose whether or not you want to add live migration capabilities, and click Next.
10. Set your default storage, and click Next.
11. Check the box for automatic restart, and click Install.

#### Creating and configuring the VMs on the RD650 server

1. Open the Hyper-V manager.
2. Right-click the host server, and choose New→Virtual Machine
3. Click Next on the Before You Begin screen.
4. Name the VM, and choose the storage option. Click Next.
5. Choose Generation 2, and click Next.
6. Enter 65536 MB for the startup memory, and click Next.
7. Choose the network connection, and click Next.
8. Choose 40GB for the disk size, and click Next.
9. Choose Install an operating system later, and click Next.
10. Click Finish.
11. When the VM has been created, right click the VM and choose Settings...
12. Change the number of processors to 12, and click Apply.
13. Click on the SCSI Controller, highlight Hard Drive, and click Add.
14. Choose Virtual hard disk, and click New.
15. Click Next on the Before You Begin screen.
16. Choose Fixed size, and click Next.
17. Name the HDD Data, and choose the SSD volume for the location. Click Next.
18. Set the size to 250 GB, and click Next.
19. Click Finish.
20. Repeat steps 13 through 19 two more times to create a 156GB Log VHD and a 175GB backup VHD, storing the Log VHD on the SSD volume, and the backup VHD on the HDD volume.
21. Install Windows Server 2012 R2 and updates on the VM following the same steps outlined in previous sections.

22. Add the three additional HDDs to the VM using Windows Disk Manager.
23. Install SQL Server 2014 and Hammer DB as outlined in previous sections.
24. Copy the backup file to the backup drive on the VM.
25. Open SQL Server Manager, and restore the database to the data and log drives via the backup file.

### Cloning VMs

1. Once the initial VM is completely setup, shut down the VM.
2. Create a copy of each VHD on the various volumes.
3. Create a new VM with 64GB of RAM and 12 vCPUs, and no VHDs.
4. Add the copied VHDs to the VM: OS, Data, Log, and Backup.
5. Repeat steps 1 through 4 two more times for the PCIe SSD scenario.

### Performing the test

Using the legacy server as our base system, we ran the TPC-H test while increasing the DOP on each run by one until the time to finish began to increase. We determined that a DOP of 4 was the ideal performance point on the legacy system, and kept the DOP consistent across all VMs and tests.

1. Open SQL Server Manager, and run the following query:

```
alter database tpch
set allow_snapshot_isolation on
```

```
alter database tpch
set read_committed_snapshot on
```

2. Close SQL Server Manager, and open HammerDB
3. Select Options→Benchmark.
4. Choose MSSQL Server and TPC-H.
5. Expand SQL Server→TPC-H→Schema Build.
6. Double-click Options, and set the scale to 100. Click OK.
7. Expand Driver Script, and double click Options.
8. Set MAXDOP to 4, and check the boxes for Refresh Function and Refresh Verbose.
9. Click OK.
10. Double-click Load.
11. In the Script Editor window, scroll down to line 436. Highlight and copy (cast(l\_quantity as bigint)) after “sum.”

Paste the phrase after “avg” later in the line, as highlighted below.

```
set sql(1) "select l_returnflag, l_linestatus, sum(cast(l_quantity as
bigint)) as sum_qty, sum(l_extendedprice) as sum_base_price,
sum(l_extendedprice * (1 - l_discount)) as sum_disc_price,
sum(l_extendedprice * (1 - l_discount) * (1 + l_tax)) as sum_charge,
avg(cast(l_quantity as bigint)) as avg_qty, avg(l_extendedprice) as
avg_price, avg(l_discount) as avg_disc, count(*) as count_order from
lineitem where l_shipdate <= dateadd(dd,-:1,cast('1998-12-01'as datetime))
group by l_returnflag, l_linestatus order by l_returnflag, l_linestatus
option (maxdop $maxdop)"
```

12. Expand Virtual User, and double-click Options.
13. Choose 1 Virtual User, and check the boxes for Show Output, Log Output to Temp, and Use Unique Log Name.

14. Click OK.
15. Double-click Create users.
16. Start Perfmon to capture CPU, RAM, and disk counters.
17. Click Start to start the Power Test run.
18. When the run finishes, stop Perfmon.
19. Save the HammerDB results text file and Perfmon output.
20. Open SQL Manager, delete the TPCH database, and create new one by restoring from the backup file.
21. Reboot the server.
22. Follow steps 1 through 16 again, only change the Max Users to 6 in step 13.
23. Once the Throughput Test has finished, save the HammerDB results text file and Perfmon output.
24. Use the HammerDB TPC-H calculator Excel file provided on their website to determine the QphH score for the run. We ran each test three times, and use the median QphH score as our official run.
25. Complete these runs on the RD630, using two VMs simultaneously on the RD650 with the database data and log files on the SSD volume, and with four VMs simultaneously on the RD650 with the database data and log files on the PCIe SSD drives, one per drive.

## ABOUT PRINCIPLED TECHNOLOGIES



Principled Technologies, Inc.  
1007 Slater Road, Suite 300  
Durham, NC, 27703  
[www.principledtechnologies.com](http://www.principledtechnologies.com)

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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.

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