



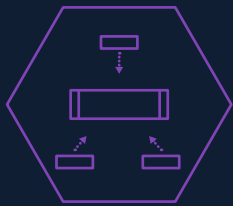
Consolidate your data analytics servers with the Dell EMC PowerEdge R740xd

A single Dell EMC PowerEdge R740xd powered by Intel Xeon Scalable processors did the data warehouse work of up to eight legacy servers

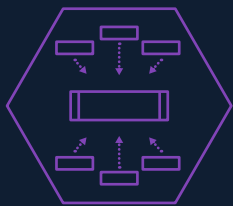
Your company is collecting more data than ever before; your customers' pain points, habits, and desires all flow in and out of your business each second. To mine the most value from that data, and to get the answers you need at a competitive speed, you need to employ server solutions powerful enough to handle complex analytics software.

In the Principled Technologies datacenter, we compared a legacy Dell EMC™ PowerEdge™ R720xd to the new PowerEdge R740xd (powered by Intel® Xeon® Scalable processors) in three storage configurations: with basic hard drives, with SATA SSDs, and with NVMe SSDs. We measured the time it took each server to complete a set of database warehouse queries, and found that the PowerEdge R740xd was more powerful after each storage upgrade. In fact, our results suggest you could replace many legacy servers with fewer of the PowerEdge R740xd.

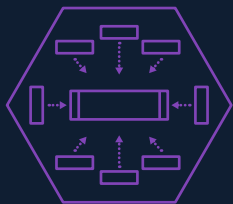
With faster query times, your business could make important decisions sooner—decisions that could mean the difference between staying ahead of the competition and losing out.



New Dell EMC server with HDDs
3x the work of the legacy server



New Dell EMC server with SATA SSDs
6x the work of the legacy server



New Dell EMC server with NVMe SSDs
8x the work of the legacy server

How we tested

We wanted to inform consumers of how the Dell EMC PowerEdge R740xd server powered by Intel Xeon Scalable processors compared to a legacy PowerEdge R720xd server in terms of querying large databases that house a business' raw data for analysis. Which of your products were in low demand last quarter? Where should the sales team spend more effort? What's the best strategy to disrupt the competition? You need these answers quickly—so hardware that decreases the time it takes to analyze your data will quickly add value to your business.

We used the data warehouse workload from the HammerDB suite of benchmarks to test each server configuration with a series of 22 unique database queries. See what we found in the next few sections. For our raw results, see [Appendix A](#).

We configured the PowerEdge R720xd server with software that would have been common at its launch: Microsoft® Windows Server® 2012 R2 and Microsoft SQL Server® 2012. The PowerEdge R740xd, however, used the latest versions of these programs. See [Appendix C](#) for information on how newer software can contribute to better performance.

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-standards: a transactional (TPC-C-like) workload and a data warehouse (TPC-H-like) workload. Our test results do not represent official TPC results and are not comparable in any manner to the official TPC-audited results. For more information about HammerDB, visit www.hammerdb.com.¹

Your current work with the Dell EMC PowerEdge R720xd

If you haven't refreshed your servers in a while, you may be using hardware and software similar to the Dell EMC PowerEdge R720xd we configured for our testing. In our datacenter, the PowerEdge R720xd with virtualized, HDD-based storage supported only a single VM. It took that VM an hour and 10 minutes to complete the 22 HammerDB queries—time that your business could use to sort through other information, especially if you wait to run analyses as a big batch in the quiet hours of the night. This may have been a competitive figure years ago, but no longer. The latest 14th generation Dell EMC PowerEdge servers are capable of much more now; as we'll see in the next few sections, your business only stands to gain in terms of performance by refreshing to modern server technology.

Refresh your servers for better insight

What would your data warehouse performance look like if you replaced your older servers with the new 14th generation Dell EMC PowerEdge R740xd but kept the same virtualized HDD storage configuration? We found the PowerEdge R740xd could handle three VMs, demonstrating that it could do the work of three HDD storage-driven PowerEdge R720xd servers. Out of those three virtual machines, the VM with the longest query time still managed to complete the HammerDB queries in just 6 minutes, or 11.5 times faster than the legacy solution. The sooner you can get key insights from data queries, the sooner you'll be able to implement solutions to make your business more efficient and profitable.

When you consolidate your years-old servers, you're also curbing datacenter costs. According to the International Data Corporation (IDC), replacing legacy servers lowers the three-year cost of datacenter operation by an average of 59 percent. IDC bases this figure on user productivity, administrative time, and infrastructure costs (facilities, power, and server maintenance).²



Upgrade server components for even faster decision-making

After upgrading from the legacy server to a basic configuration of the PowerEdge R740xd, we incrementally upgraded the server. Investing in fast SSDs can enable you to significantly increase the work your company can do. In order to fully utilize the faster drives, we doubled the RAM in the system from the 192GB we used in the previous test to match the R720xd configuration to 384GB of RAM.

When we replaced the new server's HDDs with SATA SSDs, the Dell EMC PowerEdge R740xd supported six virtual machines, thereby doing the work of six legacy PowerEdge R720xd servers with HDD-based storage. Even the slowest of these VMs took just 4 minutes and 15 seconds to complete the data warehouse queries—16.6 times faster than the legacy solution.

Our final configuration replaced the SATA SSDs with NVMe SSDs, which are capable of even faster data transfers at ultra-low latency in part because of their utilization of PCIe lanes. Again, in order to fully utilize these faster drives, we upgraded the CPUs. See [Appendix D](#) for details. Upgrading to NVMe SSDs drove the PowerEdge R740xd to complete the work of eight legacy servers by supporting eight virtual machines. In other words, you'd be able to do the same amount of work with just an eighth of your current server fleet. You'd also be able to get all that work done much faster—completing the HammerDB data warehouse queries took the slowest of these eight VMs just 3 minutes and 26 seconds, or 20.8 times faster than the legacy solution.

Remember that consolidating servers and improving data warehouse query times can help you get key insights to improve the health and viability of your business. Plus, if you can eliminate seven of every eight data warehouse servers, you'll save that much more on the cost of power, cooling, and maintenance. When a server solution enables you to analyze more data at a faster pace, you'll be able to fine-tune your business to implement solutions that can raise your bottom line.

Summary table

Time to complete 22 HammerDB queries (*faster is better*)

Dell EMC PowerEdge R720



Dell EMC PowerEdge R740xd with HDDs



Dell EMC PowerEdge R740xd with SSDs



Dell EMC PowerEdge R740xd with NVMe SSDs





What our results mean for your business

In our tests, a legacy server took 70 minutes to complete a single set of queries on one VM. Because the PowerEdge R740xd supported more VMs, each configuration was able to process multiple queries at the same time—all much faster than the legacy solution. This means the PowerEdge R740xd could run a multitude of other jobs in the time it took the legacy solution to finish just one.

Comparing each solution's efficiency	
Legacy solution	One query set in 70 minutes
PowerEdge R740xd + HDDs	Three query sets in 6 minutes, 8 seconds
PowerEdge R740xd + SATA	Six query sets in 4 minutes, 15 seconds
PowerEdge R740xd + NVMe SSDs	Eight query sets in 3 minutes, 23 seconds

Keep in mind that in a real-world environment, query times are heavily dependent on factors such as database size. So consider how this technology could help companies that run a standard set of queries every day—a retail chain, for example.

The chain records data at individual stores, but sends that data to a centralized reporting system for batch processing. By refreshing to the PowerEdge R740xd, this company could run many more jobs in the same time as its legacy solution, or compress their processing window altogether.



Conclusion: Get a system that helps businesses gain and maintain a competitive edge

A business' success depends in part on its ability to make data-driven decisions for self-improvement. Legacy servers may have been enough to deliver business insights in the past, but no longer. Newer servers like the Dell EMC PowerEdge R740xd can enable your business to expand the scope of your analyses and help management reach key decisions in less time, allowing them to stay one step ahead of the competition. With better-performing servers, you could also replace many of the servers you currently own, allowing you to save on datacenter space as well as the cost of supplying energy and cooling to all those machines.



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- 1 "HammerDB", accessed August 24, 2017, <http://www.hammerdb.com>
 - 2 Marden, Matthew and Ashish Nadkarni. "Accelerate Business Agility with Faster Server Refresh Cycles" May, 2017. Accessed September 18, 2017. <http://www.emc.rs/collateral/analyst-reports/accelerate-business-agility-with-faster-server-refresh-cycles.pdf>



On August 8, 2017, we finalized the hardware and software configurations we tested. Updates for current and recently released hardware and software appear often, so unavoidably these configurations may not represent the latest versions available when this report appears. For older systems, we chose configurations representative of typical purchases of those systems. We concluded hands-on testing on August 31, 2017.

Appendix A: Our results

The figure below shows the time it took each VM to complete the 22 queries from the HammerDB benchmark. The numbers in bold represent the longest query time for each configuration.

Query completion times (lower = better)		
Server configuration	Query time (seconds)	Query time (minutes)
PowerEdge R720xd with HDDs		
VM1	4241.668	70.694
PowerEdge R740xd with HDDs		
VM 1	321.456	5.358
VM 2	368.326	6.139
VM 3	269.82	4.497
PowerEdge R740xd with SATA SSDs		
VM 1	251.391	4.190
VM 2	253.330	4.222
VM 3	233.471	3.891
VM 4	255.219	4.254
VM 5	251.485	4.191
VM 6	236.558	3.943
PowerEdge R740xd with NVMe SSDs		
VM 1	203.441	3.391
VM 2	195.261	3.254
VM 3	192.352	3.206
VM 4	198.269	3.304
VM 5	201.956	3.366
VM 6	199.259	3.321
VM 7	206.107	3.435
VM 8	203.037	3.384



Appendix B: System configuration information

Server configuration information	Dell PowerEdge R720xd	Dell PowerEdge R740xd-HDD
BIOS name and version	Dell 2.5.4	Dell 1.0.2
Non-default BIOS settings	N/A	N/A
Operating system name and version/build number	Windows Server 2012 R2	Windows Server 2016
Date of last OS updates/patches applied	5/18/2017	6/20/2017
Power management policy	Performance	Performance
Processor		
Number of processors	2	2
Vendor and model	Intel Xeon E5-2680 v2	Intel Gold 6134
Core count (per processor)	10	8
Core frequency (GHz)	2.80	3.20
Stepping	1	4
Memory module(s)		
Total memory in system (GB)	192	192
Number of memory modules	12	12
Vendor and model	Hynix HMT42GR7MFR4C-PB	Hynix HMA82GR7AFR8N-VK
Size (GB)	16	16
Type	PC3-12800	PC4-2666
Speed (MHz)	1600	2666
Speed running in the server (MHz)	1600	2666
Storage controller		
Vendor and model	Dell PERC H710P Mini	Dell PERC H730P
Cache size (GB)	1024	2048
Firmware version	21.3.4-0001	25.5.0.0018
Driver version	6.805.3.0	6.603.7.0
Local storage (boot drives)		
Number of drives	2	2
Drive vendor and model	Dell 0B24379	Seagate
Drive size (GB)	146	300
Drive information (speed, interface, type)	6 Gb/s, SAS, HDD	12 Gb/s, SAS, HDD



Server configuration information	Dell PowerEdge R720xd	Dell PowerEdge R740xd-HDD
Local storage (testing drives)		
Number of drives	24	24
Drive vendor and model	Dell 0B24379	Dell 0B24379
Drive size (GB)	146	146
Drive information (speed, interface, type)	6 Gb/s, SAS, HDD	6 Gb/s, SAS, HDD
Network adapter		
Vendor and model	Intel Gigabit 4P I350	QLogic BRCM 10G/GbE 2+2P 57800-t
Number and type of ports	4 x 1Gb RJ45	2 x 1Gb, 2 x 10Gb
Driver version	17.5.10	8.7.26
Cooling fans		
Number of cooling fans	6	6
Power supplies		
Vendor and model	Dell PWR SPLY 750WP	Dell PWR SPLY 1100W
Number of power supplies	2	2
Wattage of each (W)	750	1100

System configuration continued

Server configuration information	Dell PowerEdge R740xd-SSD	Dell PowerEdge R740xd-NVMe
BIOS name and version	Dell 1.0.2	Dell 1.0.2
Non-default BIOS settings	N/A	N/A
Operating system name and version/build number	Windows Server 2016	Windows Server 2016
Date of last OS updates/patches applied	8/8/2017	8/8/2017
Power management policy	Performance	Performance
Processor		
Number of processors	2	2
Vendor and model	Intel Gold 6134	Intel Gold 6152
Core count (per processor)	8	22
Core frequency (GHz)	3.20	2.10
Stepping	4	4



Server configuration information	Dell PowerEdge R740xd-SSD	Dell PowerEdge R740xd-NVMe
Memory module(s)		
Total memory in system (GB)	384	384
Number of memory modules	24	24
Vendor and model	Hynix HMA82GR7AFR8N-VK	Hynix HMA82GR7AFR8N-VK
Size (GB)	16	16
Type	PC4-2666	PC4-2666
Speed (MHz)	2666	2666
Speed running in the server (MHz)	2666	2666
Storage controller		
Vendor and model	Dell PERC H730P	Dell PERC H730P
Cache size (GB)	2048	2048
Firmware version	25.5.0.0018	25.5.0.0018
Driver version	6.603.7.0	6.603.7.0
Local storage (boot drives)		
Number of drives	2	2
Drive vendor and model	Seagate	Seagate
Drive size (GB)	300	300
Drive information (speed, interface, type)	12 Gb/s, SAS, HDD	12 Gb/s, SAS, HDD
Local storage (testing drives)		
Number of drives	24	4
Drive vendor and model	Intel SSD DC S3520	Dell Express Flash PM1725a
Drive size (GB)	800	3726.8
Drive information (speed, interface, type)	6 Gb/s, SAS, SSD	32 Gb/s, PCIe, SSD
Network adapter		
Vendor and model	QLogic BRCM 10G/GbE 2+2P 57800-t	QLogic BRCM 10G/GbE 2+2P 57800-t
Number and type of ports	2 x 1Gb, 2 x 10Gb	2 x 1Gb, 2 x 10Gb
Driver version	8.7.26	8.7.26
Cooling fans		
Number of cooling fans	6	6
Power supplies		
Vendor and model	Dell PWR SPLY 1100W	Dell PWR SPLY 1100W
Number of power supplies	2	2
Wattage of each (W)	1100	1100



Appendix C: How limitations with Microsoft SQL Server columnstore indexes affected our testing

We used the columnstore indexing technology in Microsoft SQL Server to help improve query times; however, certain limitations with older versions of SQL Server affected our test methodology.

After using HammerDB to create the TPC-H-like database with traditional rowstore indexes, we used the SQL Server Management Studio to create non-clustered columnstore indexes for each database table. According to the HammerDB documentation for SQL Server, in order to get data that resembles a TPC-H workload, you must run a Power Test and a Throughput Test that both include a refresh function. This refresh function inserts and deletes rows from the ORDERS and LINEITEMS tables.

Because of the read-only limitation for columnstore indexes in SQL Server 2012, we created non-clustered columnstore indexes for every table in the PowerEdge R720xd VM's database—excluding the ORDERS and LINEITEMS tables. SQL Server 2016 supports both read and write operations for columnstore indexes, allowing us to create non-clustered columnstore indexes for each database table and take full advantage of this feature.



Appendix D: How we tested

We ran the TPC-H-like test from the HammerDB suite on a Dell EMC PowerEdge R720xd with 24 15K SAS HDDs. We started with a single VM and increased the VM count until the query completion time on the first VM increased. With this method, adding another VM increased the query completion time for both VMs, suggesting a storage bottleneck.

We then ran the same test using the same method on the PowerEdge R740xd server configured with the same HDDs. We scaled up to three VMs before reaching a storage capacity bottleneck. For the HDD tests—both on the PowerEdge R720xd and the PowerEdge R740xd, we set the amount of memory inside each VM to 50 GB to load more of the database into memory. Because of the storage I/O bottleneck in the PowerEdge R720xd configuration, we were only able to utilize roughly 26 percent of the system's total RAM. With three VMs in the PowerEdge R740xd HDD configuration, we utilized about 78 percent of the available RAM.

Next, we upgraded the storage in the PowerEdge R740xd from 24 15K SAS HDDs to 24 Intel SSD DC S3520 series SATA SSDs. After our storage upgrade, we reconfigured the RAM in the host system and inside each VM to eliminate the possibility of a memory bottleneck. We doubled the RAM in the system from 192 GB to 384 GB, and we lowered the RAM inside each VM from 50 GB to 24 GB. This allowed us to scale up from three VMs to six VMs, with room left to grow when upgrading to NVMe SSDs. After scaling up, each of the six VMs still outperformed our baseline VM.

While we still outperformed our baseline configuration using six VMs in the PowerEdge R740xd SSD configuration, we still ran into a CPU bottleneck that would prevent us from fully maximizing our NVMe SSDs in the next storage upgrade. To work around this issue, we upgraded our processors from the Intel Xeon Gold 6134 processor to the Intel Xeon Gold 6152 processor. This gave us more cores to work with, which we used to increase each VM's vCPU count from four to eight. We also upgraded from the 24 Intel S3520 SATA SSDs to four Dell EMC PowerEdge Express Flash NVMe PM1725 SSDs. With our new processors and NVMe SSDs in place, we were able to scale up to eight VMs. In this configuration, each VM outperformed our baseline.

Installing Microsoft Windows Server 2012 R2 Datacenter Edition on the Dell EMC PowerEdge R720xd server

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 the 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. Windows will begin and restart automatically.
14. At the Settings page, fill in the Password and Reenter Password fields with the same password.
15. Log in with the password you set up in the previous step.

Configuring Windows Update on the Dell EMC PowerEdge R720xd server

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.

Disabling the Windows Update Service on the Dell EMC PowerEdge R720xd server

1. After you have installed all updates, press the Start Menu button and type Services.
2. Scroll down and right-click on the Windows Update service.
3. Click Properties.



4. Choose Disabled as the startup type.
5. Stop the service if it is running.
6. Click Apply.
7. Click OK to close the window.

Formatting a Windows NTFS volume for SQL on the Dell EMC PowerEdge R720xd server

1. Right-click the start icon, and click Disk Management.
2. Right-click the disk, and click Online.
3. Right-click the disk again, and click Initialize.
4. Right click an unallocated area, and select New Simple Volume.
5. Click Next.
6. Click Next.
7. Assign a letter path, and click Next.
8. Set the Allocation Unit Size to 64K, and name the Volume Label.
9. Click Next.
10. Click Finish.
11. Repeat steps 1-10 on all data and log volumes.

Installing the Hyper-V role on the Dell EMC PowerEdge R720xd server

1. Open the Server Manager.
2. Click Manage→Add Roles and Features.
3. At the Before You Begin screen, click Next.
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. At the Things to note screen, click.
8. Choose a port for the virtual switch, and click Next.
9. Choose whether 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 Dell EMC PowerEdge R720xd server

1. Open the Hyper-V manager.
2. Right-click the host server, and choose New→Virtual Machine.
3. At the Before You Begin screen, click Next.
4. Name the VM, and choose the storage option. Click Next.
5. Choose Generation 2, and click Next.
6. Enter 51200 MB for the startup memory, and click Next.
7. Choose the network connection, and click Next.
8. Choose 40 GB for the disk size, and click Next.
9. Choose Install an operating system later, and click Next.
10. Click Finish.
11. When the system finishes creating the VM, right-click the VM, and choose Settings....
12. Change the number of processors to four, and click Apply.
13. Click the SCSI Controller, highlight Hard Drive, and click Add.
14. Choose Virtual hard disk, and click New.
15. At the Before You Begin screen, click Next.
16. Choose Fixed size, and click Next.
17. Name the HDD, and choose the Data volume as the location. Click Next.
18. Set the size to 275 GB, and click Next.
19. Click Finish.
20. Repeat steps 13 through 19 twice more to create a 115GB Log VHD and a 201GB backup VHD, storing the Log VHD on the Log volume, and the backup VHD on the Backup volume.
21. Install Windows Server 2012 R2 and any updates on the VM, following the same steps outlined in previous sections.
22. Using Windows Disk Manager, add the three additional HDDs to the VM.



Installing SQL Server 2012 on the PowerEdge R720xd VM

1. Mount the installation DVD for SQL Server 2012.
2. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2012 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 no failures appear, 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. In our tests, 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 to ensure 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 2012 Configuration Manager, and expand Protocols for MSSQLSERVER.
25. Right-click Named Pipes, and choose Enabled.
26. Click OK, and restart the SQL service.

Moving and expanding tempdb on the PowerEdge R720xd VM

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 = 'E:\Data\tempdb.mdf');
GO
ALTER DATABASE tempdb
MODIFY FILE (NAME = templog, FILENAME = 'F:\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 50GB and templog to 10GB to ensure more than enough space.
10. When the files are finished expanding, click OK.

Installing Windows Server 2016 DataCenter Edition on the PowerEdge R740xd server

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 UEFI Boot Menu.
4. Select the boot media, and press Enter.
5. When prompted to boot from DVD, press any key.
6. When the installation screen appears, leave language, time/currency format, and input method as default, and click Next.
7. Click Install now.
8. When the installation prompts you, enter the product key.
9. Select Windows Server 2016 Datacenter Edition (Server with a GUI), and click Next.
10. Check I accept the license terms, and click Next.
11. Click Custom: Install Windows only (advanced).
12. Select Drive 0 Unallocated Space, and click Next. Windows will begin and restart automatically.
13. When the Settings page appears, fill in the Password and Reenter Password fields with the same password.
14. Log in with the password you set up in the previous step.

Installing the Hyper-V role on the PowerEdge R740xd

1. Open the Server Manager.
2. Click Manage→Add Roles and Features.
3. At the Before You Begin screen, click Next.
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. At the Hyper-V Things to note screen, click Next.
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 PowerEdge R740xd

1. Open the Hyper-V manager.
2. Right-click the host server, and choose New→Virtual Machine
3. At the Before You Begin screen, click Next.
4. Name the VM, and choose the storage option. Click Next.
5. Choose Generation 2, and click Next.
6. Enter the desired amount of memory for the startup memory, and click Next. In our testing we used 51200 for the HDD test and 24576 for the SSD and NVMe tests.
7. Choose the network connection, and click Next.
8. Choose 40 GB for the disk size, and click Next.
9. Choose Install an operating system later, and click Next.
10. Click Finish.
11. After VM creation, right click the VM and choose Settings...
12. Change the number of processors, and click Apply. For our tests, we set the number of processors to four for the HDD and SSD tests and eight for the NVMe test.
13. Click on the SCSI Controller, highlight Hard Drive, and click Add.
14. Choose Virtual hard disk, and click New.
15. At the Before You Begin screen, click Next.
16. Choose Fixed size, and click Next.
17. Name the HDD, and choose the Data volume for the location. Click Next.
18. Set the size to 275 GB, and click Next.



19. Click Finish.
20. Repeat steps 13 through 19 twice more to create a 115GB Log VHD and a 201GB backup VHD, storing the Log VHD on the Log volume, and the backup VHD on the Backup volume.
21. Install Windows Server 2016 and any updates on the VM, following the same steps outlined in previous sections.
22. Using Windows Disk Manager, add the three additional HDDs to the VM.

Formatting a Windows NTFS volume for SQL on the PowerEdge R740xd

1. Right-click the start icon, and click Disk Management.
2. Right-click the disk, and click Online.
3. Right-click the disk again, and click Initialize.
4. Right click an unallocated area, and select New Simple Volume.
5. Click Next.
6. Click Next.
7. Assign a letter path, and click Next.
8. Set the Allocation Unit Size to 64K, and name the Volume Label.
9. Click Next.
10. Click Finish.
11. Repeat steps 1-10 on all Data and Log volumes.

Installing SQL Server 2016 on the PowerEdge R740xd VMs

1. Attach the installation media ISO for SQL Server 2016 to the VM.
2. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2016 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. Click the checkbox to accept the license terms, and click Next.
6. Click Use Microsoft Update to check for updates, and click Next.
7. To install the setup support files, click Install.
8. If no failures appear, click Next.
9. At the Setup Role screen, choose SQL Server Feature Installation, and click Next.
10. At the Feature Selection screen, select Database Engine Services, Full-Text and Semantic Extractions for Search, Client Tools Connectivity, Client Tools Backwards Compatibility.
11. Click Next.
12. At the Instance configuration screen, leave the default selection of default instance, and click Next.
13. At the Database Engine Configuration screen, select the authentication method you prefer. For our testing purposes, we selected Mixed Mode.
14. Enter and confirm a password for the system administrator account.
15. Click Add Current user. This may take several seconds.
16. Click the TempDB tab.
17. Change the number of TempDB files to eight, and change its location to the Data volume.
18. Change the location of the TempLog file to the Log volume.
19. Click Next.
20. At the Error and usage reporting screen, click Next.
21. At the Installation Configuration Rules screen, check that there are no failures or relevant warnings, and click Next.
22. At the Ready to Install screen, click Install.
23. Close the installation window.
24. Download and Install SQL Server Management Studio.

Expanding TempDB & TempLog files on the PowerEdge R740xd VMs

1. Open SQL Server Management Studio.
2. Expand Databases→System Databases
3. Right-click tempdb, and choose Properties.
4. 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 50 GB and templog to 10 GB to ensure more than enough space.
5. When the files are finished expanding, click OK.



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.

Creating a Database

1. Open SQL Server Management Studio.
2. Right-click Databases→New Database.
3. Name the database. We named ours tpch.
4. Click Add to add seven more database files for a total of eight.
5. Name the database files, and click OK.

Installing HammerDB

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

Populating the database

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 Options.
5. Choose 100 scale, and the number of virtual users corresponding to the number of CPU cores. Click OK.
6. Double-click Build. This build could take several hours.

Creating non-clustered Columnstore indexes for the PowerEdge R720xd VM

1. Open SQL Server Management Studio.
2. Expand Databases→tpch→Tables→dbo.customer.
3. Right-click Indexes→New Index→Non-Clustered Columnstore Index.
4. Click ADD and add all of the columns to the columnstore.
5. Click OK.
6. Repeat steps 1-5 for all tables except Orders and Linelitem.

Creating non-clustered Columnstore indexes for the PowerEdge R740xd VMs

1. Open SQL Server Management Studio.
2. Expand Databases→tpch→Tables→dbo.customer.
3. Right-Click on Indexes→New Index→Non-Clustered Columnstore Index.
4. Click ADD and add all of the columns to the columnstore.
5. Click OK.

Backing up the database

1. Open SQL Server Management Studio.
2. Right-click the TPCH database, and click Tasks→Back up...
3. Choose a location to store the backup, and click OK.



Cloning VMs on the PowerEdge R740xd

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 the desired amount of RAM and vCPUs, and with no VHDs.
4. Add the copied VHDs to the VM: OS, Data, Log, and Backup.
5. Repeat steps 1 through 4 for as many VMs that are required.

Securely erasing and seasoning the SATA SSDs and NVMe SSDs.

1. Ensure that the disks are set to Non-RAID mode in the BIOS or through the RAID controller.
2. Create a bootable USB drive with the PartedMagic ISO.
3. Insert the bootable USB into the PowerEdge R740xd.
4. Press F11 to select a boot device.
5. Select the bootable USB.
6. Select the time zone, and click OK.
7. Double-click the Secure Erase icon on the desktop.
8. From within the Internal tab, select either SATA SSD or NVMe SSD Secure Erase.
9. Check each disk you wish to securely erase, and click Next.
10. Click the check box to confirm you'd like to securely erase the SSDs, and click OK.
11. When the process is over, confirm that each SSD completed erasure successfully, and click OK.
12. Double-click the quit icon, and select Reboot.
13. After Windows reboots, open Iometer.
14. In the Disk Target tab, assign one worker to each raw disk.
15. Set the number of outstanding I/O to 256, and the Write IO data pattern to Pseudo random.
16. Click the Access Specification tab.
17. Create a new Access Specification with the following parameters:
 - a. Transfer Request Size – 128K
 - b. Percent of Access Specification – 100
 - c. Percent Read/Write Distribution – 100% Write
 - d. Percent Random/Sequential Distribution – 100% Sequential
18. Assign the newly created Access Specification to each worker.
19. Click the Test Setup tab.
20. Set the Ramp Up time to 60 seconds.
21. Set the Run Time to the appropriate amount of time it takes to fill up twice the capacity of the drives.
22. Click the green flag icon to start the seasoning.

Performing the test

Using the legacy server and one VM as our base system, we ran the TPC-H test while increasing the DOP on each run by one until the time to finish increased. We determined that a DOP of six 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 6, and check the box for Refresh Function.
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 begin 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 TPC-H database, and create a new one by restoring from the backup file.
21. Reboot the server.
22. Follow steps 1 through 16 again, this time checking the Refresh Function and Refresh Verbose boxes in step 6, and changing the Max Users to six 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 following systems/configurations:
 - With one VM on the PowerEdge R720xd
 - With three VMs simultaneously on the PowerEdge R740xd, with the database data and log files on the HDD volumes
 - With six VMs simultaneously on the PowerEdge R740xd, with the database data and log files on the SATA SSDs, and
 - With eight VMs simultaneously on the PowerEdge R740xd, with the database data and log files on the NVMe SSDs.

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