



The science behind the report:

# Get better data warehouse performance in Microsoft SQL Server 2019 with new Microsoft Azure Dds\_v5 VMs featuring 3rd Generation Intel Xeon Scalable processors

This document describes what we tested, how we tested, and what we found. To learn how these facts translate into real-world benefits, read the report [Get better data warehouse performance in Microsoft SQL Server 2019 with new Microsoft Azure Dds\\_v5 VMs featuring 3rd Generation Intel Xeon Scalable processors](#).

We concluded our hands-on testing on May 20, 2021. During testing, we determined the appropriate hardware and software configurations and applied updates as they became available. The results in this report reflect configurations that we finalized on May 13, 2021 or earlier. Unavoidably, these configurations may not represent the latest versions available when this report appears.

## Our results

To learn more about how we have calculated the wins in this report, go to <http://facts.pt/calculating-and-highlighting-wins>.

Unless we state otherwise, we have followed the rules and principles we outline in that document.

Table 1: Results of our testing

MySQL performance	Stream 1	Streams 2	Streams 3	Streams 4	Streams 5	Streams 6
8 vCPU results						
E8ds_v5	1.23	1.21	1.20	1.22	n/a	n/a
E8ds_v4	1.00	1.00	1.00	1.00	n/a	n/a
16 vCPU results						
E16ds_v5	1.26	1.24	1.24	1.26	1.27	n/a
E16ds_v4	1.00	1.00	1.00	1.00	1.00	n/a
64 vCPU results						
E64ds_v5	1.22	1.23	1.19	1.17	1.20	1.20
E64ds_v4	1.00	1.00	1.00	1.00	1.00	1.00

## System configuration information

Table 2: Detailed configuration information for the 3rd Generation Intel Xeon Scalable processor-enabled Microsoft Azure VMs we tested.

System configuration information	E8ds_v5 VM	E16ds_v5 VM	E64ds_v5 VM
Tested by	Principled Technologies	Principled Technologies	Principled Technologies
Test date	05/20/2021	05/20/2021	05/20/2021
CSP / Region	Microsoft Azure East US (Zone 2)	Microsoft Azure East US (Zone 2)	Microsoft Azure East US (Zone 2)
Workload & version	HammerDB v3.3 TPC-H-Like	HammerDB v3.3 TPC-H-Like	HammerDB v3.3 TPC-H-Like
WL specific parameters	CCI, MAXDOP 8, Lock Pages in Memory, 90% Reserved SQL Memory	CCI, MAXDOP 16, Lock Pages in Memory, 90% Reserved SQL Memory	CCI, MAXDOP 64, Lock Pages in Memory, 90% Reserved SQL Memory
Iterations and result choice	3 runs, median	3 runs, median	3 runs, median
Server platform	E8ds_v5	E16ds_v5	E64ds_v5
BIOS name and version	Microsoft Corporation Hyper-V UEFI Release v42.10, 108/276/202016	Microsoft Corporation Hyper-V UEFI Release v4.12.0, 108/276/202016	Microsoft Corporation Hyper-V UEFI Release v4.1, 10/27/2020
Operating system name and version/build number	Microsoft Windows Server 2019 Datacenter 10.0.17763 / Build 17763	Microsoft Windows Server 2019 Datacenter 10.0.17763 / Build 17763	Microsoft Windows Server 2019 Datacenter 10.0.17763 / Build 17763
Date of last OS updates/patches applied	05/13/2021	05/13/2021	05/13/2021
Processor			
Number of processors	1	1	1
Vendor and model	Intel® Xeon® Platinum 8370C	Intel Xeon Platinum 8370C	Intel Xeon Platinum 8370C
Core count (per processor)	4	4	4
Core frequency (GHz)	2.80	2.80	2.80
Number of vCPU per VM	8	16	64
Memory module(s)			
Total memory in system (GB)	64	128	512
NVMe memory present?	No	No	No
Total memory (DDR+NVMe RAM)	64	128	512
General hardware			
Storage: NW or Direct Att /Instance	NW Att	NW Att	NW Att
Local storage			
OS			
Number of drives	1	1	1
Drive size (GB)	127	127	127
Drive information (speed, interface, type)	Standard SSD	Standard SSD	Standard SSD
Temporary drive			

System configuration information	E8ds_v5 VM	E16ds_v5 VM	E64ds_v5 VM
Number of drives	1	1	1
Drive size (GB)	300	300	300
Data drive			
Number of drives	1	1	1
Drive size (GB)	127	127	127
Drive information (speed, interface, type)	Premium SSD LRS	Premium SSD LRS	Premium SSD LRS
Network adapter			
Vendor and model	Microsoft Hyper-V Network Adapter	Microsoft Hyper-V Network Adapter	Microsoft Hyper-V Network Adapter
Number and type of ports	1x 100Gb	1x 100Gb	1x 100Gb

Table 3: Detailed configuration information for the 2nd Generation Intel Xeon Scalable processor-enabled Microsoft Azure VMs we tested.

System configuration information	E8ds_v4 VM	E16ds_v4 VM	E64ds_v4 VM
Tested by	Principled Technologies	Principled Technologies	Principled Technologies
Test date	05/20/2021	05/20/2021	05/20/2021
CSP / Region	Microsoft Azure East US (Zone 2)	Microsoft Azure East US (Zone 2)	Microsoft Azure East US (Zone 2)
Workload & version	HammerDB v3.3 TPC-H-Like	HammerDB v3.3 TPC-H-Like	HammerDB v3.3 TPC-H-Like
WL specific parameters	CCI, MAXDOP 8, Lock Pages in Memory, 90% Reserved SQL Memory	CCI, MAXDOP 16, Lock Pages in Memory, 90% Reserved SQL Memory	CCI, MAXDOP 64, Lock Pages in Memory, 90% Reserved SQL Memory
Iterations and result choice	3 runs, median	3 runs, median	3 runs, median
Server platform	E8ds_v4	E16ds_v4	E64ds_v4
BIOS name and version	Microsoft Corporation Hyper-V UEFI Release v4.1, 10/27/2020	Microsoft Corporation Hyper-V UEFI Release v4.1, 10/27/2020	Microsoft Corporation Hyper-V UEFI Release v4.1, 10/27/2020
Operating system name and version/build number	Microsoft Windows Server 2019 Datacenter 10.0.17763 / Build 17763	Microsoft Windows Server 2019 Datacenter 10.0.17763 / Build 17763	Microsoft Windows Server 2019 Datacenter 10.0.17763 / Build 17763
Date of last OS updates/patches applied	05/13/2021	05/13/2021	05/13/2021
Processor			
Number of processors	1	1	1
Vendor and model	Intel Xeon Platinum 8272CL	Intel Xeon Platinum 8272CL	Intel Xeon Platinum 8272CL
Core count (per processor)	24	24	24
Core frequency (GHz)	2.60	2.60	2.60
Stepping	7	7	7
Hyper-Threading	Yes	Yes	Yes
Turbo	Yes	Yes	Yes

System configuration information	E8ds_v4 VM	E16ds_v4 VM	E64ds_v4 VM
Number of vCPU per VM	8	16	64
Memory module(s)			
Total memory in system (GB)	64	128	504
NVMe memory present?	No	No	No
Total memory (DDR+NVMe RAM)	64	128	504
General hardware			
Storage: NW or Direct Att /Instance	NW Att	NW Att	NW Att
Local storage			
OS			
Number of drives	1	1	1
Drive size (GB)	127	127	127
Drive information (speed, interface, type)	Standard SSD	Standard SSD	Standard SSD
Temporary drive			
Number of drives	1	1	1
Drive size (GB)	300	300	300
Data drive			
Number of drives	1	1	1
Drive size (GB)	127	127	127
Drive information (speed, interface, type)	Premium SSD LRS	Premium SSD LRS	Premium SSD LRS
Network adapter			
Vendor and model	Microsoft Hyper-V Network Adapter	Microsoft Hyper-V Network Adapter	Microsoft Hyper-V Network Adapter
Number and type of ports	1x 50Gb	1x 50Gb	1x 50Gb

# How we tested

## Testing overview

For this project, we tested Azure VMs featuring 2nd Generation Intel Xeon Scalable processors (Cascade Lake) vs. 3rd Generation Intel Xeon Scalable processor (Ice Lake) versions. We ran a data warehouse workload (TPROC-H from the HammerDB suite) on Microsoft SQL Server 2019 on the Azure VMs to show the difference in analysis completion times between the Azure offerings.

## Creating the Windows 2019 baseline image

This section contains the steps we took to create our baseline image.

### Creating the baseline image VM

1. Log into the Azure Portal, and navigate to the Virtual Machines service.
2. To open the Add VM wizard, click Add.
3. On the Basics tab, set the following:
  - a. Choose your Subscription.
  - b. Choose your Resource.
  - c. Name the Virtual Machine.
  - d. Choose your Region.
  - e. Leave the Availability options set to No infrastructure redundancy required.
  - f. From the Image dropdown menu, choose Windows Server 2019 Datacenter.
  - g. Leave Azure Spot instance set to No.
  - h. Select the instance size you wish to use. We used Standard B4ms.
  - i. Leave the Authentication type set to SSH public key.
  - j. Either choose a new Username or leave the default.
  - k. Choose Generate new key pair for the SSH public key source.
  - l. Enter a name for the Key pair name.
  - m. Leave Public inbound ports set to Allow selected ports.
  - n. For Select inbound ports, choose SSH (22).
  - o. On the Disks tab, set the following:
    - i. For the OS disk type, choose Standard SDD.
    - ii. Leave the default Encryption type.
  - p. On the Networking tab, set the following:
    - i. Choose your Virtual network.
    - ii. Choose Create new to create a new Public IP.
    - iii. Leave the rest of the settings at defaults.
  - q. On the Management tab, set the following:
    - i. Choose your Diagnostics storage account.
    - ii. Leave the rest set to defaults.
  - r. On the Advanced tab, leave all defaults.
  - s. On the Tags tab, add any tags you wish to use.
  - t. On the Review + create tab, review your settings, and click Create.

### Configuring Windows Server 2019

1. Open Server Manager, and click Local Server.
2. Disable IE Enhanced Security Configuration.
3. Change the time zone to your local time zone.
4. Change the name of your server. When prompted, reboot.
5. Open Server Manager again, and click Local Server.
6. Click the link to run updates.
7. Run updates, rebooting when prompted, until the server shows no new updates to install.

## Installing Microsoft SQL Server 2019 Enterprise

1. Download or copy the ISO to the server, and unzip it.
2. Double-click the Setup application.
3. Click Installation→New SQL Server Standalone installation or add features to an existing installation.
4. Choose the trial version, and click Next.
5. Check the I accept the license terms and Privacy Statement box, and click Next.
6. Check the Use Microsoft Update to check for updates (recommended) box, and click Next.
7. On the Install Rules page, click Next.
8. Check the boxes for the following features, and click Next:
  - Database Engine Services
  - Full-Test and Semantic Extractions for Search
  - Client Tools Connectivity
  - Client Tools Backwards Compatibility
9. Leave the Default instance, and click Next.
10. Leave the default Service Accounts, and click Next.
11. On the Server Configuration tab, choose Mixed Mode, and enter and confirm a Password for the SQL Server system administrator (sa) account.
12. To specify the SQL Server administrators, click Add Current User.
13. Click Next.
14. Once you've passed the rule check, click Next.
15. Click Install.
16. When the install is finished, go back to the SQL Server Installation Center, and click Install SQL Server Management Tools.
17. Download the SSMS file, and install with defaults.
18. Reboot the server when prompted.
19. Run Windows Update one more time to ensure there aren't any new updates for SQL (make sure Windows Updates are set to get updates for other Microsoft products).
20. Once you've installed all available updates, disable Windows Update service by performing the following actions:
21. Click Start.
22. To open the Services list, type `services`
23. Disable the Windows Update service.

## Locking pages in memory

1. Click Start, and type `Local Security Policy`
2. Open the program when it pops up in the search.
3. Expand Local Policies, and click User Rights Assignment.
4. In the right-hand pane, scroll down, and double-click Lock pages in memory.
5. Click Add User or Group, type `NT Service\MSSQLSERVER` and click OK.
6. To close the Properties window, click OK.
7. Close the Local Security Policy window.

## Installing HammerDB 3.3

1. Download HammerDB from: <https://hammerdb.com/download.html>.
2. Double-click the .exe file, choose English, and click OK.
3. Click Yes.
4. Click Next.
5. Chose a destination location, and click Next.
6. Click Next.
7. Click Finish.

## Creating a snapshot of the baseline VM

1. In your Azure portal, navigate to the Snapshots service.
2. To open the Snapshot wizard, click Add.

3. On the Basics tab, set the following:
  - a. Choose your Subscription.
  - b. Choose your Resource group.
  - c. Enter a name for your snapshot.
  - d. Choose your Region.
  - e. For the Snapshot type, select Full – make a complete read-only copy of the selected disk.
  - f. Choose the OS disk from your baseline VM.
  - g. For Storage type, choose Standard SSD.
4. On the Encryption tab, leave all defaults.
5. On the Tags tab, add any tags you wish to use.
6. On the Review + create tab, review your settings, and click Create.

## Creating the image with the baseline snapshot

To create an image, you must first have a Shared Image Gallery. The steps below will walk you through the creation of the gallery as well as the image creation steps. Once you have created your gallery, you will not need to do so again to add new images.

1. In your Azure portal, navigate to the Shared image galleries service.
2. To open the Add gallery wizard, click Add.
3. On the Basics tab, set the following:
  - a. Choose your Subscription.
  - b. Choose your Resource.
  - c. Name your gallery.
  - d. Choose your Region.
  - e. Enter a Description if you like.
4. On the Tags tab, add any tags you wish to use.
5. On the Review + create tab, review your settings, and click Create.
6. Click on your new image gallery, and click Add new image definition to open the wizard.
7. On the Basics tab, set the following:
  - a. Set the Operating System to Windows.
  - b. Set the VM generation to Gen 2.
  - c. Set the Operation system state to Specialized.
8. Enter desired values for the Publisher, Offer, and SKU entries.
9. Skip the Version tab.
10. Skip the Publishing options tab.
11. On the Tags tab, add any tags you wish to use.
12. On the Review + create tab, review your settings, and click Create.
13. Click on the image definition you've created, and click Add version to open the wizard.
14. On the Basics tab, set the following:
  - a. Enter a version number such as 1.0.0.
  - b. Choose the OS disk snapshot of the baseline VM you created from the drop-down menu.
  - c. Leave the rest as defaults.
15. On the Encryption tab, leave defaults.
16. On the Tags tab, add any tags you wish to use.
17. On the Review + create tab, review your settings, and click Create.

## Creating the VMs under test

In this section, we list the steps required to create a VM from the image we created previously. See Table 2 and Table 3 for the list of VMs and SSDs we used and follow the steps six times using the proper specifications for the VM you wish to create. For our testing, we used the East US Region and Availability Zone 2.

## Creating the VMs from the specialized image

1. Open the Azure Portal and navigate to the Share image galleries service.
2. Click on the Shared image gallery you created.
3. Navigate to the image version you created (should be something like 1.0.0), and click Create VM.

4. On the Basics tab, set the following:
  - a. Choose your Subscription.
  - b. Choose your Resource group.
  - c. Enter a Virtual machine name.
  - d. Choose Availability Zone, and set the Zone you desire.
  - e. Select the instance size you want.
  - f. Choose Windows Server in the license type, and choose "No" when asked if you have a Windows license you want to use.
  - g. Leave the rest as defaults.
5. On the Disks tab, set the following:
  - a. Change the OS disk type to Premium SSD.
  - b. Click Create and attach a new disk.
6. In the Create a new disk wizard, click Change size and pick the size of Premium SSD that matches your instance type.
7. Leave the rest as defaults, and click OK.
8. Skip the Networking, Management, and Advanced tabs.
9. On the Tags tab, assign any tags you wish to use.
10. On the Review + create tab, review your settings, and click Create.
11. Once the VM creation is finished, click Go to resource (or navigate to the virtual machine service and click on the new VM).
12. Click Connect→RDP, and download the RDP file.
13. Double-click the RDP file, and log in with the user and password you set.
14. Right-click the Windows Start button, and click Disk Management.
15. On the GPT partition pop-up window, click OK.
16. Right-click the Premium SSD you added, and follow the prompts to create a new NTFS volume for the database.

## Configuring Microsoft SQL Server on the VMs under test

In this section, we list the various SQL Server settings that we changed and describes the steps to change them.

### Setting the SQL Server memory reserve and max degree of parallelism (MAXDOP)

1. Open the SQL Server Management Studio.
2. Right-click on the SQL Instance, and click Properties.
3. Click Advanced node, scroll down to the Max Degree of Parallelism, and change the value to match the number of vCPUs on the system you are testing. Click OK.
4. Right-click the SQL Server VM again, and go to Memory.
5. Set the Max Memory to 90% of the total memory in the system. Click OK, and close the Properties window.
6. Right-click the SQL Server VM, and restart the service. Click Yes when prompted.

### Configuring the tempdb database

1. Open the SQL Server Management Studio.
2. Expand Databases and System databases, and right-click tempdb.
3. Add files, and change the starting size as necessary.
4. Right-click the SQL Server VM, and restart the service. When prompted, click Yes.
5. To move the tempdb to the database drive, open a new Query, and run the following command for the number of tempdb files your system has:

```
USE [master]
GO
ALTER DATABASE tempdb MODIFY FILE ( NAME = tempdev , FILENAME = 'E:\TempDB\tempdb.mdf' )
GO
ALTER DATABASE tempdb MODIFY FILE ( NAME = temp2 , FILENAME = 'E:\TempDB\tempdb_mssql_2.ndf' )
GO
ALTER DATABASE tempdb MODIFY FILE ( NAME = temp3 , FILENAME = 'E:\TempDB\tempdb_mssql_3.ndf' )
GO
ALTER DATABASE tempdb MODIFY FILE ( NAME = temp4 , FILENAME = 'E:\TempDB\tempdb_mssql_4.ndf' )
GO
```

```

ALTER DATABASE tempdb MODIFY FILE ( NAME = temp5 , FILENAME = 'E:\TempDB\tempdb_mssql_5.ndf')
GO
ALTER DATABASE tempdb MODIFY FILE ( NAME = temp6 , FILENAME = 'E:\TempDB\tempdb_mssql_6.ndf')
GO
ALTER DATABASE tempdb MODIFY FILE ( NAME = temp7 , FILENAME = 'E:\TempDB\tempdb_mssql_7.ndf')
GO
ALTER DATABASE tempdb MODIFY FILE ( NAME = temp8 , FILENAME = 'E:\TempDB\tempdb_mssql_8.ndf')
GO
ALTER DATABASE tempdb MODIFY FILE ( NAME = templog , FILENAME = 'E:\TempDB\templog.ldf' )
GO

```

Right-click the SQL Server VM, and restart the service. When prompted, click Yes.

## Running the tests

In this section, we list the steps to run the HammerDB TPC-H-like test on the VMs under test. For the maximum number of streams we ran, we followed HammerDB TPC-H recommendations for the size database we were testing. Additionally, to show the scaling of each VM pair, we ran with fewer streams. Note that for each test we ran a single-stream test first to cache the database into memory before running the second test (normally multi-stream, the exception being the single-stream test).

1. On the VM under test, restore the database under test to so that the database and log files reside on the Premium SSD.
2. Make sure your SQL settings and tempdb are configured properly according to the instructions above and the instance you're running on.
3. Open HammerDB.
4. Select Options→Benchmark.
5. Choose MSSQL Server and TPC-H.
6. Expand SQL Server→TPC-H→Schema Build.
7. Double-click Options, change the driver to ODBC Driver 17 for SQL Server, set the scale to match your database, set MAXDOP to match that of SQL Server, and check the box for Clustered Columnstore. Click OK.
8. Expand Driver Script, double-click Options, and click OK to load.
9. Expand Virtual User, and double-click Options.
10. Choose 1 user.
11. Check the boxes for Show Output, Log Output to Temp, and Use Unique Log Name.
12. Click OK.
13. To load the driver script, double-click Double-click Load.
14. Double-click Create users.
15. To capture performance metrics on the system, start Performance monitor and set to record CPU, Memory, and drive usage information.
16. To begin the run, click Start.
17. When the run finishes, stop Perfmon, and save the HammerDB results file and Perfmon output.
18. Stop the HammerDB user.
19. Double-click User options again, and set the number of users to the appropriate count for the multi-stream test.
20. Double-click Create users.
21. To capture performance metrics on the system, start Performance monitor set to record CPU, Memory, and drive usage information.
22. To begin the run, click Start on HammerDB.
23. When the run finishes, stop Perfmon, and save the HammerDB results file and Perfmon output.
24. Reboot the VM.
25. Repeat the test two more times for a total of three runs at each user count, and record the median run.

## Determining CPU vulnerability mitigation

These are the specific CPU mitigation settings that Azure reported at the time of testing.

### 3rd Generation Intel Xeon Scalable processor mitigation information

```
Vulnerability Itlb multihit: Not affected
Vulnerability L1tf: Not affected
Vulnerability Mds: Not affected
Vulnerability Meltdown: Not affected
Vulnerability Spec store bypass: Vulnerable
Vulnerability Spectre v1: Mitigation; usercopy/swapgs barriers and __user pointer sanitization
Vulnerability Spectre v2: Mitigation; Full generic retpoline, STIBP disabled, RSB filling
Vulnerability Srbds: Not affected
Vulnerability Tsx async abort: Vulnerable: Clear CPU buffers attempted, no microcode; SMT
Host state unknown
```

### 2nd Generation Intel Xeon Scalable processor mitigation information

```
Vulnerability Itlb multihit:      KVM: Mitigation: Split huge pages
Vulnerability L1tf:              Not affected
Vulnerability Mds:               Not affected
Vulnerability Meltdown:          Not affected
Vulnerability Spec store bypass: Vulnerable
Vulnerability Spectre v1:        Mitigation; usercopy/swapgs barriers and __user pointer sanitization
Vulnerability Spectre v2:        Mitigation; Full generic retpoline, STIBP disabled, RSB filling
Vulnerability Srbds:             Not affected
Vulnerability Tsx async abort:    Vulnerable: Clear CPU buffers attempted, no microcode; SMT
Host state unknown
```

Read the report at <http://facts.pt/YjbOBZq> ►

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