Improve SQL Server Performance and Lower Costs with Kingston Technology DC500M Enterprise Solid-State Drives

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Contents

Executive summary

Companies running SQL Server 2008 and SQL Server 2008 R2 faced a critical milestone in July 2019, when Microsoft's End of Support (EOS)[1] came into effect for those databases. With EOS, Microsoft has stopped releasing security updates for these on-premises SQL Server releases. As a result, such databases will face great risk of being hacked and will no longer conform to many regulatory requirements.

A cost-effective solution is needed for migrating and consolidating those SQL Server 2008[2] workloads that need to remain on-premises for regulatory reasons or due to customer preference.

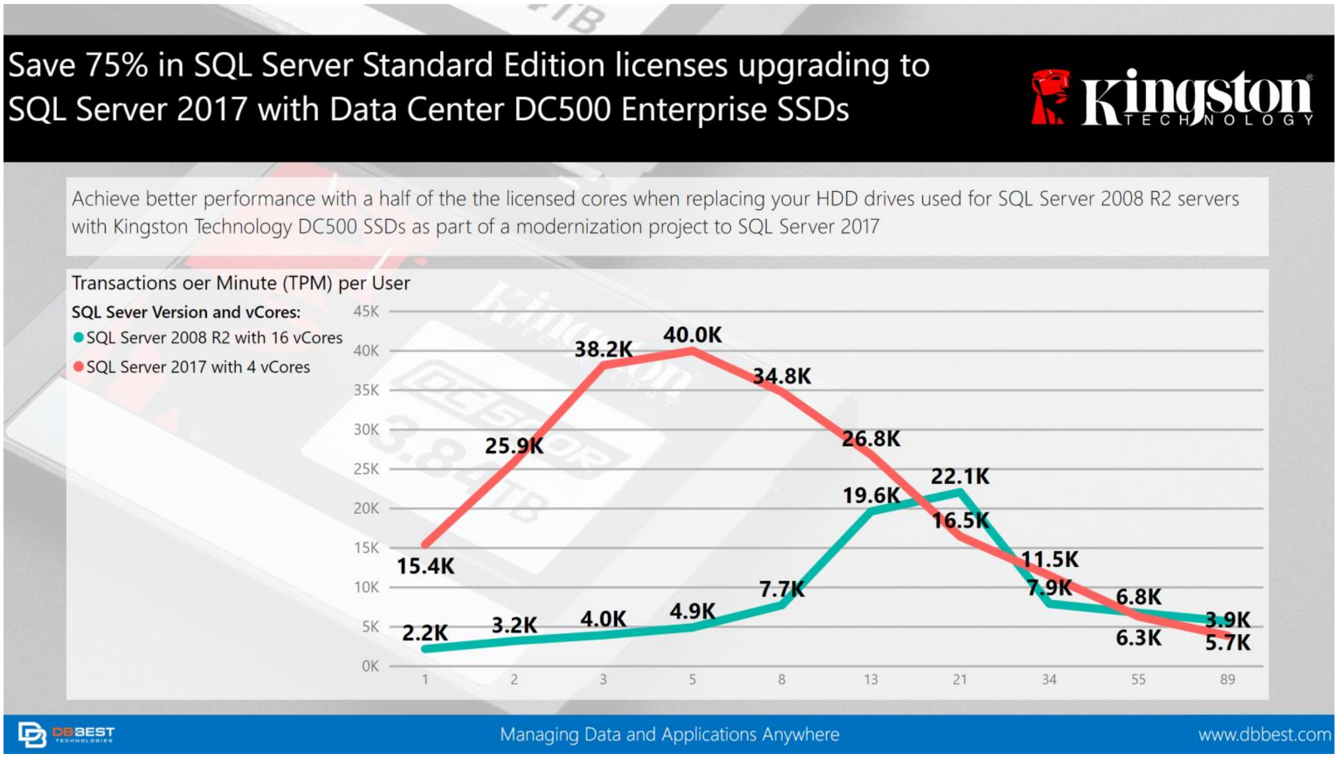
This white paper demonstrates that SQL Server 2008 workloads can cost effectively be migrated to a modern hardware and software solution using modern servers and Kingston Technology DC500M Enterprise Solid-State Drives (SSD) with Microsoft SQL 2017 Windows Server 2019 Datacenter Edition.

DB Best Technologies recently partnered with Kingston Technology to demonstrate that SQL Server 2017 with 8 virtual cores (vCores) and Kingston Technology DC500 Enterprise Solid-State Drives (SSD) runs faster than SQL Server 2008 R2 with 16 vCores using hard drives (HDD). When we work with customers looking to upgrade their SQL Server 2008 servers to newer versions of SQL Server, we typically find that these systems use HDD drives for data, log and tempdb.

[1] "SQL Server 2008 and SQL Server 2008 R2 End of Support", <https://www.microsoft.com/en-gb/sql-server/sql-server-2008>

[2] For brevity, "SQL Server 2008" refers to both the SQL Server 2008 and SQL Server 2008 R2 releases.

The chart below shows the results of running the HammerDB TPC-C benchmark using 2000 warehouses with SQL Server 2017 running on 4 vCores and Kingston Data Centre DC500M SATA 6GBps 960 GB drives, which outperforms SQL Server 2008 R2 on 16 vCores and Dell 400-ATJL 10,000 RPM SAS 12 GBps 1.2 TB HDDs.



Based on prior benchmarking performed with other hardware manufacturers and cloud vendors, we had a good idea that moving from older versions of SQL Server to SQL Server 2017 using SSD for data log and tempdb could use fewer vCores.

As you upgrade your SQL Server 2008 R2 servers to SQL Server 2017, this means that you can cut your SQL Server licensing costs by 75% with better performance!

Component	SQL Server 2017	SQL Server 2008 R2	SQL Server 2017 4 vCores	SQL Server 2017 8 vCores	SQL Server 2008 R2 16 vCores
Hardware Costs					
Dell PowerEdge R740XD Intel 4114 2400 MHz	$7,595.62	$7,595.62			
KTD-PE426/32G	$4,919.76	$4,919.76			
SEDC500M 960 GB SATA 6Gb/s	$1,815.92				
DELL 400-AJPI 1.2 TB SAS 1.2Gb/s		$1,560.00			
Sub total for hardware	**$14,331.30**	**$14,075.38**			
Software Costs					
Windows Server Data Center Edition	**$12,310.00**	**$12,310.00**			
SQL Server 2017 Standard			**$7,434.00**	**$14,868.00**	**$29,736.00**
Total			**$34,075.30**	**$41,509.30**	**$56,121.38**
Percentage of savings for the total server compared to SQL Server 2008 R2 with 16 vCores			**39%**	**26%**	**0%**
Savings in cost compared to SQL Server 2018 R2 with 16 vCores			**$22,046.08**	**$14,612.08**	**$0.00**
Savings in SQL Server licensing costs			**75%**	**50%**	**0%**

The SQL Server 2008 R2 server was configured as a server that would typically be running on older software and hardware. Specifically, we used Windows Server 2008 R2 Datacenter 64-bit for the operating system and a total of 8 Dell 10K SAS (Dell part number ST1200MM0099) drives that were configured as two physical volumes as RAID 10 for separate data and log files.

The SQL Server 2017 server was configured as a modern server. Specifically, we used Windows Server 2019 Datacenter 64-bit for the operating system and a total of 8 Kingston Technology SEDC500M960G drives that were configured as two logical volumes as RAID 10 for separate data and log files.

Both servers were configured with Windows Hyper-V. The SQL Server 2008 R2 system had 16 vCores and 128 GB of RAM for the virtual machine. The SQL Server 2017 system was tested with 8 vCores and 4 vCores with 128GB of RAM for the virtual machine.

The problem: SQL Server 2008 end of support

SQL Server 2008 is one of the most deployed SQL Server database releases, which makes Microsoft's End of Support (EOS) for SQL Server 2008 in July 2019 a critical milestone for many customers.
For database workloads that will remain on-premises due to regulatory requirements or customer preference, a cost-effective solution is needed that includes migration to supported releases of SQL Server and Windows Server[3]. Microsoft has changed to a per-core licensing model for both SQL Server and Windows Server, making licensing decisions more complicated, and poor licensing decisions more expensive.

Most customers will finally retire the 2008-era hardware on which the SQL Server 2008 currently runs on and must decide what new hardware to run their migrated workloads on. There are many choices: physical servers, servers to host virtualised workloads, private clouds; hyperconverged or disaggregated architectures; traditional SAN or DAS storage, or new software-defined storage solutions.

Changes to Microsoft's software licensing model in recent years have made licensing choices more complex, and increased the cost of software licences to the point that software cost can dominate the total cost of a system. With that comes the increased risk of making an expensive mistake if you make a poor licensing decision. Well-informed choices can minimise software licence cost, as we will demonstrate.

This white paper demonstrates how using Kingston Technology's Data Centre DC500 Enterprise Solid-State Drives (SSDs) can reduce your overall capital and licence costs by 39%.

This white paper and benchmarking project document will quantify the benefits of harnessing recent advancements in hardware system architecture and software to achieve a cost-effective solution to the challenges facing customers who must deal with the SQL Server 2008 End of Support.

[3] End of Support for Windows Server 2008 and Windows Server 2008 R2 is also coming in January 2020. See "Window Server 2008 and 2008 R2 End of Support", <https://www.microsoft.com/en-gb/cloud-platform/windows-server-2008>

The solution: Replace HDD drives with Kingston Technology Data Centre DC500 Enterprise solid-state drives (SSDs) and upgrade to SQL Server 2017

Delivering on business demands for 24/7 uptime and reliability, Kingston Enterprise SSDs offer high-performing storage that combines predictable performance with rigorously tested reliability. Kingston's DC500 Series SSDs offer features that enable data centres to select the most cost-effective SSD for their workload(s). Businesses require results in order to deliver on products, solutions and service level agreements (SLAs). Kingston's DC500 Series SSDs are designed to deliver on these expectations.

Microsoft SQL Server 2017

SQL Server 2017 delivers the reliability, security and simplified management that your mission-critical workloads need, all on a data platform with leading in-memory performance for online transaction processing (OLTP) databases.

Since SQL Server 2008 R2, the SQL Server team has delivered over 100 significant new features with the 2017 release.

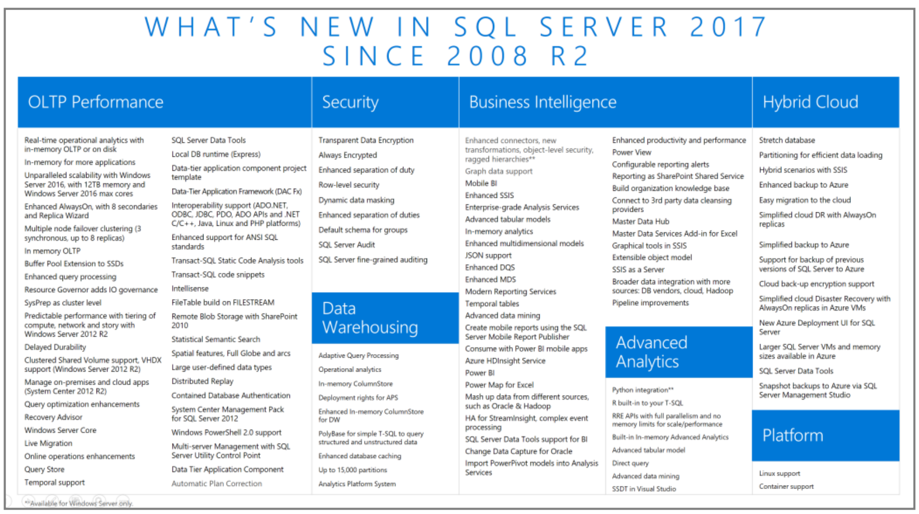


Figure 1 - New features added to SQL Server since SQL Server 2008 R2

Key OLTP processing features available in SQL Server 2017 include:

- **Performance:** SQL Server's integrated in-memory toolset goes far beyond isolated features and provides support for improving performance dramatically in a wide range of scenarios.
- **Security and compliance:** As SQL Server progresses, new capabilities have been added to protect data both at rest and in motion, with new features including Always Encrypted and Row-Level Security.
- **Availability**: Known for rock-solid, reliable performance, SQL Server is adding significant new enhancements to AlwaysOn including better load balancing and new features for flexible and efficient backups.

- **Scalability**: New advancements in compute, storage and networking will provide a direct impact on mission-critical SQL Server workloads.
- **Cloud services**: New tools in SQL Server and Microsoft Azure make it even easier to scale to the cloud; to build patching, backup and disaster recovery solutions; and to access resources wherever they are – on-premises, private cloud or public cloud.

This testing is focused on using default disk-based tables instead of taking advantage of in-memory OLTP capabilities because our goal was to show how the use of Kingston Technology’s DC500M drives with SQL Server 2017 can consolidate SQL Server 2008 workloads by running on modern hardware without making any changes to the database other than a simple upgrade.

Windows Server 2019 Datacenter

Windows Server 2019 is a cloud-ready operating system that delivers new layers of security and Microsoft Azure-inspired innovation for the applications and infrastructure that power your business. From a storage perspective, Windows Server 2019 includes new features and enhancements for software-defined storage, as well as for traditional file servers.

Kingston Data Centre DC500 series of SSD

Kingston’s Data Centre DC500 (DC500R / DC500M) series of solid-state drives are high-performance 6Gbps SATA SSDs that use the latest 3D TLC NAND, designed for read-centric and mixed-use server workloads. They implement Kingston’s strict QoS requirements to ensure predictable random I/O performance as well as predictable low latencies over a wide range of read and write workloads. They can increase productivity for AI, machine learning, big data analytics, cloud computing, software-defined storage, operational databases (ODB), database applications and data warehousing. Capacities range from 480GB, 960GB, 1.92TB, 3.84TB.

Figure 2 - Kingston Data Centre DC500M - solid state drive - 960 GB - SATA 6Gb/s

Hardware

For the purposes of this test, we used two Dell PowerEdge R740XD servers. One was used to benchmark SQL Server 2008 R2 running on Windows Server 2008 R2 using Dell 10,000 RPM SAS 1.2 TB hard drives. This would be typical of a server still running SQL Server 2008 R2. The second server was used to benchmark SQL Server 2017 running on Windows Server 2019 using DC500M 960GB solid-state drives.

Each server used two Intel Xeon Silver 4114 2.2G, 10C/20T, 9.6GT/s, 14M Cache, Turbo, HT (85W) DDR4-2400 processor for a total of 40 virtual cores (vCores).

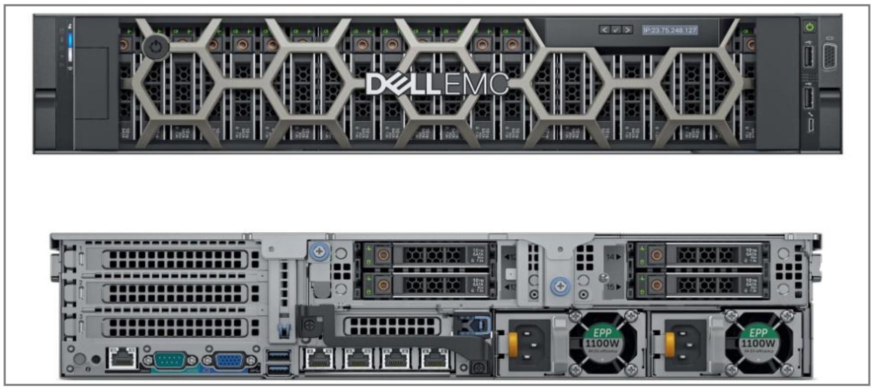


Figure 3 - PowerEdge R740xd rack server

Each server had 24 modules of Kingston’s Server Premier KTD-PE426/32G memory for a total of 768GB of RAM.

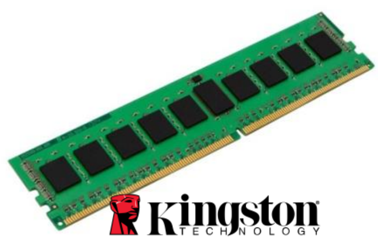


Figure 4 - Kingston’s Server Premier - DDR4 - 32 GB - DIMM 288-pin – registered memory module

For the SQL Server 2008 R2 server, we used 8 Dell - hard drive - 1.2 TB - SAS 12Gb/s drives.

Figure 5 - Dell - hard drive - 1.2 TB - SAS 12Gb/s

Four of the drives were configured using the PERC H740P RAID controller with 8GB NV cache using RAID 10 with a 64K stripe and a 64k allocation size as the logical volume used for SQL Server data files. The other four drives were also configured with RAID 10 with a 64k stripe and an 8k allocation size as the logical volume used for SQL Server log files. We used the RAID controller's Read Ahead, Write Through cache.

Software

Each bare-metal server ran with Windows Server 2019 Datacenter (10.0, Build 17763) with the Hyper-V role. We considered using Windows Storage Spaces for the attached storage. However, since Storage Spaces was not available with Windows Server 2008 R2 Datacenter, we chose to configure the disks using the RAID controller.

Each server was configured with two virtual machines, each with 16 vCores and 128GB of RAM. We used one image as a test driver VM for the execution of the HammerDB program that sends transactions to the test server.

The SQL Server 2017 workloads ran in a Hyper-V virtual machine, with Windows Server 2019 as the guest OS, running SQL Server 2017 Developer Edition, with 16 vCores to start. The SQL Server 2008 R2 workloads ran in Hyper-V virtual machines, with Windows Server 2008 R2 as the guest OS, running SQL Server 2008 R2 Developer Edition and 16 vCores.

The disk layout included the following:

Drive	Size GB	Purpose	Notes	Total size for SQL Server files used (GB)
C:	129	OS	SQL Server was installed in each VM using sysprep	
D:	282	Data	Format at 64k	TPCC Data (193), TempDB Data (16)
L:	400	Log	Format at 8k	TPCC Log (20), TempDB Log (0.5)

Figure 6 - Disk layout for SQL Server VMs running TPC-C with 2,000 warehouses for 157 GB database.

Load generation and HammerDB setup

The HammerDB tool was used to generate a TPC-C-like transactional workload for 2000 warehouses. HammerDB is commonly used for database benchmarking, and it is somewhat of an industry standard controlled by the community. TPC-C is the benchmark standard published by the Transaction Process Performance Council (TPC) for OLTP workloads. Conforming with the TPC-C specification ensures the reliability and consistency of the testing.

For the test run, we used a 157GB database that represents the medium size OLTP database based on data collected from DB Best customers. The following shows the sizes for each of the tables as reported by the **Disk Usage by Top Tables** report for SQL Server Management Studio.

This report provides detailed data on the utilization of disk space by top 1000 tables within the Database. The report does not provide data for memory optimized tables.

Table Name	# Records	Reserved (KB)	Data (KB)	Indexes (KB)	Unused (KB)
dbo.stock	200,000,000	64,134,928	64,000,000	134,896	32
dbo.customer	60,000,000	53,378,304	43,636,368	9,741,808	128
dbo.order_line	599,962,513	39,434,768	39,341,808	92,888	72
dbo.history	60,000,000	3,605,944	3,605,184	184	576
dbo.orders	60,000,000	3,093,584	1,959,184	1,134,272	128
dbo.new_order	18,000,000	321,544	320,720	736	88
dbo.district	20,000	321,016	160,000	160,952	64
dbo.warehouse	2,000	32,272	16,000	16,096	176
dbo.item	100,000	9,544	9,416	32	96

Figure 7 - Size of each table for a TPCC 2,000 warehouse database

We chose to run 10 groups of virtual users using a Fibonacci series of 1, 2, 3, 5, 8, 13, 21, 34, 55 and 89.

SQL Server setup

SQL Server 2017 Standard Edition in the virtual machines was configured as shown in the table below.

Parameter name	Minimum	Maximum	Config value	Run value
cost threshold for parallelism	-	32,767	50	50
cursor threshold	(1)	2,147,483,647	(1)	(1)
default trace enabled	-	1	1	1
max degree of parallelism	-	32,767	1	1
max server memory (MB)	128	2,147,483,647	104,857	104,857
network packet size (B)	512	32,767	4,096	4,096
query wait (s)	(1)	2,147,483,647	(1)	(1)

Figure 8 - SQL Server configuration optimised for OLTP workloads

The test results were written to the HammerDB driver VM and then loaded into Power BI to analyse the results.

Benchmarking testing scenarios

Benchmark rationale

The TPC-C benchmark has been around since 1992 with its formal definition available at tpc.org[4]. It provides a real test of SQL Server and server hardware for better understanding of the potential performance of different server configurations. DB Best uses this benchmark to baseline different sized VMs that are running on-premises or on different clouds to help customers better plan their deployments to new environments.

HammerDB is a free open source benchmarking application that supports SQL Server, Oracle Database, IBM DB2, MySQL, MariaDB, PostgreSQL, Redis and Amazon Redshift. It supports running of the TPC-C benchmark for OLTP and the TPC-H benchmark for data warehouse analytics workloads. Source code for HammerDB is available on GitHub that is hosted by the TPC so that database vendors can add their own versions of the benchmark.

HammerDB[5] can be scripted to generate databases and test data, and run the benchmarks. For this benchmark, we used the autopilot feature to run the benchmark with 1, 2, 3, 5, 8, 13, 21, 34, 55 and 89 users at a time. We like the Fibonacci sequence as it allows you to get a good feel of how the system reacts with more users.

The autopilot feature provides a way to define a ramp-up time to allow all users to start processing transactions and to heat up the database into the database server's memory. In general, it takes 1 minute to start up to 100 users. We used a ramp-up time of 3 minutes to allow enough time before the testing cycle begins.

For the test cycle, we used a 5-minute duration. During this time, the benchmark generates new orders as you would expect a typical order entry program to process transactions over the timed period. HammerDB records the actual number of transactions used to process the new orders and a value for New Orders Per Minute (NOPM) as a representation of the actual work that the database needs to accomplish.

At the end of the run, HammerDB creates log files with the transaction information for each user run. In addition, we captured basic performance counters and other system information to help correlate the results with the performance of the CPU, disk, network and memory.

[4] The list of all TPC specifications is located at http://www.tpc.org/tpc_documents_current_versions/current_specifications.asp
[5] HammerDB web site - http://www.tpc.org/tpc_documents_current_versions/current_specifications.asp

CPU performance

For CPU performance, we use a single-threaded performance test[6] using SQL Server before we start the test. In general, the Intel Xeon Silver 4114 CPU with 2.2 GHz that we used for the test has a slower clock speed than the Gold or Platinum processors[7].

In our case, we obtained a value of around 14,000. Newer processors generally run this test with a value around 7,000. However, we chose this CPU as one typically used today for running existing SQL Server 2008 R2 database solutions. (Is a value of 14000, better or worse than the 7000 value? Need clarity here for me, not for paper.)

The TPC-C benchmark favours faster CPUs. So, using a modern CPU for SQL Server 2017 will also help reduce the number of vCores required. However, disk drive performance is the largest influence on the results.

Disk performance

To understand disk performance on the Windows platform, we use an open-source program called Diskspd that was initially developed by Microsoft[8]. For Linux platforms, we use FIO. When running Diskspd, we use the guidance from SQL Server MVP Glen Berry on how to use Diskspd to match the I/O pattern used for SQL Server transactions[9]. Here is what the command line looks like:

```
diskspd -b8K -d30 -o4 -t8 -h -r -w25 -L -Z1G -c20G T:\iotest.dat > DiskSpeedResults.txt
```

Here are some highlights of running Diskspd against the data file volumes used for SQL Server 2008 R2 on HDD and SQL Server 2017 on with the DC500M both configured with four drives using RAID 10.

[6] Source code for the single threaded performance test for SQL Server is available at https://www.hammerdb.com/blog/uncategorized/hammerdb-best-practice-for-sql-server-performance-and-scalability/

[7] A full list of Intel Xeon processors and their specifications is located at https://ark.intel.com/content/www/us/en/ark/products/series/125191/intel-xeon-scalable-processors.html

[8] GitHub repository for Windows Diskspd at https://github.com/Microsoft/diskspd

[9] “Using Microsoft DiskSpd to Test Your Storage Subsystem” at https://sqlperformance.com/2015/08/io-subsystem/diskspd-test-storage

Here are the results for the HDD disk volume used for the SQL Server 2008 R2 data files.

```
Total IO
thread |       bytes     |     I/Os     |     MB/s    |  I/O per s |  AvgLat  | LatStdDev |
total:      459390976 |        56078 |       14.60 |    1869.31 |   17.119 |    23.801

Read IO
thread |       bytes     |     I/Os     |     MB/s    |  I/O per s |  AvgLat  | LatStdDev |
total:      344678400 |        42075 |       10.96 |    1402.53 |   20.563 |    21.940

Write IO
thread |       bytes     |     I/Os     |     MB/s    |  I/O per s |  AvgLat  | LatStdDev |
total:      114712576 |        14003 |        3.65 |     466.78 |    6.772 |    26.069

Latency (ms)
  %-ile |  Read (ms) | Write (ms) | Total (ms)
----------------------------------------------
    min |      0.290 |      0.259 |      0.259
   25th |      8.306 |      0.722 |      5.497
   50th |     14.220 |      2.336 |     10.825
   75th |     25.396 |      6.475 |     21.006
   90th |     42.511 |     11.673 |     37.731
   95th |     56.386 |     15.962 |     51.870
   99th |     94.808 |     73.804 |     93.303
```

Figure 9 - Data drive Diskspd results for HDD used for SQL Server 2008 R2

Compare that to the results of the data volume using Kingston Technology DC500M drives.

```
Total IO
thread |       bytes     |     I/Os     |     MB/s    |  I/O per s |  AvgLat  | LatStdDev |
total:    24128364544 |      2945357 |      767.02 |   98178.97 |    0.325 |     0.252

Read IO
thread |       bytes     |     I/Os     |     MB/s    |  I/O per s |  AvgLat  | LatStdDev |
total:    18084192256 |      2207543 |      574.88 |   73585.07 |    0.334 |     0.262

Write IO
thread |       bytes     |     I/Os     |     MB/s    |  I/O per s |  AvgLat  | LatStdDev |
total:     6044172288 |       737814 |      192.14 |   24593.90 |    0.297 |     0.219

Latency (ms)
  %-ile |  Read (ms) | Write (ms) | Total (ms)
    min |      0.074 |      0.063 |      0.063
   25th |      0.211 |      0.199 |      0.208
   50th |      0.281 |      0.257 |      0.274
   75th |      0.377 |      0.333 |      0.365
   90th |      0.524 |      0.464 |      0.512
   95th |      0.629 |      0.570 |      0.612
   99th |      1.384 |      0.868 |      1.272
```

Figure 10 - Data drive Diskspd results for DC500M drives used for SQL Server 2017

We often see this mismatch of old drives with SQL Server as part of our database upgrade practice with our customers.

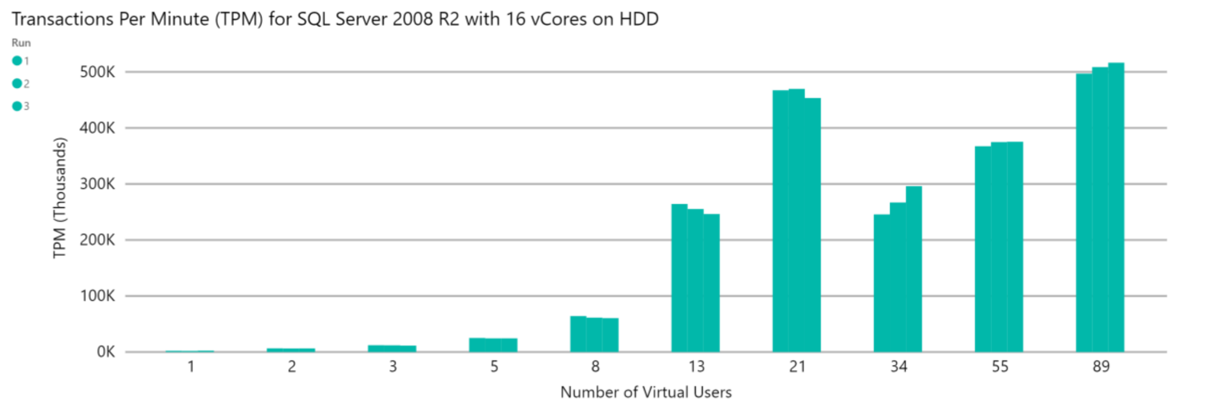
Performance metrics

During the actual test runs, we track performance using the Windows typeperf command for collecting OS and SQL Server performance counters[10].

Test results

For each of the test runs, we perform three runs and then average the performance to report the results.

Results: SQL Server 2008 R2 with 16 vCores on HDD

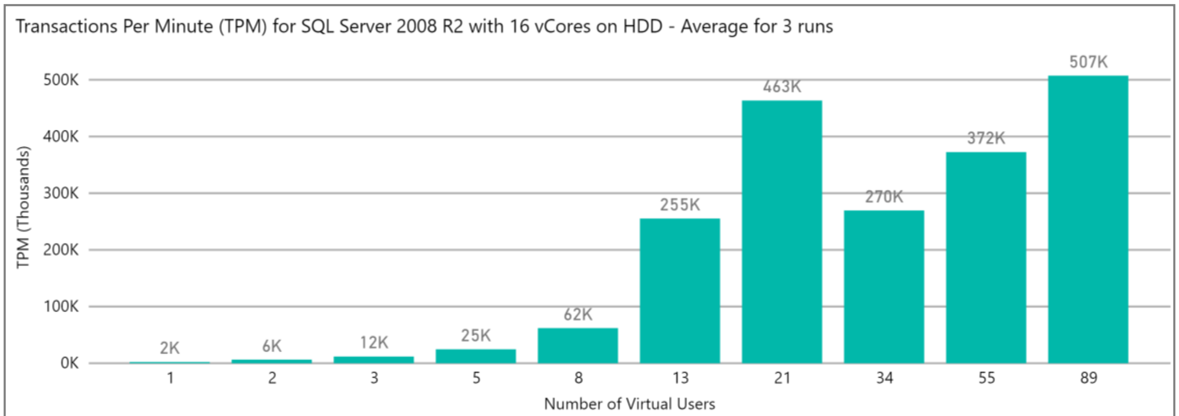


Run details for each user grouping for SQL Server 2008 R2 with 16 vCores on HDD

Run	1	2	3	5	8	13	21	34	55	89	Total
1	2,168	6,538	12,135	25,066	64,157	264,288	467,279	245,656	367,356	497,036	**1,951,679**
2	1,971	6,304	11,944	24,397	61,361	255,308	469,767	266,931	374,785	508,647	**1,981,415**
3	2,431	6,409	11,473	24,413	60,478	246,344	453,429	296,048	375,356	516,488	**1,992,869**
Total	**6,570**	**19,251**	**35,552**	**73,876**	**185,996**	**765,940**	**1,390,475**	**808,635**	**1,117,497**	**1,522,171**	**5,925,963**

Figure 11 - SQL Server 2008 R2 results with 16 vCores on HDD

[10] Documentation on Windows typeperf is available at https://docs.microsoft.com/en-us/windows-server/administration/windows-commands/typeperf

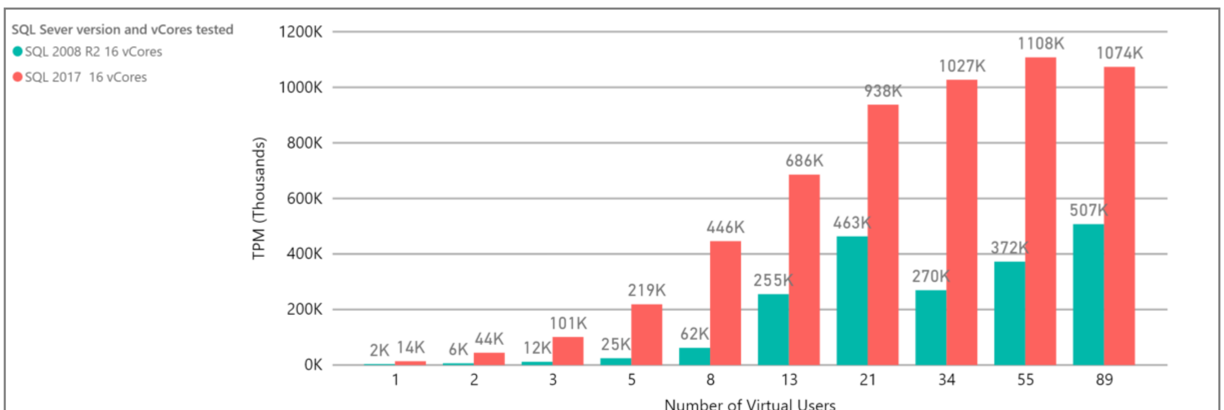


1	2	3	5	8	13	21	34	55	89
2,190.00	6,417.00	11,850.67	24,625.33	61,998.67	255,313.33	463,491.67	269,545.00	372,499.00	507,390.33

Figure 12 - SQL Server 2008 R2 with 16 vCores - Average for 3 runs

Results: SQL Server 2017 on DC500M 16 vCores

For SQL Server 2017, we first tested the system using 16 vCores to get a feeling of how it would compare to SQL Server 2008 R2 running with HDD. Here is the comparison between the two versions.



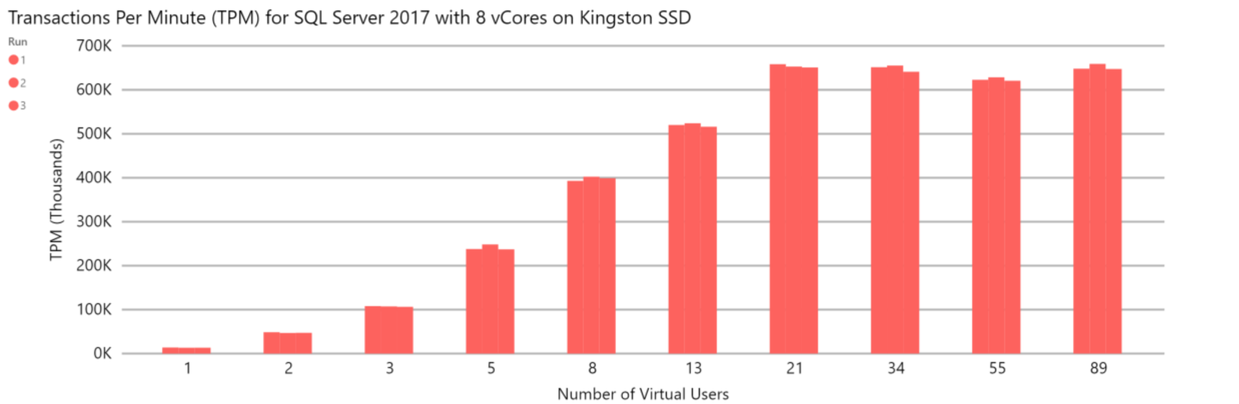
Version & vCores Tested	1	2	3	5	8	13	21	34	55	89	Total
SQL Server 2008 R2 with 16 vCores	2,190.00	6,417.00	11,850.67	24,625.33	61,998.67	255,313.33	463,491.67	269,545.00	372,499.00	507,390.33	**197,532.10**
SQL Server 2017 with 16 vCores	13,783.33	44,434.00	101,094.67	218,795.00	446,182.33	685,820.67	937,663.00	1,027,241.33	1,107,948.00	1,073,629.00	**565,659.13**

Figure 13 - Comparing SQL Server 2008 R2 on HDD vs SQL Server 2017 with DC500M drives with 16 vCores

The overall performance gain is dramatic. If users of the SQL Server 2008 R2 system were satisfied with their current performance, SQL Server 2017 with DC500M drives would amaze them. For consolidation and database upgrade projects, we look for ways to reduce costs for customers to get them to move to the latest version of SQL Server. Using DC500M drives makes it possible to reduce the vCores needed to get similar performance to their existing database solutions, due to the ability of the enterprise SSD to process more transactions with lower latency.

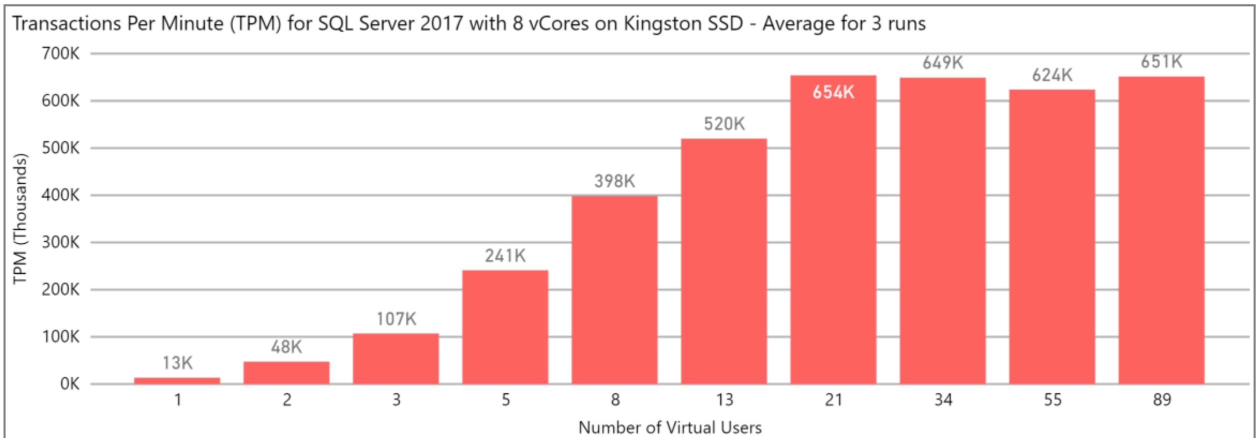
Results: SQL Server 2017 on DC500M 8 vCores

Our next iteration was to run the benchmark on a VM with only 8 vCores and the same 128GB of server DRAM. Based on our prior experience, we could have reduced the memory to 32GB and still seen similar results.



Run details for each user grouping for SQL Server 2008 R2 with 16 vCores on HDD

Run	1	2	3	5	8	13	21	34	55	89	Total
1	13,786	48,573	107,971	237,836	392,899	520,022	658,290	651,438	622,793	648,097	**3,901,705**
2	13,236	46,855	107,257	248,285	402,366	523,914	652,920	655,214	628,454	658,929	**3,937,430**
3	13,324	47,170	106,341	237,135	399,016	516,035	650,891	641,046	620,600	647,391	**3,878,949**
Total	**40,346**	**142,598**	**321,569**	**723,256**	**1,194,281**	**1,559,971**	**1,962,101**	**1,947,698**	**1,871,847**	**1,954,417**	**11,718,084**



1	2	3	5	8	13	21	34	55	89
13,448.67	47,532.67	107,189.67	241,085.33	398,093.67	519,990.33	654,033.67	649,232.67	623,949.00	651,472.33

For this test run, we kept track of the percentage of CPU used during the benchmark versus idle process time.

In chart below, the red line that starts with 94 for 1 user represents the percentage of system idle process. The green line represents the percentage of CPU time being used by SQL Server.

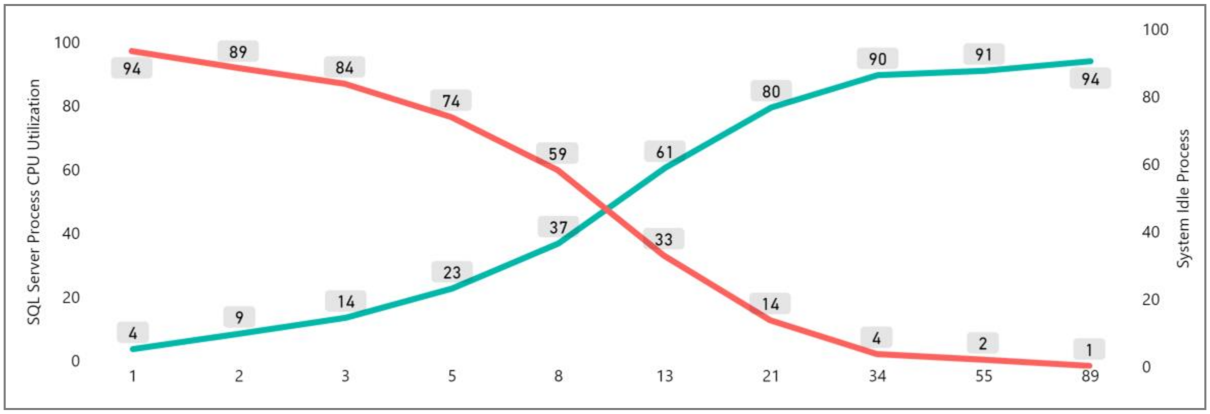


Figure 14 - SQL Server 2017 running with 8 vCores showing CPU vs idle time as a percentage

With a small number of users, SQL Server needs very little CPU to process the transaction requests. The system idle process at the lower end is mostly due to the efficiency of the Kingston DC500M drives. Essentially, the server is literally doing nothing.

As the number of users increases, CPU utilisation goes up until we start to reach CPU as a bottleneck. On the other hand, system idle processes are expected to go down as pure idle time decreases. However, another system idle process starts to creep in. This is the wait time that SQL Server needs to write data from memory into the transaction log file as the number of transactions starts to go up. This is actually a good thing.

This is essentially because the four RAID 10 drives can achieve up to 98,000 read/write IOPS with disk latency at 1.3 ms at the 99th percentile.

With 89 users, the system is running at an optimal throughout with 8 vCores with CPU at 94% and wait time of only 1%.

Contrast this with the following data from SQL Server 2018 R2 with 16 vCores and HDD.

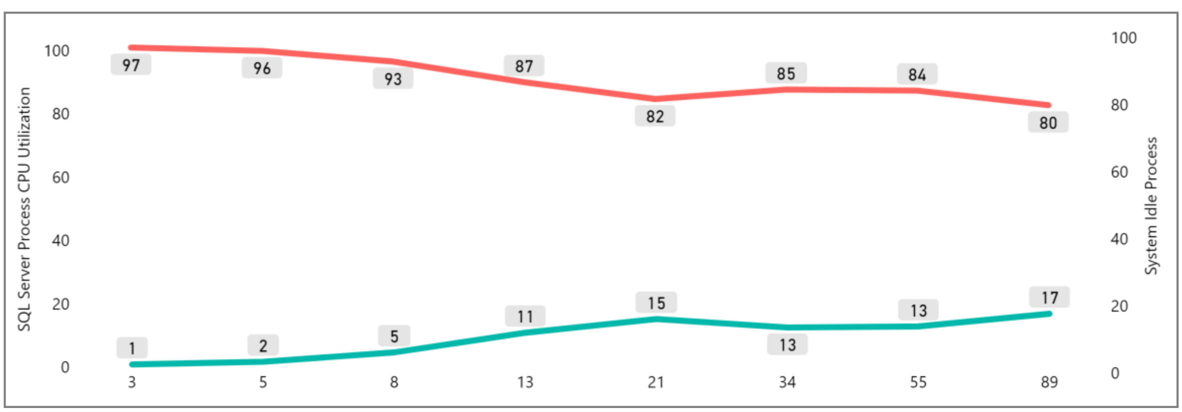
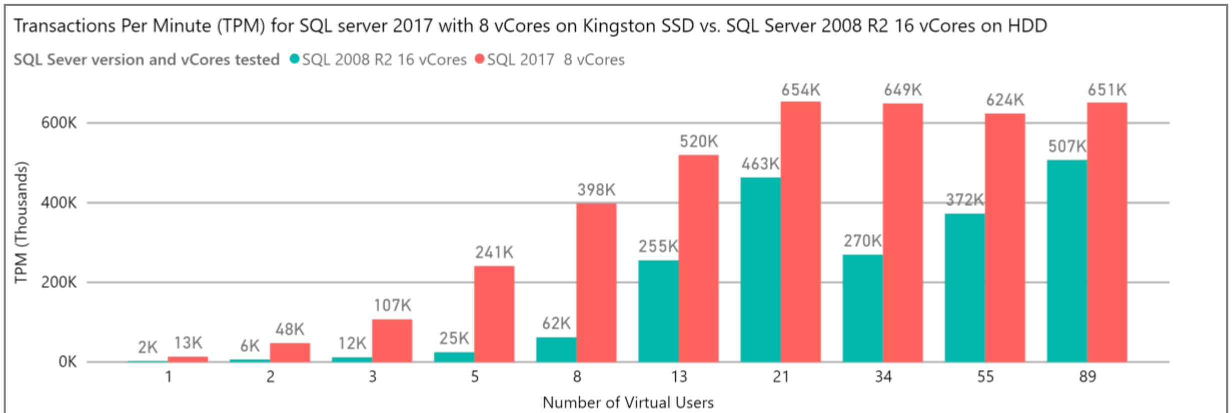


Figure 15 - SQL Server 2008 R2 running with 16 vCores showing CPU vs idle time as a percentage

CPU utilisation does not increase in the same way as with the SQL Server 2017 run because the other idle process at work is the wait time it takes for SQL Server 2008 R2 to read data from slower drives into its buffer pool cache. Since HammerDB is also issuing transactions at a high rate, SQL Server is also waiting on latches and locks due to the additional wait time.

For the HDD drives, the IOPS reported by Diskspd was only around 1900. That's more than 50 times slower than the Kingston DC500M drives!

The following is a side-by-side comparison of SQL Server 2008 R2 with 16 vCores versus SQL Server 2017 with only 8 vCores.



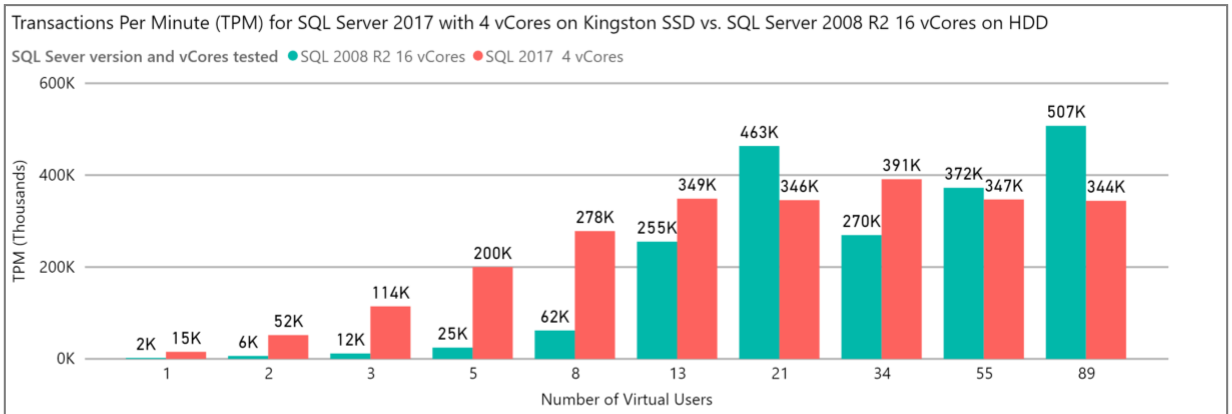
Release Cores	1	2	3	5	8	13	21	34	55	89	Total
SQL 2008 R2 16 vCores	2,190.00	6,417.00	11,850.67	24,625.33	61,998.67	255,313.33	463,491.67	269,545.00	372,499.00	507,390.33	**197,532.10**
SQL 2017 8 vCores	13,448.67	47,532.67	107,189.67	241,085.33	398,093.67	519,990.33	654,033.67	649,232.67	623,949.00	651,472.33	**390,602.80**

Figure 16 - Side-by-side comparison of SQL Server 2008 R2 with 16 vCores versus SQL Server 2017 with 8 vCores

While this shows great performance for SQL Server 2017, there is still room to cut the vCore count.

Results: SQL Server 2017 on DC500M 4vCores

To further understand how faster Kingston DC500M drives can reduce the cores needed for SQL Server, we reduced the cores to 4 vCores with 128 GB of RAM. The following chart shows the comparison in TPM with SQL Server 2008 R2 on HDD.

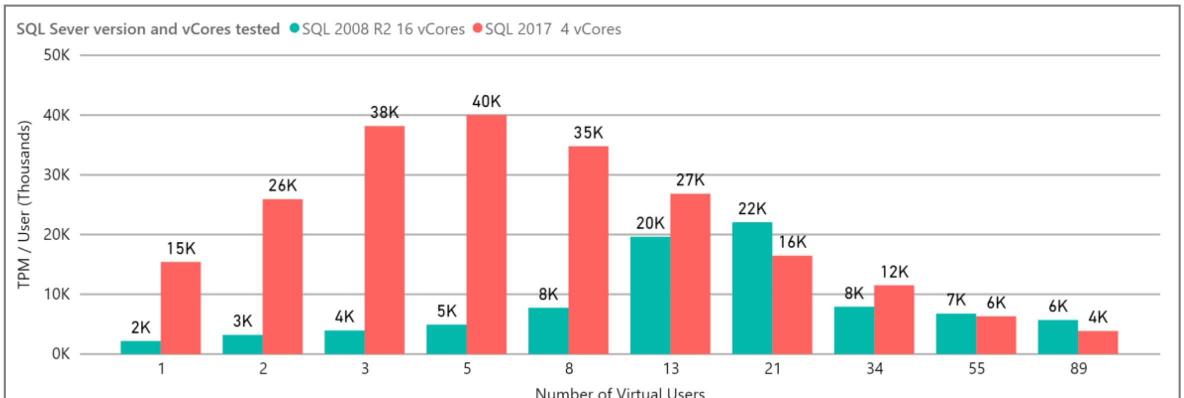


Release Cores	1	2	3	5	8	13	21	34	55	89	**Total**
SQL 2008 R2 16 vCores	2,190.00	6,417.00	11,850.67	24,625.33	61,998.67	255,313.33	463,491.67	269,545.00	372,499.00	507,390.33	**197,532.10**
SQL 2017 4 vCores	15,420.33	51,841.00	114,482.00	200,028.00	278,283.33	348,861.67	345,628.67	391,208.67	347,189.00	344,197.67	**243,714.03**

Figure 17 - Side-by-side comparison of SQL Server 2008 R2 with 16 vCores vs SQL Server 2017 with 4 vCores

This chart shows that for all users runs, the average TPM for SQL Server 2008 R2 was 197,532 versus 243,714 for SQL Server 2017 with only 4 vCores. Essentially, SQL Server 2017 using 4 vCores with Kingston DC500M drives is 1.2 time faster.

From a user perspective, the following chart shows the TPM/user for each of the user groups for SQL Server 2018 R2 with 16 vCores versus SQL Server 2017 with 4 vCores.



Run details for each user grouping for SQL Server 2008 R2 with 16 vCores on HDD

Release Cores	1	2	3	5	8	13	21	34	55	89	**Total**
SQL 2008 R2 16 vCores	6,570	9,626	11,852	14,777	23,251	58,920	66,214	23,785	20,320	17,105	**252,420**
SQL 2017 4 vCores	46,261	77,763	114,483	120,018	104,358	80,509	49,377	34,519	18,939	11,604	**657,831**

Figure 18 - Comparing TPM/user for SQL Server 2017 with 4 vCores and SQL Server 2008 R2 with 16 vCores

From a TPM/user perspective, one user in SQL Server 2008 R2 with 16 vCores on HDD was able to achieve 2,190 TPM. At 89 users, even though SQL Server 2008 R2 had 5,702 TPM/user, SQL Server 2017 with only 4 vCores and Kingston DC500M drives was able to sustain 3,868 TPM/user. From a user's perspective, SQL Server 2017 will still appear faster than SQL Server 2008 R2 by almost 1.8 times.

Conclusions

Workload consolidation increases the efficiency of IT organisations as well as cloud and hosting providers by harnessing the increasing power of modern host servers to support an increasing number of workloads. Increasing the workload density – the number of workloads running on a host server – drives the economics of consolidation, by reducing the number of host servers required to run a given number of workloads.

Kingston's high-performance data centre storage and memory solutions consisting of SSDs (DC500M) and server memory (Server Premier) enables a cost-per-performance that not only facilitates improved workload efficiencies, but can also optimise a business's profitability while reducing overall TCO (Total Cost of Ownership).

By reducing the number of host servers needed, you reduce both hardware and software licence costs. Software licence costs are critical to consider when evaluating potential savings, as shown in Appendix A – Bill of Materials for Test System, which provides the retail cost of the host server configurations used during this testing.

The software licence cost dominates the total system cost, primarily the cost of SQL Server Standard Edition per-core licences, accounting for 113% of the total system cost for 16 vCores.

Component	SQL Server 2017	SQL Server 2008 R2	SQL Server 2017 4 vCores	SQL Server 2017 8 vCores	SQL Server 2008 R2 16 vCores
Hardware Costs					
Dell PowerEdge R740XD Intel 4114 2400 MHz	$7,595.62	$7,595.62			
KTD-PE426/32G	$4,919.76	$4,919.76			
SEDC500M 960 GB SATA 6Gb/s	$1,815.92				
DELL 400-AJPI 1.2 TB SAS 1.2Gb/s		$1,560.00			
Sub total for hardware	**$14,331.30**	**$14,075.38**			
Software Costs					
Windows Server Data Center Edition	**$12,310.00**	**$12,310.00**			
SQL Server 2017 Standard			**$7,434.00**	**$14,868.00**	**$29,736.00**
Total			**$34,075.30**	**$41,509.30**	**$56,121.38**
Percentage of savings for the total server compared to SQL Server 2008 R2 with 16 vCores			**39%**	**26%**	**0%**
Savings in cost compared to SQL Server 2018 R2 with 16 vCores			**$22,046.08**	**$14,612.08**	**$0.00**
Savings in SQL Server licensing costs			**75%**	**50%**	**0%**
Percentage of the SQL Server license costs compared to the hardware and OS			**28%**	**56%**	**113%**

Figure 19 - Overall comparison of costs and how reducing vCores can dramatically lower your costs with DC500M drives

Greater workload consolidation using fewer cores means you will need fewer per-core licences – and you can achieve significant savings.

The high CPU utilisation with near-zero I/O latency indicates the SSD storage performance is high enough to keep the CPUs busy – even for the maximum user counts.

Next steps

Contact Kingston Technology for details of how Data Centre DC500 (DC500R / DC500M) Enterprise Solid-State Drives (SSDs) can optimise your business needs, improve your workload efficiencies and lower your TCO when migrating your Microsoft SQL Server 2008 workloads to SQL Server 2017.
Visit https://www.kingston.com/en/ssd/dc500-data-center-solid-state-drive to learn more about Kingston DC500 Enterprise SSDs. You can also use the Live Chat at https://www.kingston.com/en/support/technical/emailcustomerservice.

Get an assessment of your environment by DB Best

We expect no customer's host server configuration and workloads will be identical to our test environment, and the differences will affect the impact of these solutions. While we believe the assumptions and choices reflected in our test environment to be reasonable and representative, and the results we observed to reflect rigorous testing, we encourage any customer evaluating the applicability of these solutions to arrange for an assessment of their unique environment by contacting DB Best:

Reach us on the web at https://www.dbbest.com/company/contact-us/

Or contact Dmitry Balin, Dmitry@dbbest.com, or any of the paper's authors.

Appendix A – Bill of materials for test system

Server configurations

The following is a copy of the bill of materials for the Dell PowerEdge R740XD with two Intel Xeon Silver 4114 2.2G servers with a total of 20 physical cores / 40 virtual cores.

	PowerEdge R740XD - [amer_r740xd_12238] **Estimated delivery date:** Nov. 9, 2018	1	$7,595.62
210-AKZR	PowerEdge R740XD Server	1	-
329-BDKH	PowerEdge R740/R740XD Motherboard	1	-
461-AADZ	No Trusted Platform Module	1	-
321-BCRC	Chassis up to 24 x 2.5 Hard Drives including 12 NVME Drives, 2CPU Configuration	1	-
340-BLBE	PowerEdge R740XD Shipping	1	-
343-BBFU	PowerEdge R740 Shipping Material	1	-
338-BLUS	Intel Xeon Silver 4114 2.2G, 10C/20T, 9.6GT/s , 14M Cache, Turbo, HT (85W) DDR4-2400	1	-
374-BBPP	Intel Xeon Silver 4114 2.2G, 10C/20T, 9.6GT/s , 14M Cache, Turbo, HT (85W) DDR4-2400	1	-
412-AAIQ	Standard 1U Heatsink	1	-
412-AAIQ	Standard 1U Heatsink	1	-
370-ADNU	2666MT/s RDIMMs	1	-
370-AAIP	Performance Optimized	1	-
780-BCDS	Unconfigured RAID	1	-
405-AANR	PERC H740P RAID Controller, 8GB NV Cache, Adapter, Full Height	1	-
619-ABVR	No Operating System	1	-
421-5736	No Media Required	1	-
385-BBKT	iDRAC9,Enterprise	1	-
528-BCBW	iDRAC Digital License	1	-
379-BCQV	iDRAC Group Manager, Enabled	1	-
379-BCSF	iDRAC,Factory Generated Password	1	-
330-BBHD	Riser Config 6, 5 x8, 3 x16 slots	1	-
540-BBBW	Broadcom 5720 QP 1Gb Network Daughter Card	1	-
384-BBPZ	6 Performance Fans forR740/740XD	1	-
450-ADWS	Dual, Hot-plug, Redundant Power Supply (1+1), 750W	1	-
350-BBBW	No Bezel	1	-
389-BTTO	PE R740XD Luggage Tag	1	-
350-BBJV	No Quick Sync	1	-
750-AABF	Power Saving Dell Active Power Controller	1	-
770-BBBQ	ReadyRails Sliding Rails Without Cable Management Arm	1	-
631-AACK	No Systems Documentation, No OpenManage DVD Kit	1	-
332-1286	US Order	1	-
813-6068	Dell Hardware Limited Warranty Plus On-Site Service	1	-
813-6075	ProSupport: Next Business Day On-Site Service After Problem Diagnosis, 3 Years	1	-
813-6087	ProSupport: 7x24 HW/SW Technical Support and Assistance, 3 Years	1	-
989-3439	Thank you choosing Dell ProSupport. For tech support, visit //www.dell.com/support or call 1-800- 945-3355	1	-
900-9997	On-Site Installation Declined	1	-
973-2426	Declined Remote Consulting Service	1	-
370-ADNI	8GB RDIMM, 2666MT/s, Single Rank	2	-
400-ASEG	120GB SSD SATA Boot 6Gbps 512n 2.5in Hot-plug Drive, 1 DWPD, 219 TBW	2	-
400-AWLI	Intel 1TB, NVMe, Read Intensive Express Flash, 2.5 SFF Drive, U.2, P4500 with Carrier	1	-
450-AALV	NEMA 5-15P to C13 Wall Plug, 125 Volt, 15 AMP, 10 Feet (3m), Power Cord, North America	2	

Figure 20 - Dell PowerEdge R740XD bill of materials

Since Kingston Technology is a leading provider of memory for client and enterprise systems, we decided to use its KTD-PE426/32G memory module. The server used 24 modules that are currently listed on CDW[11] for $204.99 per module (as of XXX date). Total "retail" price for the server memory would be $4,919.76.

[11] List price of the Kingston Technology KTD-PE426/32G was retrieved from https://www.cdw.com/product/kingston-ddr4-32-gb-dimm-288-pin-registered/4862854?pfm=srh on 16 October 2019.

For the SQL Server 2017 test system, Kingston Technology provided 8 SEDC500M 960 GB SATA 6Gb/s drives. These drives are currently listed on CDW[12] for $226.99, for a total cost of $1,815.92 (as of XXX date).

For the SQL Server 2008 R2 test system, here is the attached bill of materials for 8 Dell 400-ATJL drives.

Billing Address	Shipping Address	Ship Method
Kingston Technology Company, Inc 17600 Newhope Street Fountain Valley CA, 92708 USA	, USA	Comments

Product ID	Description	Qty	Unit Price	Ext Amt
400-ATJL	DELL 10,000 RPM SAS HARD DRIVE 12GBPS 512N 2.5IN HOT-PLUG DRIVE - 1.2 TB,CK	8	$195.00	$1,560.00
	Pieces	8		
	Lines	1	Sub Total	$1,560.00
			Sales Tax	$0.00
			Freight	$0.00
			TOTAL	**$1,560.00**

Figure 21 - Bill of materials for 8 Dell 400-ATJL drives

The following table provides a summary of the hardware costs for the test systems.

Component	SQL Server 2017	SQL Server 2008 R2
Dell PowerEdge R740XD Intel 4114 2400 MHz	$7,595.62	$7,595.62
KTD-PE426/32G	$4,919.76	$4,919.76
SEDC500M 960 GB SATA 6Gb/s	$1,815.92	
DELL 400-AJPI 1.2 TB SAS 1.2Gb/s		$1,560.00
Total	**$14,331.30**	**$14,075.38**

Figure 22 - Hardware server costs

[12] List price for Kingston Technology SEDC500M/960G drives retrieved on 16 October 2019.

Software platforms

The system tested used Windows Server 2019 Data Center Edition and SQL Server 2017 Developer Edition. The licence costs shown below use SQL Server Standard Edition since it supports up to 24 cores and 128 GB of memory that SQL Server can use for its operating memory.

About SQL Server licensing

The SQL Server 2008 workloads envisioned in this solution used SQL Server 2008 Standard Edition and will continue to use the Standard Edition of SQL Server 2017.

When running several virtualised instances of SQL Server, there are several licensing strategies to consider[13].

- Each VM is licensed separately - each VM is licensed for Standard Edition, with a minimum of 4 core licences per VM (even for VMs using fewer than 4 virtual cores).
- Standard Edition "Open no level pricing (US$)" is $3,717 per 2 core pack[14].
- Typically, there is a 2-for-1 ratio of virtual cores (vCores) to physical cores with server hyper-threading technology that is available on the Dell PowerEdge R740XD processor.
- To license individual VMs using the Per Core model, customers must purchase a core licence for each v-core (or virtual processor, virtual CPU, virtual thread) allocated to the VM, subject to a four-core licence minimum per VM. For licensing purposes, a v-core maps to a hardware thread.

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[13] Additional information can be found in the SQL Server 2017 licensing guide at https://download.microsoft.com/download/7/8/C/78CDF005-97C1-4129-926B-CE4A6FE92CF5/SQL_Server_2017_Licensing_guide.pdf

[14] Pricing of SQL Server 2017 retrieved on 16 October 2019 from https://www.microsoft.com/en-us/sql-server/sql-server-2017-pricing

The following table shows the SQL Server licensing costs for VMs using the Per Core model with Standard Edition.

SQL Server Standard Edition 2-core pack	vCores to license	Licence cost
$3,717.00	4	$7,434.00
	8	$14,868.00
	16	$29,736.00

Figure 23 - Per Core licensing for VMs using Standard Edition

Clearly, reducing the number of vCores should be a priority when upgrading from SQL Server 2008 R2 to SQL Server 2017.

About Windows Server licensing

This system uses Windows Server 2019 Datacenter Edition; which also grants unlimited Hyper-V VMs per licensed server. Datacenter edition pricing is for 16 core licenses with a Pricing Open NL ERP (USD) of $6,155. Since each physical server had 20 cores, the cost for Window Server 2019 Datacenter Edition would be $12,310[15].

Total system costs

The following table shows the total costs of the hardware and software for the systems tested.

Component	SQL Server 2017	SQL Server 2008 R2	SQL Server 2017 4 vCores	SQL Server 2017 8 vCores	SQL Server 2008 R2 16 vCores
Hardware Costs					
Dell PowerEdge R740XD Intel 4114 2400 MHz	$7,595.62	$7,595.62			
KTD-PE426/32G	$4,919.76	$4,919.76			
SEDC500M 960 GB SATA 6Gb/s	$1,815.92				
DELL 400-AJPI 1.2 TB SAS 1.2Gb/s		$1,560.00			
Sub total for hardware	**$14,331.30**	**$14,075.38**			
Software Costs					
Windows Server Data Center Edition	**$12,310.00**	**$12,310.00**			
SQL Server 2017 Standard			**$7,434.00**	**$14,868.00**	**$29,736.00**
Total			**$34,075.30**	**$41,509.30**	**$56,121.38**
Percentage of savings compared to SQL Server 2008 R2 with 16 vCores			**39%**	**26%**	**0%**
Savings in cost compared to SQL Server 2018 R2 with 16 vCores			**$22,046.08**	**$14,612.08**	**$0.00**

Figure 24 - Total costs for running SQL Server 2008 R2 on HDD versus SQL Server 2017 with 4 and 8 vCores using Kingston DC500M drives

As you can see, by reducing the vCores from 16 to 8 needed to run SQL Server 2017 with Kingston Technology DC500M drives, you can use the savings to purchase a new server. With the further reduction of $7,434 by moving to 4 vCores, you can cover 60% of the Windows Server 2019 Datacenter edition licence costs.

[15] Windows Server 2019 Datacenter pricing retrieved on 16 October 2019 at https://www.microsoft.com/en-us/cloud-platform/windows-server-pricing

Table of figures

Trademarks