OPEN COMPOSABLE COMPATIBILITY LAB

Ultrastar® DC SN655 61.44TB SSD Test Results

The Third Party Test Results for the Ultrastar DC SN655 are based on a comprehensive evaluation to ensure compatibility, performance, and reliability performed by the Open Composable Compatibility Lab (OCCL). The assessment covers basic interoperability and specialized workload performance using industry-standard benchmarking tools.

For more information related OCCL, see: https://www.opencomposable.com/.

Drive Details

Drive	Ultrastar DC SN655[1]
Form Factor	U.3 15mm
Interface	PCIe® Gen4, NVMe™ 1.4
Security	SE
Power	16W, 20W (Default)
Power Idle	< 8W
Part Number	WUS5EC0C1ESP7Y1

The following table displays the status and results of the testing of a specific device. The four columns represent specific configurations which progressively increase in terms of complexity in the following order: Local benchmark x1 > Data24 x1 > Data24 x8 > Data24 x24. All devices will start with the Local x1 and Data24 x1. Poor performance or interoperability issues in any configuration can eliminate the device from further consideration. The individual tests are consistent with general industry practices and reporting. Western Digital's OpenFlex™ Data24 NVMe-oF™ Storage Platform extends the high performance of NVMe flash to shared storage. The storage platform provides low-latency sharing of NVMe SSDs over a high-performance Ethernet fabric to deliver similar performance to locally attached NVMe SSDs.

For additional information on Western Digital's OpenFlex Data24 NVMe-oF Storage Platform, see: https://www.westerndigital.com/products/data-center-platforms/openflex-data24-nvme-of-platform?sku=1ES2380.

Ultrastar DC SN655 61.44TB Top Line Performance

Test Description	Local x1	Data24 x1	Data24 x8	Data24 x24[2]
Read Bandwidth (128KB) MB/s	4,466	3,578	20,723	62,169
Write Bandwidth (128KB) MB/s	3,243	3,177	25,500	76,500
Random Read (4KB)K IOPS	903	839	6,969	20,908
Random Write (4KB) K IOPS	27	28	216	648
Random Mixed (4KB) K IOPS	82	84	646	1,937
4K Random Write Latency (µs)	29.9	34.0	21.8	21.8
4K Random Read Latency (µs)	108.2	105.9	105.9	105.9
4K Random Write 4-9s µs	302.1	310.6	381.4	381.4
4K Random Read 4-9s µs	307.9	303.8	309.2	309.2

[1] The Ultrastar DC SN655 SSD is available from SanDisk at: https://shop.sandisk.com/en-sg/products/ssd/internal-ssd/ultrastar-dc-sn655-nvme-ssd?sku=0TS2508.
[2] The x24 results are extrapolated from the x8 data. Given the highly independent nature of the Data24 architecture, these extrapolations are supported by the scaling trends in measured results and other historical observations.

Ultrastar DC SN655 SSD Test Results

The Normalized Test Results Table show the scalability from one to 24 devices using the Local x1 configuration as the baseline. With perfect linearity, the 8-device test would provide 8X the performance of the one device test and the 24-device test would provide 24X performance. For these charts, the baseline is always the Local x1 configuration therefore the value of the Local x1 configuration is set to 1.00X.

- IF = 1.00X: The same performance as the baseline.
- IF > 1.00X: Faster / Better performance than the baseline.
  - — Example: 2.00X is twice as fast as the baseline.
- IF < 1.00X: Slower / Worse performance than the baseline.
  - — Example: if the Normalized performance is 0.50X, then it is only one-half as fast as the Baseline.

The following table displays tests 2-4 normalized to test 1 (Local x1), the percentages in tests 2-4 should generally increase with more complex and larger configurations. The two QoS values (4-9s) by there stocastic behavior can have significant variability.

Ultrastar DC SN655 61.44TB Normalized to Local x1 Top Line Performance

Test Description	Local x1	Data24 x1[3]	Data24 x8	Data24 x24[4]
Read Bandwidth (128KB) MB/s	1.00X	**0.80X**	6.18X	13.92X
Write Bandwidth (128KB) MB/s	1.00X	0.98X	10.49X	23.59X
Random Read (4KB)K IOPS	1.00X	0.93X	5.62X	23.17X
Random Write (4KB) K IOPS	1.00X	1.04X	20.80X	24.30X
Random Mixed (4KB) K IOPS	1.00X	1.03X	15.85X	23.60X
4K Random Write Latency (µs)	1.00X	**0.88X**	1.41X	1.37X
4K Random Read Latency (µs)	1.00X	1.02X	1.03X	1.02X
4K Random Write 4-9s µs	1.00X	0.97X	9.53X	**0.79X**
4K Random Read 4-9s µs	1.00X	1.01X	1.00X	1.00X

Coefficients of Variation (CoV) are a standard statistical measure that are directly comparable to other CoVs as opposed to Standard Deviations (SD) that can only be compared if the mean is the same for two sets of data. CoV = SD/MEAN. NAND storage has a higher variability than DRAM, for example, that is highly consistent. NAND is a noise technology that has higher error rates than most solid state memory. Each manufacturing process has its own baseline error rate. These error rates are based on one second intervals provided by standard monitoring tools like iosstat.

Ultrastar DC SN655 61.44TB CoV Analysis

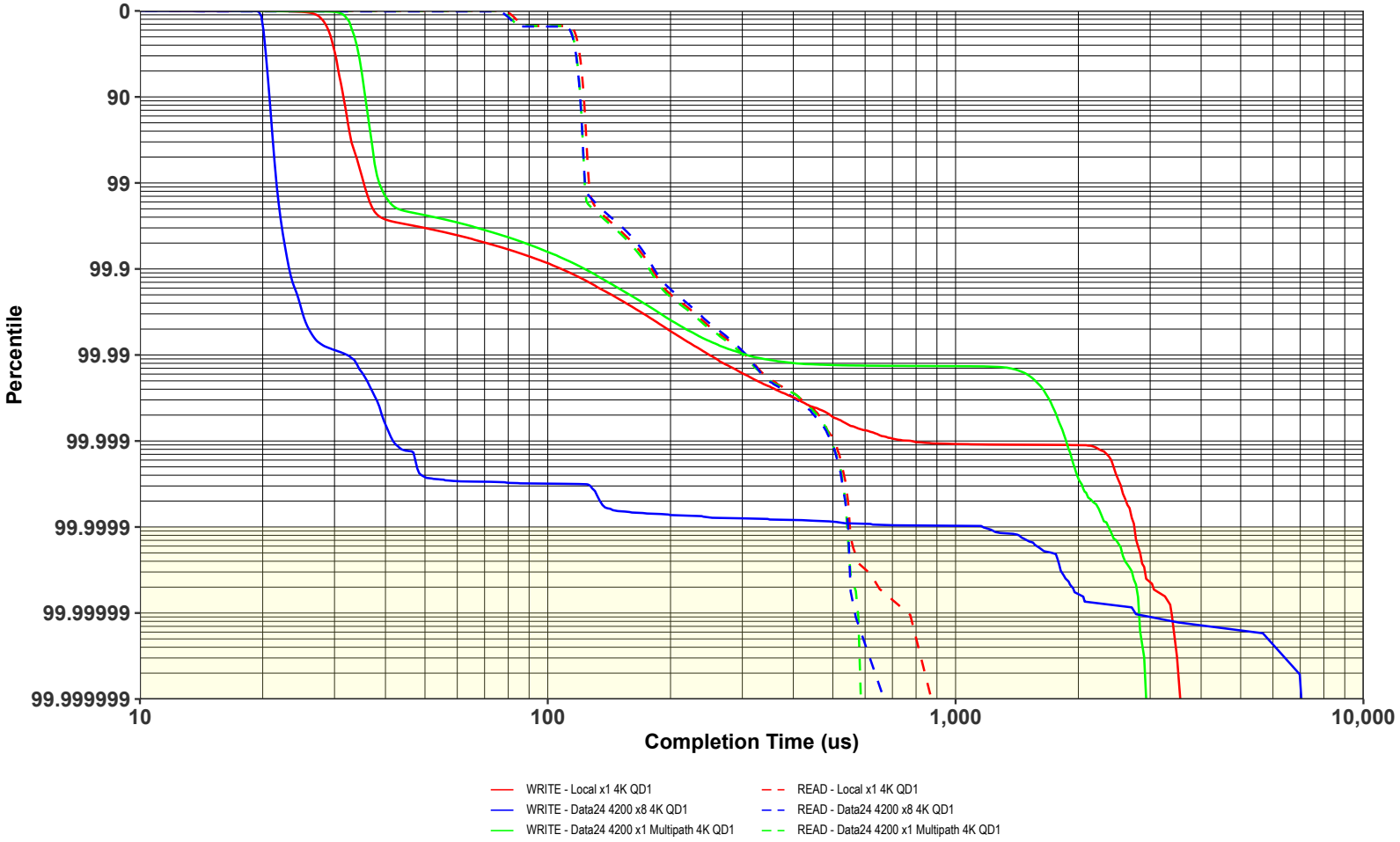
Test Description	Local x1[5]	Data24 x1[6]	Data24 x8[7]	Data24 x24[8]
Read Bandwidth (128KB) MB/s	0.04%	0.01%	0.38%	0.38%
Write Bandwidth (128KB) MB/s	0.22%	0.26%	0.02%	0.02%
Random Read (4KB)K IOPS	0.06%	0.75%	0.74%	0.74%
Random Write (4KB) K IOPS	0.07%	0.06%	0.01%	0.01%
Random Mixed (4KB) K IOPS	0.05%	0.08%	0.16%	0.16%
4K Random Write Latency (µs)	0.45%	0.47%	**2.62%**	**2.62%**
4K Random Read Latency (µs)	0.18%	0.11%	0.70%	0.70%
4K Random Write 4-9s µs	**12.10%**	**0.62%**	**14.78%**	**14.78%**
4K Random Read 4-9s µs	0.63%	0.64%	0.31%	0.31%

[5] The black values indicate X < 2%, blue values indicate 2% < X < 5%, and red values indicate X > 5%.
[4,8] The x24 results are extrapolated from the x8 data. Given the highly independent nature of the Data24 architecture, these extrapolations are supported by the scaling trends in measured results and other historical observations.
[6,7] The blue values indicate that if the Data24 x24 performance is less than 1X, the Local x1 performance is better.

Exceedance Chart

The following charts contain the most technical and most accurate information. Exceedance charts are typically used for only single drive, single process, queue depth one analysis as in the following example. The chart is the most fundamental measurement of SSD or disk performance as it shows the minimum latency as well as the expected error rate and latency for the device under test. These results are often referred to as the “number of nines”. For example, “4-9s” shows the latency or response time for 9999 of 10000 IOs. The number of IOs grows exponentially with the increase in the number of nines. The last two rows of the Top Line Performance Chart provides the 4-9s values for 4K Random Reads and Writes. Random writes are faster than random reads, because random writes are cached in the asynchronous write buffer and are periodically written to the underlying NAND media. Exceedance charts can be run and compared as long as all tests were run on similar systems using the same workload.

Latency Exceedance for Ultrastar DC SN655 61.44TB



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