KIOXIA

Performance Brief

Improving Data Analytics Performance with KIOXIA PM7 Series Enterprise SAS SSDs Compared with Enterprise SAS HDDs

Introduction

Many organizations use data analytics to gain valuable insights from the large amounts of data they collect from their data centers. To efficiently collect and analyze this data requires high throughput to handle the complex queries needed for data analysis. Legacy hard disk drives (HDDs) which can use fast storage interfaces, such as SAS, are limited by slow rotational speeds which depend on mechanical read and write heads that can cause very high latency and low throughput. Faster storage media that utilize NAND flash memory becomes necessary to fully take advantage of these storage interface speeds to support these advanced queries.

As many datasets are shared by several users, there's a need for fast access to this data from one central location. A managed storage area network (SAN) is a centralized storage system, which can be composed of multiple HDDs or SSDs that provides a pool of storage capacity managed by dedicated controllers and software. It offers managed uptime, reliability, scalability, data redundancy and security, and is a good system to use for a data analytics comparison.

An HPE MSA 2070 SAN was used to test the difference in performance between an all-flash SSD configuration and an all-HDD configuration. The system provides two controllers in an active-active configuration which are attached to two storage enclosures that allow for all-HDD, all-flash or hybrid-based storage solutions. It also provides data redundancy by offering several RAID protections, such as Modular Smart Arrays Data Protection Plus (MSA-DP+), which is an advanced RAID technology that distributes spare capacity across all drives in a disk group, enabling faster rebuild times.

KIOXIA PM7 Series Enterprise SAS SSDs are optimized for read-intensive applications and well suited for data-intensive workloads, such as data analytics, that require high throughput and low latency. The HPE MSA 2070 was equipped with two 12 gigabit per second (Gbit/s) SAS-3 cables. The KIOXIA PM7 Series Enterprise SAS SSDs are dual ported and backwards compatible with earlier SAS generations and enabled the HPE MSA 2070 to utilize both SSD and HDD configurations at the same interface speed[1]. This highlights the performance differences between an all-SSD configuration and an all-HDD configuration.

This performance brief presents presents a drive performance comparison using a data analytics workload that compares KIOXIA PM7-R Series Enterprise SAS SSDs with enterprise SAS HDDs (Vendor A) configured in an MSA-DP+ storage pool. HammerDB[2] test software was used for each drive configuration that enabled the TPROC-H[3] data analytics queries to run against an Oracle® database. The TPROC-H workload was created with a scale factor of 1,000, which was then run with one virtual user that performed the queries in succession against the database, and then seven virtual users that performed the same series of queries in parallel against the database. Each virtual user performed 22 different analytical query requests. The drive-level metrics included 'Maximum Read Throughput' and 'Maximum Read Latency' while the database metrics included 'Geometric Mean of Query Completion Times' and 'Completion Time for Entire Query Set.'

The test results show that with an all-flash configuration, the KIOXIA PM7-R Series Enterprise SAS SSDs delivered significant performance improvements when compared with the Vendor A SAS HDDs. These SAS SSDs were able to fully saturate the available throughput from the HPE MSA 2070 to the client server and delivered a significant boost when accelerating data analytics workloads in parallel from multiple users who sent queries concurrently.

Test Results Snapshot

KIOXIA PM7-R Series Enterprise SAS SSDs delivered the following performance results when compared with enterprise SAS HDDs from Vendor A:

Maximum Read Throughput
(higher is better)

1 Virtual User	7 Virtual Users
2.07x Higher	2.14x Higher

Maximum Read Latency
(lower is better)

1 Virtual User	7 Virtual Users
3.5x Lower	7x Lower

Geometric Mean of Query Completion Times
(lower is better)

1 Virtual User	7 Virtual Users
2.35x Lower	2.06x Lower

Completion Time for Entire Query Set
(lower is better)

1 Virtual User	7 Virtual Users
2.43x Lower	2.47x Lower

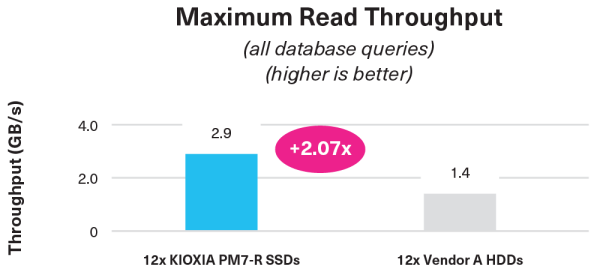
The results include a brief description of each workload test, a graphical depiction of the test results and an analysis. Appendix A covers the hardware and software test configurations. Appendix B covers the configuration setup and test procedures.

Test Results[4]

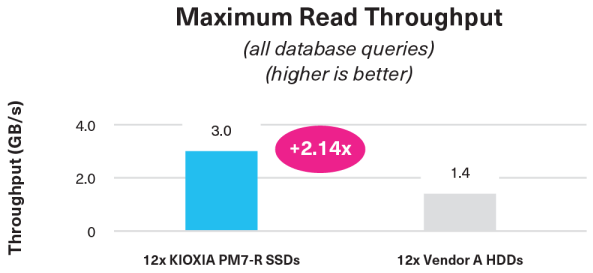
Test 1: Maximum Read Throughput

This test seeks to find the maximum read throughput that each of the drive configurations participating in the MSA-DP+ RAID set can achieve when running the underlying query set. It specifically highlights how different storage drive configurations of the HPE MSA 2070 SAN can impact the ability to speed up and run complex data analytics queries.

The read throughput was monitored while the HammerDB TPROC-H workload was run against the Oracle® database. The workload ran 22 different queries for each virtual user assigned, in a random order. For example, with 1 virtual user, this test performed the 22 queries in the query set randomly. For 7 virtual users, each individual virtual user performed the query set in a random order, for a total of 154 queries executed within the span of this test. The results are based on three test runs where the maximum of the three runs is reported in GB/s. The higher result is better.



1 Virtual User



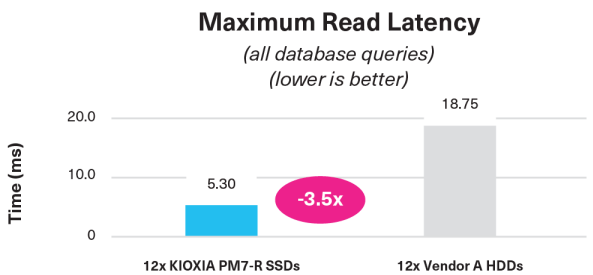
7 Virtual Users

The maximum read throughput achieved with 1 virtual user by the all-SSD configuration was 2.07x faster than the all-HDD configuration. The HPE MSA 2070 was equipped with two 12 Gbit/s cables to the client server, which meant that a throughput maximum of 3.0 gigabytes per second (GB/s) could be achieved. The all-SSD configuration was almost able to completely saturate the maximum throughput capable of the two 12 Gbit/s cables, while the all-HDD configuration was only able to use approximately half of the capable throughput.

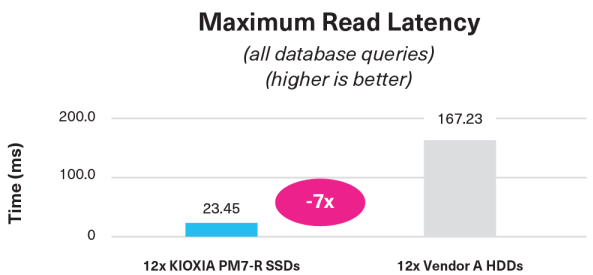
Once the virtual user count was increased to 7, the all-SSD configuration was still able to perform 2.14x faster than the all-HDD configuration. The all-SSD configuration was able to completely saturate the maximum capable throughput of the two 12 Gbit/s cables. Meanwhile, the all-HDD configuration peaked at the same 1.4 GB/s that was achieved by 1 virtual user. This result shows that the all-HDD configuration introduced a bottleneck to the system, which impacts the ability to process and serve large amounts of data simultaneously and can introduce significant degradation in performance, which in turn increases the time it takes to complete the queries in the query set.

Test 2: Maximum Read Latency

This test shows the maximum time it took to perform a read operation to the underlying RAID set in the HPE MSA 2070 SAN during the test run. The read latency includes the time it took for the read operation to successfully complete once the RAID set received the read operation request issued from the workload generator. The read latency was recorded over the timeframe of the run, and the highest latency value was reported. The results are based on three test runs where the maximum of the three runs is reported in milliseconds (ms) and are performed with both 1 and 7 virtual users. The lower result is better.



1 Virtual User



7 Virtual Users

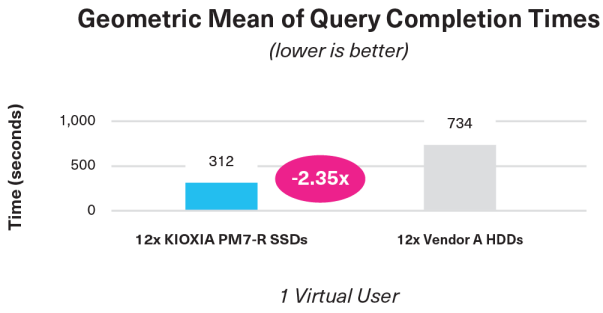
Many complex queries often include large joins and data aggregations which require scanning large amounts of data. This data can be spread randomly across storage media, as the ad-hoc nature of the queries typically involves on-the-fly answers to specific questions that require access to large datasets. Since data analytics queries can occur over data that is spread out across the underlying RAID set, this can quickly turn into a random read workload for the drives.

HDD performance significantly degrades when trying to handle random requests due to their mechanical design. Many seeks must occur to get to the right parts of the platters that have the data that need to be read. These configurations can be severely handicapped by the seek time of the actuator arm to physically read across the platters to the right track. In addition to the head being in the right position, the platter must rotate for the proper data sector to get in position under the head. Limitations on rotations per minute (RPM) speeds of HDDs can also increase the time it takes to get the data needed. These issues do not appear with SSDs as they are not limited by moving parts, and where integrated circuits and flash memory chips store the data electronically.

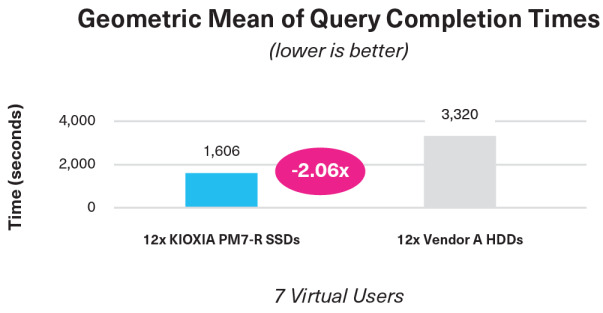
With 1 virtual user, the all-HDD configuration already had nearly 3.5x the maximum read latency when compared to the all-SSD configuration. This difference is even higher when compared with 7 concurrent virtual users, where the maximum read latency of the all-HDD configuration is over 7x the amount of the all-SSD configuration. These slow read access times from the all-HDD configuration ultimately add increased delays when processing the queries and add to the database query latency.

Tests 3 & 4: Geometric Mean of Query Completion Times and Completion Time for Entire Query Set

The geometric mean of query completion time (Test 3) shows the time it took to complete the queries in the query set. For 1 virtual user, this would be the geometric mean across the 22 queries in the query set. For 7 virtual users, this would be the geometric mean of the time required for each of the queries in the query sets to be processed by seven different virtual users. The results are based on three test runs where the maximum of the three runs is reported in seconds. The lower result is better.



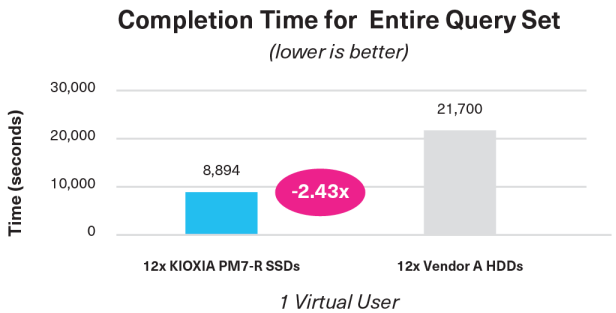
1 Virtual User



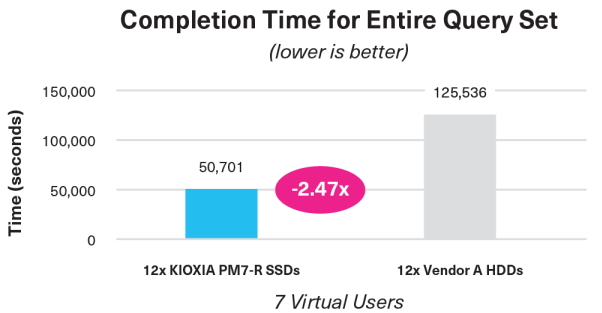
7 Virtual Users

The geometric mean of query completion times was impacted by the read throughput and latency capabilities of the all-SSD and all-HDD configurations respectively. With 1 virtual user, the all-SSD configuration was able to decrease the mean time to complete a query by almost half due to its lower latency and higher read throughput capabilities. A similar pattern was seen even when handling more queries concurrently with 7 virtual users.

The completion time for the entire query set (Test 4) is the total amount of time it took for each user to complete every query in the query set. For 1 virtual user, this is the time it took for that user to complete all 22 queries in the query set. For 7 virtual users, this is the entire time it took for all 7 virtual users to complete all 22 queries in their respective query set. The results are based on three test runs where the maximum of the three runs is reported in seconds. The lower result is better.



1 Virtual User



7 Virtual Users

As the workload ramped up, the all-SSD configuration delivered low latency, emphasizing that as more analytics were run in parallel, these SSDs returned faster query results when compared to the enterprise SAS HDDs. In many scenarios, datasets are shared and accessed by multiple concurrent users at once. When the tests were run with 7 virtual users, the disparity between the all-SSD and all-HDD configurations in overall completion time of the queries was even larger.

The results also showed that the HPE MSA 2070 all-SSD configuration was able to keep up and scale well with a rising number of users, delivering much lower latency when compared to the all-HDD configuration. The all-SSD configuration was able to service and handle more requests concurrently when compared to the all-HDD configuration. The KIOXIA PM7-R Series Enterprise SAS SSDs delivered this low latency, emphasizing that as more analytics were run in parallel, these drives delivered much faster query results versus the enterprise SAS HDDs.

With the reduced geometric means, as well as total completion time for the entire query set from the all-SSD configurations, applications that are having their storage serviced by an all-SSD configuration backed by KIOXIA PM7-R Series Enterprise SAS SSDs will be snappier and more responsive. These drives also can complete a diverse set of queries simultaneously by multiple users, showing that they are better equipped to scale an application up for various user data analytic needs when compared to enterprise SAS HDDs.

Analysis

Summation of the test results:

1 Virtual User / Scale Factor = 1,000

Test	KIOXIA PM7-R Enterprise SAS SSDs	Vendor A Enterprise SAS HDDs	KIOXIA PM7-R Advantage
Maximum Read Throughput *(higher is better)*	2.9 GB/s	1.4 GB/s	2.07x
Maximum Read Latency *(lower is better)*	5.30 ms	18.75 ms	3.5x
Geometric Mean of Query Completion Times *(lower is better)*	312 seconds	734 seconds	2.35x
Completion Time for Entire Query Set *(lower is better)*	8,894 seconds	21,700 seconds	2.43x

7 Virtual Users / Scale Factor = 1,000

Test	KIOXIA PM7-R Enterprise SAS SSDs	Vendor A Enterprise SAS HDDs	KIOXIA PM7-R Advantage
Maximum Read Throughput *(higher is better)*	3.0 GB/s	1.4 GB/s	2.14x
Maximum Read Latency *(lower is better)*	23.45 ms	167.23 ms	7x
Geometric Mean of Query Completion Times *(lower is better)*	1,606 seconds	3,320 seconds	2.06x
Completion Time for Entire Query Set *(lower is better)*	50,701 seconds	125,536 seconds	2.47x

When compared with Vendor A enterprise SAS HDDs for one virtual user, the KIOXIA PM7-R Series Enterprise SAS SSDs:

- *Delivered a maximum of 2.9 GB/s of drive read throughput, or 2.07x higher throughput*
- *Delivered a maximum of 5.30 ms of drive read latency, or 3.5x lower latency*
- *Completed each query in the query set in 312 seconds, or 2.35x faster completion times*
- *Completed the entire analytics query set in a total time of 8,894 seconds, or 2.43x faster completion times*

When compared with Vendor A SAS HDDs for seven virtual users, the KIOXIA PM7-R Series Enterprise SAS SSDs:

- *Delivered a maximum of 3.0 GB/s of drive read throughput, or 2.14x higher throughput*
- *Delivered a maximum of 23.45 ms of drive read latency, or 7x lower latency*
- *Completed each query in the query set in 1,606 seconds, 2.06x faster completion times*
- *Completed the entire analytics query set in a total time of 50,701 seconds, or 2.47x faster completion times*

Summary

This performance brief presented a drive performance comparison using a HammerDB TPROC-H data analytics workload with KIOXIA PM7-R Series Enterprise SAS SSDs and enterprise SAS HDDs from a leading provider using an HPE MSA 2070 storage array.

The HPE MSA 2070 was able to support this workload alongside the KIOXIA PM7-R Series Enterprise SAS SSDs. It allows for up to 2x more input/output operations per second (IOPS) of random performance and 30% more bandwidth of sequential performance as compared to the previous generation HPE MSA Gen6 Storage solution. The HPE MSA 2070 can scale beyond 7 petabytes[5] (PB) per array by adding up to 9 MSA 2U 12-drive and/or 24-drive expansion enclosures and new high-capacity HDD and SSD MSA media options. Users have the choice of using various networking options such as 32 gigabit[6] (Gb) Fibre Channel host connectivity or direct 12 Gbit/s SAS storage connections. These features allow businesses to start small and scale their storage as needed using a 'grow as you go' model.

Testing showed that KIOXIA PM7-R Series Enterprise SAS SSDs were able to accelerate data analytics workloads faster when compared with the enterprise SAS HDD configuration. With their high read throughput, KIOXIA PM7-R Series Enterprise SAS SSDs can effectively enable multiple users to concurrently perform advanced query analytics, and their high storage capacities can hold large databases for which these analytics will be performed on. Compared with enterprise SAS HDDs that are limited by slow rotational speeds dependent on mechanical read and write heads, KIOXIA PM7-R Series Enterprise SAS SSDs deliver lower read latency, resulting in faster querying completion times and reduced waiting periods for data retrieval.

Organizations using KIOXIA PM7-R Series Enterprise SAS SSDs would be provided with meaningful insights that enable better informed decisions much faster than enterprise SAS HDDs.

KIOXIA PM7 Series Enterprise SAS SSD Product Info

The KIOXIA PM7 Series is the 2nd generation of 24G SAS SSDs that leverages 112-layer BiCS FLASH™ 3D flash memory technology in a 2.5-inch form factor. The series is available in two configurations: (1) PM7-R Series for read-intensive applications and supports 1.92 terabyte[5] (TB) up to 30.72 TB capacities at 1 Drive Write Per Day[7] (DWPD); and (2) PM7-V Series for higher endurance mixed-use applications and supports 1.6 TB up to 12.8 TB capacities at 3 DWPD.

The PM7 Series represents KIOXIA's 7th enterprise SAS SSD generation that builds on the company's successes as a leading SAS SSD provider. More information available here.

KIOXIA PM7 Series Enterprise SAS SSD[8]

Appendix A

Hardware/Software Test Configuration

Load Generating Server Information	
Server Model	HPE ProLiant DL385 Gen10 Plus v2
No. of Servers	1

CPU Information	
CPU Model	AMD EPYC™ 7543
No. of Sockets	2
No. of Cores	32
Frequency *(in gigahertz)*	2.8 GHz

Memory Information	
Memory Type	DDR4
Memory Speed	DDR4-3200
Memory Size	256 GB

Storage Information		
Drive Model	KIOXIA PM7-R Series	Vendor A
Form Factor	2.5-inch	2.5-inch
Interface	SAS-4	SAS-3
Interface Speed	12 Gbit/s	12 Gbit/s
No. of Drives	12	12
Drive Capacity	7.68 TB	1.2 TB
Drive Writes per Day	1	1
Active Power	up to 5 watts	up to 4.88 watts

Operating System Information	
Operating System (OS)	Red Hat® Enterprise Linux® release 9.2 (PLOW)
OS Kernel	5.14.0-284.30.1.e19_2.x86_64

Database Software Information	
Database Model	Oracle® Database Enterprise Edition
Database Version	19c-1.0-1

Test Software Information	
Test Software Model	HammerDB
Benchmark	TPROC-H
Version	5.0
Scale Factor	1,000
No. of Virtual Users	1 or 7
Degrees of Parallelism	7

Appendix B

Configuration Setup/Test Procedures

Configuration Setup

An HPE MSA 2070 was set up and installed with 12 KIOXIA PM7-R Series Enterprise SAS SSDs and 12 enterprise SAS HDDs from Vendor A in one managed storage array enclosure.

Through the HPE MSA 2070 SAS Storage Management Utility, a storage pool was created using the 12 drives installed in the previous step.

A disk group was created from the storage pool, where an MSA-DP+ RAID set was created on the 12 drives.

A volume was created from the disk group that utilized the entire capacity available from the MSA-DP+ RAID set.

An HPE ProLiant DL385 Gen10 Plus v2 server was set up as a load generator and created as an initiator on the HPE MSA 2070. The volume was then attached to this host.

Red Hat® Enterprise Linux® 9 was installed on the HPE ProLiant DL385 Gen10 Plus v2 server, and the volume was then mounted.

Oracle® 19c was installed on the mounted volume and the database was tested via HammerDB software. A scale factor of 1,000 was used to emulate a very large database which analytics can be performed on.

Test Procedures

The HammerDB TPROC-H workload was then run against the Oracle instance.

Tests were run to record the query processing power of queries in a single stream (1 Virtual User) that performs advanced analytic queries in succession against the database under test. Tests were also run to record total query throughput from multiple concurrent users (7 Virtual Users) who perform advanced analytic queries in parallel against the database under test. The tests included:

Drive-level Tests:
- *Maximum Read Throughput (in GB/s)*
- *Maximum Read Latency (in ms)*

Database Tests:
- *Geometric Mean of Query Completion Times (in seconds)*
- *Completion Time for Entire Query Set (in seconds)*

The tests were run three times, and the maximum results of the three test runs were recorded.

NOTES:

[1] KIOXIA PM7 Series Enterprise SAS SSDs utilize a SAS-4 interface, which can have interface speeds up to 22.5 Gbit/s, but also support 12 Gbit/s interface speeds that the HPE MSA 2070 system controllers utilize. The HPE MSA 2070 cabling configuration used to generate the reported results in this performance brief was limited by two 12 Gbit/s SAS cables connected to the client server. The actual reported results are based on KIOXIA PM7 Series Enterprise SAS SSDs performing at an interface speed of 12 Gbit/s in dual port mode.

[2] HammerDB is benchmarking and load testing software that is used to test popular databases. It simulates the stored workloads of multiple virtual users against specific databases to identify transactional scenarios and derive meaningful information about the data environment, such as performance comparisons.

[3] TPROC-H is the decision support workload implemented in HammerDB derived from the TPC-H™ specification with modification to make running HammerDB straightforward and cost-effective on any of the supported database environments. The HammerDB TPROC-H workload is an open-source workload derived from the TPC-H Benchmark Standard and as such is not comparable to published TPC-H results, as the results do not comply with the full TPC-H Benchmark Standard. TPROC-H means Transaction Processing Benchmark derived from the TPC "H" specification.

[4] Read and write speed may vary depending on the host device, read and write conditions and file size.

[5] Definition of capacity: Kioxia Corporation defines a megabyte (MB) as 1,000,000 bytes, a gigabyte (GB) as 1,000,000,000 bytes, a terabyte (TB) as 1,000,000,000,000 bytes and a petabyte (PB) as 1,000,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1 Gb = 2^{30} bits = 1,073,741,824 bits, 1 GB = 2^{30} bytes = 1,073,741,824 bytes, 1 TB = 2^{40} bytes = 1,099,511,627,776 bytes and 1 PB = 2^{40} bytes = 1,125,899,906,842,624 bytes and therefore shows less storage capacity. Available storage capacity (including examples of various media files) will vary based on file size, formatting, settings, software and operating system, and/or pre-installed software applications, or media content. Actual formatted capacity may vary.

[6] Product density is identified based on the density of memory chip(s) within the Product, not the amount of memory capacity available for data storage by the end user. Consumer-usable capacity will be less due to overhead data areas, formatting, bad blocks, and other constraints, and may also vary based on the host device and application. For details, please refer to applicable product specifications. The definition of 1 KB = 2^{10} bytes = 1,024 bytes. The definition of 1 Gb = 2^{30} bits = 1,073,741,824 bits. The definition of 1 GB = 2^{30} bytes = 1,073,741,824 bytes. 1 Tb = 2^{40} bits = 1,099,511,627,776 bits.

[7] DWPD: Drive Write(s) Per Day. One full drive write per day means the drive can be written and re-written to full capacity once a day, every day, for the specified lifetime. Actual results may vary due to system configuration, usage, and other factors.

[8] The product image shown is a representation of the design model and not an accurate product depiction.

TRADEMARKS:

AMD EPYC and combinations thereof are trademarks of Advanced Micro Devices, Inc. HPE and ProLiant are registered trademarks of Hewlett Packard Enterprise Company and/or its affiliates. Oracle is a registered trademark of Oracle and/or its affiliates. Red Hat Enterprise Linux are registered trademarks of Red Hat, Inc. registered in the United States and other countries. TPC-H is a trademark of the Transaction Processing Performance Council. All other company names, product names and service names may be trademarks or registered trademarks of their respective companies.

DISCLAIMERS:

KIOXIA America, Inc. may make changes to specifications and product descriptions at any time. The information presented in this performance brief is for informational purposes only and may contain technical inaccuracies, omissions and typographical errors. Any performance tests and ratings are measured using systems that reflect the approximate performance of KIOXIA America, Inc. products as measured by those tests. Any differences in software or hardware configuration may affect actual performance, and KIOXIA America, Inc. does not control the design or implementation of third party benchmarks or websites referenced in this document. The information contained herein is subject to change and may render inaccuracies for many reasons, including but not limited to any changes in product and/or roadmap, component and hardware revision changes, new model and/or product releases, software changes, firmware changes, or the like. KIOXIA America, Inc. assumes no obligation to update or otherwise correct or revise this information.

KIOXIA America, Inc. makes no representations or warranties with respect to the contents herein and assumes no responsibility for any inaccuracies, errors or omissions that may appear in this information.

KIOXIA America, Inc. specifically disclaims any implied warranties of merchantability or fitness for any particular purpose. In no event will KIOXIA America, Inc. be liable to any person for any direct, indirect, special or other consequential damages arising from the use of any information contained herein, even if KIOXIA America, Inc. are advised of the possibility of such damages.