KIOXIA

Technical Brief

The New Life After SATA: Evaluating Good, Better and Best SSDs for Today's Workloads and Applications

Data centers worldwide strive to keep up with data-intensive storage and computing demands, requiring modern technologies that can deliver high performance and low latency for a variety of applications and workloads. SSDs play a big part in today's underlying storage within general-purpose servers and all-flash arrays, and are designed around interface standards such as Serial Advanced Technology Attachment (SATA), Serial Attached SCSI (SAS), and NVM Express® (NVMe®) with Peripheral Component Interconnect Express (PCIe®). Of these three common SSD interfaces, SATA data transfer performance and latency are least-suited for modern computational applications.

Here's why. The current SATA Revision 3.0 interface is only capable of delivering up to 6 gigabits per second (Gb/s) of data transfer, representing the lowest interface speed when compared to PCIe and SAS interfaces. SSDs based on SATA are built upon an HDD legacy, rather than optimized for flash memory, which is the current dominant storage technology in data centers. Also, the SATA interface can only transfer data using one lane in one direction (half-duplex), which can lead to bottlenecks in servers or storage arrays, especially those equipped with fast CPUs and high-speed DRAM. In this scenario, powerful multicore processors and an abundance of RAM will be waiting for data transactions (reads or writes) to complete which can result in an underutilization of compute resources and high ownership costs.

As the SATA interface is stalled at 6 Gb/s half-duplex data transfer performance, the PCIe interface continues to advance, innovate and deliver overwhelmingly higher bandwidth. Additionally, the current 24G SAS interface already delivers 4x the bandwidth of the SATA interface. SSDs based on these interface specifications are better positioned to keep pace with today's server and storage demands while providing advanced benefits that enable users to match the right SSDs to their application and workload requirements. As SAS and PCIe SSDs set a new bar for today's storage performance and latency, this tech brief presents today's Good-Better-Best SSD choices that leave no room for legacy SATA SSDs. These SSD choices include value SAS SSDs (a good option); PCIe data center NVMe™ SSDs (a better option), and PCIe enterprise NVMe SSDs (the best option).

Value SAS SSDs: A Good Performance Option and Direct SATA Replacement

Value SAS is the newest category of SAS SSD that moves data using the 12 Gb/s SAS-3 interface. Since most servers ship with a SAS infrastructure, value SAS and enterprise SATA SSDs can be used in the same drive bay. As an easy, cost-effective upgrade, slower performing SATA SSDs can be easily replaced with higher performing value SAS SSDs without any changes to the server or infrastructure.

From a performance perspective, value SAS is built upon a 12 Gb/s SAS interface, delivering twice the performance of 6 Gb/s SATA. Using published specifications[1] for KIOXIA RM7 Series Value SAS SSDs, and those from a leading enterprise SATA SSD provider (Vendor A)[2], the performance capabilities of each SSD class compares as:

Read or Write Operation		KIOXIA RM7 Series 12 Gb/s Value SAS	Vendor A 6 Gb/s SATA	Value SAS Gains
Sequential Read	*(in MB/s*)*	up to 1,100	up to 550	100% or 2x
Sequential Write	*(in MB/s)*	up to 1,050	up to 520	101% or 2x
Random Read	*(in IOPS^)*	up to 190K	up to 98K	93% or 1.9x
Random Write	*(in IOPS)*	up to 55K	up to 30K	83% or 1.8x

** MB/s = megabytes per second*
^ IOPS = input/output operations per second

KIOXIA RM7 Series
Value SAS SSD[3]

In a data center with random bursts and/or constant data throughput, 12 Gb/s value SAS SSDs can significantly improve the number of transactions that can be delivered when compared with enterprise SATA SSDs, as well as the number of responses to incoming queries. In addition to twice, or more, sequential performance than SATA SSDs, coupled with high random performance, value SAS SSDs are designed to be cost-competitive with SATA SSDs and a direct replacement in general-purpose servers. Connecting SAS or SATA drives simply requires a SAS host bus adapter (HBA) or Redundant Array of Independent Disks (RAID) card. By replacing SATA drives with value SAS drives in servers, users can realize much higher system level performance per dollar.

Value SAS SSDs also support a number of security options[4]. For example, KIOXIA RM7 Series Value SAS SSDs support the Sanitize Instant Erase[5] (SIE) option with Crypto Erase capabilities and self-encrypting drive[6] (SED) options.

PCIe® Data Center NVMe™ SSDs: A Better Performance Option with Cost Benefits

Data center NVMe is a category of PCIe SSD designed for read-intensive applications that provides higher performance and capacities when compared with enterprise SATA SSDs. This SSD class moves data using the PCIe interface and the NVMe protocol. Compliant SSDs connect to servers and storage arrays through the PCIe bus, bypassing the HBA to provide a performance boost over SATA or SAS connected drives. The PCIe interface also may have more available channels (lanes) for data to flow, enabling higher performance. Currently, a single PCIe 5.0 lane can move data at speeds up to 4 gigabytes per second (GB/s), enabling 2.5-inch[7] and new Enterprise and Datacenter Standard Form Factor (EDSFF) form factor SSDs to deliver content at exceptionally fast speeds.

The NVMe protocol was designed specifically for flash memory and PCIe SSDs, and provides efficient host processing of each command by supporting a queue depth of 64K commands in 64K queues. The SATA interface only supports a single queue with a maximum queue depth of 32 commands. By performing multicore processing of large I/O operations over multiple bus lanes, PCIe SSDs can reduce bottlenecks and keep data flowing into and out of server CPUs, enabling users to tackle more demanding storage workloads more quickly and efficiently.

The SATA Revision 3.0 interface theoretically provides 6 Gb/s data transfer performance or 0.75 GB/s. The SAS-3 interface provides 12 Gb/s data transfer performance or 1.5 GB/s per lane. The PCIe 5.0 interface delivers 4 GB/s of data transfer performance per lane, or close to 15 GB/s in a typical x4-lane configuration. SSDs based on the PCIe 5.0 interface and NVMe 2.0 protocol will be more responsive to data-intensive workloads and more resilient against performance degradation due to too many I/O requests when compared with enterprise SATA SSDs.

Using published specifications[8] for KIOXIA CD8P Series Data Center NVMe SSDs, and those from a leading enterprise SATA SSD provider (Vendor A)[2], the performance capabilities of each SSD class compares as:

Read or Write Operation		KIOXIA CD8P Series SSDs PCIe 5.0 x4	Vendor A 6 Gb/s SATA	PCIe 5.0 Gains
Sequential Read	*(in MB/s*)*	up to 12,000	up to 550	2,081% (21x)
Sequential Write	*(in MB/s)*	up to 5,500	up to 520	957% (10x)
Random Read	*(in IOPS^)*	up to 2,000K	up to 98K	1,940% (20x)
Random Write	*(in IOPS)*	up to 400K	up to 30K	1,233% (13x)

** MB/s = megabytes per second*
^ IOPS = input/output operations per second

KIOXIA CD8P Series
E3.S data center NVMe SSD[3]

Based on the KIOXIA CD8P Series specifications, PCIe data center NVMe SSDs deliver PCIe 5.0 performance that is up to 21x higher when compared with enterprise SATA SSDs. They support up to 30.72 terabyte[9] (TB) capacities, which is about 4x the maximum capacity of enterprise SATA SSDs at up to 7.68 TB, and are well suited for cloud applications and general-purpose servers. Data center NVMe SSDs are available in 2.5-inch and EDSFF E3.S form factors to address current and future server/storage generations, and they typically support SIE and SED security options. PCIe data center NVMe SSDs represent a lower cost alternative to PCIe enterprise NVMe SSDs, discussed in the next section, while still delivering performance that is 21x higher when compared with enterprise SATA SSDs.

PCIe Enterprise NVMe SSDs: Best Performance Option

Of the SSD interface categories, PCIe enterprise NVMe SSDs deliver the highest performance and lowest latency in each of the read/write measurements, as presented by the test comparison in the Summary section. They feature all of the PCIe interface capabilities previously discussed, with PCIe 5.0 being the current generation. Using published specifications[10] for KIOXIA CM7 Series Enterprise NVMe SSDs, and those from a leading enterprise SATA SSD provider (Vendor A)[2], the performance capabilities of each SSD class compares as:

Read or Write Operation	KIOXIA CM7 Series SSDs PCIe 5.0 x4	Vendor A 6 Gb/s SATA	PCIe 5.0 Gains
Sequential Read *(in MB/s*)*	up to 14,000	up to 550	2,445% (25x)
Sequential Write *(in MB/s)*	up to 7,000	up to 520	1,246% (13x)
Random Read *(in IOPS^)*	up to 2,700K	up to 98K	2,655% (27x)
Random Write *(in IOPS)*	up to 600K	up to 30K	1,900% (20x)

** MB/s = megabytes per second*
^ IOPS = input/output operations per second

KIOXIA CM7 Series
E3.S enterprise NVMe SSD[3]

Based on the KIOXIA CM7 Series specifications, PCIe® enterprise NVMe™ SSDs deliver PCIe 5.0 performance that is up to 25x higher compared with enterprise SATA SSDs. Similar to the data center category, this SSD enterprise-class supports up to 30.72 TB capacities (up to 4x the maximum capacity of enterprise SATA SSDs), and are available in 2.5-inch and EDSFF E3.S form factors. They, too, support similar security options. For example, KIOXIA CM7 Series enterprise NVMe SSDs support an SIE option (with Crypto Erase capabilities), SED options, and are planned to be validated as Federal Information Processing Standards FIPS 140-3 Level 2[11] drives.

With these performance capabilities and high capacities, this SSD class is ideal for data-intensive applications such as artificial intelligence (AI), machine learning (ML), deep learning, data analytics, media streaming, online transaction processing (OLTP), content delivery networks (CDNs), and large databases, to name a few.

System/Application Level Benefits with Today's SSD Technologies

This combination of newer and faster SSD technologies enables users to tailor their storage requirements to specific applications and workloads to obtain the highest value and return on investment. For example:

- PCIe enterprise NVMe SSDs, with their speed-burning performance and the lowest latency of the SSD classes, are the best match for today's data-intensive applications. They support the highest capacities and multiple security options.

- PCIe data center NVMe SSDs, designed for high-performance, read-intensive applications, are ideal for cloud, hyperscale and general-purpose server applications. They, too, support the highest capacities, feature security options and are a lower cost PCIe SSD alternative.

- Value SAS SSDs can deliver twice the performance when compared with enterprise SATA SSDs, and are a direct replacement that can be easily swapped. For any general-purpose server application that enterprise SATA SSDs are used, value SAS SSDs can store and move data much faster, and at a cost-effective price.

Summary

SSDs play a major role in today's underlying storage within general-purpose servers and all-flash arrays, and are designed around interface standards such as SATA, SAS and PCIe. The current SATA Revision 3.0 interface only delivers up to 6 Gb/s of data transfer and is half-duplex. SATA-based SSDs use a legacy HDD technology, omitting the advantages and higher performance capabilities that other interfaces can deliver.

As the SATA interface is stalled at 6 Gb/s half-duplex data transfer performance, the PCIe interface continues to advance, innovate and deliver overwhelmingly higher bandwidth, while the current 24G SAS interface already delivers 4x the bandwidth of the SATA interface. SSDs based on these interface specifications are better positioned to keep pace with today's server and storage demands. The table below is a summation of the three previously presented comparison tables:

Read or Write Operation	SATA (Vendor A)	Value SAS (KIOXIA RM7)	Value SAS Gain vs. SATA	PCIe Data Center (KIOXIA CD8P)	PCIe Data Center Gain vs. SATA	PCIe Enterprise (KIOXIA CM7)	PCIe Enterprise Gain vs. SATA
Sequential Read *(in MB/s*)*	550	1,100	2x	12,000	21x	14,000	25x
Sequential Write *(in MB/s)*	520	1,050	2x	5,500	10x	7,000	13x
Random Read *(in IOPS^)*	98K	190K	1.9x	2,000K	20x	2,700K	27x
Random Write *(in IOPS)*	30K	55K	1.8x	400K	13x	600K	20x

** MB/s = megabytes per second*
^ IOPS = input/output operations per second

Gone are the days where it makes sense to use cheap, legacy storage technology as more cost-effective, higher performing SSDs are available to provide users with better choices and benefits that match the right SSDs to their application and storage requirements.

PCIe® NVMe™ SSDs and SAS SSDs set new bars for today's storage performance and latency, leaving no room for legacy enterprise SATA SSDs, with choices that include value SAS SSDs (a GOOD option), PCIe data center NVMe SSDs (a BETTER option), and PCIe enterprise NVMe SSDs (the BEST option).

FOOTNOTES:

[1] Specifications for the KIOXIA RM7 Series Value SAS SSDs provided by KIOXIA Corporation. Vendor A specifications obtained online from the vendor. Both specifications are accurate as of the date of this publication.

[2] The Vendor A SATA SSD performance specifications were obtained online from the vendor and are accurate as of the date of this publication. Identical specifications were used for comparison with value SAS SSDs, PCIe data center NVMe SSDs and PCIe enterprise NVMe SSDs.

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

[4] Optional security feature compliant drives are not available in all countries due to export and local regulations.

[5] Sanitize Instant Erase (SIE) is a standardized feature defined by the technical committees (T10/T13) of INCITS (the Inter National Committee for Information Technology Standards) and NVM Express™, Inc.

[6] The self-encrypting drive option supports the Trusted Computing Group® (TCG) Enterprise SSC and SED with NVMe protocol supports TCG Opal and Ruby SSC.

[7] 2.5-inch indicates the form factor of the SSD and not the drive's physical size.

[8] Specifications for the KIOXIA CD8P Series data center NVMe SSDs provided by KIOXIA Corporation. Vendor A specifications obtained online from the vendor. Both specifications are accurate as of the date of this publication.

[9] Definition of capacity: KIOXIA Corporation defines a kilobyte (KB) as 1,000 bytes, 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 1Gbit = 2^{30} bits = 1,073,741,824 bits, 1GB = 2^{30} bytes = 1,073,741,824 bytes, 1TB = 2^{40} bytes = 1,099,511,627,776 bytes and 1PB = 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.

[10] Specifications for the KIOXIA CM7 Series enterprise NVMe SSDs provided by KIOXIA Corporation. Vendor A specifications obtained online from the vendor. Both specifications are accurate as of the date of this publication.

[11] KIOXIA CM7 Series FIPS SSDs are planned to be validated as FIPS 140-3 Level 2 drives which defines the security requirements for the cryptographic module by NIST (National Institute of Standards and Technology).

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