



Frequently Asked Questions

What You Need To Know About PCIe® 4.0 NVMe™ SSDs

What is PCIe 4.0?

PCI (Peripheral Component Interconnect) Express is a high-speed serial computer expansion bus standard that enables a host CPU to communicate with external devices through a direct PCIe connection to the CPU, or through an expansion card. The [PCI-SIG](#)® standards group releases new versions of the PCIe specification, and when they do, the bandwidth is typically doubled from the previous release. The latest PCIe 4.0 revision can move data at approximately 2 gigabytes per second (GB/s) per lane versus the PCIe 3.0 revision which moves data at almost 1 GB/s per lane (Table 1), doubling performance:

Specification			Throughput				
PCIe Revision	Introduced by PCI-SIG	Transfer Rate (GT/s)^	x1 (GB/s)	x2 (GB/s)	x4 (GB/s)	x8 (GB/s)	x16 (GB/s)
1.0	2003	2.5	0.25	0.5	1.0	2.0	4.0
2.0	2007	5.0	0.5	1.0	2.0	4.0	8.0
3.0	2010	8.0	0.9846	1.969	3.94	7.88	15.75
4.0	2017	16.0	1.969	3.938	7.88	15.75	31.51
5.0 (approved)	2019	32.0	3.938	7.877	15.75	31.51	63.02
6.0 (planned)	2021	64.0	7.877	15.754	31.51	63.02	126.03

[^]GT/s = gigatransfers per second

Table 1: PCIe revisions and respective performance capabilities (Source: [PCI-SIG](#))

What is the adoption rate of NVMe SSDs in data centers?

Enterprise and data center NVMe SSDs are projected to represent majority use across data centers worldwide when compared to SATA and SAS SSDs. The combined segment (in units) is expected to grow rapidly.

Why are there different classes of NVMe SSDs for data centers?

NVMe SSDs are currently segmented into two categories: (1) enterprise NVMe SSDs and (2) data center NVMe SSDs. When market research firms report market data, the NVMe SSD segment typically combines both enterprise and data center categories into one all-encompassing segment. However, enterprise SSDs and data center SSDs have very distinct differences.

Enterprise NVMe SSDs are designed for the enterprise running 24 hours/7 days per week in data center servers and storage. These SSDs deliver the highest performance any class of SSD can currently achieve and include high-end features such as dual-port, larger capacities, read-intensive and mixed-use endurance, and data protection (i.e., data integrity checking, high reliability, media wear reporting, error reporting).

Data center NVMe SSDs are designed for scale out and hyperscale environments where high read performance, Quality of Service (QoS) and power efficiency are key metrics. These drives are optimized for read-intensive applications and typically targeted at cloud workloads. Customers expect to pay less for these SSDs than their more fully-featured enterprise counterparts.

What applications can benefit from the different classes of NVMe SSDs?

Enterprise-class NVMe SSDs are targeted to high-performance server applications, of which, databases, data analytics and compute-side artificial intelligence (AI)/ machine learning (ML) are good examples:

- Database applications benefit from low latency, dual-ports for multi-path and high-availability, and high transactions per second.
- Data analytics searches benefit from high sequential and random read bandwidth.
- Compute-side AI and ML benefit from the ability to quickly feed data into DRAM and GPUs during the staging phase at very fast data transfers and perform near-immediate validation of data for corruption during the checkpoint phase.

Data center-class NVMe SSDs are targeted for general purpose server applications and scale out environments, of which, cloud compute, containers, content delivery networks (CDNs), databases and media streaming are good examples:

- Cloud compute applications benefit from high-performance and low-latency especially when compared to SATA deployments.
- Container orchestration benefit from high transfer rates and high queue depths in random read and write environments.
- Content delivery networks benefit from SSDs that excel at read-intensive workloads (typically 90% read and 10% write) prevalent in these applications.
- Database applications benefit from low-latency and high transactions per minute.
- Media streaming benefits from very high read bandwidth. Moving content into several systems as fast as possible so it can be streamed to many subscribers simultaneously is also a key benefit of these SSDs.

What emerging applications can benefit from PCIe 4.0 NVMe SSDs (examples)?

The ability to disaggregate and pool compute, storage and network resources independently, and provision the right amount of resources for each application workload, has become an emerging cloud application. This requires moving from a direct-attached storage architecture to a disaggregated shared storage model where NVMe over Fabrics (NVMe-oF™) has quickly become the network protocol of choice for cloud architectures. It provides several benefits in resource utilization while delivering nearly the same high-performance and low-latency benefits as if the NVMe SSDs were locally attached. When [cloud storage volume management software](#) operates with the NVMe-oF specification, NVMe SSDs can be pooled and accessed at much lower latencies for host sharing versus other SSD interfaces.

A second emerging application combines SAS, SATA and PCIe interfaces into a backplane managed by a Universal Backplane Management (UBM)-compliant system (the SFF-TA-1005 specification¹). This enables SAS/SATA SSDs/HDDs and NVMe SSDs to be mixed and matched within one UBM-enabled backplane. The SFF-TA-1001 specification² (also known as U.3) defines the links between the drive and backplane connectors so that PCIe, SAS or SATA interfaces, and their respective protocols, can be supported from one interface slot. The ability to add, replace or interchange SSDs within one universal tri-mode backplane configuration helps reduce TCO and storage deployment complexities. It also provides a viable replacement path between SATA, SAS and NVMe storage media while maintaining backwards compatibility with U.2 NVMe-based platforms. All of these benefits will help to increase PCIe 4.0 NVMe SSD adoption in servers.

Does KIOXIA offer PCIe 4.0-based SSDs?

KIOXIA was the first to publicly demonstrate PCIe 4.0 NVMe SSDs at Flash Memory Summit 2019 (with Broadcom® Inc.). The product demonstrations included the company's enterprise-class CM6 Series and data center CD6 Series SSDs. Both series' use KIOXIA's 96-layer BiCS FLASH™ 3D flash memory technology, are compliant with the NVMe 1.4 specification, and support 2.5-inch form factors. CM6 series offers capacities ranging from 960 GB³ to 30,720 GB (@1 DWPD⁴) and 800 GB to 12,800 GB (@3 DWPD). CD6 series offers capacities ranging from 960 GB to 15,360 GB (@1 DWPD) and 800 GB to 12,800 GB (@3 DWPD). Each series is backwards-compatible with PCIe 3.0 environments and support Sanitize Instant Erase⁵ (SIE) and Self-Encrypting Drive (SED) with TCG-Opal/Ruby encryption⁶ security options⁷, and compliant with FIPS 140-2 (Level-2) support⁸.

The CM6-V Series (3 DWPD suited for read and write mixed-use applications) features the following performance capabilities (Table 2):

CM6-V Series:

SPECIFICATION	800 GB	1,600 GB	3,200 GB	6,400 GB	12,800 GB
Sequential Read (128 KB; QD=32)	6,900 MB/s	6,900 MB/s	6,900 MB/s	6,900 MB/s	6,900 MB/s
Sequential Write (128 KB; QD=32)	1,400 MB/s	2,800 MB/s	4,200 MB/s	4,000 MB/s	4,000 MB/s
Random Read (4 KB; QD=256)	880K IOPS	1,300K IOPS	1,400K IOPS	1,400K IOPS	1,400K IOPS
Random Write (4 KB; QD=32)	100K IOPS	215K IOPS	350K IOPS	325K IOPS	325K IOPS
70%R/30%W (4 KB; QD=256)	295K IOPS	525K IOPS	750K IOPS	710K IOPS	710K IOPS
Read Latency (@ QD=1)	90 μs	90 μs	90 μs	90 μs	90 μs
Write Latency (@ QD=1)	10 μs	10 μs	10 μs	10 μs	10 μs

Table 2: KIOXIA CM6-V Series enterprise-class PCIe 4.0 SSD performance

The CD6-R Series (1 DWPD suited for read-intensive applications) features the following performance capabilities (Table 3):

CD6-R Series:

SPECIFICATION	960 GB	1,920 GB	3,840 GB	7,680 GB	15,360 GB
Sequential Read (128 KB; QD=32)	5,800 MB/s	5,800 MB/s	6,200 MB/s	6,200 MB/s	5,500 MB/s
Sequential Write (128 KB; QD=32)	1,300 MB/s	1,150 MB/s	2,350 MB/s	4,000 MB/s	4,000 MB/s
Random Read (4 KB; QD=256)	700K IOPS	700K IOPS	1,000K IOPS	1,000K IOPS	750K IOPS
Random Write (4 KB; QD=32)	30K IOPS	30K IOPS	60K IOPS	85K IOPS	30K IOPS
70%R/30%W (4 KB; QD=256)	100K IOPS	100K IOPS	180K IOPS	270K IOPS	100K IOPS
Read Latency (@ QD=1)	90 μs	90 μs	90 μs	100 μs	120 μs
Write Latency (@ QD=1)	35 μs	35 μs	35 μs	35 μs	35 μs

Table 3: KIOXIA CD6 Series data center-class PCIe 4.0 SSD performance

The main features of CM6 Series enterprise-class SSDs and CD6 Series data center-class SSDs:

Feature	CM6 Series	CD6 Series
Interface Specification	PCIe 4.0, NVMe 1.4	PCIe 4.0, NVMe 1.4
Capacities	960 GB to 30,720 GB (1 DWPD) 800 GB to 12,800 GB (3 DWPD)	960 GB to 15,360 GB (1 DWPD) 800 GB to 12,800 GB (3 DWPD)
Configurable Power	9W, 11W, 14W, 16W, 18W, 25W	9W, 11W, 14W, 16W, 18W, 25W
Single Port	Yes (single x4)	Yes (single x4)
Dual Port	Yes (dual x2)	N/A

The following tables compare CM6/CD6 Series SSDs to the previous CM5/CD5 Series generation based on PCIe 3.0 (Table 4 and Table 5). The comparisons include supported capacity ranges.

CM6-V Series vs CM5-V Series:

SPECIFICATION	Units	CM5-V SERIES SSDs				CM6-V SERIES GAINS (using Table 4)				
		800 GB	1,600 GB	3,200 GB	6,400 GB	800 GB	1,600 GB	3,200 GB	6,400 GB	12,800 GB
SR (128 KB; QD=32)	MB/s	3,250	3,250	3,350	3,350	+112%	+112%	+105%	+105%	N/A
SW (128 KB; QD=32)	MB/s	1,250	2,460	3,040	3,040	+12%	+14%	+38%	+31%	N/A
RR (4 KB; QD=256)	KIOPS	370	650	750	770	+137%	+100%	+86%	+81%	N/A
RW (4 KB; QD=32)	KIOPS	95	145	160	165	+5%	+48%	+118%	+96%	N/A
70%R/30%W (4 KB; QD=256)	KIOPS	190	310	360	380	+55%	+69%	+108%	+86%	N/A
Read Latency (@ QD=1)	μs	110	110	110	110	-18%	-18%	-18%	-18%	N/A
Write Latency (@ QD=1)	μs	30	30	30	30	-66%	-66%	-66%	-66%	N/A

Table 4: KIOXIA CM5 Series versus CM6 Series enterprise-class SSD performance (For Read and Write Latency, the smaller the number, the better the performance)

CD5 Series vs CD6-R Series:

SPECIFICATION	Units	CD5 SERIES SSDs				CD6-R SERIES GAINS (using Table 5)				
		960 GB	1,920 GB	3,840 GB	7,680 GB	960 GB	1,920 GB	3,840 GB	7,680 GB	15,360 GB
SR (128 KB; QD=32)	MB/s	3,140	3,140	3,140	3,140	+84%	+84%	+97%	+97%	N/A
SW (128 KB; QD=32)	MB/s	880	780	1,520	1,980	+47%	+47%	+54%	+102%	N/A
RR (4 KB; QD=256)	KIOPS	305	270	465	550	+129%	+159%	+115%	+81%	N/A
RW (4 KB; QD=32)	KIOPS	20	20	40	50	+50%	+50%	+50%	+70%	N/A
70%R/30%W (4 KB; QD=256)	KIOPS	50	65	115	115	+100%	+53%	+56%	+134%	N/A
Read Latency (@ QD=1)	μs	110	120	120	135	-18%	-25%	-25%	-25%	N/A
Write Latency (@ QD=1)	μs	50	50	30	30	-30%	-30%	+16%	+16%	N/A

*For Random Read, the maximum queue depth for the CD5 Series is 128 – the CD6 Series is 256

Table 5: KIOXIA CD5 Series versus CD6 Series data center-class SSD performance (For Read and Write Latency, the smaller the number, the better the performance)

The CM6 Series and CD6 Series deliver significant performance gains over the previous generation CM5 Series and CD5 Series, and reflect the performance increases associated with the PCIe 4.0 interface doubling in both transfer rate and data rate over the previous PCIe 3.0 revision.

Notes:

¹The SFF-TA-1005 (Universal Backplane Management (UBM)) is available at: <http://www.snia.org/sff/specifications>.

²The SFF-TA-1001 (Universal x4 Link Definition for SFF-8639) is available at: <http://www.snia.org/sff/specifications>.

³ Definition of capacity - KIOXIA Corporation defines a megabyte (MB) as 1,000,000 bytes, a gigabyte (GB) as 1,000,000,000 bytes and a terabyte (TB) as 1,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1 Gbit = 230 bits = 1,073,741,824 bits, 1 GB = 2³⁰ bytes = 1,073,741,824 bytes and 1 TB = 2⁴⁰ bytes = 1,099,511,627,776 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.

⁴ 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, under the specified workload for the specified lifetime. Actual results may vary due to system configuration, usage, and other factors.

⁵ The Sanitize Instant Erase (SIE), Self-Encrypting Drive (SED), FIPS (Federal Information Processing Standards) optional models are available. SIE option supports Crypto Erase, which is a standardized feature defined by NVMe Express Inc.

⁶ SED supports TCG Opal and Ruby SSCs. It has a few unsupported TCG Opal features. For more details, please make inquiries through "Contact us" in each region's website, <https://business.kioxia.com/>

⁷ Optional security feature compliant drives are not available in all countries due to export and local regulations.

⁸ FIPS drives are designed to comply with FIPS 140-2 Level 2, which defines security requirements for cryptographic module by NIST (National Institute of Standards and Technology). For the latest validation status of each model, please contact us in each region's website, <https://business.kioxia.com/>

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