Performance Brief

CM6 Series & CD6 Series SSDs Deliver Ultra-Fast PCIe® 4.0 Performance

Solid state drives (SSDs) based on the NVM Express™ (NVMe™) specification connect directly to server CPUs through the PCIe interface bus. They utilize a streamlined storage stack that does not require host bus adapters (HBAs) that SAS and SATA drives must use for backplane connections. Eliminating the HBA results in even higher performance and lower latency when compared to legacy SAS / SATA interfaces. With queue depth support of 64K commands in 64K queues, host processing of each storage instruction is tremendously more efficient with the NVMe protocol as well.

NVMe was designed specifically for non-volatile memory (NVM) SSDs and uses the PCIe interface as the physical connection between backplane NVMe SSDs and the CPU. The current PCIe 4.0 specification[1] can move data at approximately 2 gigabytes per second (GB/s) per lane, doubling performance over the previous PCIe 3.0 revision (Table 1). With faster speed for data to move, PCIe 4.0 enables NVMe SSDs and other devices to deliver faster I/O than previous PCIe revisions.

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	2019	32.0	3.938	7.877	15.75	31.51	63.02

^GT/s = gigatransfers per second

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

The performance upgrades that PCIe 4.0 deliver can be validated using KIOXIA's newly announced PCIe NVMe SSDs covering the enterprise-class CM6 Series and data center-class CD6 Series. The performance delivered by these SSDs was compared to the previous generation based on PCIe 3.0 (the CM5 Series and CD5 Series, respectively). As for the mixed-use SSD of 3,200 GB[2] capacity with three Drive Writes per Day[3] (3 DWPD), CM6-V Series performance versus CM5-V Series is as follows (Table 2):

Read / Write Operation *(for Read/Write Latency, lower is better)*	**CM6-V Series SSD (3,200 GB) PCIe 4.0**	**CM5-V Series SSD (3,200 GB) PCIe 3.0**	**CM6 Series SSD PCIe 4.0 Advantage**
Sequential Read *(128 KB; QD=32)*	6,900 MB/s	3,350 MB/s	+105%
Sequential Write *(128 KB; QD=32)*	4,200 MB/s	3,040 MB/s	+38%
Random Read *(4 KB; QD=256)*	1,400K IOPS	750K IOPS	+86%
Random Write *(4 KB; QD=32)*	350K IOPS	160K IOPS	+118%
Mixed 70%R/30%W *(4 KB; QD=256)*	750K IOPS	360K IOPS	+108%
Read Latency *(@QD=1)*	90 µs	110 µs	-18%
Write Latency *(@QD=1)*	10 µs	30 µs	-66%

Table 2: Performance comparisons between PCIe 4.0 and PCIe 3.0 using KIOXIA enterprise-class NVMe SSDs

As for the read-intensive SSD of 3,840 GB capacity, CD6 Series (1 DWPD) performance versus CD5 Series (<1 DWPD) is as follows (Table 3):

Read / Write Operation *(for Read/Write Latency, lower is better)*		CD6-R Series SSD (3,840 GB) PCIe 4.0	CD5 Series SSD (3,840 GB) PCIe 3.0	CD6 Series SSD PCIe 4.0 Advantage
Sequential Read	*(128 KB; QD=32)*	6,200 MB/s	3,140 MB/s	+97%
Sequential Write	*(128 KB; QD=32)*	2,350 MB/s	1,520 MB/s	+54%
Random Read	*(4 KB)*	1,000K IOPS (QD = 256)	465K IOPS (QD = 128)	+115%
Random Write	*(4 KB; QD=32)*	60K IOPS	40K IOPS	+50%
Mixed 70%R/30%W	*(4 KB; QD=128)*	180K IOPS	115K IOPS	+56%
Read Latency	*(@QD=1)*	90µs	120µs	-25%
Write Latency	*(@QD=1)*	35µs	30µs	+16%

Table 3: Performance comparisons between PCIe 4.0 and PCIe 3.0 using KIOXIA data center-class NVMe SSDs

From these results, the CM6 Series and CD6 Series deliver significant performance gains over the previous generation, and reflect the performance increases associated with the PCIe 4.0 interface.

Heightened Performance for Key Use Cases

The new CM6 Series and CD6 Series SSDs from KIOXIA are well-suited for many data-intensive and computational use cases that can take full advantage of the speed upgrade that PCIe 4.0 delivers. For the enterprise, some of the key use cases include:

- ***Databases**: require low-latency, dual-ports (for multi-path and high-availability), and very high transactions per second*
- ***Data Analytics**: require high sequential and random read bandwidth for analytic searches*
- ***Compute-side AI / ML**: require fast data transfers into DRAM and GPUs during staging while validating data immediately for corruption during checkpoints*

For the data center, some of the key use cases include:

- ***Cloud Computing**: require high data transfer and IOPS performance, and low-latency*
- ***Container Orchestration**: require high transfer rates and IOPS performance in combination with high queue depths in random read and write environments*
- ***Content Delivery Networks (CDNs)**: require read-intensive performance typically at 95% read and 5% write*
- ***Databases**: require low-latency and high transactions per minute*
- ***Media Streaming**: require high read bandwidth that can move content into several systems as fast as possible for streaming to many subscribers simultaneously*

Feature Comparison: CM6 Series vs CD6 Series

In general, enterprise-class NVMe SSDs are designed to run 24 hours/7 days per week in data center servers and storage to deliver the highest performance any class of SSD can currently achieve. They include such features as dual-port, larger capacities, read-intensive and mixed-use endurances, and high levels of data protection (data integrity checking, high reliability, media wear reporting and error reporting). Data center NVMe SSDs are designed for scale out and hyperscale environments, where read performance, Quality of Service (QoS) and power efficiency are key metrics. These drives are optimized for read-intensive applications and are typically targeted at cloud workloads. A comparison between the enterprise-class CM6 Series and data center-class CD6 Series are as follows:

Feature		CM6-V Series	CD6-R Series
3D NAND		BiCS FLASH™ 96-layer 3D TLC	BiCS FLASH™ 96-layer 3D TLC
Interface		PCIe 4.0 single x4 or dual x2	PCIe 4.0 single x4
Specification		NVMe 1.4	NVMe 1.4
Form Factors		2.5-inch	2.5-inch
Capacity and DWPD		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)
Performance*:			
Sequential Read	(128 KB; QD=32)	6,900 MB/s	6,200 MB/s
Sequential Write	(128 KB; QD=32)	4,200 MB/s	4,000 MB/s
Random Read	(4 KB; CM6 QD=256; CM5 QD=128)	1,400K IOPS	1,000K IOPS
Random Write	(4 KB; QD=32)	350K IOPS	250K IOPS
Mixed 70%R/30%W	(4 KB; QD=256)	750K IOPS	575K IOPS
Read Latency	(QD@1)	90 µs	90 µs
Write Latency	(QD@1)	10 µs	35 µs
Power Requirements:			
Configurable		9W, 11W, 14W, 16W, 18W, 25W	9W, 11W, 14W, 16W, 18W, 25W
Idle		< 5W	< 5W
Single Port / Dual Port		single x4 / dual x2	single x4

*Performance depends on SSD capacity and DWPD. Performance described in the table represents the highest one in each series.

In addition to the performance advantages that PCIe 4.0 delivers, both the CM6 Series and CD6 Series of NVMe SSDs deliver multiple levels of data security that include Sanitize Instant Erase[4] (SIE), Self-Encrypting Drive[5] (SED) and SED with FIPS 140-2 (Level 2)[6] optional models[7].

Sanitize Instant Erase (SIE)	Self-Encrypting Drive (SED)	FIPS 140-2 (Level 2)
SSDs supporting Sanitize Instant Erase (SIE) that completely make data in the SSD disabled quickly. The host is not required to manage the data encryption because data is automatically encrypted or decrypted by the SSD when written or read respectively. The encrypted data becomes cryptographically disabled by deleting the decryption key(s) stored in the SSD so that the SSD can be securely discarded or reused.	SSDs supporting TCG Opal/Ruby functions and that can set the flexible access-rights for each user. The host is not required to manage the data encryption because data is automatically encrypted or decrypted by the SSD when written or read respectively. Besides, PIN setting (i.e. password protection) to prevent data theft is implemented. The encrypted data becomes cryptographically disabled by deleting the decryption key(s) stored in the SSD so that the SSD can be securely discarded or reused.	Self-Encrypting Drives (SEDs) that utilize a security module validated as FIPS 140-2 (Level 2). The Federal Information Processing Standard (FIPS) 140-2 which is developed by the National Institute of Standards and Technology (NIST) specifies the security requirements to validate the encryption module design and implementation. Utilizing a security module validated as FIPS 140- 2 (Level 2) guarantees that the SSDs meet the security inspection standard defined by US government regarding the data security.

Summary

NVMe SSDs are penetrating server platforms at an increasing pace and include both enterprise and data center products. IDC predicts that PCIe NVMe SSDs will soon represent majority use (in units) across data centers worldwide[8]. Utilizing a streamlined SSD stack developed specifically for flash-based media, coupled with the ability to move PCIe 4.0 data at up to 2 GB/s per lane, NVMe SSDs can better feed server CPUs with data to address data-intensive and computational workloads. Customers are moving to NVMe SSDs for their enterprise performance requirements and cloud-based data center architectures, for their performance-centric and latency-sensitive applications. At the center of these requirements is heightened demand for NVMe-based storage where PCIe 4.0 is the latest performance upgrade, and KIOXIA's CM6 and CD6 series SSDs are delivering these enhanced capabilities.

Notes:

[1] Released by the PCI-SIG standards group.

[2] 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 = 2^{30} bits = 1,073,741,824 bits, 1 GB = 2^{30} bytes = 1,073,741,824 bytes and 1 TB = 2^{40} 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.

[3] 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.

[4] 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 NVM Express Inc.

[5] 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/

[6] KIOXIA FIPS drives utilize a security module designed to comply with FIPS 140-2 Level 2 and FIPS 140-3 Level 2, which define security requirements for cryptographic module by NIST (National Institute of Standards and Technology). For the latest validation status, please 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] Source: IDC - "Worldwide Solid State Drive Forecast Update, 2019-2023, Market Forecast-Table 12, Jeff Janukowicz, December 2019, IDC #44492119.