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:

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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) Sequential Write　(128 KB; QD=32) Random Read　(4 KB; CM6 QD=256; CM5 QD=128) Random Write　(4 KB; QD=32) Mixed 70%R/30%W　(4 KB; QD=256) Read Latency　(QD@1) Write Latency　(QD@1)	6,900 MB/s 4,200 MB/s 1,400K IOPS 350K IOPS 750K IOPS 90 µs 10 µs	6,200 MB/s 4,000 MB/s 1,000K IOPS 250K IOPS 575K IOPS 90 µs 35 µs
Power Requirements: Configurable Idle	9W, 11W, 14W, 16W, 18W, 25W < 5W	9W, 11W, 14W, 16W, 18W, 25W < 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) and Self-Encrypting Drive (SED) with TCG-Opal/Ruby encryption[5] security options[6] and is compliant to FIPS 140-2 (Level-2) support[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) 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. Being 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.