KIOXIA

Top 5 Reasons

Top 5 Reasons to Move to UFS 4.0 / UFS 4.1 Embedded Flash Memory from UFS 3.1

Universal Flash Storage[1] (UFS) is a storage standard designed for mobile devices and automotive applications. The current UFS 4.0 specification and recently announced UFS 4.1 specification deliver the industry's fastest embedded storage transfer speeds to date that enable next-generation smartphones and mobile applications to take advantage of 5G mobile networks and on-device generative artificial intelligence (AI) capabilities. UFS 4.0 / UFS 4.1 incorporate MIPI®, M-PHY® 5.0 and UniPro® 2.0 as the high-speed interface to connect a storage device with a host application processor on a system board. This fast interface supports theoretical data transfer speeds of up to 23.2 gigabits[2] per second (Gbps) per lane, or 46.4 Gbps per device. UFS 4.0 / UFS 4.1 is also backward compatible with UFS 3.1, enabling existing platforms to utilize the latest generation of flash memory technology within UFS 4.0 / UFS 4.1, while incorporating all of the existing UFS 3.1 features.

2014	**UFS 2.0 / UFS 2.1 / UFS 2.2**	11.6 Gbps
2019	**UFS 3.0 / UFS 3.1**	23.2 Gbps
2022	**UFS 4.0 / UFS 4.1**	46.4 Gbps

UFS introduced specifications and revisions, with interface speed

There are many vendors developing smartphones, tablets, gaming consoles, portable augmented and virtual reality devices, digital and surveillance cameras, digital cockpits and a host of other electronics and mobile applications based on UFS technology. Enabling these use cases are managed flash device[3] vendors, such as Kioxia Corporation, who are driving UFS 4.0 / UFS 4.1 storage technology forward. There are a number of reasons to move to UFS 4.0 / UFS 4.1 embedded flash memory from UFS 3.1, but here are the top five:

1. *Twice the Data Transfer Speed*
2. *Faster Boot-up Time*
3. *Improved Random Read/Write Performance*
4. *Enhanced Performance with Newer WriteBooster Scheme*
5. *Enhanced Security via Advanced RPMB and RPMB Purge*

#1 Twice the Data Transfer Speed

The UFS 4.0 / UFS 4.1 specifications developed by JEDEC® are upgrades that enable twice the data transfer speed versus the UFS 3.1 specification. UFS 4.0 / UFS 4.1 offer up to 46.4 Gbps per device (or 23.2 Gbps per lane), compared to 23.2 Gbps per device for UFS 3.1. Doubling the interface speed results in faster read/write device performance[4] and reduced latency to enhance overall system performance.

The ability to process more data efficiently can deliver the following key benefits to these selective applications:

- High-speed reads and writes of large data files are key capabilities for smartphones, tablets, smart TVs, cameras, and gaming consoles as faster write speeds enable applications to be installed and launched quicker. Also, transferring photos/videos from these devices to the cloud will be faster.
- Fast data transfer speeds are crucial for automotive applications to support video, faster processing of LiDAR[5] and sensor/camera vision information which makes autonomous driving a safer, and more responsive driving experience.
  - Fast sequential write speed is also required for immediate Over-The-Air (OTA) updates as the faster boot-up time enables the OTA process to start sooner as UFS 4. 0 / UFS 4.1 will be initialized quicker.
- High-speed reads and writes, with low latency, are required for smoother augmented reality (AR) and virtual reality (VR) immersive experiences.
- High-speed reads and writes, with low latency, are also required for on-device AI processing and real-time data analysis at the edge. The large language models (LLMs) stored in the UFS device need to be loaded into DRAM in a timely manner.

#2 Faster Boot-up Time and Initializations

To address faster boot-up time and initializations, newly introduced in UFS 4.0 / UFS 4.1 is the High Speed Link Startup Sequence (HS-LSS) technology (defined in MIPI® UniPro® 2.0), which is in addition to the existing Low Speed Link Startup Sequence (LS-LSS) technology in UFS 3.1 and previous UFS generations. This new capability delivers faster configuration and management software initializations through HS-LSS technology, and faster boot-ups and device initializations through 46.4 Gbps data transfers. Smartphones, PCs, automotive clusters and infotainment systems can benefit from these fast boot-ups and initializations, also delivering comfortable user experiences. For industrial scanners and Point-of-Sale systems, fast boot-up time enables these devices to respond quickly from system sleep mode.

#3 Improved Random Read/Write Performance via MCQ and Extended Initiator ID

The UFS 4.0 / UFS 4.1 Host Controller Interface (HCI) includes a significant performance feature called Multi-Circular Queue (MCQ). It allows the host to set priorities for I/O commands based on specific tasks. For example, image recording I/O commands should have higher priority than background cloud data sync I/O commands. MCQ delivers a boost to random read/write performance especially when multitasking is required.

Working in conjunction with MCQ in the UFS 4.0 / UFS 4.1 host controller is a feature called the Extended Initiator ID. It is designed for devices to manage complex data tasks quickly and efficiently, and also delivers a boost to random read/write performance for devices requiring fast and distributed data access across multiple applications.

The improved random read/write performance delivered by MCQ and Extended Initiator ID improves the user experience for smartphones, PCs, automotive applications or any application running multiple tasks simultaneously.

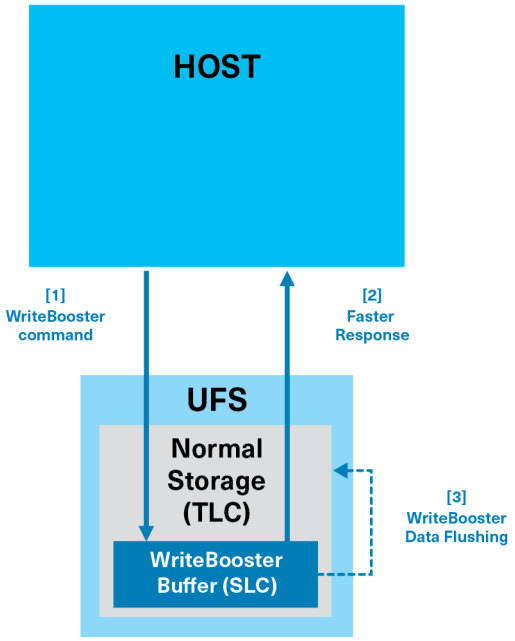
#4 Enhanced Performance with Newer WriteBooster Scheme

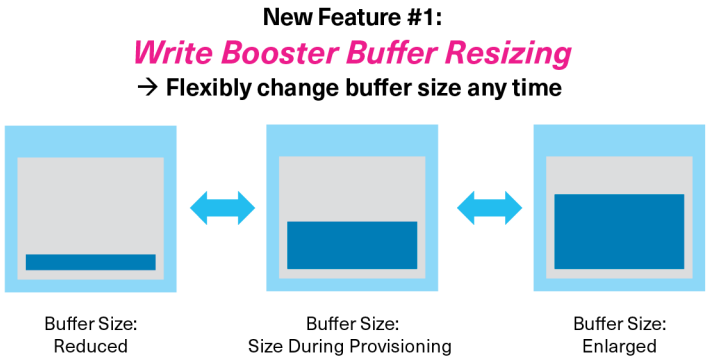
The WriteBooster feature became available in the UFS 3.1 specification to improve write speeds over UFS 2.1. It utilizes a single-level cell (SLC) Write Buffer to improve write performance. When the WriteBooster feature is enabled by the host, the UFS device will temporarily write data to the SLC Write Buffer that has a finite capacity size, and can fill up. If the capacity becomes full, the SLC Write Buffer will no longer be able to store data. If this occurs, data that was intended to be stored in the SLC Write Buffer will be written to normal storage (typically triple-level cell (TLC)), and in turn, performance will be normal. To recover the space used by the SLC Write Buffer, the host can direct the UFS device to flush data from the SLC Write Buffer to normal storage when the device is in idle or hibernate mode.

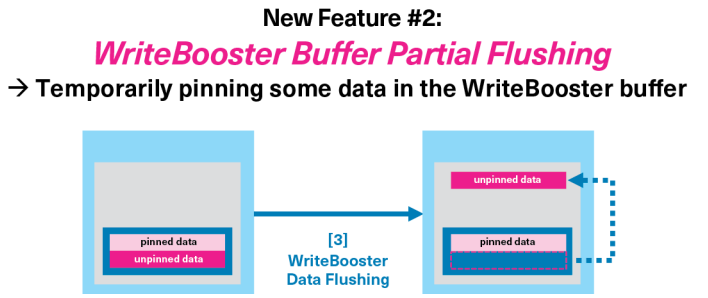
In the new UFS 4.1 specification, further enhancements were made to the WriteBooster feature that allows the buffer to be resized and partially flushed, enabling users to retain some of the data without flushing all of it to normal storage. This flexibility in resizing the WriteBooster buffer allows users to optimize the buffer size with each customer use case.

A partial flush allows certain data to be pinned in the WriteBooster buffer so that it will always be accessible from the buffer rather than from normal storage. As it is faster to access this specific data from the WriteBooster buffer versus normal storage, the system will experience enhanced overall read performance.

In many applications, users will use the pinned data setting in this newer WriteBooster scheme to achieve faster read performance of required data. Pinned SLC is synonymous to partial flushing that leaves some data in the WriteBooster buffer, and can be read faster than previous WriteBooster schemes. The image below showcases new UFS 4.1 WriteBooster features:







#5 Enhanced Security via Advanced RPMB and RPMB Purge

To keep passwords, critical business data and other important content protected from hackers and cyberattackers, the UFS specification employs Replay Protected Memory Block (RPMB), as well as secured data that can only be accessed through authentication. The authentication process enables important and confidential smartphone content to be securely stored in the RPMB Logical Unit, even if someone disassembles the smartphone and extracts the UFS information. This process does not allow data to be read from the RPMB without the proper key.

Since consumers now store more and larger personal and sensitive content on their smartphones and other mobile devices, even more robust security for users is required. In UFS 4.0 / UFS 4.1, there are two advanced features introduced for RPMB. Advanced RPMB is one of the new features that enables mobile system access to RPMB with larger data sizes per I/O transaction, up to 4 kilobytes[2] (KB), and it is a big improvement from 512 bytes supported in UFS 3.1.

There is also a new RPMB Purge feature added that will limit purge operations to RPMB and erase secure data faster when compared with existing purge operations that executed to the entire storage area. These capabilities, and more, ensure that sensitive and confidential data stored in a UFS 4.0 / UFS 4.1 device will have the added security measures to more effectively prevent unauthorized access. Faster access to the RPMB area also improves data transfer efficiency.

Product Information

KIOXIA offers a family of UFS 4.0 / UFS 4.1 high-capacity flash memories with an integrated controller that helps reduce the workload on the host processor, simplifies product development, shortens time-to-market and increases ease of use in memory products. For additional product information, select here.

Notes:

[1] Universal Flash Storage (UFS) devices are based on the UFS specification, of which, the Ver. 4.0 specification is the current release issued by JEDEC and published in August 2022. UFS 4.1 was announced by JEDEC® on January 8, 2025.

[2] 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^{50} 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.

[3] A managed flash device combines raw NAND flash memory and an intelligent controller in one integrated package, enabling internal memory management.

[4] Read and write speed may vary depending on various factors such as host devices, software (drivers, OS, etc.) and read/write conditions.

[5] LiDAR stands for Light Detection and Ranging.

Trademarks:

Disclaimers:

Information in this Top 5 Reasons document, including product specifications, tested content, and assessments are current and believed to be accurate as of the date of this publication, but is subject to change without prior notice. Technical and application information contained here is subject to the most recent applicable KIOXIA product specifications.