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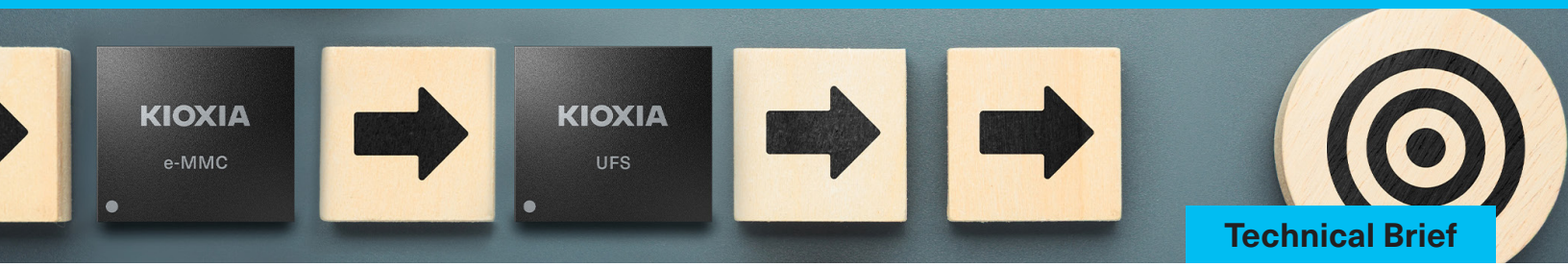


Technical Brief

Migrating from e-MMC to UFS: Design and Performance Considerations

Widely used managed flash devices[1] provide compact, reliable and non-volatile internal data storage for mobile and embedded applications. These devices are based on two JEDEC® flash memory storage technologies that include embedded MultiMediaCard (e-MMC)[2] and Universal Flash Storage (UFS)[3]. Both technologies have proven capabilities and many loyal users.

Managed Flash Device
Mobile/Embedded Applications

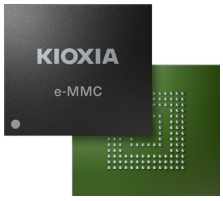
Smartphones - Tablets – Laptops - VR/AR Headsets - Digital Cameras - Smart TVs - Set-top Boxes - Game Consoles - In-Vehicle Infotainment (IVI) Systems - Advanced Driver Assistance Systems (ADAS) - IoT Gadgets - Robotics

The e-MMC v5.1 specification was released in 2015, and had minor revisions released in 2019 and 2025 (v5.1a and v5.1b, respectively). Over this time frame, data has grown exponentially, placing greater dependence on devices to deliver fast interface speed and read/write performance, high capacity, power efficiency and full-duplex communication. These demands have led several managed flash suppliers to invest in UFS and NVMe™ products to power the future and reduce development efforts on lower capacity e-MMC products commonly used in smart TV, set-top box, streaming media and IoT applications.

As many e-MMC devices are based on earlier generation flash memory products that will eventually be phased out of production, customers can anticipate e-MMC supply challenges in the months ahead. So, unless an unlikely change in the availability of e-MMC products materializes, users should prepare for the possibility of a scaled-back technology roadmap and supplier ecosystem.

UFS devices are designed to transfer data quickly and deliver fast boot ups for many applications. The technology roadmap has a history of successive generational releases since 2012 and has planned advancements that provide suppliers with confidence that the standard will evolve to address future user and product requirements. UFS is experiencing much broader adoption by suppliers, ecosystem partners and users alike when compared to e-MMC.

Given its present state, e-MMC may create challenges for users with heavy investments in this technology. Alternatively, the outlook for future UFS product availability seems more promising and migrating to a UFS infrastructure could be a viable alternative. Admittedly, a UFS migration requires commitments of both time and capital as each user must compare costs and resources versus the potential gains that UFS functionality and availability could deliver today and in the future. The cost of migration is a notable obstacle as UFS capacities begin at 64 gigabytes[4] (GB) and carry a higher price tag than lower capacity e-MMC managed flash products.



e-MMC v5.1 device
Source: KIOXIA Corporation[5]

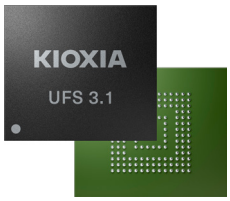
This tech brief provides a brief overview of UFS capabilities, migration paths and considerations for planning a migration from e-MMC to UFS.

UFS: The Future of Managed Flash

UFS has a proven track record of flash memory innovation since its inception, addressing the needs for ever-increasing speed, higher capacities, smaller package designs and other efficiencies required in modern embedded storage. UFS devices are well-established in the industries they serve and predominantly used in smartphones, mobile PCs/tablets and automotive IVI systems/ADAS. Emerging UFS use cases include devices and systems that require high storage performance such as robotics, drones, handheld scanners, premium consumer electronics such as AR/VR, baseboard management controllers and other intelligent edge devices such as IoT gadgets and high-end surveillance. There are several entry points to migrate from e-MMC to UFS, based on generations, but the primary challenge is cost since e-MMC customers frequently have lower capacity needs than UFS offers.

UFS 3.1: Practical Migration Entry Point

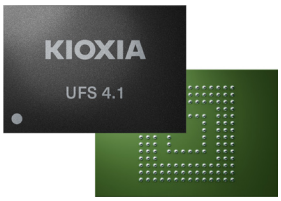
Given the cost factor, UFS 3.1 is a likely and practical entry migration point. It offers the lowest capacity at 64 GB that can scale up to 512 GB. It features a new WriteBooster buffer and a low-power Deep Sleep state on top of UFS 3.0 performance and a high-speed serial interface with full-duplex data transmission, whereas e-MMC is half-duplex.



UFS 3.1 device
Source: KIOXIA Corporation[5]

UFS 4.1: Advanced Migration Entry Point

For those more experienced with UFS and want to take a technological leap forward in speed and capacity, UFS 4.1 may be a good starting migration point and certainly costlier as its lowest capacity is 128 GB that can scale upwardly to 256 GB, 512 GB and 1 terabyte[4] (TB) capacities. Similar to UFS 4.0, it delivers tremendously faster sequential and random read/write performance versus e-MMC v5.1 and supports significantly more data per millijoule, maximizing battery life under heavy workloads despite its massive performance boost.

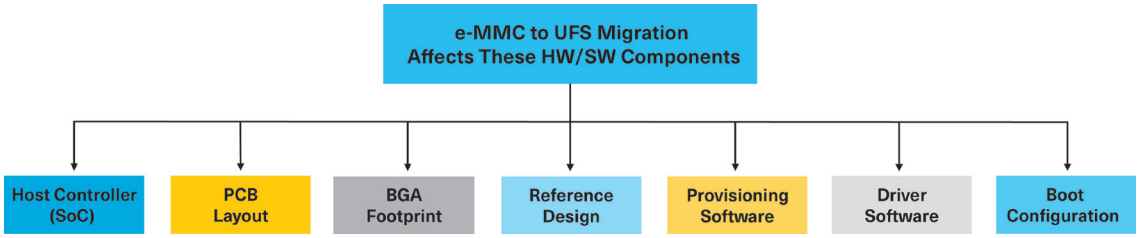


UFS 4.1 device
Source: KIOXIA Corporation[5]

It should be noted that the UFS 5.0 specification is announced and suppliers, such as KIOXIA, are offering UFS 5.0 products that are currently sampling as of this publication date. This recently released version of UFS 5.0 technology is considered too significant of a leap for e-MMC customers making an initial transition to UFS.

e-MMC to UFS Migration Overview

Migrating from an e-MMC infrastructure to UFS requires significant hardware and software redesign because the two flash memory types are electrically incompatible and use entirely different physical layers and communication protocols. This migration affects the following key hardware and software components:



- ***Host controller/System-on-Chip (SoC):*** *The application processor (SoC) must include an integrated UFS host controller, M-PHY® physical layers and UniPro® protocols. If the host controller only supports an e-MMC parallel bus, direct connection to the UFS host CPU is not possible.*

- ***Printed circuit board (PCB) layout redesign:*** *e-MMC uses an 8-bit parallel, half-duplex bus, while UFS uses high-speed serial differential pairs (TX/RX lanes) that require precise impedance-matched length tuning and signal integrity planning.*

  - *The PCB must support high-speed routing requirements including strip lines or microstrip structures.*
  - *Since UFS uses differential signal pairs, crosstalk between signals, and signals to power and GND, should be minimized.*
  - *Insertion loss should also be minimized by following the M-PHY specification.*
  - *Care should be taken to make sure that trace lengths are closely matched to avoid any skew between the RX and TX signals, as well as the differential pairs.*
  - *e-MMC and UFS operate on different power rails so it's important to verify if the Power Management Integrated Circuit (PMIC) can handle the higher peak current required in UFS.*

- ***Ball grid array (BGA) footprint:*** *Although e-MMC and UFS use soldered BGA chips, their pinout maps do not match, requiring the PCB pad layout to be redrawn.*

- ***Reference design:*** *Most SoC vendors will have a reference design board which is recommended for first-time designers. Designing a UFS reference design board from scratch if migrating from e-MMC may be time-intensive and challenging.*

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This migration also affects software requirements as follows:

- ***Provisioning software:*** *UFS specifications provide provisioning software, which is typically supplied by SoC vendors, are specialized tools or scripts that are used to configure a brand new UFS flash memory chip by dividing its total storage into separate sections called Logical Unit Numbers (LUNs). Open-source Linux® code is available called 'ufs-utils' which is similar to 'emmc-utils' for sending commands to the UFS device.*

- ***Driver software:*** *e-MMC and UFS devices use entirely different architectural designs, hardware interfaces and communication protocols, whereby the operating system cannot use the same driver for both. Legacy flash memory protocols (like SD cards) are used in e-MMC devices and operate on an 8-bit parallel, half-duplex bus. UFS devices use the SCSI architecture model paired with the M-PHY® physical layer and UniPro® protocol layer, and operate on a full-duplex, Low-Voltage Differential Signaling (LVDS) serial interface. The kernel must switch from using the standard mmc subsystem drivers to the UFS Host Controller Driver (UFSHCD) subsystem drivers. Additionally, UFS drivers support Command Queuing (CQ) to handle multiple read/write requests simultaneously, and a feature not supported by e-MMC drivers.*

- ***Boot configuration:*** *The Initial Program Loader (IPL) and secondary bootloaders must be updated to start the UFS initialization sequence, descriptor parameters and LUNs.*

Once the migration is completed, testing the UFS integration is fundamentally different than e-MMC due to its distinct architecture and interface speed. UFS utilizes a high-speed serial bus while e-MMC uses a slower 8-bit parallel bus. Designers lacking experience with serial bus designs may need to develop new skills. Additionally, the UFS serial bus is highly sensitive to noise, power, signal skews, trace lengths, etc., whereas the e-MMC parallel bus is more accepting of these issues. The maintenance and testing required (signal integrity, power integrity, protocol analysis, etc.) needs to be considered.

There is also equipment recommended for conducting signal integrity tests on the new integration:

- *An oscilloscope is required and must support appropriate M-PHY compliance test software. It is recommended that customers consult with their measurement equipment vendor to verify support.*

- *A dedicated UFS interposer is recommended to probe the UFS signals for measurement as this is a non-intrusive way to directly capture the signals on the PCB. Direct probe points on the PCB are often difficult to find or are buried within the PCB layers.*

- *A UFS-specific protocol analyzer is also required to decode the UFS signals. The analyzer needs to decode three communication layers that include the M-PHY physical layer, the UniPro protocol layer and the UFS layer. The validations across these three layers are critical for debugging any failures linked to communications between the host and UFS device.*

Planning a migration of this kind requires teams to prepare for the learning curve associated with new software, firmware and integration requirements. UFS testing and validation requires more robust planning when compared to e-MMC testing. It is recommended to contact the KIOXIA sales organization to discuss the company's design services criteria.

Summary

Product designers using managed flash technology find themselves at a crossroads where challenges in supply and market dynamics are driving critical discussions about the best path forward. A migration to a UFS infrastructure from e-MMC is worth considering because the storage demands of modern devices are outgrowing what e-MMC was designed to support. UFS has continued to evolve through multiple generations, giving suppliers and system designers a clearer path for future performance, capacity and efficiency needs. As applications become more data-intensive and user expectations rise for faster boot times, responsive performance and better power efficiency, UFS offers a potentially more viable long-term foundation than a less active e-MMC ecosystem with declining supplier focus.

Although moving from e-MMC to UFS requires significant hardware and software redesign - covering the SoC, PCB layout, power delivery, drivers, boot flow and validation processes – the outlook for future UFS product availability seems more promising and the technology roadmap is better defined. For organizations heavily invested in e-MMC, UFS migration is less of an upgrade and more about a strategic shift toward a faster, more scalable and future-ready storage platform.

General information about KIOXIA UFS products is available here.

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FOOTNOTES:

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

[2] Embedded MultiMediaCard (e-MMC) is a specification developed by JEDEC® for mobile applications. The current release is v5.1b, published in September 2025.

[3] Universal Flash Storage (UFS) is a product category for a class of embedded memory products and devices built to the JEDEC UFS standard specification. The v5.0 specification is the current release issued by JEDEC and announced in February 2026.

[4] Definition of capacity: KIOXIA defines 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.

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

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