Enabling Higher Capacity Storage with QLC UFS

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FMS the Future of Memory and Storage

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Agenda

1. Introduction to UFS
2. Why QLC?
3. QLC UFS for mobile
4. Considerations
5. Use case and market trend
6. Final thoughts

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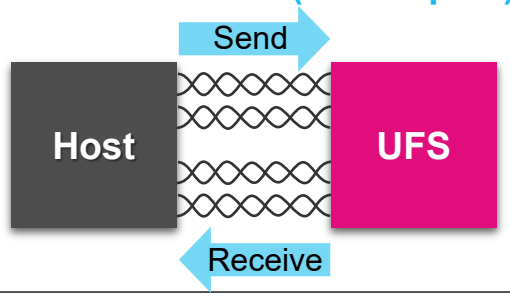
Introduction to UFS[1]

- JEDEC® standard, managed Flash storage for mobile applications
- Ideal replacement of eMMC for embedded mobile solutions
- Scalability to higher capacities and speed

		UFS	e-MMC[2]
Interface	Bus	**Serial Interface (Full Duplex)** 	**Parallel (x8) Interface**  **Half Duplex**
	Speed	**Max. 2320MB/s** (HS-G4(11.6Gbps) x 2lanes with UFS 3.0/3.1) **Max. 4640MB/s** (HS-G5(23.2Gbps) x 2lanes with UFS 4.0/4.1)	**Max. 400MB/s** (HS400 with e-MMC 5.0/5.1)
	Pin Count	1 lane : 6 (4 I/O and 2 control) 2 lane : 10 (8 I/O and 2 control)	11 (8 I/O and 3 control)
Command Set		SCSI	MMC[3]

1. Universal Flash Storage (UFS) is a product category for a class of embedded memory products built to the JEDEC UFS standard specification. 2. Electrical component qualification requirements defined by the AEC (Automotive Electronics Council). 3. The MultiMediaCard (MMC) standards are managed by JEDEC.

Significance of QLC[1]

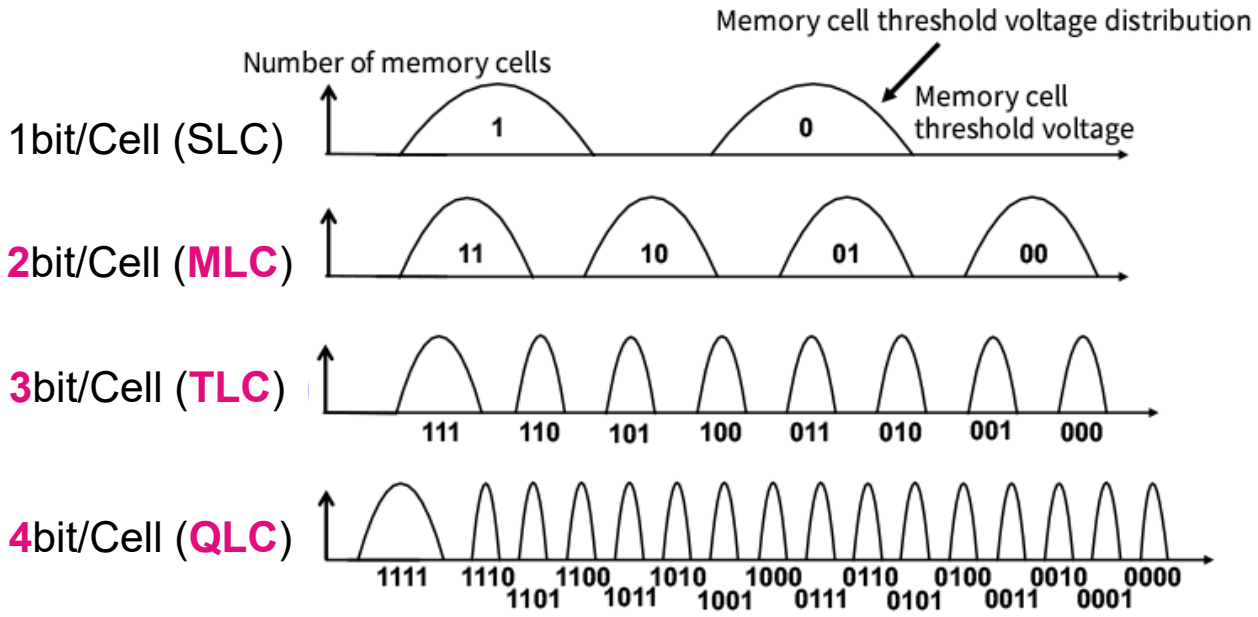
- Enables 4-bits per cell (16 Vth levels) for high density data storage
- Large capacity at lower cost per bit can be ideal for HDD displacement
- Ideal for read intensive applications targeting SSDs for enterprise, data centers, and client SSDs

Long lifespan (high reliability)

High performance (write, readout)

Large capacity

Low cost (cost per amount of data)

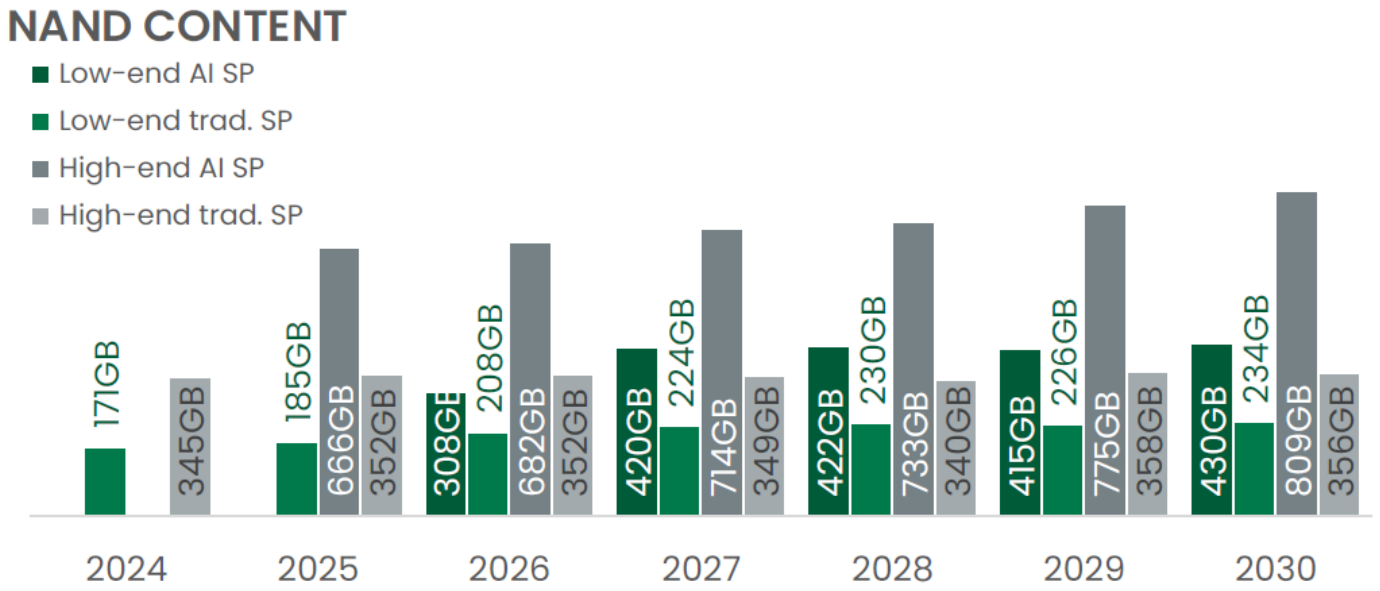


Source: KIOXIA Corporation: https://www.kioxia.com/en-jp/rd/technology/multi-level-cell.html

 1. Quad-level Cell (QLC).

Benefits of QLC UFS for Smartphones

- **On-device AI**
  - High-end smartphones are beginning to support on-device generative AI capabilities.
  - These capabilities are expected to become widely integrated into smartphones in the near future.
- **Need for Local Storage**
  - Locally stored LLMs needed for security and privacy of user information generated from AI
  - Multiple LLMs may be stored for different applications and models
- **Lower Carbon Footprint**
  - Manufacturing perspective uses same process as TLC[1]
  - Overall lower carbon footprint per GB



Source: TechInsights Inc., NAND Market Report Q4 2025

1. Triple-level Cell (TLC).

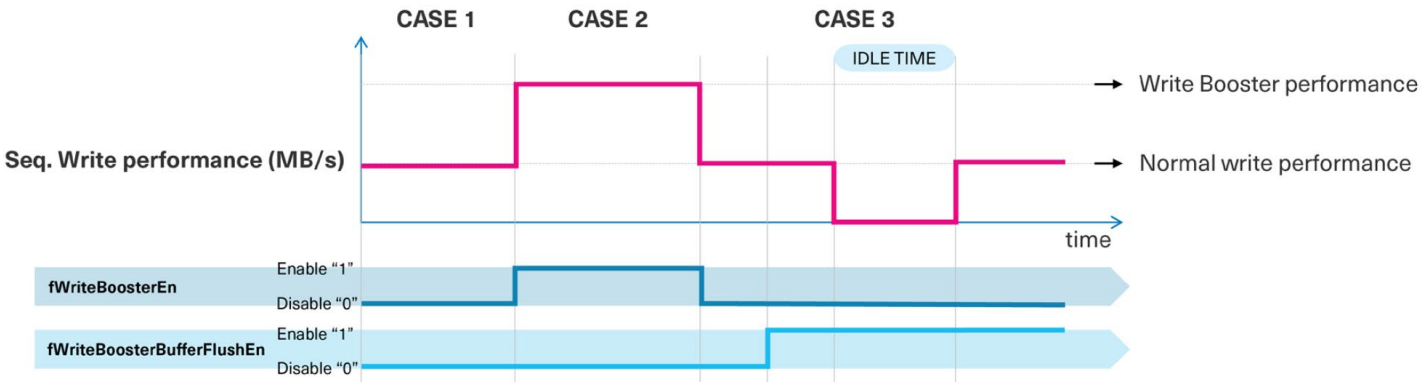
Considerations Facing QLC UFS

- **Performance**
  - How to achieve sufficient performance for smartphones?
  - User should not experience significant latency with QLC
- **Reliability**
  - QLC has lower write/erase endurance than TLC
  - QLC has more voltage levels than TLC, may have higher bit error rate
  - UFS controller is more complex to decode multiple voltage levels, and handle larger bit error rates
- **Sourcing**
  - Viability of multiple sources for QLC UFS
  - Dependent on market adoption in smartphones

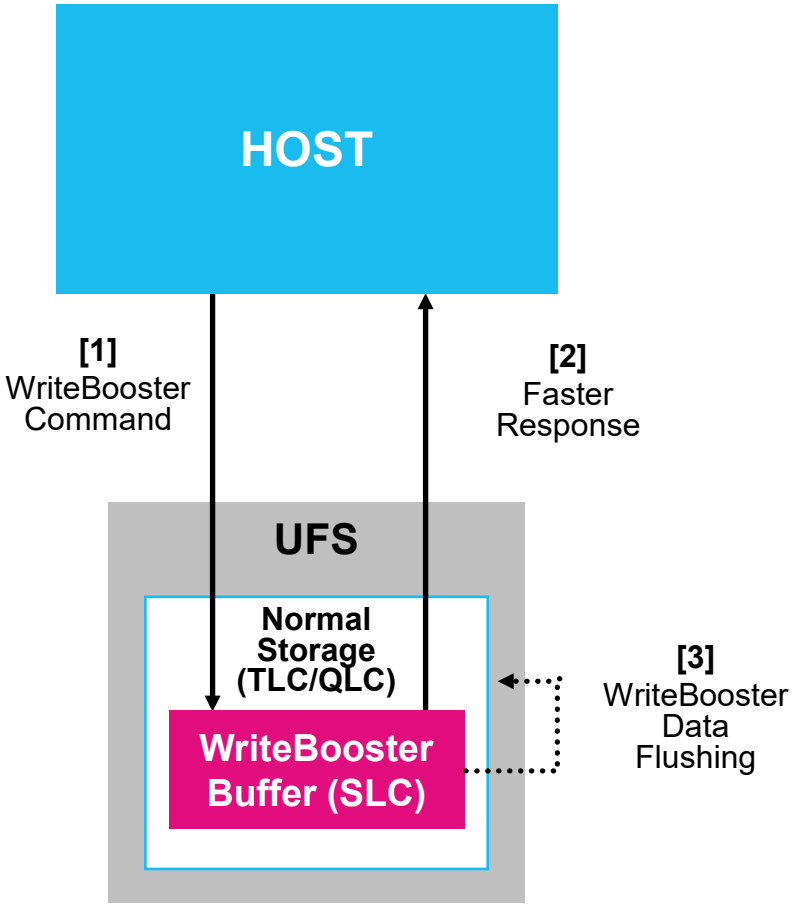
1. Secure digital cards (aka SD cards)

Performance: WriteBooster for Fast Sequential Write Speeds

- **UFS 3.1 introduced WriteBooster feature**
  - UFS stores incoming data in an SLC buffer
  - Achieves faster write speeds
- **WriteBooster can be implemented in either TLC or QLC**
  - Implemented in UFS controller
- **Equivalent sequential and random write performance possible between TLC and QLC UFS**



Source: KIOXIA, Understanding WriteBooster Feature, Technical Brief

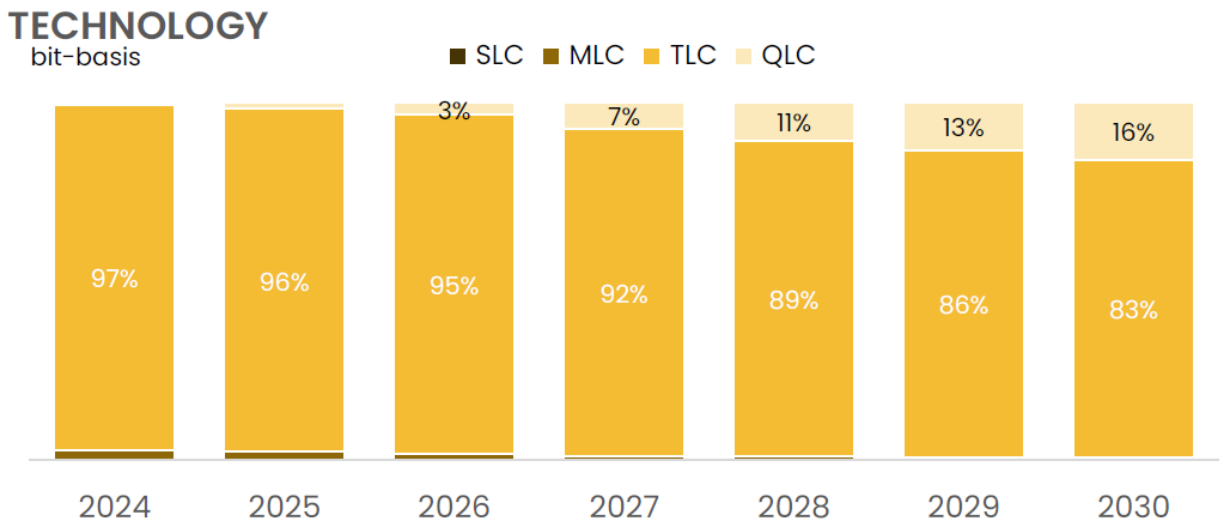


Source: KIOXIA, Top 5 Reasons to Move to UFS 4.0 / UFS 4.1

Smartphone Use Cases

- **Typical Smartphone User Consumes About 20-40 GB/day[1]**
  - TBW[2] is about 42.77 TB over 3 years
  - Typical 512 GB UFS today has TBW of 500 TB[3]
  - Only 9% of the lifespan of the UFS is used
  - QLC can address typical smartphone use case
- **Market Trends**
  - Expect early adopters in 2026
  - Gradual trend to increase adoption could be similar to MLC to TLC transition in the past
  - Once proven, could transition to mid tier phones (larger volume)

Smartphone NAND Usage



Source: TechInsights, Inc. NAND Market Report Q4 2025

1. Data consumption is extrapolated based on information published by JEDEC® Standard, JESD219A, SSD Endurance Workloads. JEDEC is a registered trademark of the JEDEC Solid State Technology Association. 2. Terabytes Written (TBW). 3 Assuming 3,000 W/E cycle for TLC and WAF=3 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.

Final Thoughts

QLC UFS is a viable solution for smartphones to address on-device generative AI and the need for additional storage for security and privacy.

QLC UFS can achieve similar performance to TLC based on the sophisticated controller design that manages nuances of QLC technology.

Please visit the KIOXIA booth for more information about our QLC UFS.

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