KIOXIA

Why is pSLC NAND Technology a Good Fit for IoT Devices?

Artificial Intelligence and Machine Learning Create Write-Intensive Workloads

Within many Internet of Things (IoT) devices is an operating system (OS), updatable ‘Over-The-Air’ (OTA) software, sensors and other tools that connect and exchange data with other IoT devices and systems over the Internet, all working together to deliver captured data to service providers. Some collected data requires artificial intelligence (AI) to respond to real-time developing situations or to review / analyze historical data looking for areas where IoT processes can be improved. Machine learning (ML) takes this one step further by analyzing behavioral system and device patterns from captured data and interprets operational scenarios from which it can learn.

Since many IoT devices are battery-operated, they have very small footprints for data storage, creating even further design challenges. To address these challenges, Single-Level Cell (SLC) NAND flash memory is often used within IoT devices. Embedded Multi-Media[1] (e-MMC) card flash memory is also used in cases when the IoT devices are driven by a Linux® or Android™ OS.

With the pervasive use of AI and ML, data process cycles have been accelerated, including data collection, storage, upload, analysis, update and download. As a result, write endurance is very important for IoT devices as it directly affects access performance and device lifecycles. It is for these reasons that pseudo SLC (pSLC) NAND technology may be a good fit for some IoT devices.

What is pSLC NAND Technology?

Pseudo SLC is not NAND flash memory: it’s a capability within NAND flash memory and configured in the Enhanced User Data Area[2]. Using pSLC effectively converts Triple-Level Cell (TLC) NAND flash memory (3-bits per cell) or Multi-Level Cell (MLC) NAND flash memory (2-bits per cell) to SLC-like cells (1-bit per cell). When configured to pSLC NAND technology, each cell’s reliability, specifically Write/Erase (W/E) endurance and data retention characteristics, substantially improve (Figure 1). However, the trade-off is a reduction of bits available for storage in the area allocated for pSLC.

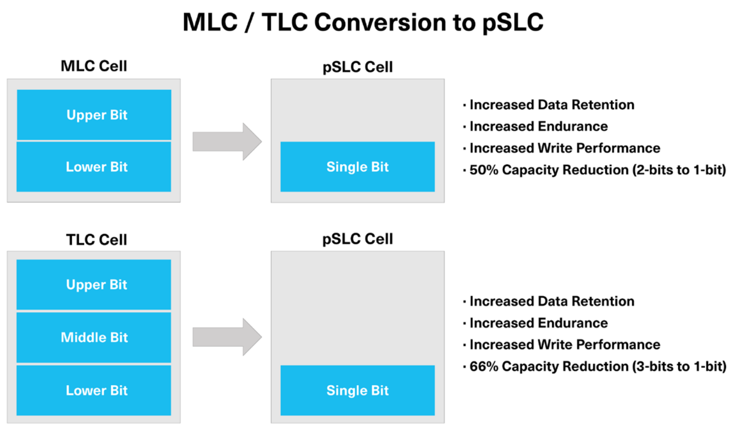


Figure 1 depicts the use of pSLC NAND technology in MLC and TLC NAND devices

A pSLC cell, for example, can potentially support up to ten times[3] more W/E cycles than an MLC (or TLC) flash memory cell. However, the MLC configuration in pSLC mode reduces the density by half, and when this is factored in, the net result of a device configured in pSLC mode may enable five times more W/E cycles versus the same device configured with MLC flash memory.

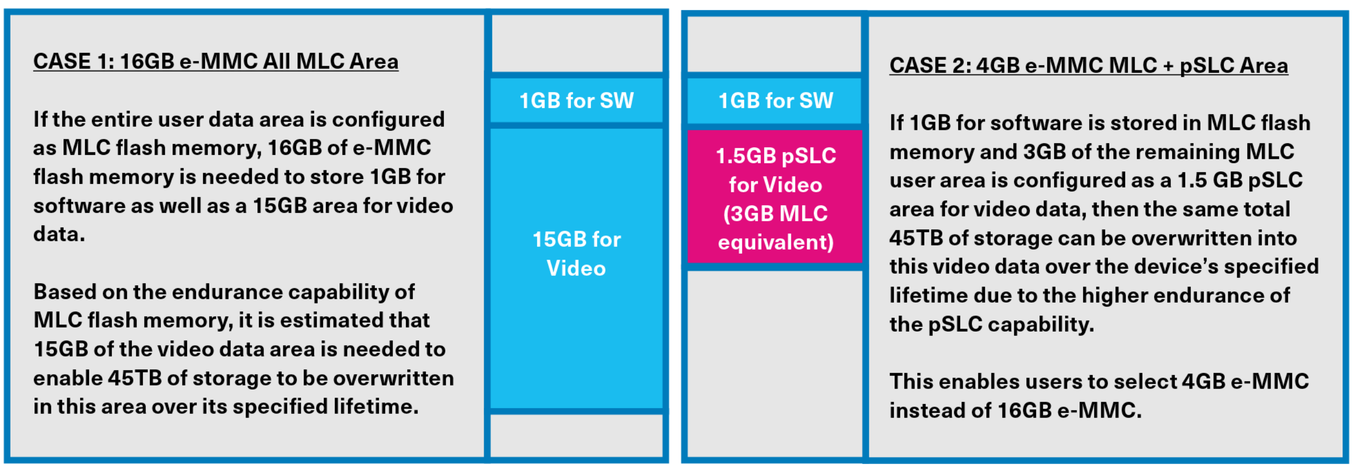
Configurable pSLC Partition Applications

The pSLC partition within MLC and TLC NAND flash memory can be configured to support write intensive applications or applications that require an extra boost in write performance. These applications include dashcams / security cameras, network security firewalls and RAID cards. Examples follow:

Example 1: Partially Configured pSLC e-MMC Application

pSLC NAND technology can reduce device costs by using lower density storage. This is prevalent in write-intensive applications where video data is stored frequently, and in real-time, such as dashcams and security cameras.

Assuming 1 gigabyte[4] (GB) is used for device software and 45 terabytes[4] (TB) of data are expected to be written in its lifetime, then there are two MLC use cases to consider:



Example 2: Fully Configured pSLC e-MMC Application

Another example of how TLC NAND flash memory can be configured to support improved endurance can be seen in network security firewalls commonly found in corporate data centers and enterprises. In this example, e-MMC flash memory is used as cache storage for all data logs generated by the security firewall. Advanced firewalls can generate up to 10GB of write operations to e-MMC flash memory per day. In this scenario, non-volatile memory is needed, instead of DRAM cache, to ensure that these vital data logs are not lost if sudden power loss or system failure were to occur.

When e-MMC flash memory is completely partitioned in pSLC mode, density is reduced by 50% for MLC flash memory. However, endurance will be significantly improved. In this example, a 10GB per day workload may be able to last approximately 6.6 years when 8GB e-MMC flash memory is configured entirely in pSLC mode. In standard mode, a 10GB per day workload may be able to last approximately 1.3 years (Figure 2).

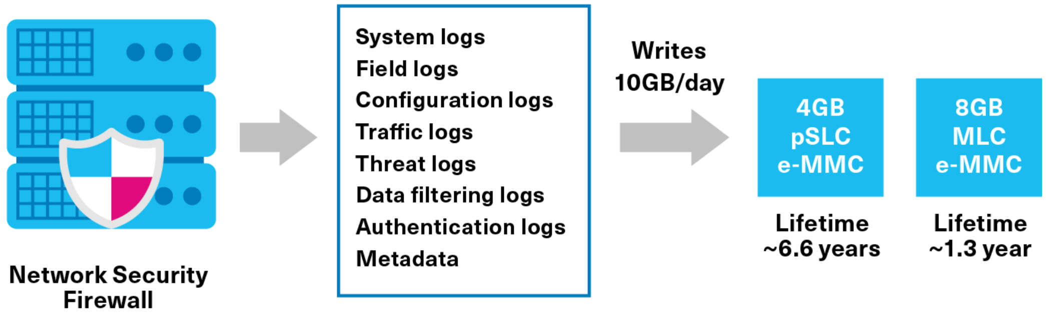


Figure 2 depicts an approximate 5-year improved lifetime when pSLC NAND technology is used versus MLC flash memory

Example 3: Applications Requiring Increased Write Performance

pSLC NAND technology can be configured to deliver an extra boost in write performance, especially for applications that require fast sequential write performance. NVDIMMs (non-volatile dual inline memory modules) that include DRAM, NAND flash memory and external super-capacitor (supercap) power sources are one example (Figure 3). During a sudden power loss or system failure, the supercaps are capable of delivering temporary power to the NVDIMM module, and contents within DRAM are transferred to e-MMC flash memory for data backup. When power or the system is restored, the contents within e-MMC flash memory are loaded back to DRAM.

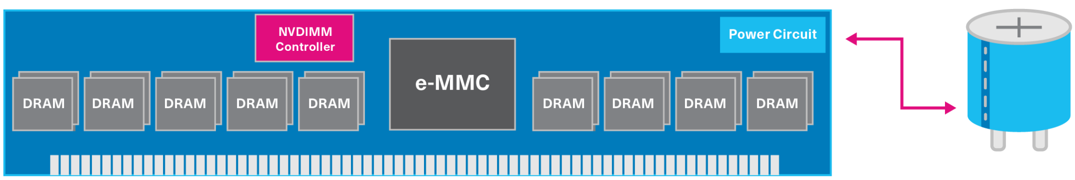


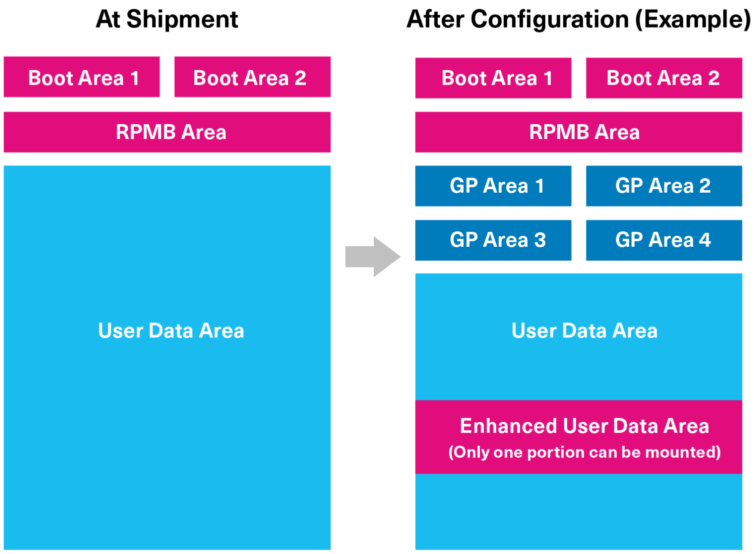
Figure 3 depicts a standard NVDIMM application with DRAM, e-MMC flash memory, controller and supercap

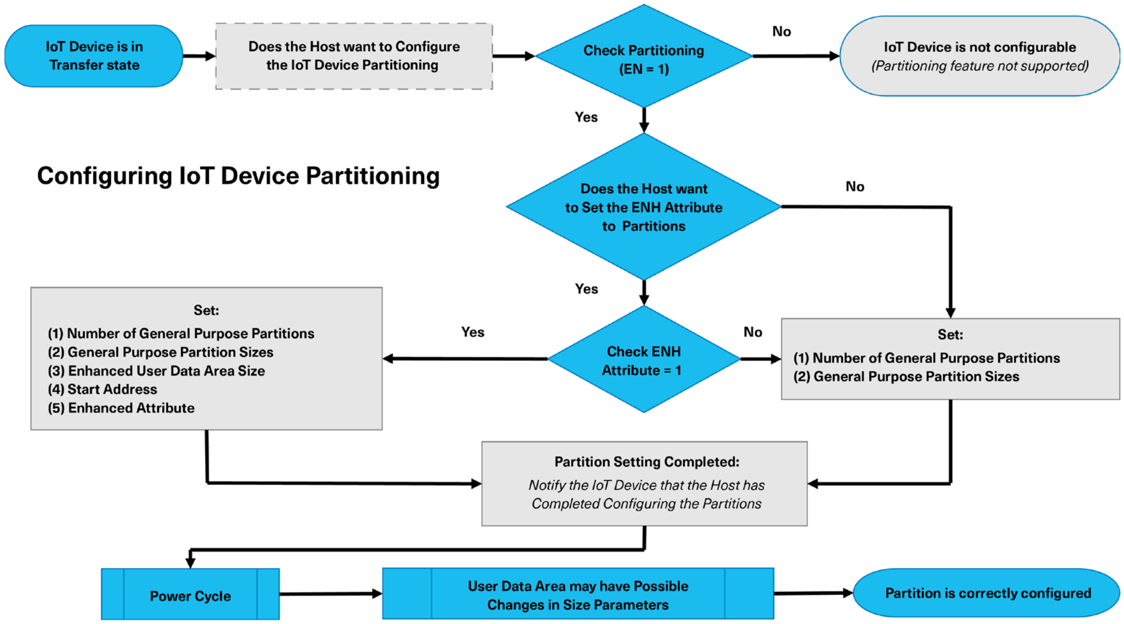
Since the supercap can only provide backup power for a brief period of time, it is absolutely critical that write speed of e-MMC flash memory be boosted to ensure that all data contents are successfully transferred. As pSLC NAND technology delivers a write performance improvement versus MLC or TLC flash memory, it is ideal for applications that require fast sequential write performance.

How to Configure the pSLC Partition?

When an e-MMC-based device ships, the e-MMC flash memory area consists of a User Data Area Partition; two Boot Area Partitions; and an RPMB Area Partition. Up to four General Purpose (GP) Area Partitions and the Enhanced User Data Area can be configured to pSLC mode (per right image). In the Enhanced User Data Area, 'only one portion can be mounted' means that the user cannot set two individual Enhanced User Data Areas within the same User Data Area. Only one contiguous Enhanced User Data Area can be set. The Enhanced User Data Area does not exist by default and must be set by the user.

The process flowchart below is a Joint Electron Device Engineering Council (JEDEC®) standard that covers the basic partitioning procedures for configuring IoT devices in the Enhanced User Data Area:





Configuring IoT Device Partitioning

Since the Enhanced User Data Area size and attribute setting is a one-time programmable action, KIOXIA America, Inc. recommends that customers contact their e-MMC NAND flash memory supplier for a consultation on the Enhanced User Data Area configuration as well as lifetime analysis.

Summary

IoT devices may make human lives better, smarter, safer, and more secure through AI and ML capabilities. pSLC NAND technology can assist IoT devices especially for recording logs and video streams, for learning from AI and ML capabilities, and for frequent algorithm updates. The tradeoff of pSLC NAND technology is that it sacrifices density, so the applications that may include pSLC technology should be carefully discussed with e-MMC suppliers.

Additional KIOXIA product information is available here.

NOTES:

[1] Embedded Multi-Media (e-MMC) is a specification developed by JEDEC. It refers to an integrated circuit package that consists of a multimedia card interface, NAND flash memory and a flash memory controller, available in standard BGA packages. The v4.41 specification was released by JEDEC and published in March 2010. The current release is v5.1, published in February 2015.

[2] Although pSLC mode is a useful technique to provide better data retention and endurance, and faster read and write performance, other technologies or techniques can be applied to the Enhanced User Data Area. Therefore, it is not mandatory to implement pSLC mode as the Enhanced User Data Area. Please check with suppliers regarding how the Enhanced User Data Area is configured.

[3] Source: Embedded Computing Design, "Different Priorities," Section: 'Interesting Alternatives,' November 16, 2020, https://www.embeddedcomputing.com/technology/storage/different-priorities.

[4] 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 1Gbit = 2^{30} bits = 1,073,741,824 bits, 1GB = 2^{30} bytes = 1,073,741,824 bytes and 1TB = 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.

TRADEMARKS:

DISCLAIMERS: