SiliconMotion

WHITE PAPER

Silicon Motion's Ferri Family

Optimizes Embedded Flash-based Storage for Automotive Use

The In-Vehicle Infotainment (IVI) systems in new car designs today have a huge appetite for data storage capacity – and this appetite is only set to grow. Mapping and navigation, music and entertainment, mirroring of smartphone user interfaces and other IVI applications are occupying a growing memory footprint in cars: forecasts suggest that the user-data storage requirement in high-end vehicles, which was typically around 32GB in 2014, will likely rise to the range of 256-512GB in 2020.

At one time, the car maker's choice of high-capacity data storage technology was the familiar Hard Disk Drive (HDD), but reliability and lifetime concerns have seen it fall out of favour to be replaced in modern designs by the solid-state drive (SSD) or embedded Multimedia Card (eMMC).

Certainly the solid-state solution for data storage is inherently better suited to the requirements of car makers, which maintain extremely strict processes and qualification criteria for components and modules built into their products in order to maintain high quality and reliability standards. Unlike an HDD, an SSD or eMMC contains no moving parts, it cannot suffer mechanical failure and is not vulnerable to damage from shock or vibration.

Nevertheless, the NAND Flash arrays on which the SSD and eMMC are based have inherent characteristics which can cause data corruption or data loss, if they are not properly managed. On its own, therefore, the replacement of an electro-mechanical system with a solid-state system does not guarantee a long lifetime of reliable performance. This article outlines the failure modes of solid-state data storage systems, and explains technologies and processes being used today to provide tight control of the reliability and lifetime of the latest high-capacity SSDs and eMMCs.

Automotive industry's preference for MLC NAND

NAND Flash is the basic memory type found today in billions of smartphones, tablets, media players and set-top boxes, and is also the storage medium in SSDs and eMMCs. NAND Flash is available in three main types: Single-Level Cell (SLC), Multi-Level Cell (MLC) and Triple-Level Cell (TLC). The newest version of TLC, 3D TLC, uses a stacked configuration to achieve even higher memory density than TLC. The memory density of MLC Flash is lower than TLC but higher than SLC.

In automotive SSD and eMMC applications, MLC NAND is preferred today because it provides high density and high reliability at a low cost, and with a lower susceptibility to data loss and corruption than TLC NAND. Data storage capacity of up to 64GB is typically available today in MLC NAND-based eMMC products, and up to 512GB in MLC NAND-based SSDs.

The use of MLC NAND Flash does, however, pose some risk to data integrity and retention. What is this risk, and how should automotive users expect the manufacturers of SSDs and eMMCs to manage it?

Second, Silicon Motion has extended the scope of its data protection to allow for the elevated bit error rates commonly experienced when a NAND Flash block has undergone many program/erase cycles. Conventional BCH or RS techniques for ECC are capable of 100% data correction at low bit-error rates, but as a NAND Flash array ages the bit error rate rises. Conventional consumer SSDs and MMCs leave uncorrected errors that go beyond the capability of the BCH or RS algorithms.

But for automotive applications, the Ferri Family products implement additional error correction, as shown in Figure 3. Low Density Parity Check (LDPC) algorithms are applied to recover corrupted words (1kB blocks). Silicon Motion also implements Page RAID algorithms capable of recovering a complete 16kB page that contains corrupt data. Together, these technologies ensure the integrity of Read/Write operations, free of bit errors, across the entire rated cycle life of the NAND Flash array.

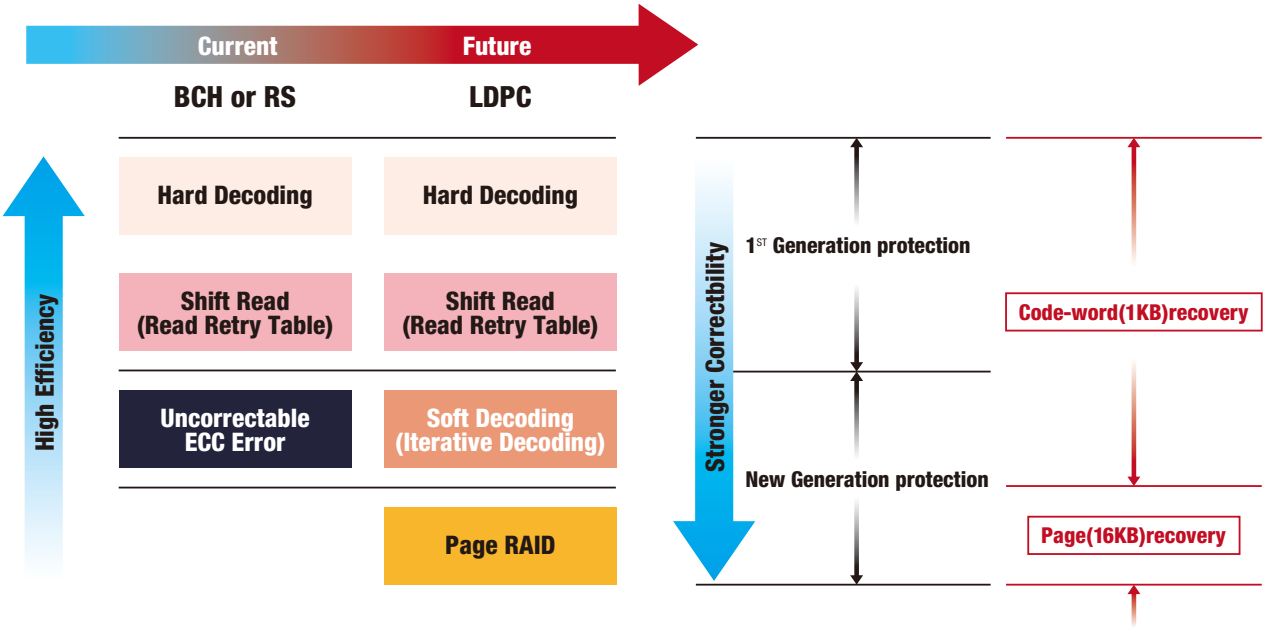

Fig.3:LDPC and Page RAID error correction schemes for extended ECC operation

Mitigating effects of thermal stress

Data retention is a critical performance parameter for automotive manufacturers: it measures the period over which a bit of data will be retained after being written to a cell. This period is strongly temperature-dependent, as the table in Figure 4 shows. This also shows that data retention in the MLC NAND type is markedly shorter than in SLC NAND.

Temp	SLC @ max PE	MLC @ max PE
40	75.58 Mo	12 Mo
55	12 Mo	1.88 Mo
70	2.14 Mo	0.34 Mo
85	0.45 Mo	0.07 Mo

Fig.4:data retention in NAND Flash is affected by operating temperature, number of Program/Erase (PE) cycles, and NAND type

Technology implemented in Ferri Family products protects against data retention failure by intelligently scanning blocks and cells, and refreshing those which are at risk of data loss. This Intelligent Scan & DataRefresh function draws on data about the bit error rate per block derived from ECC operation: at a user-selectable threshold for the bit error rate, a Data Refresh is performed (see Figure 5). As Figure 4 shows, at elevated operating temperatures the data retention duration shortens dramatically. Silicon Motion's Intelligent Scan & DataRefresh function automatically increases the frequency of scanning at higher operating temperatures.

Intelligent Scan & DataRefresh can also prevent data loss caused by read disturbance.

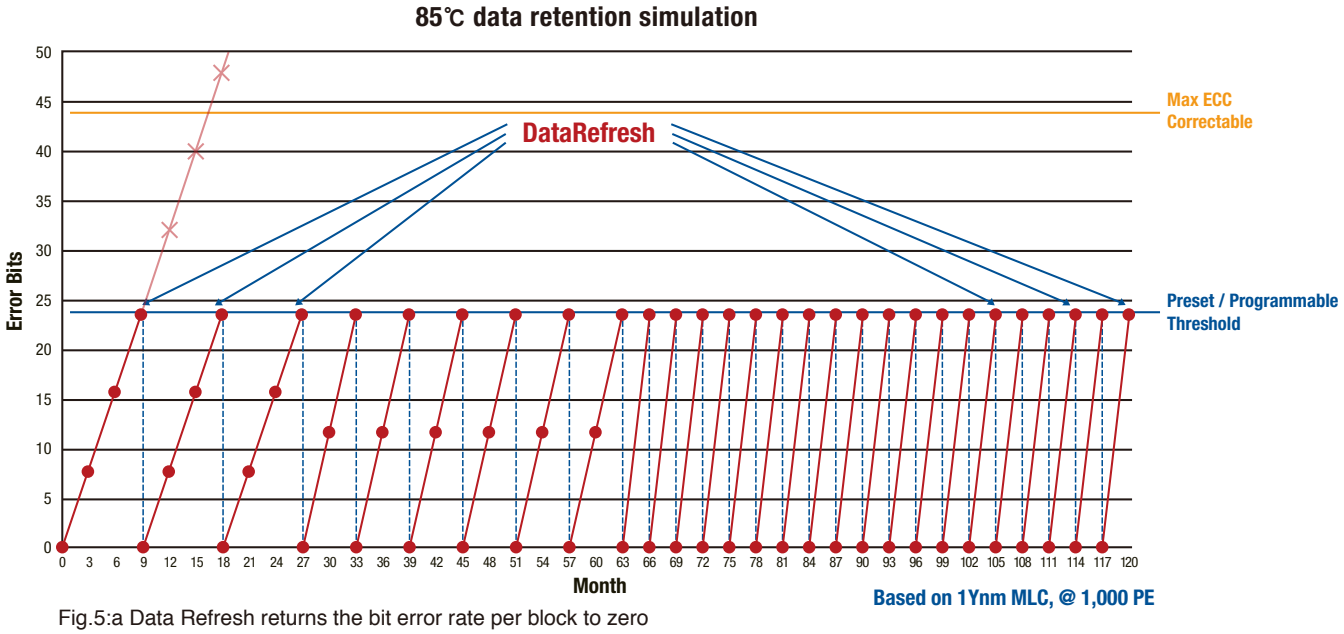

Fig.5:a Data Refresh returns the bit error rate per block to zero

Embedded board-level solutions for mass data storage

As this article has shown, the reliability and data integrity of an SSD or eMMC can be greatly enhanced through the application of burn-in, advanced forward error correction and data refresh functions. Silicon Motion meets the uncompromising requirements of the automotive industry in its AEC-Q100 qualified Ferri Family products through:

- 100% screening of every cell, page and block, and comprehensive quality control before shipping, resulting in very low dppm rates
- End-to-end data protection with NANDXtend ECC technology to extend operating lifetime
- IntelligentScan & DataRefresh for enhanced data retention

Ferri Family products available today are:

- FerriSSD, a 20mm x 16mm BGA package in densities up to 256GB
- Ferri-eMMC, available in various compact BGA packages conforming to the JEDEC industrial standards, in densities up to 128GB

Ferri Family storage solutions are particularly well adapted to the needs of the automotive market, providing a combination of long-term reliable operation, data integrity and data retention to ensure that the solid-state memory matches the quality and reliability of any other electronics system in a vehicle.

For more information about FerriSSD® module, please go to **www.siliconmotion.com** or send email to **ferri@siliconmotion.com**

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