

# Engineering MLC Flash-Based SSDs to Reduce Total Cost of Ownership in Enterprise SSD Deployments

Executive Summary  
Market Dynamics  
Future of Flash Technology  
Delivering Greater Endurance, Performance, and Reliability  
Conclusion

STEC's CellCare™ Technology Enables  
Deployment of Cost-Effective MLC  
Flash-Based Enterprise-Grade SSDs

## Executive Summary

The introduction of higher density, lower cost MLC flash components in consumer electronics products has driven dramatic growth in these market segments. To meet the demand for low-cost MLC flash chips, flash suppliers have invested billions of dollars in high-capacity manufacturing facilities. At the same time, enterprise IT organizations have sought higher-density SSDs at more competitive price points. Bringing the high-performance and low-power of MLC-based SSDs to enterprise-class server and storage applications requires wider acceptance of enterprise-class MLC flash-based solid-state drives.

While cost reductions triggered by MLC flash have set the stage for wider SSD adoption, the industry now needs to introduce techniques designed to overcome the inherent deficiencies of this MLC flash technology. The reliability and endurance characteristics of MLC SSDs must be improved to extend the application of MLC flash into enterprise-class SSD applications that demand ultimate performance and reliability. Without these improvements, the adoption of MLC flash-based SSDs may be limited to consumer applications.

Simply substituting MLC flash media for SLC flash will not by itself enable the lower cost, more reliable SSDs required for the enterprise. To meet more stringent requirements, MLC flash-based SSDs must be specifically designed for the enterprise environment. STEC's SSD controllers with CellCare Technology meet this set of requirements for enterprise-class endurance and performance with advanced signal processing and adaptive flash management algorithms.

This white paper describes the rapidly evolving enterprise storage market and provides a comparison of the different types of flash memory components currently used in SSDs, including the reliability and endurance characteristics of different flash products. The paper concludes with a review of how STEC's CellCare Technology enables the use of MLC flash-based SSDs to reduce total cost of ownership (TCO) while meeting the stringent requirements of next-generation enterprise storage applications.

## Market Dynamics

SSDs are a disruptive technology that are forcing a paradigm shift in an otherwise stagnant storage segment once dominated by hard disk drives (HDDs). SSDs have become one of the fastest growing market segments in the technology sector. As with any new technology, enterprises SSDs were initially brought to market by industry innovators and were deployed by early adopters. The market is now entering the next stage of its evolution by bringing enterprise-class SSDs to growing numbers of IT applications. To successfully make this transition, the technology must advance even further along the price/density curve.

As shown in Figure 1, the enterprise SSD market is expected to see a large growth in shipment volumes and density, accompanied by a further decline in average selling prices.

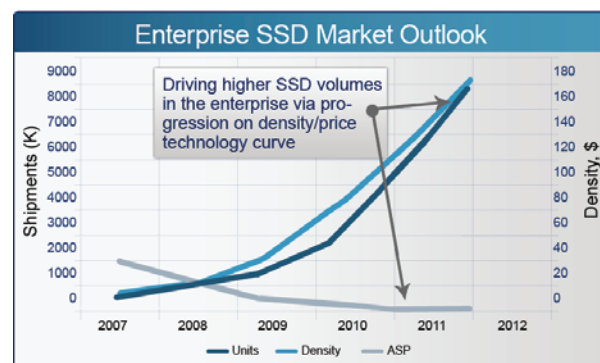


Figure 1: Enterprise SSD Market Outlook

The introduction of MLC flash-based SSDs into the enterprise market is expected to drive continuing growth in SSD density and volumes.

While MLC flash is attractive for its price and density characteristics, there is a problem with MLC technology. Its relatively poor endurance and performance characteristics in its raw state make it unsuitable for enterprise applications. The solution for SSD manufacturers is to deploy advanced controller technology to offset these deficiencies. STEC's CellCare Technology is designed for this specific purpose, making it the key ingredient for MLC flash-based, enterprise-class SSDs.

## Future of Flash Technology

To understand the benefits of CellCare Technology, it is first necessary to review the different types of flash memory currently available and then take a look at the future of flash technology.

The three types of NAND flash memory include single-level cell (SLC), multi-level cell (MLC) and so-called “enhanced” MLC (eMLC). The essential difference between SLC and MLC/eMLC is the number of bits that stored per NAND cell. SLC stores 1 bit of data per cell, while MLC and eMLC store 2 bits of data per cell. Table 1 captures the main differences between these types of flash memory.<sup>1</sup>

SLC, MLC and eMLC Comparison			
3xnm Lithography	SLC Flash	MLC Flash	eMLC Flash
Bits/Cell	SLC Flash 1	2	2
Endurance	100K	3K	10K-30K
ECC Capability	8b/512B	24b/1KB	24b/1KB
Density	16GB	32GB	32GB
tPROG	0.5ms	1.2ms	2-2.5ms
tERASE	1.5-2ms	3ms	3-5ms
Useful Life Performance	Constant	Reduces	Reduces

Table 1: SLC, MLC and eMLC Flash Memory Comparison

By definition, SLC NAND flash is a more reliable technology, supporting more than 100,000 write cycles per cell. This characteristic makes it the flash technology of choice for enterprise applications, with SLC flash-based SSDs providing a useful life of 10-20 years, based on manufacturer specifications. MLC flash memory is less reliable and withstands no more than 3,000 write cycles per cell in 3xnm technology. The limited write endurance of MLC flash makes it well suited for consumer applications, where the media is primarily used for reading. As shown in Table 1, eMLC NAND flash delivers marginally better write endurance, but at the expense of some performance.

At first glance it may seem that eMLC flash memory could be used to produce enterprise-grade SSDs, but a more detailed analysis proves otherwise. The reason is that eMLC flash is created by the process of die-screening consumer MLC flash for marginally higher endurance, or by static tweaking of flash process parameters such as increasing erase time to slow wear-out characteristics and by increasing program time. The result is higher endurance, with slower performance.

This slowdown renders eMLC flash unsuitable for true enterprise-class applications.

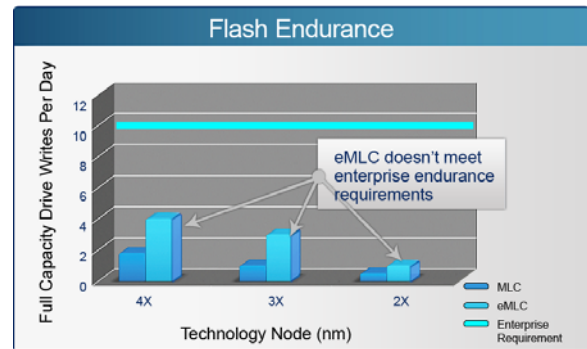


Figure 2: Flash Endurance vs. Technology Node

Figure 2 also shows that neither MLC nor eMLC flash meet the endurance requirement of 10 full drive capacity writes-per-day. What’s more, endurance and retention capabilities decrease significantly as process geometries shrink.

Figure 3 shows that write performance for MLC flash is 30-40 percent lower than SLC flash media, and eMLC flash performance is 20 percent lower than MLC flash. Flash manufacturers specify the error correction code (ECC) that is needed to achieve the specified endurance cycles. MLC and eMLC flash require higher ECC capabilities because their endurance characteristics are lower than SLC flash.

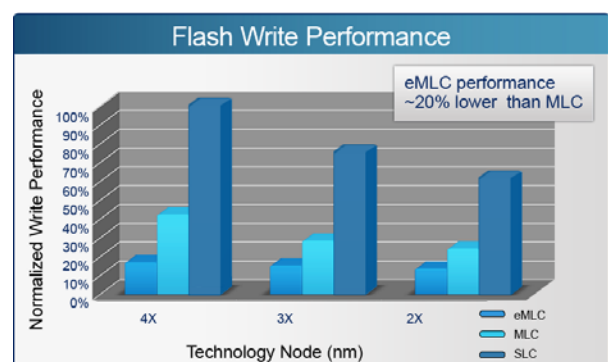


Figure 3: Flash Write Performance vs. Technology Node

In addition, the bit error rate (BER) of eMLC and MLC flash increases during the useful life of the product, which makes the components increasingly prone to failure as they are programmed and erased. The read performance of eMLC flash deteriorates during the

<sup>1</sup>MLC page size is 2x SLC page size. tPROG cycle for MLC enables 2x writes compared to SLC.

## Future of Flash Technology

(continued)

life of the product, which makes eMLC flash unsuitable for ever-intensive enterprise deployments that demand consistent SSD performance.

MLC vs. eMLC Comparison			
	Performance	Endurance	Cost
MLC Flash	Better	Low	Low
eMLC Flash	Low	Better	High

Table 2: MLC vs. eMLC Flash Memory Comparison

As shown in Table 2, eMLC flash technology bridges endurance gaps at the expense of lower performance, since multiple read retries are required due to increased bit errors during the life of the media.

## Delivering Greater Endurance, Performance, and Reliability

The wide adoption of MLC flash in the consumer space, provides economies that makes it very attractive from a density and cost perspective. Performance, reliability, availability and endurance of MLC-based SSDs are directly dependent on the design of the SSD controller.

Essentially, the controller is the brain of the SSD and the main differentiator that determines the behavior, performance and suitability of the SSD for enterprise applications. The primary functions of the controller include responding to host commands, transferring data between the host and flash media and managing the flash media to achieve high reliability and endurance.

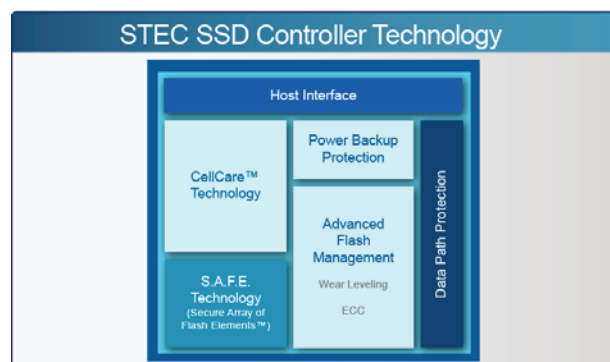


Figure 4: STEC SSD Controller Technology

How well a controller manages the flash memory determines whether the SSD can be used in enterprise applications requiring 24/7/365 uninterrupted operations under heavy read and write workloads.

STEC's CellCare Technology provides three definitive benefits in enterprise-class SSDs:

- Improved endurance of MLC media;
- Enhanced performance;
- Reduced media access error rate and consistent performance over useful life of the drive.

As shown in Figure 4, STEC SSD controllers with proprietary CellCare Technology actively manage and extend the life of the MLC NAND flash while simultaneously improving the performance.

CellCare technology improves SSD endurance through the use of adaptive flash management algorithms. Proactive cell management throughout the life of the SSD provides improved reliability and reduced bit error rates. In addition, CellCare Technology employs advanced signal processing techniques to dynamically manage how the flash wears. This eliminates the need for read-retries by accessing error-free data, even at vendor-specified endurance limits. In addition, techniques such as predictive read-optimization ensure there is no loss of performance during the useful life of the drive.

CellCare Technology also incorporates controller-based media access management, which dynamically adjusts over the lifetime of the media to reduce the Uncorrectable Bit Error Rate (UBER). Advanced ECC techniques enable a higher degree of protection against media errors, leading to improved endurance of MLC flash media while maintaining or delivering high performance. CellCare Technology also enables the use of low-cost flash in enterprise applications by improving overall endurance and performance over the useful life of the drive.

As shown in Figure 5, MLC flash-based SSDs with CellCare Technology can sustain a rate of more than 10 full-capacity drive writes per day for 5 years, without sacrificing performance.

## Delivering Greater Endurance, Performance, and Reliability

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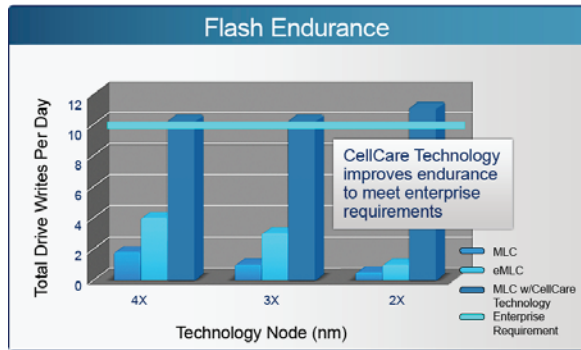


Figure 5: MLC Flash-based SSDs with CellCare

Table 3 shows a cost/benefit comparison when CellCare Technology is applied to MLC flash in SSDs. Note that performance and endurance improves, while implementation cost remains low.

Benefit Comparison			
	Performance	Endurance	Cost
MLC Flash	Better	Low	Low
eMLC Flash	Low	Better	High
MLC Flash with CellCare Technology	Best	Best	Best

Table 3: Benefit Comparison: MLC vs. eMLC Flash and MLC Flash with CellCare Technology

As shown in Figure 6, next-generation enterprise SSDs using STEC's CellCare Technology and MLC or eMLC flash media can provide better performance and endurance compared to SSDs using generic MLC or eMLC NAND flash memory.

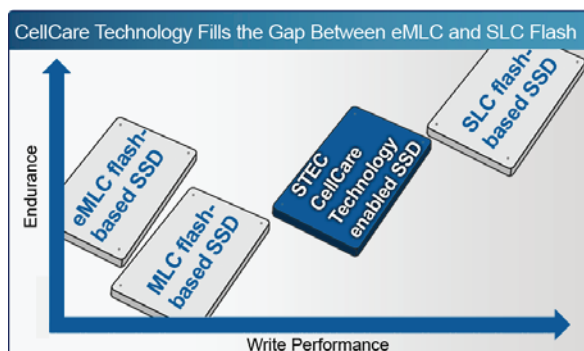


Figure 6: CellCare Technology Endurance vs. Write Performance

## Conclusion

The reliability, availability and serviceability needs of an SSD are ultimately met by the SSD controller. STEC's SSD controller with integrated CellCare Technology provides enterprise-class endurance and improved performance for MLC flash media by using advanced signal processing and adaptive flash management algorithms. The option to incorporate MLC flash-based SSDs into enterprise infrastructure in addition to SLC flash-based solutions lets IT managers choose the best solution for their specific enterprise application requirements.

The flexibility provided by enterprise-class MLC SSD alternatives enables OEMs to deploy these devices in the most demanding enterprise environments, leading to improved performance, higher reliability and reduced power, space, and energy consumption.

All of these factors contribute to lower total cost of ownership in SSD implementations in next-generation servers and data centers compared to systems relying on legacy hard-drive technologies. STEC continues to address the needs of next-generation data centers by reducing capital equipment and operating costs for cost-effective, enterprise-class SSDs.

For more information, please visit [www.stec-inc.com](http://www.stec-inc.com).