



WHITE PAPER

pSLC Storage Solutions as an Optimal Choice for High-Endurance Industrial Applications

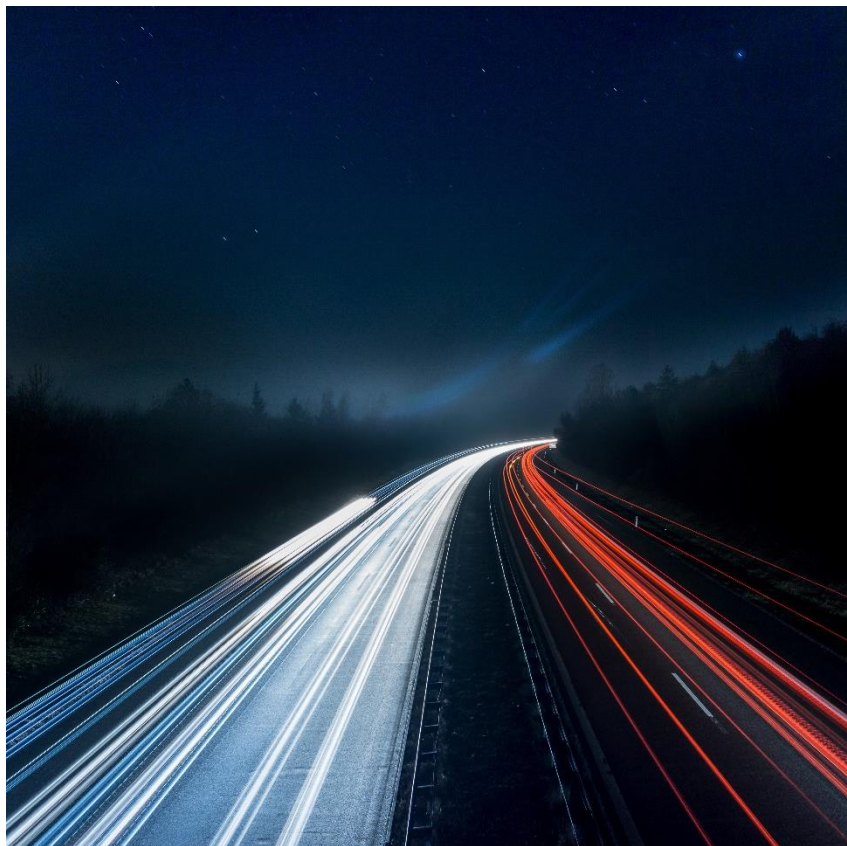


Content

Executive Summary.....	3
Introduction	4
Challenges in Industrial Storage Solutions	5
Overview of pSLC Technology ..	6
Performance Comparison: pSLC vs. MLC in Industrial Settings ...	8
pSLC: A Better Choice Than MLC for High-Endurance Needs	12
Conclusion and Recommendations.....	13

Executive Summary

While 3D TLC and 3D QLC NAND technologies have become mainstream due to their high capacity and cost advantages, industrial environments often demand storage solutions that prioritize endurance over raw storage density. Despite the significant improvements in capacity, the physical limitations of these newer NAND types make them less ideal for high-stress, continuous-use applications. Exascend offers a solution that balances endurance, price, and capacity with its pSLC (Pseudo Single-Level Cell) technology. This paper explores how pSLC serves as a high-performance alternative for customers using MLC and needing greater endurance, particularly in eMMC, SD/microSD cards, and SSD modules.



Introduction

The Rise of 3D TLC and 3D QLC NAND

In recent years, 3D TLC and 3D QLC NAND technologies have replaced older SLC and MLC as the mainstream NAND flash solutions¹. Their cost-per-bit efficiency and larger capacities have made them popular for consumer and enterprise applications. However, while they excel in capacity and price, their lifespan in continuous, high-stress environments is limited due to inherent physical characteristics.

Problem Statement: Endurance Matters in Industrial Applications

For industrial applications that involve continuous read/write operations and use embedded, non-replaceable storage, endurance becomes the key factor. Industries like manufacturing, automotive, and automation require storage that can match the long service life of the equipment it supports. While MLC has traditionally been preferred over TLC for its better durability, Exascend's pSLC technology offers an even better solution, combining TLC's pricing and capacity benefits with superior endurance.

¹ <https://www.computerweekly.com/feature/QLC-edges-into-mainstream-but-what-are-its-advantages>

Challenges in Industrial Storage Solutions

Extreme Conditions and Continuous Operations

In industrial environments, storage must withstand extreme conditions such as high temperatures, dust, or constant vibration, while performing continuous data write/erase operations. These systems need more than just large storage capacity—they require durable, reliable solutions capable of maintaining performance over years of use.

Life/Price/Capacity Trade-offs

The main challenge for industrial storage is balancing three critical factors:

- **Endurance:** The lifespan of storage under heavy read/write cycles.
- **Price:** The cost per unit of storage.
- **Capacity:** The amount of data the storage can hold.

While 3D TLC and QLC provide advantages in terms of capacity and cost, they fall short on endurance. Conversely, SLC offers the highest endurance but at a much higher cost and lower storage density. Exascend’s pSLC technology provides the ideal middle ground, delivering extended endurance without the steep price or capacity limitations of SLC.

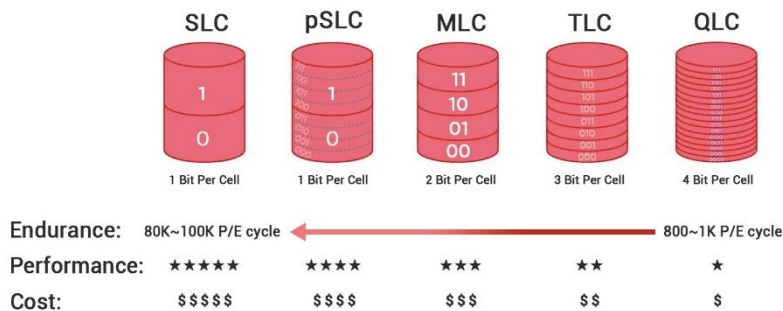


Figure 1: Comparison of various NAND types.

Overview of pSLC Technology

What is pSLC?

pSLC technology builds on 3D TLC NAND by using each cell to store only one bit of data, mimicking the performance characteristics of SLC NAND. This approach results in significantly improved endurance and performance compared to standard 3D TLC or even MLC, while keeping costs much lower than pure SLC².

² <https://www.techtarget.com/searchstorage/feature/A-pseudo-SLC-flash-primer-Benefits-and-drawbacks>

Advantages of pSLC Over MLC and 3D TLC

- **Endurance:** pSLC achieves far greater endurance than MLC and 3D TLC, making it suitable for continuous operations and harsh environments.
- **Reliability:** In industrial environments where data integrity is crucial, pSLC's error rates are significantly lower, even at high temperatures and with constant data writes.
- **Performance:** pSLC delivers faster write speeds than MLC, making it critical for applications requiring quick data transfers and real-time processing.
- **Power Efficiency:** pSLC is more power-efficient than 3D TLC, thanks to its faster program and erase operations.
- **Resilience Against Power Loss:** Since pSLC stores one bit per cell, it is more resilient to sudden power loss, minimizing the risk of data corruption across other NAND pages, unlike 3D TLC.

Broad Application Across Products

Exascend applies pSLC technology to eMMC, SD/microSD cards, and SSD modules. This broad product portfolio ensures that customers across various industries can find pSLC solutions that meet their specific storage needs while balancing endurance, capacity, and price.

Performance Comparison: pSLC vs. MLC in Industrial Settings

Test Methodology

Exascend conducted comparative performance and reliability tests between its pSLC devices and another brand's MLC devices under high-stress conditions, including intensive data write/erase cycles and an accelerated aging process at elevated temperatures. These tests simulated the demanding environments typical of industrial applications, focusing on performance and data reliability.

- **Devices Under Test (DUTs):** Two 16GB devices, one based on MLC NAND and the other on pSLC NAND.
- **Test Conditions:** Both DUTs underwent an accelerated aging process at a high operating temperature of 125°C.
- **Data Program and Erase Cycles:** Each device was subjected to program and erase cycles, with a total of 60TB of data written and erased.
- **Data Verification and Performance Testing:** At 32 and 64 hours, data was written and read again to verify whether the flash memory was operating correctly and to assess any performance impact.

Test Results

- **After 32 Hours:** The MLC DUT showed significant performance drop, while the pSLC DUT maintained its original performance with no signs of wear.

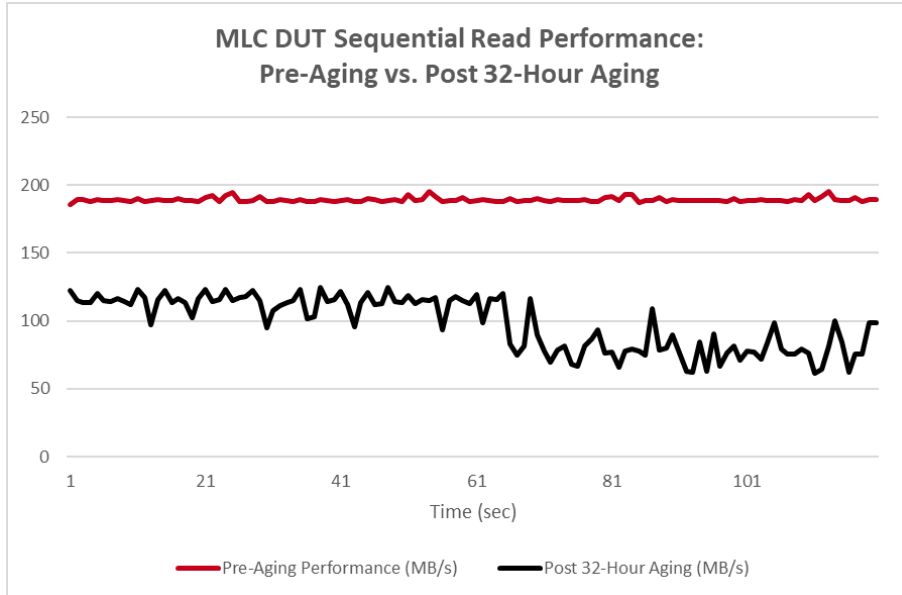


Figure 2: Performance decline in MLC DUT after 32-hour aging.

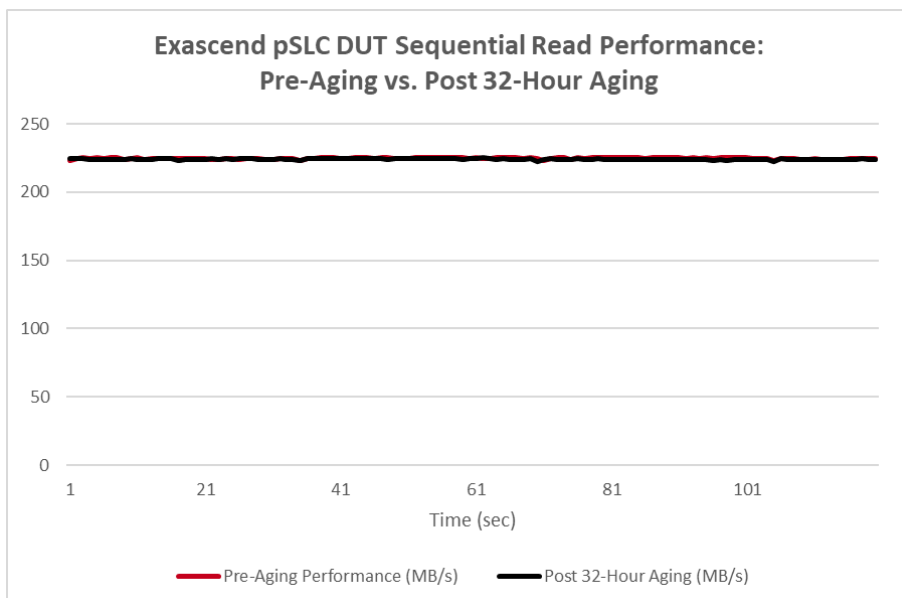


Figure 3: Exascend's pSLC DUT maintains performance with no wear after 32-hour aging.

- **After 64 Hours:** As shown in the figure, the MLC DUT encountered an LBA error, preventing further performance and data comparison tests. In contrast, Exascend's pSLC DUT successfully passed both the data comparison and performance tests, continuing to operate normally.

```

Line 78139: [000-02-05-007]ERROR: Encounter DMC error on LBA 0xab80...
Line 82248: [000-02-05-043]ERROR: Encounter DMC error on LBA 0xae80...
Line 86357: [000-02-05-001]ERROR: Encounter DMC error on LBA 0xaf80...
Line 90466: [000-02-05-035]ERROR: Encounter DMC error on LBA 0xb080...
Line 94575: [000-02-06-056]ERROR: Encounter DMC error on LBA 0xb380...
Line 98684: [000-02-06-032]ERROR: Encounter DMC error on LBA 0xb680...
Line 102793: [000-02-06-021]ERROR: Encounter DMC error on LBA 0xb780...
Line 106902: [000-02-06-058]ERROR: Encounter DMC error on LBA 0xbb80...
Line 111011: [000-02-06-049]ERROR: Encounter DMC error on LBA 0xc680...
Line 115120: [000-02-06-026]ERROR: Encounter DMC error on LBA 0xcc80...
Line 119229: [000-02-07-020]ERROR: Encounter DMC error on LBA 0xe680...
Line 123338: [000-02-07-010]ERROR: Encounter DMC error on LBA 0xe780...
Line 127447: [000-02-07-015]ERROR: Encounter DMC error on LBA 0xeb80...
Line 131556: [000-02-07-038]ERROR: Encounter DMC error on LBA 0xfd80...
Line 135665: [000-02-12-057]ERROR: Encounter DMC error on LBA 0xc6780...
Line 139774: [000-02-12-049]ERROR: Encounter DMC error on LBA 0xc6880...
Line 143883: [000-02-12-006]ERROR: Encounter DMC error on LBA 0xc6980...
Line 147992: [000-02-12-033]ERROR: Encounter DMC error on LBA 0xc6a80...
Line 152101: [000-02-12-029]ERROR: Encounter DMC error on LBA 0xc6b80...
Line 156210: [000-02-13-053]ERROR: Encounter DMC error on LBA 0xc6c80...
Line 160319: [000-02-13-026]ERROR: Encounter DMC error on LBA 0xc6d80...
Line 164428: [000-02-13-006]ERROR: Encounter DMC error on LBA 0xc6e80...
Line 168537: [000-02-13-030]ERROR: Encounter DMC error on LBA 0xc6f80...
Line 172646: [000-02-13-026]ERROR: Encounter DMC error on LBA 0xc7080...
Line 176755: [000-02-13-022]ERROR: Encounter DMC error on LBA 0xc7180...
Line 180864: [000-02-13-002]ERROR: Encounter DMC error on LBA 0xc7280...
Line 184973: [000-02-13-046]ERROR: Encounter DMC error on LBA 0xc7580...
Line 189082: [000-02-13-002]ERROR: Encounter DMC error on LBA 0xc7680...
Line 193191: [000-02-14-014]ERROR: Encounter DMC error on LBA 0xc7880...
Line 197300: [000-02-14-032]ERROR: Encounter DMC error on LBA 0xc7980...
Line 201409: [000-02-14-028]ERROR: Encounter DMC error on LBA 0xc7a80...
Line 205518: [000-02-14-024]ERROR: Encounter DMC error on LBA 0xc7b80...
Line 209627: [000-02-14-020]ERROR: Encounter DMC error on LBA 0xc7c80...
Line 213736: [000-02-14-010]ERROR: Encounter DMC error on LBA 0xc7d80...
Line 217845: [000-02-14-035]ERROR: Encounter DMC error on LBA 0xc7e80...
Line 221954: [000-02-14-030]ERROR: Encounter DMC error on LBA 0xc7f80...

```

Figure 4: Data errors in MLC DUT after 64 hours at high temperatures.

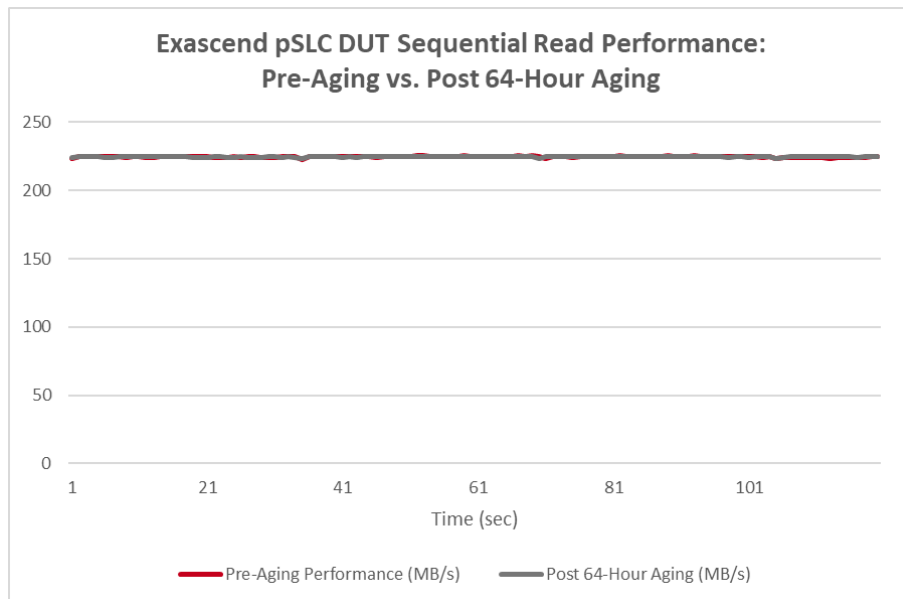


Figure 5: Exascend's pSLC DUT passes data comparison and performance tests, operating normally.

Conclusion

These results clearly demonstrate that pSLC offers superior endurance and reliability compared to MLC under extreme industrial conditions, making it a better choice for demanding applications.



pSLC: A Better Choice Than MLC for High-Endurance Needs

Endurance and Performance Balance

For customers who have traditionally relied on MLC for its higher endurance compared to TLC, pSLC represents an attractive upgrade. pSLC not only offers better endurance than MLC but also provides faster performance and greater reliability under extreme conditions. Given its close price point to MLC, pSLC offers a more efficient and durable solution for those concerned with the service life of their storage.

TLC's Role for Less Demanding Applications

It's important to note that while pSLC is ideal for high-endurance environments, 3D TLC remains an excellent solution for applications where capacity and cost are the primary concerns. Exascend's TLC products continue to serve a broad range of industries with excellent storage performance at a competitive price point.

pSLC Use Cases in Industrial Environments

- **Embedded Systems:** Where storage is difficult to replace or upgrade, such as in manufacturing or automotive systems.
- **Harsh Environments:** Where systems are exposed to extreme conditions like high temperatures, dust, or vibrations, making reliability critical.
- **Data Logging and Monitoring:** Where constant data collection is required, such as in surveillance systems or industrial sensors.

Conclusion and Recommendations

In industrial environments where endurance is crucial, Exascend's pSLC storage technology offers the ideal balance between durability, price, and capacity. pSLC outperforms MLC in terms of longevity and reliability while being a cost-effective alternative to SLC. Engineers and product managers looking for a high-endurance storage solution should consider pSLC as a clear upgrade over MLC, without compromising performance or price.

Exascend's TLC solutions continue to serve applications that prioritize capacity and cost, but for those requiring a balance of endurance and affordability, pSLC provides a compelling solution for long-term industrial performance.

Exascend's pSLC – Balancing Life, Price, and Capacity

Next Steps and Recommendations

We recommend that customers currently using or evaluating MLC solutions consider pSLC as a viable alternative. By conducting pilot projects and endurance testing, engineers and product managers can experience the benefits of pSLC firsthand in terms of service life, performance, and total cost of ownership (TCO).



About Exascend

Exascend is a service-oriented provider of cutting-edge storage and memory solutions, specializing in low-power, high-performance, and high-reliability products. We offer a wide range of storage solutions including SSDs, memory cards, managed NAND, and DRAM. With end-to-end capabilities spanning hardware, firmware, software, engineering, manufacturing, and customization, we empower global customers to push the boundaries of innovation, offering quality, reliability, and flexibility.

Exascend Global

Room 1, 6F, No. 288, Sec. 6, Civic Blvd., Xinyi Dist.,
Taipei City 110, Taiwan.

exascend.com

Copyright © 2024 Exascend, Inc. All rights reserved. Information contained in this document, including but not limited to any instructions, descriptions, and product specifications, is considered proprietary and confidential to Exascend, Inc. and shall not be modified, used, copied, reproduced or disclosed in whole or in part, in any form or by any means, electronic or mechanical, for any purpose, without the written consent of Exascend, Inc.