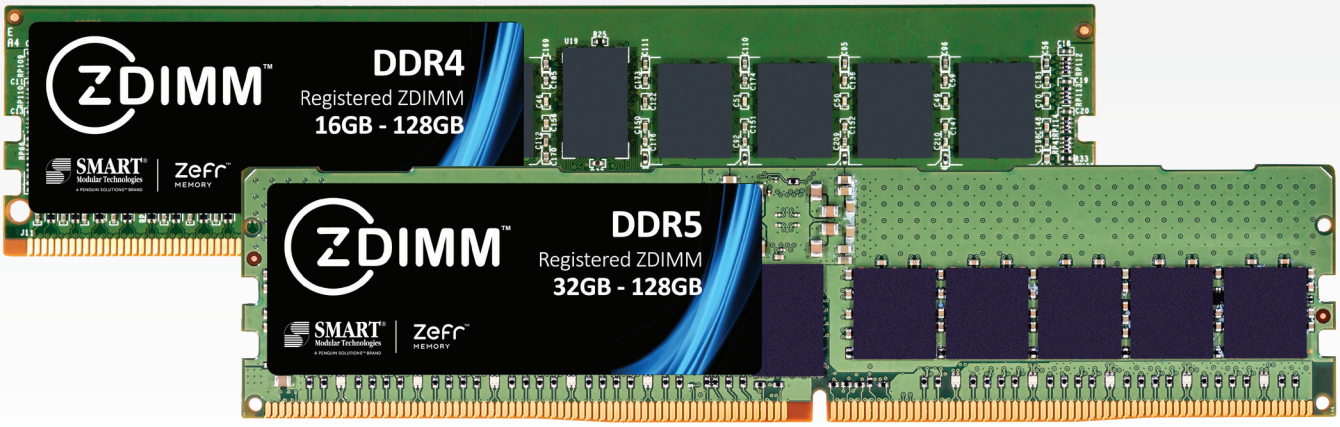
Zefr™ MEMORY



White Paper M-WP015

Zefr™ High Reliability Memory

September 2024

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Introduction

SMART Modular Technologies' Zefr High Reliability Memory is an innovative solution designed to address the critical need for uninterrupted operation in data-intensive computing environments. This proprietary technology employs a unique screening process that eliminates over 90% of memory reliability failures, optimizing memory subsystems for maximum uptime. Zefr Memory is specifically engineered to meet the demanding requirements of data centers, hyperscalers, high performance computing (HPC) platforms and other environments that run large memory applications and depend on continuous operation.

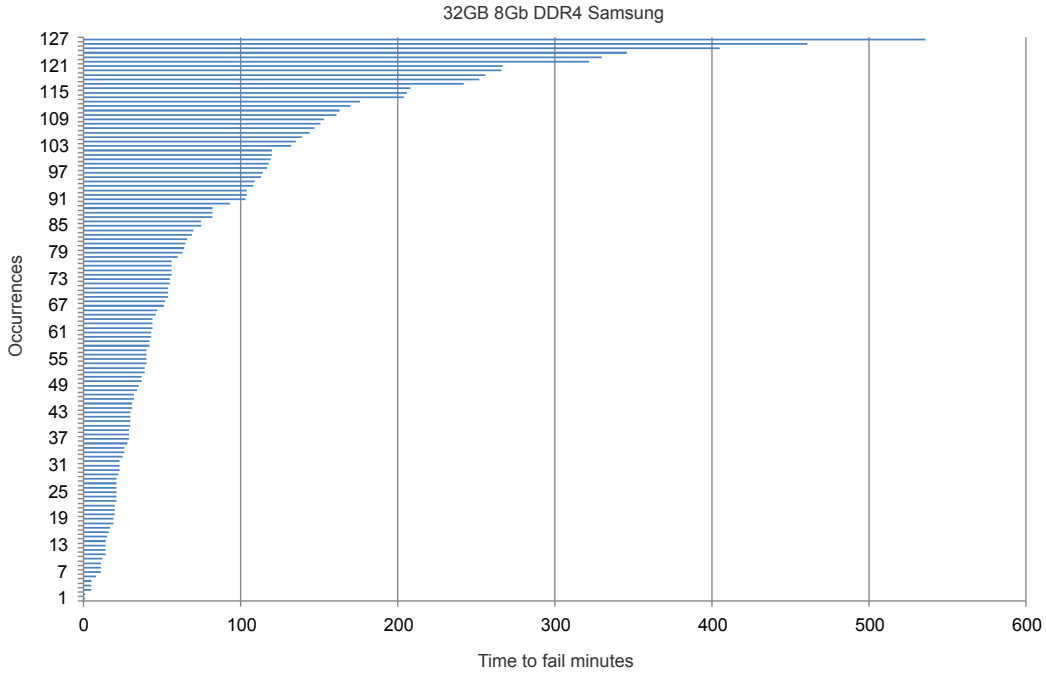
By identifying and filtering out marginal components that may compromise memory reliability, Zefr Memory significantly reduces system start-up delays and errors that can lead to inefficiencies, higher maintenance costs and lower system yield rates. This advanced memory solution has been rigorously tested under real-world conditions to ensure the industry's highest levels of uptime and reliability.

Zefr Memory is particularly valuable for applications that require extended periods of uninterrupted computation, such as artificial intelligence (AI), machine learning (ML), simulations and in-memory databases. It enables complex algorithms and data-intensive processes to run to completion without interruptions or time-consuming restarts, thereby preserving valuable resources and maintaining operational efficiency. By integrating SMART's Zefr Memory, system designers and end users can expect enhanced computing performance and a significant boost in overall system reliability.

Testing Methodology

SMART Modular Technologies employs a carefully calibrated burn-in process for its Zefr High Reliability Memory, striking a critical balance between rigorous testing and real-world performance. This process is based on extensive field test data and modeling, ensuring that modules are stressed to their maximum thresholds while still reflecting normal operating conditions over their service life. The burn-in duration is meticulously determined to confidently identify all potential flaws, significantly reducing deployment issues.

In the chart below, a representative test of 31 modules revealed that all failures, including single-bit errors, occurred within the first 600 minutes of burn-in. Modules that pass this critical period undergo extended testing, often for several days, to confirm their long-term reliability. This comprehensive approach allows SMART to deliver memory modules with exceptional durability and performance, meeting the stringent uptime requirements of data-intensive.

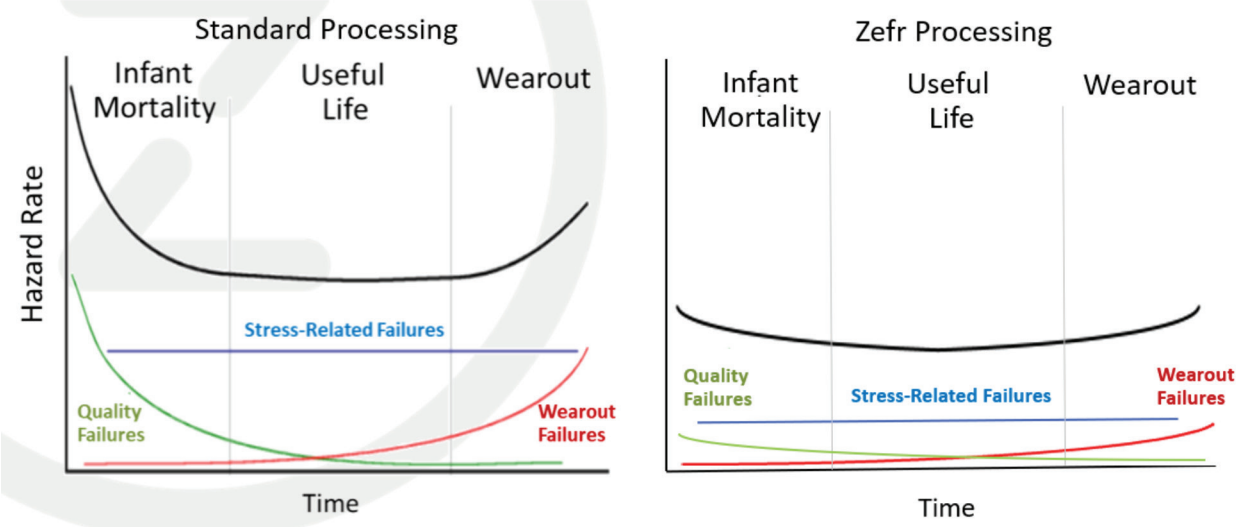


Zefr™ MEMORY

Five key testing methodology components ensure that only the highest reliability memory modules achieve Zefr memory classification.

- Demanding test scripts
- Real-world server motherboards
- High speeds
- Elevated temperatures
- Extended test durations.

As a result, failures over time show dramatically reduced, and in many cases, were eliminated over the lifetime of the Zefr DIMMs compared to memory modules that undergo only standard processing.



Test Scripts

SMART culls DIMMs with potential vulnerabilities and data dependent failures by running test scripts and programs that randomly exercise the entire memory array with over 98% coverage and 35% higher power draw than standard memory test programs. Memory modules that record even a single error code correction (ECC) occurrence are disqualified from Zefr classification.

Server Motherboards

Tests on actual Intel or AMD motherboards ensure that only dual in-line memory modules (DIMMs) that perform in true, real-world systems get selected.

High Speed

Tests at high speeds ensure that only DIMMs with robust timing margins get selected.

Elevated Temperatures

DIMMs with devices susceptible to infant mortality due to a variety of failure mechanisms such as metal migration get screened as they get tested at ~70°C ambient temperature. Running the systems at this temperature with 100% DRAM utilization pushes the DRAM case temperature to +85°C.

Extended Test Duration

Seven-to-ten-hour test durations ensure that the DIMMs are capable of performing reliably for applications that run continuously for longer periods of time.

Zefr Memory: Applications and Benefits

SMART Modular Technologies' Zefr memory offers significant advantages in high-performance computing environments, substantially reducing memory-related system failures over the deployment lifetime. This technology is particularly beneficial for:

AI and Data Mining: Enabling real-time algorithm processing for large-scale data analysis

Machine Learning: Facilitating high-volume data processing in real-time

Simulations: Supporting complex modeling for financial markets, government functions, and trend analysis

In-Memory Databases: Enhancing performance and reliability for data-intensive applications

Operational Efficiency

Booting a server with 96 modules of 64GB LRDIMMs, a typical configuration for these applications, can be challenging. System testing, which may take days, often requires restarts due to standard memory subsystem failures. Zefr modules significantly mitigate this issue, reducing both downtime and associated costs.

Cost Savings

SMART's joint monitoring of fallout and field failure data has demonstrated substantial cost savings for customers. In one case study:

Metric	Value
Modules Shipped	141,000
Field Failures (Standard)	2,834
Field Failures (Zefr)	226
Total Cost Savings	$13 million

With each service call potentially costing up to $5,000 (factoring in field technicians, data center downtime, material costs, and operational maintenance), the reduction in field failures from 2,834 to 226 represents significant savings. By implementing Zefr memory, organizations can dramatically improve system reliability, reduce maintenance costs, and minimize disruptive downtime in critical computing environments.

Comprehensive Zefr Memory Solutions

SMART Modular Technologies offers a suite of value-added services alongside its Zefr memory products, leveraging its expertise as a custom memory manufacturer.

Advanced Tracking and Analysis

Serialization: SMART implements a robust tracking system that monitors every phase of Zefr module production, including:

- Manufacturing test history
- Field traceability
- System-level tests
- Burn-in processes

This comprehensive approach ensures full visibility into each module's lifecycle, enhancing quality control and facilitating rapid issue resolution.

Failure Analysis: SMART collaborates closely with engineers during trial runs and engineering sample phases. This partnership enables continuous refinement of the manufacturing process, resulting in modules with minimal error rates.

Commitment to Excellence

SMART is dedicated to providing original equipment manufacturers (OEMs) customers with enterprise memory modules of unparalleled quality and reliability. The company's focus on adopting the latest technologies and methodologies ensures that its products remain at the forefront of the industry.

Zefr memory is positioned as a premium solution for enterprises requiring the highest levels of reliability and performance in their memory subsystems.

Zefr Memory Offering

Product Family (Type)	Capacity
DDR5 RDIMM	16GB to 256GB
DDR4 RDIMM	8GB to 256GB

Note: Zefr Memory is available in other module form factors for DDR3, DDR4, and DDR5 based on customer requests.

Zefr™ MEMORY

For more information, please visit: **www.smartm.com**

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