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E2 SSD FORM FACTOR: THE NEW SUPERHERO IN HIGH-DENSITY STORAGE

Executive Summary

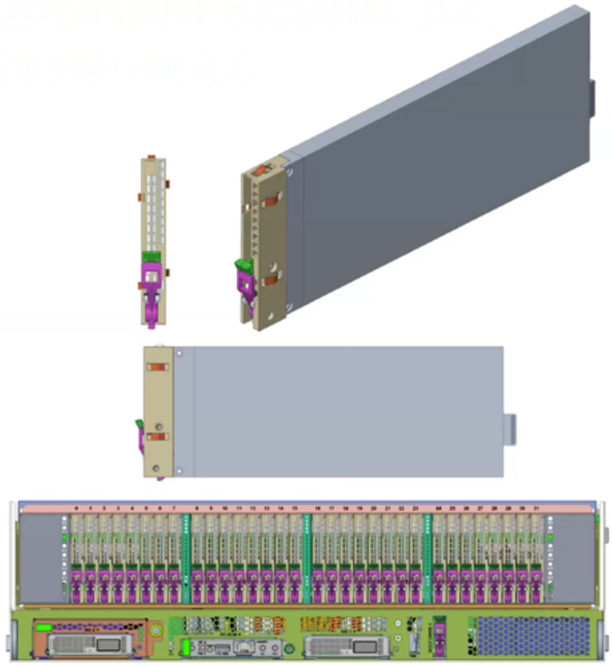
Emerging workloads across AI, big data, IoT, and hyperscale compute require a rethinking of storage infrastructure. As data volume surges, particularly in the “warm data” tier, where information is accessed frequently but not in real-time, existing storage form factors struggle to scale simultaneously in terms of capacity, density, power, and performance.

Enter the E2 SSD form factor, developed jointly by the Storage Networking Industry Association (SNIA) and the Open Compute Project (OCP). Purpose-built for ultra-dense storage environments, E2 enables up to 1 petabyte (PB) of QLC NAND flash per device, leveraging PCIe 6.0 NVMe, within a compact thermal-optimized footprint.

Since the inception of flash storage, form factors have evolved from mechanical drive mimics (2.5” SATA) to purpose-built enterprise storage designs. These include M.2, U.2/U.3, EDSFF variants, and now the next frontier: E2.

STORAGE EVOLUTION:

From Spinning Disks to Petabyte Flash



The storage industry has experienced a remarkable evolution over the past five decades – from magnetic platters to NAND flash arrays – shaped by growing demands for capacity, reliability, speed, and energy efficiency.

In the 1980s and 1990s, storage was dominated by spinning disk hard drives (HDDs), prized for their low cost-per-gigabyte. As digital content, databases, and internet usage expanded, higher capacities were achieved through advances in perpendicular magnetic recording (PMR) and helium-filled enclosures, culminating in enterprise-grade HDDs reaching 20-60 TB in the early 2020s.

However, HDDs exhibited critical shortcomings:

- Latency typically in the millisecond range (5,000–8,000 μs)
- High failure rates in dense environments
- Significant cooling and vibration isolation requirements

This led to the rise of NAND flash storage in the early 2000s. With zero seek time, microsecond latency, and solid-state durability, SSDs transformed laptop, desktop, and enterprise performance. Early form factors like 2.5“ SATA SSDs were drop-in replacements, constrained by SATA's bandwidth (~6 Gbps).

The subsequent introduction of NVMe and PCIe-based SSDs in U.2, M.2, and later EDSFF formats unlocked:

- Direct CPU access via PCIe lanes
- Gigabyte-per-second throughput
- Sub-100μs latency
- Smaller thermal envelopes and better rack utilization

Despite these improvements, the growing volume of semi-active “warm data” exposed a market gap between high-cost performance SSDs and high-latency HDDs.

Key KPIs that shaped this transition include:

- IOPS per watt: SSDs dramatically outpace HDDs (e.g., 100K vs. 400 IOPS)
- Throughput per U: Increasing demand to store more per rack unit
- Cost-per-GB: QLC NAND and controller advances narrow SSD-HDD cost gap
- MTBF and reliability: SSDs exhibit fewer mechanical failures, especially in high-vibration environments
- Cooling efficiency: High-density SSDs consume less power per TB compared to HDDs at scale.

The introduction of the E2 form factor responds precisely to this intersection: the need to store massive datasets close to compute, with flash-grade reliability, at a cost that competes with HDD-based systems in warm-tier architectures.

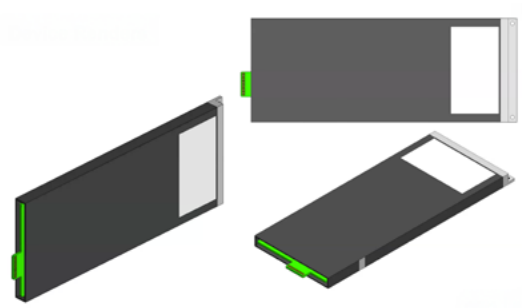
As AI workloads, video surveillance, genomic data, and IoT sensors flood data centers with petabytes of mid-use data, E2 SSDs offer a scalable solution that fits within the thermal, vmechanical, and economic envelope required by tomorrow's data-driven infrastructure.

Metric	E2 SSD	E3.L (EDSFF)	U.3 NVMe	3.5" HDD	Comment
Max Capacity	1 PB	64 TB	32 TB	30–60 TB	E2 leads in density
Interface	PCIe 6.0 x4 NVMe	PCIe 4.0/5.0	PCIe 3.0/4.0	SATA/SAS	Cutting-edge interface
Power Draw	20–80W	20–40W	10–25W	5–15W	High power density
Latency	~20–40 µs	~20 µs	~40–60 µs	~5–8 ms	Flash vs HDD
Sequential Read	8–10 MB/s per TB	50–70 MB/s	80–100 MB/s	2–3 MB/s	Performance balance
Sequential Write	2–4 MB/s per TB	30–50 MB/s	50–80 MB/s	1–2 MB/s	Write limited by QLC
Random IOPS	5–10K	100K+	50–80K	200–400	IO intensive advantage
Dimensions	200x76x9.5mm	318x76x9.5mm	100.45x69.9x15mm	146x101.6x25.4mm	Compact
Cooling	Hybrid/Liquid	Air/Liquid	Air	Air	Needs advanced cooling
Hot-Swap	Yes	Yes	Yes	Yes	All support hot-swap

Technical & Mechanical Comparison of E2 vs Existing Form Factors

ENGINEERING **PROFILE**

E2 SSDs leverage QLC NAND with SLC cache zones for burst write performance. NVMe 6.0 x4 interface ensures high bandwidth. Thermal design requires hybrid or liquid cooling at scale due to a peak draw of up to 80W. NVMe-MI support allows rich telemetry and power management.



USE CASES:

- **Data Centers & Hyperscalers:**
  Up to 40 PB in 2U nodes. Suitable for warm object storage, logging infrastructure, and compliance storage.
- **AI/ML Training and Inference:**
  Caches datasets for frameworks like TensorFlow and PyTorch. Stores model checkpoints locally.
- **AI-Powered Workstations:**
  Ideal for 3D simulation, CAD/CAM, media rendering with petabyte-class local storage.
- **Robotics & Autonomous Systems:**
  Stores real-time sensor data from LiDAR/radar. Useful for debugging and compliance logs.
- **Industrial IoT & Edge Compute:**
  Retains data in disconnected environments. Enables localized analytics buffering.

E2 SSDs offer rack-space savings, energy efficiency, and a clear path to replace high-cap HDDs for warm-tier workloads. With maturing QLC economics, TCO parity is expected within 12–18 months.

LOOKING AHEAD

Micron and PureStorage have both contributed to the first drafts of the standard and presented their first prototypes: PureStorage, a 300TB E2, and Micron, one with more than 500 TB.

In parallel, the Open Compute Project is standardizing chassis and airflow infrastructure for server platforms. However, the server platforms are not supporting E2 yet, and it will be a while before memory manufacturers will be able to turn this new standard into a deployable product.

REFERENCES

1. Micron – EDSFF E2: A New Form Factor for Meeting Rack Scale Cost, Power, and Bandwidth per TB Goals
   Micron discusses the EDSFF E2 form factor's advantages in rack-scale deployments, focusing on cost, power efficiency, and bandwidth per terabyte.

2. Open Compute Project – Catalina EDSFF Reference Design Specification v1.0.1
   This document outlines the base, design, and product specifications for PCIe Gen5 NVMe SSDs in EDSFF, providing insights into the Catalina project's objectives.

3. Kioxia – EDSFF: A New SSD Form Factor for Next-Gen Servers and Storage
   Kioxia presents the benefits of EDSFF, including improved signal integrity, higher power support, and enhanced performance for next-generation servers and storage solutions.

4. Tom's Hardware – A New SSD Form Factor Can House a Staggering 1,000,000 GB of Storage
   An overview of the E2 SSD form factor's potential, highlighting its massive storage capacity and the challenges associated with power consumption and thermal management.

5. EaseUS – A New SSD Form Factor Poised to Redefine High-Capacity Storage
   This article discusses the E2 form factor's role in bridging the gap between high-capacity HDDs and high-performance SSDs, emphasizing its suitability for „warm“ data storage.

6. SNIA – SSD Form Factors Resource Guide
   The Storage Networking Industry Association provides detailed information on various SSD form factors, including dimensions, interfaces, protocols, and use cases.

7. Open Compute Project – Exabyte-scale Flash with OCP and ExaDrive®
   A presentation detailing the integration of exabyte-scale flash storage solutions within the Open Compute Project's framework, emphasizing the role of standardized form factors.

8. Western Digital – Top Considerations for Enterprise SSDs
   This white paper explores key factors in selecting enterprise SSDs, including form factor considerations, performance metrics, and reliability features.

9. SNIA – NVMe SSD Classification White Paper 2023
   A comprehensive guide on NVMe SSD classifications, detailing use cases across enterprise servers, storage systems, and data center environments.

10. Samsung – PM1743 Enterprise SSD
    Samsung's PM1743 SSD showcases the capabilities of the EDSFF E3.S form factor, offering high performance and capacity for enterprise applications.

11. Innodisk – EDSFF E1.S 4TG2-P NVMe SSD
    Innodisk's E1.S 4TG2-P SSD exemplifies the application of the EDSFF E1.S form factor, designed for edge servers with features like power loss protection and wide temperature tolerance.

ABOUT US

MEMPHIS Electronic has been in the memory business for over 30 years. Due to our focus on memory only, we developed into a Memory Competence Center with an unmatched line card of over 18 different memory manufacturers (Samsung, Nanya, SK Hynix, Winbond, Huawei, SkyHigh, Ramxeed, Intelligent Memory, Apacer, Longsys, ESMT, Biwin and many more). We combine this with comprehensive supply chain solutions.

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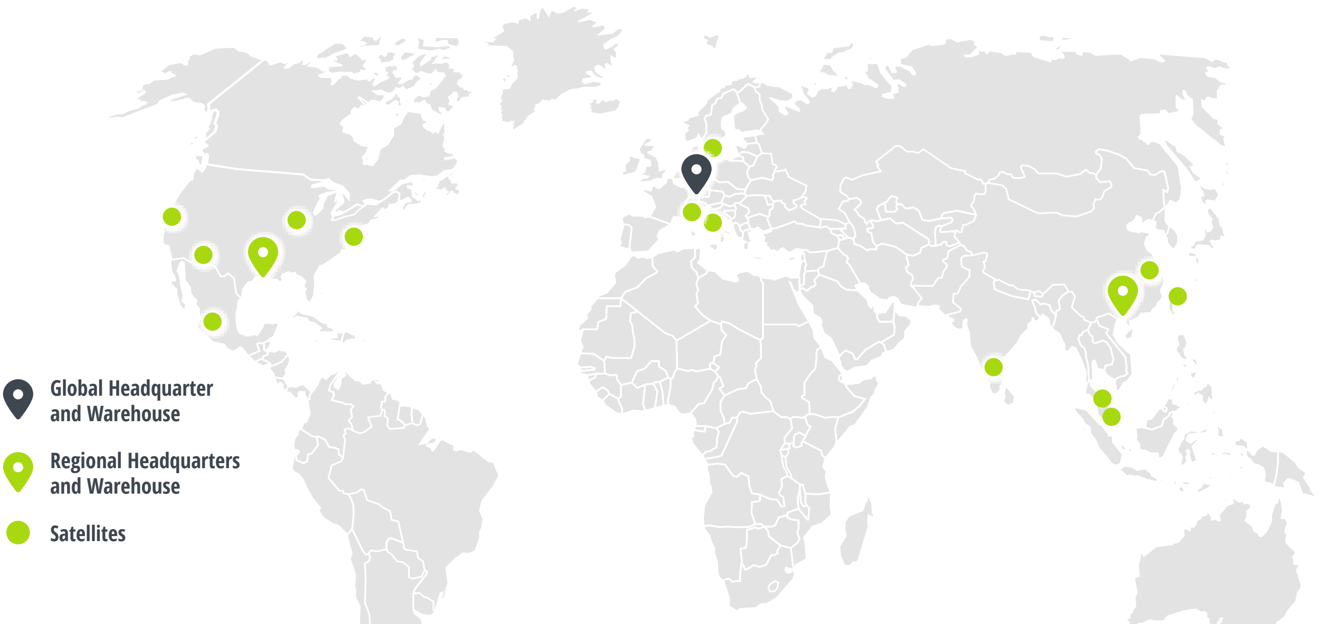

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