Spending on Enterprise SSDs now outpaces Enterprise HDDs

SSDs Continue to Expand in the Datacenter

Optimizing the Ecosystem for Solid State Drives

- Power
- Performance
- Endurance Ranges
- Connectivity
- Form Factors
- Software
Datacenter NVMe Growth Outpaces the Market

Datacenter NVMe SSDs vs Enterprise NVMe SSD
Unit Shipments

Evolution of Enterprise SSD Form Factors

Flexibility to offer various options for length, width, and height with manageability, serviceability, and thermal consideration built-in.
A New Era in the Enterprise Market with Solid State Storage in the Forefront of modern Datacenters Driving Digital Transformation

NVMe SSDs have moved in the mainstream and Datacenter NVMe SSD Growth Outpaces the Market

Optimizing IT Infrastructure for Solid State Storage to be More Efficient, Flexible, and Scalable will be Key to Drive Future of Digital Infrastructure
For More Information

Jeff Janukowicz
Research Vice President
jjanukowicz@idc.com

For more information, please visit, www.idc.com and search for: NAND flash or Solid State Drive
OCP Workshop: Data Center NVMe SSD and EDSFF

A Media Perspective
Focus on the data center market, specifically server, storage, and networking

Hardware reviews are in-data center in three Silicon Valley data centers

Covered OCP since OCP Summit was in the Santa Clara Convention Center

Readers come from different aspects including IT admins, programmers, procurement, "server enthusiasts"

Serve The ...

STH was founded in June 2009

- Focus on the data center market, specifically sever, storage, and networking
- Hardware reviews are in-data center in three Silicon Valley data centers
- Covered OCP since OCP Summit was in the Santa Clara Convention Center
- Readers come from different aspects including IT admins, programmers, procurement, “server enthusiasts”
Key Topics

- Insights STH Coverage Thus Far
- Marketing Perspective on Overcoming Adoption Barriers
- Closing Thoughts
Sample “Ruler” Coverage

The Intel Ruler SSD: Already Moving Markets

Where Cloud Servers Come From Visiting Wiwynn in Taipei

Hands-on with Supermicro 1U Half Petabyte EDSFF Server

Kioxia EDSFF SSD adding Momentum with New Development

Open Storage Platform Collaboration with Samsung

AIC FB127-AG Innovative NF1 AMD EPYC Storage Solution
Key Coverage Insights

Key Questions Asked from STH Coverage

- Where can I buy?
- When will servers have this?
- Which format will win?
- Are there other drive options?
- Why do we need this?
- Does XYZ vendor make a server?

Patrick’s Key Insights:
- Early in cycle
- Uncertainty on scope
- Uncertainty on “winner”

Sample size: 912 e-mails + article comments
Counting instances so one email/comment may have multiple summarized questions
High Engagement Rate

Coverage Statistics

• Next-gen SSD Form Factor Articles (non-review)
  • 22% longer time on page than benchmark
  • 41% higher page views in first 72 hours
  • 9% better “long tail” page views after first quarter

• Hands-on piece with Supermicro
  • #1 Video at the time
Market Perspective

2.5” seen as a “safe” choice in the industry

V.

“Do I want to be an infrastructure hero?”
Market Perspective

Need benefits beyond the “ultra-technical”

2.5” SSDs had benefits of:
• Higher reliability
• Lower latency
• Higher throughput

Why does a buyer care about thermal design?
Market Perspective

Diverging Data Center Densities

As power consumption rises, we are seeing two classes emerge. Those prepared for higher-power and those without.

Next-generation NVMe form factors such as the OCP NVMe SSD standard will be easier for hyper-scale to consume than many higher-margin enterprise customers.
Closing Thoughts

• There is a surprising amount of market interest

• Now that standards are being driven, it is time to get messaging aligned

• Need a vision around the art of possible for next-gen drives
EDSFF: Meeting System Needs

Anthony Constantine
Principal Engineer, Intel
What is EDSFF?

• Multiple usages = Multiple form factors

• One connector and interface

• One common set of specifications
Updates in the Specifications

SFF-TA-1009 Rev 3.0 (pin/signal spec)
- Electrical Requirements for 16 and 32 GT/s
- Lots of cleanup

SFF-TA-1008 Rev 2.0 (E3 form factor)
- Length, connector position change
- Other changes

New: SFF-TA-1023 (Thermal Characterization)
- Currently a draft
- Device characterization methodology

Expect more updates soon!
Want to know more?

Visit: http://www.snia.org/sff/specifications

- SFF-TA-1002: Card Edge multilane protocol agnostic connector
- SFF-TA-1006: Enterprise and Datacenter 1U Short Standard Form Factor (E1.S)
- SFF-TA-1007: Enterprise and Datacenter 1U Long Standard Form Factor (E1.L)
- SFF-TA-1008: Enterprise and Datacenter Form Factor (E3)
- SFF-TA-1009: Enterprise and Datacenter Standard Pin and Signal Specification

Participate:

- SFF: https://www.snia.org/sff
- OCP: https://www.opencompute.org/projects/storage

Adopt EDSFF!
OCP v2.0 Major Changes

04/21/2021

Lee Prewitt - Microsoft
Major Additions

- Latency Monitor (Log Identifier C3h) and Latency Monitor (Feature Identifier C5h)
- Latency Monitoring Feature Set Theory of Operation
- Unsupported Requirements (Log Identifier C5h)
- PLP Health Check Interval (Feature Identifier C6h)
- Power Loss Protection requirements
- Additional Thermal Throttling requirements
- Additional NVMe Basic Management Command requirements
- Additional Security requirements
- Additional Label requirements
HPE and Dell Add an Enterprise Perspective

- Renamed from “NVMe Cloud SSD Specification” to “Datacenter NVMe SSD Specification”
- Support for Multiple Namespaces
- Added requirements for several more commands: Sanitize, NVMe-MI Send/NVMe-MI Receive, Write Zeros, Compare, Write Uncorrectable
- Added Device Capabilities (Log Identifier C4h)
- Added NVMe-MI 1.1b Requirements
- Component Measurement and Authentication (CMA) requirements
- Device Profiles
Surprisingly Few Differences

<table>
<thead>
<tr>
<th>Requirement ID</th>
<th>Description</th>
<th>Configuration Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP-CFG-1</td>
<td>Factory Default Sector Size.</td>
<td>A: 4096-byte</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B: 512-byte</td>
</tr>
<tr>
<td>DP-CFG-2</td>
<td>Number of Namespaces Supported.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NSM-4 (16 Namespaces)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NSM-5 (16 Namespaces per TB)</td>
</tr>
<tr>
<td>DP-CFG-3</td>
<td>Retention Time based on RETC-1 (data retention time)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Month</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Months</td>
</tr>
<tr>
<td>DP-CFG-4</td>
<td>NVMe Basic Supported.</td>
<td>R</td>
</tr>
<tr>
<td>DP-CFG-5</td>
<td>Max M.2 top side height.</td>
<td>FFM2-3 (top-side height)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TBD</td>
</tr>
</tbody>
</table>
## Minor Additions

### NVMe-OPT-4
- The device shall only reset the Timestamp value on a power cycle.

### SMART-29
- **199:192**
- **PCIe Link Retraining Count**
- **8**

This is a count of the number of PCIe Link Retraining events. This count shall only increment during run time. It shall not increment during training or power fail. This shall be cleared to zero on factory exit.

### FWUP-10
- Firmware activation shall not cause user data to be lost or destroyed.

### FWUP-11
- Firmware activation without reset shall preserve the running state of the device (e.g., Opal locking state, Set Features, etc.).

### SECTOR-4
- The device shall support 512-byte and 4096-byte logical block sizes.

### TTR-19
- When the CC.SHN register is written to notify the device to shutdown it shall not be assumed that power will be lost even after CC.EN is cleared to 0. Under these conditions the device shall continue to function properly based on the NVMe and PCIe Specifications.

### REL-5
- The AFR targets in REL-1 (MTBF of 2.5 million hours) and REL-2 (MTBF of 2.0 million hours) shall be maintained up to a continuous reported composite temperature of 77°C (170°F) (WCTemp) with less than 1% of the device lifetime above WCTemp.

### GFF-6
- A CAD file of each supported form factor shall be provided.

### PWR-8
- A device shall not consume more power than the PCI-SIG Slot Capabilities register Slot Power Limit regardless of other settings (e.g., PSD in NVMe) and report Entry and Exit Latencies of FFFFFFFFh for all Power State Descriptors above the Slot Power Limit.

### FFE1S-12
- A x4 device shall only have a 1C connector.

### DEVLM-1
- The device shall not have any restrictions on the number of times any of the following events can occur: Firmware downloads and activation supported. See FWUP-2 (number of firmware downloads); or Changing password when taking/changing ownership via TCG; or Crypto erase or block erase (format); or Power cycles; or Set/get features (including power state changes); or Log page or debug log retrievals.

### FFE1L-12
- A x4 device shall only have a 1C connector.
Next Generation Flash

Ross Stenfort, Facebook
3.30 Billion People Monthly
2.60 Billion People Daily
E1.S 25mm Flash Platforms

Hyperscale Benefits:
- High Density
- Enables up to ~6 PB per rack
- Low Airflow (CFM/W)
- Flexible CPU/Flash Ratios
- Excellent Serviceability
Datacenter NVMe SSD Specification Benefits

- Aligns SSD needs and requirements between Hyperscale/OEMs and SSD makers

- What is included in the specification?
  - NVM Express
  - PCI Express
  - SMART Logs
  - Reliability
  - Thermal
  - Power
  - Security
  - Form Factor
  - SMBUS
  - Tooling

- Everything Needed to build a Datacenter NVMe SSD

➢ Datacenter NVMe SSD and E1.S: Next generation technology ready to solve today’s problems

Link to 1.0 specification can be found under OCP Contributions: https://www.opencompute.org/documents/nvme-cloud-ssd-specification-v1-0-3-pdf
Thank You
E3.S ENABLES NEXT-GEN DEVICES AND OPEN NVME SSD SPECS

Paul Kaler, Future Storage Architect
E3.S ENABLES EASY TRANSITION TO NEXT-GEN DEVICES

• E3.S 2U designs can share a chassis with existing form factors
  • Support both E3.S and 2.5” drive cages for easy customer transition—mix SAS/SATA/NVMe
  • Swap two E3 thins for one E3.S 2T (thick)
  • Intermix NVMe and CXL devices
  • Shared bays increases flexibility and reduces cost

• Supports large FPGA and SoCs
  • Future devices types (e.g., NIC, TPU/GPU, CSD)

• E3.S better airflow and thermals than 2.5”
  • Enables higher TDP downstream components
  • Higher performance devices

E3.S enables easy transition to next-gen devices
**E3.S Enables Easy Transition to Next-Gen Devices**

- Smaller connector enables smaller backplanes—reduces airflow impedance

- Better thermals enables up to 40W for E3.S 2T
  - Enables full saturation of PCIe Gen5 x4 NVMe and CXL devices
  - Provides thermal room to grow for PCIe Gen6 performance

- Cost effective performance scaling
  - Mix E3.S thin and thick to optimize performance without requiring PCIe switches
  - Higher MTBF & lower solution cost

- E3 thin enables excellent performance density for 1U as well
  - 20 drives for 2x the IOPS and bandwidth compared to 2.5”
HPE has traditionally developed custom firmware specifications for drives to achieve critical benefits:

- Ensure consistent behavior
- Assurance of Supply – consistent behavior enables multi-source
- Faster issue resolution by specifying additional telemetry and metadata logs
- Improved quality – spec out best practices from lessons learned

HPE sees significant commonality with the features and requirements specified in the Cloud spec

- Leverage to drive economies of scale and improve quality

- Open requirements enable more complete 3rd party compliance tests

HPE, Dell, Facebook, and Microsoft are working towards a common spec for both Enterprise and Cloud use cases which encompasses new form factors like E3.S – part of the EDSFF family

Almost Complete! We hope to be releasing the final Datacenter NVMe SSD Specification very soon.
THANK YOU

Paul Kaler, Future Storage Architect
EDSFF E3 Form Factor
More than just SSDs

Bill Lynn – System Architect
E3 - Flexible Form Factor

- Family of devices allows multiple device types with different power profiles
- Common device bay mechanics (smaller devices fit into larger device bays)
- Supports multiple link widths (x2, x4, x8, and x16)
- Requires a mechanical device carrier which allows for OEM ID customization
1U E3 Example Chassis Configuration

Max Storage Config

20x E3.S or E3.L Storage Devices

Storage Config with airflow

Airflow

SCM Config

SCM

E3 FH 2x

Airflow

SCM

SCM

4x E3.S or E3.L SCM or I/O Devices

4x E3.S or E3.L Storage Devices

4x E3.S or E3.L Storage Devices

4x E3.S or E3.L SCM or I/O Devices
2U E3 Example Chassis Configuration

Max Storage Config

Storage Config with airflow

SCM Config

Airflow

40x E3.S or E3.L Storage Devices

16x E3.S or E3.L Storage Devices

4x SCM or I/O Devices

16x E3.S or E3.L Storage Devices

4x SCM or I/O Devices

Max Storage Config

Storage Config with airflow

SCM Config

Airflow

40x E3.S or E3.L Storage Devices

16x E3.S or E3.L Storage Devices

4x SCM or I/O Devices

16x E3.S or E3.L Storage Devices

4x SCM or I/O Devices
Future Device Types

- Moving the E3 connector to 19.54mm allows for the use of a 4C+ connector used by OCP 3 NIC
- Allows standard networking connectors in an E3 2T form factor
- Allows for potential future higher power devices
Shipping now in a server near you: EDSFF

Jonathan Hinkle, Executive Director and Distinguished Researcher – System Architecture, Lenovo Enterprise and Cloud Research | April 2021
**Promise of EDSFF**  
(Enterprise and Datacenter Standard Form Factor)

Optimized for scaling solid-state devices in datacenter systems

- Family of cards leveraging same connector, pinout, behavior
- Better cooling, streamlined power delivery, modularity, density of drives
- Higher and scalable system capacity and performance to meet various workload needs
- Ready for future interfaces like CXL and new applications like memory, accelerators

Industry standard EDSFF connector

Improved airflow through connector

1U rack-space optimized E1.S

2U rack-space optimized E3.S thick

1U capacity-optimized E1.L
Promise of EDSFF – shipping now

Now Available: Lenovo’s new Icelake servers leveraging the EDSFF E1.S

- 1U rack server with 16 x E1.S drives: higher system storage performance with lower power and lower cost mainstream NVMe drives
- Improved airflow and system cooling for overall better TCO

16x EDSFF drives with integrated diagnostics panel

16x EDSFF drives (drive bay covers removed)

Lenovo SR630 V2: 2-socket high-volume 1U rack server
Promise of EDSFF – shipping now

EDSFF E1.S also enables high performance with 3X density, providing new value in computing systems

- Lenovo 3U SR670 V2 (dense) supports two CPUs and up to 8 double-wide adapter cards for applications like AI acceleration
- It can do this while still offering high performance storage with 6x E1.S NVMe drives.
Promise of EDSFF – shipping now

SN550 V2 Compute Sled: 2 x u.2 → 6 x E1.S, enabling new density of integrated compute and storage

Effective storage performance and capacity in every node
Smarter technology for all

thanks.
EDSFF Overview

Jonmichael Hands, Sr. Strategic Planner
Intel Non-Volatile Memory Solutions Group
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OC P NVMe SSD and EDSFF Workshop – April 27

- EDSFF overview
- Market data
- Hyperscale view
- OEM view
- SSD vendor view
What is EDSFF?

- Enterprise and Data Center SSD Form Factor
- Improved thermals, power, and scalability
- High-speed common connector, pinout – scalable to faster speed PCIe
- Integrated serviceability, hot-plug support
- Built in LEDs, carrier-less design
- Customizable latch for toolless serviceability
EDSFF History

Q1 2017
EDSFF group formed

Q3 2017
Intel launches “ruler” SSD at FMS and intention to contribute to EDSFF

Q4 2017
EDSFF hands off specs to SNIA SFF-TA

Q2 2018:
pin/signal spec Rev 2.0, E1.S 1.1, errata

Q3 2018
E1.S Rev 1.1 to add support for 9.5mm and 25mm thick enclosures

Q2 2019
E1.S Rev 1.3a to add x8 support

Q3 2019
E1.S Rev 1.3a to add x8 support

Q4 2019
OCP Storage Workgroup discuss use of EDSFF

Q1 2020
E1.S 1.4 add 15mm

Q2 2020
Updated E3 spec in review

SFF-TA-1009 1.0 published (pin/signal spec)
EDSFF Family

• Family of form factors and standards for data center NVMe SSDs
• E1.S for scalable & flexible performance storage
• E1.L for high capacity storage (e.g. QLC)
• E3 high performance SSD for 2U server / storage
## Intel Recommended Platform Design Guidance

<table>
<thead>
<tr>
<th></th>
<th>2U Server</th>
<th>1U Server</th>
<th>Storage/JBOF</th>
<th>Enterprise Storage Array</th>
<th>Boot</th>
</tr>
</thead>
<tbody>
<tr>
<td>(PCIe 4.0)</td>
<td>U.2 15mm</td>
<td>OEM: U.2</td>
<td>E1.L or U.2</td>
<td>U.2 Dual Port</td>
<td>M.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hyperscale: U2 or E1.S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hyperscale: E1.S</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PCIe 4.0 → 5.0.  U.2 & M.2 → EDSFF

PCIe G3/4/5 SSD Transition

PCIe SSD Form Factor Mix

Source: Forward Insights Q1’21
Example - Dense NVMe U.2 Server

Source: https://www.storagereview.com/review/dell-emc-poweredge-r740xd-nvme-server-review
E1.L Storage Reimagined.

Scalable, thermal efficient, and dense, E1.L is a building block for high-volume storage. E1.L allows increased storage density, scaling, improved serviceability, and more efficient cooling optimized for 1U servers.
E1.L optimized for capacity storage

<table>
<thead>
<tr>
<th>System Level Design Principles</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated drive enclosure, customizable LEDs, and latch for servicing</td>
<td>Better serviceability, manageability, and removes cost from server</td>
</tr>
<tr>
<td>Fully passive backplane</td>
<td>Reduced complexity increases reliability, lowers cost</td>
</tr>
<tr>
<td>Optimized PCIe routing - No cables, no PCIe AICs to connect SSDs</td>
<td>Lower cost attach per drive, better signal integrity</td>
</tr>
<tr>
<td>Simplified enclosure management</td>
<td>For servicing drives and reducing downtime</td>
</tr>
</tbody>
</table>
E1.L Server and JBOF

E1.L optimized for lowest TCO on QLC NVMe

E1.L optimized for TB/rack unit & performance
## E1.S – power and thermal options

<table>
<thead>
<tr>
<th>Enclosure Parameter</th>
<th>5.9mm Device</th>
<th>Device with Heat Spreader (8.01mm)</th>
<th>Device with Symmetric Enclosure (9.5mm)</th>
<th>Device with Asymmetric Enclosure (15mm)</th>
<th>Device with Asymmetric Enclosure (25mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended sustained power (W)</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Enclosure Max Inlet air temperature, 950 m to 3050 m (° C)</td>
<td>35 - (1° C for 175 m of elevation gain)</td>
<td>35 - (1° C for 175 m of elevation gain)</td>
<td>35 - (1° C for 175 m of elevation gain)</td>
<td>35 - (1° C for 175 m of elevation gain)</td>
<td>35 - (1° C for 175 m of elevation gain)</td>
</tr>
<tr>
<td>Add in card to add in card pitch (mm)</td>
<td>9</td>
<td>11</td>
<td>13</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td>Recommended Fan Pressure loss across device (Pascal)</td>
<td>83</td>
<td>52</td>
<td>64</td>
<td>40</td>
<td>21</td>
</tr>
<tr>
<td>Airflow, average min per device (CFM). 1 CFM = 1.7 m³/h</td>
<td>1.41 – (0.01 CFM for every 1° C below 35° C inlet temp)</td>
<td>1.71 – (0.06 CFM for every 1° C below 35° C inlet temp)</td>
<td>2.02 - (0.02 CFM for every 1° C below 35° C inlet temp)</td>
<td>1.5 - (0.02 CFM for every 1° C below 35° C inlet temp)</td>
<td>4.10 - (0.04 CFM for every 1° C below 35° C inlet temp)</td>
</tr>
</tbody>
</table>
E1.S Optimal for 1U Performance Scalability

Baseline
10 x U.2 SSD

Max Fit
32 x E1.S 9.5 mm (Horizontal BP)

Max Fit
24 x E1.S 15 mm (Horizontal BP)
EDSFF E3 for Dummies

- E3 is a family of four form factors with a common 76mm height

  - **E3.S**
    - 76mm x 112.75mm x 7.5mm
    - Target to support from 20W to 25W
    - Optimized for primary NAND storage in Servers
  
  - **E3.S, 2x**
    - 76mm x 112.75mm x 16.8mm
    - Target to support from 35W to 40W
    - Support for higher power devices like CXL based SCM
  
  - **E3.L**
    - 76mm x 142.2mm x 7.5mm
    - Target to support up to 40W
    - Support for higher capacity NAND storage
  
  - **E3.L, 2x**
    - 76mm x 142.2mm x 16.8mm
    - Target to support up to 70W
    - Support for higher power devices like FPGAs and accelerators

**Note** - A thick device will fit into two thin slots

- A short device will fit into a long slot
2U 2S Spread – E3.S x 7.5 & 16.8

Baseline
OCP Data Center NVMe SSD and EDSFF Workshop
1U 2S Spread – E3.s x 7.5 & 16.8

Mechanical Fit Study
OCP Data Center NVMe SSD

Jonmichael Hands, Sr. Strategic Planner
Intel Non-Volatile Memory Solutions Group
OCP Cloud NVMe® SSD Spec

- NVM Express Specification Features
  - Vendor unique log pages
- PCI Express® Specification Features
- SMART Log Requirements
- Reliability, Endurance, Thermal, Power Requirements
- Management
- Security Requirements
- Labeling, Compliance
- Form Factor Requirements
- Open source tool access requirements
OCP Cloud NVMe® SSD Specification

- SMART Cloud Attributes Log Page, C0
  - Physical media units read/written (to calculate WAF)
  - Bad user and system NAND blocks
  - XOR recoveries
  - Uncorrectable error count
  - Soft ECC errors
  - End-to-end correction counts
  - System data % used
  - Refresh counts

- User data erase counts
- Thermal throttling status and counts
- PCIe correctable errors
- Incomplete shutdowns
- % free blocks
- Capacitor health
- Unaligned IO
- Security version
- PLP status
- Endurance estimate

C0 log page allows for deeper predictive analytics and health monitoring
Intel EDSFF SSDs

Jonmichael Hands, Sr. Strategic Planner
Intel Non-Volatile Memory Solutions Group
Intel. A History of Advancing EDSFF.

**Standards**

**Products**
- Q4 2017: “Ruler” launched Intel® SSD DC P4500
- Q2 2019: 1st to market E1.L Intel® SSD D5-P4326
- Q4 2019: 1st to market E1.S Intel® SSD DC P4511
- Q3 2017: E1.L portfolio scales to 30.72TB Intel® SSD D5-P5316
- Q4 2020: E1.S portfolio expansion Sampling 2021
- Q4 2017: EDSFF hands specs to SNIA SFF-TA
Intel EDSFF products in production today

Intel® SSD DC P4510, TLC NVMe
15.36TB, E1.L 9.5 & 18mm @ 25W

Intel® SSD D5-P4326, QLC NVMe
15.36TB, E1.L 9.5 & 18mm @ 25W

Intel® SSD DC P4511, TLC NVMe
4TB, E1.S @ 12.5W
Intel® SSD D5-P5316 Key Specifications – QLC

<table>
<thead>
<tr>
<th>Spec</th>
<th>Gen to gen</th>
</tr>
</thead>
<tbody>
<tr>
<td>4K Rand. Read</td>
<td>Up to 800K IOPS</td>
</tr>
<tr>
<td>128K Seq. Read</td>
<td>Up to 6800 MB/s</td>
</tr>
<tr>
<td>Endurance (Total PB Written)</td>
<td>Up to 18PB (3K P/E Cycles)</td>
</tr>
</tbody>
</table>

**Form Factor & Capacity**

- **Form Factor**: U.2 15mm/E1.L
- **Storage capacity**: Industry-leading QLC storage capacity¹⁹ up to 30.72TB

See Appendix for workloads and configurations. Results may vary.
Intel E1.S Products for cloud

Intel® Optane™ SSD P5801X
Fastest SSD in the world now in E1.S¹
400/800GB. Sampling Q3’2021

Intel® SSD D7-P5520, 1.92, 3.84, 7.68TB, E1.S
9.5/15mm @ 10,14,20W
OCP Data Center NVMe 2.0 compliant
Sampling in 2021

¹ Source – Intel. As compared to generally available PCIe Gen x4 Enterprise and Data Center industry SSDs.
Intel Data Center Cloud Platform for E1.S

"Vulcan City"
OCP NVMe SSD and EDSFF Workshop
April 27, 2021
KIOXIA: OCP NVMe SSD and EDSFF Workshop

**OCP**
- KIOXIA has had a long-term relationship
- Active participation since inception
- Provided significant feedback for improvement

**SNIA**
- KIOXIA is an active participator in SNIA SFF organization, previously on EDSFF consortium
- Planning other EDSFF compliant form factor apart from E1.S

**KIOXIA**
- KIOXIA announced industry’s first PCIe® 4.0 SSD using OCP NVMe SSD spec*
- Keenly listening to enterprise customers as well
- Opportunistically promoting OCP NVMe SSD Cloud spec

Industry Alignment on Product Requirement is a Win-Win!

KIOXIA XD6 Series Features

Next Generation Hyperscale Data Center Optimized PCIe SSDs
- Proprietary KIOXIA architecture, controller, hardware and firmware purpose-built for hyperscale environments

OCP NVMe Cloud SSD Design
- Meets form factor, performance, power & thermal requirements
- Enables customers to take advantage of economies of scale

Excellent QoS and Reliability
- Consistent performance, latency and reliability in demanding 24x7 data center environments

| Specifications |
|-----------------|-----------------|
| Form Factor     | E1.S 9.5/15/25mm|
| Flash Memory Type| BiCS FLASH™ 3D TLC Flash Memory |
| Interface Specification | PCIe® 4.0 x 4L, NVMe® 1.3c |
| Performance     |                 |
| User Capacity*  | GB              |
| Sequential Read 128KiB* (QD=32) | MB/s |
| Sequential Write 128KiB* (QD=32) | MB/s |
| Random Read 4KiB* (QD=256) | KIOPS |
| Random Write 4KiB* (QD=128) | KIOPS |

*KIOXIA Corporation definition of capacity: 4 KiB = 4,096 bytes, 128 KiB = 131,072 bytes, GB = 1,000,000,000 (10^9) bytes and a terabyte (TB) as 1,000,000,000,000 bytes (see end of presentation for full capacity disclaimer). Subject to change.

PCIe is a registered trademark of PCI-SIG. NVMe is a registered trademark of NVM Express, Inc.

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Definition of capacity: KIOXIA defines a megabyte (MB) as 1,000,000 bytes, a gigabyte (GB) as 1,000,000,000 bytes and a terabyte (TB) as 1,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1GB = $2^{30} = 1,073,741,824$ bytes and therefore shows less storage capacity. Available storage capacity (including examples of various media files) will vary based on file size, formatting, settings, software and operating system, such as Microsoft Operating System and/or pre-installed software applications, or media content. Actual formatted capacity may vary.

All company names, product names and service names may be trademarks of their respective companies.

Images are for illustration purposes only.

© 2021 KIOXIA America, Inc. All rights reserved. Information, including product pricing and specifications, content of services, and contact information is current and believed to be accurate on the date of the announcement, but is subject to change without prior notice. Technical and application information contained here is subject to the most recent applicable KIOXIA product specifications.
OCP Workshop

Eric Pike
Sr. Director, Cloud Segment Marketing
April 27, 2021
**EDSFF SSD Portfolio**

Single connector and pinout for FF family – overall industry benefit

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**E1.L 18mm & 9.5mm**

- 1U optimized
- Improved manageability and serviceability
- High density and improved data center TCO

**E1.S**

- High-performance server optimized
- Hot-plug and serviceability
- Power and thermals for mainstream SSDs (2TB – 8TB)

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**Improve SSD density, thermals, power and scalability**
Datacenter NVMe™ SSD Specification

• Common drive specs help the ecosystem

Encourages industry collaboration and discussion

Standardization of the common features

Improved understanding of the cloud requirements

Improved Time to Market

Enables open source tools to manage the SSDs
Samsung SSD
OCP NVMe SSD and EDSFF Workshop
# Samsung EDSFF is ready

<table>
<thead>
<tr>
<th>Model</th>
<th><strong>PM9A3</strong></th>
<th><strong>PM1743</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cell Technology</strong></td>
<td>V6 TLC</td>
<td>V6 TLC</td>
</tr>
<tr>
<td><strong>Interface</strong></td>
<td>PCIe Gen4 1x4</td>
<td>PCIe Gen5 1x4, 2x2</td>
</tr>
<tr>
<td><strong>Form Factors</strong></td>
<td>E1.S 9.5mmT, 15mmT, 25mmT E1.L 9.5mmT</td>
<td>E3.S 1T</td>
</tr>
<tr>
<td><strong>Endurance</strong></td>
<td>1 DWPD</td>
<td>1 DWPD</td>
</tr>
<tr>
<td><strong>Features</strong></td>
<td>• Optimized performance and latency for hyperscale environments • Improved health monitoring and debugging features • Enhanced security features</td>
<td>• High performance PCIe Gen5 SSD for enterprise applications • Provides enhanced data encryption and attestation</td>
</tr>
<tr>
<td><strong>Schedule</strong></td>
<td>Available now</td>
<td>Available in Q2’22</td>
</tr>
</tbody>
</table>

Notes: All product plans and roadmaps are subject to change without notice.
Samsung supports OCP NVMe SSD v1.0

**PM9A3 Available Now!**

- E1.S form factor

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**Health Monitoring**
- Telemetry for failure analysis
- Capacitor health log
- Firmware activation history
- Performance monitoring log

**Reliability**
- UBER < 1 sector per $10^{17}$ bits read
- End to end data protection
- MTBF 2.0 million hours
- Global wear-leveling

**Security**
- AES-XTS 256 bit encryption
- Anti-rollback protection, TCG Opal
- Secure boot, Key revocation

**NVMe CLI Plug-in**

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<table>
<thead>
<tr>
<th>Form factors</th>
<th>Capacities</th>
<th>OCP v1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1.S</td>
<td>1TB-8TB</td>
<td>Support</td>
</tr>
<tr>
<td>E1.L</td>
<td>16TB</td>
<td>Support</td>
</tr>
<tr>
<td>M.2</td>
<td>1TB-4TB</td>
<td>Support</td>
</tr>
<tr>
<td>U.2</td>
<td>1TB-16TB</td>
<td>Support</td>
</tr>
</tbody>
</table>

Notes: All product plans and roadmaps are subject to change without notice.

- Less Risk during SSD dev with combined requirements
- Enables to manage massive SSD at rack-scale
- Enhances security and data protection to solve today's datacenter challenges
- Expedites failure analysis with open-source tools
A journey shared takes us beyond
Micron and OCP: Aligned Values

**Acceleration Catalysts**
Solving difficult problems with open and innovative developments. Micron continues to accelerate solutions with our public, open, validated reference architectures.

**Focus on Efficiency**
OCP’s focus on efficiency – in energy use, cost, design and space use is tightly aligned to Micron’s sustainability commitment.

**Align and Contribute to Open Industry Standards**
Micron demonstrated our belief in the universal benefits of open designs when we released our Heterogeneous-Memory Storage Engine to the open-source community.

Uniform, complete standards help democratize data and drive responsible business practices and continuity.
Micron and OCP: What’s Next

Broad form factor range consolidates around demand-driven standards

**EDSFF**: Accelerating Adoption
Industry sees value in form factor optimization for flash

**E1.S** dominant EDSFF variant

**Consolidation is coming:**
Industry can’t sustain offering 11 form factors (in addition to long tail of legacy form factors)

- **Near term**: Micron sees focus around E1.S
- **Longer term**: E1.S still dominant, E1.L support for large capacities and E3 growth aligned with PCIe Gen5

![Coming Form Factor Shift](image)

**Flash-optimized Flexibility**

Source: Forward Insights (02/21)
Units: user PB
Datacenter NVMe SSD Spec Enablement

- **Datacenter NVMe SSD Spec enables a SSD supplier to build more common HW/FW for users**
  - Existing standard spec allows a high level of flexibility so users could choose many different directions from others

- **Security requirement is enhanced across the board**
  - Secure boot, Authentication and transaction path security requirements become clear and robust

- **However, there’s some scope to improve going forward**
  - Depending on users, unused features could be categorized as mandatory and this may add burdens to suppliers
  - Spec update frequency may need to be managed to be predictable to help the efficient product-planning

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**Without Datacenter NVMe SSD spec**

**With Datacenter NVMe SSD Spec**

<table>
<thead>
<tr>
<th>OEM #1</th>
<th>OEM #2</th>
<th>Data Center #1</th>
<th>Data Center #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>FW Change Amount</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SSD platform (Common HW/FW)**

<table>
<thead>
<tr>
<th>New User #1</th>
<th>New User #2</th>
<th>New User #n</th>
</tr>
</thead>
<tbody>
<tr>
<td>New User #1</td>
<td>New User #2</td>
<td>New User #n</td>
</tr>
</tbody>
</table>
SKhynix Products Supporting DC NVMe SSD Spec

- **SKhynix has been offering products that support the Datacenter NVMe SSD spec**
  - PE8111 E1.L and PE8110 E1.S are developed based on the Datacenter NVMe SSD spec v1.0a and those are being shipped to customers
  - New products coming up next aim to meet DC NVMe SSD Spec V2.0

- **PCIe Gen5 SSDs are expected to be developed in EDSFF form factor and Datacenter NVMe SSD spec**
  - Not only E1.S/E1.L but E3 SSD is being planned for PCIe Gen5 and it will be based on version 2.0

<table>
<thead>
<tr>
<th>Product</th>
<th>E1.S 15mm</th>
<th>E1.L 18mm / 9.5mm</th>
<th>E3.x (TBD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>PE8110</td>
<td>PE8111</td>
<td>Next generation</td>
</tr>
<tr>
<td>Interface</td>
<td>PCIe Gen4x4</td>
<td>PCIe Gen3x4</td>
<td>PCIe Gen5</td>
</tr>
<tr>
<td>Capacity</td>
<td>1920GB – 7680GB</td>
<td>15360 – 30720GB</td>
<td>TBD</td>
</tr>
<tr>
<td>Read / Write Bandwidth</td>
<td>6500 / 4400 MB/s</td>
<td>3550 / 3300 MB/s</td>
<td>TBD</td>
</tr>
<tr>
<td>Read / Write IOPS</td>
<td>1100 / 160 KIOPS</td>
<td>750 / 105 KIOPS</td>
<td>TBD</td>
</tr>
</tbody>
</table>

(source: SNIA)
Datacenter NVMe Spec and FADU SSD Offering
# OCP NVMe Datacenter Specification

<table>
<thead>
<tr>
<th>March 2019</th>
<th>Dec 2019</th>
<th>Nov 2020</th>
<th>March 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Heat sinks for EDSFF Standardized</td>
<td>New OCP Cloud SSD specification</td>
<td>HP and Dell Extend spec to E3</td>
<td>Boot Drive Specification</td>
</tr>
</tbody>
</table>

- **Sep 2019**
  - We start on E1.S OCP standard FFs
  - And heat Sinks

- **April 2020**
  - We demo Worlds first OCP Cloud SSDs at Open compute with a Supermiro box

- **Nov 2020**
  - We start compliance work with UNH-IOL
  - We announce Delta Gen4 OCP Drive

- **Now**
  - Gen 3 OCP SSD MP
  - Gen4 NVMe DC SSD Working Samples
# FADU NVMe Datacenter SSDs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SR in MB/s</td>
<td>3500</td>
<td>7300</td>
<td>14,600</td>
</tr>
<tr>
<td>SW MB/s</td>
<td>2700</td>
<td>4600</td>
<td>12,000</td>
</tr>
<tr>
<td>RR in KIOPS</td>
<td>800</td>
<td>1490</td>
<td>3500</td>
</tr>
<tr>
<td>RW in KIOPS</td>
<td>100</td>
<td>180</td>
<td>410</td>
</tr>
</tbody>
</table>

In Real workloads
We get excellent Random Read in Mix workloads/
Recovery after Burst/QOS and Max latency

www.fadu.io
Thank You
Datacenter NVMe SSD Validation

Microsoft - Adam Guy
Teledyne LeCroy – Nick Kriczky
UNH-IOL – David Woolf
Datacenter NVMe SSD Test Strategy

✓ Validation against the Datacenter NVMe SSD Specification ensures the target device complies with the wide array of common requirements across multiple datacenter customers
  ✓ Common & deterministic SSD functionality in-system
  ✓ Numerous datacenter opportunities from one leveraged SSD design
Test suites for Datacenter NVMe SSD Spec compliance are in-progress
  ✓ First intercept is revision 1.0a

Microsoft is generating initial test specifications mapping to requirement ID’s
  ✓ Test specifications only apply to requirements that can be validated in a black box fashion

Test specs are subsequently reviewed & approved by key stakeholders

Test case implementation based upon approved test specifications
  ✓ 1.0a effort currently in-progress at Teledyne LeCroy and UNH-IOL, independently
Teledyne LeCroy – Everywhere You Look

Teledyne LeCroy Protocol Analyzers

OakGate SSD Validation Platforms

Epic Environmental Chamber Platforms

Early Design & Development

Design and Development

Validation

Pre-Production

Production

Field Failure Analysis

Teledyne LeCroy

Epic Environmental Chamber Platforms

OakGate SSD Validation Platforms

Teledyne LeCroy Protocol Analyzers

PCI EXPRESS

CXL Compute Express Link

nvm EXPRESS

USB

OPEN Compute Project

FCIA

Serial Attached SCSI

Ethernet
Teledyne LeCroy Datacenter NVMe SSD Specification

OCP Conformance
Test Equipment and Software

Performance
- OCP Workload Spec

Power/Thermal
- Thermal Reporting
- Thermal Throttling
- Thermal Shutdown
- Power Management

Reliability
- Firmware Crash, Panic or Assert
- Time to Ready
- Incomplete Shutdown

Telemetry
- Controller-Initiated
- Host-Initiated
- Data Verification

Form Factor & Labeling
- Hot Swap
- M.2
- E1.S
- E1.L
- Labeling

Security
- Secure Boot
- Unsupported Features & Commands

NVMe
- NVMe Resets
- Controller Config & Behavior
- Command, Feature & Log Page Support
- Firmware Update Requirements

PCIe
- Boot
- Resets
- Completion Timeout
- Payload Size
- Error Logging
- Low Power Modes

Teledyne LeCroy
OakGate Technology
Austin Labs

Test Suite Development and Conformance Testing Services
UNH-IOL published test plan for DatacenterSSD in mid 2020, and is actively working with key stakeholders on adding and upgrading tests.

- DatacenterSSD spec explicitly requires NVMe v1.4 compliance, therefore, UNH-IOL INTERACT Test Tool, currently widely used for NVMe v1.4 compliance, has integrated add-on support for DatacenterSSD compliance into a single tool.
UNH-IOL Tool Support for DatacenterSSD

UNH-IOL INTERACT Test numbers correlate to Test Plan

UNH-IOL Test names correlate directly to DatacenterSSD Spec

DatacenterSSD tools currently being demonstrated at customer sites
Thank You!