Intel Technology Innovations Fill the Memory and Storage Gap
Performance and Capacity for Every Need

Intel 3D NAND Technology
- Lower cost & higher density

Intel® Optane™ Technology
- Higher performance

Intel® 3D NAND SSD

Intel® Optane™ SSD

Intel® Optane™ Memory

Cost: LOWER to HIGHER
Delay: LESS to MORE
Intel 3D NAND Leadership

Up to 20% Higher Areal Density\textsuperscript{1} vs. Competition

<table>
<thead>
<tr>
<th>Denser memory array</th>
<th>More efficient utilization</th>
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<tr>
<td>Intel floating gate cell has a smaller footprint\textsuperscript{1}</td>
<td>Intel CMOS under array</td>
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Accelerating Moore's Law into 3 Dimensions

| Architected for capacity scaling leadership | Faster cadence generation to generation |

Why Does This Matter?

The combination of performance, capacity and cost of Intel\textsuperscript{®} 3D NAND SSDs will rapidly accelerate HDD replacement.

\textsuperscript{1}Comparing areal density of Intel measured data on 512GB Intel 3D NAND to representative competitors based on 2017 IEEE International Solid-State Circuits Conference papers citing Samsung Electronics and Western Digital/Toshiba die sizes for 64-stacked 3D NAND component.
Intel® 3D NAND SSDs
Transforming the economics of storage with trusted, breakthrough 3D NAND technology

Architected for capacity and cost

- Architected for highest areal density
- Optimized for manufacturing efficiency

Built on a proven process

- Leader in flash cell technology evolution and scaling
- Accelerated development
- First to high volume manufacturing with 64-Layer TLC

Enabling disruptive opportunities

- Growing capacity faster than the market
- Rapid portfolio expansion
- Space and power efficient capacities reduce TCO


Based on Intel internal forecasting 2016-2017. Forecasts are Intel estimates, based upon expectations and available information and are subject to change without notice.
Intel® Optane™ Technology: 3D XPoint™ Memory Media

Cross Point Structure
Selectors allow dense packing and individual access to bits

Breakthrough Material Advances
Compatible switch and memory cell materials

Scalability
Memory layers can be stacked in a 3D manner

High Performance
Cell and array architecture that can switch states much faster than NAND
Storage Performance Characterization

Latency vs. Load: NAND SSD vs. Intel® Optane™ SSD (Intel® SSD DC P3700 vs. Intel® Optane™ SSD DC P4800X)

10x latency reduction
- < 10µsec latency

100x QoS improvement
- < 200µsec 99.999th r/w

Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as “Spectre” and “Meltdown.” Implementation of these updates may make these results inapplicable to your device or system. Common Configuration – Intel 2U Server System, OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Performance – measured under 4K 70-30 workload at QD1-16 using fio-2.15. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Vs. NAND based SSD.
Breakthrough Performance

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Predictably Fast Service

Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown." Implementation of these updates may make these results inapplicable to your device or system. Common Configuration – Intel 2U Server System, OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. QoS – measures 99% QoS under 4K 70-30 workload at QD1 using fio-2.15. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.
Responsive Under Load

Average Read Latency under Random Write Workload

- Intel® SSD DC P3700 Avg Read Latency
- Intel® Optane™ SSD DC P4800X Avg Read Latency
- Random Write

1. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown." Implementation of these updates may make these results inapplicable to your device or system.

Responsiveness defined as average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 2.15. Common Configuration - Intel 2U Server System, OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Latency – Average read latency measured at QD1 during 4K Random Write operations using fio-2.15. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.
Ultra Endurance

Architected for endurance scaling

- ‘Write in place’ technology
- Non-destructive write process

Up to 10x more Total Bytes Written at similar capacity

1. Comparing projected Intel® Optane™ SSD 750GB specifications to actual Intel® SSD DC P4600 1.6TB specifications. Total Bytes Written (TBW) calculated by multiplying specified or projected DWPD x specified or projected warranty duration x 365 days/year. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.
# Intel® Data Center SSDs – Current Products

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<th>Use Case</th>
<th>Endurance</th>
<th>Interface</th>
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<td>Very High</td>
<td>PCIe*</td>
<td>Intel® Optane™ SSD DC P4800X: U.2 15mm: 375GB, 750GB</td>
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<td></td>
<td>Endurance</td>
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<td>AIC: 375GB, 750GB</td>
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<td>Intel® Optane™ SSD DC P4800X with Intel® Memory Drive Technology: U.2</td>
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<td>15mm: 375GB, 750GB</td>
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<td>AIC: 375GB, 750GB</td>
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<td></td>
<td>HHHL (CEM3.0)</td>
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<td>Server Performance</td>
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<td>DC P4600: AIC: 2TB, 4TB</td>
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<td>SATA</td>
<td>DC S4600: 2.5&quot;: 240GB, 480GB, 960GB, 1.92TB</td>
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<tr>
<td>Standard</td>
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<td>DC P4510: U.2 15mm: 1TB, 2TB, 4TB, 8TB</td>
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<td></td>
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<td>DC P4500: U.2 15mm: 1TB, 2TB, 4TB</td>
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<td></td>
<td>AIC: 4TB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SATA</td>
<td>DC S4500: 2.5&quot;: 240GB, 480GB, 960GB, 1.92TB, 3.84TB</td>
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<td>DC S3520: M.2 80mm: 150GB, 240GB, 480GB, 760GB, 960GB</td>
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<td>Low Power</td>
<td>Standard</td>
<td>PCIe*</td>
<td>DC P4501: U.2 7mm: 500GB, 1TB, 2TB, 4TB</td>
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<td>DC P3100: M.2 80mm: 128GB, 256GB, 512GB, 1TB</td>
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<td>Value Performance</td>
<td>Value</td>
<td>PCIe*</td>
<td>DC S3110: M.2 80mm: 128GB, 256GB, 512GB</td>
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<td>SATA</td>
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*Other names and brands may be claimed as the property of others.*
PCI Express* SSD Form Factor Evolution

**M.2**
M.2 initially designed for client and mobile use. Used in data center for boot or compute nodes, but lacks hot-plug support and requires carrier cards / heatsinks to manage thermals.

**U.2**
U.2 2.5in x 15mm and 7mm supports hot-plug and serviceability, designed to share physical dimensions with HDDs for hybrid HDD/SSD server designs. Mainstream PCIe* SSD form factor.

**AIC**
PCle* low profile add-in-cards have broadest compatibility with the most mature ecosystem and compliance. Shares same form factor with network cards, graphic cards, etc.

**RULER**
Built for data center racks
High per drive, per server and per rack capacity
Improved manageability and serviceability
Efficient thermal design
Integrated enclosure, latch, LEDs

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AN SSD REVOLUTION.

“RULER” FORM FACTOR FOR INTEL® SSDs.

Designed from the ground up to optimize rack efficiency, the new Ruler Form Factor delivers unparalleled Space-Efficient Capacity, Operationally-Efficient Design and Scalable Manageability. Now available with the cloud-inspired Intel® SSD DC P4500 Series.
Optimized Storage for Data Center Racks.

**Space Efficient Capacity**
- Storage density optimized design delivers higher per drive capacity
- 1U optimized form factor delivers up to 32 drives per U for higher per server capacity

**Operationally Efficient Design**
- Up to 55% more thermally efficient than 15mm U.2\(^1\)
- Consolidate racks to reduce opex
- System-based design approach enables more efficient solutions

**Efficient Management at Scale**
- Front loading and hot swappable
- Integrated power cycling enables remote, drive specific reboot
- Expanded and programmable LEDs enable indication of more device states

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1. Source – Intel. Results have been estimated or simulated using internal analysis or architecture simulation or modeling, and provided for informational purposes. Simulation includes "ruler" form factor for Intel® SSD DC P4500 4TB ruler, U.2 15mm Intel® SSD DC P4500, 3 drives in sheet metal representation of server, 12.5mm pitch for "ruler", 1000m elevation, limiting SSD on case temp of 70°C or thermal throttling performance, whichever comes first. 5°C guardband.
Optimized for Space Efficient Capacity per Server

2U SERVER

U.2 15mm 4TB

up to 96 TB

1U SERVER

RULER 8TB

up to 256 TB

Storage Capacity

5.3x More TB Per Rack Unit

<table>
<thead>
<tr>
<th>System Type</th>
<th>Standard 2U Server</th>
<th>Intel® AF1000 Server</th>
</tr>
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<tbody>
<tr>
<td>Rack space</td>
<td>2U</td>
<td>1U</td>
</tr>
<tr>
<td>SSD form factor</td>
<td>U.2 15mm</td>
<td>Intel ruler</td>
</tr>
<tr>
<td>Number of SSDs per server</td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td>Capacity per drive</td>
<td>4TB</td>
<td>8TB</td>
</tr>
<tr>
<td>TB/rack unit</td>
<td>48TB</td>
<td>256TB</td>
</tr>
</tbody>
</table>

1. Source – Intel. Comparing maximum capacity per 1 rack unit of Intel® Server Board S2600WP Family, 24 U.2 bay option using 4TB U.2 15mm Intel® SSD DC P4500 to 8TB Intel® AF1000 Server design, 32 “ruler” drive bays using 8TB “ruler” form factor for Intel® SSD DC P4500.
Thermal Efficient Design

THERMAL EFFICIENCY

UP TO 55% LESS AIRFLOW\(^1\) VS U.2 15MM

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Built in Serviceability

Programmable LEDs to quickly locate failed drives, offline drives, and unpopulated slots.

Carrier-less design with integrated pull tab removes need for drive carriers.

Enclosure Management with slot level power control enables single drive isolation or system level power loss.
“Ruler” Form Factor for Intel SSDs Roadmap

- Move Ruler to compliance with EDSFF specifications
- Expand portfolio to include Intel® Optane™ SSDs in 2018
Notices & Disclaimers

Intel technologies’ features and benefits depend on system configuration and may require enabled hardware, software or service activation. Performance varies depending on system configuration.
No computer system can be absolutely secure.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. For more complete information about performance and benchmark results, visit [http://www.intel.com/benchmarks](http://www.intel.com/benchmarks). Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit [http://www.intel.com/benchmarks](http://www.intel.com/benchmarks). Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown." Implementation of these updates may make these results inapplicable to your device or system.

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