Testing for PCIe SSD Compatibility and Performance

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Teledyne LeCroy Corporation is the leader in Serial Data Test solutions
  - Founded in 1964
  - Headquarters in Chestnut Ridge, NY
Teledyne LeCroy’s Protocol Solutions Group (PSG) was formed in October 2004 with the acquisition of CATC Corporation
  - PSG Headquarters in Santa Clara, CA
  - Part of the Serial Data Division of LeCroy
  - Catalyst was acquired & added to PSG in 2006
PSG specializes in providing complete protocol solutions for a wide range of serial data standards
  - Products range from production tools to full protocol analysis systems with intuitive user interfaces and complete traffic generation
PCI Express is Moving to Storage

Storage

SSDs

Hybrid Drives

San Switches

NAS

RAID Systems
Common SSD Test Setup

**SSD Device Controller Test**
- SSD Controller (DUT)
- Exerciser
- Test Platform
- Protocol Analyzer

**SSD Driver Host Test**
- System Board (DUT)
- Exerciser Device Emulator
- Interposer
- Protocol Analyzer
PCIe SSDs Require New Testing Methodologies

- PCIe SSDs combine various storage protocol layers on top of the PCI Express electrical, link and transaction layers.
- The PCIe protocol is very different than previous storage protocols.
- New tools and testing methodologies are required to meet the challenges of high performance SSDs.
High Level Decoded Commands

Hierarchical break down from ATA command down to low level packet
PCI Express Performance Tools

- Measure and monitor PCIe SSD performance details
  - PCIe Packet Metrics
  - Timing Calculator - Bandwidth, Link Utilization
  - Post Capture Bus Utilization Graph Tool
    - Latency, Throughput Views
  - Real Time Statistics Graph Tool

- Understand link behaviors and improve SSD performance
  - Flow Control View
  - Link Tracker
  - LTSSM State View

<table>
<thead>
<tr>
<th></th>
<th>Upstream</th>
<th>Downstream</th>
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<tr>
<td>Link Utilization</td>
<td>45.127 %</td>
<td>44.546 %</td>
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<tr>
<td>Time Coverage</td>
<td>45.072 %</td>
<td>44.493 %</td>
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<tr>
<td>Bandwidth</td>
<td>9025.43 Mb/s</td>
<td>8909.10 Mb/s</td>
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<tr>
<td>Data Throughput</td>
<td>592.29 MB/s</td>
<td>598.72 MB/s</td>
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<tr>
<td>Packets/second</td>
<td>19696168.45</td>
<td>24833612.81</td>
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Most Application Targeted Adaptors/Probes in the Industry

- G2 AMC Interposer
- G2 Express card Interposer
- G2 External PCIe Cable Interposer
- G2 HP Blade Interposer
- G2 XMC Interposer
- G2 External PCIe Cable Interposer
- G2 MiniCard Interposer
- G2 CPCI Serial Interposer
- G2 Express Module Interposer
- G2 VPX Interposer
- G3 90 Degree Interposer
- G3 MidBus Probe
- G2 AMC Interposer
- G3 Multi-lead Probe
- G3 Express Module Interposer
- G3 SFF-8639 Interposer(S/D)
- G3 M.2 Interposer
- Reducers & Adapters
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Form Factor/Connectivity and Probing

- **CEM add-in card**
  - NVMe/SATA/SCSI
  - PCIe 2.0/3.0
  - x1, x4, x8

- **M.2 storage card** (i.e., NGFF)
  - NVMe/SATA
  - PCIe 2.0/3.0
  - X2, x4

- **SFF-8639 based drive**
  - NVMe/SATA/SCSI
  - PCIe 2.0/3.0
  - x2, x4
PCIe Single Port Usage Model

PCIe Host

Root Complex

PCIe Switch

Endpoint
PCIe SSD

Endpoint
PCIe SSD

Endpoint
PCIe SSD

PCIe Switch

Endpoint
PCIe SSD

Endpoint
PCIe SSD

PCIe Switch

Endpoint
PCIe SSD

Endpoint
PCIe SSD

Endpoint
PCIe SSD

PCIe Switch

Endpoint
PCIe SSD

Endpoint
PCIe SSD

Endpoint
PCIe SSD
SFF 8639 Connector

- The SFF Committee has developed the specification.
- Intended for PCIe connections to SSDs (Solid State Drives) for the enterprise market of servers and storage systems.
- Supports:
  - Single port SATA
  - Dual port SCSI Express
  - Dual port SAS
  - Multilane SAS (12 Gb/s, 4 lanes)
  - PCIe Gen3x4 (8 GT/s, 4 lanes)
Protocol Analysis with the Single Port SFF-8639 Interposer

Supports

- NVM Express G3x4
- SATA Express G3x2
- SCSI Express G3x4
SFF-8639 to PCIe Connector Adaptor

Supports Single Port Drives
- PCIe 1/2/3
- x1, x2, x4
- 2 ½ inch drives

The answer to companies looking for 8639 backplanes for test
Dual Port PCIe Usage Model

Interconnect

PCle Host

Root Complex

PCle

PCle Switch

Endpoint

PCle SSD

Endpoint

PCle SSD

Endpoint

PCle SSD

Endpoint

PCle SSD

Endpoint

PCle SSD

Endpoint

PCle SSD

Endpoint

PCle SSD

Endpoint

PCle SSD
Dual Port SFF-8639 Interposer

Supports
- Gen3 Supported
- Host Interface Support
  - NVM Express Dual x2
  - SCSI Express Dual x2
- 2 PCIe link A/B port support
- 2 ½ and 3 inch drive support
SFF-8639 to PCIe Connector Adaptor

Supports Port B
- PCIe 1/2/3
- x1, x2, x4
- 2 ½ inch drives

The answer to companies looking for 8639 backplanes for test
M.2 Card Format Defined

- 5 lengths from 30mm-110mm
- Single and double sided versions
- Double sided connector will accept both modules
M.2 Interposer for PCIe 3.0

- Speeds: PCIe 1/2/3
- Lane width: x2/x4
- Socket types: 2/3
- M.2 module lengths: 42mm x 22mm, 60mm x 22mm, 80mm x 22mm, and 110mm x 22mm
- SRIS supported
- Dimensions
  - Connector cable 18 inches
  - Carrier Board 5.13 x 9.05 inches
  - Interposer Board .824 x 1.65 inches
M.2 to PCIe Connector Adaptors

Two types of Interposer

- Socket 2 devices
  - B-type
  - PCIe 1/2/3
  - x1, x2
- Socket 3 devices
  - M-type
  - PCIe 1/2/3
  - X1, x2, x4
Exercisers are the best way to test error handling between systems and storage devices in PCI Express.

Emulation Scripts are run on exercisers and create low level bus traffic that can be accurately, repeatedly, and precisely created to assess performance in real-world conditions for a drive or host. No software driver required.
NVMe Conformance Testing

- Tests defined in NVMe Interop Test Suite document (publically available at www.iol.unh.edu)
- Test tools used to check proper construction and response to different NVMe Stimuli
- Admin Commands, NVM Commands, Controller Registers
NVMe Integrators List

- Hosted by UNH-IOL at www.iol.unh.edu
- Opt-in list of qualifying NVMe products
- No PCIe component to qualification today
- UNH-IOL does offer PCIe testing to complement NVMe testing, but it is not a component of the NVMe IL qualification

NVMe Host Qualification
- Perform Interop Test against 4 different SSDs
  - Pass with 3 SSDs
  - Pass = data transfers without errors

NVMe Device Qualification
- Perform Interop Test against 4 different hosts, pass with 3 Hosts
  - One of the hosts must be either the Windows or Linux Reference Driver
  - Pass all conformance tests
UNH-IOL (University Of New Hampshire IOL) and the NVM Express Promoters Group are collaborating to create an interop and conformance test program centered at UNH-IOL. They have created a multi-vendor test bed to help products prove interoperability, and conformance test services to prove that products follow the NVMe specification correctly.

Feb 24, 2014.
Conclusion

- New testing methodologies are needed for NVM Express, SCSI Express and SATA Express.
- Protocol analysis and test tools can show developers useful details about PCIe SSD transactions between the storage host and controller.
- Host and device emulation can discover performance, error handling and protocol issues that affect the quality of products.
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