Testing for PCIe SSD Compatibility and Performance

Jan 21, 2013

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Product Marketing Manager

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Teledyne LeCroy

- 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
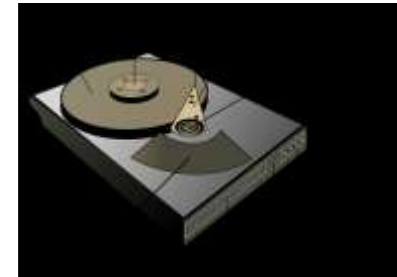
Agenda

- Brief overview of new SSD types

- Testing SSD Devices

- NVM Express

- SCSI Express

- SATA Express

Storage Devices

- Hard disk drive(HDD) technology
  - Uses mechanical moving parts to store data

HDD

- Solid State Drive(SSD) technology
  - Emulates a hard disk drive by using NAND Flash components and controller

SSD

- Hybrid Hard Drive (HHD),
  - Combines high performance SSD technology with high capacity SATA drives
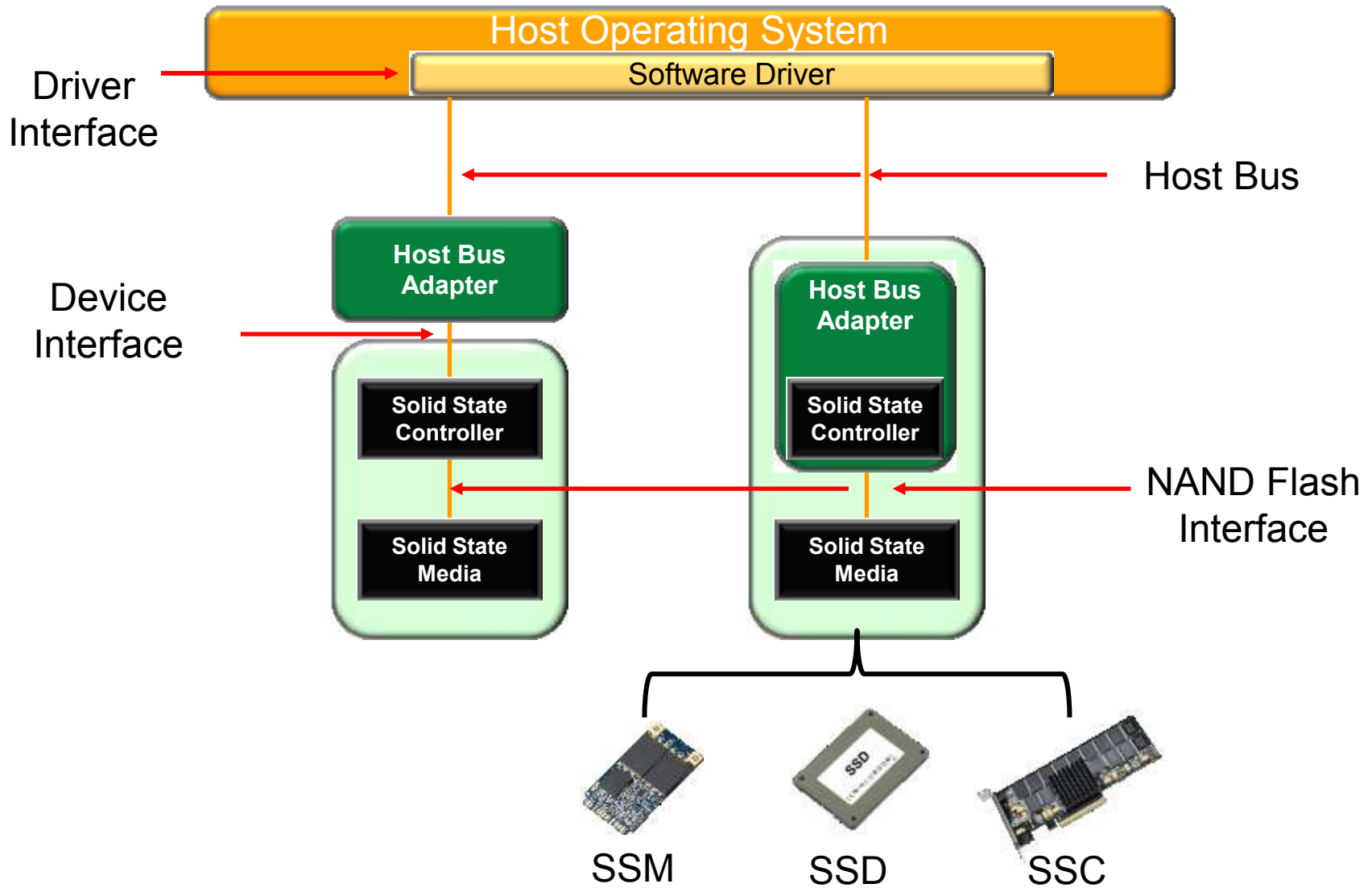
HHD

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SSD Devices

Host Operating System

Software Driver

Driver Interface

Host Bus

Device Interface

Host Bus Adapter

Host Bus Adapter

Solid State Controller

Solid State Controller

NAND Flash Interface

Solid State Media

Solid State Media

SSM

SSD

SSC

PCIe SSDs Require New Testing Methodologies

- PCIe SSDs combine various storage protocol layers on top of the PCI Express electrical, link and transaction layers.

- New tools and testing methodologies are required to meet the challenges of high performance SSDs.

| Storage |
| Transaction |
| Link |
| Physical |
| Logical |
| Electrical |
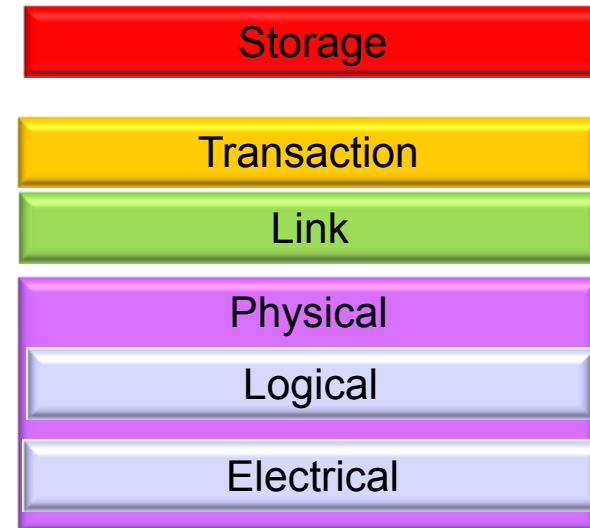
SSD Device Controller Test

Exerciser

SSD Driver Host Test

Exerciser Device Emulator

Interposer

Protocol Analyzer

System Board(DUT)

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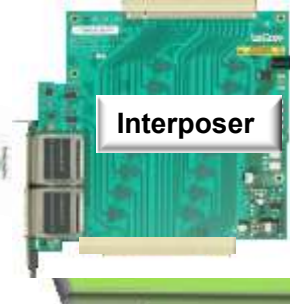
Testing Storage Interfaces

Test Points of Interest

1. System board and HBA
2. HBA and Storage Media
3. System board and PCIe Storage Media

Host Bus

PCIe

1

2

HBA

CTRL

Storage Media

3

PCIe CTRL

Storage Media

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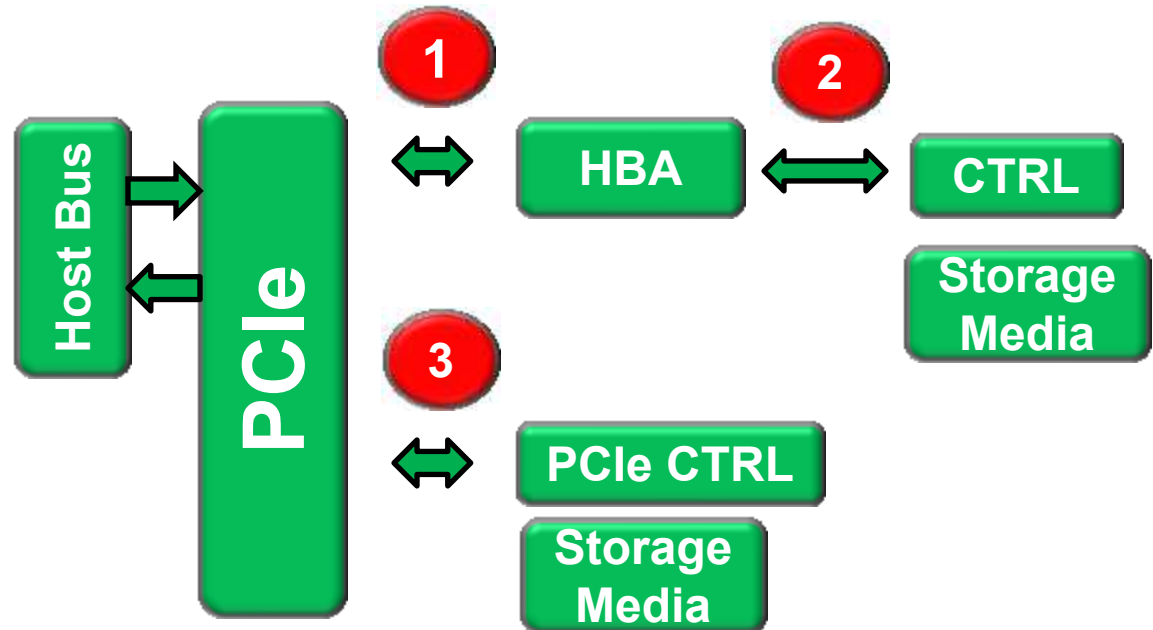
PCI Express Performance Tools

- **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

Bus Utilization	Upstream	Downstream
Link Utilization	45.127 %	44.546 %
Time Coverage	45.072 %	44.493 %
Bandwidth	9025.43 Mb/s	8909.10 Mb/s
Data Throughput	592.29 MB/s	598.72 MB/s
Packets/second	19696168.45	24833612.81
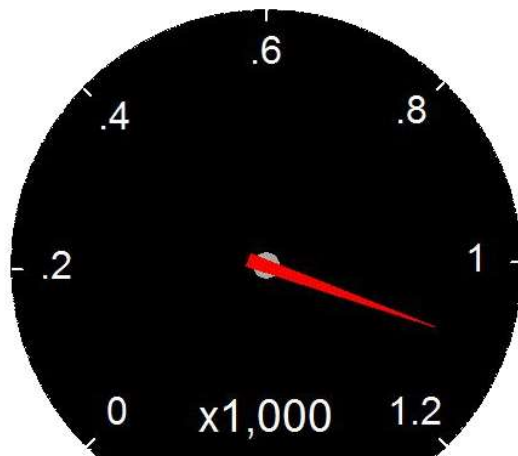
Tests That Are Interesting to Developers

- Correct operation of storage devices
    - Check for each Admin and NVM command if the device fetches the correct number of commands for each SQ(Submission Queue) tail register write and from the correct SQBR.
    - Check if PRP(Physical Region Page) is accessed based on correct pointer supplied by the command.
    - Check if the completion is issued with correct identifiers and written to correct memory location and head pointer updated correctly.
    - Check if interrupt is issued and if the host did not consume all the completions if the device does not overwrite unconsumed completions.
- Compliance Tests for SSD Devices

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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)
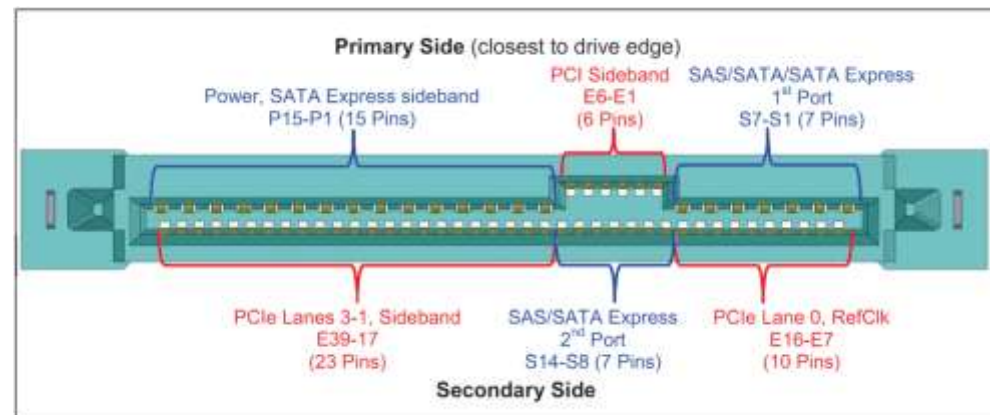
SFF 8639 Connector
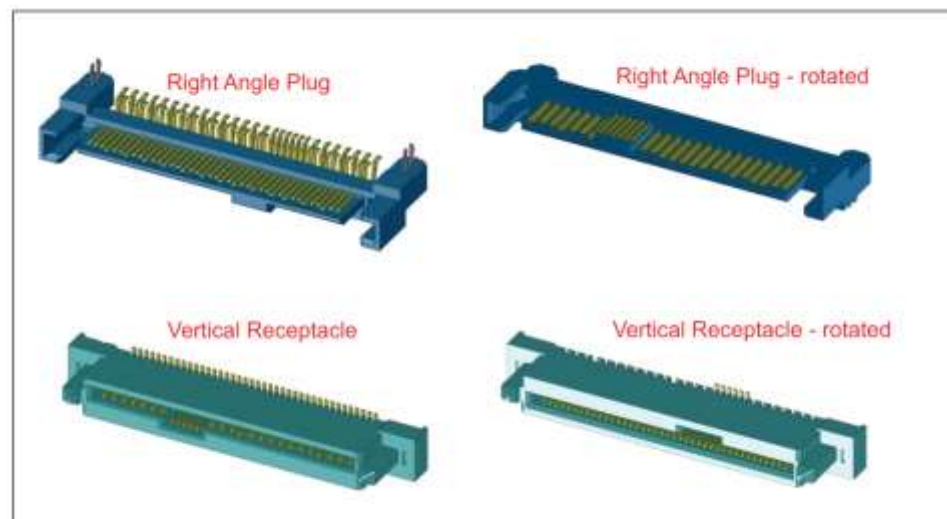
Express Bay- Multi- Function Bay

- Multi-function SAS/PCIe bay
  - Uses SFF-8639 Multi-function connector
  - Supports a range of devices
  - 12Gb/s SAS
  - PCIe SSD
    - NVMe, SOP-PQI, Proprietary
    - 6Gb/s SATA
    - Multilink SAS (4 SAS Ports)
    - SATA Express
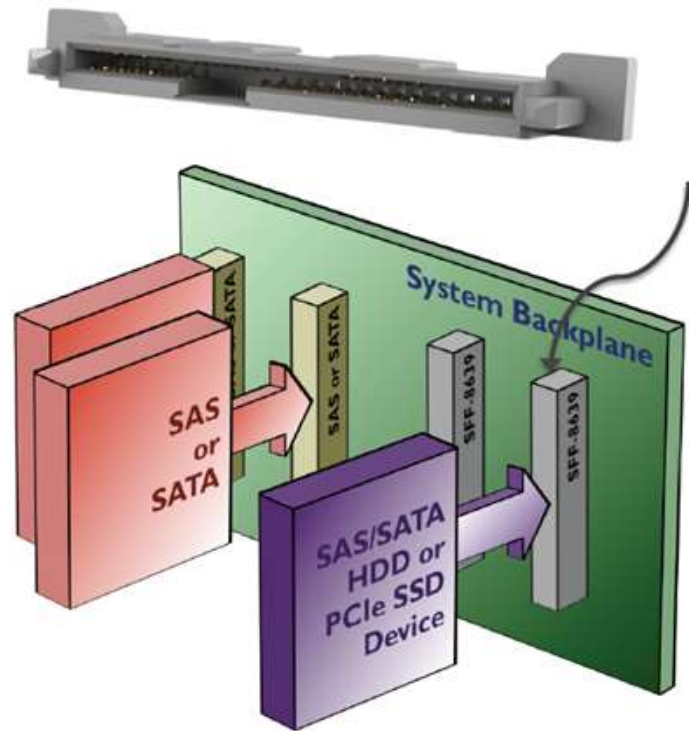
SNIA 2012

New

SFF-8639 Connector
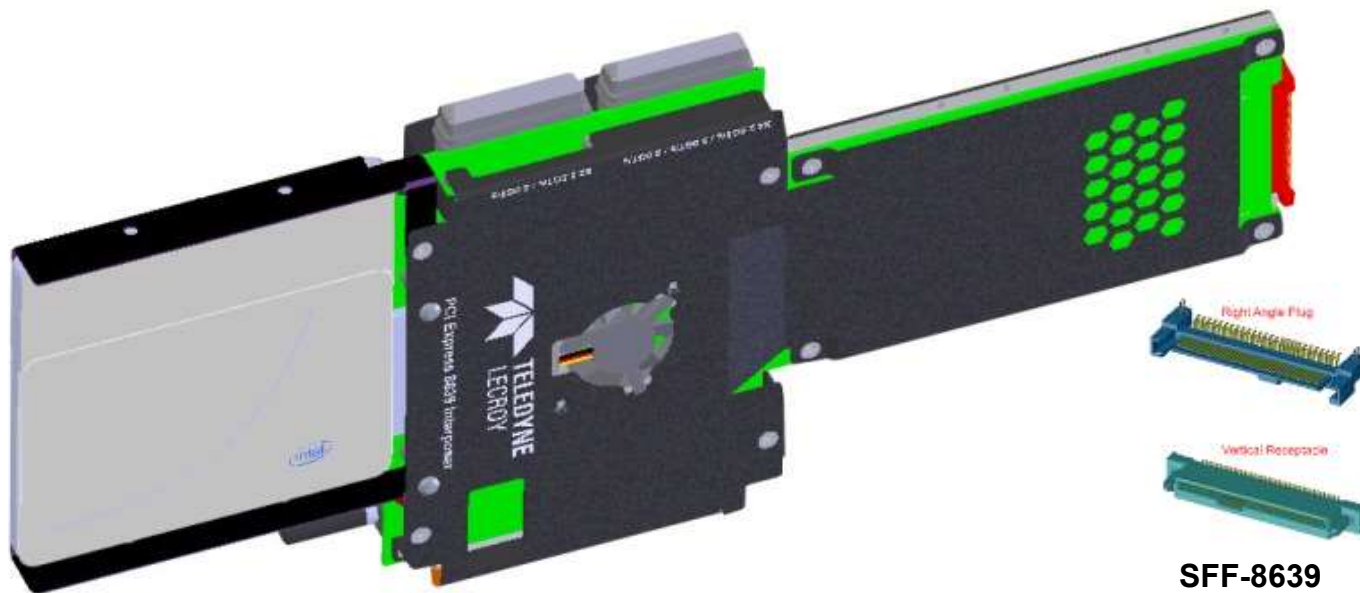
PCIe Protocol Analyzer

Protocol Analyzer cable

SSD

SFF-8639 Interposer

Supports

- NVM Express   x4
- SATA Express x2
- SCSI Express   x4

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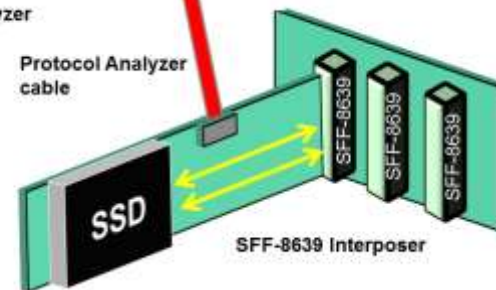
SFF 8639 Interposer(Single Port)

x2

x4

SFF-8639 Connector

SSD

x4   x2
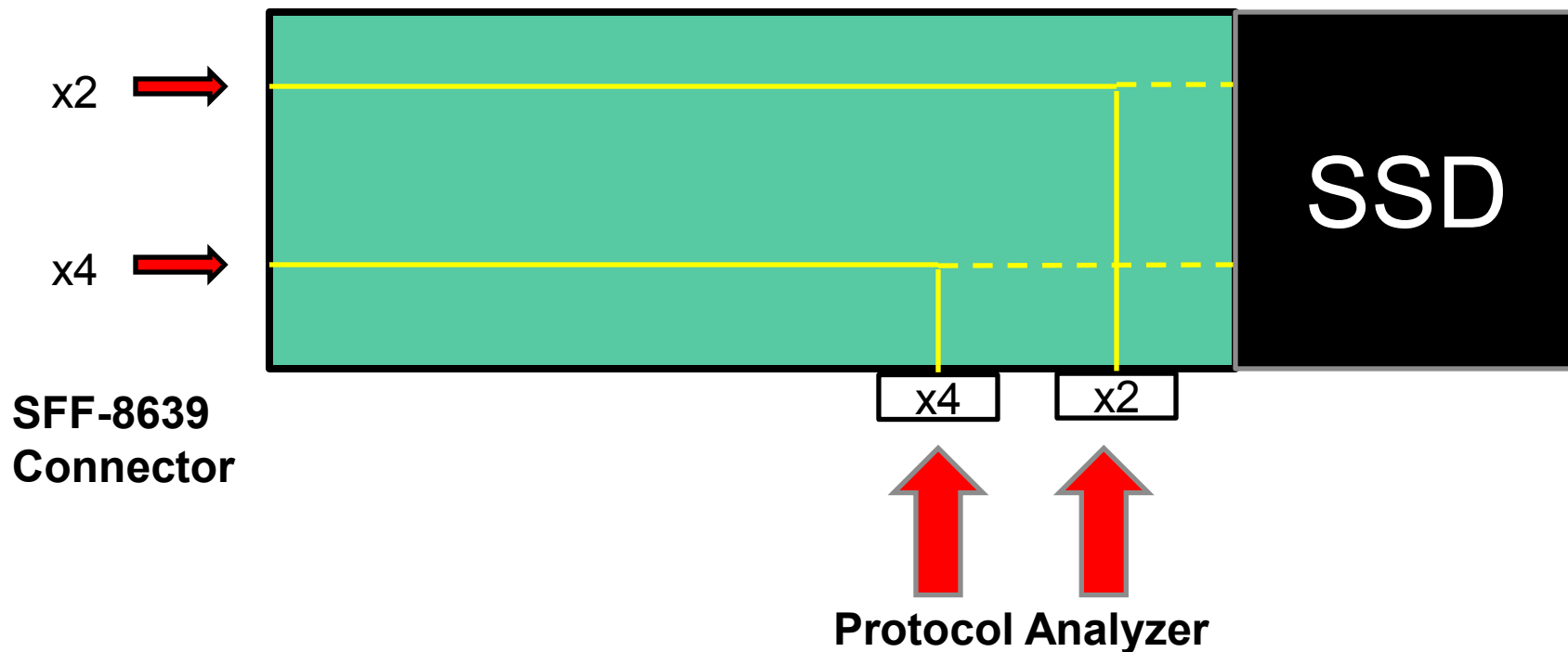
Protocol Analyzer

Supports
NVM Express   x4
SATA Express x2
SCSI Express   x4

SFF 8639 Interposer(Dual Port)

x2 →

x2 →

SSD

SFF-8639 Connector

x2   x2

↑   ↑

Protocol Analyzers
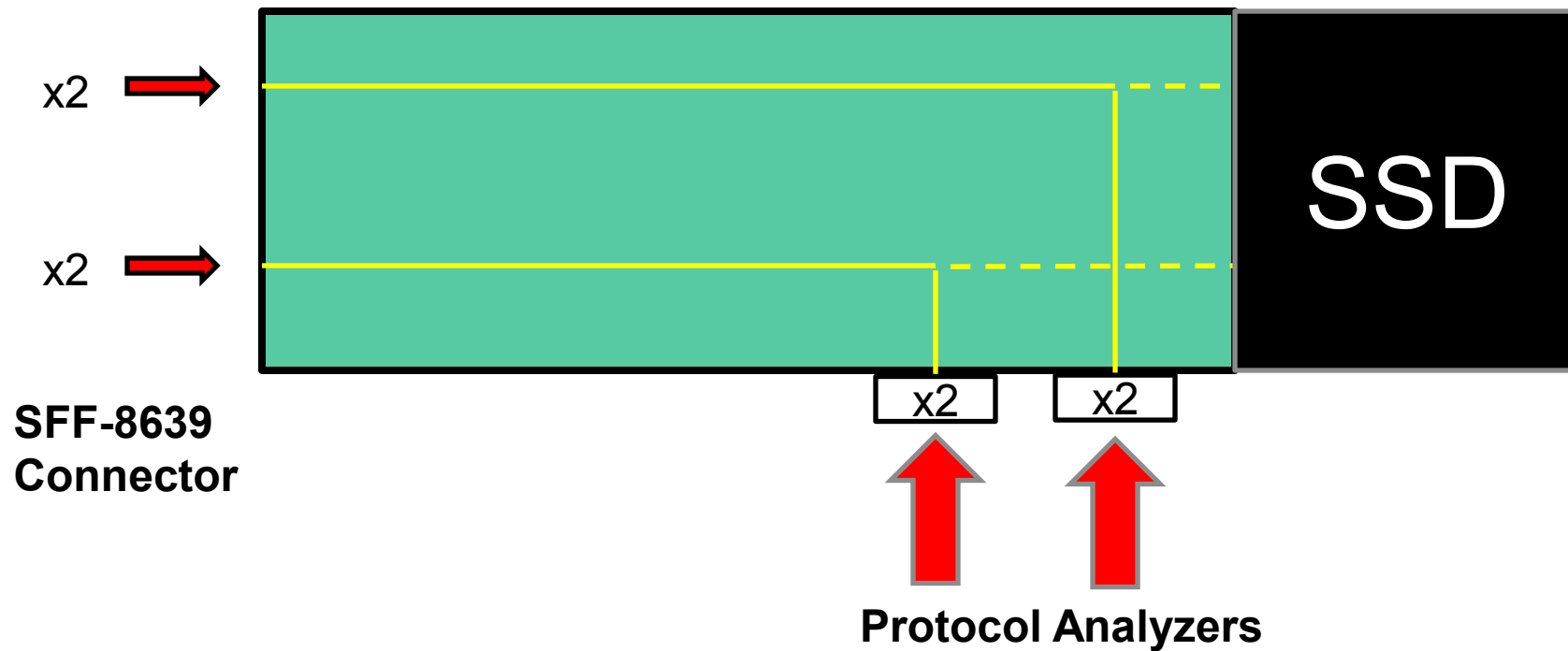
Supports	
NVM Express	Dual Port
SCSI Express	Dual Port

Requires two Protocol Analyzers

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NVM Express 1.0c Analysis Decode

Courtesy SanDIsk 2012

- NVMe is a standardized high performance queuing interface and command set optimized for PCIe SSDs
- NVMe is scalable from client to enterprise applications
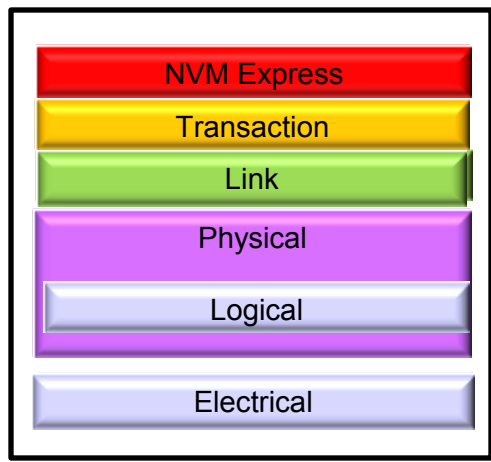
Testing PCIe SSD and Systems

- Supports the Windows 7 NVMe Driver
- Emulates all NVMe Registers
- Admin Commands
- NVM Commands
  - Write
  - Read
  - Compare
  - Extensible for Vendor Specific Commands
- Queue Management
- Come up in Device Manager
- Extensible Vendor Specific Features (for Get/Set Features)
- Complete commands via fused Commands (i.e. Compare & Write)

Summit Z3-16 Protocol Exerciser

NVMe Compliance and Interoperability Testing

- 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 will be creating a multi-vendor test bed to help products prove interoperability, and conformance test services to prove that products follow the NVMe specification correctly.
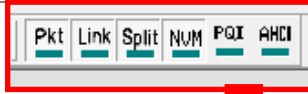- Targeting Jan 2013.

University of New Hampshire
InterOperability
Laboratory

NVMe SSD ComplianceTester

Exerciser
Running Compliance Tests

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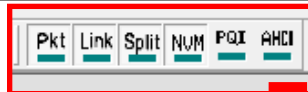
SCSI Express SOP Analysis Decode

Courtesy SanDIsk 2012

- SCSI Express is based on the SCSI over PCIe (SOP) host interface specification which enables SCSI initiators communicating to SCSI targets over PCIe through the PQI transfer layer
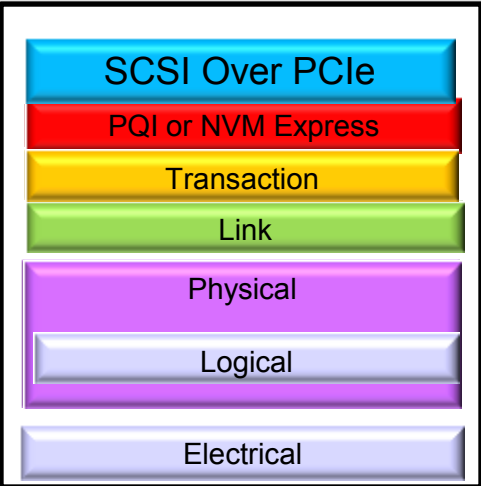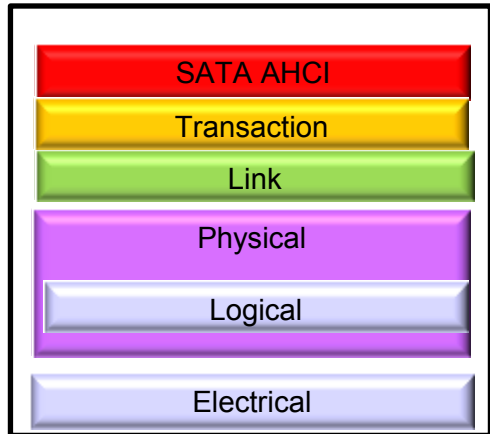
SATA Express Analysis Decode

Port control setup address of Command list

Port control setup address of FIS

- SATA Express enables new devices to be developed that utilize the faster PCIe interface and maintain compatibility with a broad base of existing SATA applications.

| SATA AHCI |
| Transaction |
| Link |
| Physical |
| Logical |
| Electrical |

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Tools for PCIe SSD Technologies

| SSD Protocols	Analyzer	Exerciser
PCI Express	Summit T3-16 Summit T3-8 Summit T28	Summit Z3-16 *Host/Device Emulation*
NVM Express	Summit T3-16/ T3-8/ T28 *SSD Decoding*	Summit Z3-16 *NVMe Host/Device Emulation*
SCSI Express(SOP/PQI)	Summit T3-16/ T3-8/ T28 *SSD Decoding*	Summit Z3-16 *SCSI Express Host Emulation*
SATA Express (AHCI/PCIe)	Summit T3-16/ T3-8/ T28 *SSD Decoding*	Summit Z3-16 *SATA Express Host Emulation*

nvm EXPRESS

STA SCSI Trade Association

SCSI Express

SERIAL ATA

SATA Express

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Conclusion

- New testing methodologies are needed for NVM Express, SCSI Express and SATA

- Protocol analysis 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.
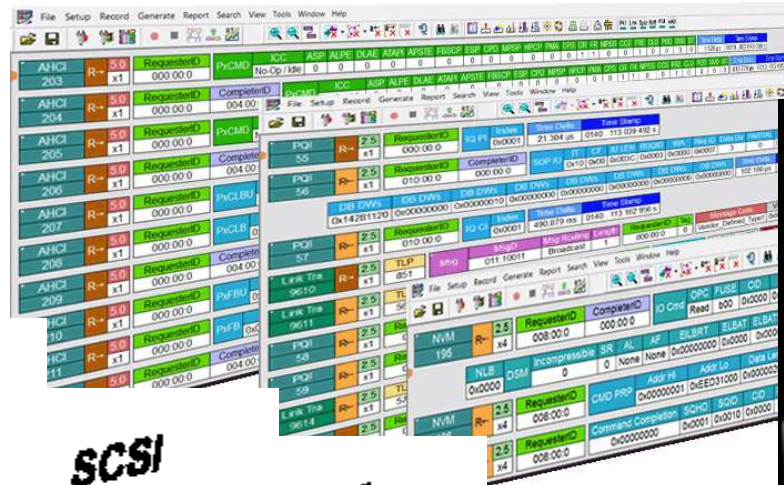
Sata Express

SCSI Express

NVM Express

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Summit T3-16 Analyzer

Summit T3-8 Analyzer

Summit T28 Analyzer

Summit Z3-16 Exerciser with Test Platform

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