SD Express Innovations
Public Webinar

* SD Express Speed Class was published with Part 1 SD Specification v9.1 in October 2023

December 2023
Forward-Looking Statements

During our webinar today we will be making forward-looking statements. Any statement that refers to expectations, projections or other characterizations of future events or circumstances is a forward-looking statement, including those relating to industry trends, standardization plans and any SD Association’s related plans. Actual results may differ materially from those expressed in these forward-looking statements due to various factors. We undertake no obligation to realize these forward-looking statements, which speak only as of the date hereof.

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Agenda

☐ SD Express & Speed Class Introduction
  – Yosi Pinto, Chairman and Technical Committee Chair

☐ SD Express Speed Class Specification Overview
  – Tadashi Ono, UHS TG Co-Chair
SD Express Innovations Webinar

SD Express & Speed Class - Introduction

Yosi Pinto, Chairman, SD Association
Senior Technologist at the Consumer Solutions Division in Western Digital (formerly SanDisk) and Chairman of the Board and the Technical Committee chair at the SD Association
The SD Association

Almost 800 members...leaders from all market segments

Card Manufactures
Connector Vendors
Chipset Vendors
Imaging
Mobile
Compute
Drones
Entertainment
Gaming

KIOXIA
SAMSUNG
Qualcomm
arm
Intel
NVIDIA
AMD
NXP
Microsoft
Apple
SanDisk
Panasonic
Lexar
Micron
Kingston
SiliconMotion
Texas Instruments NY
Motorola
Amazon
Nintendo
DJI
Parrot
PHISON
Synopsys
Cadence
Tuxera
Xilinx
Amphenol
CASIO
OLYMPUS
Leica
Nikon
Canon
Garmin
Bosch
Hyundai
Yamaha
Amitec Electronics
KYOCERA
SEIKO
JVC
RICOH
Fujifilm
Hitachi
Hikvision
Thinkware

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SD Association (SDA) was formed in 2000

>6 Billion SD & microSD cards sold by 2021*. SD is the de-facto worldwide removable memory card standard

- **2000**: SD base specification (SD Ver 1.0/Ver 1.01)
- **2004**: High Speed mode of 25MB/s (SD Ver.1.10)
- **2005**: microSD Introduced (microSD Ver1.0)
- **2006**: SDHC Introduced (SD Ver.2.00)
- **2009/10**: UHS-I mode 104MB/s, SDXC (SD Ver.3.00/3.01)
- **2011**: UHS-II mode 312MB/s (SD Ver.4.00)
- **2017**: UHS-III mode 624MB/s Command Queue Low Voltage (SD Ver.6.00)
- **2020**: SD Express w/PCIe4x2 ~4GB/s (SD Ver.8.00)
- **2022**: Boot/TCG/RPMB (SD Ver.9.00)
- **2023**: SD Express Speed Class microSD Express w/PCIe4x1 (SD Ver.9.10, microSD v8.0)


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Technology and Market Evolution

...the circle of on-going evolution

Evolving technology trends push memory interface requirements to higher sequential and random performance levels

Evolving removable memory devices with higher performance enables new usage models and market opportunities
SD Express Card – What is it?

- The same known form factors with two interfaces allowing backward compatibility:
  - NVMe™ + PCIe® interface
    - SD7.x → PCIe Gen3 x1
    - SD8 → PCIe Gen3x2, PCIe Gen4x1 or Gen4x2
  - SD interface (UHS-I up to 104MB/s)

![SD Memory Cards diagram]

- Same full size SD:
  - 32.0 × 24.0 × 2.1 mm
- Same microSD size:
  - 15.0 × 11.0 × 1.0 mm
SD Express: Running Towards New Horizons

PCIe® and NVMe™ memory card interfaces delivers performance and advanced protocols required for the next generation of memory-intensive high-performance applications
SD Express Card Applications

- **Multi-Channel Video Capturing** ➔ requires multi-stream high speed recording and captures a large amount of data
- **Hand-held Gaming devices** ➔ requires more memory and high-speed capability for real-time usage
- **Mobile devices – Tablets, Chromebooks and Smartphones** ➔ Real memory expansion allows running Apps from cards
- **VR & AR video** ➔ requires a high-speed real-time 3D view of 360°
- **4K cameras are everywhere and growing 8K, 12K, 8K 360°, Drones, Action Cameras and 3D VR cameras with huge data/speed requirements**
- **Multi-Channel Cameras, Multi-sensor Data Collection Multimedia Apps running from cards**
- **Semi-embedded applications (IoT, Mobile-Compute, etc.) ...driven also by the Right-to-Repair legislations**
SD Express Card

Featuring...

- Electrical Interface – SD DAT0-3 are MUXed with PCIe sideband signals and REFCLK

- Initiate either directly from the PCIe/NVMe or SD
  - Fully compatible to PCIe/NVMe standards. Identifies itself as a standard NVMe Memory

- Boot, TCG and RPMB may be supported by the SD interface (SD9) as well

- SD Express Speed Classes (SD9.1) may assure minimum performance levels
It’s coming… Eco-system adoption so far

SD Express and microSD Express cards are expected to be available by the major card manufacturers, everywhere around the globe.

SD Express adoption has already begun!

Chipsets & Bridge Solutions
A few leading chipset vendors

Compute
ASUS  (link)  (link)
acer  (link)
Lenovo  (link)
MSI  (link)  (link)  (link)

Cards and Card Controllers manufacturers
Lexar  (link)  (link)  (link)
SanDisk  (link)  (link)  (link)
ADATA  (link)  (link)  (link)

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Implementation of SD Express Host Interface

SDA provides a recommended host implementation design solution

SD Express Host Implementation Guideline

- Use existing building blocks of SD3 host and PCIe
- Provides backward compatibility to SD UHS-I
- Existing PCIe/NVMe drivers can be used
- The SD drivers updates are provided in flow charts
- Thermal handling recommendations are provided

Video
Off-the-shelf Available Bridges

Bridge Controller Solutions

**BayHub**
PCIe to SD Express Bridge Solution enabling SD Express hosts and readers
www.bayhubtech.com
Katsutoshi.Akagi@bayhubtech.com

**Genesys**
PCIe to SD Express Bridge Solution enabling SD Express hosts and readers
Seanhy.chen@genesyslogic.com.tw

**Realtek**
PCIe/USB to SD Express Bridge Solution enabling SD Express hosts and readers
www.realtek.com/en
jim_shiau@realtek.com

**J Micron**
USB 3.2(Gen2) to SD Express Bridge Solution enabling SD Express hosts and readers
www.jmicron.com
gordonchang@jmicron.com

**Host’s Chipset**

**Bridging chip**

**PCIe**

**Or**

**USB**

**SD Express**
SD UHS-I
SD UHS-II
All supported in a single slot

SD (full-size) Connectors for all types of cards are available from various UHS-II connector vendors

*microSD connectors that support all types of cards are available by Amphenol*
Available Test Tools and Test Accessories

Bus Analyzers, Protocol Analyzers, Test Suites are available now

SD Express Test Fixtures – for SD7.x and SD8 -

• Enables Host and Card vendors to test their SD Express’ PCIe interface using standard test equipment
• The set is available for our members to borrow from our approved labs (GRL and Allion)

SD Express dedicated Protocol and Test tools -

• Prodigy –SD Express protocol analyzer using PGY PCIe3/4 x4
• Testmetrix - SD Express Engineering / Self-Compliance Tester with integrated Protocol Analyzer VTE-7100
Speed Classes in Removable Memory Cards

Products with removable or semi-removable memory cards

Who enjoys having speed classes?

- Consumers who own any of those products and expect to get the promised features
- Product manufacturers may specify what speed class is required to ensure specific features
- It is known to be most important for continuous video recording, but it can be important for other applications like – multi-stream recording, fast reading of ‘heavy’ video/graphic files in VR Headset or Gaming and more…

Various products may require minimum assured memory access performance to assure proper support of their expected sequential and random operation.
# Speed Classes in Removable Memory Cards

## Speed Class Definition Involves….

- RD/WR Block sizes and recording periods
- Stream and Queue handling
- Suspend/Resume conditions
- Power management conditions
- Thermal management
- Various measurement conditions
- ….  

## … and who should care about this spec?

- **Host, Chipset and Card vendors:**
  - RAM sizes ➔ final product cost
  - Amount of testing ➔ production cost
  - Architecture changes ➔ potential re-design costs

- **Memory vendors:**
  - Technology limits
  - Optimization of maintenance and wear leveling
  - Optimization of performance utilization

- **NVMe drivers’ developers:**
  - Optimization and generalization of drivers across all the NVMe eco-system
SD Association Membership

As a member you...

- Get ACCESS TO ALL SPECIFICATIONS
- May have ACCESS to specification drafts BEFORE THE RELEASE, while they are under development
- May INFLUENCE specifications under development and/or next-generation standards
- Receive updates on SD roadmap
- May participate in Interoperability events

<table>
<thead>
<tr>
<th>Member Benefits</th>
<th>Executive</th>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be a candidate to serve on the Board of Directors</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Voting Rights in SDA, including Committees and Workgroups</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Ability to chair Committees and Workgroups</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Participate in Committee and Workgroup all email reflectors, except closed</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Obtain pre-release access to documents and deliverables</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Ability to make proposals for additions and/or modifications for SD Specifications</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Ability to execute the SD Association License Agreement</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Access to the SD specification matrix</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Participate in and contribute to Committee and Workgroup activities</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Attend General and Interim Meetings</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Access to the “Members Only” website</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Participate in Interoperability Test Events</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Participate in marketing events and workshops</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Annual Dues</td>
<td>$4500</td>
<td>$2500</td>
</tr>
</tbody>
</table>

To join the SDA follow this link
Thank you
Overview of SD Express Speed Class

Tadashi Ono, UHS TG Co-Chair,
SD Association
Senior Expert at Advanced Research Lab. in Panasonic Connect Co., Ltd., and co-chair of the UHS TG for the SD Association.
Agenda

☐ Introduction
  – Background and Goal
  – Application Examples

☐ Target and Approach
  – Target of the Specification
  – Supporting Speed Classes
  – Approach for Standardization

☐ Technical Features
  – Power Management
  – Thermal Management
  – Multi-stream Access Rule
  – Suspend and Resume

☐ Summary
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Summary
Background and Goal

☐ Background

– Recent imaging equipment needs to support recording bit rates over 100MB/s, in addition, some appliances also require multiple-stream recording in real-time
– The current SD specification guarantees to record one stream data up to 90MB/s by the conventional Video Speed Class (VSC)
  This specification does not satisfy these market requirements

☐ Goal

– Establishing SD Express Speed Class specification which realizes
  • Several hundreds of MB/s for guaranteed recording speed, and
  • Multiple-stream recording to an SD Express memory card
Application Examples

- **Professional Camcorder**
  - Recording a high bitrate stream (cinema quality) with several hundreds of MB/s

- **Surveillance Camera**
  - Aggregating several streams captured by multiple cameras onto one SD card
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Summary
Target of the Specification

☐ Available Speed Classes are 150, 300, 450 and 600
- They guarantee stream recording with 150, 300, 450 and 600MB/s respectively
- Card can record **up to 8 streams** in parallel if the sum of these recording speeds is within the supported class

☐ If card supports specific SD Express Speed Class, it shall also support all lower classes
- e.g. If card supports Class 600MB/s, it can also support Class 150MB/s, 300MB/s and 450MB/s

☐ For each Speed Class, cards shall deliver performance in all supported PCIe bus modes
- e.g. If card has PCIe Gen4x1 mode and supports Class 300MB/s, card shall recognize it in Gen3x1 mode as well

### PCIe Bus Speed Mode Requirements for Each SD Express Speed Class

<table>
<thead>
<tr>
<th>SD Express Speed Class (if card supporting)</th>
<th>PCI Express Bus Speed Modes (Interface Modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gen3x1</td>
</tr>
<tr>
<td>150 (MB/s)</td>
<td>M</td>
</tr>
<tr>
<td>300 (MB/s)</td>
<td>M</td>
</tr>
<tr>
<td>450 (MB/s)</td>
<td>M</td>
</tr>
<tr>
<td>600 (MB/s)</td>
<td>M</td>
</tr>
</tbody>
</table>

“M”: This bus mode is mandatory when card supports the corresponding SD Express Speed Class

“MiS”: This bus mode is mandatory if card supports both the corresponding SD Express Speed Class and the bus speed mode
Supporting Speed Classes

- Supporting SD Express Speed Class is optional for SD Express memory cards

- In addition, SD Express Speed Class specification is defined independent to that of the VSC
  - This means all types of SD Express cards described in the following table are allowed

<table>
<thead>
<tr>
<th>Type</th>
<th>Supporting SD Express Speed Class</th>
<th>Supporting VSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Supporting the original speed class (C2, C4, C6, and C10) and the UHS speed grade (U1 and U3) are also optional for all types of SD Express Card above in the table.
Approach for Standardization

☐ Referring to the conventional VSC specification
  – Introducing specific functions operated by CMD20
  – Supporting Suspend / Resume to save available memory areas

☐ Keeping high affinity with the NVMe specifications
  – Streams Directive
    • SWS (Stream Write Size)
      – Optimal size unit for the stream recording, similar to RU (Recording Unit) Size in the VSC
    • SGS (Stream Granularity Size)
      – Optimal size for managing streams, similar to AU (Allocation Unit) Size in the VSC
    • Stream Identifier
    • etc.
  – Dataset Management (DSM)
    • Operations of CMD20 are mapped to a DSM command
  – Vendor Specific Area in the ICDS (Identify Controller Data Structure)
    • Introducing new parameters related to Power and Thermal Management
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☐ Summary
Power Management (1)

☐ Background
- In accordance with the NVMe, an SD Express memory card indicates Power State Descriptor (PSD) and associated Max Power (MP) supported by the card
  - Host selects one of available PSDs
  - PSD0 specifies the highest MP in the card

☐ Issue
- Basically, speed class recording does not require maximum power
- If host chooses PSD0, card may consume excessive power even if it is unnecessary

An Example of PSD for Gen4x1 (bus speed is up to 2GB/s)

<table>
<thead>
<tr>
<th>Power State Descriptor (PSD)</th>
<th>Max Power (MP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSD0</td>
<td>2.8W</td>
</tr>
<tr>
<td>PSD1</td>
<td>2.5W</td>
</tr>
<tr>
<td>PSD2</td>
<td>1.8W</td>
</tr>
<tr>
<td>PSD3</td>
<td>1.44W</td>
</tr>
<tr>
<td>PSD4</td>
<td>0.72W</td>
</tr>
<tr>
<td>PSD5</td>
<td>N/A</td>
</tr>
<tr>
<td>PSD6</td>
<td>N/A</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>PSD30</td>
<td>N/A</td>
</tr>
<tr>
<td>PSD31</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Each PSD is assigned in top-aligned and descending order of MP.
Solution

Before starting the speed class recording, host should take the following steps to save power:
1. Reading “Speed Class Power State” in the Vendor Specific Area of the ICDS
2. Setting the PSD to the card which corresponds to the target speed class (Class 450 in this example)

Result

By these operations, card recognizes the appropriate Max Power during the speed class recording
• 1.8W (< 2.8W) in this example

### Power State Descriptor (PSD) and Max Power (MP)

<table>
<thead>
<tr>
<th>PSD</th>
<th>Max Power (MP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSD0</td>
<td>2.8W</td>
</tr>
<tr>
<td>PSD1</td>
<td>2.5W</td>
</tr>
<tr>
<td>PSD2</td>
<td>1.8W</td>
</tr>
<tr>
<td>PSD3</td>
<td>1.44W</td>
</tr>
<tr>
<td>PSD4</td>
<td>0.72W</td>
</tr>
<tr>
<td>PSD5</td>
<td>-</td>
</tr>
<tr>
<td>PSD6</td>
<td>-</td>
</tr>
<tr>
<td>PSD30</td>
<td>-</td>
</tr>
<tr>
<td>PSD31</td>
<td>-</td>
</tr>
</tbody>
</table>

### Vendor Specific Area

<table>
<thead>
<tr>
<th>Byte Offset (for Gen4x1)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3120 (Class 150)</td>
<td>84h (PSD4)</td>
</tr>
<tr>
<td>3121 (Class 300)</td>
<td>83h (PSD3)</td>
</tr>
<tr>
<td>3122 (Class 450)</td>
<td>82h (PSD2)</td>
</tr>
<tr>
<td>3123 (Class 600)</td>
<td>81h (PSD1)</td>
</tr>
</tbody>
</table>
Thermal Management (1)

- **Background**
  - NVMe has a thermal throttling mechanism to avoid card’s destruction by temperature rise.
  - There are two thresholds for the thermal throttling set by the host:
    - TMT1: activating a light throttling
    - TMT2: activating a heavy throttling (critical for the speed class recording)

- **Issue**
  - If these threshold settings are not appropriate, card cannot maintain the target recording speed due to the heavy throttling.
  - Temperature characteristic depends on card implementation.

---

<table>
<thead>
<tr>
<th>Card Internal Temp.</th>
<th>Recording Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Speed</td>
</tr>
<tr>
<td>TMT1=TMT2</td>
<td>Target speed</td>
</tr>
<tr>
<td>Start heavy throttling</td>
<td>Impossible to maintain the target speed</td>
</tr>
</tbody>
</table>

Unpreferable Example of Thermal Management
Thermal Management (2)

- **Solution**
  - Card indicates its specific thermal thresholds (SCTMT1/2) for maintaining the target recording speed, and host sets these values as TMT1/2 respectively.

- **Result**
  - Card can keep the target recording speed during the speed class recording.
Multi-stream Access Rule (1)

☐ Background
- To minimize the overhead of programming to NAND, stream data shall be written continuously from the starting address of SGS unit that is fully vacant

☐ Issue
- Suppose the stream data with different SIDs are recorded to SGS units in receiving order
- Even stream data with SID=2 are deleted, these SGS units cannot be used for stream recording because they are not fully vacant

* SGS unit: Memory area for optimal stream management

Stream data with SID=1 and SID=2 are recorded in SGS units in receiving order

Stream data with SID=2 are deleted

These SGS units cannot be used for another stream recording
Multi-stream Access Rule (2)

☐ Solution
- Introducing the following multi-stream access rule
  - Each SGS unit can be occupied by data with only one SID
  - Stream data with SID=1 and SID=2 are recorded in SGS unit A and B respectively

☐ Result
- After deleting stream with SID=2, SGS unit B can be reused for storing another stream data
- This ensures efficient memory usage when host repeats recording and deleting video streams in a card
Suspend and Resume (already introduced in the VSC)

Objective of Suspend and Resume
- For power saving, most DSLRs or Camcorders will completely turn off after video recording
- Suspend and Resume functions are introduced to SD Express Speed Class as well as the VSC, in order to record stream data in the memory efficiently
  - Basically, Host shall record stream data from the start address of the SGS unit
  - By executing “Suspend AU/SGS” to suspend stream recording at the SD Express SUS_ADDR, Host can resume it from this address (not a start address) by “Resume AU/SGS”

<table>
<thead>
<tr>
<th>Bytes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>03:00</td>
<td>10000200h  (SD Express SUS_ADDR 1)</td>
</tr>
<tr>
<td>07:04</td>
<td>20000C00h  (SD Express SUS_ADDR 2)</td>
</tr>
<tr>
<td>11:08</td>
<td>00000000h  (SD Express SUS_ADDR 3)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>31:28</td>
<td>00000000h  (SD Express SUS_ADDR 8)</td>
</tr>
</tbody>
</table>
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  - Thermal Management
  - Multi-stream Access Rule
  - Suspend and Resume

☐ Summary
☐ SD Express Speed Class is defined for realizing high-speed, multi-stream video recording over PCIe bus
  – A cinema quality video with 600MB/s
  – Up to 8 streams in parallel for surveillance camera, etc.

☐ New features are introduced to the SD Express Speed Class for stable video recording and efficient memory use
  – Power and Thermal Management for maintaining the target recording speed
  – Multi-stream access rule for reusing SGS units after deleting stream data
Question and Answer Session
Questions?

- Use the GoToWebinar Control panel on your screen and choose the Question or Chat option to submit your question to our panel.
After the Webinar

☐ You will receive an email with a link to download the presentation and access to the on-demand recording of the webinar – feel free to share with your colleagues

☐ More information on SD Express is available at:

☐ Download our white papers on SD Express and other specifications:
Thank you for attending!