SD Association

SD Express Innovations

Public Webinar

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

December 2023

Disclaimers and Trademarks

SD Association

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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- NVM Express™ and NVMe™ are trademarks of NVM Express, Inc.

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 Association

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 | …

SD Specification Evolution

SD Association (SDA) was formed in 2000

>6 Billon 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)

2018/19

SD Express & microSD Express
(PCIe®3/NVMe™) 985MB/s, SDUC

(SD Ver.7.00/7.10)

2020

SD Express w/PCIe4x2 ~4GB/s

(SD Ver.8.00)

2022

Boot/TCG/RPMB

(SD Ver.9.00)

New

2023

SD Express Speed Class
microSD Express w/PCIe4x1

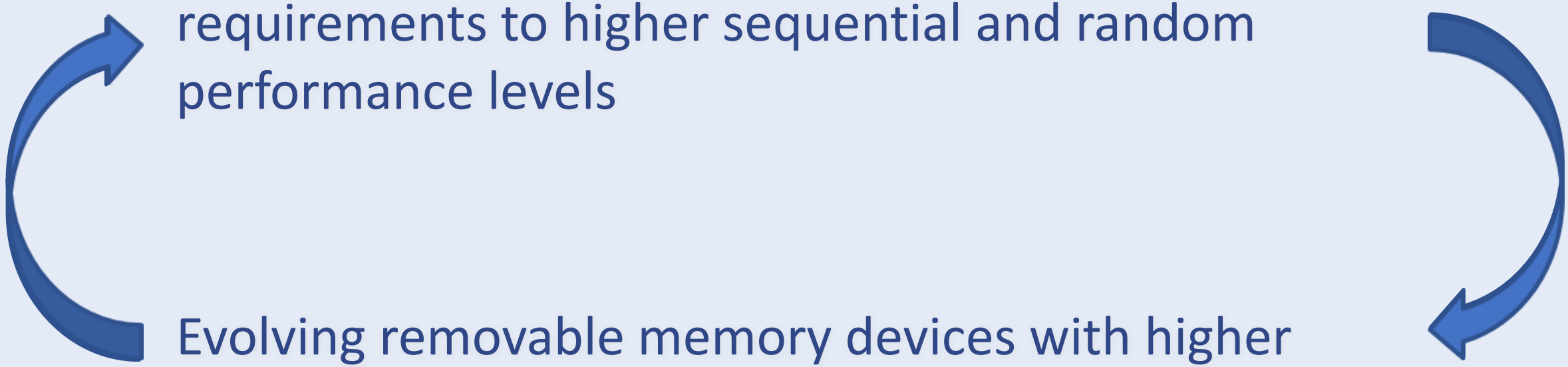
(SD Ver.9.10, microSD v8.0)

* Source: Estimation using news published by SanDisk in 2015 (“2 Billion microSD cards sold by 2015”) + TrendForce’s report from 2019 (“total of ~3 billion cards sold within 2016-2019”) and report from Futuresource of total of ~1M sold between 2020-2021

Technology and Market Evolution

…the circle of on-going evolution

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



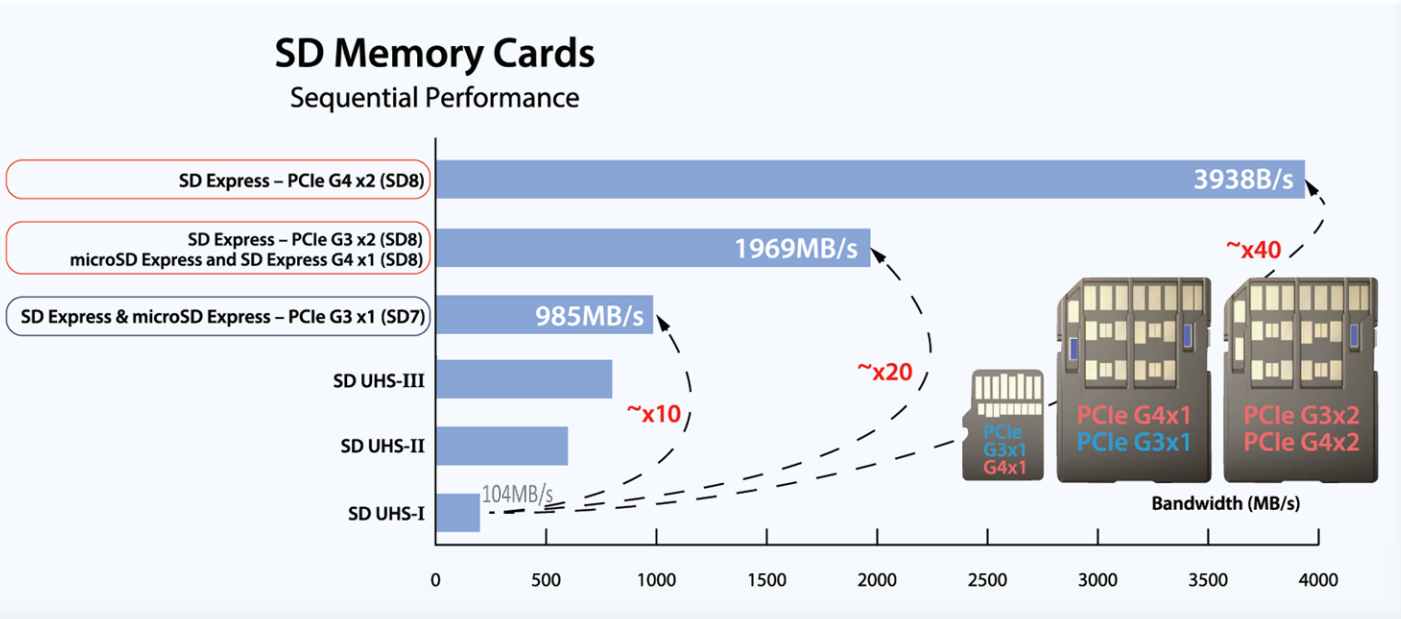
Evolving removable memory devices with higher performance enables new usage models and market opportunities

SD Express Card – What is it?

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

Same full size SD:
32.0 × 24.0 × 2.1 mm

Same microSD size:
15.0 × 11.0 × 1.0 mm

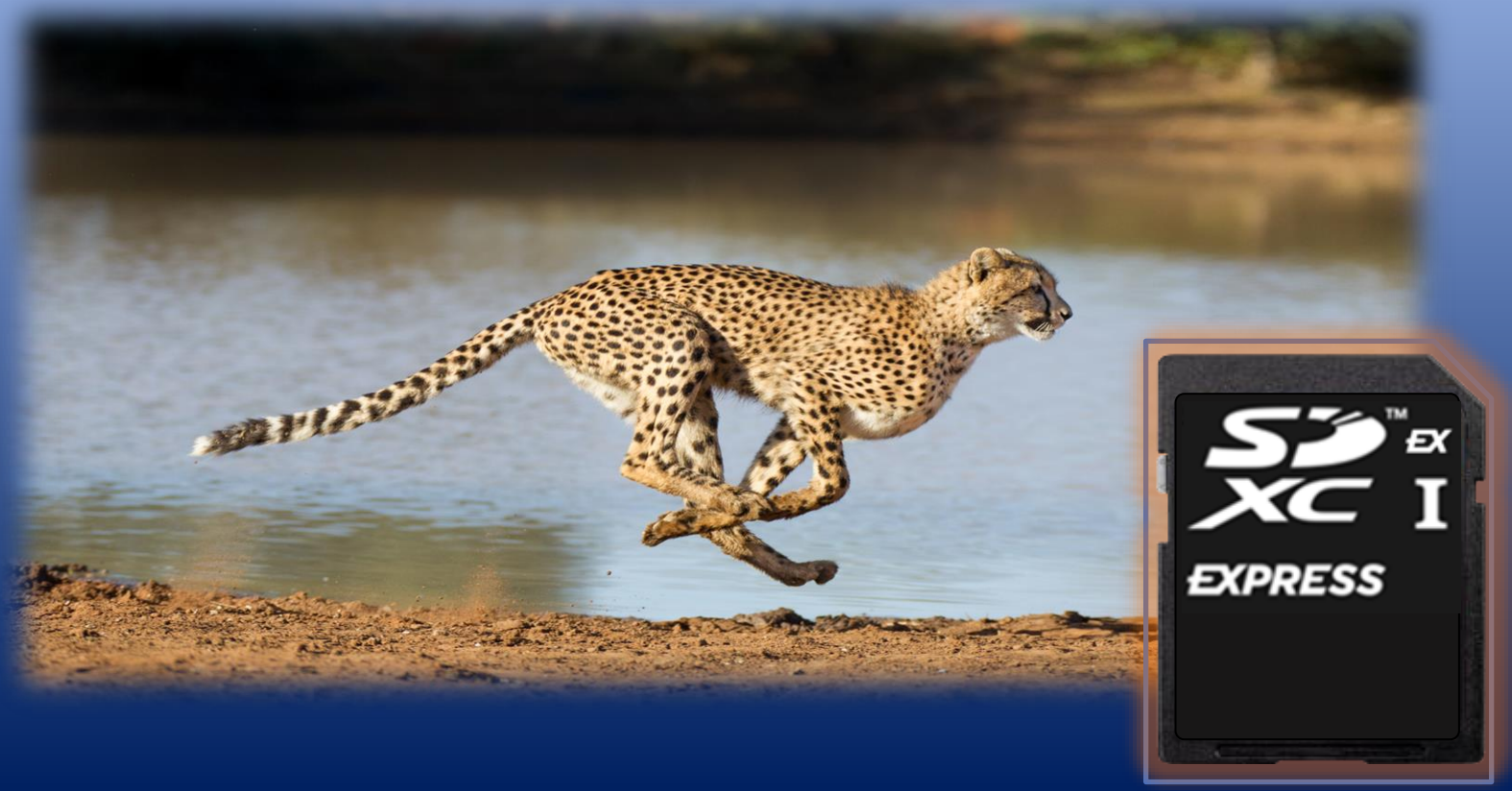


SD Express: Running Towards New Horizons

SD Association

PCIe® and NVMe™ memory card interfaces

delivers performance and advanced protocols required for the next generation of memory-intensive high-performance applications



EXPRESS

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°

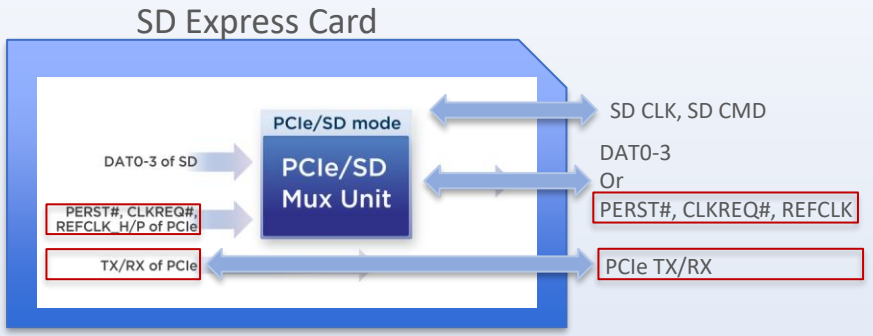
4K cameras are everywhere and growing 8K, 12K, 8K 360° , Drones, Action Cameras and 3D VR cameras with huge data/speed requirements

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

From PCIe-SIG Spec

PCI CODE AND ID ASSIGNMENT SPECIFICATION, REV. 1.9

Base Class	Sub-Class	Programming Interface	Meaning
01h	05h	20h	ATA controller with ADMA interface - single stepping (see Note 2)
		30h	ATA controller with ADMA interface - continuous operation (see Note 2)
	06h	00h	Serial ATA controller - vendor-specific interface
		01h	Serial ATA controller - AHCI interface (see note 7)
		02h	Serial Storage Bus Interface
	07h	00h	Serial Attached SCSI (SAS) controller - vendor-specific interface
		01h	Obsolete
	08h	00h	Non-volatile memory subsystem - vendor-specific interface
		01h	Non-volatile memory subsystem - NVMHCI interface (see note 8)
		02h	Non-volatile memory subsystem - NVM Express interface (see Note 6)
	09h	00h	Universal Flash Storage (UFS) controller - vendor-specific interface
		01h	Universal Flash Storage (UFS) controller - Universal Flash Storage Host Controller Interface (UFSHCI) (see Note 5)

- 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 Association

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

- GENESYS LOGIC (link)
- JMicron (link)
- REALTEK (link)
- BayHub (link)

Compute

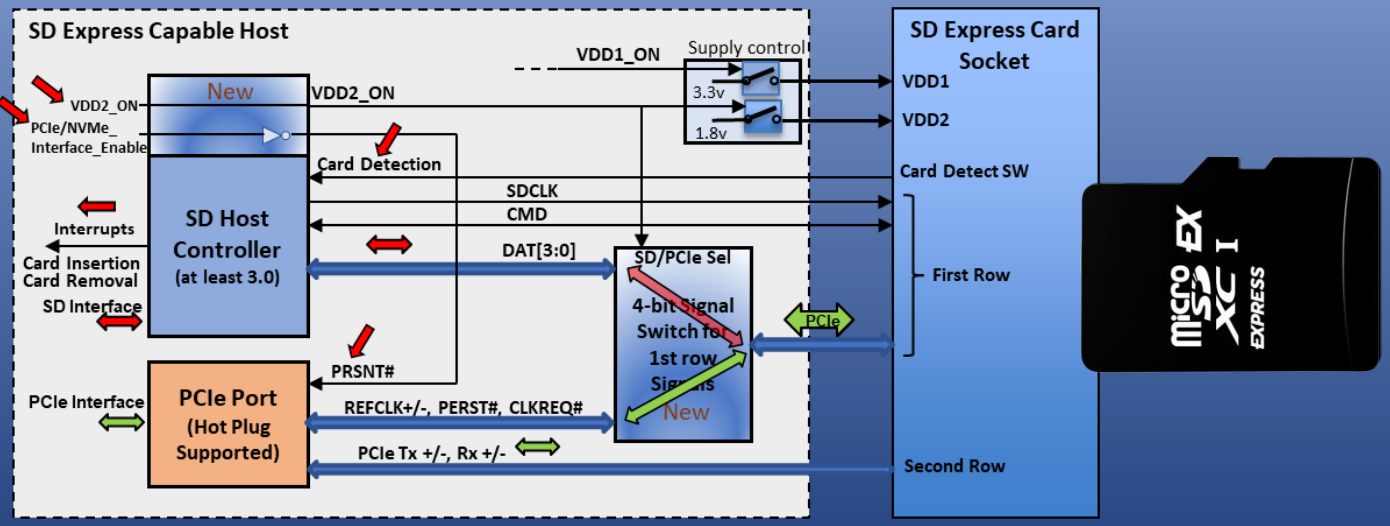
- ASUS (link) (link)
- acer (link)
- Lenovo (link)
- msi (link) (link) (link)
- hp (link) (link)

Cards and Card Controllers manufacturers

- Lexar Link
- SanDisk A Western Digital Brand Link
- ADATA Link
- PHISON Link
- SiliconMotion Link

Implementation of SD Express Host Interface

SDA provides a recommended host implementation design solution



SD Express Host Controller – Full Circuit Example

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 LOGIC

PCIe to SD Express Bridge Solution enabling SD Express hosts and readers

www.genesyslogic.com.tw/en
Seanhy.chen@genesyslogic.com.tw

REALTEK

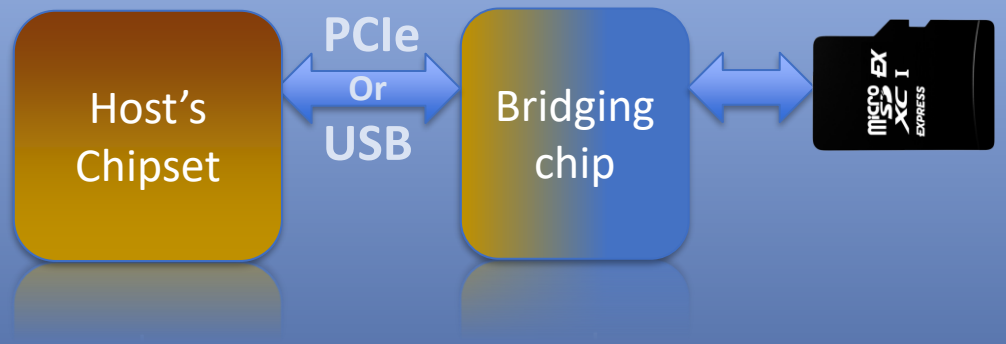
PCIe/USB to SD Express Bridge Solution enabling SD Express hosts and readers

www.realtek.com/en
jim_shiau@realtek.com

JMicron

USB 3.2(Gen2) to SD Express Bridge Solution enabling SD Express hosts and readers

www.jmicron.com
gordonchang@jmicron.com



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

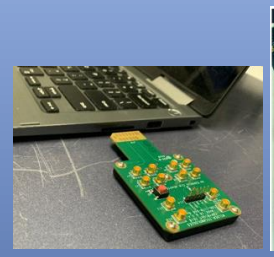
Amphenol

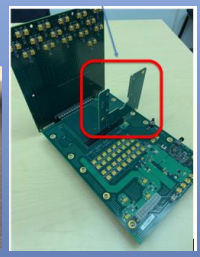
Available Test Tools and Test Accessories

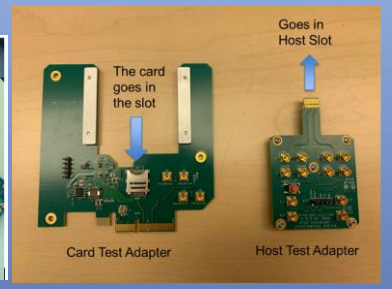
Bus Analyzers, Protocol Analyzers, Test Suites are available now

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)

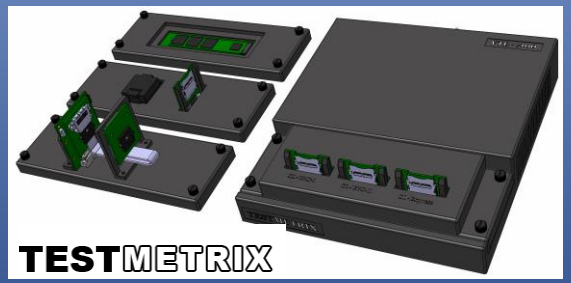






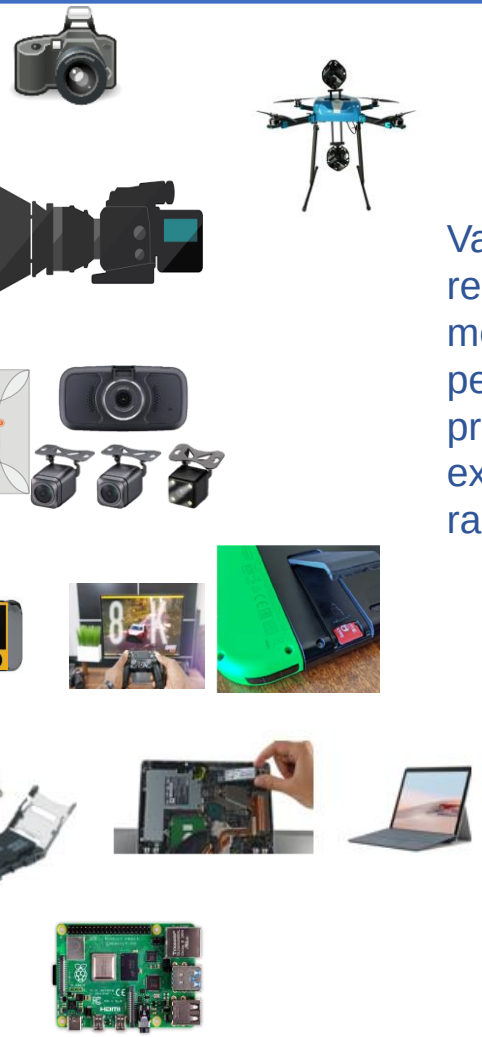
SD Express dedicated Protocol and Test tools -

- 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



Various products may require minimum assured memory access performance to assure proper support of their expected sequential and random operation

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…

Speed Classes in Removable Memory Cards

SD Association

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

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

To join the SDA follow this link

Thank you

SD Express Innovations Webinar

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.

Panasonic

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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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

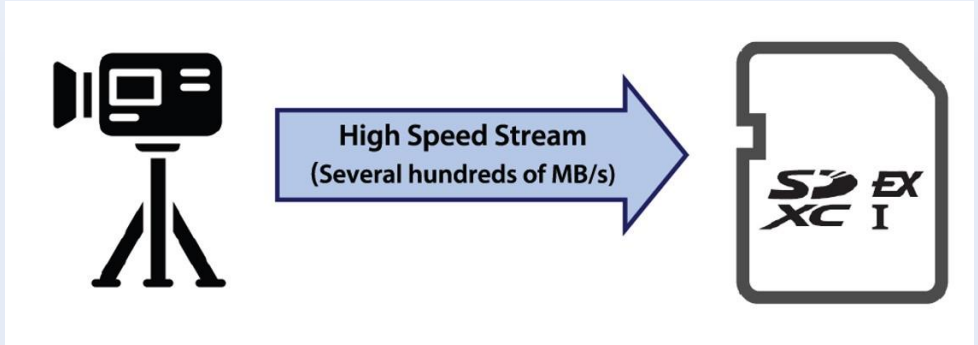
☐ Goal

- 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

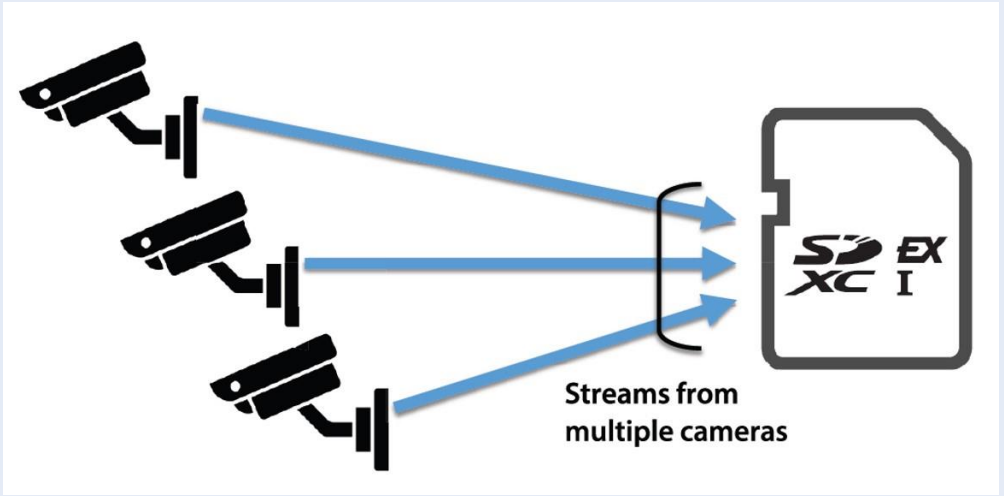
☐ Professional Camcorder

– 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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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

SD Express Speed Class (if card supporting)	PCI Express Bus Speed Modes (Interface Modes)			
	Gen3x1	Gen3x2	Gen4x1	Gen4x2
150 (MB/s)	M	MiS	MiS	MiS
300 (MB/s)	M	MiS	MiS	MiS
450 (MB/s)	M	MiS	MiS	MiS
600 (MB/s)	M	MiS	MiS	MiS

"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

Type	Supporting SD Express Speed Class	Supporting VSC
1	No	No
2	No	Yes
3	Yes	No
4	Yes	Yes

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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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

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

Power State Descriptor (PSD)	Max Power (MP)
PSD0	2.8W
PSD1	2.5W
PSD2	1.8W
PSD3	1.44W
PSD4	0.72W
PSD5	N/A
PSD6	N/A
:	:
PSD30	N/A
PSD31	N/A

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

Power Management (2)

Solution

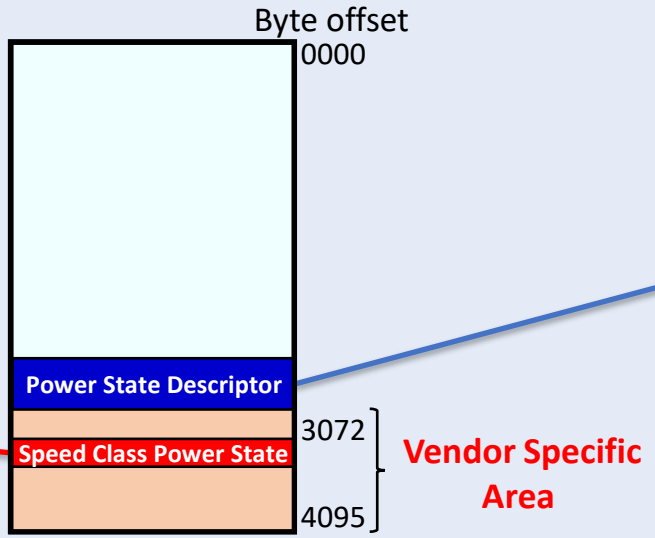
- Before starting the speed class recording, host should take the following steps to save power:
  1. Reading “Speed Class Power State” in the Vendor Specific Area of the ICDS
  2. Setting the PSD to the card which corresponds to the target speed class (Class 450 in this example)

Result

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

Byte Offset	Value
3120 (Class 150)	84h (PSD4)
3121 (Class 300)	83h (PSD3)
3122 (Class 450)	82h (PSD2)
3123 (Class 600)	81h (PSD1)

Speed Class Power State (for Gen4x1)



Identify Controller Data Structure (ICDS)

Power State Descriptor (PSD)	Max Power (MP)
PSD0	2.8W
PSD1	2.5W
PSD2	1.8W
PSD3	1.44W
PSD4	0.72W
PSD5	-
PSD6	-
:	:
PSD30	-
PSD31	-

PSD (for Gen4x1)

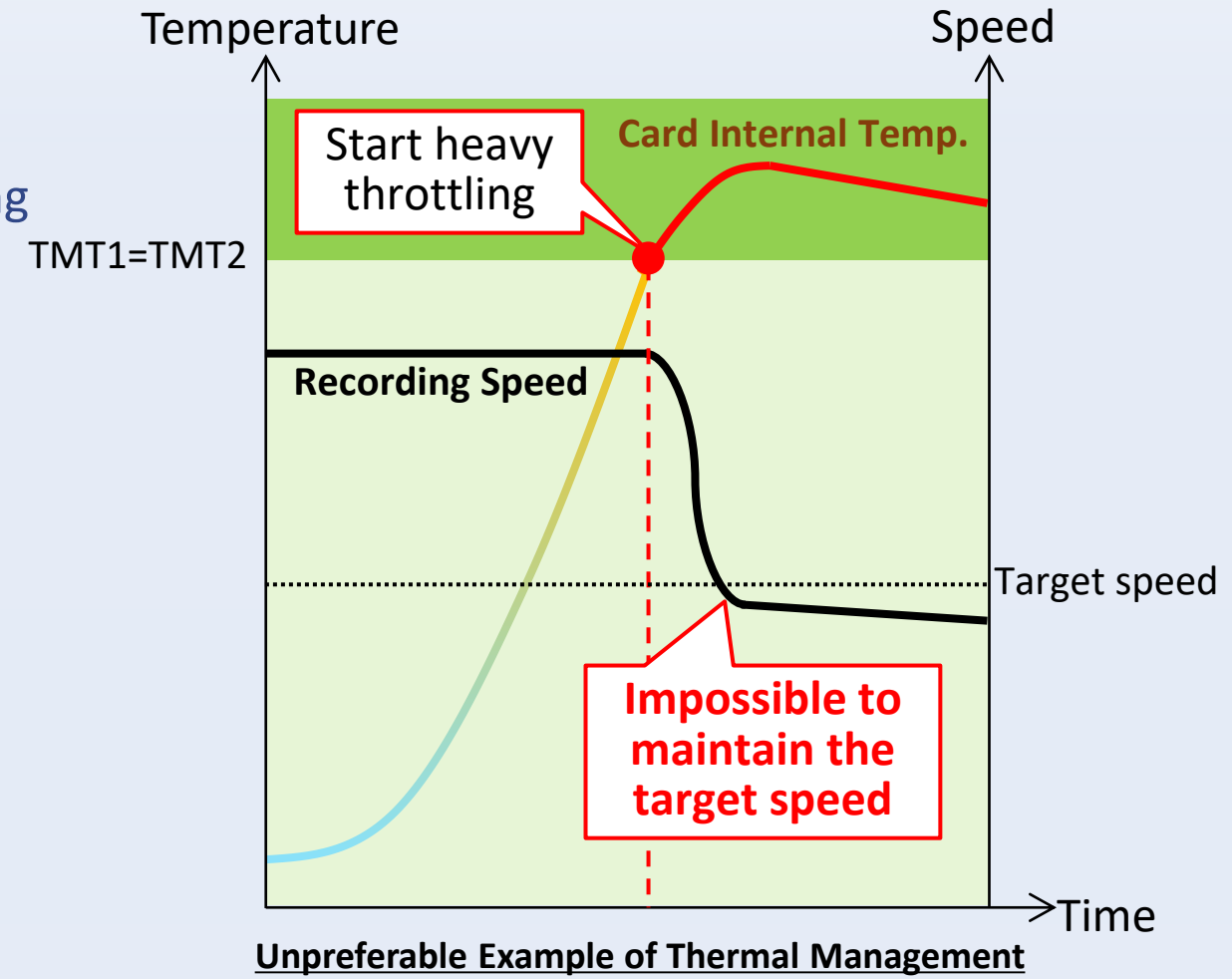
Thermal Management (1)

☐ 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



Unpreferable Example of Thermal Management

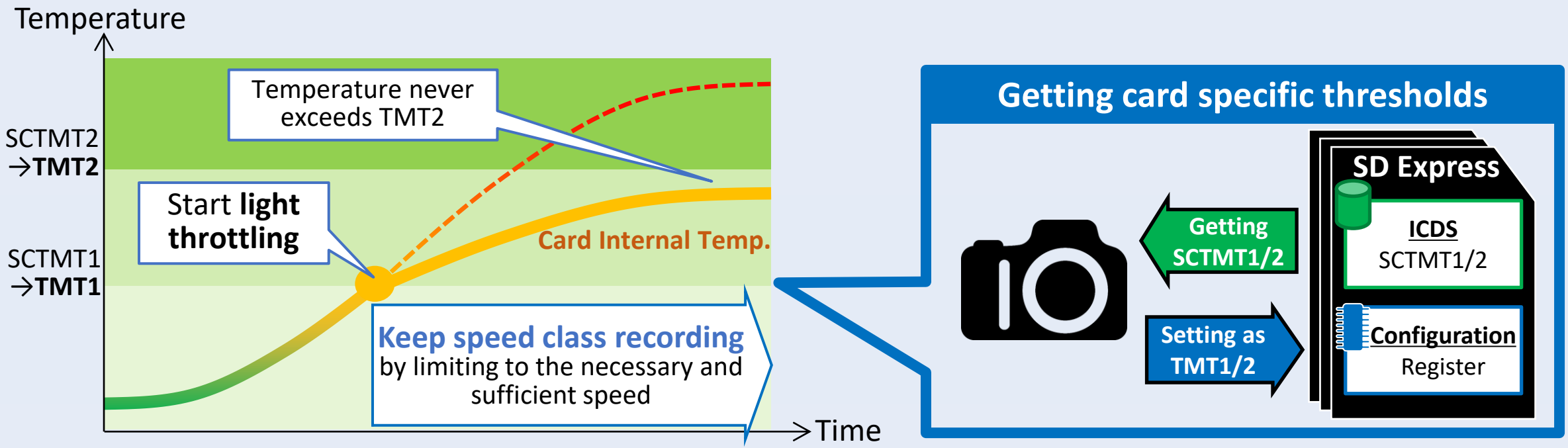
Thermal Management (2)

☐ 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

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

These SGS units cannot be used for another stream recording

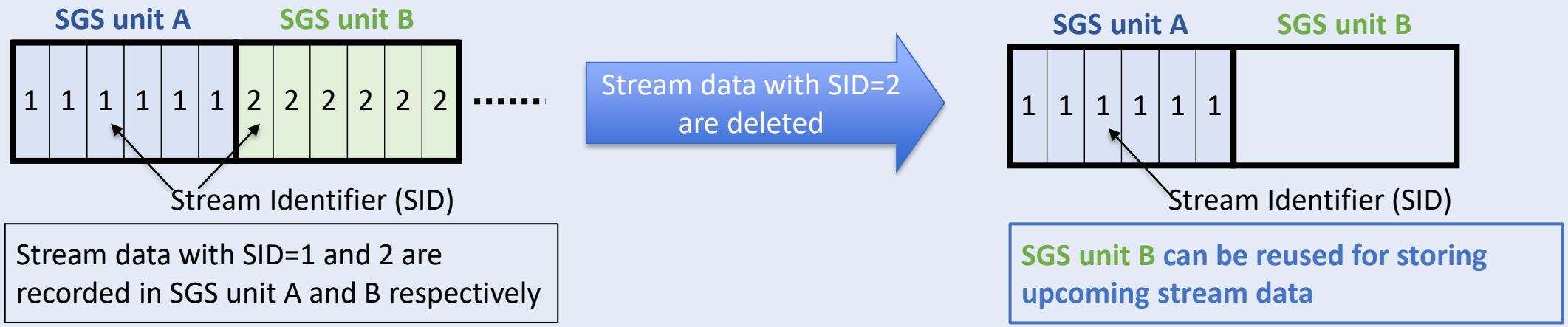
Multi-stream Access Rule (2)

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

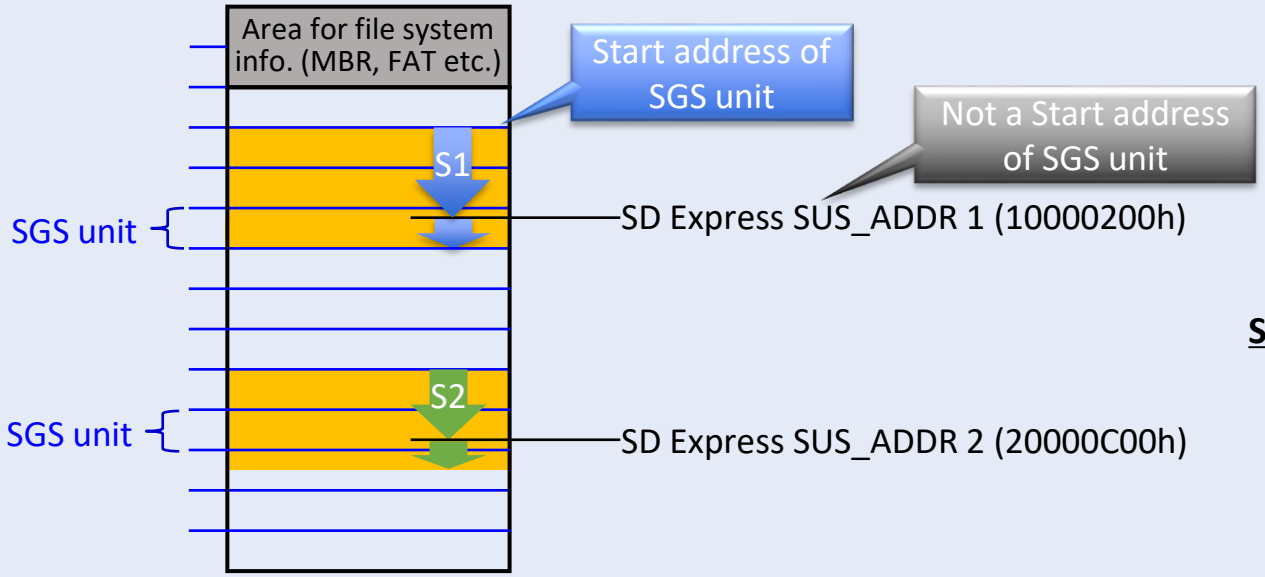
- After deleting stream with SID=2, SGS unit B can be reused for storing another stream data
- This ensures efficient memory usage when host repeats recording and deleting video streams in a card



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”



Memory Area in the SD Express Memory Card

SD Express SUS_ADDR Obtained by Get Log Page Command

Bytes	Description
03:00	10000200h (SD Express SUS_ADDR 1)
07:04	20000C00h (SD Express SUS_ADDR 2)
11:08	00000000h (SD Express SUS_ADDR 3)
:	:
31:28	00000000h (SD Express SUS_ADDR 8)

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  - Approach for Standardization
- Technical Features
  - Power Management
  - Thermal Management
  - Multi-stream Access Rule
  - Suspend and Resume
- **Summary**

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:
  - https://www.sdcard.org/developers/sd-standard-overview/bus-speed-default-speed-high-speed-uhs-sd-express/
- ☐ Download our white papers on SD Express and other specifications:
  - https://www.sdcard.org/downloads/pls/latest_whitepapers/

Thank you for attending!