



NVMe[®] Adoption by SD[™] & microSD[™] Memory Cards

Sponsored by NVM Express organization, the owner of NVMe specifications

Speaker



Michael Lavrentiev
Technologist
SD Association

- Chair of SWG at SDA since 2018
- Developed SD Express since Nov 2016
- Contributor to SDA since 2012

- Technologist, Systems Design Engineering @ Western Digital
- Contributed for the development of new generations of market leading SD and microSD cards.
- Handled product management and product requirements for various flash memory solutions
- Before joining Western Digital, worked at KLA-Tencor, RSIP, Gyrus-ACMI and Intel.

- Earned M.Sc. in Electrical Engineering from the Technion – Israel Institute of Technology.

Legal Disclaimer

Forward-Looking Statements

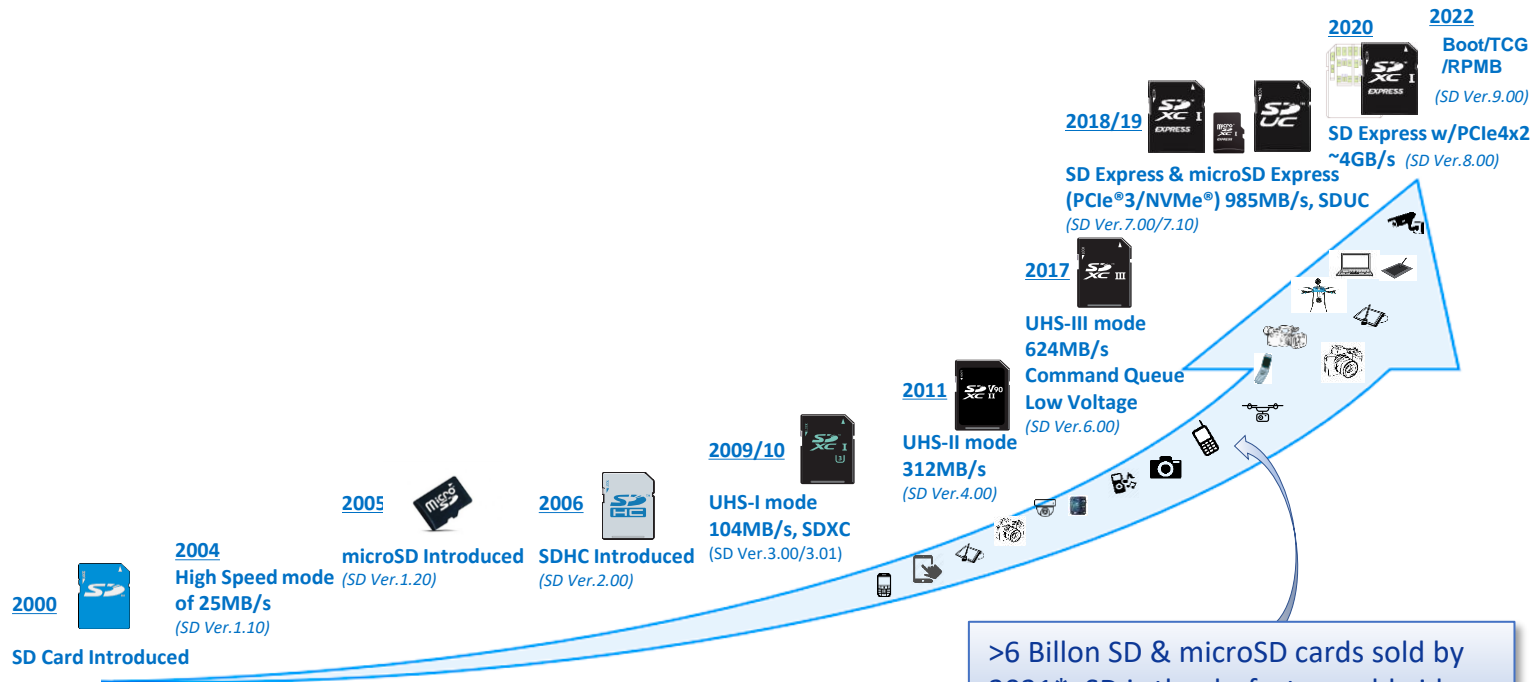
During our meeting today we will be making forward-looking statements.

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.

SD Association

- 20 years + created innovative specifications meeting industry and consumer needs
- Strategically maintains the relevance and value of industry leading SD memory cards for consumer and industrial uses
 - ~800 members related to removable cards eco-system (cards, connectors, memory devices and host vendors)
 - A unique structure with Technical, Marketing and Compliance capabilities all working together to meet industry needs

SD Card Specifications Evolution



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

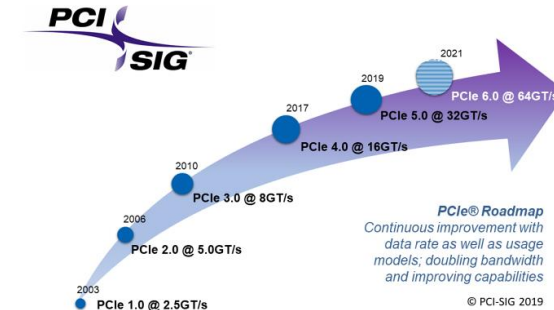
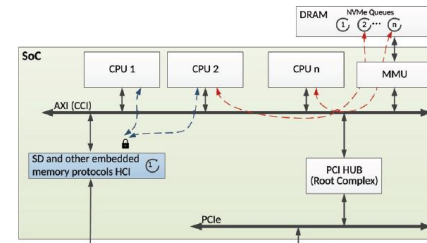
* Source: Estimation using news published by SanDisk in 2015 ("2 Billion microSD cards sold by 2015") + TrendForce's report from 2019 ("total of ~3 billion cards sold within 2016-2019") and report from Futuresource of total of ~1B sold between 2020-2021

Technology and Market 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*

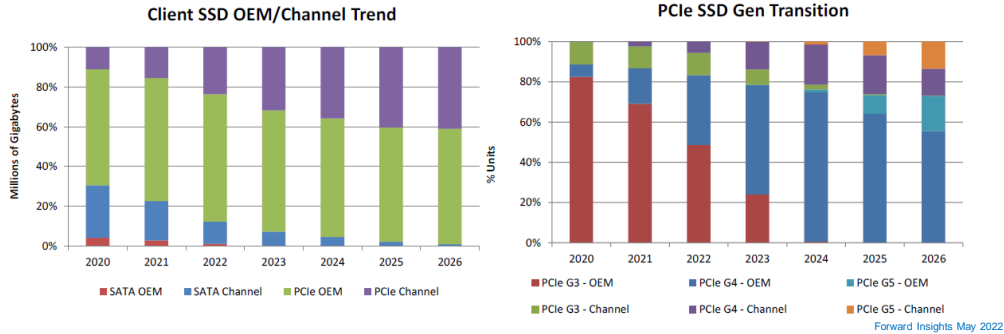
Technology and Market Evolution

- Multi-core processors – high processing power with multitasking
- Very high-definition video (imaging) and graphics (gaming)
- Higher speed interfaces – Internal and external (USB-C, PCIe[®] 4 & 5)

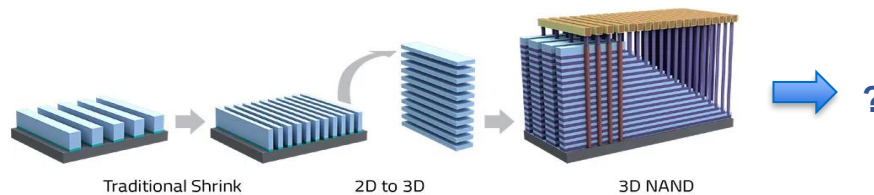


Technology and Market Evolution

- NVMe®/PCIe® is gaining popularity as the de-facto highly capable memory interface standard for the next generation computing, mobile computing, gaming and more

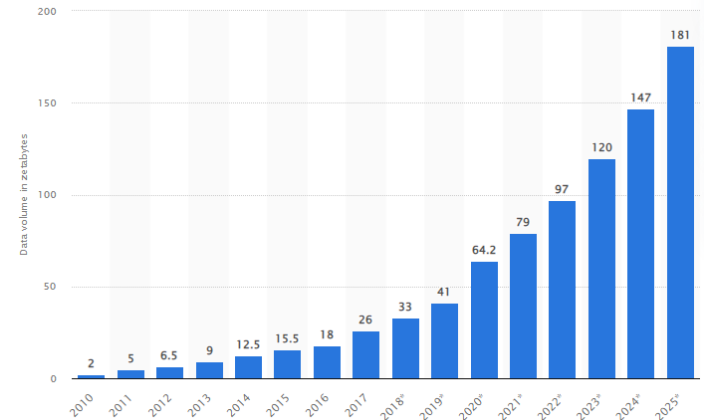


- The flash memory technology continues to evolve allowing higher performance access and higher capacities in small devices



Technology and Market Evolution

- Despite growth of cloud services, there is a continuously growing demand for embedded and removable memory **at the edge**
- 5G Networks – more generated data...
increase data collection at the edge
- High-performance removable cards enable new usage models: system memory expansion, flexible (replaceable) system memory, an application running on extended memory, multiple simultaneous access, and simply faster access



IDC/Statista 2021

Technology and Market Evolution

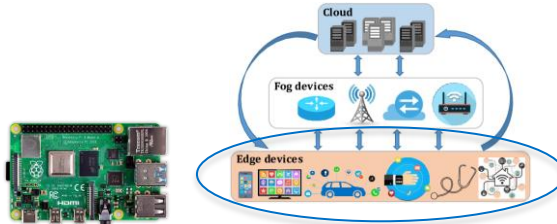
- *Evolving technology trends push memory interface requirements to higher sequential and random performance levels*
- *Evolving removable memory devices with higher performance enables new usage models and market opportunities*

New Memory Capabilities Open New Opportunities

- Special Imaging - VRs, 360°, drones, extreme cameras (high performance)



- IoT (low power, security, some with high performance, boot)



New Memory Capabilities Open New Opportunities

- Gaming (high performance, high capacity)

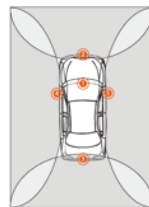


- Mobile computing (very high performance, high capacity)



New Memory Capabilities Open New Opportunities

- Multi-channel Dash cameras and Surveillance cameras
(multi-stream recording, high capacity,
high endurance)



- Extra high-resolution imaging – 8K/12K raw
(high performance, high capacity)



- New Fast Boot, TCG and RPMB features open new opportunities for cards bound to hosts as either replacing embedded or adding secure applications – like semi-embedded memory for IoT, low-cost compute, gaming

SD Express: Running Towards New Horizons

PCIe® and NVMe® Memory Card Interfaces

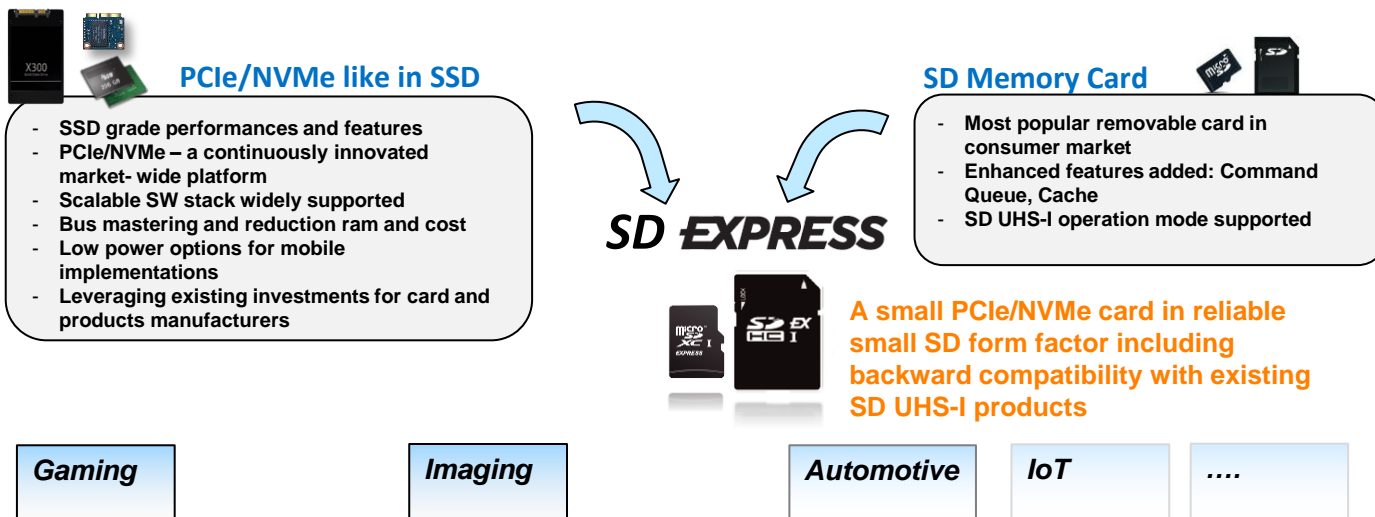
Delivers performance and advanced protocol required for the next generation of memory-intensive high-performance applications



EXPRESS

SD Express Cards

SD Express cards are SD cards that support both: PCIe®/NVMe® interface and the standard legacy SD (UHS-I) interface, allowing backward compatibility



SD Express Card Main Characteristics

NVMe[®] + PCIe[®] interface, in addition to:

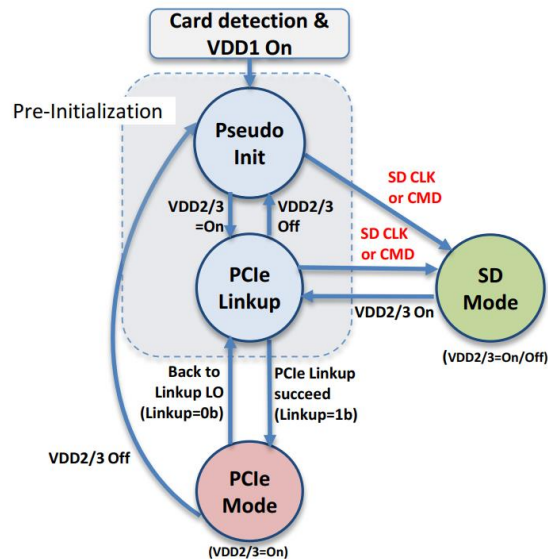
- SD interface (UHS-I up to 105MB/s)
- May be initiated directly either from the PCIe/NVMe or SD
- ESD protection up to 4KV on all pads
 - Same as legacy SD card requirements
- Hot Plug In/Removal support is mandatory
- Device Tx coupling capacitors to be placed on the host side

SD Express Modes and Initialization

The card may be initiated either through the SD interface **or** through PCIe[®]/NVMe[®] interface

If SD is initiated first – the host may check if the card support PCIe and switch to PCIe if supported

Card internal states:



PCIe[®] Identification Class

PCIe/NVMe[®] interface is compatible with the existing PCIe/NVMe standard

SD Express card in PCIe mode of operation identifies itself as:

- Standard Non-Volatile Memory subsystem – NVM Express[®] Interface
- Base Class=01h, Sub Class=08h and Programming Interface = 02h

From PCIe-SIG Spec




PCI CODE AND ID ASSIGNMENT SPECIFICATION, REV. 1.9

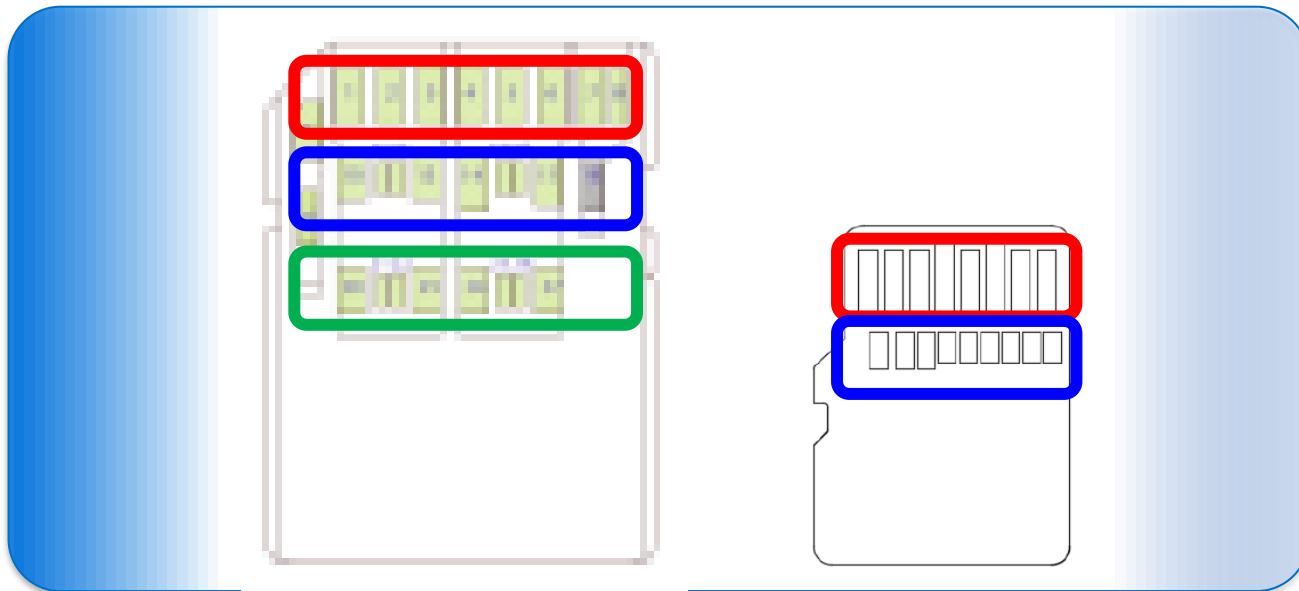
Base Class	Sub-Class	Programming Interface	Meaning
01h	05h	20h	ATA controller with ADMA interface - single stepping (see Note 2)
		30h	ATA controller with ADMA interface - continuous operation (see Note 2)
	06h	00h	Serial ATA controller - vendor-specific interface
		01h	Serial ATA controller - AHCI interface (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)	

SD Express Card Spec Evolution

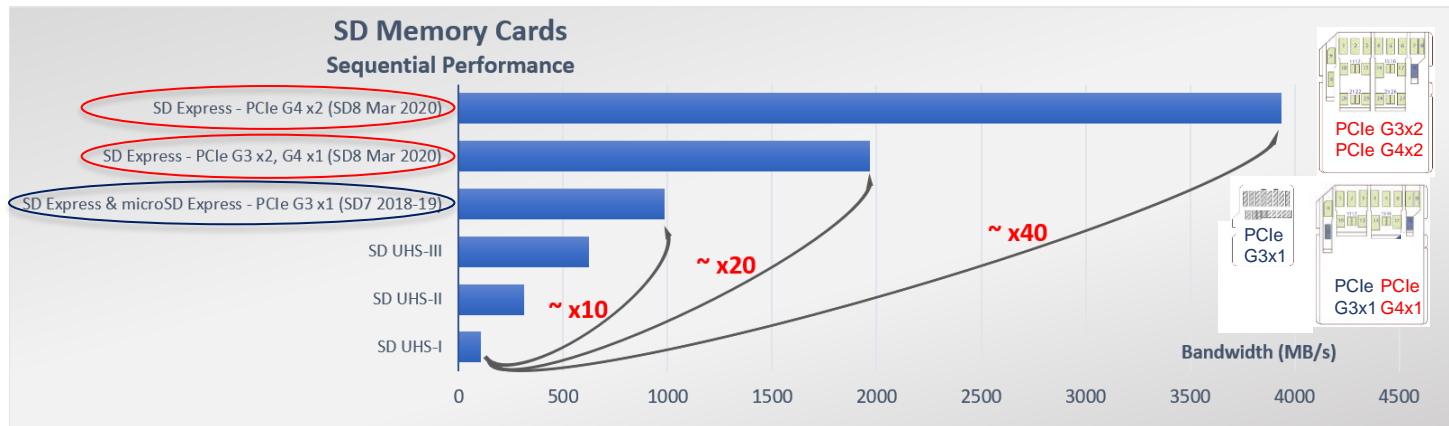
- SD7.0 and SD7.1
 - Introduced the full-size SD Express and microSD Express, respectively, supporting the PCIe® 3.1 interface up to 985MB/s
- SD8.0
 - Introduced the full-size SD Express supporting PCIe 4.0 x2 interface up to 4GB/s
 - microSD with PCIe 4.0 will probably follow (*not yet announced by SDA*)
- SD9.0
 - Introduced TCG, RPMB and Boot features to SD

SD Express Cards Pinout

-  =1st row: conventional SD in SD mode **or** PCIe[®] side band (PERST#, CLKREQ#, REFCLK+/-) in PCIe mode
-  =2nd row: PCIe 1st lane differential IO's in PCIe mode – SD 7.X
-  =3rd row: PCIe 2nd lane differential IO's in PCIe mode – SD8.0



SD Memory Card Bit Rates



Allowed Power States (Max Power)

- Max Current for each power rail depends on the bus mode
- Supported power states are defined according to the card type

Power State (Max Power)		
Card Type		
G3L1	G3L2 / G4L1	G4L2
		4.0W
		3.2W
	2.8W	2.8W
	2.5W	2.5W
1.8W	1.8W	1.8W
1.44W	1.44W	1.44W
0.72W	0.72W	0.72W

SD7.x → 0.72 through 1.8W (same power levels as legacy SD spec)
SD8.0 → 2.5W through 4.0W

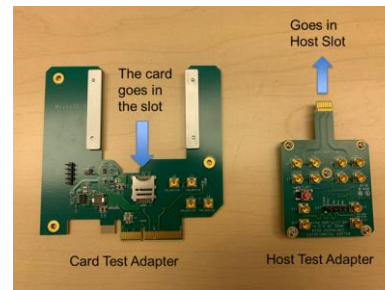
* PCIe® interface supports low power sub-states

PCIe® and NVMe® Interfaces – Test Advantages

Many Bus Analyzers, Protocol Analyzers, Test Suites are in the market...

- SD Express Test Fixtures – for SD7.x
(SD8 will be released soon)
- Enables Host and Card vendors to test their SD Express's PCIe interface using standard test equipment
- The set is available for borrow by our members at our approved labs

(GRL and Allion)



Flash Memory Summit

nvm
EXPRESS®

SD9 New Features - background

- SD Express opens new opportunities and use cases for SD and microSD memory cards. Some of the potential usages :
 - Chromebooks (as its system memory or memory expansion), drones, surveillance cameras, dash cameras, gaming consoles, virtual reality (VR) headsets/glasses, small IoT modules and more
- The Right-to-Repair legislation in EU and other areas – demands new serviceability requirements and storage is one of the targeted components
- SD memory cards may replace embedded devices in small systems (i.e. IoT, Drones) and SD Express enhances this opportunity for devices that needs higher speed memory
- Use of SD as semi-embedded memory may allow:
 - Reduced memory components
 - Easy memory upgrade and improved serviceability options



Right To Repair



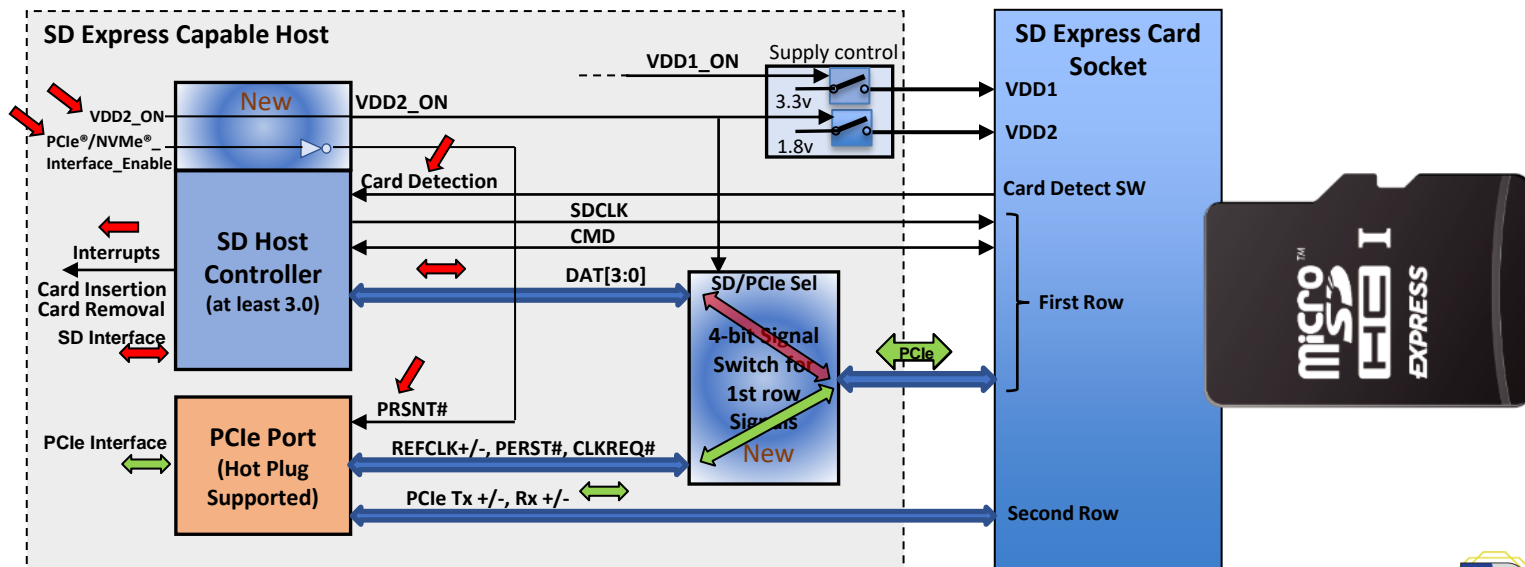
Flash Memory Summit

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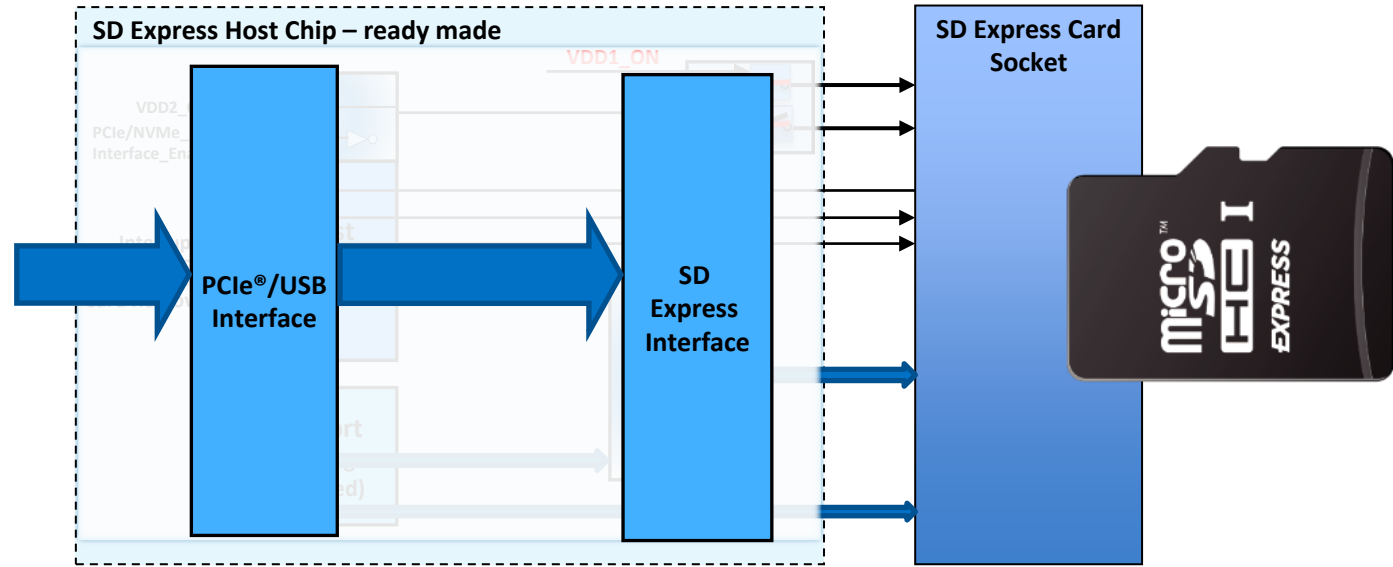
SD9.0 – What does it include?

- Boot
 - Fast Boot and Secure Boot features give cards the ability to serve as a device's boot code memory by using a simple and easy fast boot code uploading process, along with secured methods of providing boot code updates
- TCG Storage
 - A secured storage method defined by the **Trusted Computing Group** adding a self-encrypted drive capability
- Replay Protected Memory Block (RPMB)
 - Offers a secured hidden memory accessible only through a secured authentication process and provides a secured write-protect mechanism, secured boot code update and replay protection security mechanism
- SD9.0 features provide enhanced features that may open new opportunities for SD cards usually tightly bound to a specific host product as:
 - Semi-embedded devices replacing the soldered embedded memory (IoT, Chromebooks etc)
 - As a secured memory for OEM applications (ie Gaming, Automotive, VR etc)

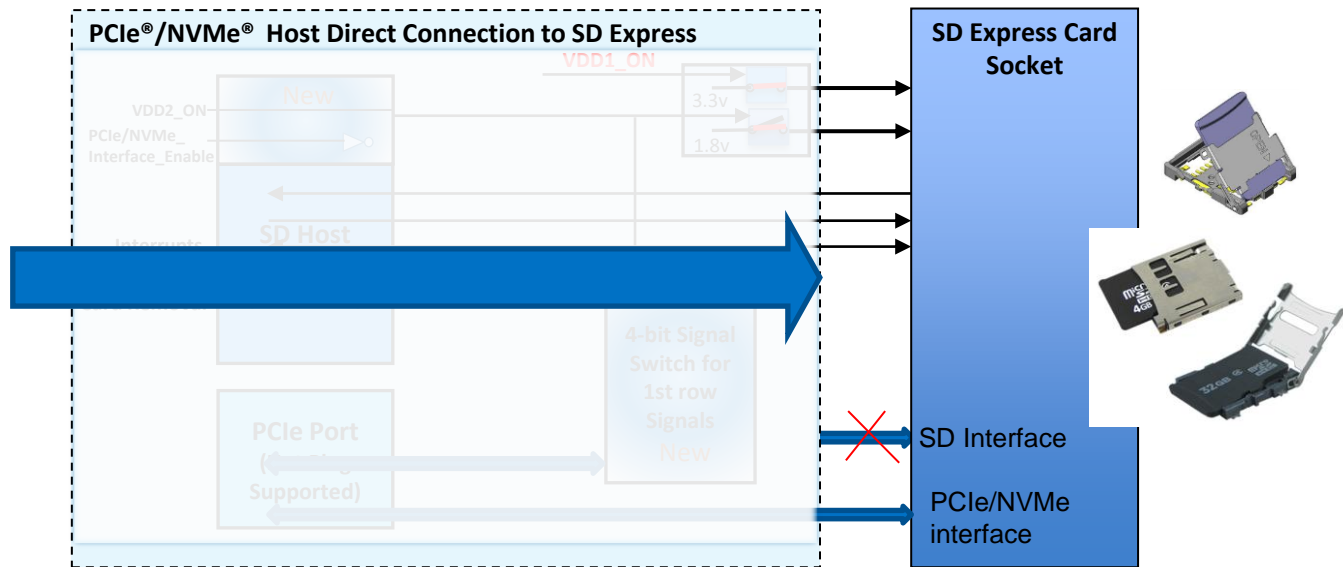
How To Implement SD Express Host



SD Express Host - other possible methods



SD Express Host - other possible methods



A glimpse into the future

- SD Express Cards → New speed classes
- microSD Express Card's natural evolution → PCIe[®] 4.0 support
- SD Association plans to open the org for specifications of new FF's with or without SD interface



Thank You

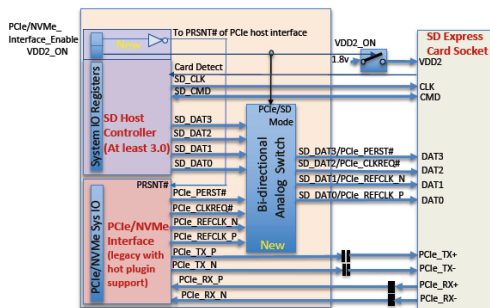


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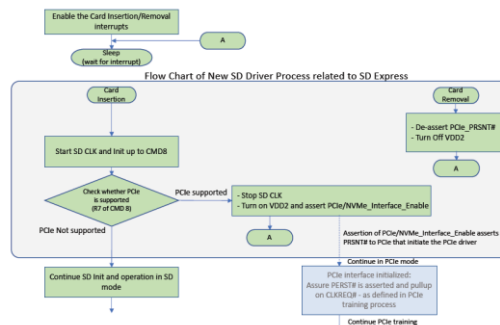
Questions?

SD Express and SD 9.0 Materials Freely Available

SD Express Host Implementation Guideline



Update to existing SD Driver –
As explained in
Implementation Guideline



[SDA Brochure](#) – updated for SD9.0

Whitepapers:

- [SD Express Memory Cards with PCIe® and NVMe™ Interfaces](#)
- [SD Express and microSD Express Cards: The Best Choice for Your Future Product Designs](#)
- [Boot, TCG and RPMB – The New Security Features Introduced in SD 9.0](#)

... and more at <https://www.sdcard.org/>

