Increasing Mobile Storage Bandwidth

“To UHS-II or Not to UHS-II ?”

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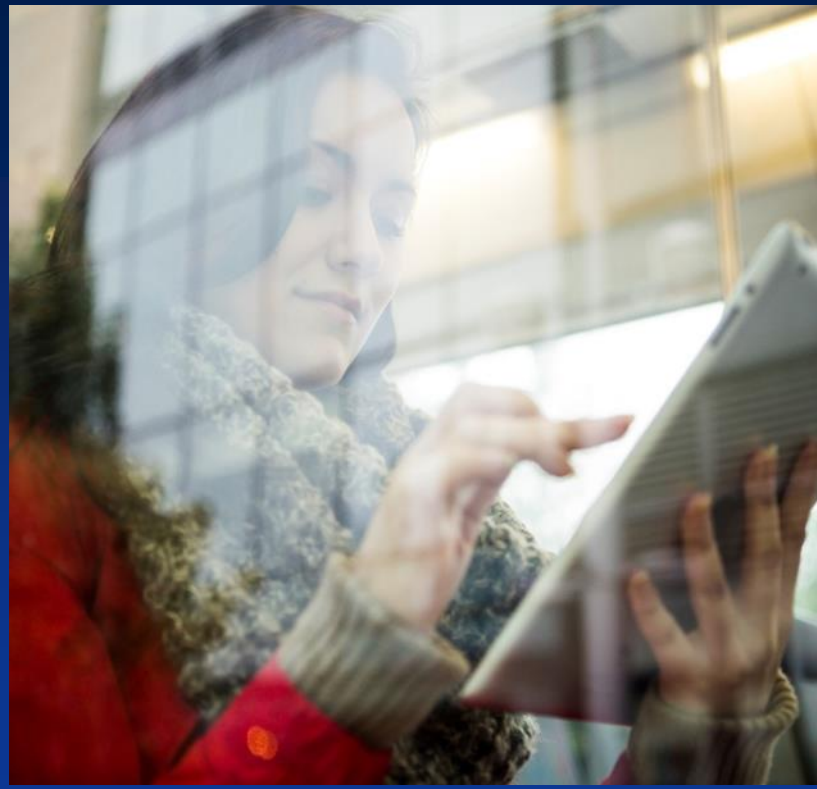
Agenda

- SD™ Standard evolution
- Why we need High Speed for SD?
- UHS-II overview and adoption
- Energy consumption of UHS-II vs UHS-I
- How Performance can be assured?
  The Speed Class Advantage



Forward-looking statement

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 Card Association's related plans. Actual results may differ materially from those expressed in these forward-looking statements due to a various factors detailed under the caption "Risk Factors" and elsewhere in the documents we file from time to time with the SEC, including our annual and quarterly reports. We undertake no obligation to update these forward-looking statements, which speak only as of the date hereof.

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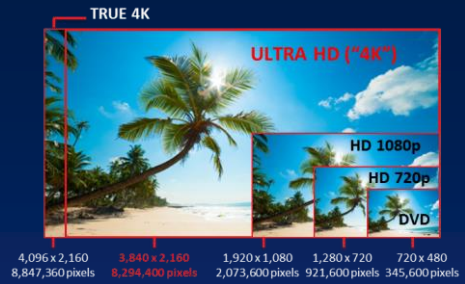
Market Trends Driving SD Card Innovations

Flash Memory SUMMIT

4K-Ultra HD Video / New High-Density Flash Tech's

- Innovations: Larger flash densities, 30MB/s speed class (U3) specification, new Video Speed Class definitions underway



Computational Photography, Large File Sizes, Faster Embedded Storage, Faster I/Os

- Innovations: UHS-II interface mode, multi-file recording

Security Applications and Wireless Connectivity (niche markets)

- Innovations: smartSD, Wireless iSDIO

Other market evolutions:

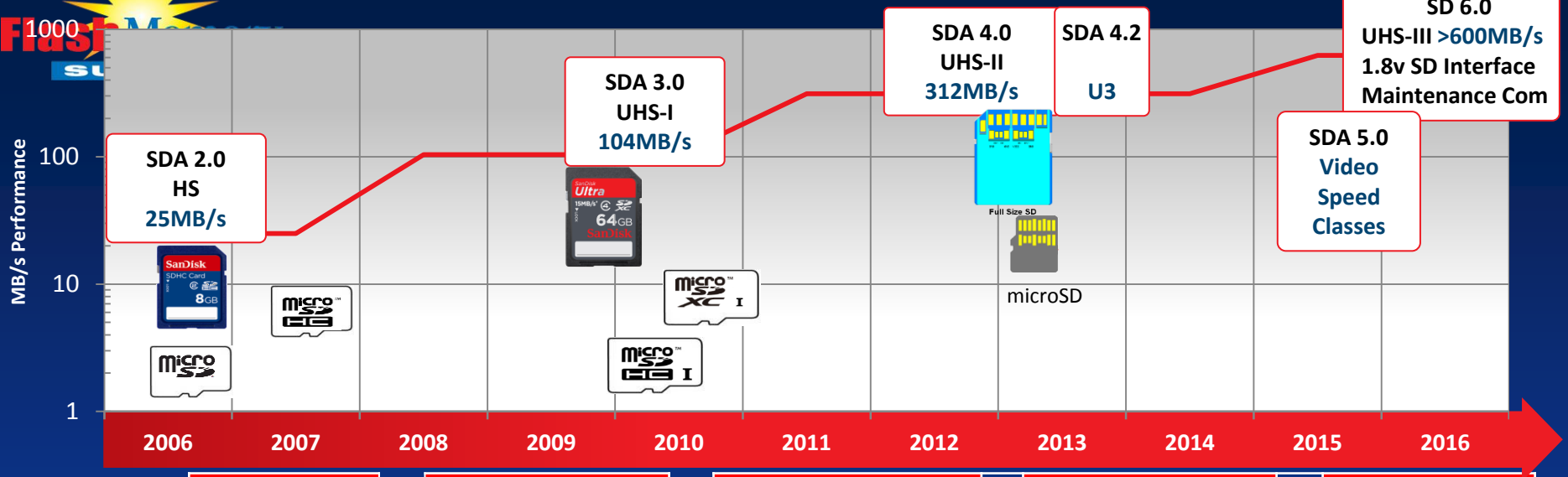
Apps may be run directly on SD cards (Android M, Win-Mobile 8.1/10), Home PVR / DVR, Automotive, IoT

- Innovations* : Health report, Increased endurance and temperature range, "Computing Grades" features (IOPS, Discard, etc..)

** Some products for these categories are currently offered as proprietary products by SD card manufacturers. Standardization is under consideration*

SD Interface Evolution

* Standards under development



	SD2.0	SD3.0	SD 4.0 / 4.2	SD 5.0 (Q4/15)*	SD 6.0 (2016)*
Capacity	Up to 32GB	Added 64GB to 2TB (SDXC)	No change	No change	No change
File System	Fat12/16 & FAT32	Adds exFAT	No change	No change	No change
Bus Speed	Up to 25MB/s	Optional support for UHS-I Up to 104MB/s	Optional Support for UHS-II Up to 156MB/s FD, 312MB/s HD	No Change	UHS-III >600MB/s
Speed Class	Speed Class (2, 4, 6)	Additional Speed Class SC10 & U1	New Speed Class U3 added in v4.2 (Aug13)	New Video Speed Class Range V6-90 + MultiFile recording	No change

Market Evolution Driving Higher Speed Interface to SD in mobile devices

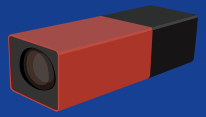
Flash Memory SUMMIT

High Capacity / High Speed Drivers

4K DSLR/Video

4K Video Recording (4K videos)

Light Field Lenses Computational Photography



4K Smart Phone

4K Tablet & Ultrabooks

4K Recorder

>300MB/Sec

microSD with UHS-II

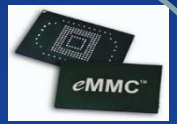
High speed Download/Upload

~1000MB/s

~700MB/s

~100MB/s (Peak)

500MB/s



~400MB/s

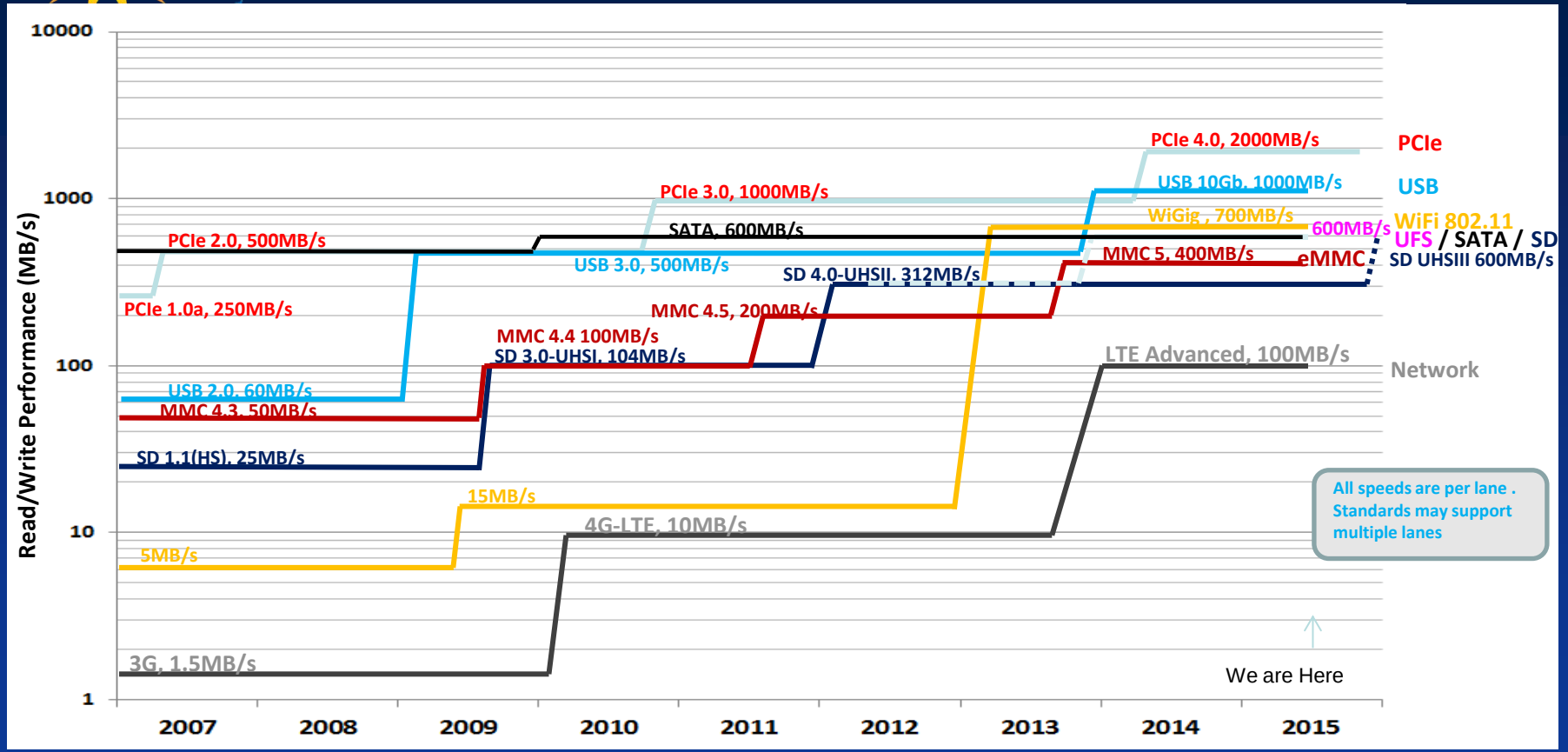
~2000MB/s

Internal Memory Data I/Os

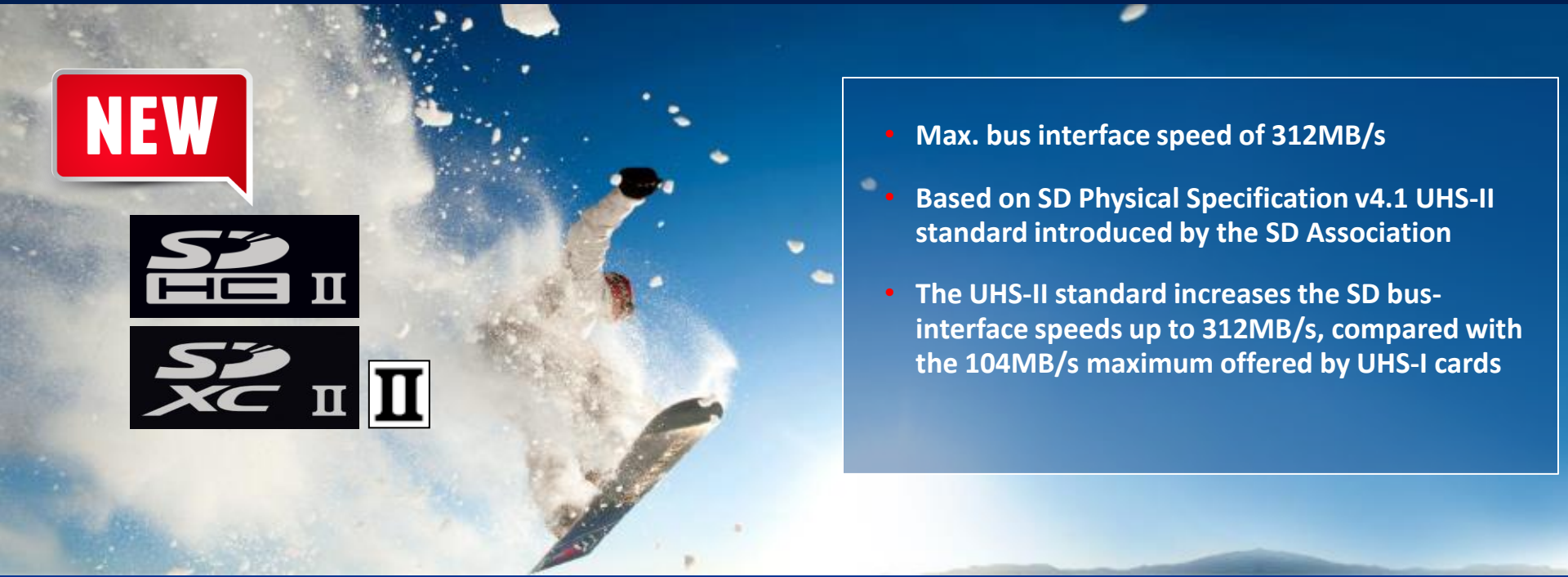
Caching streamed content

- Eliminates bandwidth latency
- When no internet access available

Mobile/Tablets continue to increase its I/O data bandwidth



What is UHS-II?

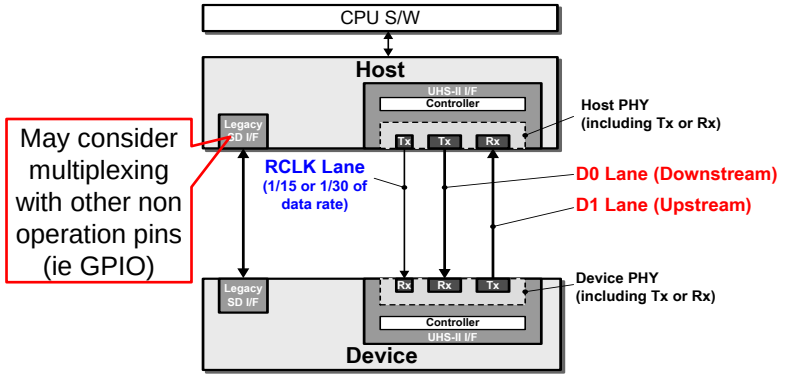


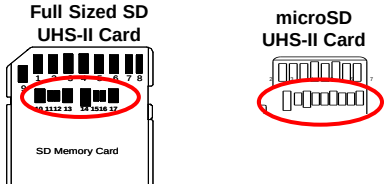
- Max. bus interface speed of 312MB/s
- Based on SD Physical Specification v4.1 UHS-II standard introduced by the SD Association
- The UHS-II standard increases the SD bus-interface speeds up to 312MB/s, compared with the 104MB/s maximum offered by UHS-I cards

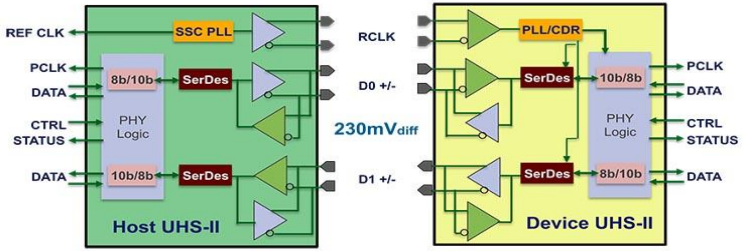
Photo: © Corey Rich, SanDisk Extreme Team.

SD4.1 UHS-II Overview

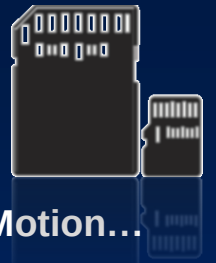
- **2 High-Speed Serial LVDS Data Lanes**
  - Full duplex up to 156MB/sec (one lane)
  - Half duplex up to 312MB/sec (dual lane)
- **Legacy SD Compatibility**
  - Support both UHS-I and UHS-II interface
  - UHS-II host compatible with existing SD cards
  - Legacy SD commands encapsulation
- **I/O Low Power Consumption**
  - UHS-II using 0.2-0.4V vs. 1.8V in UHS-I
  - UHS-II supports low voltage IO from power up
- **Low EMI**
  - Due to Diff low voltage signaling
  - Spread Spectrum Clocking Support







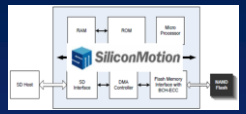
Adoption of UHS-II in 2015



- **Cards & Controller Manufacturers: Micron, Panasonic, SanDisk, Toshiba, Phison, Silicon Motion…**







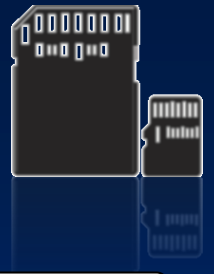
- **UHS-II Notebooks/Laptops: AVAILABLE NOW!** (Lenovo, Panasonic, Dell, Toshiba and more)

- **UHS-II Video Camera: AVAILABLE NOW!** (Few Panasonic models)


- **UHS-II Still Camera: AVAILABLE NOW!** (Fujifilm, Samsung, Olympus)

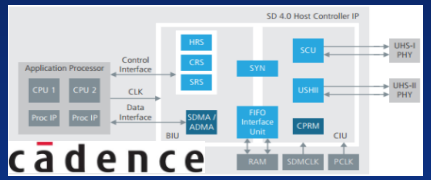
- **UHS-II Card Readers: AVAILABLE NOW!**

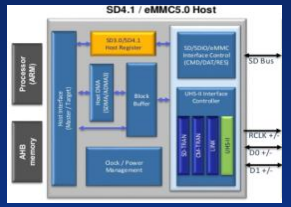
Adoption is Plentiful and Simple

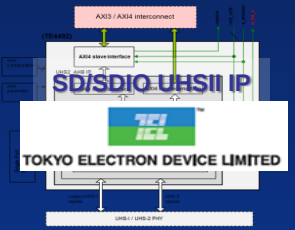


- **Bridging Technologies allowing fast and minimum risk adoption:**
  - SATA/USB3/PCIe to UHS-II bridges provided by Bayhub, Realtek and Genesys

  - UHS-II interface IP provided by Cadence, Socionext (Fujitsu), TED, Arasan and others

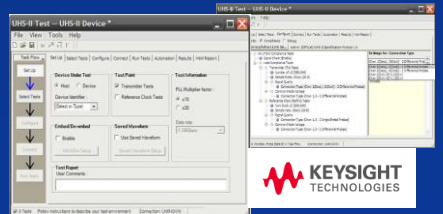


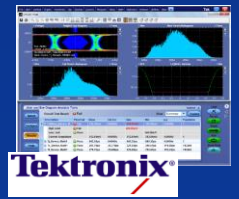




- **SDA released full Test Guidelines and supports several Test houses allowing convenient UHS-II self compliance testing**
- **Testers & Lab Services: AVAILABLE NOW!**
  - Tektronix, Keysight(Agilent), SolidGear, GRL+TED and Allion Lab have testers and/or test lab services

ALLION Engineering Services



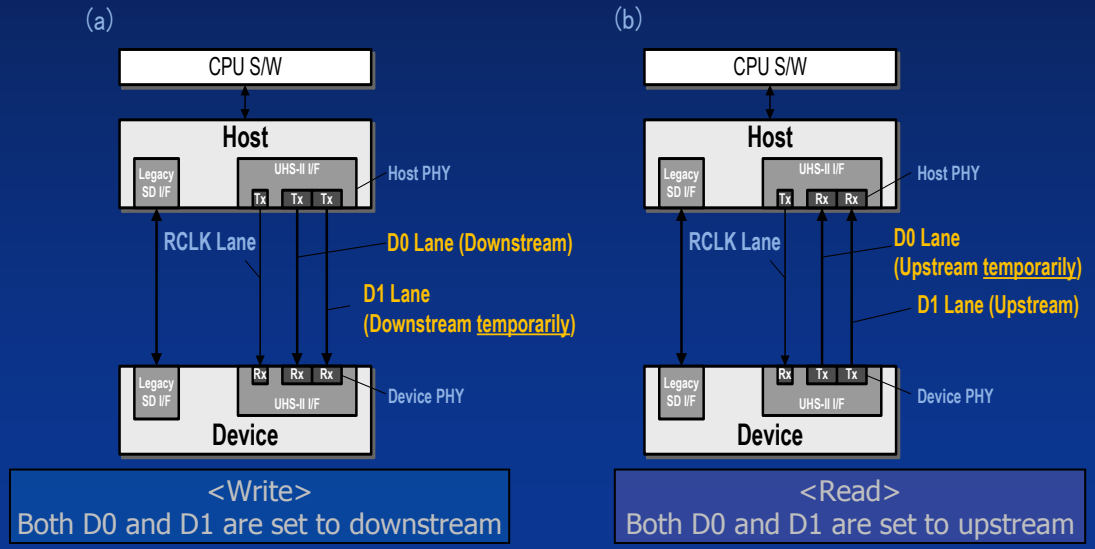


UHS-II is saving energy…

- **UHS-II include various power control/modes:**
  - EIDLE + Low Power Mode (LPM) operation [active mode – RCLK/PLL on]
  - Dormant [RCLK & PLL off]
  - Hibernate Mode [Dormant + Vdd1 off]
- **If Bursts are used – EIDLE/LPM mode may be used between bursts**
- **‘Race for Idle’ method may save energy**
  - Either by sending single shot of high speed and wait in LPM
  - Or by using series of Bursts and LPM in between

UHS-II is saving energy… (cont)

- **UHS-II supports Full & Half Duplex Modes of operation**
  - Data rate can be doubled by setting D0 and D1 to the same direction during data transfer



At high speed burst, HD consumes around 15% less energy compared to FD mode

* Per SanDisk internal measurements

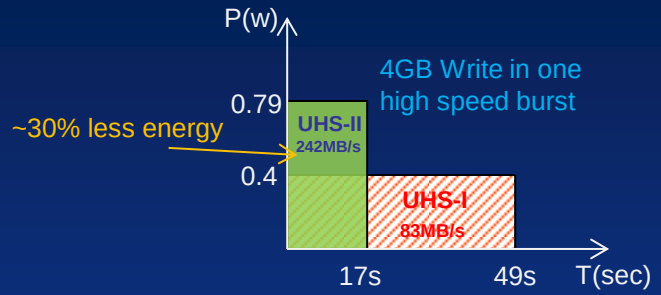
  - One I/O set of single UHS-II channel is utilized as two lanes
    Double data rate for same clock rate is achieved

UHS-II is saving energy… (cont)

- **Power/Energy comparison measurement of UHS-II vs UHS-I shows:**
  - Case of single high speed burst observations:

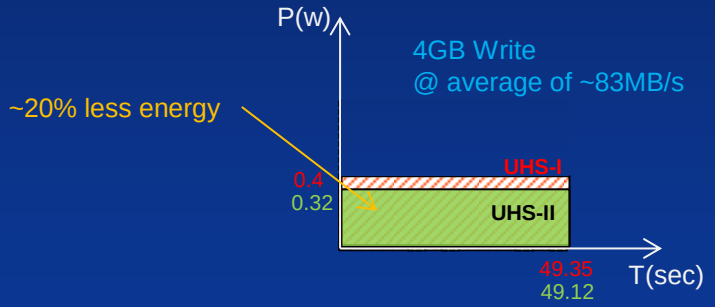
    In WR operation: ~30% less energy (watt/sec)

    In RD operation: ~40% less energy (watt/sec)



  - Case of multi bursts and LPM between observations:

    In WR & RD : ~20% less energy (watt/sec)



- **Power consumption in 'sleep' modes:**
  - In Dormant, UHS-II ≈ UHS-I cards
  - In Dormant/Hibernate UHS-II ➔ ~60-75% less power (0.2mW vs 0.6-0.8mW)

* Highly dependent on the memory type and power design implementation

All SanDisk measurements presented are implementation dependent and done on specific products and under specific test conditions. Therefore it is not guaranteed to get same results under any other test conditions.
The bursts+LPM shown in the chart are just for illustration. Exact number of bursts used in the actual test may vary.

UHS-II is saving you energy – Conclusion…

- **Power/Energy comparison measurement of UHS-II vs UHS-I shows:**
  - UHS-II interface may consume less energy in compare to UHS-I
  - If battery life is important → UHS-II is preferable even if max seq performance requirements are only 90MB/s

UHS-II interface

UHS-I interface

Speed Class Advantages

- **Provides Classification of card's performance**
  - Enables a method of communicating to consumers the performance needs of specific Products
- **Assures minimum performance for video recordings and similar applications**
  - Various recording conditions (ie Multi-File recording)
  - Allows efficient utilization of advanced NAND Flash Technologies
  - Opens new opportunities for hosts and cards
- **Enables High Speed Applications**
  - Host may use card with Speed Class for direct high speed access applications – like 2K HD, 4K UHD Video and 8K in the future
- **Improves the card's usage as memory extension**
  - Not just a slow storage area for pictures, music and documents

Example of Host Product Manual's requirement:
"For optimal performance user shall use microSD with at least 3."

The Speed Class – Today and Future

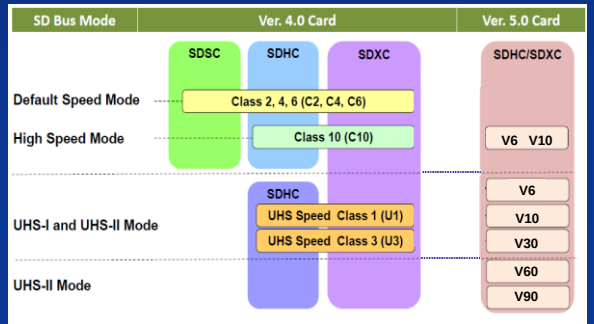
- **Performance is achieved by cooperation of both sides**
  - Card shall assure Speed Class Compliance
  - Hosts (OS/Drivers) must adopt the Speed Class access requirements

Todays' situation:

- SC4/6/10 and U1/U3 are currently defined ➔ Video recording on DVC and DSC use them
- Phones and Tablets did not adopt, yet, the Speed Class usage ➔ usage of card stays limited
- In Mobile - end user decision is usually made per ➔"higher Speed Class is better…"

SDA is targeting the following:

- One set/range of Speed Classes from low to high (V6, V10, V30, V60, V90..)
- Promote the market to migrate/adopt the usage of Video Speed Classes
- Spec release expected in Q4/15



Speed Class	UHS SC	Video SC	Minimum Performance	Example 2015 Applications
Class 2			2 MB/s	SD video recording
Class 4			4 MB/s	HD Video recording including 720p to 1080p/1080i
Class 6		V6	6 MB/s	
Class 10	U1	V10	10 MB/s	Full HD (1080p) video recording, consecutive recording of HD stills and large HD video files (4K lower frame rates & pixel depth)
	U3	V30	30 MB/s	4K Standard
		V60	60MB/s	4K High Quality, 8K Standard
		V90	90MB/s	8K High Quality

Summary

- SD Standard is continuously evolving per market needs
- Data rates increase of wireless & connected demands high speed access to SD
- SD-UHS-II standard enables higher speed data access with less energy consumption (even @ UHS-I data transfer speeds), keeping backward compatibility to legacy SD
- Infrastructure of Test Guidelines, Test Tools and Test Labs established, allowing easier self compliance, minimizing interoperability issues
- Adoption of UHS-II in Imaging market, laptops and readers is ongoing
- Various UHS-II bridging technologies allows faster and less-risky adoptions
- Speed Class adoption by Product Manufacturers may open new opportunities relying on assured minimum performance

You are all welcome to visit SanDisk at booth #207 and SDA at booth #119
to find out more about our solutions and ask questions

Thank You

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