SD + PCIe/NVMe card
New Innovations in SD Cards Lead the Way to Mobile Everything

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Director, Standards in CTO Office at Western Digital

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Mobile and Mobile Computing Market Trends
More content = More memory

More 4K UHD video driving larger video file sizes

4k/8k video ➔

Smartphone
4 Minutes of Video

Action Cam
4 Minutes of Video

600MB  1.0GB*

661MB  1.6GB*

Social media ➔

More memory and More sequential Performance...

More Smartphones = More Content...

1.2T Mobile Photos per year

350M Photos uploaded per day on Facebook (Aug 2017)

95M Images uploaded per day on Instagram (Jan 2017)

400 hours of video uploaded to YouTube per minute (Mar 2017)
More content generators = More memory

Drones, Action Cam, 360°, Virtual Reality

GoPro® Odyssey = 16 cameras, each taking a microSD card
360Heros 360Orb = 24 cameras, each taking a microSD card

More memory and More Performance...

More Streaming content allowed to be saved on SD

The top 5 music streaming services all offer downloads for offline listening
- Spotify and Tidal High Fidelity Audio
- 3000 High Fidelity songs = 30GB*
  - Standard song = 3-4MB
  - Hi-Fi song = 15-30MB+

Source: Approximations from Tidal
Mobile Phones = Main content generator

Mobile phones market continue to grow

Number of phones with microSD slot is growing

Phone manufacturers brings back microSD slots – appreciate user’s benefits

97% of Mobile phones introduced in Q1/17 include microSD slot

Source: Strategy Analytics, October 2016
Mobile Technology is developing rapidly

- Growing performance levels of IOs wireless (WiFi/WiGig...) and wired (USB3...)

- Rapid developments in APs technology (Multi cores, Speed, RAM increase etc.)

- Embedded storage is transitioning to more advanced protocols opening new opportunities (UFS and PCIe/NVMe)

Evolving technology trends push the memory interfaces requirement for additional higher random & sequential performance
Client Computing, Imaging, Automotive – all transition to higher speed interface

**Client SSD**
- PCIe/NVMe is rapidly gaining popularity - expected to become most dominant in 2018
- PCIe Gen 4 is expected to gain traction by 2019/20

**Automotive ... IoT**
- Growing demand for high speed multi-tasking environment is expected in various emerging markets
  - Autonomous Vehicles and Connected Cars with multi sensors data collections /processing
  - Multi channels video capturing
- Imaging market is already heading to PCIe

Evolving technology trends push the memory interfaces requirement to higher sequential & random performance levels

Source: Forward Insights, May 2017
microSD = Real Memory Expansion

It is not just content saving anymore…

Apps consume significant amount of memory…

Win Mobile and Android allows today to store & run applications from cards

Sequential Perf is not enough for Apps running…
SD Memory Card Standard Brings New Opportunities In Mobile
New SD Standard Features

- SDA defined until today sequential writes performance standards serving mainly imaging and video capturing

- New market demands → new SD spec features introduced:
  - Application Performance Classes – Assured certain Random & Sequential performance under specified conditions. Allows common language for the eco-system (further info)
  - New SSD like features added to SD – Command Queuing, Cache and Maintenance
  - Adding PCIe/NVMe interface to SD card is under definition – may open new opportunities (1)

(1) Currently under definition in SDA’s Spec WG
(2) The microSD-PCIe card illustration is shown just for this presentation and it does not represent any official SDA standard, yet.
SD Standard Interface Evolution

SD 2.0
- HS
- 25MB/s

SD 3.0/3.01
- UHS-I
- 104MB/s

SD 4.0
- UHS-II
- 312MB/s

SD 5.0
- Video
- Speed
- Classes

SD 5.1
- App Perf
- Class A1
- Discard

SD 6.0
- A2,
- CMD Queue
- Cache Maint
- 1.8v card
- UHS-III
- (624MB/s)

SD 7.0
- Released
- Feb 2017
- SD + PCIe/
- NVMe

SD 6.1
- [TBA]


SD x.x = SDA released standard

SD x.x = SDA Standards under development

(1) SDA is not obligated to any forward looking statements – refer to the detailed disclaimer
Next Generation SD card – currently discussed in SDA’s Specification WG with following basic concepts:
- Adding PCIe/NVMe interface
- Existing SD form factor
- Full backward compatibility with billions of host devices

The SD-PCIe TG is in advance stage of the proposals discussion
If you would like to contribute to the Next Gen standard, please, join the SD-PCIe TG activity in SDA

(1) The microSD-PCIe card illustration is shown just for this presentation and it does not represent any official SDA standard, yet
Why PCIe/NVMe?
Storage Interfaces in Smart Client Devices
Current view

PCIe exists for peripheral IOs in all mobile devices
PCIe Trend in Mobile (Phones & Mobile Computing)

- Today - all mobile SoC have between 1 to 3 PCIe ports
- PCIe is the chosen Chip-to-Chip high speed connection
  - Ex. Qualcomm 8994 has 2x PCIe ports for Modem, WiFi or WiGig
- Major market leaders adopting PCIe/NVMe
  - Google Chromebook (refer to Google’s presentation in FMS 2016)
  - MacBook and iPhone
  - In imaging – All high-end market is moving to PCIe memory interface (CF cards, XQD etc)...

SD-PCIe adoption may be relatively easy:
- Enabling PCIe/NVMe does not require new IP technology development
- NVMe SW stack is already available today in open source
- Test tools for protocol testing are available off-the-shelf
Many Bus Analyzers, Protocol Analyzers, Test Suites are in the market…
### Protocol Comparison Highlights

<table>
<thead>
<tr>
<th>Item</th>
<th>SD 6.0</th>
<th>eMMC 5.1</th>
<th>UFS 2.1</th>
<th>PCIe/NVMe</th>
<th>NVMe Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bus Mastering</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes (native)</td>
<td>• Key feature, host offload</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Performance (efficient host architecture)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Device to device</td>
</tr>
<tr>
<td><strong>Driver Stack</strong></td>
<td>Complicated</td>
<td>Complicated</td>
<td>Complicated</td>
<td>Light protocol (new, build for performance)</td>
<td>• Performance (reduce host latency)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Reduced power</td>
</tr>
<tr>
<td><strong>Multi Initiators and Multi Queue (no locking mechanism)</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>• Multi core and multi tasking</td>
</tr>
<tr>
<td></td>
<td>• One queue</td>
<td>• One host controller</td>
<td>• One host controller</td>
<td>• Each core may have its own queue</td>
<td>• System performance</td>
</tr>
<tr>
<td></td>
<td>• One host controller</td>
<td>• Serial access</td>
<td>• One host controller</td>
<td>• More than one core may manage the storage device</td>
<td>• Lower Latency and Power</td>
</tr>
<tr>
<td></td>
<td>• Serial access</td>
<td></td>
<td>• Serial access</td>
<td></td>
<td>• Better balance between cores</td>
</tr>
<tr>
<td><strong>Host Memory Buffer (HMB)</strong></td>
<td>No</td>
<td>No</td>
<td>Yes (by spec extension, not yet by design)</td>
<td>Yes (native)</td>
<td>• System flexibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Performance (example: L2P table)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Cost reduction</td>
</tr>
</tbody>
</table>
Physical Comparison Highlights

- Active Power consumption is about energy consumed.
- Mobile acceptable ranges can be achieved with:
  - L1 sub-states in Standby
  - Half Swing mode in Active.

<table>
<thead>
<tr>
<th>Item</th>
<th>PCIe Gen3</th>
<th>PCIe Gen2</th>
<th>M-PHY Gear3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Speed [Gbps]</td>
<td>8</td>
<td>5</td>
<td>5.83</td>
</tr>
<tr>
<td>PHY overhead</td>
<td>128/130 [GB/s]</td>
<td>8/10, 500[MB/s]</td>
<td>8/10, 583[MB/s]</td>
</tr>
<tr>
<td>Active Power [mW]</td>
<td>60 (L0)</td>
<td>46 (L0)</td>
<td>58 (HS)</td>
</tr>
<tr>
<td>Standby Power [mW]</td>
<td>0.11 (L1.2)</td>
<td>0.11 (L1.2)</td>
<td>0.2 (H8)</td>
</tr>
</tbody>
</table>

1) pci-sig.com: “L1 PM Substates with CLKREQ, Revision 1.0a”
2) Source: SanDisk/WD. Data based on PHY power estimates of PCIe vs. MPHY. For mobile low power application half swing (400mvp-p) and de-emphasize mode in its transmit circuit and passive CTLE in its receive equalization circuit are assumed.
Real SSD for Mobile and other markets
Using the old faithful SD card

SSD PCIe/NVMe
- Latest SSD grade performance
- PCIe/NVMe – a continuously innovated market-wide platform
- Scalable SW stack widely supported
- Bus mastering and reduction ram and cost
- Low power options for mobile implementations
- Leveraging existing investments for card and products manufacturers

SD Memory Card
- Most popular removable card in consumer market
- Enhanced features added: Command Queue, Cache
- SD UHS-I operation mode supported

SD PCIe/NVMe card with backward compatibility to existing billions host devices in the market
If you want to influence or track the next generation SD standardization, you are welcome to join the SDA and SD-PCIe TG

Thank You

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