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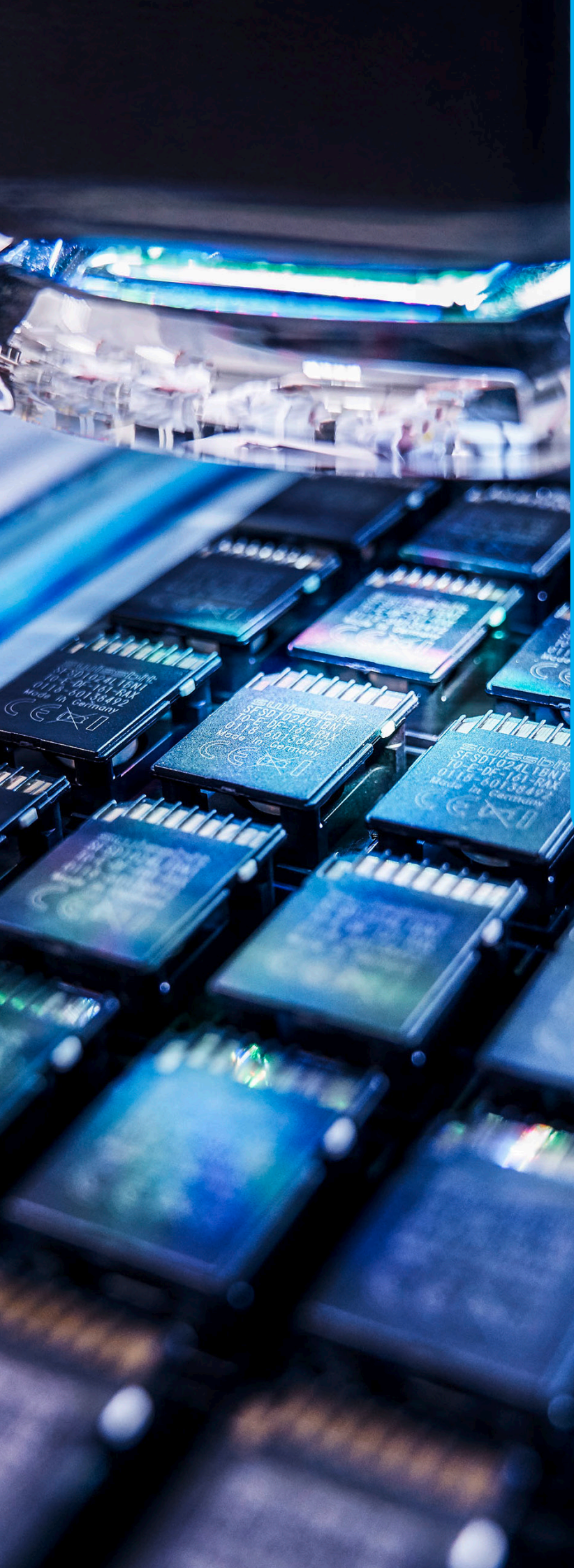
White Paper

SD Express: The Next Chapter of Industrial Memory Cards?



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1. Introduction

A memory card, sometimes also called flash card, is a compact, rewritable storage medium on which any data, such as logging data, images, audio and video, can be stored. The data is stored using flash memory technology. Memory cards are used for devices with space constraints, such as dashcams or medical equipment, and are available in several formats. Today, SD and microSD cards are the formats most widely used in the industrial market.

The world's reliance on SD memory card technology keeps growing. Yet, the read and write performance powering data-hungry applications has held back manufacturers. In June 2018, the SD Association, which establishes SD memory card standards, published a specification for SD Express memory cards for the first time. This allows the cards to transfer data at a rate of nearly four gigabytes per second, thanks, in part, to the use of PCIe 4.0 and NVMe interfaces commonly found in solid state drives. That faster transfer rate might be essential as emerging technologies, such as 5G, artificial intelligence (AI), and decentralized edge-centric models, become widely deployed. This changes the momentum from a "cloud-first" to a "data-first" approach. This puts the workload back on the Core and Edge and not only leads to massively increased need of storage, but also requires more bandwidth/performance from a memory device. Because it is a major challenge to predict the amount and type of data to be stored, OEM manufacturers tend not to use fixed storage to avoid downtime due to depleted storage devices.

With the introduction of two new SD memory card formats, SD Express and micro SD Express, it appears that a format war is on the horizon. The goal of this white paper is to give an objective comparison of the two competing SD representatives and to serve as a possible decision support.

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2. A brief history of SD memory cards

An SD memory card, short for Secure Digital memory card, is a type of removable memory card used to read and write large quantities of data in a wide variety of PLCs, including Industrial PCs, HMIs, medical devices, and more. The SD memory card debuted in 2001 and is the successor to the MultiMediaCard (MMC). It was one of a number of competing memory card formats in use by consumer electronics, such as the CompactFlash card, which, while still in use, is much less common than it was in decades past. Meanwhile, SD memory cards have become the default standard of memory cards for most consumer electronics and have brought ideal conditions, resulting in it becoming widely deployed in industrial electronics. A smaller version, the Micro SD memory card, is commonly used in dashcams, drones, and other devices where physical space is more of a premium.

The great benefit of SD memory cards lies in their small form factor; the fact that they represent removable storage; and the great host system availability through the huge consumer market. The SD Association (SDA) standard is clearly specified and has an extensive feature set.

3. PCIe eats the world

Conventional SD memory cards supporting UHS-I, which is the widely deployed speed class supported by host controllers, provide maximum sequential read speeds up to ~90 MB/s (theoretical max is 104MB/s), which is enough to transfer 1,000 high-resolution photos and 30 minutes of 4K video in less than 5.5 minutes. For the random write use case, the limit is about 1k IOPS, which is already starting to become a bottleneck for some PLC applications. Other bottlenecks include the increased demand for low latency and the power consumption in relation to performance.
To eliminate these bottlenecks and to realize the vision of a universal Industry 4.0 solution, all electronic devices will have to communicate on the basis of PCIe/NVMe. The process will probably be analogous to the consolidation of data communication protocols towards Ethernet, which started in the mid-2000s with mobile backhaul networks and is now tackling building automation networks.
If the user wants to operate several storage devices in an application, it will be much easier to realize with a uniform protocol system. Host controllers no longer need to be able to handle different protocols. A consolidation of bus systems also introduces the potential for more innovation. The vision is one single interface for peripheral computer components with a reduced number of bridge chips required for "translation" to legacy interfaces (e.g., memory, graphic cards, networking cards, etc.) communicating via PCIe/NVMe.
When the SD Association (SDA) originally launched SD Express in June 2018, it set a high standard for manufacturers to incorporate supercharged removable storage into their designs. Section 8.0, which outlines an NVMe-compliant, PCIe interface option for both SD and microSD, has been updated with the newest release. With the implementation of NVMe 1.3, the PCIe interface provides a scalable approach for enhanced performance in flash-based storage devices while adhering to industry standards currently in use on other devices, such as SSDs.

4. What is SD Express?

The basic idea of SD Express is to leverage the existing, state-of-the-art interface and integrate it into the most popular form factors for removable storage – SD memory cards. There is a well-established ecosystem consisting of hardware, OS, and drivers and communities (e.g., SDA, PCI-SIG) supporting PCIe/NVMe implementation on SD Express.
SD Express is the next generation SD memory card standardized by the SD Association and is an evolution of the existing standard.
The SD interface, along with the most advanced memory interface protocols of PCIe and NVMe, brings the favorite SD standard to new SSD levels of performance, enabling exceptional new user experiences for multi-processing environments in real time.
This takes advantage of the benefits of both the high performance and reliability of SSDs as well as the small size of SD and microSD memory cards.

Figure 1: SD Express unites the well-established SD interface with the most advanced memory interface protocols of PCIe and NVMe.

The SD Express standard utilizes a single PCIe lane for both full size SD Express and microSD Express – setting the data transfer performance of both options to 1GB/sec. A comparison table below highlights all of the significant differences between the Express and conventional SD and microSD cards:

*SDR (Single Data Rate) 104 and all traditional SD speed classes are optional

	SD	microSD	SD Express	microSD Express
Speed Class	UHS-I	UHS-I	PCIe Gen4	PCIe Gen3
Lanes	-	-	1 or 2 lanes	1 lane
Performance	Up to 104 MB/s	Up to 104 MB/s	Up to 4GB/s 40 x faster	Up to 1 GB/s 11 x faster
Backward Compatibility	NA	NA	SD UHS-I (SDR 104*)	microSD UHS-I (SDR 104*)
Size	32.0 x 24.0 x 2.1 mm	11.0 x 15.0 x 1.0 mm	32.0 x 24.0 x 2.1 mm	11.0 x 15.0 x 1.0 mm

Table 1: Key differentiators between conventional SD and microSD cards and their respective SD Express variants.

Benefits

As shown above, performance is the key differentiator and one major benefit of SD Express. The read and write performance serves data-hungry applications, such as video drones, 3D medical imagery, or industrial VR cameras, compared to standard SD memory cards. The speed difference is illustrated in Figure 2. It is obvious that recording a medical imaging data set the size of up to 10 GB results in a catastrophic impact on the writing performance in the standard SD memory card case. By employing an SD Express card, the same data set size can be written with negligible time.

As a result of adding PCIe to the SD (UHS-I) interface, SD Express cards can be used interchangeably with both new SD Express-capable hosts and billions of older SD hosts in use today. Despite being backwards compatible, SD cards, however, may not reach their full performance potential due to varying hosts.

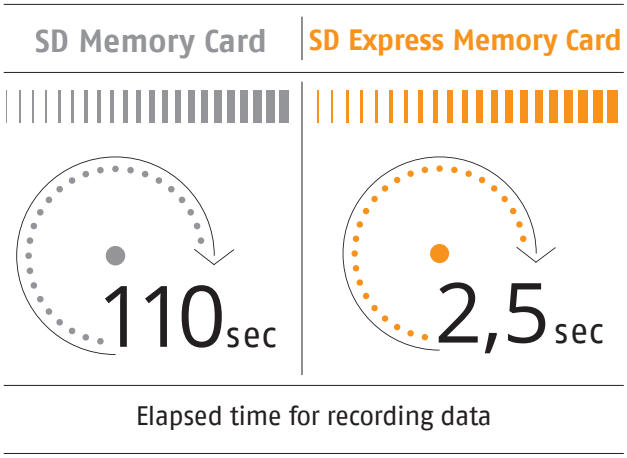


Figure 2: Schematic representation of the time required to record a data set of 10 GB for SD and SD Express cards.

SD Express Benefits

- Compatible with SD hosts
- Compatible with PCIe hosts
- More than 40 times faster than SD speed classes
- Low latency
- Extremely compact form factor

SD Express Cons

- Must have two controller functions in card and host
- Dual interface host ASIC required
- Plastic housing with typical PCIe heat emission
- PCIe not necessarily hot-pluggable (depends on host)

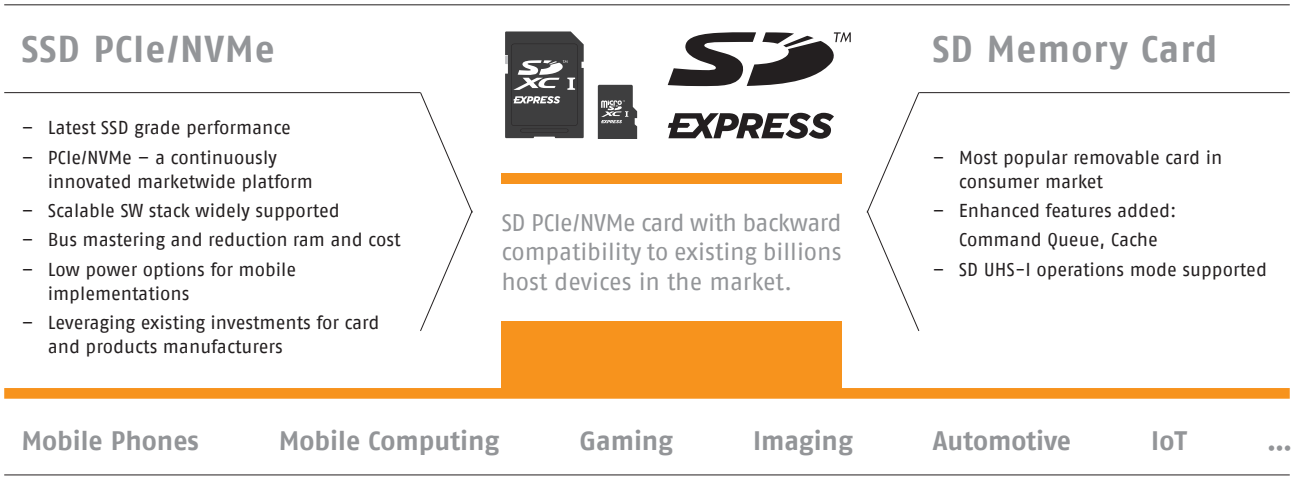


Figure 3: Combining the worlds of PCIe/NVMe and SD memory cards – SD Express.

5. Use cases

SD Express will be ideal for the demanding high-performance content applications of today and the future. Therefore, the new standard provides advantages for three major areas. The first major area is applications that demand massive capacity, such as high-end imaging with increased resolution and frames that requires increased bandwidth. This applies to applications such as super-slow motion video, RAW continuous burst-mode photography, and 8K/16K video capture and playback.

The second type of applications can be found in evolving, speed-hungry IIoT infrastructures. For those, performance and minimal latency is required for accessing databases, booting the OS, accessing external cache, etc. of cutting edge Industrial IoT and networking applications.

The third aspect where SD Express comes into play is with the harmonization of chipsets in order to reduce architectural complexity. SD Express functions as one single interface for peripheral computer components with a reduced number of bridge chips for interfacing with legacy interfaces, such as memory, graphic cards, networking cards, etc., communicating via PCIe/NVMe.

6. SD Express technical specifications

Before delving into its design, it is important to understand that the SDA has not launched a microSD card with PCIe 4.0 + NVMe technology. For the time being, it is limited to full-sized SD memory cards.

The new SD Express card comes in three variations:

- **A single-lane PCIe 4.0 interface**
  capable of up to 2 GB/s (4.0 x 1)
- **A dual-lane PCIe 3.1 interface**
  capable of up to 2 GB/s (3.1 x 2)
- **A dual-lane PCIe 4.0 interface**
  capable of up to 4 GB/s (4.0 x 2)

Dash Cams
- High video speed class
- Quick media swap

Medical / Healthcare
- High resolution imaging
- High speed data transfer

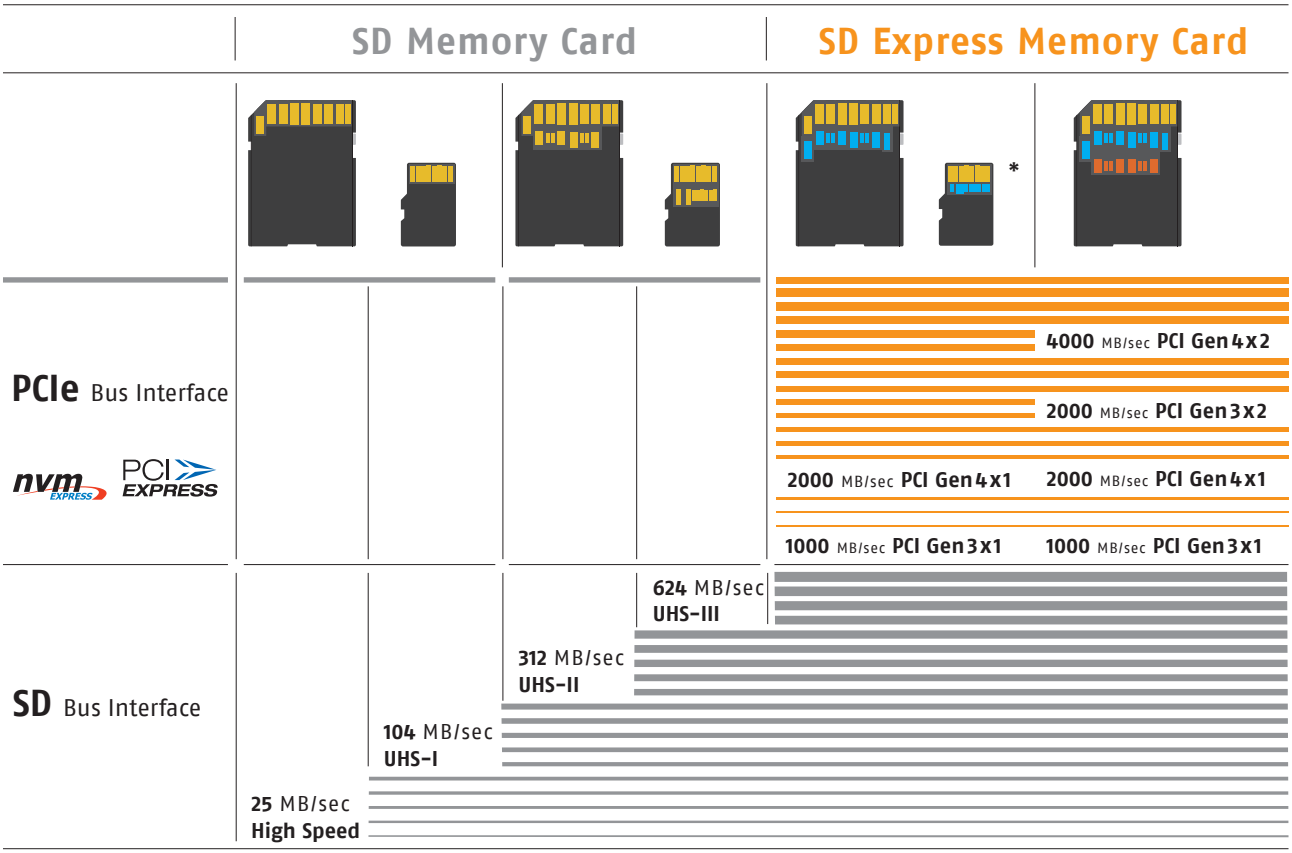
Automation
- Easy installation transfer
- Wide temperature

Data Loging
- Multiple channel recording
- Easy data transport

Edge Computing
- Latency
- Wide temperature

High End Camera
- High image rate
- Quick media swap

Figure 4: Overview on potential use cases for SD Express.



* microSD Express supports only PCIe Gen3x1

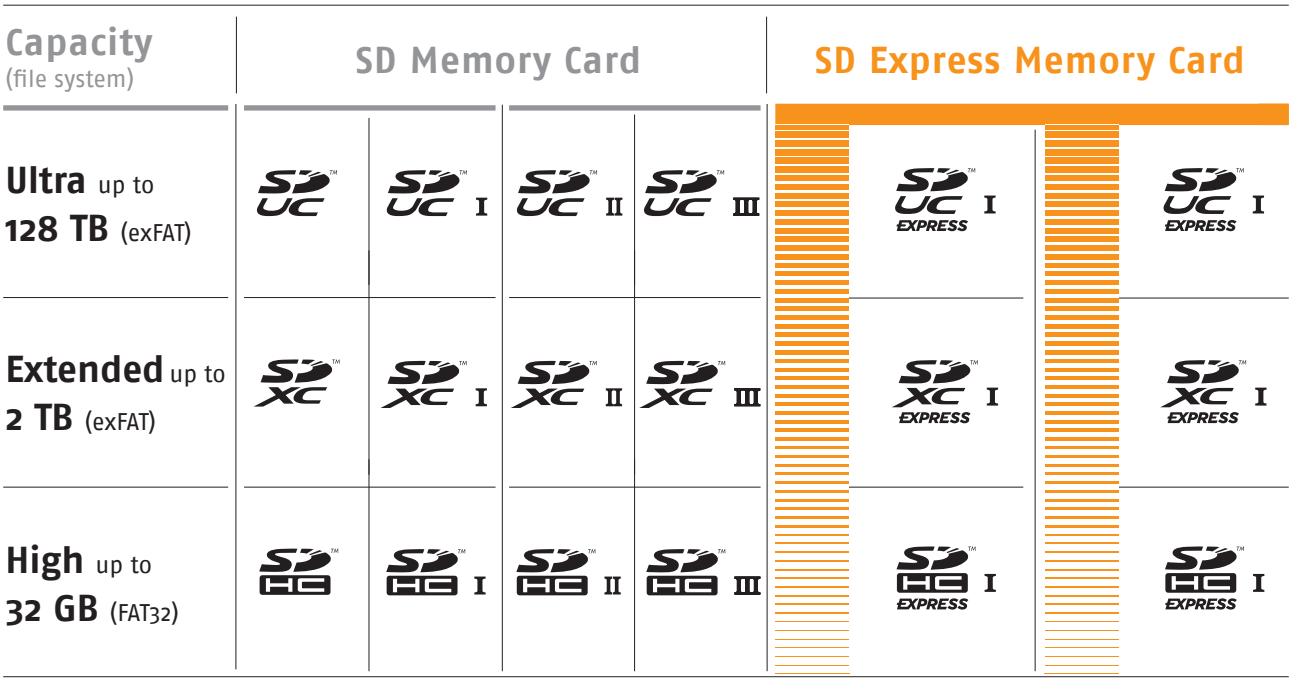


Figure 5: SD cards: past, present and future pin layouts, bus interfaces, and capacities.

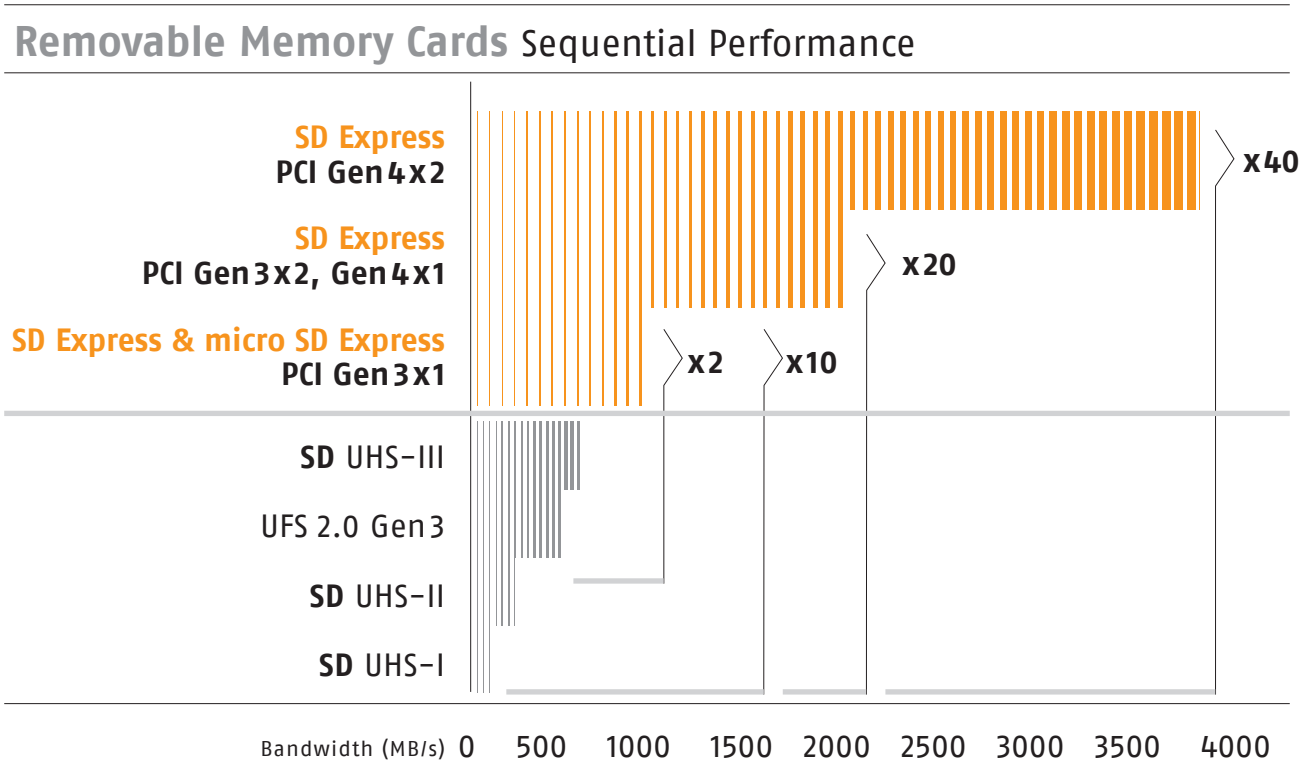


Figure 6: A performance comparison of different SD and SD Express card specifications.

Figure 7 shows that SD Express uses the identical ports and connections as the earlier UHS-II interface (but not backwards compatible with UHS-II). The differential interface, on the other hand, currently supports up to PCIe 4.0 and has a single lane. As previously stated, it can reach 2 GB/s. As can be seen in Figure 7, there is a third row of pins to accommodate two PCIe lanes. It is capable of implementing PCIe 3.1 and 4.0 interfaces with speeds up to 4GB/s. Aside from that, an additional pin 19 has been added to dual-lane cards to provide greater power (3.3 V). Furthermore, pin 18 has been saved for future usage of an optional 1.2 V supply.

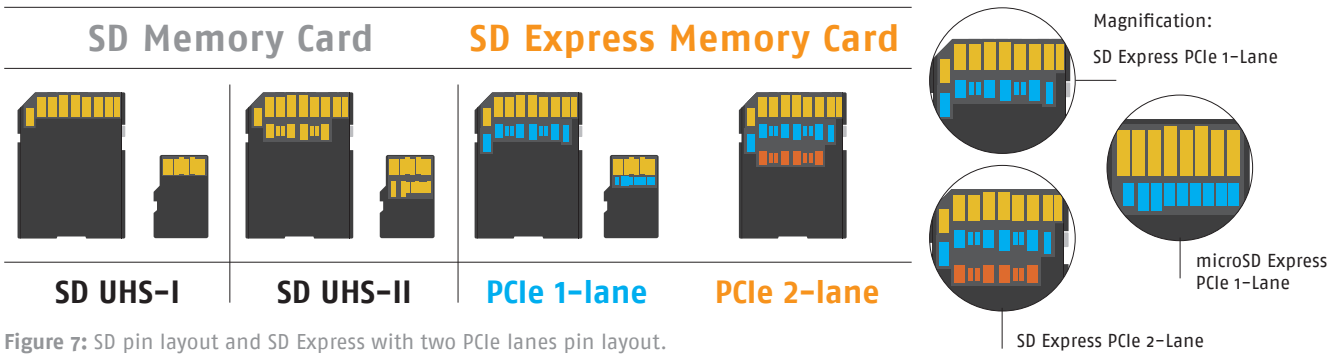


Figure 7: SD pin layout and SD Express with two PCIe lanes pin layout.

The first row of the new SD Express card architecture is based on the UHS-I interface, which is a very beneficial feature. This implies that, while being a cutting-edge and incredibly fast memory card, SD Express will be backward compatible with billions of existing SD host devices. Users will be able to use the SD Express card on older devices and card readers without the need to purchase a suitable SD Express card reader. However, it should be noted that the specified Gigabit transmission speed is not available in this case.

For the sake of completeness, it should be mentioned that the SDA also announced the UHS-III Speed Class in February 2017. However, since the standard was announced, no UHS-III SD card have yet appeared on the market or been announced. There are also no devices equipped according to this standard.
In addition, the SDA has implemented the following security features in the latest SD 9.0 standard. An exact consideration of all details of the individual features, as well as potential use cases, is not part of this white paper.

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 adds a self-encrypted drive capability.

Replay Protected Memory Block (RPMB)

RPMB offers a secured, hidden memory accessible only through a secured authentication process and provides a secured write-protect mechanism and a secured boot code update and replay protection security mechanism.

7. Design-in considerations

There are three different host types that can use SD Express:

1. The host supports both SD and PCIe interface. This is the most flexible solution. The performance advantage of SD Express cards can be used, but normal SD cards still work.

Figure 8: PCIe / SD support – most flexible solution – any card/ interface can be used

2. The host supports only the SD interface. In this case, an SD Express card is operated like a normal SD card, and there is no performance advantage.

Figure 9: SD-only host (not reasonable to use SD Express card here)

3. The host supports PCIe only. This is possible in principle, since SD Express cards can boot in PCIe mode. However, this configuration is not recommended because it is not possible to operate normal SD cards in the host.

Figure 10: Native connection – PCIe-only support – not recommended because there is a SD card slot but SD cards are not recognized

8. Conclusion

As one of the globally leading manufacturers of industrial SD cards, Swissbit is also a driving force behind the research and development of industrial-grade SD Express and microSD Express products. Swissbit's work on SD Express technology is built on the established SDA specification 9.0 and is using the same footprint as existing SD and microSD memory products.

Whether the IIoT and medical market is ready and receptive to this new technology remains to be seen. As with any technology revolution, it takes time to understand which product will prevail. What is certain is that PCIe will eat up the world and eventually all storage products will migrate their bus systems to PCIe. SD Express competes with CF Express and, of course, with embedded solutions such as PCIe BGA or SSDs. It remains to be determined, however, which variant will prevail. In the meantime, Swissbit is preparing itself and its customers for the migration to SD Express.

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List of abbreviations

AI	Artificial Intelligence
BGA	Ball Grid Array
DDR	Double Data Rate
HMI	Human Machine Interface
IIoT	Industrial Internet of Things
IOPS	Input/output operations per second
IoT	Inter of Things
LLC	Limited Liability Company
ML	Machine Learning
NVMe	Nonvolatile Memory Express
OEM	Original Equipment Manufacturer
OS	Operating System
PCIe	Peripheral Component Interconnect Express
PLC	Programmable Logic Controller
SDR	Single Data Rate
TCG	Trusted Computing Group
VR	Virtual Reality

About Swissbit

Swissbit AG is the leading European manufacturer of storage, security and embedded IoT solutions for demanding applications. As trusted partner, Swissbit empowers the digital and connected world by reliably storing and protecting data in industrial, security and IoT applications.

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