



SD Association

SD Express Speed Class – As introduced in SD 9.1 Specification

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Executive Summary

The release of the SD Express card specifications (SD7.x and SD8.0) was a major evolutionary step for the SD memory card standard, introducing a massive increase in its sequential performance capabilities.

Full-size SD and microSD form factors are the leading removable memory cards in the consumer and industrial markets.

In addition to the technical specifications developed by the SD Association (SDA), the organization always encourages adding features and markings to provide proper communication between application-host vendors and their consumers who purchase cards in stores, ensuring the full functionality of the features provided by host vendors.

An excellent example of feature marks are the Speed Classes introduced by SDA years ago, allowing various video equipment vendors to inform consumers which card should be used to ensure proper recording and flawless playback. Continuing this methodology, after introducing SD Express, it was determined that it would be helpful to introduce the SD Express Speed Class to define performance levels—features introduced in the SD9.1 specification.

This specification defines the access rules required to ensure the minimum defined performance of the PCIe™ and NVMe™ interface, including multi-stream recording of up to eight streams.

Also, it introduces two features for Maximum Power and Thermal Management to ensure cards and host devices perform at their best while ensuring minimum access performance.

This whitepaper explains what SD Express memory cards are, what speed class is, why it is necessary, and the speeds defined for SD Express Speed Class marks.

Introduction

What is an SD Express Card?

SD Express memory cards are the newest generation of SD memory cards supporting the PCIe and NVMe interface beside the legacy SD UHS-I interface on the same card.

The first SD Express cards were introduced with SD7.0 specifications for the full-size SD form factor supporting PCIe Gen 3 x1 lane interface. SD7.1 added the same capability to the microSD form factor. Then, SD8.0 introduced additional PCIe interfaces – PCIe Gen 4 x1, PCIe G3 x2 and PCIe Gen4 x2. Throughout this whitepaper we will use the words “SD Express memory cards” for both form factors.

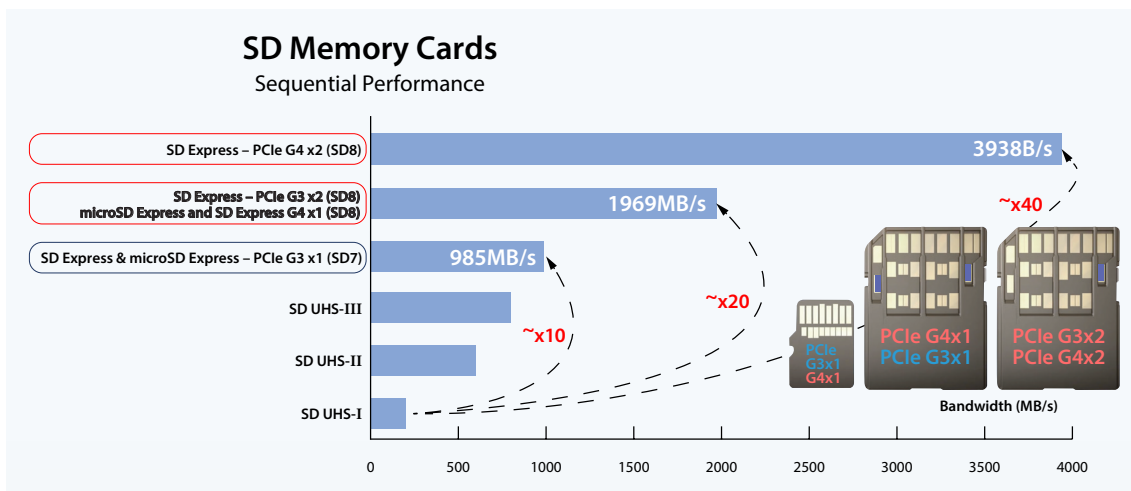


Figure 2-1 SD card speeds - from UHS-I to SD Express

SD Express is the most significant evolution for SD since it was introduced. This new generation of cards answers new and evolving market needs to support increased performance requirements of controllers, memories, and other application interfaces. SD Express can fully support almost any use case demanding higher speed removable or semi-removable memory cards using the widely adopted SSD technology.

The SD Express specifications give host devices flexibility, allowing the operation of the card through the PCIe interface or the SD interface, delivering backward compatibility with existing UHS-I hosts. The PCIe interface may be accessed and operated directly from any PCIe / NVMe host using standard PCIe/NVMe drivers because the SD Express card is introduced to the host as a standard NVMe memory device. Implementing an SD Interface requires a hardware update of the host SD interface. SDA has provided several [whitepapers](#) explaining how easy it is to add SD Express to virtually any host device.

What is Speed Class? Why do we need it? Who should care about this?

There are various applications in the market using SD memory cards. The first group of applications saves offline content, like pictures and documents. Another group uses cards for real-time recording or reading of content, such as video recorders/players and gaming devices, to name a few. The first type of application usually does not require any assured performance; however, the second requires minimum assured performance to ensure proper operation and playback. The SDA uses Speed Class levels to define a common language between host device manufacturers, card manufacturers, and consumers. Manufacturers mark those levels on the card by noting the guaranteed minimum sequential performance supported by the card under pre-defined conditions.

As a continuation of the existing [Video Speed Class](#) for the SD interface, a new set of SD Express Speed Classes was created for the PCIe/NVMe interface. These speed classes define

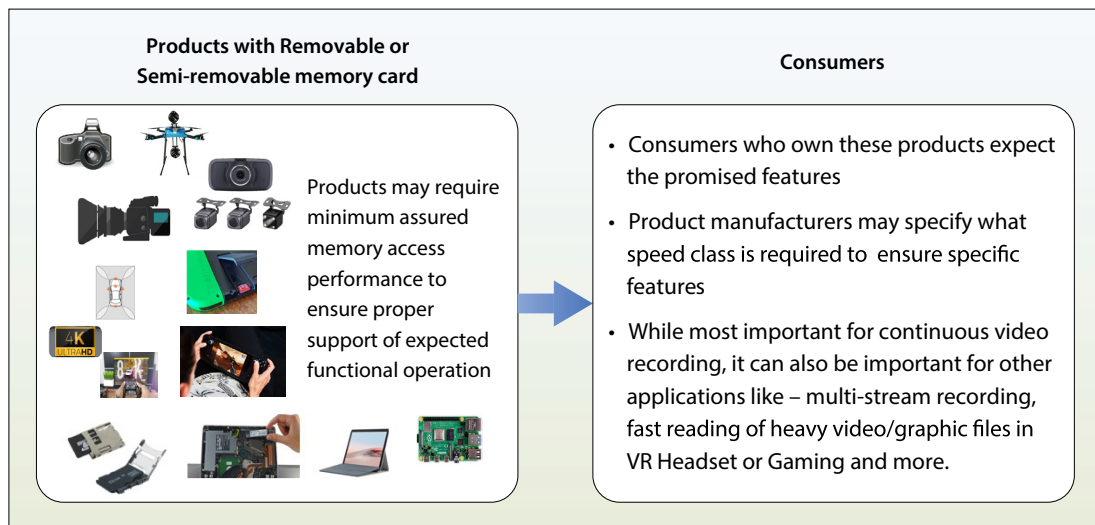


Figure 2-2 Why is Speed Class important?

minimum sequential performance levels for SD Express memory cards when a host device accesses the card through the PCI/NVMe interface. Importantly, these classes support multi-stream recording as defined by NVMe version 1.4.

This specification involves various aspects of the card's characteristics, host device characteristics and the host's card access drivers. Anyone involved in these areas who plans on complying with this specification will want to understand this specification.

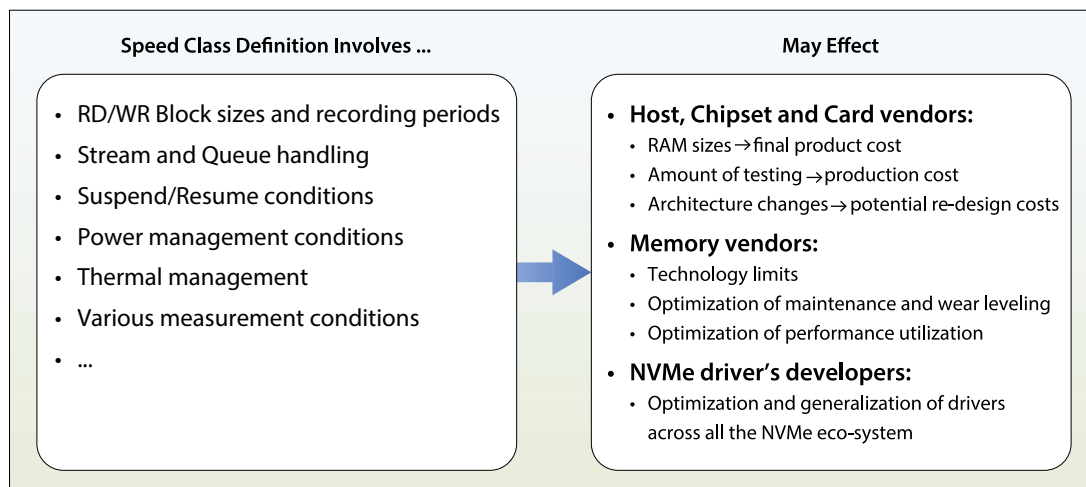


Figure 2-3 SD Express Speed Classes Vendor Impact

SD Express Speed Class Goals and Implementation Examples

The SDA created several Speed Class specifications for real-time stream recording. These include Speed Class, UHS Speed Class, and Video Speed Class. The SDA also standardized SD Express card with PCIe bus and operated by NVMe protocol for several GB/s data transmission.

Imaging equipment is required to support high-speed stream recording exceeding 100MB/s for 4K/8K intra videos* or RAW contents. These requirements are often found in professional camcorders or high-end digital single-lens reflex cameras (DSLR) that need to record video streams with several hundreds of MB/s (Figure 3-1 (a)). Moreover, there is a demand to aggregate multiple streams captured by surveillance or in-vehicle cameras onto one SD memory card, considering data portability and/or captured data management (Figure 3-1 (b)).

The current Video Speed Class specification guarantees recording just one data stream and is limited to a minimum of rate. For example, V90 ensures a minimum of 90MB/s in real-time recording. The SD Express Speed class defines a few minimum assured performance levels using the PCIe/NVMe interface, including multi-stream recording.

Real-time recording for high resolution and non-compressed video and/or multiple stream recording onto one card interface are examples supporting the need for SD Express Speed Class. It ensures specific minimum performance levels when using the PCIe/NVMe interface of SD Express memory cards.

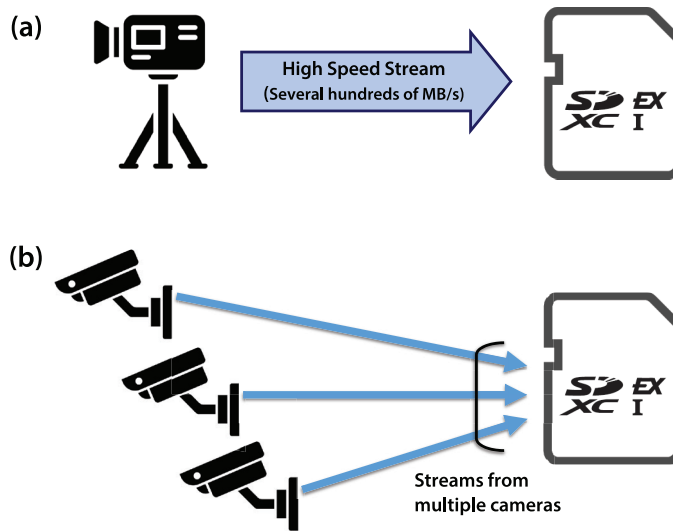


Figure 3-1 SD Express Speed Class Application Examples

(*) [Intra video](#), is a compression technique performed relative to information contained only within the *current frame*, and *not relative* to any other frame in the video sequence. Therefore, it is usually larger in size.

SD Express Speed Classes - Overview

SD Express Speed Classes 150, 300, 450, and 600 are the newly defined classes. For example, SD Express Speed Class 600 means stream recording speed at a minimum of 600MB/s is guaranteed when both the card and host device use the PCIe bus and conform to the SD Express Speed Class access rules defined in the specification. In addition, up to eight streams can be recorded simultaneously. Multiple data streams may be recorded as long as the sum of the recording speed for these streams is within the supported speed class. In addition, sequential performance is guaranteed even when write and read operations are mixed. Figure 4-1 illustrates examples of bandwidth allocation when a card supports Class 600:

- (a) 8 writing streams at 75MB/s each
- (b) 1 writing stream at 530MB/s, and 7 writing streams at 10MB/s each
- (c) 2 writing streams at 100MB/s, 2 writing streams at 50MB/s, 2 reading streams at 100MB/s, and 2 reading streams at 50MB/s for each.

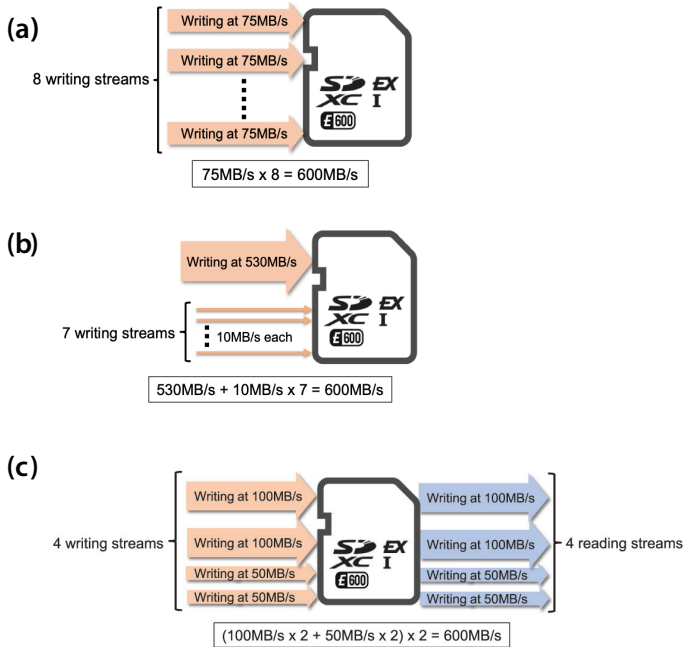


Figure 4-1 Examples of Stream Bandwidth Allocation in SD Express Speed Class

Similar to all prior Speed Classes, if the card supports a specific SD Express Speed Class, it must also support *all lower classes*. Therefore, when the card supports SD Express Speed Class 600, it needs to also support SD Express Speed Classes 450, 300, and 150. Moreover, cards with SD Express Speed Class must perform at the minimum speed for all PCIe bus modes defined in any SD Express specification. For example, if a card has PCIe Gen4 x1 mode and supports Class 300, the card must also perform equally when used in PCIe Gen3 x1 mode, which is mandatory for all SD Express memory cards.

The SDA created the following SD Express Speed Classes to meet the requirements of any SDXC or SDUC Host Device/ Ancillary Products that require minimum writing performance using the PCIe/NVMe interface of SD Express for real-time video recording, to name one use. The SD Express Speed Class Pictographs will help users identify the performance capabilities of the SDXC/SDUC Memory Cards offering the SD Express Bus and the performance requirements of SDXC/SDUC Host/Ancillary Products equipped with an SD Express Bus.

SD Express Speed Classes	SD Express Speed Class Pictographs	Minimum Read/Write Performance
SD Express Speed Class 150		150 Mbytes/Sec
SD Express Speed Class 300		300 Mbytes/Sec
SD Express Speed Class 450		450 Mbytes/Sec
SD Express Speed Class 600		600 Mbytes/Sec

Table 4-1 SD Express Speed Classes marks and their related minimum assured performance

Table 4-1 describes each SD Express Speed Class and minimum data transfer rate of the corresponding SDXC/SDUC Memory Cards. The SD Express Speed Class Pictographs indicated on a card or packaging or in a manual shall be identical to the SD Express Speed Class Identifier stored in the Identify Controller Data Structure of the SD Express card.

The SD Express Speed Class specification is based on the NVMe v1.3 or later specification. This maintains compatibility with general SD Express host devices, while allowing some vendor-specific features supporting SD Express Speed Class features.

New Features for SD Express Speed Class

The new features found in the SD Express Speed Class specification 9.1 are:

- Power Management
- Thermal Management
- Access Rule for Multi-stream Recording.

Power and Thermal Management features are introduced to maintain faster recording speed with hundreds of MB/s. The Access Rule for Multi-stream Recording feature ensures efficient memory use when performing multi-stream recording.

Power Management

The NVMe specification has a thermal throttling function to protect memory devices from breakdowns caused by heat. This function allows the device to reduce the access speed to the memory when the internal temperature reaches a defined threshold. Therefore, it is essential to suppress temperature increases in the card to maintain higher recording speeds, especially when speeds exceed 100MB/s.

An SD Express card indicates several Maximum Power (MP) values supported by the card. The card consumes power up to one of the MP values set by the host device. When the host device initializes the card, it detects MP values from the card and selects the largest MP value, allowing it to reach its best performance.

Sometimes, a card's best performance is not always required for every action; therefore it is unnecessary to always specify the largest MP value. The SD 9.1 specification also introduces a new power management feature. The card suggests necessary and sufficient MP values according to the targeted SD Express Speed Class and the selected PCIe bus mode. Using this feature, the host device can select an appropriate MP value depending on the card's capabilities so that the card does not consume excessive power for the targeted recording.

Thermal Management

Power saving and card temperature management are essential to maintain targeted recording speed. There are two internal card temperature thresholds related to the thermal throttling set by the host device. The first threshold is for activating a light throttling, and the second is for a heavy one. The second threshold is critical for the speed class recording because the card cannot continue to record due to heavy throttling. In addition, the first threshold is effective to reduce temperatures through light throttling, not to exceed the second threshold. These thresholds are key parameters for controlling the card temperature to maintain the target recording speed. Since every card may offer unique performance capabilities based on its structure or materials, it is impossible for the host device to know the appropriate values of every card in advance.

To resolve this issue, the SD 9.1 specification introduced Thermal Management where the card indicates a group of its specific thermal thresholds. The host device may then set appropriate Thermal Management parameters for the card according to the target class and the selected PCIe bus mode, much like an MP value for power management.

With this feature, the host can adequately control card's internal temperature to maintain the target recording speed for each connected card.

Access Rule for Multi-stream Recording

In order to minimize the overhead of programming time to NAND flash memory, conventional Speed Class specifications regulate the stream recording rule that stream data shall be written continuously from the starting address of a specific memory unit that is fully vacant. This is now called an SGS unit by SD Express Speed Class. Note that SGS stands for Stream Granularity Size and is originally defined in the NVMe specification.

For multi-stream recording, different stream data are recognized by the Stream Identifier (SID). Considering the actual usage of a host device with multiple cameras, the device usually transmits a block of stream data individually regardless of the SID. In this case, programmed data in the SGS unit is multiplexed in terms of the SID, and such an SGS unit cannot be used for stream recording even if one of the stream data is deleted, but this is not optimum for achieving efficient memory use.

To resolve this issue, the SD 9.1 specification defines an access rule that each SGS unit can be occupied by stream data with only one SID. As shown in Figure 5-1, stream data with SID=1 and SID=2 are written in SGS unit A and B respectively, regardless of card's receiving order. After deleting stream data with SID=2, SGS unit B can be reused for recording upcoming stream data because it is fully vacant. This rule ensures efficient memory usage when the host device repeats recording and deleting video streams in a card.

In addition, the Current Address Saving feature found in Video Speed Class is also available in this specification. It enables host resume recording from the middle of an SGS unit for its effective use, even after a power cycle.

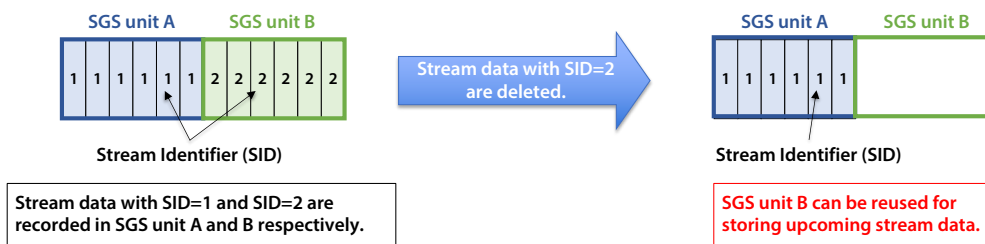


Figure 5-1 Accessing Rule for Multi-Stream Recording

Summary

Any host/ancillary device planning to implement SD Express memory cards and utilize its high-speed sequential access for applications that require a minimum assured read/write performance level – the SD Express Speed Classes are important specifications to adopt. Accessing the card using the specified access rules and handling the thermal and power management wisely as the specification defines to meet the SD Express Speed Class in an optimized manner.

Card vendors producing SD Express memory cards will want to support this specification and communicate the minimum assured performance of an SD Express Class, allowing consumers to know which card will best fit their product, whether that is a camera, drone, VR, gaming console, etc.

The SD Express Speed Class features defined in the SD 9.1 specification, is supported by an updated SD Logo Guideline, providing all the required information necessary for any company to support it.