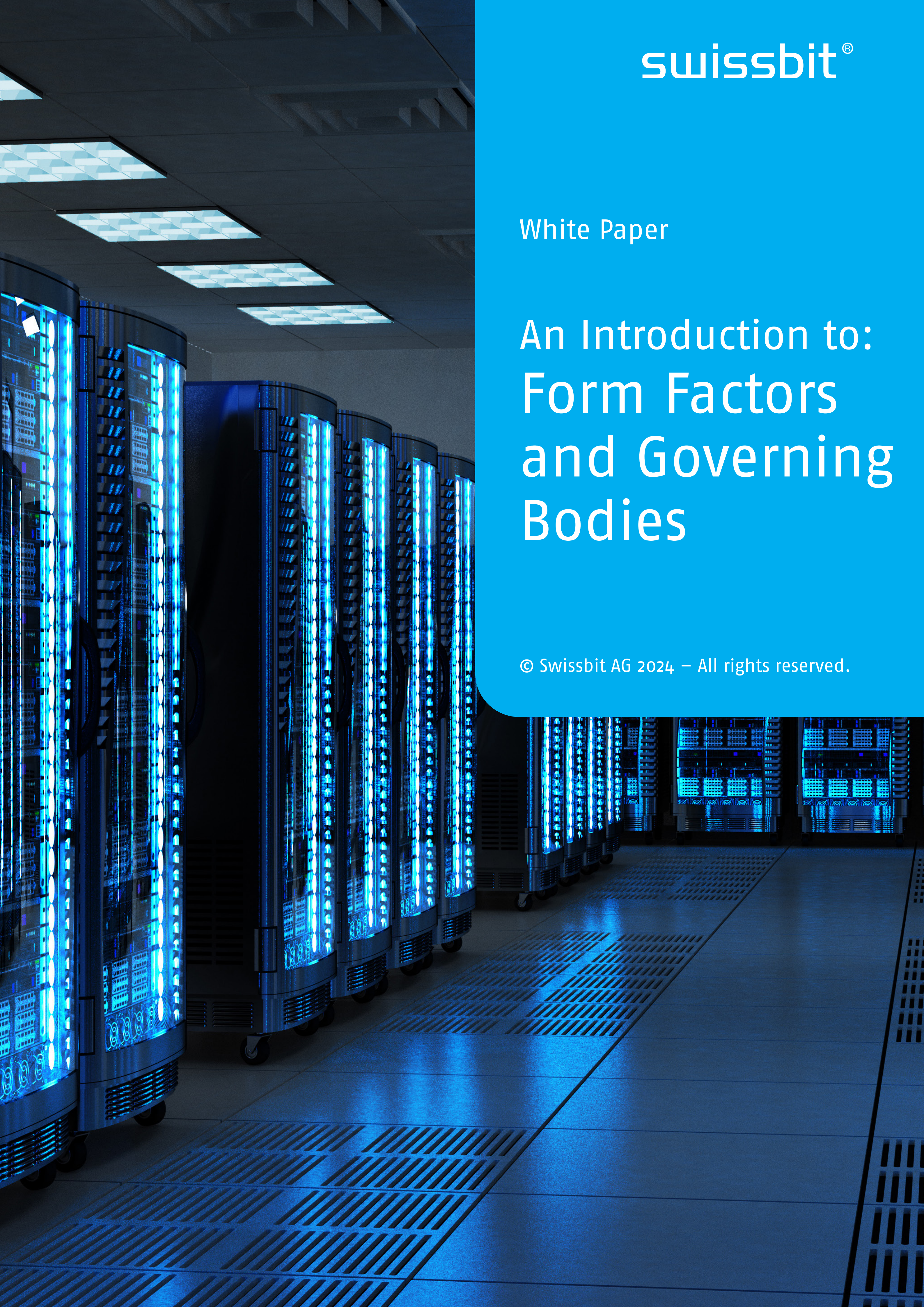


White Paper

An Introduction to: Form Factors and Governing Bodies

swissbit®

Table of Contents

1.Introduction

Most form factors in today's data storage landscape are defined by governing bodies that set different specifications to standardize them and enable interoperability. These governing bodies address the physical specifications of the form factors, as well as the connectors.

There are also cases where form factors either encompass multiple interface protocols or are the result of a proprietary solution becoming a quasi-standard.

In this paper, the current flash memory form factors will be presented, and explained with some additional details (size, connectors, interface, performance, market, etc.). Because form factors and interfaces often correlate, the paper is organized according to the interfaces, as this is often the first requirement of the memory system imposed by the host side.

2. Flash Memory Controller

The controller is the brains of any NAND flash storage system. It ensures that data received from the host is sent to the flash and can be retrieved later.

It translates and amends read/ write/ status commands of the mass storage protocol to different commands of the flash components. It also translates host Logical Block Addresses (LBAs) or sector addresses that are managed by the file system to physical locations or addresses on the flash. The controller ensures compatibility at both ends and manages all inherent flash deficiencies.

The flash controller is inherently associated with the memory system interface and form factor/ host interface. These characteristics drive the type of application and domain in which the memory system can be used, as requirements differ in different settings (industrial/ automotive/ consumer).

Flash controllers translate data between a host system and flash memory. To ensure interoperability, the controller must have the right interface to connect with the host system. Different flash controller characteristics make systems more tailored to specific applications.

3. Controller Interface to Host System

The host-side interface of the flash controller manages the communication and data traffic received from and sent to the host system. Details depend on the chosen host interface protocol or standard. For any given host interface, a set of form factors will then be available to the system integrator. The final decision for the form factors can be dictated by the form factor of the systems being replaced, by mechanical or thermal constraints imposed by a particular domain or application, or by other factors such as cost, performance, robustness, availability, or mechanical preferences.

All protocols differ in several respects – not only performance and compatibility, but also robustness and signal transmission quality, driver strength, and error correction for noise on the line.

Also, certain standards may or may not include features such as health monitoring (e.g., SMART for ATA-based protocols) or firmware update options, sanitization, or security. As they are associated with the host interface, those features are inherently associated with the form factors.

There is sometimes confusion between the card form factor, the connector, the interface, and the host protocol. Some terms like USB can define the interface and the connector, while others, like SD, define the card form factor, the interface and the connector (although many versions exist).

The system host and the domain or application will generally be major drivers to decide on the interface and the form factor. It is important to weight the different options to evaluate what is the best scenario for a specific application.

Interface Protocol	Standardization entities for protocol and/or form factors	Interface speed range	Form factors
P-ATA	Parallel ATA (PATA) CompactFlash Association	8.3 MB/s (PIO 2) to 166 MB/s (UDMA7)	CF Cards 2.5" SSD PCMCIA cards
SATA	SATA International Organization (SATA-IO), JEDEC for some form factors (MO-xxx)	150 MB/s (SATA 1.0) to 600 MB/s (SATA 3.0)	M.2 2.5" SSD MO-297 MO-300 (mSATA) CFast
PCIe / NVMe	PCI-Sig, NVM Express, SATAe based on PCIe, CF-Express based on PCIe, coming: SDx based on PCIe	2 GB/s to 16 GB/s (G5-4L)	PCI-card 2.5" drive M.2 Cfexpress, E1, SDexpress
USB	USB Implementers Forum (USB-IF)	12.5 MB/s up to 5 GB/s (USB 4)	USB Flash drive or disk eUSB module custom form factors
SD	SD Association	10 MB/s to 624 MB/s UHS III	SD Card miniSD Card microSD Card
eMMC	JEDEC	100 MB/s (4.41) to 400 MB/s (5.1)	100 to 163 ball BGA packages
UFS	JEDEC	300 MB/s (G2-1L) to 1.2 GB/s (G3-2L)	UFS module (similiar to eMMC) UFS card (similiar to microSD)

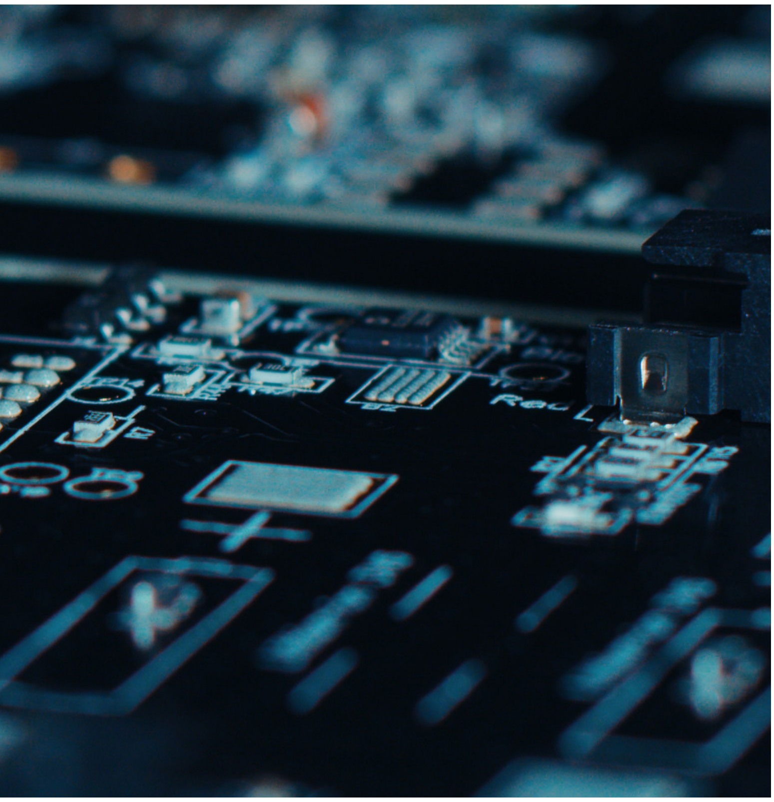
Table 1: Interface and form factor overview

4. Governing Bodies

The standards are generally developed by standardization committees. For certain form factor standards, there is cooperation between different groups.

Organisation	Description
ANSI	ATA Parallel and Serial (from IDE), SCSI
CFA	CompactFlash Association (CF, CFAST, XQD, CFexpress)
JEDEC	SSD, UFS, eMMC
MIPI-A	MIPI Alliance (M-PHY used for UFS)
MMCA	Multimedia Card Association (for earlier version of eMMC)
P-ATA	Parallel ATA
PCI-SIG	PCI Special Interests Group (PCIe)
PCMCIA	Personal Computer Memory Card Association (PC-card aka PCMCIA card)
SATA-IO	SATA International Organization (SATA, SATA-e)
SDA	Secure Digital Association
USB IF	USB Implementers Forum
4C-Entity (related to SD)	Governs the right for CPRM (Content Protection for Recordable Media) and CPPM (Content Protection for Pre-recorded Media)

Table 2: Governing Bodies Overview



5. SD Card

SD and microSD cards are widely used removable storage devices commonly found in cameras, smartphones, tablets, and other portable electronic devices. They are designed as small, portable, and convenient storage solutions and are used where there is a need for small replaceable media without high performance requirements.

SD cards use a push-push mechanism where they can be inserted into and removed from a compatible slot. The cards come in different capacities ranging from a few megabytes (MB) to several terabytes (TB), with SDHC (Secure Digital High Capacity) and SDXC (Secure Digital Extended Capacity) being common variations that support higher capacities.

SD cards can support different data transfer speeds, denoted by classes or UHS (Ultra-High-Speed) ratings, which indicate the minimum sustained write speeds. They are used in various devices such as digital cameras, video recorders, game consoles, and some laptops.

Fig. 1: Swissbit SD Card

6. microSD Card

microSD cards or uSD are smaller versions of SD cards and are primarily designed for use in smaller devices where space is limited, such as smartphones, tablets, DIN rail housings and wearable devices.

Like SD cards, microSD cards also use a push-push mechanism for insertion and removal and come in various capacities and have similar speed ratings as SD cards.

Both SD and microSD cards are widely supported by different manufacturers and offer compatibility with a wide range of devices. They provide portable and flexible storage options, allowing users to easily transfer and store data between devices or expand the storage capacity of their electronic devices.

Figure 2: microSD Card by Swissbit

Card speed	Pin numbers	Bus interface	Bus speed	SD spec version	Remarks
Default speed	9		12.5 MB/s	1.01	
High speed	9		25 MB/s	2.00	
UHS-I	9	SDR12	12.5 MB/s	3.01	
	9	SDR25	25 MB/s		
	9	SDR50, SDR50	50 MB/s		
	9	SDR104	104 MB/s		
UHS-II	17	FD156	156 MB/s	4.10	Full duplex
	17	HD312	312 MB/s		Half duplex
UHS-III	17	FD312	312 MB/s	6.00	Full duplex
	17	FD624	624 MB/s		Full duplex
PCIe based	18	G3-L1	1 GB/s	7.00	

Table 3: SD Specifications and modes

Form factor	Dimensions (L×I×T)	Interface	Connector	Remarks
SD	32.0×24.0×2.1 mm	UHS-I	9 pins	
		UHS-II	17 pins	Not widely used
		UHS-III	17 pins	Not widely used
mSD	21.5×20.0×1.4 mm		11 pins	Almost disappeared
uSD	15.0×11.0×1.0 mm	UHS-I	8 pins	
		UHS-II	16 pins	Not widely used
		UHS-III	16 pins	Not widely used

Table 4: Physical characteristics of SD cards

7. USB Interface

The USB interface was introduced in the mid-1990s. Over time, it has evolved to provide faster data transfer rates, increased power delivery, and improved versatility. The various USB generations include:

- USB 1: The original USB standard, introduced in 1996, offered data transfer rates of up to 12 Mbps (megabits per second). It was commonly used for low-speed devices like keyboards and mice.
- USB 2.0: Introduced in 2000, this version increased the data transfer rate to 480 Mbps.
- USB 3.0/3.1/3.2: These versions, introduced in 2008, 2013, and 2017 respectively, brought significant improvements in data transfer speed
- USB 4: Introduced in 2019 is the latest generation of USB and offers even higher data transfer rates. It supports speeds up to 40 Gbps and incorporates Thunderbolt 3 technology. USB 4 is backward compatible with previous generations.

USB rev.	Speed grade	Bus speed	Actual max. workload
USB 1.0	Low speed	1.5 Mb/s	
USB 1.1	Full speed	12 Mb/s	
USB 2.0	High speed	480 Mb/s	35 MB/s
USB 3.0	Super speed	5 Gb/s	400 MB/s
USB 3.1	Super speed 10 Gb	10 Gb/s	900 MB/s
USB 4.0	Thunderbolt 3	40 Gb/s	

Table 5: USB Generations Overview

8. eUSB Modules

The embedded USB, or eUSB, form factor, may not upon first glance look like the traditional USB flash drive consumers know and use- It does however continue to be a very popular solution for industrial applications as it is more rugged and durable.

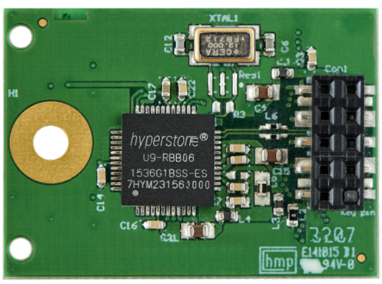


Figure 3: eUSB module based on Hyperstone controller

9. USB Flash Drive

USB flash drives are a widely used form factor used for connecting various devices to computers and other electronic devices. USB has become the standard interface for connecting peripherals, such as keyboards, mice, printers, external hard drives, smartphones, and many other devices.

Figure 4: Swissbit USB Key Flash Drive

In addition to the familiar USB Type-A and Type-B connectors, USB Type-C has gained popularity in recent years. The USB Type-C connector is smaller and reversible, meaning it can be plugged in either way. It can support high-speed data transfer, power delivery, and video output, making it a versatile connector for various devices.

The connectors used for USB flash drives are mostly as follows:

Most common connector for USB Flash memory	Remarks
Type A Standard USB plug (most common), USB 2/USB 3	USB-IF std
Type A Mini USB plug, USB 2/USB 3	USB-IF std
Type A Micro USB plug, USB 2/USB 3	USB-IF std
Type C USB plug (most recent)	USB-IF std
eUSB connector (de facto standard)	De facto std
Proprietary connector	M.2, for example for heavy industrial applications

Table 6: Connectors for USB Flash Memory

USB form factors offers numerous advantages, including its widespread adoption, compatibility across devices, ease of use, and support for various data transfer rates and power delivery. It has become an essential technology for connecting and powering a wide range of devices in today's digital ecosystem..

10. e.MMC

e.MMC is both an interface and a form factor in itself. It is an all-in-one solution as both the flash memory and its controller are present in the same package making it optimal for compact systems.

e.MMC exists in 100, 153 and 169 ball packages and is based on an 8-bit parallel interface. In most industrial applications, ruggedness is prioritized over performance, hence e.MMC 4.5 is still widely used. By contrast, consumer applications are often driven by performances with e.MMC5.x as a key enabler in smartphones.

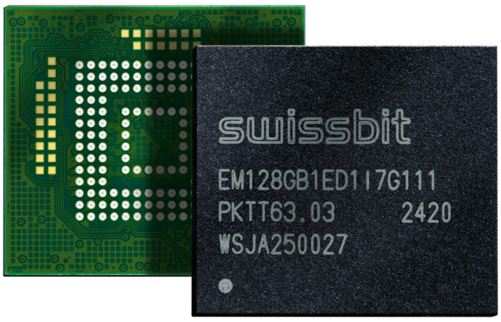


Figure 5: Swissbit EM-30

eMMC rev.	Bus speed	Remarks
eMMC 4.3	52 Mb/s	Add sleep mode, write protect, reliable write, etc.
eMMC 4.41	100 Mb/s	Add DDR, TRIM, high-priority interrupt, multiple partition, etc.
eMMC 4.5	200 Mb/s	Add sanitize and cache commands, high-speed mode HS200
eMMC 5.0	400 Mb/s	Add FFU, health monitoring, high-speed mode HS400
eMMC 5.1	400 Mb/s	Add command queueing, secure write

Table 7: e.MMC Specifications Overview

11. ATA Interface

When ANSI adopted IDE, originally developed by IBM, it renamed it ATA for Advanced Technology Attachment. The ubiquitous parallel cable could be found in most computers. A major issue appeared when computers were integrated into smaller cases. The ATA was later renamed as PATA (P-ATA) in order to distinguish it from the new generation of the interface SATA (Serial ATA).

Different generations of the ATA interface have been developed. The most recent ones are summarized below. Ultra DMA or UDMA also evolved in parallel, to define the protocol between a host and a device.

ATA generation	Description	UDMA
ATA-3	Increased reliability but remembered for introduction of SMART (Self-Monitoring Analysis and Reporting Technology). Still largely adopted nowadays even for other interfaces	n/a
ATA/ATAPI-4	Data transfer up to 33 MB/s – added AT Attachment Packet Interface (ATAPI)	UDMA-2
ATA/ATAPI-5	Data transfer up to 66 MB/s	UDMA-4
ATA/ATAPI-6	Data transfer up to 100 MB/s	UDMA-5
ATA/ATAPI-7	Data transfer up to 133 MB/s	UDMA-6

Table 8: ATA Generations Overview

12. Compact Flash Cards

Compact Flash has been around since the mid-1990s but has since been replaced in a number of consumer products by smaller form factor options. However, it is still a popular format in industrial settings, as the card is simply robust.

CF revision	Speed	
CF 4.1	Up to 133 MB/s	Up to UDMA-6
CF 5.0	Up to 133 MB/s	Up to UDMA-6
CF 6.0	Up to 167 MB/s	Up to UDMA-7

Table 9: CF Generations Overview

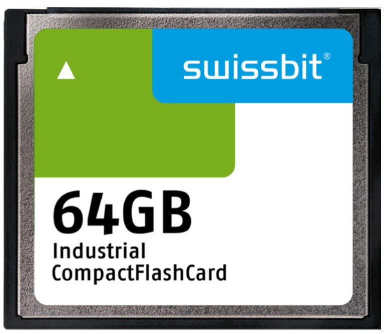


Figure 6: Swissbit CompactFlash Card

13. PATA SSDs

PATA SSDs were once widely used in industrial storage applications due to their robust nature compared to HDDs. However, they have since been almost completely replaced by SATA.

14. SATA Interface

Serial ATA or SATA was meant to replace Parallel ATA or PATA in computers. The main issue with PATA was linked to the wide bus, which had to be routed.

Today, there are different generations of SATA.

	Raw bit rate	Maximum transfer rate	Remarks
SATA 1.0	1.5 Gb/s	150 MB/s	
SATA 2.0	3 Gb/s	300 MB/s	
SATA 3.0	6 Gb/s	600 MB/s	8 b/10 b encoding
SATA 3.1	6 Gb/s	600 MB/s	mSATA
SATA 3.2		1969 MB/s	SATA Express SATA M.2 USB 3.1

Table 10: SATA Generations Overview

SATA drives are found in many different form factors. The most common is the 2.5-inch SSD drive

It is also important to note the 1969 MB/S listed in the above table is only achieveable with SATA express and was not widley accepted or implemented after the emergence of PCIe.

15. CFast Cards

CFast has the same form factor as Compact Flash but is based on the Serial ATA (SATA 2) interface instead of PATA. The pin-out is different from a CF card, though, with a 7-pin data connector and a 17-pin power connector.

CFast and CF cards are not directly compatible, but an adaptor can be used. As SATA can also emulate PATA command protocol, it is possible to use a CFast card in older CF systems. For CFast 1.0/1.1, the maximum transfer rate is the same as SATA 2.0, 300 MB/s, therefore it gives better performance than CF/ PATA, which is limited to a maximum transfer rate of 167 MB/s at best. CFast 2.0, introduced in 2014, uses SATA 3.0 capable of reaching a maximum transfer rate of 600 MB/s.

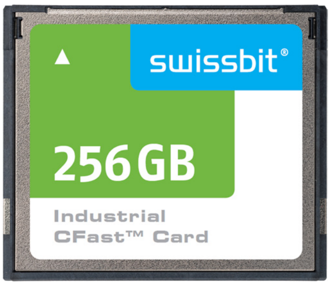


Figure 7 : Swissbit CFast Card

16. 2.5 Inch Drive

Popular formats for HDD were the 3.5-, 2.5- and 1.8-inch drives. The size indication is the size of the rotating disk in the HDD, and not the size of the casing. SDD has widely adopted the 2.5-inch disk drive format so that an HDD can be replaced easily with a 2.5-inch SATA 3 AHCI SSD drive. This gives a very effective path to upgrade the memory of a laptop. These drives can also be used externally.

Figure 8: 2.5" Swissbit SATA SSD

17. mSATA

mSATA is a smaller form factor than the SATA SSD. It comes as a PCB board, in three different formats:

- Half-Slim MO-297 (54 × 39 × 4 mm) (about half the size of a credit card)
- mSATA MO-300A (30 × 51 × 8 mm)
- mSATA-mini MO-300A (30 × 26.8 × 4 mm)

It also looks like the mini-PCIe card, but they are not directly electrically compatible. The mSATA bandwidth is the same as SATA 3 – 6 Gb/s.

The mSATA form factor is most used in lower-power devices like netbooks, but also in commercial applications. Its specification also describes how to map mSATA to mini-PCIe. The interface of mSATA is the same as the regular Serial ATA – the cards simply look different.

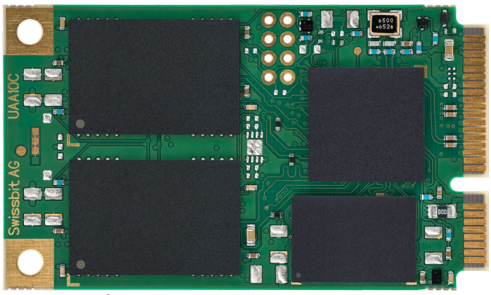


Figure 9: Swissbit mSATA Board

18. micro SSD

The specification for Micro SSD (aka µSSD) was developed by SATA-IO and uses a JEDEC standard form factor.

It defines the electrical pin-out of a BGA for a SATA3 interface. As per eMMC or UFS, the package is soldered directly onto the motherboard, removing the need for connectors.

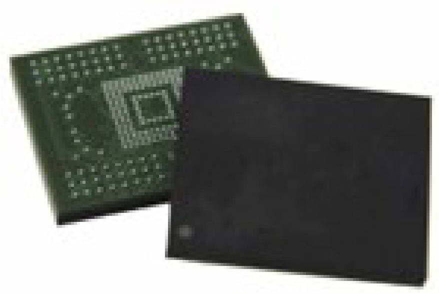


Figure 10: Example of MicroSSD

19. M.2 Specification

Initially developed by Intel and known as Next Generation Form Factor (NGFF) the M.2 specification was developed to provide a more versatile, compact, and high-performance storage solution that could meet the demands of modern computing devices.

PCI-SIG originally defined the M.2 form factor, then SATA-IO adopted M.2 in the SATA 3.2 specifications. These specifications also defined SATA express.

M.2 is therefore more flexible than the previously defined mSATA form factor. It supports not only SATA, but also PCIe and USB 3 interfaces. As a result, it extends the possible applications and can also be found supporting different host protocols, either AHCI or NVMe.

As a result, it is difficult to define M.2 as easily as most other card form factors. Many variants of M.2 cards exist. It can have up to 4× PCIe lanes, one SATA 3 and one USB 3 port. Both SATA and PCIe buses can be used at the same time (if supported by both host and device) There are also multiple connector and key IDs for each.

Key ID	Supports
B	SATA
M	PCIe (×2 or ×4) and SATA
B+M	SATA or PCIe
A	PCIe (×2) and USB
E	PCIe (×2) and USB
A+E	PCIe (×2) and USB

Table 11: Key IDs for M.2

20. M.2 SATA

M.2 SATA is a form factor and interface specification for solid-state drives (SSDs) that utilizes the M.2 slot on motherboards. M.2 SATA SSDs are a popular choice for storage in laptops, desktops, and other devices due to their compact size, high performance, and energy efficiency.

M.2 SATA drives use the SATA III (6.0 Gbit/s) interface, which is the same interface used by traditional 2.5-inch SATA hard drives and SATA SSDs. This interface allows for easy integration into existing systems without requiring specific hardware support.

M.2 SATA SSDs offer significantly faster data transfer rates compared to traditional mechanical hard drives. Although they are not as fast as M.2 NVMe SSDs, which can reach much higher speeds, M.2 SATA drives still provide a noticeable improvement in system responsiveness and file transfer speeds. The sequential read and write speeds of M.2 SATA SSDs typically range between 500 and 600 megabytes per second (MB/s).

M.2 SATA SSDs come in a small and thin form factor, often referred to as Next Generation Form Factor (NGFF). The physical dimensions vary, but the most common size is 22 millimeters in width and either 30, 42, 60, 80, or 110 millimeters in length. The compact design makes M.2 SATA drives suitable for slim devices with limited space.

21. M.2 Module PCBS 2242, 2280

PPCB 2242 and PCB 2280 refer to specific form factors for M.2 SSDs. The numbers in 2242 and 2280 represent the dimensions of the PCBs.

Specifically, PCB 2242 refers to an M.2 SSD with a width of 22mm and a length of 42mm. PCB 2280: represents an M.2 SSD with a width of 22mm and a length of 80mm.

These form factors are important considerations when choosing an M.2 SSD for a particular system. The length and width determine the physical size and compatibility of the SSD with the M.2 slot on the motherboard or expansion card.

It is worth noting that there are various other M.2 form factors available, such as 2230, 2260, and 22110, each with different lengths. The specific form factor required depends on the capabilities and compatibility of the motherboard or device in which the M.2 SSD will be installed.

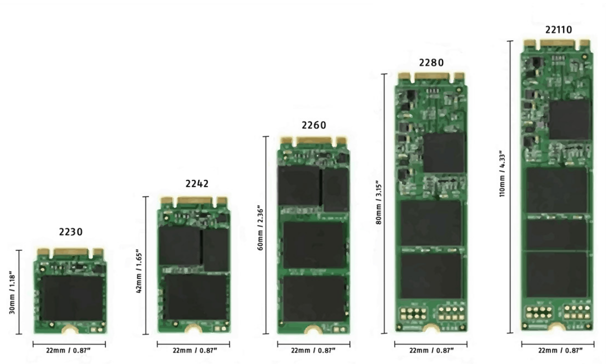


Figure 11: M.2 PCB Form Factor Sizes

22. M.2 BGAs: 1620, 2024

M.2 BGAs come in different dimensions and sizes. The numbers in BGA 1620 and BGA 2024 represent the size of the BGA packages. For example, BGA1620 is 16 mm x 20 mm.

The specific BGA package type is important when it comes to compatibility with the PCB and the intended use of the IC. The number of solder balls determines the number of connections available for transmitting data, power, and other signals between the IC and the PCB. Different ICs may require different BGA package sizes based on their pin count and functionality. BGA packages offer advantages such as reduced PCB footprint, improved thermal performance, and enhanced electrical characteristics. They are commonly used in various electronic devices, including computers, mobile devices, gaming consoles, networking equipment, and other high-performance systems.

Figure 12: PCIe NVMe M.2 1620 BGA SSD by Swissbit

23. M.2 PCIe

M.2 PCIe SSDs are designed to leverage the high-speed capabilities of the PCIe (Peripheral Component Interconnect Express) interface, offering even faster data transfer rates compared to M.2 SATA SSDs.

PCIe is a high-speed serial interface that provides significantly faster data transfer rates compared to SATA III. M.2 PCIe SSDs can take advantage of multiple PCIe lanes (e.g., x2, x4, x8, or x16) to achieve higher speeds. Subsequently, M.2 PCIe SSDs offer significantly faster performance than both traditional hard drives and M.2 SATA SSDs. The exact performance depends on the specific drive model, but M.2 PCIe SSDs can achieve sequential read and write speeds of several gigabytes per second (GB/s).

M.2 PCIe SSDs come in the same small and thin form factor as M.2 SATA SSDs, often referred NGFF, however they utilize the PCIe interface, specifically PCIe 4.0 or newer versions.

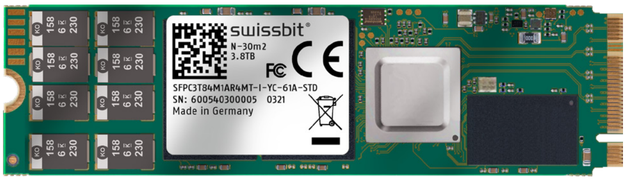


Figure 13: M.2 PCIe Card

Typically, M.2 PCIe further uses the NVMe (Non-Volatile Memory Express) protocol, which is specifically designed to optimize the performance for PCIe-based SSDs. NVMe allows for improved command handling, reduced latency, and increased parallelism, enabling the SSD to fully leverage the high bandwidth of the PCIe interface.

24. PCI Express Interface

PCI express (PCIe) is a high-speed serial bus standard used to connect various components within a computer system. It is a widely adopted interconnect technology that provides a fast and efficient data transfer between the motherboard and peripheral devices.

PCIe offers several advantages over its predecessor, the parallel-based PCI (Peripheral Component Interconnect) bus. It utilizes a point-to-point serial connection, allowing for higher data transfer rates and increased scalability. PCIe supports multiple lanes, each capable of carrying data in both directions simultaneously. This enables multiple devices to communicate with the host system concurrently.

The most common use of PCIe is for connecting expansion cards, such as graphics cards, network adapters, sound cards, and storage controllers, to the motherboard. It also serves as the interface for internal storage devices like NVMe SSDs.

.

PCI Express version	Raw bit rate	Bandwith/lane	Max bandwidth (16x)
PCIe 1.0	2.5 GT/s	256 MB/s	4 GB/s
PCIe 2.0	5 GT/s	500 MB/s	8 GB/s
PCIe 3.0	8 GT/s	~1 GB/s	~16 GB/s
PCIe 4.0	16 GT/s	~2 GB/s	~32 GB/s
PCIe 5.0	32 GT/s	~4 GB/s	~64 GB/s

Table 12 PCIe Generations Overview

25. PCIe Cards

PCIe cards are defined by their number of lanes. There are four different card formats ×1, ×4, ×8 or ×16. All the cards are composed of a first set of 11 pins, then a key notch, and finally the remaining number of pins according to the number of channels.

Number of lanes	Number of pins (per side)	Width
×1	18	25 mm
×4	32	39 mm
×8	49	56 mm
×16	82	89 mm

Table 13 PCIe Card Specifications

26. Mini PCIe Card

The PCI Express Mini Card was developed by PCI-SIG to replace the Mini PCI form factor. The Mini PCIe card supports both 1× PCIe and USB 2 interfaces. A Mini PCIe card can be used in the PCIe slot using a passive adaptor.

The form factor for mSATA and Mini PCIe is similar, and both cards can fit in the mini PCIe slot. However, they use different host interfaces, respectively SATA and PCIe, and the host connected to the PCIe slot must support the corresponding interface.

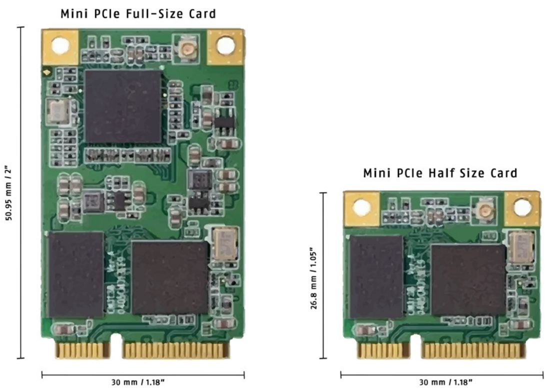


Figure 14: Mini PCIe card and half size mini PCIe card dimensions

27. SATA Express (SATAe)

SATA Express is a computer bus interface that supports both Serial ATA and PCI Express storage devices. Initially standardized in the SATA 3.2 specification, the governing body SATA-IO introduced the specification to significantly increase the bandwidth.

A connector was defined for backward compatibility that could support both SATA 3 x2 and PCIe x2 interfaces.

SATA express supports three different device interfaces:

- SATA 3 interface
- PCIe using AHCI
- PCIe using NVMe

28. CF Express Card

CFexpress, also known as CompactFlash Express, is a high-performance memory card format that was introduced in 2016. It is designed as a successor to the CompactFlash (CF) and XQD card formats, offering significantly faster data transfer speeds and improved storage capabilities.

CFexpress utilizes the PCIe (Peripheral Component Interconnect Express) interface to achieve high-speed data transfer rates. It leverages the NVMe (Non-Volatile Memory Express) protocol, which is optimized for solid-state storage, to deliver fast and efficient performance.

The data transfer speeds of CFexpress cards can vary depending on the specific implementation and PCIe generation. CFexpress Type B cards using PCIe 3.0 can achieve read and write speeds of up to 1,700-1,800 MB/s. CFexpress Type B cards utilizing the newer PCIe 4.0 interface can offer even faster speeds, reaching up to 3,500-4,000 MB/s.

CFexpress has gained popularity in professional photography and videography due to its high-speed performance, making it suitable for capturing high-resolution images and video footage. It is also used in other applications that require fast and reliable storage, such as industrial cameras, professional audio recorders, and high-end computing devices.

Figure 15. Industrial CFexpress card by Swissbit

29. SD Express Card

SD express refers to a next-generation SD memory card standard that combines the popular SD card form factor with the high-speed PCIe and NVMe interfaces. SD express cards leverage the PCIe and NVMe protocols to achieve faster speeds and lower latency compared to traditional SD cards, which typically use slower interfaces like SD, SDHC, or SDXC.

The SD express standard supports different versions, such as SD 7.0, SD 8.0, and so on, each introducing new features and improved performance. These cards can offer faster read and write speeds, making them suitable for applications that require quick data access, such as high-resolution photography, 4K or 8K video recording, and high-speed data transfers.

SD express cards are backward compatible with existing SD card slots but may require a compatible host device with PCIe and NVMe support to achieve their full performance potential. It is important to note that while SD Express cards use PCIe and NVMe interfaces internally, the physical form factor remains the same as traditional SD cards, ensuring compatibility with a wide range of devices that support SD cards.

Figure 16: SD Express Cards

30. XFM Express

XFM express is a new form factor for PCIe/NVMe devices. Featuring a powerful combination of small size, speed, and serviceability, XFM express technology was developed to enhance next-generation mobile and embedded applications.

The XFM express XT2 from KIOXIA is the first product to meet the specification of the new JEDEC standard.

31. E1.S

E1.S is one of the form factors defined by the EDSFF working group, a group comprised of major industry players such as Intel, Samsung, Seagate, and Western Digital. The EDSFF working group also defines other form factors, such as E1.L, E3.S, and E3.L, each with different physical dimensions and capabilities.

EDSFF stands for "Enterprise and Datacenter Storage Form Factor," and it is a standard for solid-state drives (SSDs) used in enterprise and data center environments.

E1.S refers to a specific size and shape for SSDs. The "E" stands for EDSFF, and the "1.S" indicates the first size category within the standard. The E1.S form factor is designed to provide a balance between storage capacity and physical space efficiency.

EDSFF E1.S SSDs are typically used in servers and storage systems, offering high-performance storage solutions with high capacity. These SSDs are hot-swappable, meaning they can be inserted or removed from a running system without shutting it down, enabling easier maintenance and upgrades in data center environments.

.

32. U2, U3

Developed by the SFF (Small Form Factor) Committee, the U.2 form factor, also known as SFF-8639, is a specification for solid-state drives (SSDs) and hard disk drives (HDDs) used in enterprise and data center environments. The U.2 form factor is designed for high-performance storage devices that use the Serial Attached SCSI (SAS) or Non-Volatile Memory Express (NVMe) interface. It utilizes a 2.5-inch drive enclosure and a standardized connector, making it compatible with existing drive bays and backplanes designed for 2.5-inch drives.

The U.2 connector has a total of 68 pins, which include both power and data connections. It supports multiple data lanes for high-speed data transfer, enabling faster performance compared to traditional 3.5-inch or 2.5-inch drive form factors.

One of the advantages of the U.2 form factor is its versatility. It allows for the use of both SAS and NVMe protocols, providing flexibility in storage system designs. This makes it suitable for a wide range of applications, including servers, storage arrays, and high-performance computing environments. 0

U.3 is the newer connector specification developed by the Small Form Factor (SFF) Committee designed to provide a versatile and high-performance interface for connecting storage devices to computer systems. Compared to U.2, U.3 connectors are designed to provide even more versatility and compatibility. They also have a 68-pin form factor and use a 2.5-inch drive bay, like U.2 connectors. However, the key difference is that U.3 connectors support multiple interface options, including SAS (Serial Attached SCSI), SATA, and PCIe. This allows for even greater flexibility in connecting various types of storage devices.

In summary, while both U.2 and U.3 connectors provide high-performance and versatile options for connecting storage devices, U.3 offers broader compatibility by supporting multiple interface options (SAS, SATA, and PCIe) in a similar 2.5-inch form factor. U.2, on the other hand, primarily supports SATA and PCIe interfaces in the same form factor.

33. Conclusion

Flash memory systems are available in many different form factors. Each form factor has specific mechanical characteristics and a logical host interface. The choice of form factor is driven by these, and generally driven by the system level. The host must accommodate the interface, and the system level design must be designed for the form factor. Also, to be considered alongside the NAND flash memory types are other characteristics, such as, performance, endurance, reliability, End-of-Life, temperature, cost, and flash type.

A lot of those characteristics are driven by the NAND flash memory controller. It is a major contributing factor, and it needs to be chosen wisely according to the system requirements. For example, industrial requirements are very different from commercial applications. Many alternatives for storage systems and their controllers exist in terms of interface options, form factors and quality levels. If the storage system is vital for your application and holds sensitive data, or if failure would result in costly down-time, you need to choose your controller carefully – know your requirements.

.

Do you have any questions? Get in touch!

Swissbit Europe (HQ)
Tel. +41 71 913 03 00
sales@swissbit.com

Swissbit North America
Tel. +1 978-490-3252
salesna@swissbit.com

Swissbit Japan
Tel. +81 3 6258 0521
sales-japan@swissbit.com

Swissbit Asia
Tel. +886 912 059 197
salesasia@swissbit.com

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.

www.swissbit.com