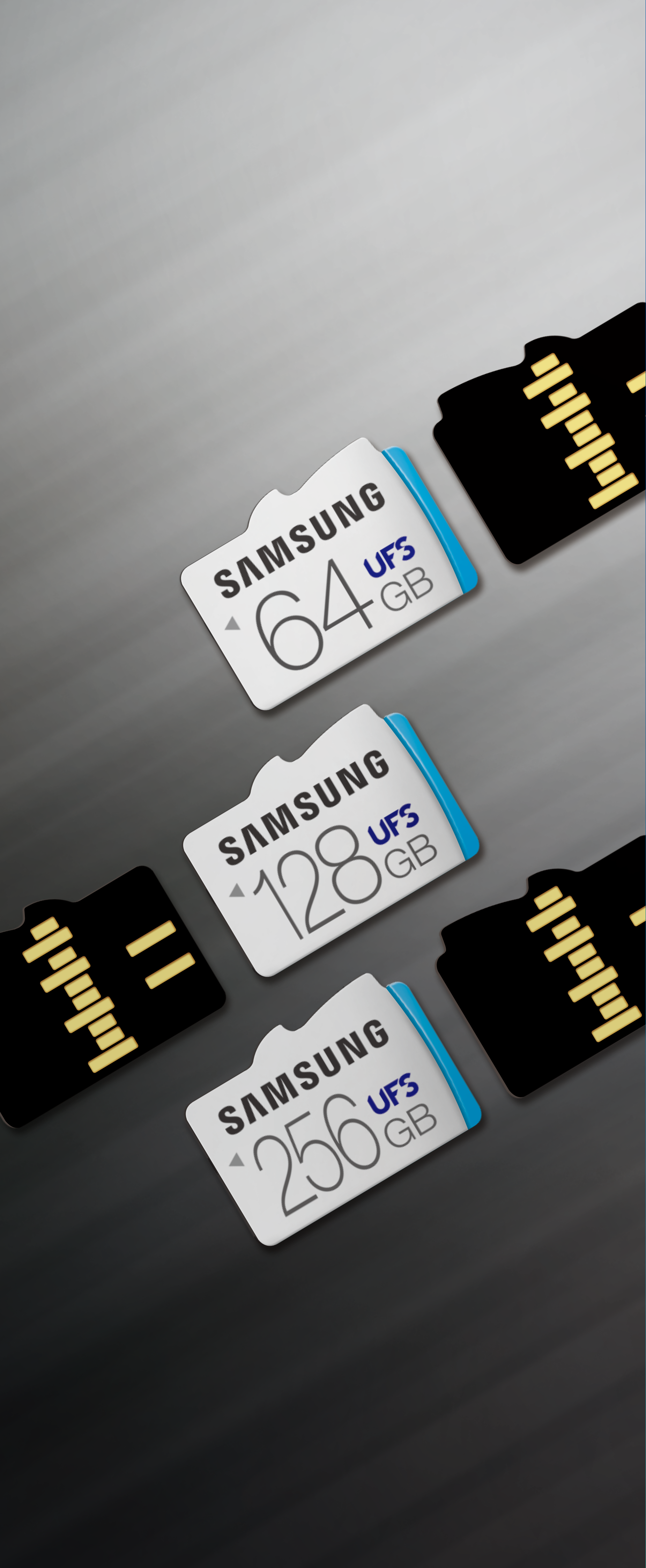


Samsung UFS Card

State-of-the-Art Storage Card Delivering Superior Performance and Reliability: SSD Performance in a Memory Card

White Paper

SAMSUNG

Technology & Market Trends: UFS and UFS Card

Executive Summary

This white paper explains how the features of Universal Flash Storage (UFS) card, including extreme performance, efficient power consumption, higher reliability, and exceptional user experiences for multi-processing environments, provide a massive improvement over the 20-year-old SD card technology.

The purpose of this paper is to encourage host OEMs to adopt the UFS card by providing details on the UFS card technology inside and financial advantages.

Figure 1. As small as the size of a fingernail, yet delivering SSD performance

Technology & Market Trends: UFS and UFS Card

JEDEC [1] is the most well-known international technology standard organization for DRAM, LPDDR, GDDR and NAND Flash-based storage, including UFS. Due to its distinguished performance, UFS has been adopted as the primary storage solution for the majority of smartphones today.

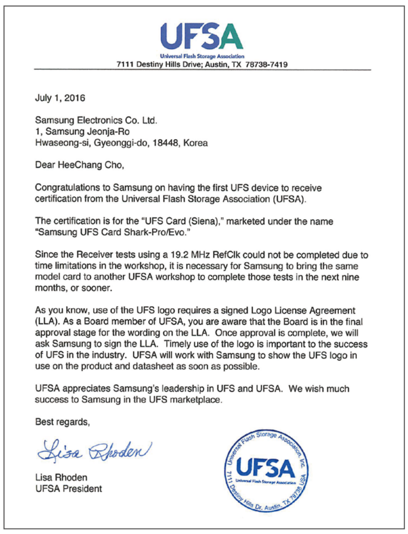
To provide extremely high card storage performance, the industry defined and introduced removable card storage solutions based on UFS standards. On March 29, 2016, the JEDEC published standard UFS card v1.0 standard specifications for removable cards that perform at speeds up to 600MB/sec. In January 2018, JEDEC published UFS card v1.1 specifications that improve power consumption and stability.

(1) The JEDEC (www.jedec.org) Solid State Technology Association is an independent semiconductor engineering trade organization and standardization body. JEDEC has more than 300 members, including some of the world's largest computer companies. Its scope includes the standardization of solid-state devices, and it develops standards for semiconductor devices.

To enhance interoperability between the host device and the UFS card, the UFSA (UFS Association), an industry association that promotes the use of UFS and UFS cards, released the first UFS Card Certification test specification (CTM v1.0) on April 7, 2016.

For UFS card certification, the UFSA runs CTM compliance test specification workshops. In July 2016, the Samsung UFS card received the world's first UFS card certification. To improve performance and power consumption efficiency for mass production, Samsung enhanced its UFS card with a new CTM v1.3 UFSA certification in November 2017.

Samsung is preparing to launch the world's first UFS card with several major OEM partners, and continues to build the UFS ecosystem through numerous industry collaborations.


UFSA
Universal Flash Storage Association
7111 Destiny Hills Drive; Austin, TX 78738-7419

July 1, 2016

Samsung Electronics Co. Ltd.
1, Samsung Jeonja-Ro
Hwaseong-si, Gyeonggi-do, 18448, Korea

Dear HeeChang Cho,

Congratulations to Samsung on having the first UFS device to receive certification from the Universal Flash Storage Association (UFSA).

The certification is for the "UFS Card (Siena)," marketed under the name "Samsung UFS Card Shark-Pro/Evo."

Since the Receiver tests using a 19.2 MHz RefClk could not be completed due to time limitations in the workshop, it is necessary for Samsung to bring the same model card to another UFSA workshop to complete those tests in the next nine months, or sooner.

As you know, use of the UFS logo requires a signed Logo License Agreement (LLA). As a Board member of UFSA, you are aware that the Board is in the final approval stage for the wording on the LLA. Once approval is complete, we will ask Samsung to sign the LLA. Timely use of the logo is important to the success of UFS in the industry. UFSA will work with Samsung to show the UFS logo in use on the product and datasheet as soon as possible.

UFSA appreciates Samsung's leadership in UFS and UFSA. We wish much success to Samsung in the UFS marketplace.

Best regards,

Lisa Rhoden

Lisa Rhoden
UFSA President

Universal Flash Storage Association, Inc.
UFSA
7111 Destiny Hills Dr. Austin, TX 78738 USA

Figure 2. Samsung UFS card receiving the world's first certification from the UFSA

UFS Card vs. SD Card

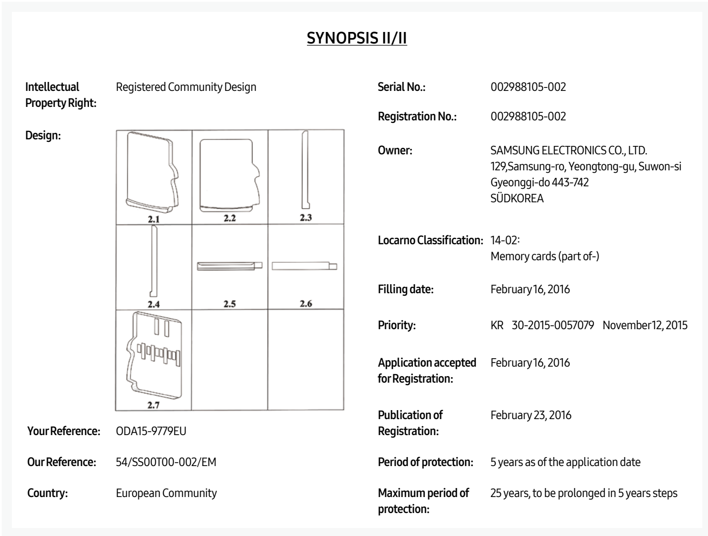
UFS Card vs. SD Card 1)

Financial Advantage

When the JEDEC published the UFS card standard in March 2016, Samsung held all of the design patents on the UFS card and declared them as a RAND solution to accelerate industry adoption. Samsung then actively promoted UFS technology as a storage interface solution, and distributed the royalty-free form factor unless necessary for cross license purposes to protect the Samsung business.

This royalty-free approach provides a substantial financial benefit compared to the SD card pricing structure with costly royalties borne by vendors.

1. In this white paper, 'SD card' means SD UHS-I Card, as SD card is more commonly known and recognized in the market.


SYNOPSIS II/II

Intellectual Property Right:	Registered Community Design	Serial No.:	002988105-002
		Registration No.:	002988105-002
Design:	2.1 2.2 2.3 2.4 2.5 2.6 2.7	Owner:	SAMSUNG ELECTRONICS CO., LTD. 129,Samsung-ro, Yeongtong-gu, Suwon-si Gyeonggi-do 443-742 SÜDKOREA
		Locarno Classification:	14-02: Memory cards (part of-)
		Filling date:	February 16, 2016
		Priority:	KR 30-2015-0057079 November 12, 2015
		Application accepted for Registration:	February 16, 2016
Your Reference:	ODA15-9779EU	Publication of Registration:	February 23, 2016
Our Reference:	54/SS00T00-002/EM	Period of protection:	5 years as of the application date
Country:	European Community	Maximum period of protection:	25 years, to be prolonged in 5 years steps

Figure 3. Samsung's patent on UFS card form factor and design

Performance Advantage

When comparing UFS card to SD card for its performance, sequential read performance, UFS card performs five times faster than the SD card when it comes to booting and game loading times. In random read/write performance—i.e., several apps running in parallel or mirroring the current smartphone environment, the UFS card shows benchmark performance improvements of 70 times faster than the SD card.

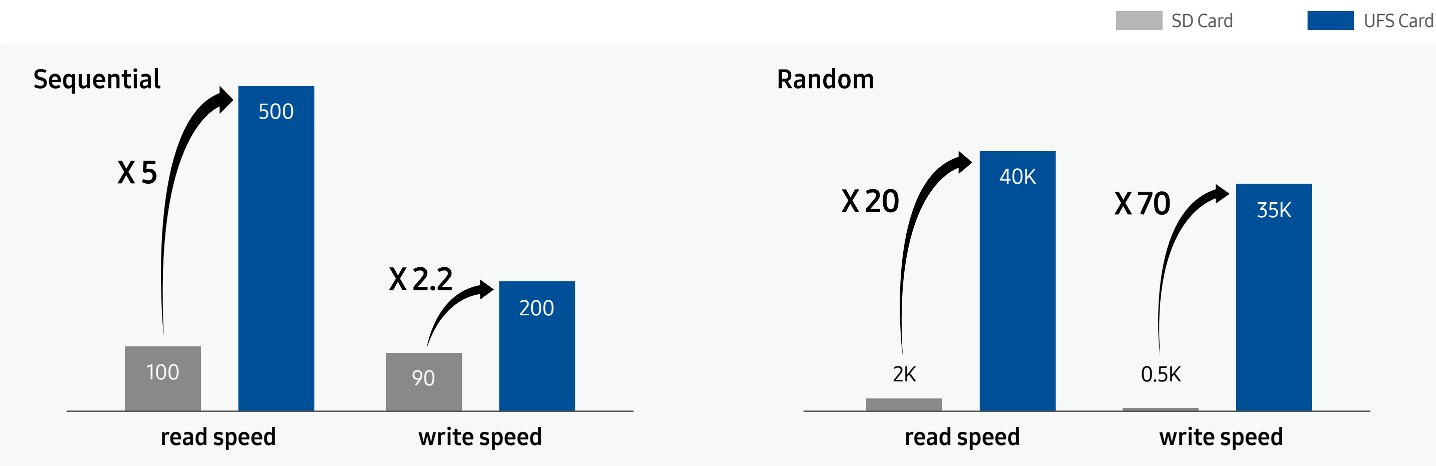


Figure 4. Measured performance: SD card vs. UFS card (Crystal Disk Benchmark)

The superior UFS card performance is the result of several advanced features integrated into UFS technology, such as task queuing, asynchronous I/O protocol and fast I/O speeds of up to 600MB/sec. The SD card (UHS-I), on the other hand, uses a 20-year-old protocol of synchronous I/O, and can only reach a maximum speed of 104MB/sec.

UFS Card vs. SD Card

Power Consumption Advantage

The command and data signals of an SD card require 3.3V at the initialization stage and 1.8V for read/write operation. The SD card uses 6 signals of 1.8V (4 data signals, 1 command signal, 1 clock signal), which collectively consume a large amount of power.
In contrast, the UFS card uses a lower 0.2V or 0.4V swing of one pair of differential signals, which dramatically reduces power consumption.

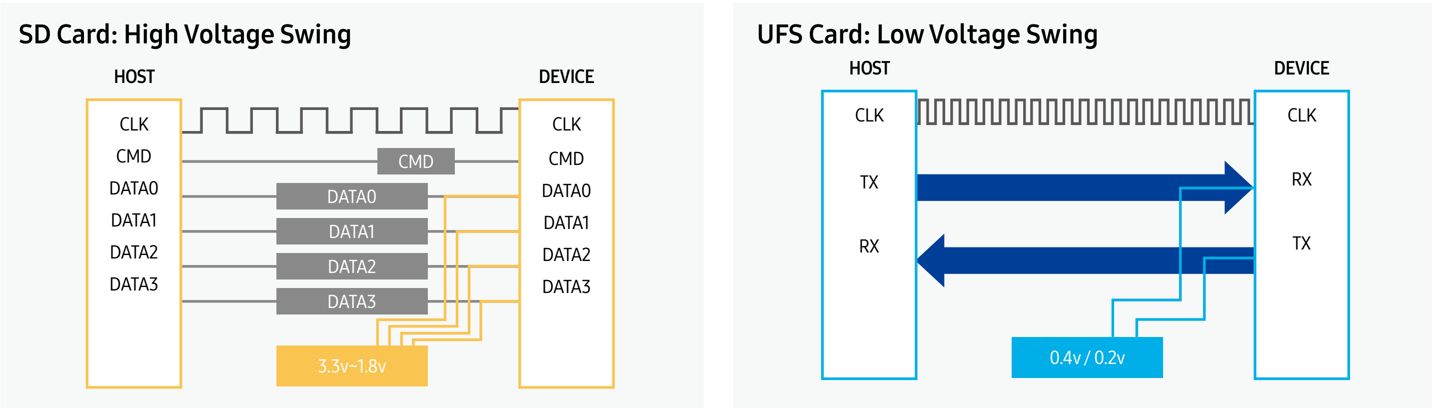


Figure 5. Slower signaling in SD card with 3.3v/1.8v vs. Faster signaling in UFS card with 0.4v/0.2v

Not only the UFS card provides superior performance, it is also 10 times more energy efficient as it consumes less power than the SD card in transferring the same amount of data.

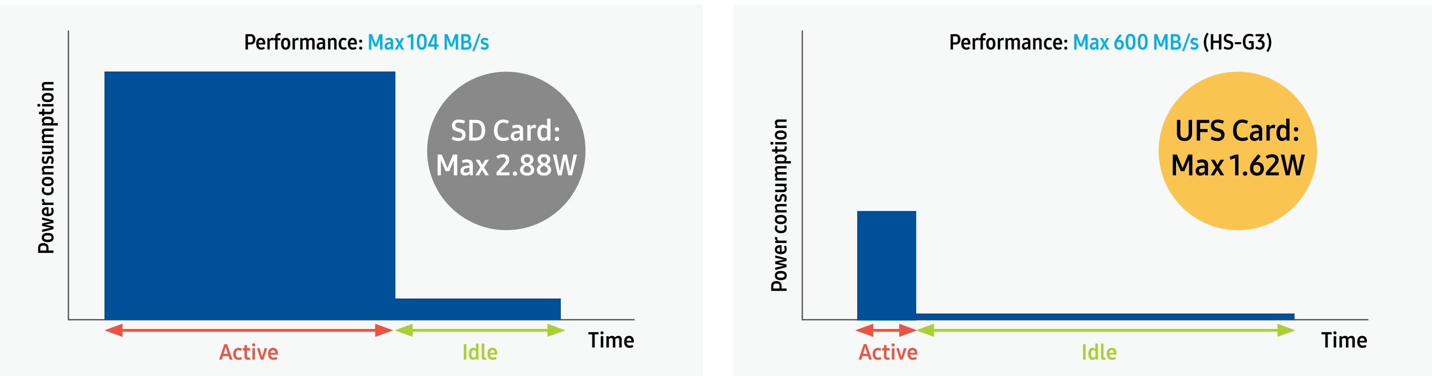


Figure 6. Maximum power consumption: SD card vs. UFS card

Power Reliability Advantage

	SD Card	UFS Card
RMS (Root Mean Square) Power Consumption	MAX 2.88W in 1,000 msec intervals • Loose condition draws more power in a shorter time interval, which may lead to system level instability	MAX 1.62W in 100 msec intervals • 10x more strict condition to reduce variation in power consumption between devices • 1.7x Longer battery life compared to the SD card
Peak Power Consumption	Specificaiton does not exist. • Requires host device OEM to assign bigger power budget for covering wide range of peak power for various SD vendors and their various SD card products	Peak power spec exists as 5us intervals • 500mA @3.3v VCC & 400mA @1.8v VCCQ) • With more strict specification in power consumption for a device to meet, host device OEM can safely allocate PMIC based on peak power specifications

Table 1. Power consumption comparison between SD card and UFS card

SAMSUNG

UFS Card vs. SD Card

For the SD card, the RMS power consumption specifications are managed in one-second period interval, and the fact that there is no peak power consumption specifications can be an issue. Because of the long one second time intervals, it is more likely for the SD card to exceed the allocated power budget set by the host device and could cause data loss or system instability. For this reason, host OEMs are challenged to allocate the precise power budget for the SD card slot, and/or they overcompensate by provisioning a much larger than needed power budget. For UFS cards, however, RMS power consumption specifications are managed in 100ms period intervals, and peak power consumption is defined below 500mA in 5us intervals, therefore providing superior performance with less of a power budget.

Advanced Differential Signal Advantage

The UFS card implements a state-of-the-art differential serial signal technology, while the SD card uses a single-ended signal pad. The UFS card also offers low voltage swing, differential signaling and fewer signals routing that result in reduced Electromagnetic Interference (EMI) than the SD card.

Benefits of differential signaling in UFS card include:

- **Resistance to EMI and Crosstalk**
  If EMI or crosstalk is introduced from outside the differential conductors, it is added equally to the inverted and non-inverted signals. Thus, the receiver circuitry greatly reduces the amplitude of the interference or crosstalk.
  The following figure compares EMI measurements of SD card to UFS card in the same physical environment. For the UFS Card, EMIs for all frequency ranges are below the upper limit of the specification with much margin. For the SD card, however, satisfying the EMI spec is very difficult, so EMIs are much worse than UFS Card as below Figure 7.

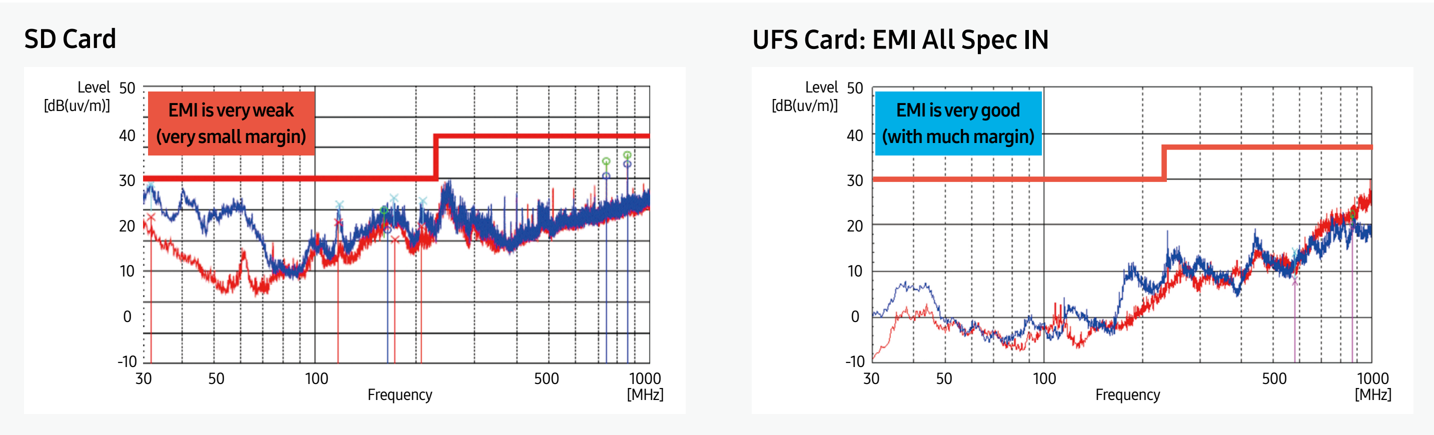


Figure 7. EMI test results: SD card vs. UFS card

- **Reduction to EMI and Crosstalk**
  Two signals in a differential pair create electromagnetic fields that are (ideally) equal in magnitude but, opposite in polarity. This is applied in the UFS card and ensures that emissions from two conductors will largely cancel each other out.

- **Better Signal-to-Noise Ratio**
  Differential signals in a UFS card can use lower voltages and still maintain adequate signal-to-noise ratio (SNR) due to improved resistance to noise, while the single-ended signals in a SD card require a steady high voltage to ensure adequate SNR.

- **Less Complexity in Receiver Circuitry**
  With differential signals integrated into the UFS card, determining the logic state is simpler, just like comparing voltages of inverted and non-inverted signals. However, in the single-ended systems of SD cards, the receiver circuitry is more complicated, and the value of reference voltage, as well as variations and tolerances, should be taken into consideration.

UFS Card vs. SD Card

Advantages of Professional Physical/Link and Command Layer

UFS card architecture is built on state-of-the-art industry proven protocols: M-PHY and UniPro of the Mobile Industry Processor Interface (MIPI) Alliance standard are adopted for the physical and link layers, and the SCSI command is adopted for the command layer.

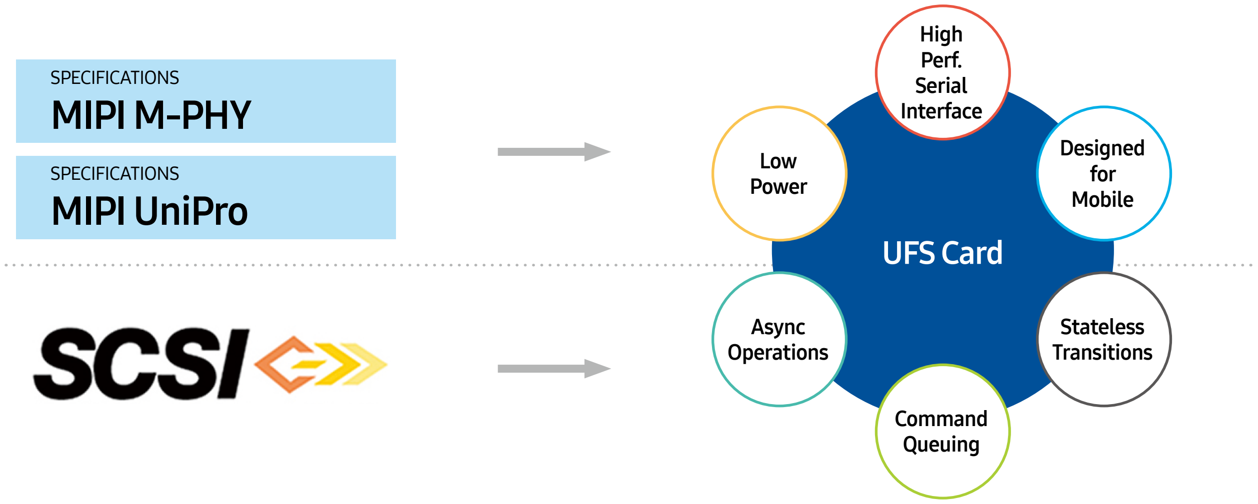


Figure 8. UFS Card is based on state-of-the-art MIPI and SCSI specs.

- **M-PHY Physical Layer**
  MIPI[1] M-PHY is a serial interface with ultra-high bandwidth and reliability, specifically developed for the high-demand performance and low power requirements of mobile applications. The interface offers a low active power level and a near-zero idle power level for noteworthy reductions in device power consumption.

- **UniPro Link Layer**
  MIPI UniPro is a high-speed link technology for interconnecting integrated circuits in mobile and mobile-influenced electronics. UniPro provides detection and recovery from I/O errors on the hardware layers without requiring restarting from the host.

- **SCSI Command Layer**
  The UFS standard adopts the well-known SCSI architecture model and advanced command protocols, including command queuing features. SCSI is widely used in many storage protocols such as USB3.0, SAS and more.

  By including the state-of-the-art MPHY physical layer, UniPro link layer and SCSI command layer, UFS card delivers high reliability, performance and power optimization, which are essential for in-vehicle and mobile systems.

1) MIPI (Mobile Industry Processor Interface, www.mipi.org), is a global, open membership organization that develops interface specifications for the mobile ecosystem, including mobile-influenced industries.

UFS Card vs. SD Card

Advantage of Parallel Execution for Multi-Processing

The SD card uses an older, more primitive I/O interface protocol - synchronous I/O. This means, when the host sends a command to the SD card, it must wait for the completion of the command execution before sending the next command. This I/O method was designed for a single process model, which was the standard 20 years ago; however, in today's multi-processing environment, this I/O architecture is neither appropriate nor effective.

For example, if one application is using I/O operation in SD Card, then all other applications cannot start their I/O until the previous I/O operation is completed.

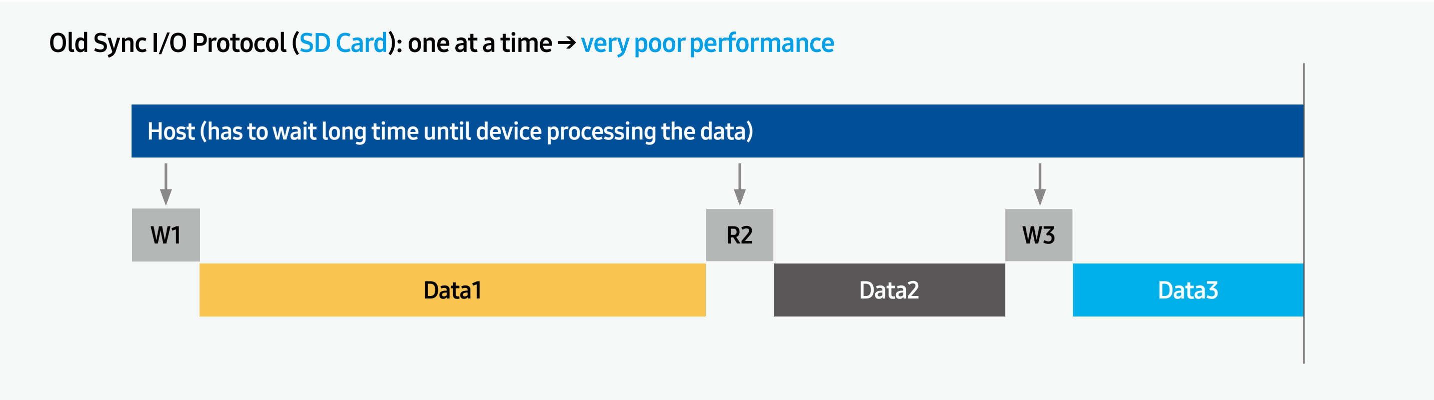


Figure 9. SD card style synchronous I/O protocol (one-at-a-time commands; host must wait for the completion of previous operations)

Therefore, the SD card synchronous I/O interface may degrades the overall system throughputs, leading to a poor user experience. For instance, thumbnail photos shown in a smartphone photo gallery could appear as empty white screens for one or two seconds when the user scrolls the photo gallary, or a video game could drop several video frames to catch up with the real-time game speed, making a moving object on the game screen appear unnatural.

In contrast, the UFS host can send commands continuously, even while the UFS card is transferring data and processing previous commands. This allows an application to perform read-or-write operations while other applications simultaneously run without sluggish performance.

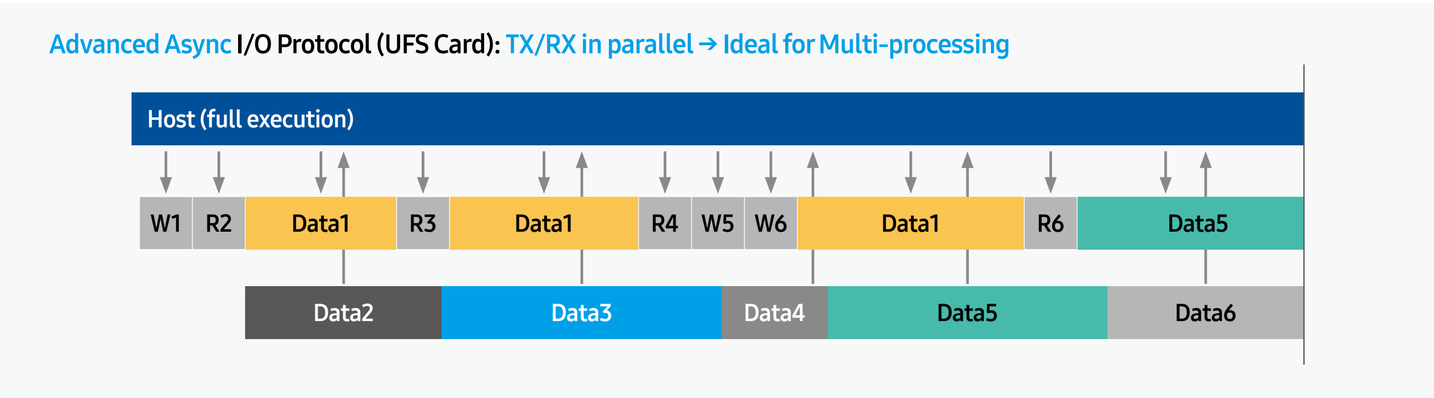


Figure 10. UFS card with advanced asynchronous queuing I/O protocol (read & write operations performed in parallel; multiple application can perform I/O for multiprocessing environments such as Android OS, Window OS, Apple iOS, etc.)

Since read and write operations can be performed in parallel on the UFS card, total throughput given to the end-user is a summation of read and write performance. This cannot be achieved in an SD card due to its fundamental single protocol architecture.

Furthermore, up to 32 commands can be queued in the UFS card. This means that a UFS card can perform out-of-order and parallel processing to maximize the system throughput.

System Architecture for UFS Card Support

Soft Migration From SD Card to UFS Card

Even though the SD card I/O architecture and performance seems to be very poor in nowadays technical point of view, SD cards are found in today's most mobile IT products. Therefore, from the moment the UFS card was designed, soft migration from the SD card to the UFS card needed to be considered. To support the migration, the overall outer dimension of the UFS card is determined to support a combo socket for both microSD card and UFS card. To avoid any electrical problem with the signal pins of the microSD card, the first row is left empty except VCC and GND, and the second row is used for the signal pins on the UFS card.

Therefore, a host device can support both a microSD card and a UFS card using just one combo slot for a soft migration from microSD card to UFS card. The reference combo socket is standardized in JEDEC as a Socket Mechanical Outline specification (SO-022A). Amphenol provides a combo socket that implements the SO-022A JEDEC standard.

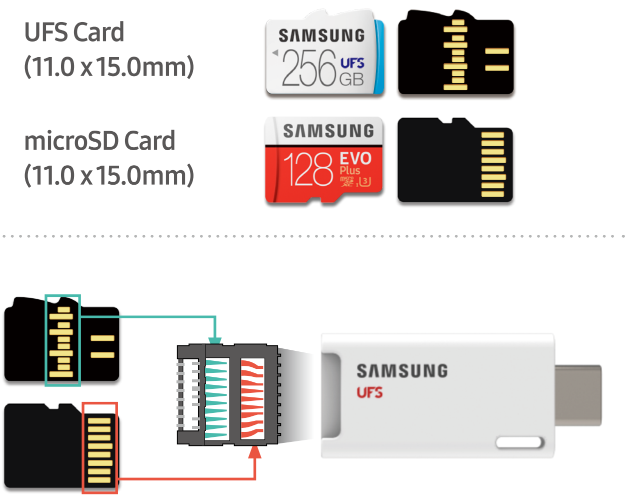


Figure 11. UFS Card Form Factor & Combo Socket

System Architecture for UFS Card Support

For the host system architect and designer, the following section provides an overview of how a UFS card supporting architecture can be designed.

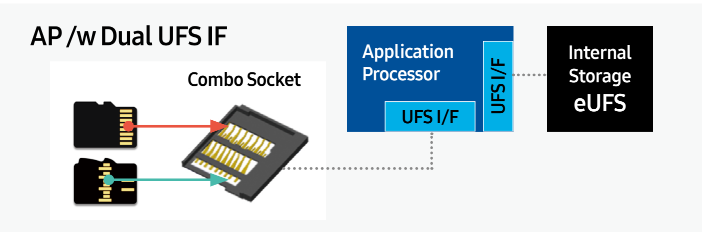


Figure 12. System Design for AP/CPU Supporting Two UFS Interfaces

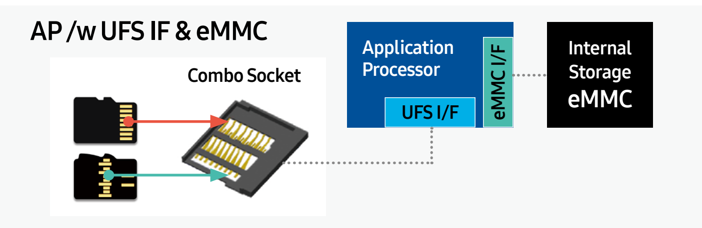


Figure 13. System Design for AP/CPU Supporting Only One UFS Interface

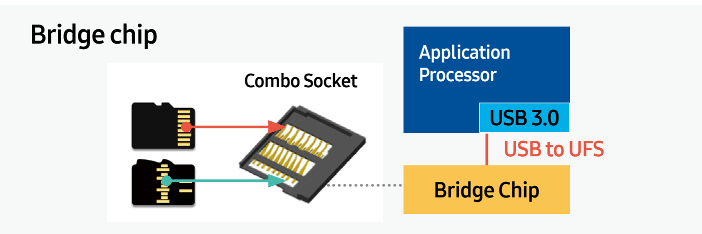


Figure 14. System Design for AP/CPU Using Bridge Chip (UFS-to/from-USB)

- **AP/CPU Supporting Two UFS Interfaces**
  With an AP/CPU supporting two UFS interfaces, one UFS interface can be used for connecting the embedded UFS and the other UFS interface can be used for connecting the UFS card. If both a microSD card and a UFS card need to be supported with a single slot,the UFS card/microSD card combo socket can be used until microSD card is phased out of the market.

- **AP/CPU Supporting Only One UFS Interface**
  Most AP/CPUs are likely to support the eMMC [1)] interface until UFS replaces eMMC completely. Therefore, the UFS interface can be used for connecting the UFS card, and the eMMC interface can be used for connecting eMMC as the embedded storage.

  1) eMMC stands for embedded MMC, which is one of the storage standards of JEDEC. eMMC has been used in mobile products, including smartphones, for more than 10 years. In 2016, JEDEC defined the UFS standard to replace the role of eMMC, in order to provide a better performance and a lower power solution.

- **AP/CPU Supporting USB interface**
  If the host device does not have any UFS interface in its AP/CPU, a Bridge Chip can be used to support the UFS card. Most AP/CPUs support multiple USB interfaces, and a Bridge Chip for UFS-to/from-USB is available in the market. For example, SMI provides a USB 3.1(5Gbps) to/from UFS Bridge Chip solution.

System Board Design Guidelines

System Board Design Guidelines for Supporting UFS Card

This section provides detailed information to board design engineers on designing system boards that support UFS cards.

- **Socket Schematic for Host Board**

  The following figure shows a recommended schematic for a UFS card, with all signal connections and passives needed. The purpose of the resistor connected on the CLK line is to reduce signal distortion and EMI by damping. The CLK as a toggle signal provides high power spectral density so the damping resistor can lower phenomena by reducing the slew rate of the CLK signal. The value can be selected between 0 and 47 Ω depending on the system environment. From a practical standpoint, if the CLK trace is routed as a strip line or at inner layer, the series damping resistance may be removed.

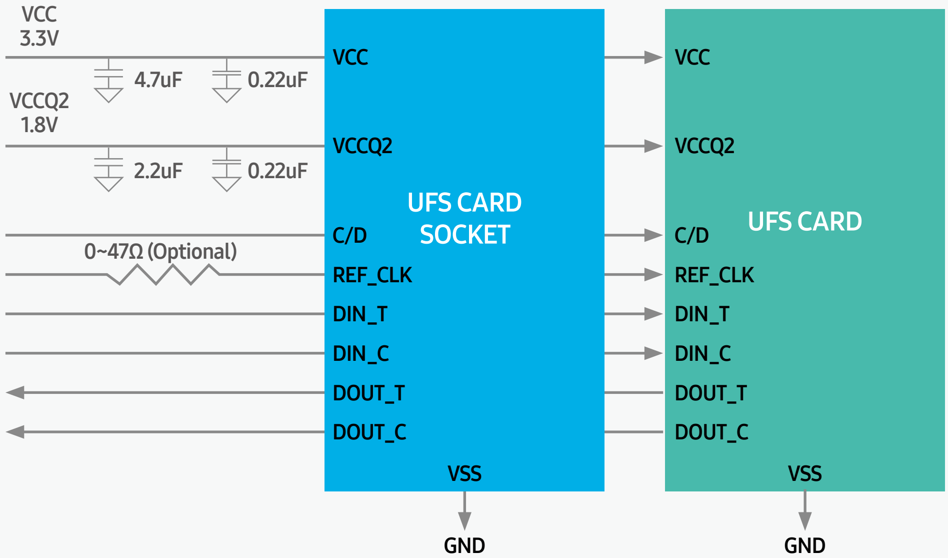


Figure 15. UFS Card Schematic with Socket

- Table 2 shows the Power Delivery Network (PDN) for supporting the UFS card. This PDN is designed to provide stable and uniform voltages for all devices. Commonly observed as a jitter or signal distortion, power noise, which is the voltage fluctuation of PDN, could significantly affect the timing and the digital signal integrity.

	1.8V(VCCQ2)	3.3V(VCC)
De-cap Combination	2.2uF + 0.22uF	4.7uF + 0.22uF
DC Resistance [1)]	<126 mΩ	<126 mΩ
AC Impedance @ 20 MHz [2)]	<126 mΩ	<126 mΩ

1) Resistance from PMIC output to UFS socket SMT pad.
2) Impedance from MLCC to UFS socket SMT pad, including the value of PCB traces

Table 2. Power Delivery Network (PDN)

System Board Design Guidelines

- **Signal Routing Guideline**
  Table 3 shows the allowable signal length depending on the UFS high-speed gear.

	HS-Gear1/2	HS-Gear3
Signal line length	<= 140 mm	<= 90 mm
Length difference between DP and DN	<= 0.5 mm	<= 0.5 mm

Table 3. Max Signal Line Length on Board

- **Socket Layout Guideline**
  A large pad size and small pad pitch will result in low differential impedance. To minimize differential impedance discontinuity (target 100ohm), copper removal beneath the socket SMT pad (only for DIN_T/C, DOUT_T/C) is required, as shown in Figure 16.
  With a normal socket SMT pad dimension, copper removal of about 300um depth (considering PCB stack-up) is recommended.

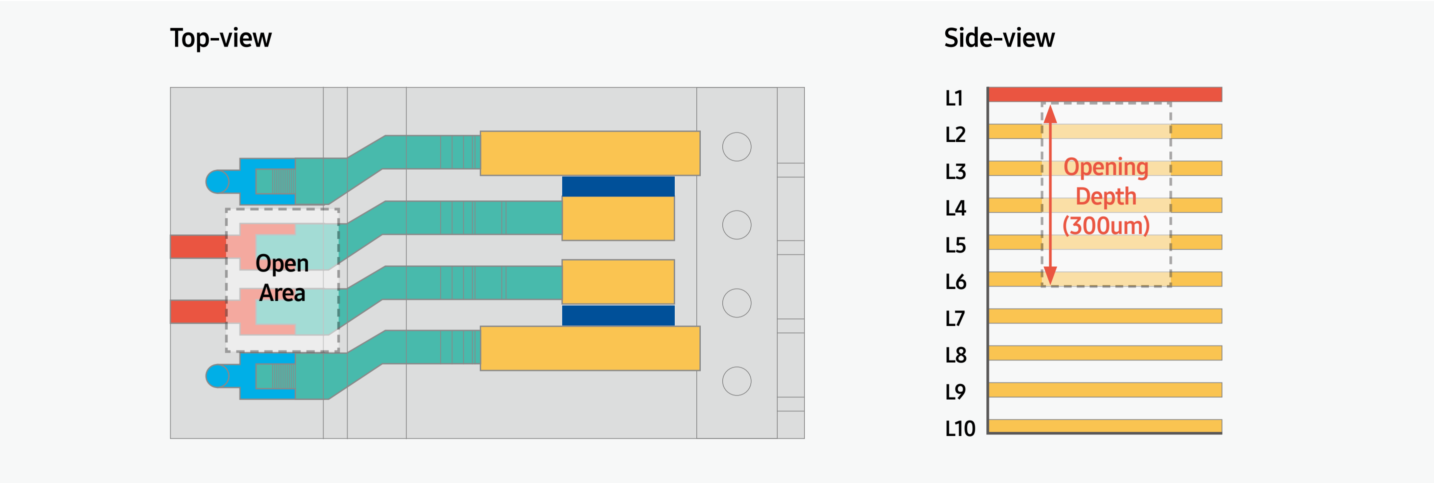


Figure 16. UFS Card Schematic with Socket

- **Electrical Characteristics (Insertion/Return loss) for UFS Card Socket**

	Requirement for UFS Socket
Rpin [1)]	<= 18 mΩ
Lpin [1)]	<= 2.32 nH
SDD11 (@6GHz)	<= -5.91 dB
SDD21 (@6GHz)	<= -2.25 dB

1) Rpin and Lpin is partial loop value from SMT pad to Card Contact.

Table 4. Recommended Electrical Characteristics for UFS Card Socket

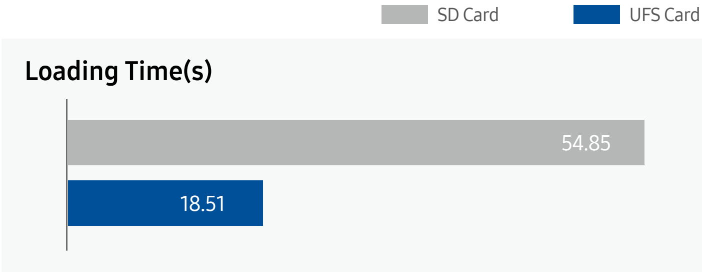
SAMSUNG

Performance Comparison

Performance Comparison between UFS Card and SD Card

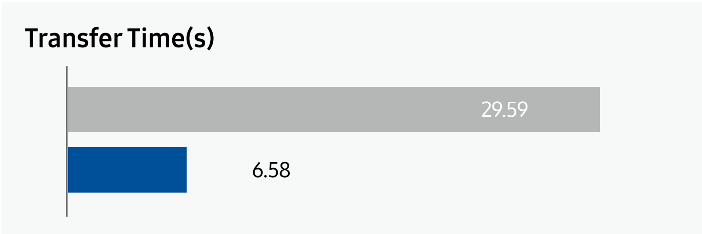
Although some software is not yet optimized for UFS card, the performance difference between SD card and UFS card is in evident across three key usage scenarios. In identical testing environments, the UFS card outperformed the SD card by up to 3 times in loading time and by up to 4.5 times in data transfer speeds.

- **[Usage Scenario #1] Transferring Large File Sizes**
  The same 4GB Adobe Photoshop file takes 54 seconds to load from a SD card, while only 18 seconds to load from a UFS card. The UFS card shows 3 times faster performance than the SD card in this usage scenario.



Usage Scenario #1. Loading of Photoshop File (4GB file size)]

- **[Usage Scenario #2] Transferring Multiple Files**
  As mobile devices continue to proliferate worldwide, consumers have a massive volume of files on their devices such as thousands of high-quality photos and HD videos in the gallery. It took a microSD card 29 seconds to transfer 1,000 files, but only 6 seconds for a UFS card, which translates into 4.8 times better performance in a sequential data reading usage scenario.



Usage Scenario #2. Transferring 1,000 files

In January 2018, JEDEC UFS v3.0 announced support of HS-Gear 4 (12 Gbps per lane). By adopting the HS-G4 in the next version of UFS card specifications, the maximum interface performance of a UFS card will reach up to 1200MB/sec from current 600MB/sec, which means performance is soon to be doubled.

Conclusion

In summary, the UFS card shows overwhelming performance enhancements, including 5 times higher sequential read performance and 70 times higher random write performance, with lower power consumption than the SD card across benchmark applications. This outstanding improvement comes from the advanced technologies included in the UFS card architecture: parallel read and write operations, queuing and out-of-order execution to maximize performance, the allowance of mixed and interleaved data transfers so applications are not blocked by I/O of other applications, lower power consumption by adopting power optimized physical layers and so on.

All of these advanced UFS technologies are ideal for multi-processing environments, including Linux, Android OS, Window OS, and Apple iOS, which are used in most smartphones and tablets, as well as VR, AR, DRON, high-end DSLR cameras and other electronic devices. Currently, there are many companies collaborating to develop the ecosystem for UFS card, providing solutions across UFS card sockets, UFS card controllers, USB-to-UFS Bridge Chips, file systems and more. Moreover, many device manufacturers are creating products that support UFS card.

The industry leading performance of the UFS card is relevant for A/I and 5G applications as well.

Annex A - UFS Top Level & System Architecture

[A-1] UFS Top Level Architecture

The UFS specification adopts MIPI MPHY and UniPro specifications as its interconnection layer. MIPI is a standard organization defining interface spec for mobile products. UPIU (UFS Protocol Interface Unit) and its communication protocol, UFS Transport Protocol (UTP), are defined on the UniPro. Some of SCSI commands are adopted as UFS commands. These commands are contained in a UPIU packet as payload to be communicated between the UFS host and UFS storage device.

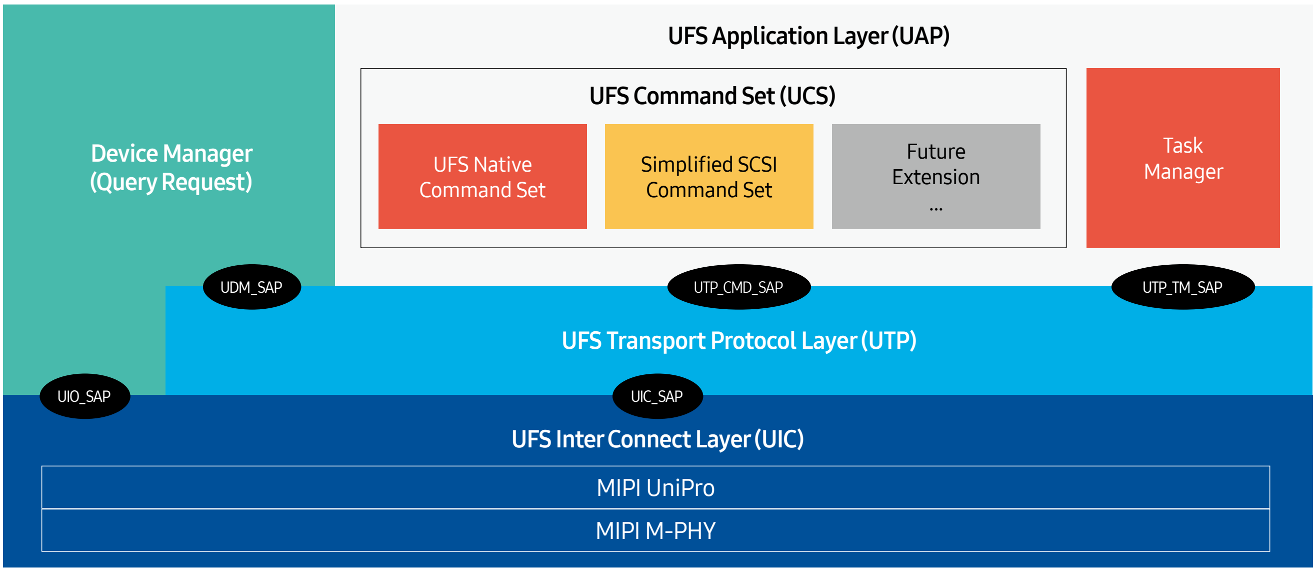


Figure 17. UFS Top Level Architecture

[A-2] UFS System Architecture

The embedded UFS card is connected with the UFS host with 4 types of pins (Reference Clk, Data-In, Data-Out, Reset) as shown below. Since Data-In, Data-Out is used in parallel, maximum throughput is the summation of maximum read performance and maximum write performance.

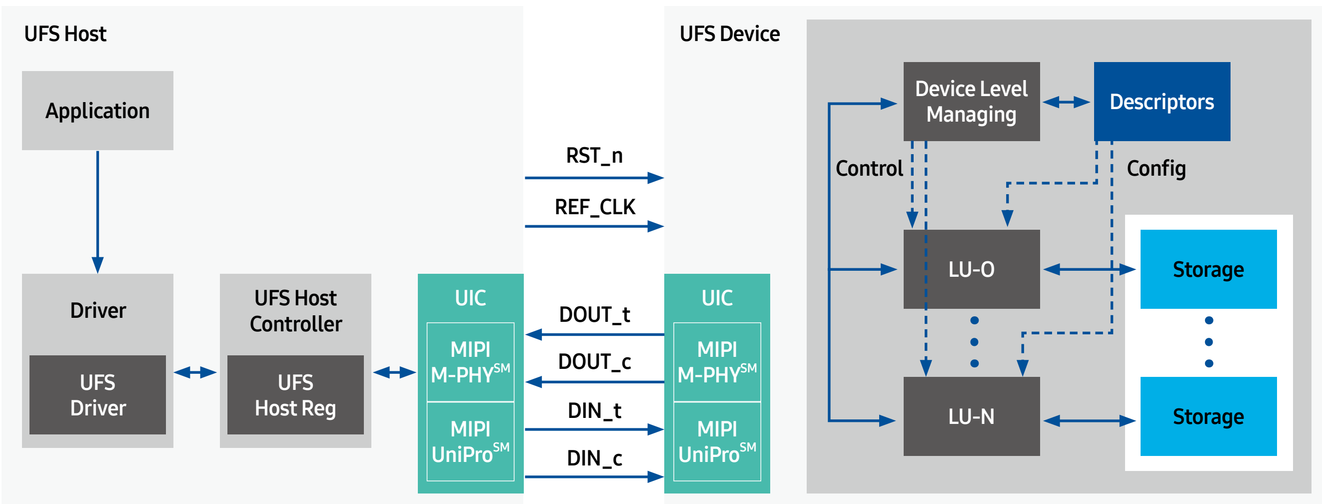


Figure18. UFS System Architecture

SAMSUNG

Annex B – UFS Card Mechanical Form Factor Standard

[B-1] UFS Card Form Factor (MO-320A)

The JEDEC published its UFS card protocol specification, JESD220-2, which is defined through the JC64.1 technical committee. The UFS card mechanical form factor specification, MO-320A, was defined through JC11 technical committee and published as well. This MO-320A specification defines detailed UFS card form factor, as well as detailed dimension information following the ASME Y14.5-2009 mechanical dimension guidelines, which could enable any company to make the same UFS card with the same physical dimensions.

This mechanical outline for the UFS card may be downloaded from the following link: https://www.jedec.org/system/files/docs/MO-320A.pdf (JEDEC log-in required for downloading).

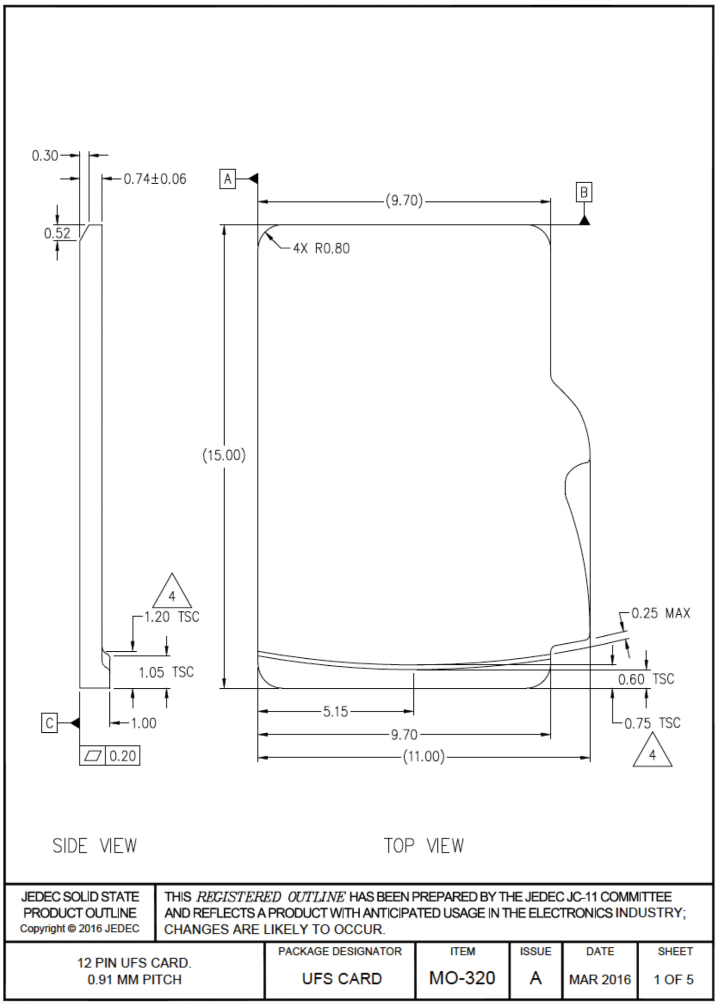


Figure 19. 12-pin UFS Card (11x15) Top/Side View

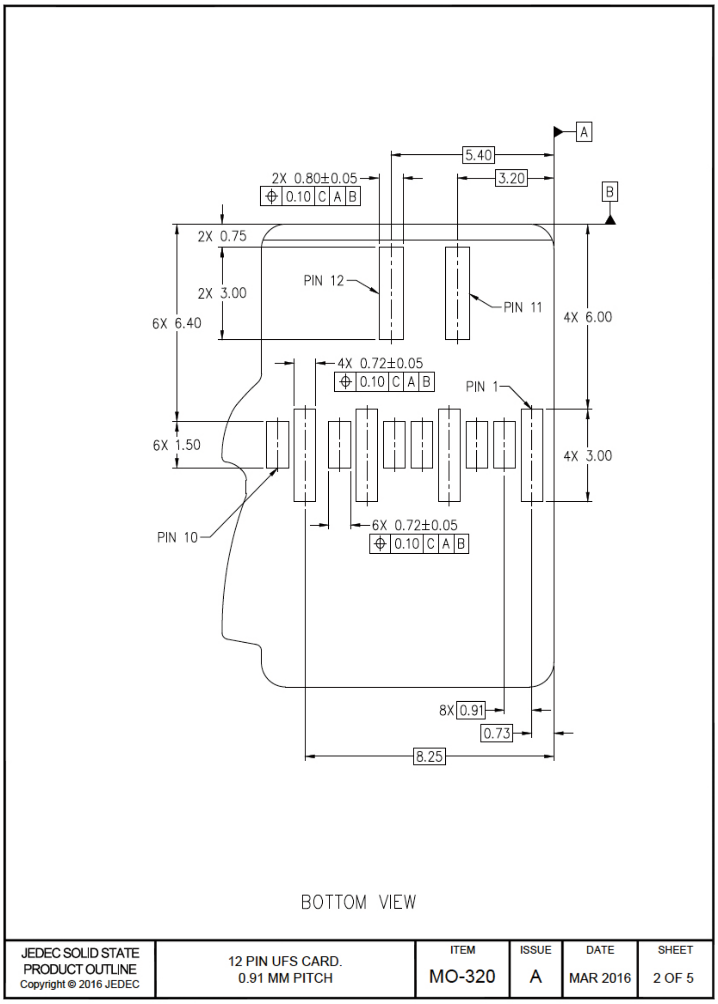


Figure 20. 12-pin UFS Card (0.91mm pitch) Bottom View

[B-2] UFS Socket Factor (SO-022)

Amphenol, a company that specializes in socket design and development, created a host side socket that is aligned to the UFS card form factor, MO-320A. Amphenol's host side socket design is published as a reference socket design aligned with UFS card form factor standard MO-320A. Socket design may vary depending on the allowed area by each smartphone OEM vendor and requirements, such as a combination of microSD and uSIM, etc. However, this standard socket (SO-022) can be used for the OEM vendor, for applications including VR, DRON, Note PC etc., which is a relatively flexible space for the socket area. OEMs can purchase this standardized host side socket and develop their host products to easily support the UFS card, which can shorten the development and production time of their products.
This reference combo socket for the UFS card may be downloaded from the following link: https://www.jedec.org/system/files/docs/SO-022A.pdf (JEDEC log-in required for downloading)

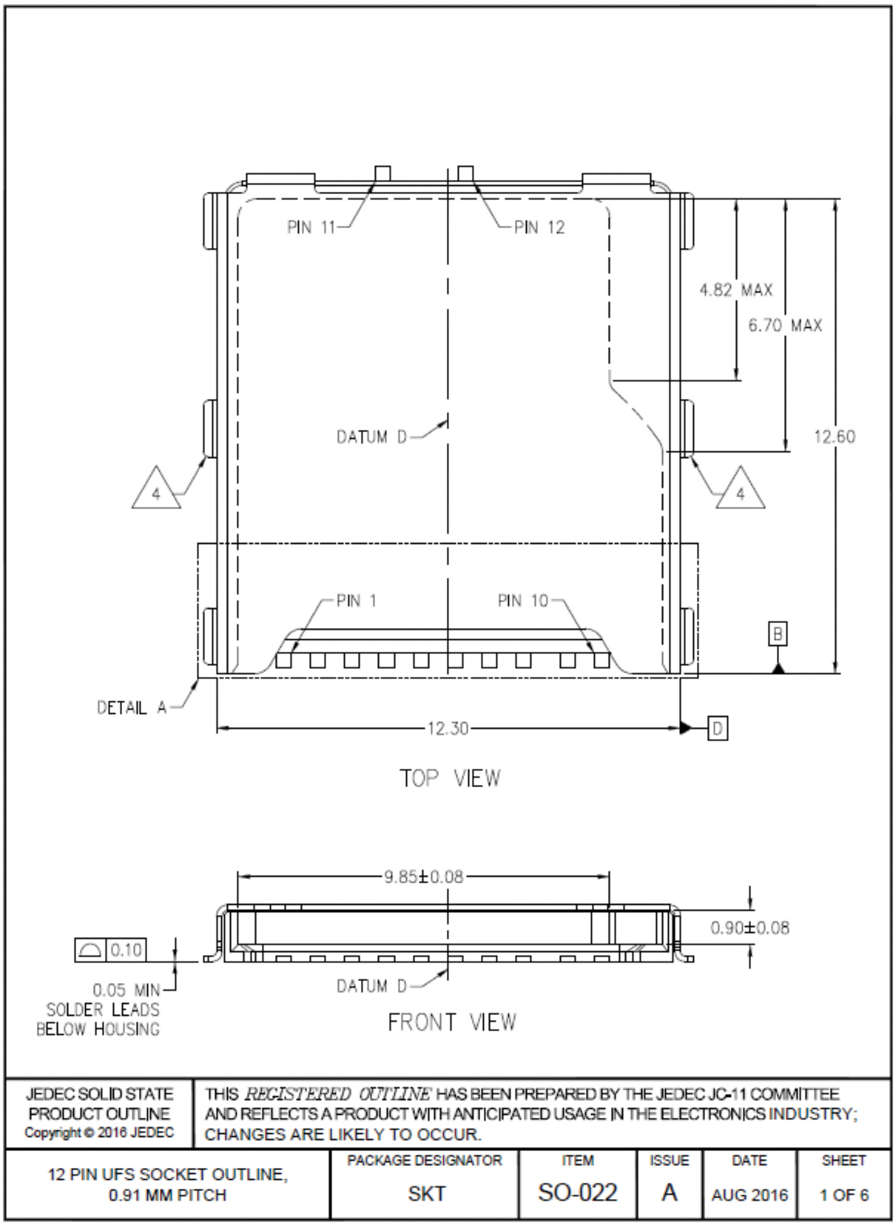


Figure 21. Reference Socket Mechanical Spec (SO-022) Aligned to UFS Card

Annex C - Industry Collaboration: JEDEC, MIPI, UFSA

[C-1] UFS Product Related Standard Organization: Role & Collaboration

UFS is strongly supported by 3 global standard organizations: JEDEC, MIPI and UFSA. The following shows the scope and relationships amongst those three standard organizations.

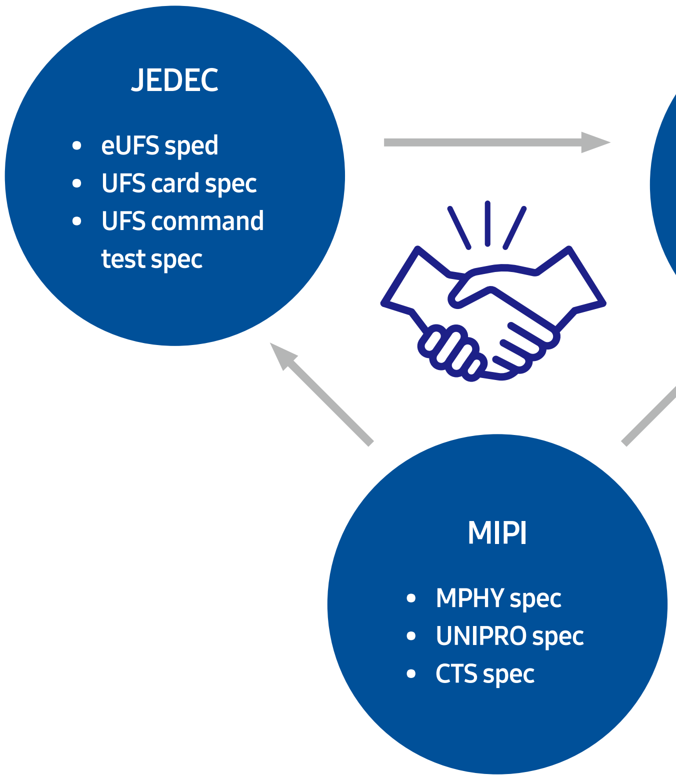


Figure 22. Three International Standard Organizations Supporting UFS & UFS Cards

JEDEC (www.jedec.org) defines industry standards related with memory and storage semiconductors, including DDR DRAM, LPDDR, GDDR, UFS, NVM future memory and more. JEDEC also provides storage standards for UFS and UFS cards, for embedded and external storage for mobile IT products.

UFSA (UFS Association, www.ufsa.org) is an industry association designed to promote UFS. For interoperability between UFS host and UFS storage devices, compliance test specifications (CTM v1.0) were published in April 2016, and are used for compliance certification programs for improving interoperability between UFS cards and UFS hosts.

MIPI (www.mipi.org) is an international standard organization that defines interfaces for mobile products. JEDEC adopted the MIPI MPHY specification and the UniPro specification as the interconnection layer of UFS. By adopting physical and link layers from professional standard organizations, UFS specification may improve more efficiently.

Annex D – UFS Card Press Release Link

[D-1] JEDEC UFS Card Publication Announcement

- http://www.jedec.org/news/pressreleases/jedec-publishes-universal-flash-storage-ufs-removable-card-standard March 30, 2016

[D-2] UFSA CTM v1.0 Compliance Test Specification

- https://ufsa.org/2016/04/usfa-rolls-out-compliance-test-matrix-for-ufs-interoperability-on-heels-of-ufs-card-standardization-by-jedec/ April 7, 2016

[D-3] Samsung UFS Card: World's First UFSA Certified Press Release (posted in UFSA)

- https://ufsa.org/2016/07/samsung-introduces-worlds-first-universal-flash-storage-ufs-removable-memory-card-line-up-offering-up-to-256-gigabyte-gb-capacity/ July, 2016

About Samsung Electronics Co., Ltd.

Samsung inspires the world and shapes the future with transformative ideas and technologies. The company is redefining the worlds of TVs, smartphones, wearable devices, tablets, digital appliances, network systems, and memory, system LSI and LED solutions. For the latest news, please visit the Samsung Newsroom at **news.samsung.com.**

Samsung Electronics Co., Ltd.
129 Samsung-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do 16677, Korea **www.samsung.com** 2018-05

SAMSUNG