

# High Performance Universal Flash Storage (UFS) Solutions

Next-generation Storage Solution

Brochure



## Key Benefits of UFS

- Low Energy Consumption
- Low Voltage Differential Signaling
- Fast Performance with High Speed Serial Interface
- Reliable advanced physical, link, and command protocol layers
- Removal storage UFS Cards with random write speeds up to 70 times faster than SD cards

## Low power, high performance, and reliable storage

Consumers today expect nearly instant access to feature-rich applications and high-quality multimedia which can sometimes be massive in size. With this around-the-clock demand for content on mobile devices, wearables, IoT devices, and automobiles, a reliable, high speed yet low power, versatile storage solution is needed.

Universal Flash Storage (UFS) is an advanced, high performance interface designed for computing and mobile systems such as smartphones and tablets where power consumption needs to be minimal. The latest UFS interface protocols are optimized for efficient throughput, system performance and reliability.

When using UFS solutions, power consumption is reduced due to the near-zero idle power level which, when combined with the Mobile Industry Processor Interface (MIPI)<sup>1</sup> power-saving specifications, significantly reduces device power consumption. UFS standards also adopt the well-known Small Computer System Interface (SCSI)<sup>2</sup> Architecture Model and command protocols that support multiple simultaneous commands and command queuing features to enable highly efficient multi-thread programming. This is a significant difference compared to legacy flash-based memory cards and embedded flash solutions which can only process individual commands, thereby limiting random read/write access performance.

The UFS card is the leading technology solution for removable storage that delivers superior sequential and random read/write performance—critical for modern connected devices storing content such as drones, 360-degree devices with multiple 4K/8K recording cameras or sensors, as well as smartphones and tablets.

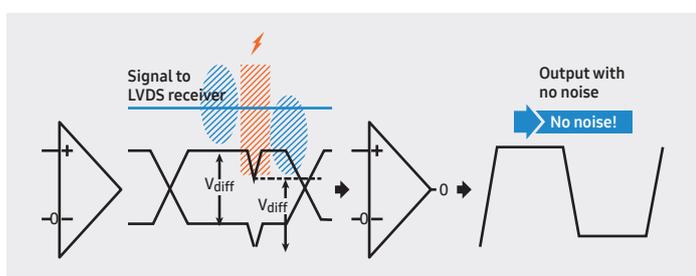
**SAMSUNG**

# UFS – A High Performance, Low Power Interface for Mobile Devices

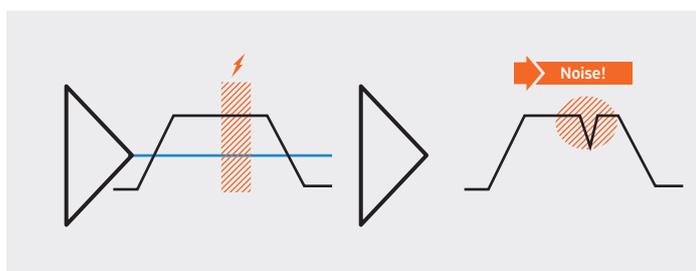
The major differences between eUFS/UFS Card over the older signaling architecture based eMMC/SD cards are its high speeds and low power serial interface with high reliability.

First, UFS serial interface uses differential signaling to provide higher noise immunity. In devices with limited power access such as mobile devices, it is crucial to use lower supply voltage to conserve power and reduce emitted electromagnetic radiation. Lowering the supply voltage, however, reduces noise immunity. To overcome this, differential signaling is used, which provides higher noise immunity compared to a single-ended system.

UFS (Serial Interface)



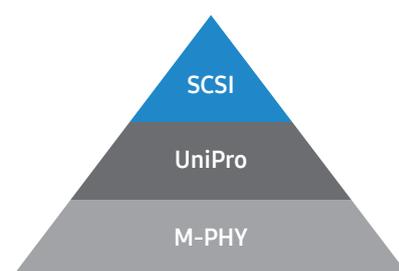
eMMC/SD (Parallel Interface)



The serial interface technology used in UFS significantly improves signal integrity, enabling high-speed signaling with low signal voltages- around 0.2 to 0.4v. Thanks to this, devices can operate at high bandwidth speeds- up to 6 Gbps for UFS Card v1.0/v1.1 and up to 12 Gbps for eUFS v2.0/2.1. The enhanced performance improves audio and video content management, high-resolution multimedia capture and download experiences, navigation responsiveness, hands-free voice commands, and can accelerate social media interplay. UFS adopts a combination of M-PHY / Unipro® physical and link layers and SCSI standard protocols, which enable a consistent and efficient error handling process—essential for next generation mobile, connected devices and in-vehicle systems.

UFS detects and recovers from I/O errors through the UniPro hardware layer automatically, and provides reliable data transmission through the M-PHY hardware layer. SCSI command protocols and architectures have evolved in various storage solutions for over 25 years, so systems built on the SCSI command protocol are stable and reliable.

Key Structure for reliability



Beginning with UFS v3.0<sup>3</sup>, UFS supports advanced data refresh and temperature notification features for superior system reliability for automotive applications.

When the device's temperature crosses the upper or lower temperature boundary, the device indicates this situation to the host automatically. If the host receives this indication, the host can lower temperatures with actions such as running a cooling fan or lowering the workload to the device. This prevents the UFS storage from crossing well-defined upper temperature boundaries, thereby allowing its NAND cells to flawlessly function within volatile temperature environments, as can be found in automotive applications.

In light of the UFS's high performance and reliability, Samsung has seen adoption in the mobile market. Samsung will continue to satisfy the growing storage needs of the industry by offering a variety of advanced UFS lineups, while more thoroughly addressing the ever-increasing demand for leading-edge memory solutions in other market segments, too.

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

<sup>2</sup> SCSI (Small Computer System interface, <http://www.t10.org/>) standards define commands, protocols, electrical, optical and logical interfaces. SCSI is most commonly used for hard disk drives and tape drives, but it can connect a wide range of other devices, including scanners and CD drives.

<sup>3</sup> UFS v3.0 specification was published in Jan. 2018. Samsung is under preparation to launch UFS v3.0 products which can be used for upcoming mobile products for the AI and 5G era.

# eUFS – An Ultra-Fast Embedded Storage Solution to Replace eMMC

Mobile CPU, GPU and networks are becoming faster with each generation. Internal storage or flash memory has become a potential bottleneck for performance. Samsung has produced the industry's first flash storage memory that adheres to the UFS v2.1 standard, promising SSD speeds with the low power consumption levels of previous eMMC. Since then, UFS has begun to replace the role of eMMC in the market.

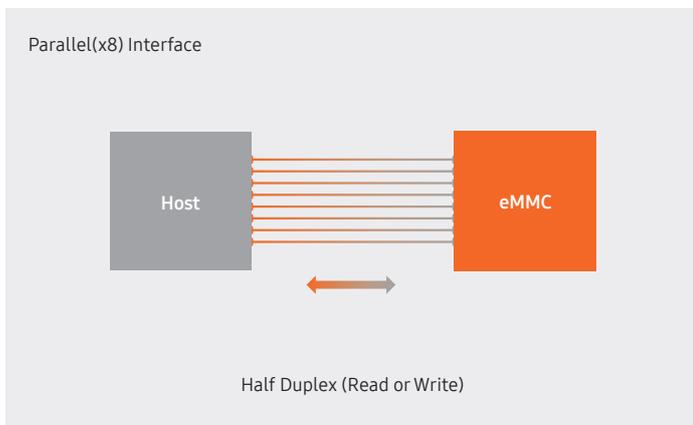
UFS improves read and write performance of flash memory in two ways. First, unlike eMMC, there are dedicated channels for reading and writing data allowing for simultaneous read/write data flow. The second advantage of UFS is Command Queuing. This is the efficient grouping and (re)ordering of read or write commands to maximize the performance throughput. With eMMC, the system was required to complete a prior command before starting the next. Although UFS's queuing mechanism is mimicked in eMMC v5.1, the final version of eMMC in JEDEC, it only imitates the queuing concept, so the actual performance gains are limited.

Compared to eMMC 5.1, sequential read is improved by 550MB/s and sequential write by 50 MB/s to 880MB/s and 200MB/s, respectively. UFS 2.1 random read and write speeds, measured in input/output operations per second (IOPS) both measure at 40,000 IOPS, a 25,500 IOPS increase in random read and a 25,600 IOPS increase in random write over eMMC 5.1 . Overall these changes in performance have a significant impact on user experience.

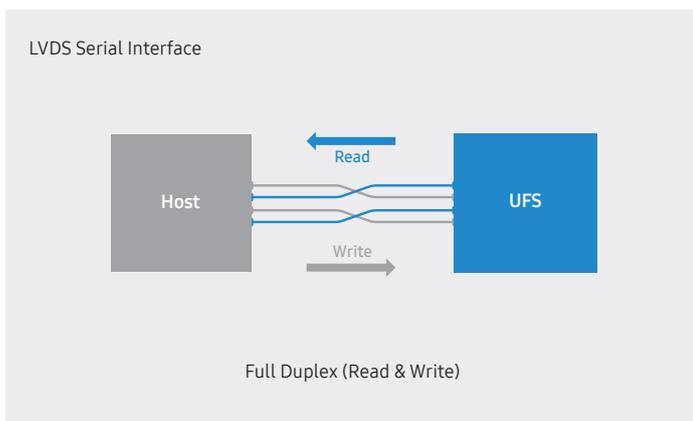
Standard	Introduced	Sequential Read (MB/s)	Sequential Write (MB/s)	Random Read (IOPS)	Random Write (IOPS)
UFS2.1	2016	880	200	40,000	40,000
UFS2.0	2014	480	170	25,000	17,700
eMMC5.1	2014	330	150	14,500	14,400
eMMC5.0	2013	260	140	6,500	13,000

Note) Performance Measurement density : 128 GB

## eMMC



## UFS



To maximize performance and energy efficiency, Samsung integrated proprietary technologies: the 64-layer 512 Gb V-NAND advanced circuit design. This is an advanced power management technology built to minimize energy consumed despite the 512 GB eUFS containing double the cells of the 256 GB and, featured in the 512 GB eUFS, a new controller chip to accelerate the mapping process when converting logical block addresses to physical blocks.

# UFS Card – A Memory Card up to 70 Times Faster than SD Cards

## High Speed External Storage Memory Card

The Samsung UFS Card is specifically designed for advanced applications that require fast and large external storage for content such as 4K/8K video recording, 360-degree VR, RAW images and high-end mobile devices.

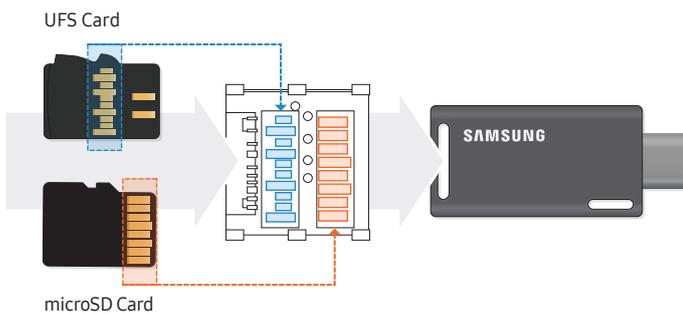
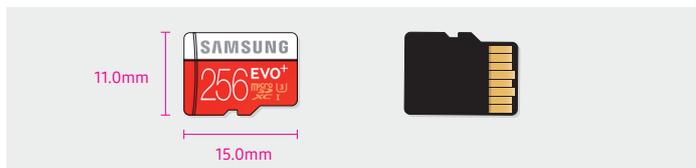
Since the JEDEC UFS v1.0 Card specification release in March of 2016, Samsung acquired the world's first certification of UFSA in 2016. After the release of the UFS v1.1 specification in January 2018 by JEDEC and certification of the CTM v1.3 specification by UFSA, Samsung passed the compliance certification from UFSA with the newly developed UFS card supporting the UFS Card v1.1 specification.

Samsung's UFS Card supports a sequential data transfer speed of up to 500 MB/s—comparable in speed to a SATA3 SSD. The UFS Card has a similar form factor to the standard microSD (11x15mm) and is designed so that both UFS Card and microSD cards can be used in a single combo socket. The UFS Card form factor is designed using the concept of a shark's fin, and the pins are carefully allocated to avoid any electrical issues with microSD cards when a combo socket is adopted into a device.

### UFS Card

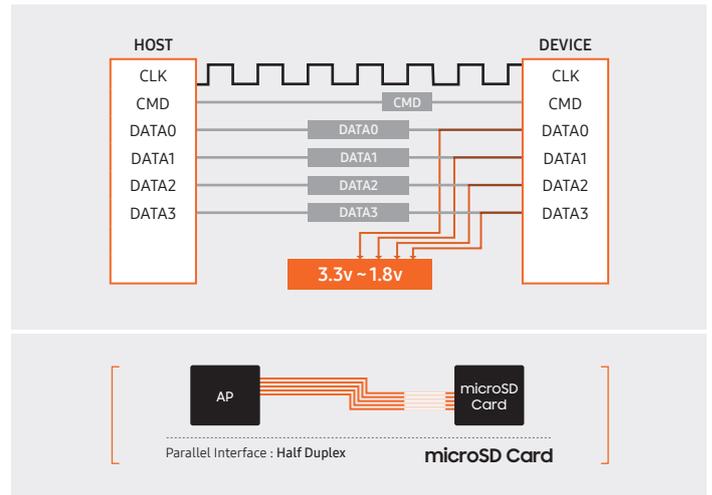


### microSD Card

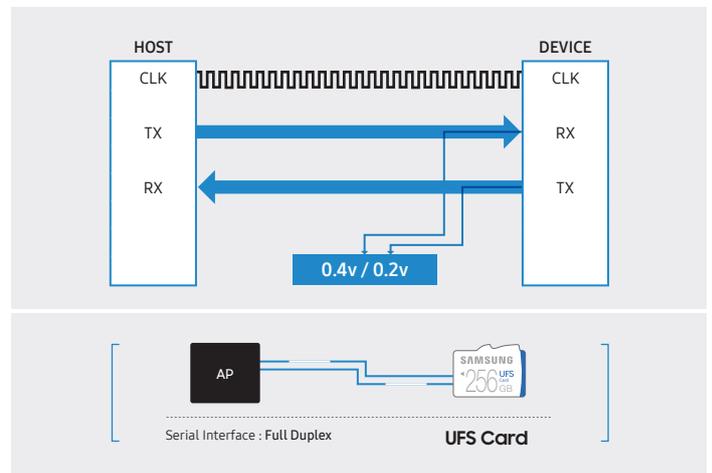


A UFS Card supports high speed serial interface and separated TX/RX lanes to allow simultaneous data transmission between the host system and UFS storage device for higher efficiency multitasking.

### SD Card I/F (Low Speed Parallel interface)



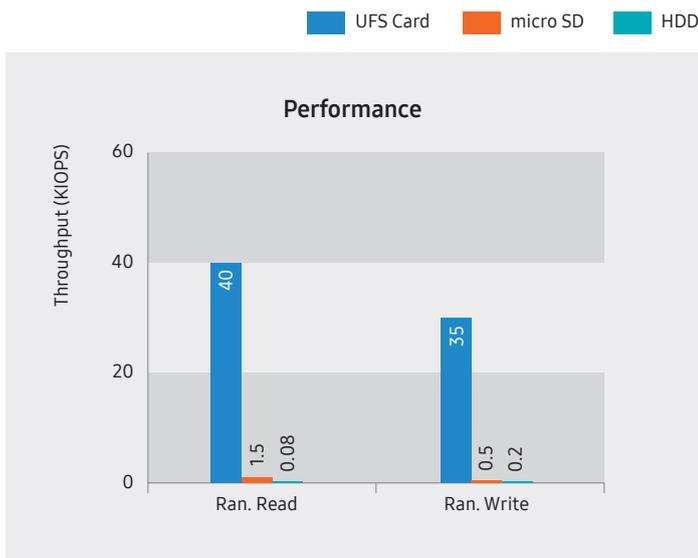
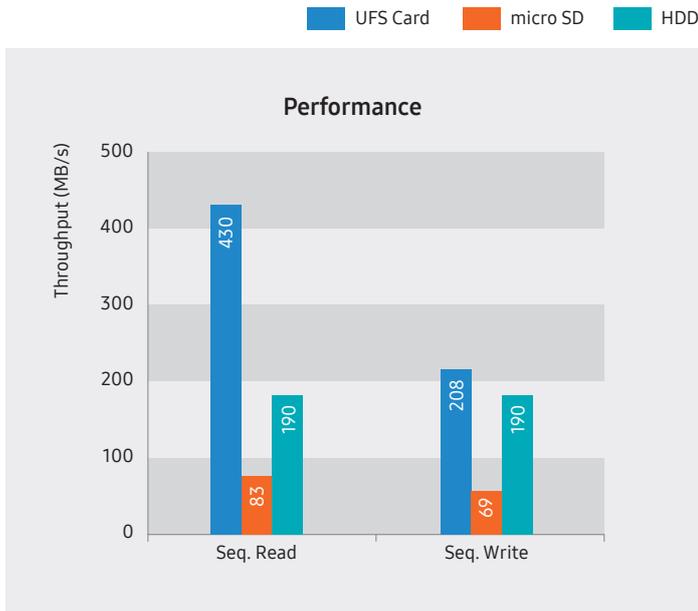
### UFS Card I/F (High Speed Serial interface)



According to performance measurements using Crystal Disk Mark, in the same hardware environments, the sequential read performance related to tasks such as fast booting and fast game loading shows 5 times faster speeds than the SD card.

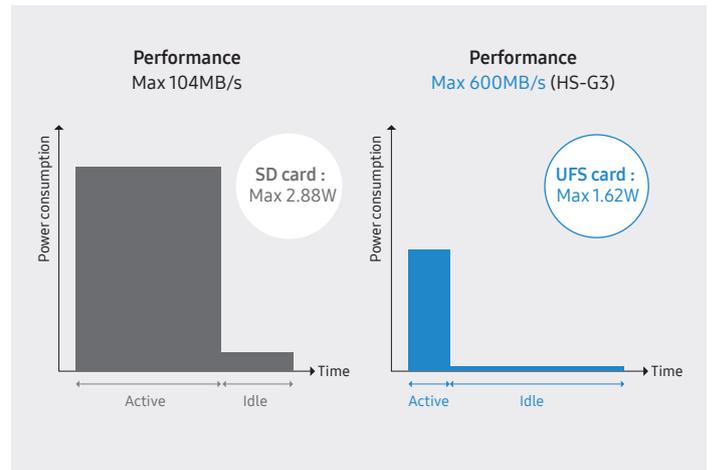
In the case of random read/write performance, which is related to many apps running in parallel similar to modern smartphone environments, up to 25 and 70 times higher performance was observed, respectively.

# UFS Card



Commands and data signals of SD cards require 3.3V at the initialization stage and 1.8V for read/write operations. An SD card uses 6 signals at 1.8V (4 data signals, 1 command signal, 1 clock signal) which consumes a large amount of power.

On the other hand, a UFS card uses 0.2V or 0.4V for one pair of differential signals, which can dramatically reduce power consumption as well. As a result, while providing extremely higher performance, the maximum power consumption of the UFS card is only 60% of the SD card. From the perspective of power efficiency, power consumption while transferring the same amount of data is x10 times better with the UFS card than the SD card.



Samsung provides 3 densities for its UFS Card lineup: 64GB, 128GB and 256GB. Depending on market requirements, higher densities like 512GB or higher could be supplied in the future. Samsung UFS Card supports the UFS Card v1.1 specification which was revised in January 2018. (UFS Card v1.1 is based on UFS v2.1 specification, so most of the features supported in UFS v2.1 are supported.)

## Samsung UFS Card Technical Specification

Form Factor	11 x 15 x 1.0 mm
Capacity	64 GB, 128 GB, 256 GB
Host Interface	UFS v1.1, Gear3 x 1Lane
NAND Flash	Samsung 4 <sup>th</sup> Gen V-NAND
Sequential R/W (MB/s)	Up to 500 / 200
Random R/W (IOPS)	Up to 40K / 35K

\* The test result can be affected by many factors including OS, CPU, file system, data pattern and so on.

# uMCP- A One-Chip Solution Embedding UFS and DRAM

Before UFS was developed, eMCP, a one-chip solution embedding eMMC and mobile DRAM, had been used in most mobile products. However, the performance of eMCP based on eMMC is not enough considering the era of AI and 5G networks.

As mentioned previously, UFS is replacing eMMC with its superior performance and lower power consumption than eMMC, so the industry is demanding a one chip solution with UFS technology.

The Samsung flagship GX128.48 uMCP is among the highest capacities available and unifies DRAM and NAND flash technology into a single low-profile, small-form-factor package while incorporating 128 GB of UFS-based fourth-generation NAND flash storage and 6 GB LPDDR4X DRAM.

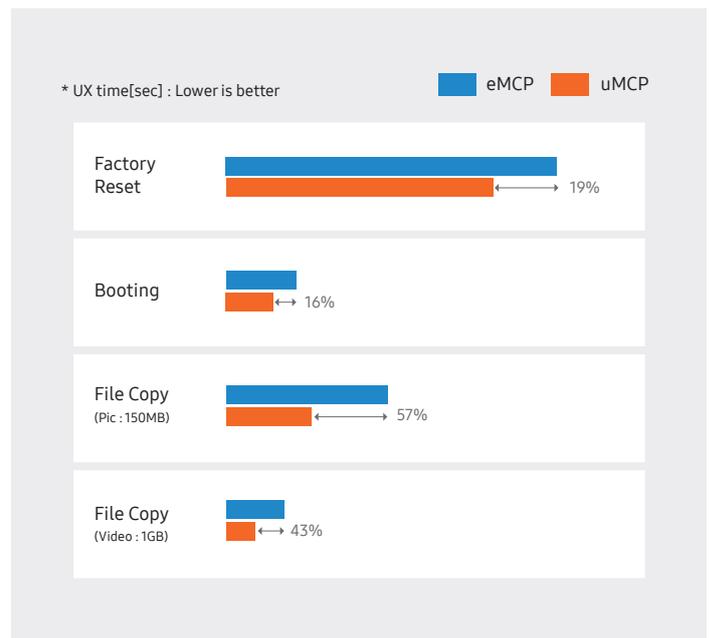
Using Samsung's industry-leading 18nm process technology, the GX128.48 uMCP is 17% thinner than previous generation eMCPs and measures 11.5 x 13 x 1.2mm which provides high capacity on a small PCB real estate.

The following are performance comparisons between uMCP and eMCP for three UX scenarios.

- 1) **Factory Reset** is the process to reset a device to default settings.
- 2) **Booting time** is the amount of time it takes for the initial screen to appear.

### 3) File Copy tests two scenarios:

- a) Copying 1000 photos totaling 150 MB, which discloses the device's real random read/write performance. uMCP-based host users can save their time up to 57% versus an eMCP-based host
- b) Copying a 1 GB video file, which discloses the device's real sequential read/write performance. uMCP-based host users can save up to 43% more time than an eMCP-based host.



## For more information

For more information about Samsung UFS, visit [www.samsung.com/semiconductor](http://www.samsung.com/semiconductor)

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