[Template:Other uses](/wiki/Template:Other_uses" \o "Template:Other uses) [Template:Use mdy dates](/wiki/Template:Use_mdy_dates) [thumb|upright=1.4|right|A size comparison of an mSATA](/wiki/File:M.2_and_mSATA_SSDs_comparison.jpg) [SSD](/wiki/Solid-state_drive) (left) and an M.2 2242 SSD (right)

**M.2**, formerly known as the **Next Generation Form Factor** (**NGFF**), is a specification for internally mounted computer [expansion cards](/wiki/Expansion_card) and associated connectors. It replaces the [mSATA](/wiki/MSATA) standard, which uses the [PCI Express Mini Card](/wiki/PCI_Express_Mini_Card) physical card layout and connectors. M.2's more flexible physical specification allows different module widths and lengths, and, paired with the availability of more advanced [interfacing](/wiki/Interface_(computing)) features, makes the M.2 more suitable than mSATA for [solid-state storage](/wiki/Solid-state_storage) applications in general and particularly for the use in small devices such as [ultrabooks](/wiki/Ultrabook) or [tablets](/wiki/Tablet_computer).[[1]](#cite_note-1)[[2]](#cite_note-2)[[3]](#cite_note-3) [Computer bus](/wiki/Computer_bus) interfaces provided through the M.2 connector are [PCI Express 3.0](/wiki/PCI_Express 3.0) (up to four [lanes](/wiki/PCI_Express_lane)), [Serial ATA 3.0](/wiki/Serial_ATA 3.0), and [USB 3.0](/wiki/USB 3.0) (a single logical port for each of the latter two). It is up to the manufacturer of the M.2 host or device to select which interfaces are to be supported, depending on the desired level of host support and device type. The M.2 connector has different keying notches that denote various purposes and capabilities of M.2 hosts and modules, preventing plugging of M.2 modules into feature-incompatible host connectors.[[1]](#cite_note-1)[[2]](#cite_note-2)[[4]](#cite_note-4) In addition to supporting legacy [Advanced Host Controller Interface](/wiki/Advanced_Host_Controller_Interface) (AHCI) at the logical interface level, M.2 specification also supports [NVM Express](/wiki/NVM_Express) (NVMe) as the logical device interface for M.2 PCI Express [SSDs](/wiki/Solid-state_drive). While the support for AHCI ensures software-level backward compatibility with legacy SATA devices and legacy [operating systems](/wiki/Operating_system), NVM Express is designed to fully utilize the capability of high-speed PCI Express storage devices to perform many [I/O](/wiki/I/O) operations [in parallel](/wiki/Parallelism_(computing)).[[1]](#cite_note-1)[Template:Rp](/wiki/Template:Rp)[[5]](#cite_note-5)

## Contents

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## Features[[edit](/index.php?title=(none)&action=edit&section=1)]

[thumb|right|upright=1.9|A high-level overview of the](/wiki/File:SATA_Express_interface.svg) [SATA Express](/wiki/SATA_Express) software architecture, which also applies to M.2.[[1]](#cite_note-1)[Template:Rp](/wiki/Template:Rp) It supports both legacy SATA and PCI Express storage devices, with [AHCI](/wiki/AHCI) and [NVMe](/wiki/NVMe) as the logical device interfaces.[[5]](#cite_note-5)[Template:Rp](/wiki/Template:Rp)

[Buses](/wiki/Bus_(computing)) exposed through the M.2 connector are [PCI Express](/wiki/PCI_Express) 3.0, [Serial ATA](/wiki/Serial_ATA) (SATA) 3.0 and [USB](/wiki/USB) 3.0, which is [backward compatible](/wiki/Backward_compatible) with USB 2.0. As a result, M.2 modules can integrate multiple functions, including the following device classes: [Wi-Fi](/wiki/Wi-Fi), [Bluetooth](/wiki/Bluetooth), [satellite navigation](/wiki/Satellite_navigation), [near field communication](/wiki/Near_field_communication) (NFC), [digital radio](/wiki/Digital_radio), [Wireless Gigabit Alliance](/wiki/Wireless_Gigabit_Alliance) (WiGig), [wireless WAN](/wiki/Wireless_WAN) (WWAN), and [solid-state drives](/wiki/Solid-state_drive) (SSDs).[[6]](#cite_note-6) The [SATA revision 3.2](/wiki/SATA_3.2) specification, in its gold revision [Template:As of](/wiki/Template:As_of), standardizes the M.2 as a new format for storage devices and specifies its hardware layout.[[1]](#cite_note-1)[Template:Rp](/wiki/Template:Rp)[[7]](#cite_note-7) The M.2 specification provides up to four [PCI Express lanes](/wiki/PCI_Express_lane) and one logical [SATA 3.0](/wiki/SATA 3.0) (6 Gbit/s) port, and exposes them through the same connector so both PCI Express and SATA storage devices may exist in form of M.2 modules. Exposed PCI Express lanes provide a pure PCI Express connection between the host and storage device, with no additional layers of [bus](/wiki/Bus_(computing)) abstraction.[[8]](#cite_note-8) [PCI-SIG](/wiki/PCI-SIG) M.2 specification, in its revision 1.0 [Template:As of](/wiki/Template:As_of), provides detailed M.2 specifications.[[1]](#cite_note-1)[Template:Rp](/wiki/Template:Rp)[[9]](#cite_note-9) There are three options available for the logical device interfaces and command sets used for interfacing with M.2 storage devices, which may be used depending on the type of M.2 storage device and available [operating system](/wiki/Operating_system) support:[[1]](#cite_note-1)[Template:Rp](/wiki/Template:Rp)[[5]](#cite_note-5)[[8]](#cite_note-8)

Legacy SATA

Used for SATA SSDs, and interfaced through the AHCI driver and legacy SATA 3.0 (6 Gbit/s) port exposed through the M.2 connector.

PCI Express using AHCI

Used for PCI Express SSDs and interfaced through the [AHCI](/wiki/AHCI) driver and provided PCI Express lanes, providing [backward compatibility](/wiki/Backward_compatibility) with widespread SATA support in operating systems at the cost of not delivering optimal performance by using AHCI for accessing PCI Express SSDs. AHCI was developed back at the time when the purpose of a [host bus adapter](/wiki/Host_bus_adapter) (HBA) in a system was to connect the CPU/memory subsystem with a much slower storage subsystem based on rotating [magnetic media](/wiki/Magnetic_storage); as a result, AHCI has some inherent [inefficiencies](/wiki/NVMe_vs_AHCI) when applied to SSD devices, which behave much more like [DRAM](/wiki/DRAM) than like spinning media.

PCI Express using NVMe

Used for PCI Express SSDs and interfaced through the [NVMe](/wiki/NVMe) driver and provided PCI Express lanes, as a high-performance and scalable host controller interface designed and optimized especially for interfacing with PCI Express SSDs. NVMe has been designed from the ground up, capitalizing on the low latency and [parallelism](/wiki/Parallelism_(computing)) of PCI Express SSDs, and complementing the parallelism of contemporary CPUs, platforms and applications. At a high level, primary [advantages of NVMe over AHCI](/wiki/NVMe_vs_AHCI) relate to NVMe's ability to exploit parallelism in host hardware and software, based on its design advantages that include data transfers with fewer stages, greater depth of [command queues](/wiki/Command_queue), and more efficient [interrupt](/wiki/Interrupt) processing.

## {{Anchor|FORM-FACTORS|KEYING}}Form factors and keying[[edit](/index.php?title=(none)&action=edit&section=2)]

[thumb|right|upright=1.5|An M.2 socket on a](/wiki/File:M.2_connector_on_a_computer_motherboard.jpg) [computer motherboard](/wiki/Computer_motherboard), visible in the upper-left portion of the picture. The socket is keyed in the M position and provides two positions for the mounting screw, accepting 2260 and 2280 sizes of M.2 modules.

The M.2 standard has been designed as a revision and improvement to the [mSATA](/wiki/MSATA) standard, with the possibility of larger [printed circuit boards](/wiki/Printed_circuit_board) (PCBs) as one of its primary incentives. While the mSATA took advantage of the existing [PCI Express Mini Card](/wiki/PCI_Express_Mini_Card) (Mini PCIe) [form factor](/wiki/Form_factor_(design)) and connector, M.2 has been designed from the ground up to maximize usage of the PCB space while minimizing the module footprint. As the result of the M.2 standard allowing longer modules and double-sided component population, M.2 [SSD](/wiki/SSD) devices can provide larger storage capacities and can also double the storage capacity within the footprints of mSATA devices.[[1]](#cite_note-1)[Template:Rp](/wiki/Template:Rp)[[3]](#cite_note-3)[[10]](#cite_note-10) M.2 modules are rectangular, with an [edge connector](/wiki/Edge_connector) on one side (75 positions with up to 67 pins, 0.5 mm pitch, pins overlap on different sides of the PCB), and a semicircular mounting hole at the center of the opposite edge. Each pin on the connector is rated for up to 50 [V](/wiki/Volt) and 0.5 [A](/wiki/Ampere), while the connector itself is specified to endure up to 60 mating cycles. The M.2 standard allows module widths of 12, 16, 22 and 30 mm, and lengths of 16, 26, 30, 38, 42, 60, 80 and 110 mm. Initial line-up of the commercially available M.2 expansion cards is 22 mm wide, with varying lengths of 30, 42, 60, 80 and 110 mm.[[2]](#cite_note-2)[[4]](#cite_note-4)[[11]](#cite_note-11)[[12]](#cite_note-12) An M.2 module is installed into a mating connector provided by the host's circuit board, and a single mounting screw secures the module into place. Components may be mounted on either side of the module, with the actual module type limiting how thick the components can be; the maximum allowable thickness of components is 1.5 mm per side. Different host-side connectors are used for single- and double-sided M.2 modules, providing different amounts of space between the M.2 expansion card and the host's PCB.[[3]](#cite_note-3)[[4]](#cite_note-4)[[11]](#cite_note-11) Circuit boards on the hosts are usually designed to accept multiple lengths of M.2 modules, which means that the sockets capable of accepting longer M.2 modules usually also accept shorter ones by providing different positions for the mounting screw.[[13]](#cite_note-13)[[14]](#cite_note-14)

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|  |  |  |
| --- | --- | --- |
| M.2 module keying and provided interfaces[[4]](#cite_note-4)[Template:Rp](/wiki/Template:Rp)[[11]](#cite_note-11)[Template:Rp](/wiki/Template:Rp)[[15]](#cite_note-15) | | |
| **Key ID** | **Notched pins** | **Provided interfaces** |
| A | 8–15 | [PCIe](/wiki/PCIe) ×2, USB 2.0, [I2C](/wiki/I2C) and [DP](/wiki/DisplayPort) ×4 |
| B | 12–19 | PCIe ×2, SATA, USB 2.0 and 3.0, audio, [UIM](/wiki/User_identity_module), [HSIC](/wiki/HSIC), [SSIC](/wiki/SSIC), I2C and [SMBus](/wiki/SMBus) |
| C | 16–23 | Reserved for future use |
| D | 20–27 |
| E | 24–31 | PCIe ×2, USB 2.0, I2C, [SDIO](/wiki/Secure_Digital_Input_Output), [UART](/wiki/UART) and [PCM](/wiki/I2S) |
| F | 28–35 | Future Memory Interface (FMI) |
| G | 39–46 | Reserved for custom use (unused in the M.2 specification) |
| H | 43–50 | Reserved for future use |
| J | 47–54 |
| K | 51–58 |
| L | 55–62 |
| M | 59–66 | PCIe ×4, SATA and SMBus |

[Template:Col-break](/wiki/Template:Col-break)

|  |  |  |
| --- | --- | --- |
| Maximum component thickness on M.2 modules[[4]](#cite_note-4)[Template:Rp](/wiki/Template:Rp)[[11]](#cite_note-11)[Template:Rp](/wiki/Template:Rp) | | |
| **Type ID** | **Top side** | **Bottom side** |
| S1 | 1.20 mm | [Template:N/A](/wiki/Template:N/A) |
| S2 | 1.35 mm | [Template:N/A](/wiki/Template:N/A) |
| S3 | 1.50 mm | [Template:N/A](/wiki/Template:N/A) |
| D1 | 1.20 mm | 1.35 mm |
| D2 | 1.35 mm | 1.35 mm |
| D3 | 1.50 mm | 1.35 mm |
| D4 | 1.50 mm | 0.70 mm |
| D5 | 1.50 mm | 1.50 mm |

[Template:Col-end](/wiki/Template:Col-end)

[thumb|upright=1.8|right|M.2 keying notches in B and M positions; overlapping of the pins on different sides of an M.2 module is also visible.](/wiki/File:M2_Edge_Connector_Keying.svg)[[16]](#cite_note-16)

PCB of an M.2 module provides a 75-position edge connector; depending on the type of module, certain pin positions are removed to present one or more keying notches. Host-side M.2 connectors (sockets) may populate one or more mating key positions, determining the type of modules accepted by the host; [Template:As of](/wiki/Template:As_of), host-side connectors are available with only one mating key position populated (either B or M).[[4]](#cite_note-4)[[11]](#cite_note-11)[[16]](#cite_note-16) Furthermore, M.2 sockets keyed for SATA or two PCI Express lanes (PCIe ×2) are referred to as "socket 2 configuration" or "socket 2", while the sockets keyed for four PCI Express lanes (PCIe ×4) are referred to as "socket 3 configuration" or "socket 3".[[1]](#cite_note-1)[Template:Rp](/wiki/Template:Rp)[[17]](#cite_note-17) For example, M.2 modules with two notches in B and M positions use up to two PCI Express lanes and provide broader compatibility at the same time, while the M.2 modules with only one notch in the M position use up to four PCI Express lanes; both examples may also provide SATA storage devices. Similar keying applies to M.2 modules that utilize provided USB 3.0 connectivity.[[4]](#cite_note-4)[[16]](#cite_note-16)[[18]](#cite_note-18) Various types of M.2 devices are denoted using the "WWLL-HH-K-K" or "WWLL-HH-K" naming schemes, in which "WW" and "LL" specify the module width and length in millimeters, respectively. The "HH" part specifies, in an encoded form, whether a module is single- or double-sided, and the maximum allowed thickness of mounted components; possible values are listed in the right table above. Module keying is specified by the "K-K" part, in an encoded form using the key IDs from the left table above; it can also be specified as "K" only, if a module has only one keying notch.[[4]](#cite_note-4)[[11]](#cite_note-11) Beside socketed modules, the M.2 standard also includes the option for having permanently [soldered](/wiki/Soldering) single-sided modules.[[11]](#cite_note-11)

## See also[[edit](/index.php?title=(none)&action=edit&section=3)]

[Template:Portal](/wiki/Template:Portal)

* [List of device bandwidths](/wiki/List_of_device_bandwidths)
* [Solid-state drive configurations](/wiki/Solid-state_drive_configurations)

## References[[edit](/index.php?title=(none)&action=edit&section=4)]

[Template:Reflist](/wiki/Template:Reflist)

## External links[[edit](/index.php?title=(none)&action=edit&section=5)]

[Template:Commons category](/wiki/Template:Commons_category)

* Official [Template:Official website](/wiki/Template:Official_website) (SATA-IO) website
* Official [Template:Official website](/wiki/Template:Official_website) (PCI-SIG) website
* [Understanding M.2, the interface that will speed up your next SSD](http://arstechnica.com/gadgets/2015/02/understanding-m-2-the-interface-that-will-speed-up-your-next-ssd/), [Ars Technica](/wiki/Ars_Technica), February 9, 2015, by Andrew Cunningham
* [Samsung XP941 M.2 PCIe SSD Review (512 GB)](http://www.thessdreview.com/our-reviews/samsung-xp941-m-2-pcie-ssd-review-512gb/), September 22, 2013, by Les Tokar
* [LFCS: Preparing Linux for nonvolatile memory devices](https://lwn.net/Articles/547903/), [LWN.net](/wiki/LWN.net), April 19, 2013, by Jonathan Corbet
* [PCIe SSD 101: An Overview of Standards, Markets and Performance](http://web.archive.org/web/20140202110152/http://www.snia.org/sites/default/files/SNIASSSIPCIe101WhitePaper1.12013.pdf), [SNIA](/wiki/Storage_Networking_Industry_Association), August 2013, archived from the original on February 2, 2014
* [Template:YouTube](/wiki/Template:YouTube), November 18, 2013
* [Template:US patent](/wiki/Template:US_patent)[Template:Snd](/wiki/Template:Snd) US patent 20130294023, November 7, 2013, assigned to Raphael Gay

[Template:Computer-bus](/wiki/Template:Computer-bus) [Template:Solid-state drive](/wiki/Template:Solid-state_drive)

[Category:2013 introductions](/wiki/Category:2013_introductions) [Category:Computer connectors](/wiki/Category:Computer_connectors) [Category:M.2](/wiki/Category:M.2) [Category:Motherboard expansion slot](/wiki/Category:Motherboard_expansion_slot) [Category:SATA Express](/wiki/Category:SATA_Express) [Category:Serial ATA](/wiki/Category:Serial_ATA)