SSD Buying Guide

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Note: drives are not in any particular order, but are same-line for similar hardware

DESKTOP/LAPTOP USE

In most cases and for most users a SATA SSD will be sufficient for everyday use. The NVMe protocol has many advantages, for example better efficiency with less overhead, but these performance benefits are minor for the average user. Both SATA (AHCI) and NVMe drives come in the M.2 form factor although some M.2 sockets only support one protocol or the other. A SSD, regardless of type, is in general a huge upgrade from a mechanical HDD. However, not all SSDs are created equal, and it can be difficult to decide on one given the current market.

SATA

SATA SSDs come in both the 2.5" and M.2 form factors. It's also possible to place them into enclosures, for example for transmission over USB, but this requires UASP support for proper use of TRIM/UNMAP. SSDs in an enclosure will also take a performance hit. Generally, only SSDs with a DRAM cache should be used for OS/mixed-use except on light or secondary machines. SSDs intended for storage or games will mostly be engaged in read operations and as such DRAM is not as critical. The presence of SRAM in the controller does not count as having DRAM. While an OS SSD might be only 120GB in size, a storage drive will usually be 480GB or more.

BUDGET SATA

Micron 1100[1] | Crucial MX300

Team L5 Lite 3D

ADATA SU800 | HP S700 Pro | Team Delta RGB SSD

Gigabyte UD Pro | Seagate BarraCuda SSD

Kingston HyperX Fury | Kingston UV500

PERFORMANCE SATA

Samsung 860 EVO

Crucial MX500

WD Blue 3D | SanDisk Ultra 3D

Intel 545s

[1] The Micron 1100 is the OEM variant of the consumer Crucial MX300.

SECONDARY SATA

Kingston A400[2]

Inland SATA SSD | Patriot Burst | PNY CS900

ADATA SU650 | HP S700 Non-Pro

Hyundai Sapphire

Silicon Power A55/S55

Gigabyte SSD Non-Pro

Crucial BX500 | Mushkin Source

Team MS30[3]

WD Blue Non-3D

STORAGE/GAMES

Kingston A400[2]

ADATA SU650 | HP S700 Non-Pro

Hyundai Sapphire

Micron 1100 | Crucial MX300

ADATA SU800 | HP S700 Pro | Team Delta RGB SSD

Inland SATA SSD | Patriot Burst | PNY CS900

Gigabyte SSD Non-Pro

Silicon Power A55/S55

Crucial BX500 | Mushkin Source

Team MS30[3]

ADATA SU630 (QLC)

Samsung 860 QVO (QLC)[4]

WD Blue Non-3D

[2] This drive has 2D/planar TLC but is exceptionally common.
[3] This drive comes in the M.2 form factor only. It should have the same hardware as the BX500, but unconfirmed.
[4] This drive has DRAM cache but is not also listed under Budget SATA due to QLC performance.

NVME

The NVMe protocol has many advantages over AHCI related to commands, queue depth, interrupts, parallelism/threads, general efficiency, I/O and processing overhead, IOPS, latency, raw bandwidth, etc. Most general users will only see small performance gains, for example with game load times, by moving to a NVMe SSD over SATA. Consumer motherboards are currently quite limited in PCIe lanes and therefore potential bandwidth, with some exceptions.

However, M.2 sockets with PCIe support are becoming more common especially with PCIe 4.0 support on the way from AMD. There are users who like to have that extra performance under-the-hood for when they might need it. NVMe drives inherently should not add a lot of cost so a budget variant may be a viable option for those who are not on a strict budget. Not all NVMe drives are created equal despite the belief that they all have the same performance profile.

Mobile and small form factor machines can benefit from the superior power and thermal footprint found with four-channel controllers and single-sided drives. QLC is also useful here as it has a higher density than MLC and TLC while potentially being cheaper. Additionally, NVMe can cut down further by omitting DRAM cache, using NVMe's HMB technology to use system memory instead. For the Mobile/SFF/Budget category, I suggest the HMB drives for capacities at 512GB or less and the QLC drives (660p, P1) only at 1-2TB.

DESKTOP/PERFORMANCE

ADATA SX8200 Non-Pro | HP EX920 | Mushkin Pilot | Intel 760p[5]

MOBILE/SMALL FORM FACTOR/BUDGET

Intel 660p (QLC) | Crucial P1 (QLC)[6]

HP EX900

ADATA SX6000 Pro

ADATA SX6000 Lite

WD SN500

[5] The Intel 760p, unlike the other drives that share its hardware, is single-sided up to and including the 1TB SKU.
[6] The Crucial P1 differs from the 660p in some ways: more DRAM cache, double-sided w/DDR4 at the 2TB SKU.

WORKSTATION USE

Those with systems that have higher demands, specifically production and development, may opt for higher-end NVMe drives. These demands can include everything from mass virtual machines, media creation, server tasks, programming with development environments, 3D modeling, and much more. Requirements can still differ, however; a mixed-use machine might benefit from consumer-type performance, such as random 4K low queue depth. Or maybe all that is needed is higher queue depth performance along with sustained write performance. And lastly, someone might require write endurance with a high TBW/DWPD (warranty) rating.

PROSUMER

WD Black (2018)[7] | WD Black SN750[8] | SanDisk Extreme Pro NVMe

PROSUMER & CONSUMER

MyDigitalSSD BPX Pro | Corsair MP510 | Addlink S70 | Seagate FireCuda/BarraCuda 510 | Silicon Power P34A80 | Sabrent Rocket | Inland Premium | Team MP34 | Gigabyte Aorus

Samsung 970 EVO

Samsung 970 EVO Plus[9]

ADATA SX8200 Pro | HP EX950 | Mushkin Pilot-E

HIGH ENDURANCE

MyDigitalSSD BPX Pro | Corsair MP510 | Addlink S70 | Seagate FireCuda/BarraCuda 510 | Silicon Power P34A80 | Sabrent Rocket | Team MP34 | Gigabyte Aorus

Samsung 970 Pro[10]

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[7] This drive, along with the 970 series and the smaller capacity (<=512GB) E12 drives, is single-sided.
[8] Updated version of the WD Black (2018): new firmware, heatsink, and a 2TB SKU.
[9] Updated version of the 970 EVO: 96L NAND, refined firmware.
[10] This drive is MLC-based and has no SLC cache so has consistent write performance. MLC has three times higher raw endurance than TLC. The SATA-based 860 Pro also technically fits here.

NOTES

It's difficult to cover all the different questions people might have about selecting the proper SSD for their needs. In many cases any SSD will do, and in most cases any drive under the SATA Performance heading will be the best compromise. This guide is not intended to encourage people to go one way or another, or to choose one brand over another; rather, it is to offer a form of differentiation based on the hardware specialization of the drives. Manufacturers do choose to go after specific markets when they design their drives.

The information that follows is presented to cover some drives you might come across that are not explicitly listed in the guide. Note that Optane and OEM drives are considered outside of the guide's scope and are therefore omitted. I also cover what I term "obsolete" drives that have been effectively replaced by superior alternatives, despite still being available. I also briefly delve into the technology and hardware behind SSDs. Lastly, a glossary is offered that breaks down the various acronyms used in the guide.

OTHER DRIVES

Mushkin Reactor – Budget SATA

Crucial BX300 – Budget SATA

SanDisk Ultra II – Budget SATA

Samsung 850 EVO – Performance SATA

Various Toshiba/OCZ, Plextor, etc. – assume Secondary SATA

OBSOLETE DRIVES

Kingston A1000 | Inland NVMe Basic/Pro SSDs | Corsair MP300 | SBX | Patriot Scorch

ADATA SX6000 Non-Pro

Samsung 960 EVO[11]

UNCOMMON/OTHER DRIVES

2D/planar MLC drives w/DRAM – equivalent to ADATA SU800

2D/planar MLC drives w/o DRAM (e.g. HP M700) – equivalent to Inland SATA SSD

2D/planar TLC drives (e.g. WD Green SSD) – should be avoided in most cases

HP S600, Team L5 Lite 2D – garbage tier

Bill-of-material (BOM)[12] **drives (e.g. SanDisk SSD Plus) – avoid or Storage/Games**

[11] This drive is not obsolete from a performance standpoint, there are simply better alternatives.
[12] These drives have variable hardware and are therefore considered inconsistent.

TECHNOLOGY

Although SSDs seem to be a confusing mish-mash of terminologies they essentially break down into their hardware components: the controller, which usually determines if it has DRAM cache or not, and the NAND or flash memory. To see combinations, check summary after the glossary. Note that firmware and error-correction (ECC) also impact performance and endurance.

DRAM cache increases NAND lifespan by reducing write amplification (WAF) and also increases write performance. It is used to store mapping/translation data and can defer changes to the “table of contents” information as contained on the drive’s NAND. NVMe drives can use HMB technology to use system memory with a small performance penalty. Ideally, DRAM (or HMB) should be present in primary and mixed-use drives and with anything of importance.

NAND comes in 2D and 3D (BiCS) forms with more layers for the latter usually being better as it allows for a balance between performance, density, and endurance. The flash has a native speed (MT/s) as well as a faster pSLC/SLC buffer with some reserved (over-provisioned) space for wear-leveling and garbage collection (GC). Most drives are now TLC with MLC becoming less common and QLC more common; more levels means more voltage states, increasing density at the cost of performance and endurance.

CONTROLLERS & DRAM/HMB

SMI SM22xx/SM22xxEN – DRAM cache

SMI SM22xxXT – DRAM-less (SM2263XT – DRAM-less w/HMB)

Phison S10 – DRAM cache

Phison S11 – DRAM-less

Marvell 88SS1074 – DRAM cache

Marvell 88NV1120 – DRAM-less

Samsung – DRAM cache

Maxio MAS0902A-B2C – DRAM-less

Realtek RTS5760 – DRAM cache (Realtek RTS5763/DL – DRAM-less w/HMB)

NAND

IMFT or Intel/Micron, most commonly paired with SMI controllers

Toshiba, most commonly paired with Phison controllers

SanDisk, used in WD and SanDisk drives

Samsung, used in Samsung drives

GLOSSARY

2D/planar – two-dimensional NAND. Older type of NAND that is moving out of production except for budget-oriented drives. Also called planar because it sits on a plane.

3D – three-dimensional NAND. Newer type of NAND with a varying amount of layers. The third dimension offers more space between cells, reducing cell-to-cell interference. This allows greater headroom for a balance between higher density, higher performance, and endurance.

32L – 32-layer 3D NAND.

64L – 64-layer 3D NAND.

96L – 96-layer 3D NAND.

AHCI – advanced host controller interface. An old standard that did not anticipate the very low latencies and very high IOPS of solid state devices.

ARM – Arm Holdings. Designer of microcontrollers including the ones found in SSDs.

BCH – Bose-Chaudhuri-Hocquenghem codes, an ECC scheme as used on some SSD controllers like the Phison S10.

BiCS – bit cost scaling; in general BiCS = 32-layer, BiCS2 = 48-layer, BiCS3 = 64-layer, and BiCS4 = 96-layer.

CE – chip enable. Effectively, the maximum number of targets or dies per controller channel.

Conversion – conversion of SLC blocks to native NAND (e.g. TLC) used with dynamic SLC cache, for example Micron's DWA.

DDR3 – double data rate 3rd generation SDRAM. DRAM used in older computers and as DRAM cache on many SSDs. Also found in a low-profile form factor (LPDDR3).

DDR4 – double data rate 4th generation SDRAM. Type of DRAM now common in computers and for DRAM cache on some SSDs. Also found in a low-profile form factor (LPDDR4).

Direct-to-TLC – method of writing directly to native NAND when the SLC cache is exhausted.

DRAM – dynamic random-access memory. Volatile memory that is significantly faster than the flash used in a SSD, used as cache for mapping/translation and wear-leveling data.

DWA – dynamic write acceleration. Micron's method of converting blocks between SLC and the native format on-the-fly as deemed necessary.

DWPD – drive writes per day. This is a measure of how many actual writes can be done to the NAND per day while not exceeding the warrantied TBW.

ECC – error-correcting code. Used in SSDs to correct data errors, with limits. Initial TLC drives would slow down due to reliance on ECC to read “fuzzy” data that had remained unchanged. This was fixed with static data refresh algorithms that rewrite stale data, but it began as an issue with TLC due to the increased amount of voltage states and thus sensitivity. ECC is a critical aspect of SSD endurance. Some controllers, like the Phison S10, suffer for using BCH-based ECC in comparison to the now more-common LDPC-based ECC.

Folding – transfer of data from SLC blocks to a MLC/TLC/QLC block, for example 3 SLC blocks to 1 TLC block. Reduces NAND wear as this is written sequentially but is less performant. Can be done on-die without intervention of the controller or DRAM.

FTL – flash translation layer. Enables the OS to treat the SSD like a HDD, providing translation of addresses and garbage collection. Often in DRAM and SLC cache for faster accesses.

GC – garbage correction. The consolidation of written data to allow for the erasure of blocks, usually in tandem with wear-leveling.

HDD – hard disk drive. A mechanical/magnetic hard drive utilizing heads and platters for non-volatile storage.

HMB – host memory buffer. A NVMe technology that allows a SSD to utilize system memory (RAM) for DRAM cache instead of having dedicated memory on the drive’s PCB.

IMFT – IM Flash Technologies. Joint-founded by Intel and Micron, recently fully acquired by Micron. Manufactures NAND.

IOPS – input/output operations per second. This is a measure of how many input and output operations can be completed per second.

LPDC – low density parity codes. A type of ECC increasingly used by modern SSDs.

M.2 – previously NGFF or next generation form factor. A socket that accepts a varying length of device, not limited to SSDs, with “keying” of the connector/fingers to determine the interface. Can act as direct PCIe and/or expose as USB and SATA.

MLC – multi-level cell, often taken to indicate double-level cell. Twice the capacity of SLC but with only one-tenth the endurance, and less performance as well. Two-bit with four voltage states.

MT/s – megatransfers per second. Number of operations per second that transfer data, related to ONFI/Toggle with NAND.

NAND – not-and logic gate. Equivalent to an AND gate followed by a NOT gate.

NVMe – NVM Express, or non-volatile memory express. A protocol designed for the future of storage with superior capabilities to AHCI.

ONFI – Open NAND Interface Working Group. A group focusing on open standards for NAND.

Overprovisioning – reserving NAND for the controller's usage to assist in wear-leveling, garbage collection, performance (static SLC and FTL), and other uses. Increases endurance and often write performance.

PCB – printed circuit board. The portion of the drive that supports and connects other components.

PCIe – PCI Express, or peripheral component interconnect express. Serial connection acting as a switch to provide communication between devices and the CPU.

P/E – program/erase cycles. Once data is written to the NAND it has to be erased to be rewritten. This value is therefore how many writes the cells can withstand before the data becomes corrupt and unreadable. This is a measurement of endurance. A 1TB drive of 1,000 P/E QLC NAND can withstand, for example, about 1PB of writes before accounting for the WAF.

pSLC – pseudo-SLC. Usually TLC NAND acting in SLC mode. Referred to as "SLC cache," this uses three times the capacity for the same amount of data with the advantage of faster speeds. pSLC can be static or dynamic and some drives have both. Blocks in SLC mode can move to blocks of native NAND in a process known as folding. pSLC can be flushed to TLC in the background and, when full, newer controllers can write directly to the TLC portion of the drive.

QLC – quad-level cell. Four times the capacity of SLC but with only one-third the endurance of TLC, and less performant. Four-bit with sixteen voltage states.

SATA – serial advanced technology attachment. Old bus interface/standard for storage devices.

SCSI – small computer system interface. Set of standards for computers to communicate with peripheral devices via commands.

SDRAM – synchronous dynamic random-access memory.

SKU – stock keeping unit. Distinct type of item, used to connote a specific model and capacity.

SLC – single-layer cell. The least-capacious but most performant type of flash with the highest endurance. Single-bit with two voltage states.

SMI – Silicon Motion. Designer of many SSD controllers.

SRAM – static random-access memory. All SSD controllers have this type of local memory in small amounts. It can be used like DRAM cache, but is faster; basically CPU cache.

SSD – solid state drive. Device using circuits as memory to provide non-volatile storage.

TBW – total bytes written. Amount of actual data written to the NAND.

TLC – triple-level cell. Three times the capacity of SLC but with only one-third the endurance of MLC, and less performant than both. Three-bit with eight voltage states.

TRIM/UNMAP – commands to mark data blocks as no longer needed. TRIM as a SATA command marks blocks as free for rewriting which improves performance and endurance. UNMAP is a SCSI command that works similarly for block reclamation.

UASP – USB attached SCSI protocol. Uses the SCSI command set for USB devices, including external SSDs.

USB – universal serial bus. Standard for connections and communication between computers and peripheral devices. Several different iterations with varying bandwidth.

WAF – write amplification factor. The proportion of how much is written for an actual piece of data; if the drive ends up doing 15GB of writes for 10GB of final data, this is a WAF of 1.5, which is not uncommon with consumer workloads. Impacts wear.

WD – Western Digital. Manufacturer of storage devices including SSDs. Owner of SanDisk.

Marvell 88SS1074[13]

2D/Planar TLC NAND from SanDisk (15nm)

WD Blue Non-3D

32L 3D TLC NAND from IMFT (384-Gbit)

Micron 1100

Crucial MX300

64L 3D TLC NAND from SanDisk

WD Blue 3D

SanDisk Ultra 3D

64L 3D TLC NAND from Toshiba

Kingston HyperX Fury

Kingston UV500

Marvell 88NV1120[14]

32L 3D TLC NAND from IMFT (384-Gbit)

Hyundai Sapphire

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[13] The Marvell 88SS1074 is dual-core, four-channel (4x2 CE) with DRAM cache.

[14] The Marvell 88NV1120 is dual-core, two-channel (2x4 CE) without DRAM cache.

SMI SM2258[15]

32L 3D TLC NAND from IMFT (384-Gbit)

ADATA SU800

HP S700 Pro

Team Delta RGB SSD

64L 3D TLC NAND from IMFT

Crucial MX500

Intel 545s (uses SM2259, variant of the SM2258)

SMI SM2258XT[16]

32L 3D TLC NAND from IMFT (384-Gbit)

ADATA SU650

HP S700 Non-Pro

Silicon Power A55/S55

64L 3D TLC NAND from IMFT

Crucial BX500

Mushkin Source

Team MS30

96L 3D TLC NAND from IMFT

Crucial BX500 (960GB)

Micron 1300

[15] The SMI SM2258 is single-core, four-channel (4x2 CE) with DRAM cache.
[16] The SMI SM2258XT is single-core, four-channel (4x2 CE) without DRAM cache.

SMI SM2262[17]

64L 3D TLC NAND from IMFT

ADATA SX8200 Non-Pro

HP EX920

Mushkin Pilot

Intel 760p

SMI SM2262EN[18]

64L 3D TLC NAND from IMFT

ADATA SX8200 Pro

HP EX950

Mushkin Pilot-E

SMI SM2263[19]

64L 3D QLC NAND from IMFT

Intel 660p

Crucial P1

SMI SM2263XT[20]

64L 3D TLC NAND from IMFT

HP EX900

Phison S10[21]

64L 3D TLC NAND from Toshiba (BiCS3)

Gigabyte UD Pro

Seagate BarraCuda SSD

[17] The SMI SM2262 is dual-core, eight-channel (8x4 CE) with DRAM cache.
[18] The SMI SM2262EN is dual-core, eight-channel (8x4 CE) with DRAM cache.
[19] The SMI SM2263 is dual-core, four-channel (4x4 CE) with DRAM cache.
[20] The SMI SM2263XT is dual-core, four-channel (4x4 CE) without DRAM cache but with HMB.
[21] The Phison S10 is quad-core, eight-channel (4x8 CE) with DRAM cache designed for 2D/planar NAND.

Phison S11[22]

2D/Planar TLC from Toshiba (15nm)

Kingston A400

64L 3D TLC NAND from Toshiba

Inland SATA SSD

Patriot Burst

PNY CS900

Gigabyte SSD Non-Pro

Phison E12[23]

64L 3D TLC NAND from Toshiba

MyDigitalSSD BPX Pro

Corsair MP510

Addlink S70

Seagate FireCuda/BarraCuda 510

Silicon Power P34A80

Sabrent Rocket

Inland Premium

Team MP34

Gigabyte Aorus (RGB)

Samsung Proprietary

64L 3D TLC NAND from Samsung

Samsung 860 EVO (SATA – Samsung MJX[24])

Samsung 970 EVO (NVMe – Samsung Phoenix[25])

64L 3D QLC from Samsung

Samsung 860 QVO (SATA – Samsung MJX[22])

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[22] The Phison S11 is single-core, two-channel (2x8 CE) without DRAM cache.
[23] The Phison E12 is quad-core, eight-channel (4x8 CE) with DRAM cache.
[24] The Samsung MJX is tri-core, eight-channel (8x8 CE) with DRAM cache.
[25] The Samsung Phoenix is penta-core, eight-channel (8x8 CE) with DRAM cache.

96L 3D TLC NAND from Samsung

Samsung 970 EVO Plus (NVMe – Samsung Phoenix)

Realtek RTS5760[26]

32L 3D TLC NAND from IMFT (384-Gbit)

ADATA SX6000 Non-Pro

Realtek RTS5763DL[27]

64L 3D TLC NAND from IMFT

ADATA SX6000 Pro

ADATA SX6000 Lite

WD Proprietary

64L 3D TLC NAND from SanDisk

WD Black (2018)[28]

SanDisk Extreme Pro NVMe

WD SN750

WD SN500[29]

Maxio MAS0902A-B2C

64L 3D QLC from IMFT

ADATA SU630

[26] The Realtek RTS5760 is four-channel (4x2 CE) with DRAM cache.
[27] The Realtek RTS5763DL is four-channel (4x2 CE) without DRAM cache but with HMB.
[28] The controller in the WD Black (2018) and SN750 is tri-core, eight-channel with DRAM cache.
[29] This controller lacks corresponding DRAM and also does not utilize HMB

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