Choosing a Solid State Drive Form Factor:

Which is Right for You?

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Introduction

Solid state drives have been changing the data storage industry for quite some time now. Higher performance and lower prices have granted them an incredible rise in popularity over the past five years, particularly in the consumer space. With this in mind, the following buyer's guide is designed to outline each of the various SSD form factors so readers know which type is right for them. The form factors are as follows: SATA, AHCI-based PCI Express, NVMe-based PCI Express, and M.2.

Although we will discuss different types of solid state drives, this paper will not recommend specific manufacturers or drive models. All storage devices eventually fail, and we wouldn't want anyone to think otherwise solely based on our recommendation. If you are interested in viewing user ratings and other information on various solid state drives, pcpartpicker.com and newegg.com are two good part-aggregating sites to help you begin your search, while thessdreview.com offers some great in-depth reviews of drives.

SATA

The SATA interface is currently the most popular form factor for solid state drives. It stands for Serial ATA and has seen multiple revisions over the years, beginning with the release of SATA 1.5Gbps (~150MB/sec) in 2003. Throughput improved until 2013 when SATA Express was released, allowing for up to 1969MBps throughput. It should be noted that SATA Express is actually a hybrid specification for both SATA and PCI Express storage devices. It might seem odd that these transfer rates are jumping between being listed in megabytes and gigabits, but this is the way the industry discusses them, so this is the way we will list them. SATA was originally designed for compatibility with HDDs, so it is unsurprising that many solid state drives have overstepped the throughput capabilities of SATA 6Gbps (~600MB/sec). Having said that, many SSDs are still made on the SATA 6Gbps specification and most consumer drives today are near the upper limit for read speeds on this specification.

Cost

Standard 2.5-inch consumer SATA drives have seen remarkable advancement in the last five years. Not only has performance increased, but there has also been a drastic reduction in dollars per gigabyte of storage. For example, in 2013, a 500GB SATA SSD cost around $375. As of September 2015, the cost of a 500GB SATA solid state drive is around $170. Incredibly, prices are expected to continue a downward trend over the next few years due to the release of 3D NAND technology.

Capacity

SATA SSDs come in just about any size you could ever want. Since NAND storage capacity is no longer constrained to two-dimensional planes, multiple solid state drive manufacturers have announced their intentions to release 10TB, 15TB, and even 30TB SSDs in the next few years. While 10 and 15 terabyte drives are just over the horizon, the 30TB SSD likely won't be seen until 2018 (barring any sudden technological or manufacturing developments). While these drives will have a high cost at launch, their creation will drive down prices for the rest of the consumer SSD market in addition to assisting the advancement of SSD technology. They will also likely only be available in enterprise storage solutions for some time after their release, but this is the case with just about every SSD technological advancement.

Recommendation

The low cost of SATA drives makes them an ideal choice for normal consumers without heavy performance demands or anyone who needs multiple drives, such as in a RAID setup. As of September 2015, typical sequential speeds for a SATA SSD are around 500+MB/sec reads and 300-500MB/sec writes. This will obviously vary depending on which drive you purchase, but these numbers should provide a fairly accurate frame of reference. These read/write numbers should not be surprising, considering the throughput on SATA caps at around 600MBps. It is really more of a soft cap anyway, as performance can be improved by setting up multiple drives in RAID 0 or 5, or whichever performance-oriented RAID level you prefer.

In brief, SATA drives are great for the average consumer, lower-level enthusiasts, and some small businesses that require decent performance at a low cost. The price can't be beat within the solid state industry at around 30-50 cents per gigabyte, and with prices expected to drop while capacities go up, the future looks very promising for these drives.

AHCI-Based PCI Express (PCIe)

PCIe, or Peripheral Component Interconnect Express, is the name of the extremely fast and relatively expensive solid state drives seen in the high-end enthusiast and enterprise markets. This form factor is typically only referred to as PCIe or PCI Express, however in this instance we are using the qualifier AHCI because there are currently multiple technical specifications for PCIe drives.

AHCI, or Advanced Host Controller Interface, is a hardware device that allows software to communicate with an attached SATA storage device. Since AHCI was originally designed for traditional hard drives, and more specifically for SATA devices, it can be somewhat cumbersome with PCIe devices. We won't get into too much detail on AHCI since it is not important in the context of this guide. The only thing to take into consideration is that AHCI can slightly bottleneck your PCIe drive.

Compatibility

One reason to go with AHCI is that it is supported on basically everything since it has been around for about ten years now. You won't have to worry about compatibility short of whether or not your motherboard offers the right PCIe lanes in addition to just the physical space of your computer case. If you're just looking for fast boot times, an AHCI-based PCIe drive is great because they are optimized with most Intel chipsets and offer great boot times.

Once NVMe is more widely supported, AHCI will likely no longer be the best. As an aside, I can't stress enough how important compatibility is. Before you purchase anything, triple check that you will actually be able to use it in your system. The motherboard should indicate which PCIe lanes are available and your PCIe drive should indicate which lanes it requires to perform at its best.

Why are they so expensive?

Aside from how fast they are, there are a few reasons PCIe drives are relatively expensive. Whereas normal SATA drives come in models such as 120GB, 256GB, and 500GB, typical PCIe drives begin at capacities of around 400GB. Depending on the model, they can also go as low as around 256GB and up to 4TB. The typically larger capacity is necessary because most of the time these drives will be used in a server, data center or for some other enterprise use. Further, their cost per gigabyte is still higher than consumer SATA SSDs because they use enterprise quality flash and possess much greater resistance to failure, such as having capacitors to flush data in the event of sudden power loss. Even if you do purchase a smaller, consumer-sized PCIe drive, it will still be more expensive than SATA consumer SSDs of comparable size due to these improved features.

Performance

Moving on to the raw numbers, a typical PCIe drive running the AHCI protocol can expect sequential reads of around 2400MBps and writes of 1200MBps. This goes up every year and depends heavily on what the drive is optimized for, since PCIe drives are often used in fairly specific enterprise situations. The performance of the drive you choose should be based heavily upon what your specific workload needs are. Whether that is read-intensive, write-intensive, or both, you should know what is required.

Cost and Recommendation

As far as price goes, AHCI-based PCI Express drives usually hover around or above the $1 per gigabyte level. They are toward the top of the price charts and this shouldn't be surprising given how much performance you get. While generally slightly cheaper than NVMe-based PCIe drives, they have a similar price curve that can really ramp up to ridiculous prices, given the insane performance needs of high-end enterprise data solutions. If you need a solid state drive that offers nearly the best performance available and are willing to pay a premium to get it, AHCI-based PCIe drives are a good solution. They're not quite as fast as NVMe-based drives, but they are more widely compatible and will work with almost any motherboard.

FIGURE 1: A typical Intel SATA SSD. The SATA inputs can be seen on the right side of the image. For size reference, this drive is 7mm thick.
Photo Credit: Intel Free Press https://flic.kr/p/aELu1u

FIGURE 2: An Intel enterprise-grade PCIe drive. They are quite large and require more than twice the space of a typical SATA SSD.
Photo Credit: Vernon Chan https://flic.kr/p/nTa46v

NVMe-Based PCI Express (PCIe)

These drives are essentially the same as PCI Express drives with AHCI, but instead they run the NVMe protocol. NVMe, or Non-Volatile Memory Express, is a newer technical specification that was created to fully take advantage of the speed of newer solid state drives. The latency is about half the time of AHCI, allowing for greater throughput than AHCI allows.

Compatibility

One important thing to keep in mind is that with any new technology, compatibility can be an issue. In this instance, be aware of the compatibility of your motherboard when considering an NVMe-based PCIe. If you've purchased a motherboard released in the past six months, you're likely fine. On the other hand, if you purchased your motherboard a year or two ago, there's a chance it will not be compatible. Some manufacturers are releasing driver updates to accommodate some legacy boards for these newer drives, but many will not be seeing updates.

If you're not sure whether or not your board is compatible, try to get in touch with the manufacturer or ask around on forums to find out. If you can't find out, it's always better to err on the safe side and buy something you know you can use.

Performance

In terms of performance, NVMe-based PCIe drives are the absolute best of the best. Performance will vary wildly depending on the drive but for a frame of reference, some drives are capable of up to 5000MBps sequential reads and 3000MBps sequential writes. This is what the drive is rated for and therefore will likely never have to reach that level, but once again, the bandwidth and performance is theoretically there if you need it.

Cost

Since NVMe drives are the new gold standard, prices have been varying quite a lot. For a drive like the one just mentioned, you can expect to pay $3 per gigabyte of storage or more. Conversely, there are some NVMe drives that can be purchased for prices comparable to a normal AHCI-based PCIe drive, or around $1 per gigabyte.

Recommendation

If you are looking for a top of the line solid state drive, an NVMe-based PCI Express drive is for you. Assuming you want a top of the line drive, you should not be surprised if you have to purchase a new motherboard to support such a drive. This fall of 2015, we can expect a lot more compatibility with the motherboards being released, as there are plenty of NVMe drives coming out. Through next year, the prospects for these drives only get better as they will become more and more mainstream.

If you're considering buying one of these, it might be better to wait a little bit, perhaps until around the holiday season, as this is when many tech products are launched to take advantage of all the gift giving. Keep your eyes peeled for deals and new releases at year's end, as you are certain to find something fantastically fast to put in your system at a reasonable price.

M.2

M.2, pronounced M-dot-two (everyone specifies this for some reason), is a small-form-factor drive similar in size to a large USB stick. Despite their size and shape (of which there are actually many different possible dimensions), these drives are capable of delivering great performance.

Protocol

While there is only one connection possible through the M.2 form factor, that is, the M.2 connection, there are actually multiple protocols that may run on these drives. The performance of your M.2 drive depends heavily on which protocol it is running. Currently, M.2 drives offer a standard SATA protocol, a PCIe Gen 2 x2 protocol, or a PCIe Gen 2 x4 protocol. If you have a desktop computer, there is really no point in getting a SATA M.2 drive if you already have a SATA drive installed. The only time it is really recommended to go for a SATA M.2 drive is if you want to implement one of these as a solution in a laptop of some sort, or if you value the small form factor and lack of wires required in installing one.

The great thing about M.2 drives is that they may be connected directly to a PCIe bus and offer way better throughput, theoretically up to 2GBps. The word theoretically is used here because these numbers are almost never reached outside of rigorous testing.

Compatibility

One thing to be wary of with M.2 drives is the multiple dimensions and the many possible "key" configurations. The dimensions are measured in millimeters and can usually be figured out by looking at the name of the drive. For example, if there's a drive than includes the number "2280," that M.2 drive has a width of 22mm and a length of 80mm. This number should be distinguished from the number that many model numbers have, such as 950 or 3700, neither of which signify a possible configuration. If you're really desperate to find out the dimensions of an M.2 drive, it should be included in the rest of the information about the drive. Since they're so small, you shouldn't ever run into an issue with the size of a drive.

The more important thing to watch out for is the key configurations, which are the little notches at the end of the drive where you plug it into the motherboard. There are at least twelve different key configurations, signified by a singular letter (such as "B" or "M"), and each of them is used for a different type of connection.

When considering compatibility, look for the key configuration and find out not only if your motherboard supports it, but also if that type of M.2 drive is what you're looking for in terms of performance. Many of the possible keys are "reserved for future use" right now, so it isn't as complicated as it sounds. There's really only two you need to be concerned with right now and those are B and M.

Performance

In terms of performance, a SATA M.2 will offer sequential read/writes similar to any other SATA SSD. When you step up to a PCIe Gen2 x2 M.2, your reads go up to just below 600MBps and your writes sit somewhere around 700MBps. If you go even higher up the chain to a PCIe Gen2 x4 M.2, you can expect reads of up to 1900MBps and writes of around 1200MBps. It will vary quite a lot depending on which drive you purchase, but these are the actual speeds of some versions of these drives so it should give you an idea.

Recommendation

At the end of the day, whether or not you purchase an M.2 drive depends heavily on how much of a technological early adopter you are. The cheaper SATA versions can be great in notebook/laptop solutions since they're so small and offer great performance. The PCIe versions aren't really worth it unless you go for a more expensive PCIe Gen2 x4, at which point you might even consider just going for a normal PCIe. They do offer great performance and are incredibly small, so if you're trying to pack a lot of punch into a smaller case, M.2 is probably right for you.

In terms of price, an M.2 drive will run anywhere from 60-90 cents per gigabyte. They're slightly cheaper than most PCIe drives, but not quite as cheap as SATA drives. Once again, if you're looking for performance in a small form factor, M.2 drives are a great solution. They're great in either a notebook or a desktop, but for any sort of enterprise solution, we have yet to hear of their use.

FIGURE 3: This image shows the incredibly small size of M.2 drives relative to a desktop case. That little stick is as thin as the PCB in a normal SSD.
Photo Credit: Gilbert Sopakuwa https://flic.kr/p/wPXW9P

Wrap-Up

It should be clear by now that every drive is going to have its strengths and weaknesses. If you want a cost effective solution, you're going to have to sacrifice some performance and go for a SATA drive. If you want amazing performance with compatibility, you're going to have to pay a premium and go for an AHCI-based PCIe. If you want even more performance for potentially more money and risk incompatibility, go for NVMe. If you want something in between cost-effective and performance-based that comes in an incredibly small form factor, buy an M.2 drive.

Above all else, think about what you will actually be using your computer for. It's easy to get caught up in the latest technology trends and buy something you don't really need. If you have loads of cash to spare, it probably isn't as much of an issue. But if you're reading this buyer's guide, you probably want to make an informed decision and maintain your status as a savvy consumer. Whatever the case, we hope this guide was helpful in learning about each form factor and is able to lead you to the right solid state drive.

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