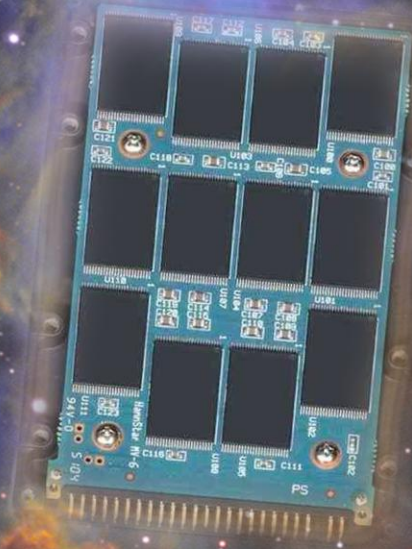# hard drive
of the
future

your guide to
solid state drives

by lachlan roy

Your Guide To Solid State Drives

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Edited By: Justin Pot

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Introduction

To start I'd like to thank you for downloading this guide and taking the time to read it. I hope you'll find it useful and that it'll help you when you're looking to upgrade or replace your computer.

My aim is to explain to you all there is to know about solid state drives in a manner that's enjoyable to read and easy to understand while still providing plenty of useful information. It's more of a sub-guide to my other manual – Your PC, Inside and Out – which explains what all the different parts of a computer are, what they do and how they work together.

Solid State Drive? What's that?

You may have seen a lot of talk about *Solid State Drives* recently. In the last six months or so they've really taken the mid-range to high end computing world by storm. If a manufacturer decides to include a solid state drive in their computer they'll make sure that you know it's there. But *what are they?*

A solid-state drive (or *SSD*) is a *storage device* that performs the same functions as a *hard disk drive* (which you may know as a hard drive or an HDD). This means that it's used to store data for your computer to access, including the computer's operating system, its programs and all your files such as documents, pictures, music and videos. The larger the drive, the more you can store on it. It gets its name from the fact that it has *no moving parts*, hence making it 'solid state'.

However, while they fulfil the same role, SSDs and HDDs have some crucial differences, which I'll explain later.

A Quick History of SSDs

Solid State Drives in the literal sense have been around since the 1950s, although it wasn't until 1983 that the first "modern" solid state drive was readily available: Sharp's PC-5000 laptop's internal storage held a whopping *128 kilobytes* of data and used magnetism in a similar way to today's magnetic hard drives. 1GB of flash memory would have cost $1 million. Crazy, huh?

In 1986 a company called Santa Clara Systems introduced "BatRam", which used 4MB modules that acted in a similar way to today's Random Access Memory (RAM) and required batteries to retain the data if the system lost power.

It wasn't until 1995 that flash-based solid-state drives were released, which work the same way that today's solid-state drives do and which don't require a constant supply of power to hold on to their data. At this point solid-state technology was embraced by the aerospace and military industries. It would take almost 15 years before the technology became commercially viable for use in mainstream computers.

Flash made its debut in the public eye in the form of memory cards for digital cameras, such as the Compact Flash (CF) card in 1996, where 2MB of storage would cost you $149 (or $74,500/GB).

The USB Flash Drive (or *Memory Stick*) first showed up in late 2000, when IBM released its 8MB "DiskOnKey" for $49 ($6,125/GB). This was still comparatively extremely expensive, but makes quite a bit of sense when put into context; the alternative was the 3.5" floppy disk that held 1.44MB of data. The IBM DiskOnKey held more than 5 times as much data in one place and was not susceptible to scratches, magnetism or dust. It was significantly faster, too!

USB Flash storage understandably caught on in a big way and by 2003 was widely available in 32, 64 and 128MB capacities from a myriad of manufacturers. A 64MB flash drive would usually cost around $70 ($1095/GB), and it only got cheaper from there. Today you can get a 4GB drive for $3 ($0.75/GB), the average size drive is 16GB for $15 ($0.93/GB), and they are available in sizes up to 256GB for $100 ($0.40/GB).

Flash storage made its first massive appearance for *internal* storage in consumer electronics in 2005, but not in computers. The iPod Shuffle and the iPod Nano were among the first devices to bring flash memory to millions. They were by no means the first to use the technology; Rio released its PMP300 way back in 1998, which got you 32MB of storage for $200. However, Apple's wild success with the iPod and then the iPod Nano transferred instantly to the Shuffle and Nano, which started with 512MB or 1GB and 2GB or 4GB of storage, respectively.

In 2007 Alienware, a company that specialises in making gaming laptops and desktops, introduced a 32GB SSD as an option for custom machines. This 32GB drive cost a steep $500 ($15/GB), especially painful as it meant sacrificing a much roomier hard drive for the privilege.

In 2008 Apple unveiled the MacBook Air for the first time. This thin laptop offered an optional 64GB SSD or an 80GB 1.8" conventional hard drive. This was the first mainstream 1.8" SSD; again, users had to pay a pretty penny for it. How much exactly? $1300 (or a whopping $20/GB)! While it's worth noting that 1.8" drives cost significantly more to manufacture, that doesn't really change quite how inaccessible the option was to most consumers.

In late 2010 Apple updated the MacBook Air to a new model, and made a big push for SSDs. The latest models have *no option for magnetic hard drives at all*, and shifted from the standard "SSD in a hard drive enclosure" to a new form factor that they dubbed as a "Blade SSD" which connected straight to the motherboard using the mini-PCIe interface.

Hard drive goes where?

Different Kinds of Solid State Drives

Technology

DRAM

This is one of the oldest kinds of SSDs but is still reasonably common today in certain situations. The DRAM SSD isn't particularly practical for most users; its capacity is usually very small (normally up to 8GB because it takes its storage from the same RAM modules which you plug straight into your motherboard – see my other guide for more information), the price to capacity ratio is extremely high and it requires a constant supply of power even when the computer is switched off otherwise all the data is lost.

However, it still remains one of the fastest types of solid-state drive and is perfect for those requiring extremely high data access for temporary data (such as video editors).

Flash (NAND)

This is by far the most common type of solid-state drive on the market today. While not quite as fast as a DRAM drive it is still much faster than a magnetic hard drive and has the added advantage of not requiring a constant power supply. You get much more bang for your buck, too.

MLC vs. SLC

If you start researching solid-state drives you'll hear a lot about MLC and SLC drives.

It's quite simple, really – MLC stands for *multi-level cell*, whereas SLC stands for *single-level cell*. This means that each *transistor* (or *cell*) in an MLC drive holds two bits of information, whereas in an SLC they only hold one.

When checking for data, an SLC drive only needs to check if the bit is a 1 or a 0. On the other hand, each cell in an MLC drive has four states: 11, 10, 01 or 00. This process takes around 3 times longer to perform.

The result is that an SLC has faster transfer speeds, lower power consumption and has more read-write cycles, but has half of the storage density of an MLC drive for

the same number of transistors, making it much more expensive for a drive with the same capacity. This makes them prohibitively expensive for consumer use, but perfect for enterprise servers that need the extra performance and reliability.

Hybrid Drive

For a little while a couple of years ago hybrid drives were deemed to be *the* future of computer storage, but then they sunk without a trace.

What is a hybrid drive? You can probably guess just from the name and the picture on the right here. It's a hybrid between a magnetic hard drive and a solid-state drive; a magnetic hard drive with a small amount of SLC flash memory to help speed up boot times and start up applications. The files required for boot up and program files you are likely to use are stored in the flash memory for quick access while still giving you the large capacities that magnetic drives are perfect for.

Interface

ATA/SATA

The vast majority of solid-state drives you'll buy today are designed to replace a magnetic hard drive and fit into the same space. That meant using the same data connector – a SATA port (or an IDE port for older systems).

PCIe

Other SSDs have taken a less conventional approach by utilising the much faster bandwidth available to PCI Express (PCIe) devices. These tend to be a little more expensive and you'll likely lose a precious 16x slot to accommodate one (or lose performance and use a 1x slot), but the performance increase usually makes it worth it and it frees up a SATA port for another hard drive.

Mini-PCIe

You'll find these SSDs in netbooks and, more rarely, on mini-ITX and some micro-ATX motherboards. This again allows for high performance storage that doesn't take up one of the few SATA ports you'll find on one of these motherboards.

Form Factor

5.25"

This has always been a favourite form factor for the DRAM SSD, as it gives plenty of room for lots of RAM slots, the power connector, a battery in case of even a temporary power outage that could wipe all the data on the drive as well as the controllers necessary to manage the data.

3.5"

Although not popular in the mainstream market, the 3.5" solid-state drive's *raison d'être* is in servers that need the extremely high performance that SSDs offer (particularly SLC SSDs) but which also need high quantities of data.

Consumer SSDs usually don't get any larger than 480GB and that's certainly by using MLC, not SLC. 3.5" SSDs, on the other hand, are able to read and write data at up to 750MB/s (that's almost 3 times the speed of a high-performance mainstream drive) and reach capacities of up to 1TB.

Of course, these drives are of the sort that if you need to ask how much they cost then you almost certainly can't afford them!

2.5"

These are by far the most common sized solid-state drives for both laptops and desktops in the consumer space. Many SSDs ship with some form of 2.5" to 3.5" drive bay adapter to allow them to be used in desktops that up until recently almost exclusively used 3.5" magnetic hard drives. However, with the increasingly popular solid-state drives becoming more readily available many new cases (particularly gaming cases) are coming up with their own ways to accommodate the smaller SSDs.

1.8"

The 1.8" form factor has never been overwhelmingly popular for storage devices in general, and even less for computers, the main exception being the first and second generation Apple MacBook Airs. Instead they've usually been used in digital audio players (DAPs) like the iPod Classic and its predecessors.

However, just because the demand for 1.8" SSDs isn't high doesn't mean that they don't exist. One particular use that is unique to 1.8" solid-state drives is for older systems; a small SSD with an IDE connector can be plugged straight into the port on a motherboard for a low-profile system drive. Sure, it means you can't connect a second drive to that channel, but the advantages of a solid-state drive usually outweigh those of having another optical drive!

"Blade"

The "Blade" form factor basically refers to solid state drives which consist of little more than the flash chips and the circuit board and controller they're attached to. The term was coined by Apple when they released the latest version of the MacBook Air in late 2010, denoting their long, thin and narrow shape and their lack of an enclosure that takes up lots of extra room with no true benefit. However, "blade" SSDs have been around for a while, albeit as much shorter chips that plugged into the mini PCIe interface and were the same size as a Wi-Fi PCIe card to maximise compatibility.
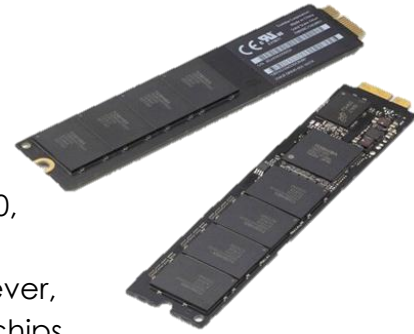
Although they are currently only found in Apple's latest MacBook Airs, these solid-state drives are set to be used by many other manufacturers, hopefully making them a much more widespread form factor that becomes cheaper and more readily available.

Other

There are other SSD form factors ranging from the common to the uncommon. Did you know that Compact Flash (CF) and Secure Digital (SD) cards are solid-state drives? That's right, the memory card you use in your camera can be used to store an operating system and applications that can be booted like from a hard drive. Under most circumstances it's not particularly recommended, but it *is* possible!

Also quite common are the PCIe-based drives as you've seen above, which are about the same size and shape as a low-end graphics card.
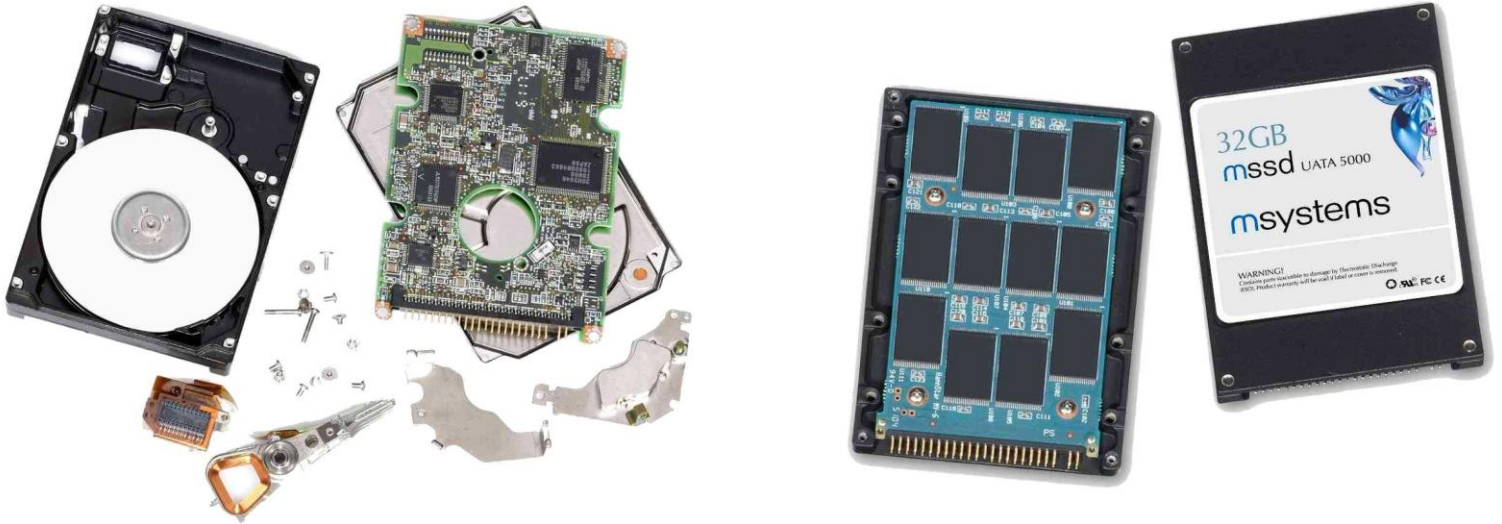
There are other, less common form factors that range from the tiny – like the InnoDisk SATADOM (SATA Disk On Module) drive that is barely larger than the SATA connector itself and draws its power from the motherboard – to the massive DRAM drives that are much larger than their 5.25" counterparts.

Yes, that is a standard SATA connector!

SSDs vs. Conventional Hard Drives

As you can see from the picture above, the main difference between a hard drive and a solid-state drive is that the solid-state drive is a lot more... well... solid! The lack of moving parts in the SSD is what gives it so many of its advantages, such as its speed and durability. There's a lot less that can go wrong when you don't have to worry about things wearing out or breaking.

Of course, conventional hard drives are still a lot more widespread than SSDs, and it'll be a while before they're rendered obsolete. While SSDs are much faster it's much easier to get your hands on a very high capacity HDD.

How do they work?

If a solid-state drive doesn't have any moving parts, how does it store data? Instead of using motors and magnets, they use electrical current to signify the 1s and 0s that all data is comprised of.

While a magnetic hard drive works by changing the magnetism of *sectors* on a spinning *platter*, solid-state drives have lots and lots of tiny *transistors*. When an electrical current is able to pass through a transistor it represents a 1, and a 0 is represented when a transistor does not accept current.

Every solid-state drive has a *controller*. This is a processor that is responsible for reading and writing to the transistors and passing this data to the rest of the computer system to be used. It also manages all the data on the drive, keeping track of where data is stored and making sure that data is distributed over the

transistors evenly in a process called *wear levelling* to maximise the performance and longevity of the drive.

A blank drive starts off with all transistors representing 1s (as opposed to a magnetic drive, which is all 0s when blank) allowing current to pass through. To 'write' a 0, voltage is applied to one piece of silicone in the transistor called the *control gate*. This starts a process that causes another piece of silicone called the *floating gate* to fill with electrons. When the floating gate is filled with electrons the transistor will no longer accept a current, causing it to represent a 0.

To *read* data a current is sent to the area of the drive where the data is held and the transistors assigned to the data will either allow the current to pass through or not, providing a string of 1s and 0s (*binary data*) which is then interpreted by the computer.

Cells are grouped into *pages*, which are usually 4KB. This is the smallest level of data that can be written to a SSD. Similarly, pages are grouped into *blocks*, which are typically made up of 128 pages (512KB). Taking it one step further, blocks are organised in groups of 1024 to form *planes*, which are usually 512MB in size. Multiple planes make up one of the flash chips you can see on an SSD circuit board.

For a more in-depth explanation there's a whole dedicated to it over at *HowStuffWorks*.

Should I get one?

Advantages

Speed

This is the biggest reason to go for an SSD; they're much, much faster than conventional hard drives in two different ways. First of all, because there are no moving parts there is no wait. While the drive spins up or for a head to move to the correct place to start reading the data there is very little waiting time, or *latency*. Since data can be read from anywhere in the drive pretty much instantly, tasks which rely on lots of data being read from all over the place (such as loading the operating system when you start your computer, starting an application or loading a game) are completed much, much faster.

How much faster? Well, when comparing identical machines running identical installations, it's not uncommon for the computer with an SSD to start up in *less than half* the time of the computer with a conventional magnetic drive. This has the added benefit that you never have to defragment your files, which is always a nice perk.

As well as outperforming HDDs in random reads, SSDs also have the upper hand in *sustained* reading and writing (which is when you're reading and writing large files like videos, for example). A typical new magnetic hard drive will be able to read at 60-80 MB/s, whereas a midrange solid-state drive will be able to read at anywhere from 175-250 MB/s.

Durability

The other major advantage that SSDs have is again due to their lack of moving parts. When nothing moves there's very little that can physically go wrong with the drive, making it virtually invulnerable to vibrations, magnetism or being dropped – things that would seriously damage a magnetic drive.

This makes SSDs perfect for laptops and other smaller portable devices that get moved around a lot.

Noise

Yet another benefit of having no moving parts is the SSD's silence. Hard drives make a surprising amount of noise, especially when they're flat out. Having a drive that completely outperforms a conventional hard drive while making no noise at all is a definite plus.

Power Consumption

One of the big things that defines a laptop is its battery life – what's the point of a portable computer if the battery only lasts an hour from being fully charged?

Luckily, most solid-state drives draw a third to a half less power than even "low power" hard drives. This puts less strain on your battery, allowing it to last longer.

Temperature

If you've ever been poking around inside a computer while it's switched on you'll have probably discovered that hard drives get hot when they're in use for long periods of time. Really hot. Rotating platters 7200 times a minute isn't exactly the best way to keep a motor cool, and that heat has to go somewhere!

Furthermore, hard drives (like other components) need to be kept cool – extended periods of high temperatures reduce its reliability and lifespan. That means extra fans, which means extra noise (see above).

SSDs, on the other hand, generate very little heat and require no cooling. What's not to like?

Disadvantages

Price

What's not to like? Well, unfortunately SSDs are still very much a developing market, so you still pay a massive premium for all those advantages.

As of January 2011, you'll pay about £0.03 ($0.05) per GB for a large-capacity hard drive, whereas even the cheapest 128GB SSD will set you back £1.40 ($2.20) per GB. Yes, they do aim to do different jobs, but it just goes to show that it'll be a while before SSDs are ready to fully replace HDDs.

Reliability/Longevity

The other major problem SSDs have is with longevity. As fast as the technology allows solid-state drives to be, it limits them in that each transistor may only be written to a certain number of times before it becomes "stuck" and cannot be written to any more. While the SSD's *controller* helps to handle this by distributing writing between the transistors with *wear levelling*, eventually the drive *will* start to become very unreliable very quickly.

This is the solid-state drive's main Achilles heel, especially as the platters on magnetic hard drives don't have this limit. While a HDD will eventually fail and become unusable, this is usually due to the motor or the read/write head wearing out while the platters containing the data remain intact.

Although this sounds scary it should be made clear that the theoretical lifespan of the transistors in a solid-state drive is around *50 years*. Even if this is only theoretical, most SSDs *should* last 3-4 years, after which you'll probably be looking for an upgrade anyway.

Long Term Performance

Due to the way that data is dealt with on an SSD (including wear levelling), over time the drive becomes full of data even when you've carefully managed your disk space and deleted any files that you aren't using and according to the Operating System you still have plenty of free space left.

While this doesn't stop you from continuing to add data to the drive until you have filled the capacity of the drive, over time the writing speed of the drive appears to become slower and slower. Put simply, this is because as the drive's pages are all filled it needs to rearrange data to free more pages to write to.

There's a great description of how this works over at _AnandTech_. Again, I'll put the link at the end of this guide as well so you can get at it easily.

With earlier SSDs the only way to reverse the performance degradation was to do a hardware-level wipe of the drive. While this would make the drive act like a brand new drive it also involved losing all the data on the drive. Thankfully there are now ways to alleviate the degradation without wiping the drive, usually involving either a command called _TRIM_ or by the controller automatically carrying out a process called _garbage removal_ in blocks that aren't being used.

Data Recovery

Usually it takes a long time for a hard drive to fail, giving you plenty of warning and the opportunity to back up the data to another source. You don't get that with a solid-state drive; when a drive fails, it fails completely and instantly. When that happens, it's virtually impossible to retrieve the data.

The easy solution to this is to take regular backups of your data (which you should technically be doing anyway!), but that's not always feasible, particularly in a laptop.

The Bottom Line

Solid-state drives have plenty of advantages that in most cases far outweigh the disadvantages. If you're looking to upgrade your computer an SSD will give you by far the biggest tangible performance increase. The added speed and the ruggedness make an SSD a no brainer, particularly in a laptop.

So the question becomes less "Should I buy one at all?" and more "Should I buy one _yet_?" This question is a lot harder to answer, especially as prices continue to drop. Currently I would say that right now the price premium for SSDs keeps them firmly in the "only for enthusiasts" range at the moment. Give it 6-12 months or so and I think prices will be ready for everybody to start using them. Having said that, if you're building a gaming PC then you're probably spending a little more on other components anyway, so go for it!

Things to Look Out For

Capacity

Obviously it's important to get a drive that's big enough to hold your operating system, programs and data. The trick is to find the right balance between the right capacity and a reasonable price.

The way flash memory works means that the capacity is based on the *base 2* measurement, the same way as RAM. This means that the vast majority of SSDs will come in capacities of 32, 64, 128 or 256 gigabytes, although 512GB and 1TB drives are also available albeit hideously expensive. Some manufacturers label their drive as 30GB, 60GB or 120GB to make the capacities "easier to understand".

The approach many people take is to buy a SSD for nothing but their Operating System, Applications and documents that they use all the time, relegating all the other data like other documents, music, pictures and videos to a secondary, magnetic drive (whether internal or external).

In this scenario, a 64GB drive is perfect for most users whereas users with lots of large applications (such as gamers) or those wanting to run multiple operating systems (such as *dual-booting* Windows and Ubuntu) are probably better off with a 128GB drive. Just remember, you can leave free space on a drive but you can't make it bigger when you run out of space! It's important that you decide what you want to do with the drive and estimate how much space it will take to hold all your programs.

Finally, be wary about buying a drive that is significantly cheaper than all the other SSDs with similar capacities. There's usually a very good reason for it!

Brands

Some brands are more reliable than others when it comes to manufacturing SSDs. The main manufacturers are *Corsair*, *Intel*, *Kingston, OCZ* and *Samsung*. That's right, the same companies that make power supplies, processors and RAM are making solid-state drives, too. You'll also find familiar storage brands like *Western Digital* and *Seagate* making SSDs, but just because they make good magnetic drives doesn't necessarily mean that they make good flash drives!

However, the big names aren't always the best choice. Although not a well-known name in the mainstream space, a company called *Other World Computing* (*OWC*) is highly praised for their extremely high-performance and reliable SSDs. Best of all, these drives are competitively priced, too. Having said that, if you would really prefer the peace of mind of buying from a company that you recognise, you usually can't go wrong with a Corsair, Intel or Samsung drive.

Controllers

The *controller* manages the data on the solid-state drive and keeps track of where the data is kept. It's very important to have a decent controller or the performance of the drive is seriously impaired. The first mainstream solid-state drives relied on a controller made by a manufacturer called *JMicron*. These drives had great *sustained read and write* performance (that is, they were able to transfer large files much faster than a magnetic drive), but they had big problems with *random* read and writes, which resulted in extremely high latency and could often cause the computer in question to lock up for a full second or two when performing even simple tasks. That's not a very pleasant way to use a computer!

Manufacturers learned from their mistakes quickly and now very, very few (if any) solid-state drives still have this problem, but it's still important to keep an eye out for the controller which a particular solid-state drive uses when you're shopping for one. If possible avoid SSDs based on a *JMicron* controller. The main ones you'll want to get will use either the *Indilinx "Barefoot"* or *SandForce* controllers. Intel and Samsung also make their own SSD controllers that perform well, too.

TRIM Support

TRIM support is extremely important when it comes to buying an SSD. As I mentioned a bit earlier, TRIM is a command which can be utilised by the Operating System to tell the SSD that it has deleted files and gives it the chance to free up pages that aren't being used any more by rewriting the block when it's not in use. This means that the block doesn't need to be rewritten while you're trying to write to it, which is what causes the performance degradation in the first place.

The vast majority of drives do have TRIM support, so it's more a case of double checking to make sure it has it so that you don't end up with one of the few that doesn't. Some older drives didn't have TRIM support to start with but have a few pins near the SATA connector which allow you to update the controller's *firmware* and add TRIM support that way. It's just worth double checking!

You can find read more about TRIM support over at the main MakeUseOf site.

Image Acknowledgement

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