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Your PC, Inside and Out

Part II: CPU, RAM, Storage, Video Card and Expansions

By Lachlan Roy

LachlanRoy.com

YOUR PC, INSIDE AND OUT: PART 2

By: Lachlan Roy
http://lachlanroy.com

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Welcome to Part II of this MakeUseOf guide! Here you'll find information about CPUs, RAM, storage, video cards and other expansions for your PC. For information on a computer's chassis, power supply and motherboard, please download Part I at MakeUseOf.com.

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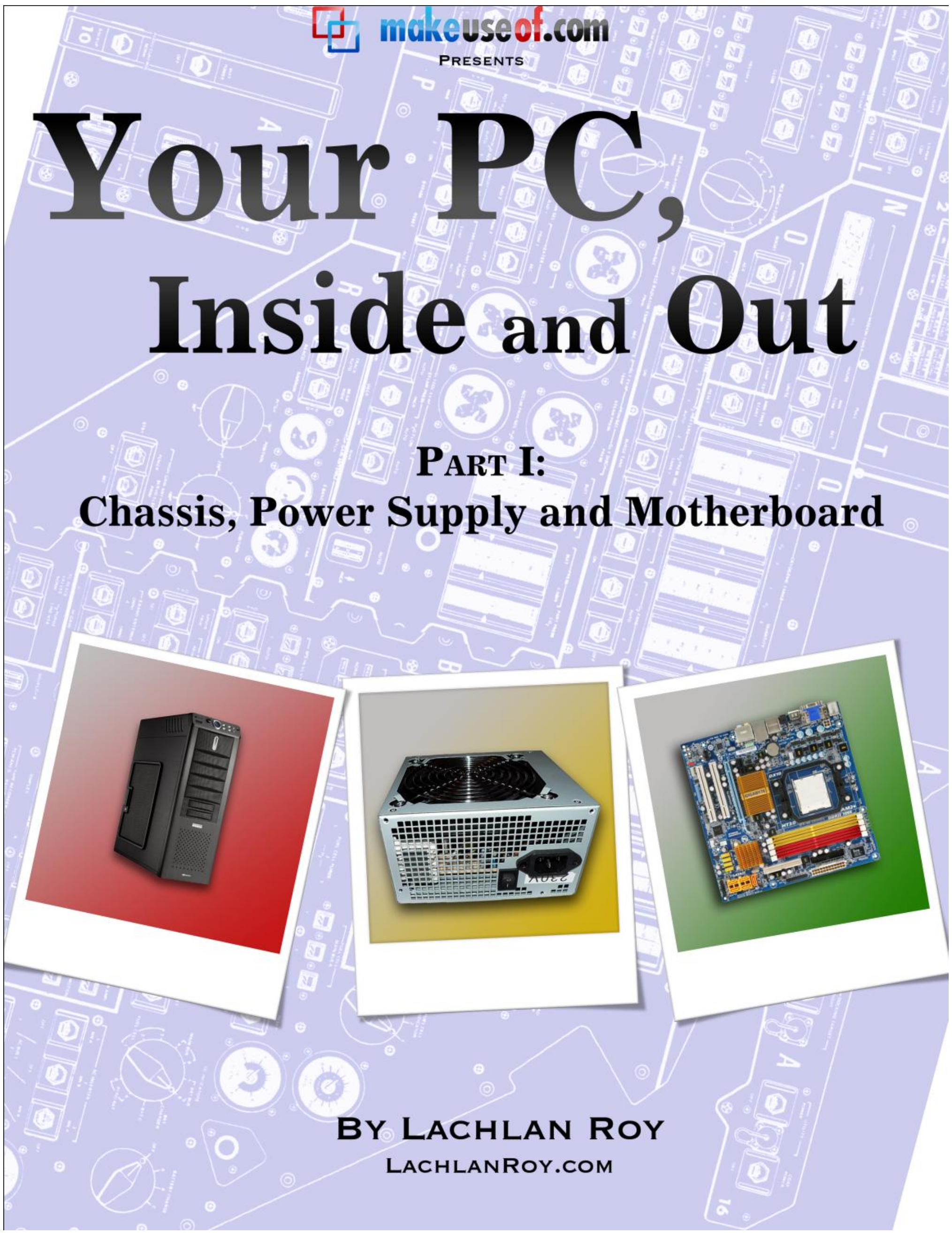
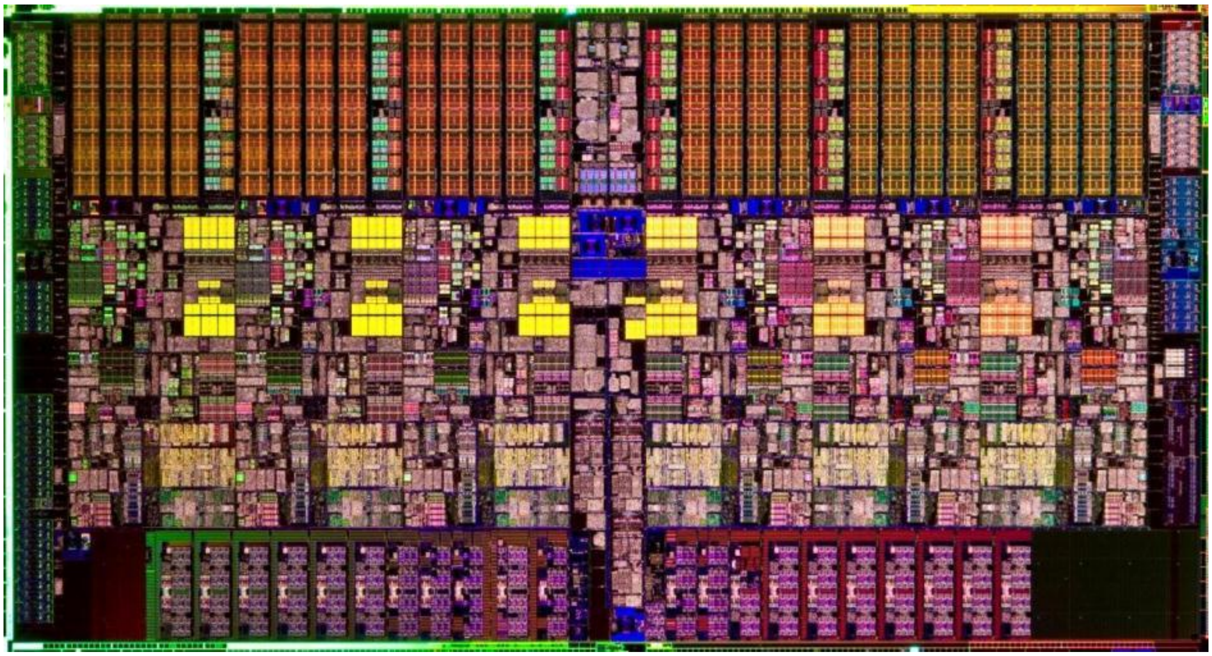


Chapter 1: CPU (Processor)

The *CPU* (*Central Processing Unit*) or *processor* is the ***brain*** of the computer – it's where all the calculations are carried out. Short of gaming, pretty much all the work a computer does is carried out by the CPU; while *RAM* and *hard drives* are important, they simply act as storage while data manipulation is carried out by the processor.



The die or internals of Intel's i7 980x – the most powerful consumer CPU currently

… and the same processor held in the hand for a size reference

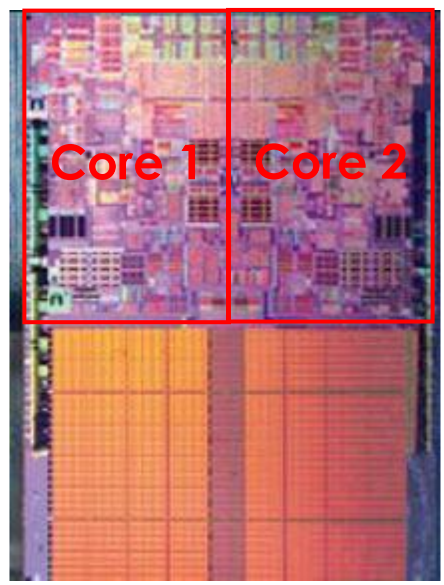
Clock Speed

One of the most common things you'll see when looking at CPU specifications is the processor's *clock speed*, measured in gigahertz (GHz), with 1GHz being equal to 1 billion hertz or *cycles per second*. This means that a 1GHz processor is able to carry out 1 billion calculations every second. As a general rule of thumb a processor with a higher clock speed is more powerful than one with a lower clock speed.

However this isn't the whole story, as different CPUs can do different amounts of work per cycle. One way to understand this is to imagine two people trying to fill identical swimming pools from a well with nothing but buckets. If both buckets were the same size, the faster person would be the one who can make more trips between the well and their swimming pool in the same time frame. However, the slower person could fill their pool just as fast if they carry more water per trip with a bigger bucket.

Multiple Cores

When looking to buy a new computer, you'll be constantly barraged with mentions of *cores* – dual cores! Quad cores! Hexa-core processors! What does it actually mean?



Up until 2004, all processors had just one *core*, or processing unit. A processor was made faster by increasing that core's *clock speed*. The disadvantage to this was that higher clock speeds generated much more heat, leading to massive, noisy *heatsinks*. It eventually reached the stage where it was simply infeasible to keep increasing the clock speed.

The solution was to create a processor with two cores – that is, a single processor with two smaller, lower speed processing units which can carry out different instructions. The benefit in this is obvious – why force a single unit harder and harder to do lots of things at once when you can split the work between two slightly less capable units? Many hands make light work, as they say.

The first generations of dual core processors – the Intel Celeron D and AMD Athlon 64 X2 families, for example – weren't much more efficient than their single-cored predecessors. In fact, before the technology was perfected they generated more heat than ever. However, over time they've become better and better; most new computers have at least two cores, with single core CPUs used only for the absolutely cheapest computers (as well as for applications where lots of processing power simply isn't needed, ie netbooks).

Most of the performance gains do come down purely to clock speeds again. As an example, let's compare a 3.0GHz dual core processor with a 2.6GHz quad core processor. This means that the dual core processor has 2 cores each running at 3.0GHz, giving the "equivalent" of a single core processor running at 6.0GHz. Although each core on the quad core processor is running 400MHz slower, there are four cores – 4 cores each running at 2.6GHz gives the "equivalent" of 10.4GHz.

So by that logic, surely all quad core processors must be better than dual core processors, and all hexa-core processors must be better than quads, right? Well, it's not quite as simple as that, because it depends on what you want to do with the computer. Most of the time computers are now used to doing lots of different things at once; opening a lot of tabs in a web browser, word processing, listening to music and instant messaging all at the same time. This is where multi-core processors excel, as they are able to split up the tasks and distribute them between the cores; the more cores you have, the more your CPU can handle at once.

However, there are some single tasks which require lots of processing power – editing video, working with large images in Photoshop or playing games, for example. Up until very recently most computer applications haven't been designed to make proper use of multiple cores. In this case, a processor with *fewer* cores at *higher clock speeds* will perform better.

Cache

When doing some deeper research on different CPUs, you may come across *cache*, measured in kilobytes (KB) or megabytes (MB). This is a place where the most frequently used data is stored so that it is quickly accessible by the processor. Most recent CPUs have at least 2 levels of cache (L1 and L2), with newer and more powerful ones having a third level (L3). L1 is the fastest but smallest level of cache, whereas the higher levels tend to have much higher quantities but are slower (although still faster than accessing the data from the *RAM*). Most processors split the cache up amongst the cores, although some do have a single cache for all cores to access. In almost all circumstances more cache is better.

AMD vs. Intel

Although there used to be many companies that used to mass market CPUs, the vast majority of the desktop and laptop CPU market share is split between two companies; AMD and Intel. While other companies such as ARM and VIA are still around and producing processors for other sectors (mobile devices and low power commercial uses, respectively), they do not produce processors for desktops and laptops.

So, what's the main difference between AMD and Intel processors? It used to be efficiency – AMD processors would be just as powerful as Intel's while performing at *lower clock speeds*. Intel focused on increasing clock speeds whereas AMD focused on increasing the amount of work done per cycle.

Right now the main difference is value and backwards compatibility vs. performance. At most performance levels AMD tends to produce processors at a more competitive rate to Intel. Furthermore, AMDs new CPUs (using the *AM3* socket) are still compatible with older AMD-based motherboards with the *AM2+* socket, making it relatively painless to upgrade to the latest processor technology.

Intel's instead decided to make a clean break with its new processors, introducing two new sockets (*Socket 1156* and *Socket 1366*) and making backwards compatibility impossible. However, Intel's most powerful processor is 25-50% faster than AMD's - the only downside is that it costs over three times as much!

To put it another way, for those looking to upgrade from an older AMD-based system, those looking for a good balance between price and performance and those who don't mind going without cutting edge technology, an AMD-based computer makes the most sense.

On the other hand, for those where money is no object or performance is particularly important, an Intel-based system is probably a better bet.

Of course, this is all assuming you're looking into building your own computer. If you just go to a store your mind will be made up for you; 80% of the time the computer will be built around an Intel CPU. That's by no means a bad thing; you don't need to go hunting for an AMD computer necessarily. Just bear this in mind if you look into building your own computer.

CPU Heatsinks

With all the work that the CPU does in such a small space it's not surprising that they tend to generate a *lot* of heat. Of course, this heat has to go somewhere – if the CPU gets too hot it'll be damaged and won't work anymore. There are a lot of delicate electronics in there!

That's where the *CPU heatsink* comes in. Just look for a big hunk of metal with a big fan on it. That'll be the heatsink! The CPU is under that, and it's the only thing keeping your CPU from melting itself to your motherboard. Just kidding! If for some reason the CPU doesn't get cooled properly it'll shut itself off before any real damage can be caused.

So how does a heatsink work? Well, the heatsink uses levers or screws to keep the heatsink pressed tightly against the CPU. A tiny amount of *thermal paste* between the two removes absolutely all the gaps. Heat is then transferred from the surface of the CPU's heat spreader to the heatsink via conduction. The heat spreads throughout the heatsink out to the edges of the heatsink, which are split into lots of thin *fins*. This greatly increases the surface area of the heatsink so when the fan on top blows down it pushes cooler air over the hot fins, taking heat away from the heatsink.

The only problem is that the stock cooler doesn't do the best job in the world. Yes, it keeps the processor cool enough that it doesn't overheat, but it usually doesn't do it efficiently or quietly. As a result the CPU heatsink is often the noisiest part of the computer.

There are many manufacturers who realise this is the case, so you'll find lots of companies which sell *after-market CPU coolers*. These tend to be much bigger, providing many more fins and a much, much larger surface area for the heat to be transferred away from the heatsink. A bigger heatsink also means that it can carry a larger fan which can spin slower to move the same amount of air, thus creating next noise.

And you haven't seen the fan that goes

To move the heat faster after-market coolers tend to use more *heat pipes*, which use liquids to transfer heat faster to the far ends of the heatsink. You can see that the heatsink before, the *Scythe Mugen 2*, has 5 heat pipes which go from the top of the heatsink, all the way down and through the main block before moving back up the other side. Compare that to the size of the stock AMD heatsink, and you can see why it can keep a processor at room temperature while staying pretty much silent!

Chapter 2: RAM (Memory)

RAM (short for *Random Access Memory*, sometimes referred to by retailers as just *memory)*, is similar to the ***short term memory*** of the computer. Things the computer accesses regularly (like frequently used *program files*) or needs to store temporarily (like something you *cut* or *copy* to the clipboard in the *operating system* to *paste* somewhere else) are stored in RAM.

The RAM used by the vast majority of computers today is *SDRAM*, or *Synchronous Dynamic Random Access Memory*. All this means is that the RAM carries out instructions in sync with the CPU, and isn't something which you'll need to recall often (if ever). RAM is referred to as *random access* because anything stored in RAM can be accessed in the same amount of time, regardless of where it's stored on the module. This is different to the way a *hard drive* works, which uses physical parts that need to move to the correct place to access data.

Since it doesn't have to wait for physical parts to find the data, RAM is much faster than *magnetic media* (hard drives) and *optical media* (CD/DVD drives); however, there is a massive trade-off: RAM is an example of *volatile memory*. This means that all the data stored in RAM is lost when the computer is turned off while data kept on a hard drive (which is a *non-volatile* form of storage) is kept safe and sound.

The other big difference between RAM and hard drives is the price to capacity ratio. The average price for 4 *gigabytes* of "value" RAM is the roughly the same price as a 1.5 *terabyte* (or roughly 1500 gigabytes) hard drive.

How much do you need?

While more RAM is better, there isn't much point in getting much more RAM than you need. Most desktop motherboards have 4 memory slots, and for both DDR2 and DDR3 2GB sticks are currently the most economical size to buy. This means that it's not difficult to get 8GB of RAM in a desktop these days. Notebooks generally have 2 slots, so the economical max is 4GB (which many laptops ship with by default). But how much do you actually need?

It really depends on the rest of your system; the specs of the other hardware in your computer, the operating system you're running and what you intend to use the computer *for*. Hardware-wise, it makes no sense to have 4GB of RAM if you're running an old Pentium 4 on Windows XP – sure, you'll have a lot of RAM, but performance is being held back by other components.

As a general guide OS wise (I'll be referring to Windows here; if you're using Ubuntu chances are you already know enough about computers and Macs tend to work well with most amounts of RAM). A guaranteed minimum for XP (particularly the latest versions) is 1GB; Windows Vista and 7 really should have a minimum of 2GB. You can get away with less. XP can run *alright* with 512MB (0.5GB), and Vista and 7 can get away with 1GB, but in all cases you'll have subpar performance. On the other hand, for general use 2GB is a great amount for XP and anywhere between 3-4GB for Vista and 7.

Of course, if you're planning on doing intensive work with your computer – video editing, Photoshop work, playing games and the like – you might want to consider adding more. Right now, 4GB is the sweet spot, and few people will benefit from using more.

RAM Sizes

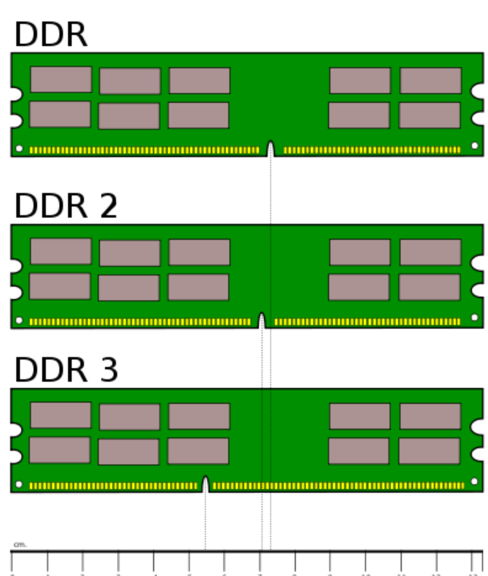
There are two main RAM sizes – *DIMM* (used in desktops) and *SO-DIMM* (used in notebooks and some Mini-ITX based computers). DIMM stands for *Dual In-line Memory Module*, and the SO in SO-DIMM simply stands for *Small Outline*. Most people just refer to them as *Desktop* and *Laptop* memory, which is definitely easier to remember.
It goes without saying that a SO-DIMM will cost significantly more than a DIMM with the same capacity, as it has to fit the same amount of memory into a footprint about half the size.

Things to Look For When Buying RAM

There are a few things you need to keep an eye on when going out to buy RAM, either as an upgrade or for a new computer. The big thing is choosing the right socket/speed – these are related as I'll explain below.

Socket

Besides the different sizes of RAM (DIMM and SO-DIMM), each has different generations – the most common now are *DDR(1)*, *DDR2* and *DDR3*.
DDR stands for *Double Data Rate*, with the number following simply being the generation; that is to say, DDR2 replaced DDR as the standard type of memory around 2004. DDR3 in turn became the most common type of memory for new computers in late 2009.



Each generation of DDR runs at different voltages and significantly different speeds; as such, newer kinds of RAM are not backwards compatible (nor can you use older generations of DDR in newer motherboards). To prevent this from happening the different generations have notches in different locations along the bottom, making it impossible to plug them into the wrong sockets, as you can see in the illustration.

Speed

Each generation of DDR is in general much faster than the last. However, each generation has multiple speeds. That is to say, each has multiple clock speeds (and therefore multiple theoretical maximum *bandwidths* or *data transfer speeds*).
These are referred to in set ways – the format *DDRx-yyy* refers to the data rate (measured in *MT/s*, or *MegaTransfer per second*, where a megatransfer is 1 million transfers of data) of the RAM (for example, DDR2-800 means DDR2 memory with a data rate of 800MT/s, which usually has a bandwidth of 6400MB/s), whereas the format *PCx-yyyy* refers to the module's theoretical bandwidth (for example, PC3-10600 means DDR3 memory with a bandwidth of 10666MB/s, which usually has a data rate of 1333MT/s).

Either way, you need to make sure that you get a speed which your motherboard can support.

Voltage

Although this is a minor thing to look for, you also need to make sure that the voltage which the RAM runs at is compatible with your motherboard, too. This was more of a problem when both DDR3 and Intel's socket 1156 were introduced. Most memory manufacturers were producing DDR3 memory running at around 1.8V (similar to DDR2s standard voltage), whereas motherboards based on socket 1156 generally only support RAM running at 1.5V. Now most DDR3 RAM runs at 1.5V so you're unlikely to run into any problems, but it's worth double checking just to make sure.

Brands

This is another one of those things where different people swear by different brands. The two manufacturers who tend to be recommended the most are *Kingston* and *Corsair*. Other brands like *Crucial*, *Hynix* and *OCZ* seem to produce fairly reliable RAM too, but Kingston and Corsair are the two kings of memory.

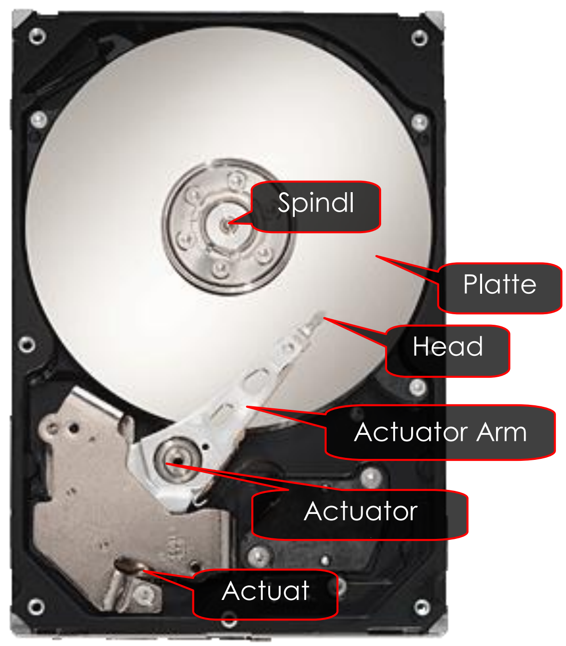
Chapter 3: Storage Devices

Just as RAM is like the computer's ***short-term memory***, storage devices act like the computer's ***long-term memory***; unlike RAM, storage devices don't lose data when they lose power.

The most common type of storage device is the *magnetic hard drive*. Also common are the various kinds of optical disks such as CDs and DVDs, which I'll cover in terms of the drives used to *read* from them and *write* to them.

Hard Drives

Magnetic (Conventional)



This is by far the most common storage device for computers. It offers great capacities for relatively low prices, and is generally very reliable and durable. Hard drives like the one you'll find in your desktop today have been around since 1983; the smaller 2.5" drive you'll find in a laptop has been around since 1988.

The technology and scale used to make a magnetic hard drive work is truly astonishing. Put simply, data is stored on *platters*, which are coated in a thin layer of magnetic material. The platters are spun very fast on the *spindle* by a motor (most recent desktop hard drives rotate the platters 120 times *every second!*).

Another motor uses an *actuator arm* to move a device called the *head* back and forth over the platters. Data is *written* to the platter by changing the magnetisation of very small regions of the magnetic material. Data is *read* by detecting the magnetisation of the material in these regions which is then interpreted as binary data (either a *1* or a *0*).

To give a sense of scale, the head would be like a Boeing 747 flying just 45 feet above the ground at over *300,000 mph* and counting every single blade of grass. Impressive stuff, right?

As remarkable as this technology is, the magnetic hard drive is still based on moving parts. These parts will inevitably wear out over time, eventually making it very, very difficult to retrieve the data. The average desktop hard drive lasts for around 4 years; the average laptop drive, for 3.

Older drives typically connect to the motherboard with an *IDE* cable and receive power from the PSU through a *molex connector*. Newer drives instead use a *SATA* cable and are powered through a *SATA power connector*.

Brands

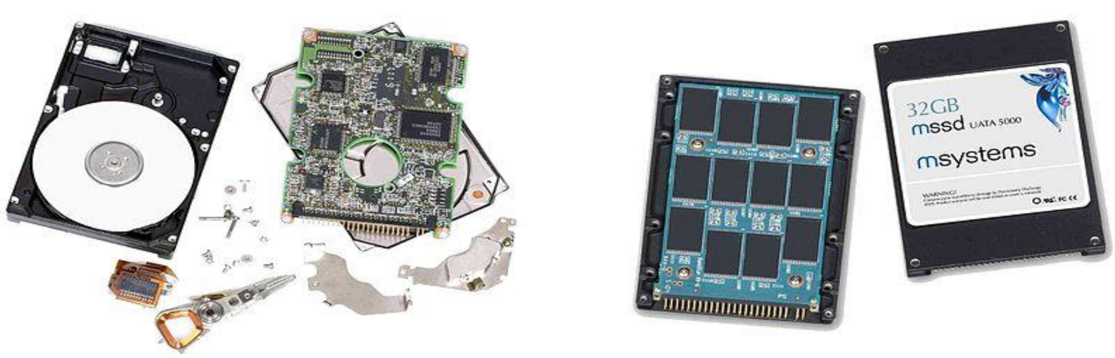
Like most kinds of components, hard drive manufacturers all have fierce loyalty and criticisms – the "best brand" and the brands to avoid constantly change depending on who you ask. I myself prefer drives from *Seagate* and *Samsung*, as I've had a few bad experiences with *Western Digital*. Other people will tell you the exact opposite.
No matter which brand you choose you'll almost certainly have no problems. If the data on the hard drive is invaluable, you really should be making backups anyway, which will protect you if your hard drive fails.

Having said that, most people agree that drives from *Maxtor* and *Hitachi* are better off avoided. Both of these companies are notorious for having big problems with their drives in past years. While there's every chance that their reliability has significantly improved, many people will still refuse to buy a drive from them.

Solid State Drives (SSDs)

Solid state drives are a relatively new arrival to mainstream computing but are already making big waves. Instead of relying on platters and moving parts, SSDs rely on flash chips – similar to the ones you'll find in USB memory sticks and in flash-based iPods like the Nano or Touch.

They perform much, much better than magnetic hard drives in a number of ways; there are no moving parts so they're silent, cool and much more durable than a traditional hard drive. They also use much less power and take very little



A comparison between the parts of a conventional hard drive and an SSD; No moving parts makes mechanical failure almost impossible.

time to start up. Finally, because they work in largely the same manner as RAM, it is possible to access files from multiple areas of the drive unlike magnetic drives which require the movement of the head to the area that needs to be read.

To give an idea of the performance of an SSD, look up "SSD boot test" on YouTube – you'll find a few different videos showing just how fast they are. Multiple tests show the exact same computer booting in half the time with a SSD.

Of course, this new technology doesn't come cheap, and it isn't without its problems. As of writing, a typical hard drive will give you around 30GB/£ (or 20GB/$). On the other hand, even the most price-efficient SSD will cost you £1.15/GB (or $1.85/GB), or to put it another way, 0.85GB/£ (or 0.5GB/$). You'll easily spend much more on a higher performance SSD. This essentially means that you either need lots of money for a big drive, or you need to have another conventional drive for the storage of most of your media.

Also, despite not having any moving parts, current SSDs have limited lifespans which are shorter than that of a conventional drive. Having said this, newer SSDs are said to have lifetimes an order of magnitude longer, placing them in line with conventional drives.

Should you get one?

Whether you should buy a SSD or not depends on a number of factors – your disposable income and how important performance and reliability all need to be taken into account. It's difficult to recommend a SSD to a casual computer user just yet; the added performance just isn't worth the extra cost unless you use your computer all the time. The key word there is *yet* – budget drives are becoming more commonplace, and the overall price to capacity ratio is falling rapidly.

On the other hand, if you use your computer all the time, performance is important to you and/or your drive's reliability is tantamount, you may want to consider getting a SSD. Yes, you'll pay a heavy premium over a fast hard drive, but the advantages are truly worth it.

Brands

For budget SSDs, look no further than *Kingston's SSD-Now!* series. They've been in the memory business for a long time, and their SSDs get very good reviews. The cheaper *Onyx*drives by *OCZ* are also worth looking at.

For midrange SSDs, *Onyx 2* and *Vertex* series drives by *OCZ* and *Samsung* drives are the way to go. If you have a lot of money to burn, *OCZ*'s *Vertex 2* and *Agility 2* drives, Intel's

X25-M and *X25-V* drives and *OWC's Mercury Extreme* SSDs provide by far the best performance.

What numbers are important?

Capacity

As you might suspect, it's important to get a hard drive with the right capacity. In the vast majority of cases, a larger hard drive is better – just because you only have a certain amount of data at the moment doesn't mean that over time you won't need more.

On the other hand, if you've only got about 20GB of data at the moment it makes little sense to buy a hard drive with 1TB (or 1000GB) of storage. Smaller capacity drives tend to be faster, make less noise and use less power because they usually have fewer platters.

For a laptop, 160GB or 250GB is perfect. For a desktop, a 320GB drive is the biggest drive that is likely to be single-platter. My suggestion would be to get a computer with a single-platter *primary drive*, and to add your own high-capacity drive yourself if you need more storage. If you need lots more storage and you have a laptop, you're better off getting a high capacity drive *external drive*.

Cache

Remember the CPU's cache? Hard drives have something very similar. It only has one level, and it isn't as fast as the CPU's cache, but hard drives have a relatively small amount of storage for data that is likely to be accessed regularly, too. In this case more cache is better.

As of writing, most hard drives have 32MB of cache. It's not imperative, but try to get one of these if at all possible. While it's not the end of the world if you get a drive with 8 or 16MB of cache, you'll probably find performance isn't *quite* as smooth.

RPM (Drive Speed)

The speed of the hard drive is very important, too. Magnetic hard drives have two main speeds – 5,400rpm and 7,200rpm (although you can also buy 10,000rpm drives). It's fairly obvious that a 7,200rpm hard drive will perform significantly better than a 5,400rpm drive. However, there is a downside – the trade-off for speed is higher power consumption, higher temperatures and more noise.

As a general rule of thumb, laptops tend to use 5,400rpm drives while desktops tend to have 7200rpm drives. Having said that, it's not uncommon to find a 7,200rpm drive in a laptop when high performance is required, nor is it uncommon for high-capacity drives used as extra storage to be running at 5,400rpm to save power and noise.

Optical Drives

Anything which can read *optical discs* (that is, CDs, DVDs or the more recent HD-DVDs and Blu-Ray discs) is referred to as an *optical drive*.

Optical drives share data with the computer in the same way as hard drives; that is, they are connected to the motherboard either with an *IDE* cable or a *SATA* cable. They also use the same power connectors to receive power from the power supply; older drives using an IDE connector typically use the *molex* power connector, whereas newer drives with the SATA connector use the newer SATA power connector as well.

So, how does an optical drive actually work? No matter what kind of disc the drive is reading or writing to, the process is practically identical.

When a disc is inserted into the drive it is rotated by a motor in a way which is somewhat similar to the spinning of a hard drive's *platters*. However, while a hard drive is designed to spin at a *constant speed* (measured in revolutions per minute or RPM), an optical drive is designed to spin a disc to achieve a *constant data rate*. As the circumference of the disc is higher towards the outside of the disc and the data must be read at a constant rate, a disc will spin slower when accessing data closer to the outside of the disc and faster when accessing data closer to the centre.

Data is stored on a disc by pressing pits into a very thin reflective surface along a data path often referred to as the disc's *groove*. The disc drive uses a laser and photodiodes (which detect light) which travel along this groove (similar to the way a needle passes along a vinyl record). When the laser travels over a pit the light is refracted differently to when the laser travels over the flat surface of the disc. This is detected by the photodiodes, which then output electrical signals that can be interpreted by the computer as data.

Writing to a disc is a little different. *Write once* discs like *CD-R*s have a layer of organic dye as well as the reflective layer. Data is written to the disc with a much more powerful laser which is used to heat tiny sections of the dye, changing the reflectivity of the dye. The heated areas cause differences in light refraction in the same way the pits of pressed CDs do.

Rewritable discs like *DVD-RWs* work slightly differently again. Instead of using a layer of organic dye these use a phase-change layer. These start off in a crystalline state which can then be changed to an amorphous state by heating with a more powerful laser. Again, the amorphous sections of the disc act like the pits of a pressed disc. However, unlike the organic layer this change is reversible by reheating the amorphous sections, which causes them to revert to a crystalline state.

Brands

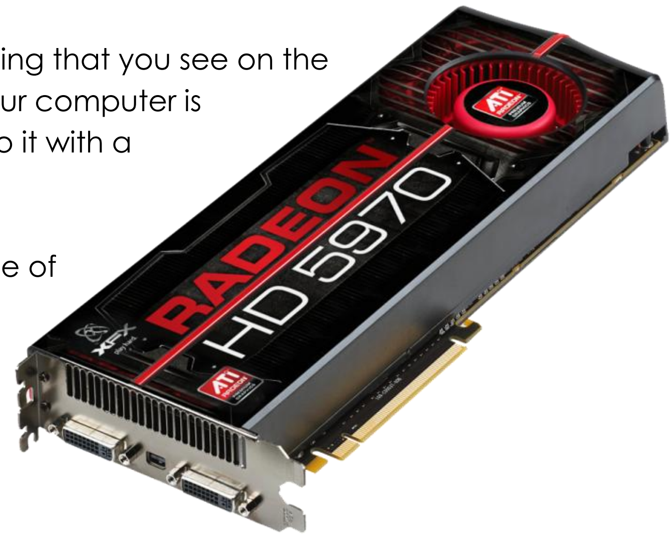
It's quite difficult to go wrong with any manufacturer, but I personally prefer optical drives by *Samsung* or *LG*. You may come across a brand called *Lite-On* – these drives are manufactured by *Sony*, and also seem to be fairly reliable.

Floppy Drives

Once *the* storage device of choice, floppy disks were wildly popular from the mid-1970s until the late-1990s. Even after being replaced by hard drives for the operating system, programs and data in the 80s, they continued to be used as portable storage. Eventually they were superseded by USB drives and CDs and DVDs.

It's very unlikely that you'll find a floppy disk drive in any new computer – the reasoning is that if you really need access to one you can always purchase an external floppy disk drive that plugs into your computer via USB.

Chapter 4: Graphics Cards



The *graphics card* or *video card* generates everything that you see on the screen. Without one there is no way to see what your computer is doing (meaning that you would have to connect to it with a different computer to control it effectively).

It's for this reason that the graphics card is easily one of the most important parts of the computer for a gamer – without a powerful graphics card the game can't run at full settings or at full speed, giving a sub-par playing experience.

Internal Connectors

PCI

The first mainstream 3D graphics cards acted just like any other expansion card, plugging into one of the computer's ubiquitous *PCI slots*. The PCI slot could only provide at most 25W, so the more powerful cards received additional power directly from the PSU via a *molex connector*.

AGP

As demand for graphics cards increased and they became more powerful it soon became apparent that the PCI interface couldn't provide enough bandwidth. Intel then designed the *Accelerated Graphics Port*, or *AGP*, the first slot dedicated to a graphics card. The advantages of this were two-fold; the first generation AGP slot could provide double the bandwidth of a PCI slot, and it didn't have to share bandwidth with other expansion cards (as a PCI graphics card did).

As they continued to become more powerful new generations of AGP slots were created, each bringing double the bandwidth of the last. The last version of AGP provided 8x the bandwidth of the first, and 16x the bandwidth of a PCI slot.

With greater performance came greater power usage, and eventually a molex connector just wasn't enough anymore. The molex connector was replaced by a new connector – the 6-pin connector which has now come to be known as the *PCIE power connector*. After the introduction of this new high-power connector newer generations of AGP slots no longer provided any significant power to the graphics card.

Approaching the end of the AGP era the most powerful graphics cards required not one, but two 6-pin connectors.

PCIe

By 2004 graphics cards were starting to reach the bandwidth limits that AGP could provide. Intel, Dell, IBM and HP worked together to produce a newer slot – PCI Express, or *PCIe*. The first full length PCIe slot (a 16x slot) could provide double the bandwidth of an AGP slot. Newer generations have been introduced over the years; the newest, PCIe v2.1, provides 4x the bandwidth of the fastest AGP slot, or *64x* the bandwidth of a PCI slot. PCIe 3.0, which is due to become mainstream in 2011, will double that bandwidth again.

Power consumption for the most powerful graphics cards continues to increase. Two six pin connectors are no longer enough for the most power-hungry cards. An 8-pin connector was introduced which could provide twice the power of a 6-pin. The most powerful graphics cards currently use an 8-pin plus a 6-pin.

Discrete graphics cards are now by far the most power-hungry components found in computers today.

IGP vs. Discrete Graphics

The thing is, not everybody *needs* a massive, power-sucking graphics card. For basic computer usage like browsing the web, watching a video or two, word processing or checking your email, a big graphics card is complete and utter overkill.

That's where an *Integrated Graphics Processor* (or *IGP*) comes in. Around 90% of prebuilt computers ship with integrated graphics. They're much cheaper than a discrete graphics card; they also use a lot less power and therefore make much less heat (and a lot less noise from cooling).

For most people this is perfect – it'll take anything they throw at it without any problems. However, there is a downside (for those keeping count). The *Graphics Processing Unit (or GPU)* in an IGP is much less powerful than one you'll find in even a low-midrange graphics card, so you'll be stuck when you *do* want to do something a bit more intensive. Furthermore, the IGP uses PCIe lanes, meaning that even if you do add a powerful graphics card later it won't perform as well.

On top of that, the IGP has very little of its own memory if it has any, instead having to use part of the system's RAM. This is an inefficient and slow way of providing the GPU with memory as well as depriving the rest of the system of some of its RAM.

So, should you go for a computer with an IGP, or should you go down the discrete graphics route? It really does depend on what you plan to do with the computer. If you plan to play any 3D games on it you're almost certainly better off to get a computer with even a moderately powerful discrete graphics card. If, on the other hand, you don't ever plan to do anything more intensive than watch high definition video, you'll save money and have a quieter computer if you get a computer with integrated graphics.

Video Connectors

VGA (Video Graphical Array)

This is probably the most common video connector for computers, despite the introduction of newer and more capable connectors such as DVI and DisplayPort. It carries an *analogue* video signal. You'll find it on most laptops as well as quite a few discrete graphics cards (although most tend to neglect them for another DVI port).

DVI (Digital Visual Interface)

This connector was released in 1999 to replace the VGA interface. While it hasn't replaced it for most users it is the connector of choice for gamers. It carries a *digital* video signal, and can handle much higher *resolutions* than VGA.

S-Video

Before HDMI came along, S-Video was the way to connect video devices to your TV, including your computer, since it provided much better quality than component. While you won't get the resolution you would through a VGA or digital connector (most people can't get much more than a crisp 1024x768 resolution), it's still fine for watching video or doing some light browsing.

HDMI

This is the new connector for connecting pretty much anything to new, high definition TVs. HDMI is very similar to DVI, but with one crucial difference; HDMI is also able to carry an audio signal, so both sound and video are transferred with just one cable.

DisplayPort/Mini DisplayPort

This is the newest type of display connector, first introduced in 2007. It was meant to fully replace DVI and VGA, but is yet to have any major impact. An interesting feature is its ability to carry data other than video and audio data. This means, for example, that a monitor could provide multiple USB expansion ports and still only connect to the computer via DisplayPort. The latest version is also capable of transferring ethernet data using the same, single cable.

A smaller version of the connector called *Mini DisplayPort* was introduced by Apple shortly after the introduction of its big brother. It has been incorporated into all of Apple's computers, from the lowly Mac Mini to the MacBook Pro, to the Mac Pro powerhouse. It is just as capable as the full sized port, just smaller. As such it has enjoyed deeper market penetration than the original port; so much so that it has started to appear on gaming graphics cards instead of the full sized DisplayPort.

AMD/ATI vs. nVidia

Similar to the way in which motherboards are made by multiple manufacturers but largely based on chipsets designed by AMD and Intel, graphics cards are made by multiple manufacturers but largely based on designs by two major companies – *ATI* (which is now owned by AMD and uses the same name) and *nVidia*.

Also just like motherboards, neither is *better* than the other. As with many things, what you're planning to do with the computer will affect which is the better one to go for.

For example, video quality has always been one of AMD/ATI's strengths – watching movies is generally accepted to look "better" through an AMD/ATI card due to more accurate temperatures, contrast and detail levels. The performance to price ratio tends to be better for ATI cards, too (although this is not always the case).

Finally, AMD/ATI cards tend to focus more on efficiency more than raw power – while they may not always outperform nVidia's offerings at the same price point, they'll usually use significantly less power (and be quieter as a result).

On the other side of the fence, nVidia's cards go for all out raw power, making them attractive to "hardcore" gamers. While they may not be quiet, cheap or have the same image quality, nVidia packs a lot of features which AMD/ATI cards simply don't have – a dedicated physics chipset called PhysX and support for 3D gaming (think 3D glasses), to name a couple.

Multiple Graphics Cards

Regardless of which type of graphics card you go for, you might want to consider adding a second one. Although they use different names, both companies provide the technology to use multiple graphics cards – ATI's technology is called *CrossFire* (or *X-Fire)*, whereas nVidia uses the term *SLI*.

However, there are some caveats. First of all, CrossFire and SLI are company-specific; that is, you can only use ATI cards or you can only use nVidia cards – no mixing. The limitation goes further than that, though. In almost all cases you can only use the same model card, and in many cases the cards need to be identical. This means, for example, that if you have an ATI 5850 made by XFX you would have to buy *another* ATI 5850 made by XFX for CrossFire to work.

Performance Scaling

You would assume that by joining two graphics cards together that because you have access to twice as much memory and two GPUs that you would get double the performance. However, this isn't the case. Particularly with early implementations of SLI and CrossFire multiple GPUs would have very small performance gains – in some cases they actually *decreased* performance!

Newer implementations are much more effective though, in no small part due to software companies embracing the technology. Both AMD/ATI and nVidia's latest offerings are able to provide up to a 90% performance increase by adding a second card.

Is it worth it?

In most cases it's not, *at least to begin with* – you're much better off to start off with a single, more powerful graphics card. This will provide better performance off the bat and gives you the option of adding another card of the same type later to give it a second performance boost.

What numbers are important?

Video Memory (VRAM)

This is by far the most advertised number when it comes to graphics cards. Video Memory (or *VRAM*) is similar to regular system RAM, but it is integrated into the graphics card itself and cannot be upgraded. It is mainly used for storing *textures*, which are the images on the surfaces of 3D models which give them their appearance. Higher quality textures look much better (and more realistic) but use up a lot more space as a result. VRAM is also used to store *Z-buffer data*, which manages the depth coordinates in 3D graphics.

As well as *capacity*, it is also important to look for the *speed* of the VRAM. Similar to the different generations of *DDR RAM*, there are different generations of VRAM with the naming scheme *GDDRx*, where x is the generation of memory. As of writing, the latest generation is *GDDR5*. Also like RAM, this memory can run at different clock speeds to provide better performance.

Put simply, the higher each number is, the better. However, this is not the most important aspect to a graphics card.

Graphics Processing Unit (GPU)

The most important specification of a graphics card is *Graphics Processing Unit*, or *GPU*. This is the part which does all the thinking of the graphics card, much like a specialised *CPU*. This is usually what the model number of a graphics card refers to.
Right now the naming convention for each graphics card is as follows:

- nVidia cards currently use the naming scheme *GTS/GTX xyy* – simply put, GTX is more powerful than GTS, *x* is the generation of card and *yy* denotes the level of performance. For example, the *GTS 450* is one the latest mid-range nVidia graphics card but it is not as powerful as the *GTX 295*, which is two generations old but the most powerful graphics card in its generation, with power comparable to a *GTX 480*.
- AMD/ATI cards currently use the xyz0 naming scheme – x is the generation number, *y* is a rough performance level and z is a performance sublevel. For example, the *5750* belongs to the 5th generation of cards under the current naming scheme, is the lowest of the high mid-range of single-gpu cards (it is not as powerful as a *5770* or any of the *58z0* cards). The AMD 4870 was from the previous generation but was the most powerful card in its generation, with performance similar to a *5770*.

Just in case you're still a bit confused, this link has a chart which shows the hierarchy of the different graphics cards and will give you a bit of an insight to the naming scheme. Higher numbered models have more *universal shaders*, *texture units*, *raster operators (ROPs)* and have GPUs which run at *faster clock speeds*. In all cases, the higher the number, the better the card.

Power Consumption and Connectors

This isn't really complicated – your PSU can only output a certain amount of power, and it only has a certain number of PCIe connectors. On top of making sure that your graphics card will fit into the slot on your motherboard you will also need to make sure that your power supply is able to accommodate the extra strain of the potential graphics card.

Which card do you buy?

As always, the card that is perfect for you will change depending on what you want to do. The higher the resolution of the screen you want to use, the more powerful the card you'll need. General usage requires very little power, watching high definition video requires more, but new video games will require a much more powerful card if you want to play them on full settings.

To give you an idea of what you need (or what your budget will get you), I couldn't recommend Tom's Hardware more. Clicking that link will take you to their graphics card section. All you need to do is click on the latest article named "Best Graphics Cards for the Money" and choose your budget.

As far as brands are concerned, differences in performance vary very little as they are all largely based on the reference designs which AMD and nVidia release. Instead different brands are judged on their customer service and warranty.

The best manufacturers are almost unanimously *XFX*, *Sapphire* and *Gainward*. Once you choose which model of graphics card you want, look for those names first. More often than not they'll carry a small price premium over other brands but their customer service and warranty makes it well worth it.

If you can't get a hold of a card by one of these manufacturers, *Palit* (which owns Gainward) also makes very good cards, as does *Asus*.

Chapter 5: Expansion Cards

Expansion cards do what they say on the tin – they provide extra functionality to the computer which isn't provided by any of the other components. They typically connect via the PCI interface, but more recently they have become more readily available on the PCIe interface.

I'll quickly run through each of the more common expansion cards and briefly explain what each one does.

Networking

As the name suggests, these cards allow the computer to join to a *computer network*, allowing it to "talk" to other computers.

Ethernet

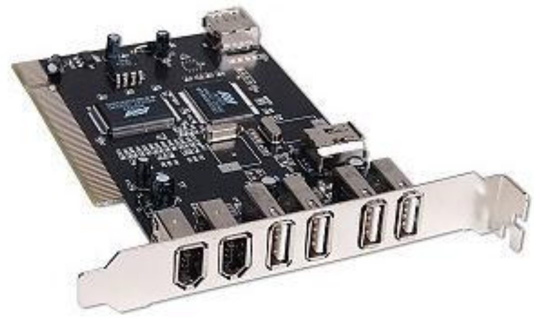
Although most modern motherboards have built in gigabit ethernet, an older computer may require an ethernet port to connect to the internet (or an internal network). Ethernet network cards are one of the types of cards which have switched to PCIe, although PCI versions are also readily available.

Wireless (Wi-Fi)

Ethernet ports may be widely found on desktops, but many lack wireless connectivity. A Wi-Fi expansion card will fix this problem quickly and easily. However, USB wireless dongles are widespread and cheap, so you might possibly be better off with one of these instead.

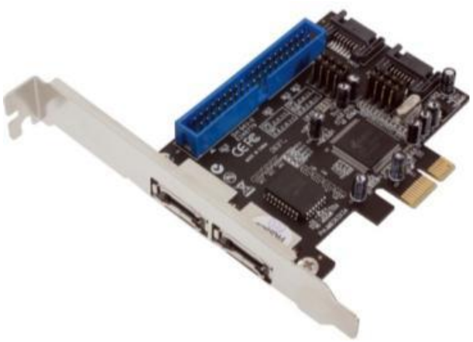
Sound Card

Yes, most motherboards now come with built in support for 7.1 channel surround sound, but sometimes there'll never be a substitute for high quality electrical components for a dedicated device. A dedicated sound card will often provide much higher quality sound providing you have the sound system to back it up.



Extra I/O (USB, FireWire etc.)

Sure, new motherboards support 12 USB ports and 2 FireWire ports, but you can never have too many! Besides, you may want to breathe some life back into an older computer that was around before USB 2 (or USB 1, for that matter). These PCI cards will give you all the ports you need.



Storage Controllers

Perhaps it's time to give your old faithful computer an upgrade – maybe it's time to get one of those new-fangled SATA hard drives. Hold on, it doesn't have any SATA ports! Not to worry, a storage controller has got you covered. It'll get you the ports you need; IDE, SATA or eSATA, it doesn't matter. You can be safe in the knowledge that you'll be able to connect that new hard drive or optical drive.

TV Tuners

One thing which a lot of people overlook is that their PC can make a great *Digital Video Recorder* (or *DVR*). Just get one of these TV tuner cards into your PC and you'll be recording video from the TV in no time. Dual tuners even let you watch something while recording something else at the same time. Pretty cool, eh?

Chapter 6: Upgrading Your Computer

Upgrade or Replace?

So, you've got a computer that's a few years old and it seems to be getting slower and slower, and it just doesn't seem capable of doing what you want it to do any more. It gradually gets worse and worse until suddenly you can't take it anymore. Something needs to be done, but then you're suddenly struck with a dilemma. What should you do? There's a brand new computer out there somewhere with your name on it, but what about this one? It's been your faithful companion for years. Surely you can't just give up on it, can you?

It's always tough trying to decide what to do in a situation like that, particularly since computers are now a commodity – it doesn't cost much to replace what you bought a few years ago with something significantly more powerful.

I would say that if the computer is three years old or less, then it's worth repairing and upgrading rather than replacing the whole computer. You'll be amazed at what an extra stick of RAM, the addition of a discrete graphics card or a replacement hard drive will do for your computer!

Having said that, perhaps it's better to check on the software before you start making any changes to the hardware; make sure you haven't got any viruses slowing down your computer, take all the rubbish that's choking your computer as it starts up and just generally give it a good de-gunking.

Oh, and if it's running Windows Vista, upgrade it to Windows 7. Now.

On the other hand, if your computer is older than that (particularly 5 years or older), maybe it's time to start looking at a new computer. The technology in your computer has been superseded and it'll likely be costly to find compatible components to *upgrade* your computer. It takes very little time and money to add an expansion card to bring SATA hard drives to your computer, true, but chances are your motherboard won't support a new processor or new RAM. Sometimes it's just better to cut your losses and go for something new.

But whatever you do, don't throw that old computer away! Get yourself a new computer, move all your data over, then buy a new hard drive for your old one and repurpose it. It could be a second computer for internet banking and accessing and managing sensitive data once in a blue moon; you could add a few high capacity hard drives and put it in the attic to run all the time as a file server or for backing up the new computer to. It could even be an extra computer for another family member. The point: that computer is far from useless! Even if it seems too slow to run Windows, you can always put Ubuntu on there. Try something new!

To sum up, computers are useful for longer than you might think. If your computer is starting to get painfully slow, there are some relatively cheap and quick things you can do to speed them up again. If it gets to a point where you're ready for something new, you can replace *and* upgrade. Look at the upside – you have two computers now!

Choosing what to upgrade

So, you've decided to upgrade your computer to get a few more years out of it before you bite the bullet and buy a new one. Great choice! But where do you start?
If your computer is getting painfully slow or making strange crunchy noises and it's a few years old, the first thing you'll want to do is to change out the hard drive. As you've read, a hard drive usually lasts 3 to 4 years before it starts to fail. Swap that out and it'll be like you've got a brand new machine for a fraction of the cost! Best of all, it's not difficult to get all the data moved over to the new hard drive.

If you don't think it's the hard drive, you might want to check how much RAM your computer has. Do you have enough installed? It might be worth getting an extra stick or two. Just make sure that you get the right type of RAM for your computer.

Maybe your computer works just fine, but it's so *noisy!* Check to see if your computer's CPU heatsink is clogged up with dust and clean that out first. If it's still a major problem, looks like it's time to get yourself an after-market cooler. Just make sure that you measure how much room you have first – heatsinks tend to be a lot larger than you'd think!

If your computer is new enough to have a PCIe slot, you might also want to add or replace a discrete graphics card for some extra grunt.

The problems with upgrading

Unfortunately, sometimes it's just not practical to upgrade your computer. The motherboard often becomes the limiting factor after a while – and that's simply not economical to replace. By the time you buy a new motherboard, you'll probably need a new CPU to go with it, new RAM, possibly a new PSU… you see where I'm going with this. Buying new big parts for an old computer just isn't worth it, because even if you *can* find compatible parts for your PC, you'll be paying big bucks for a marginal performance increase. You could probably spend the same amount of money on a prebuilt budget machine (or even a net-top) which would have the same (if not better) performance while being next to silent and using a fraction of the power. Or, conversely, the money could be put towards a slightly more expensive machine which would eat your old machine for breakfast.

Building your own

So, after reading this guide you suddenly feel empowered to make an informed decision about getting a new computer. That's great! But why not take it one step further and build a computer for yourself? Wait, hear me out. It's not as crazy as you think.

Yes, you could buy a cheap prebuilt computer from a big company like Dell or HP, and it'd be fine. It'd work for a while, but those computers are built to break after a few years so that you go out to buy a new one straight away.

On the other hand, you can build your own computer. You won't be able to build a budget computer for the same price as you could buy one from a big company, but once you start spending enough money for a mid-range or high-end computer, you'll start seeing *big* savings.

But that's not all. Not only will you save money, but you'll have the satisfaction of knowing that it's something *you built*. Furthermore, because *you* built it, you know *exactly* what's going into it. The computer is made just for you, *by* you.

On top of that, you'll end up with a computer running software that *you* choose. No preinstalled trials or bloat ware to slow your computer down. No frustration of coming across something and not having a clue what it does. Everything on the computer is there because *you* put it there.

Maybe I'm starting to win you over. Maybe you were sold already. Perhaps you're still hesitant though – just because you know what everything in the computer does doesn't mean that you can just go out and build a computer, right? Well, perhaps, but you have a good idea of what you need to build one, and what you're looking for in a computer. That's all you need to get started. There are plenty of places you can go to get help building your first computer – MakeUseOf has a guide to help you get started, and there's a big guide over at Tom's Hardware which will go into plenty of depth for when you're ready to take the plunge.

Postscript

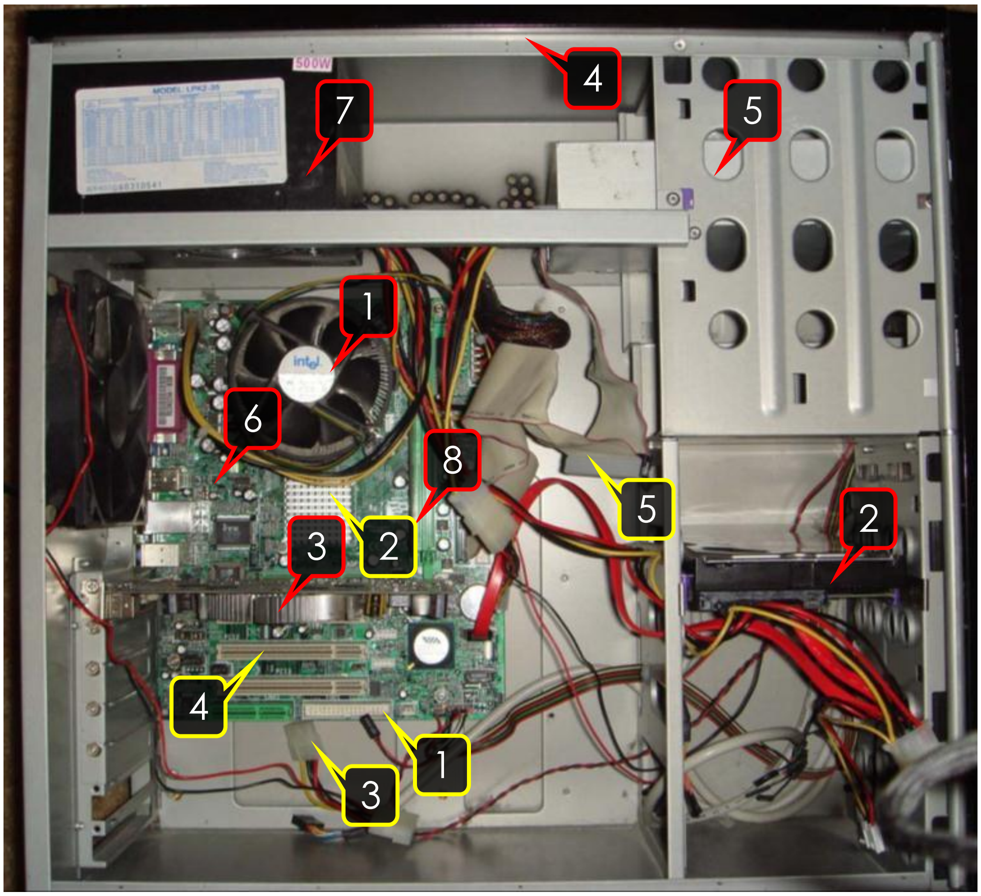
Well, that's the end of my guide. I'd like to thank you for taking the time to read it, and I hope you've found it informative and interesting. With this guide as a base you can go on to learn so much more – a lot of it has been just glanced over in the interest of time and space. The internet is full of information, from specialised websites like Tom's Hardware to sites like Wikipedia to internet forums ran by people just like you.

I hope I've been able to teach you something, and with any luck I've managed to spark an interest in computers and how they work while showing that they aren't quite as scary and alien as so many people seem to think. Computers and how they work fascinate me and have become a passion of mine, and I can't wait to see where they go from here.

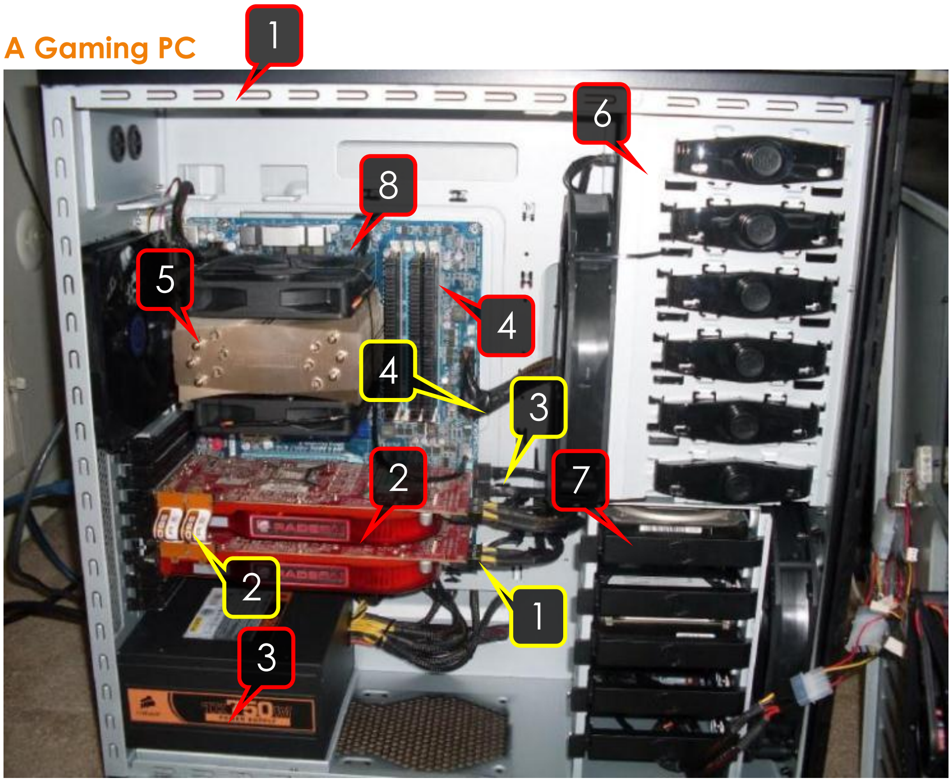
A Quick Test

As a purely optional extra, here's a quick test. I'll show you pictures of a budget computer and a top of the range gaming PC – see how many components you can recognise! Red numbers are main components, and yellow numbers are bonus points.

A Budget PC



A Gaming PC



Answers

A Budget PC

1:CPU/Heatsink
2:Hard Drive
3:Graphics Card
4:Case/Chassis
5:Optical Drive
6:Motherboard
7:Power Supply
8:RAM
1:Floppy Connector
2:Northbridge
3:Molex Connector
4:PCI Slot
5:IDE Cable

A Gaming PC

1:Case/Chassis
2:Graphics Card
3:Power Supply
4:RAM

5:CPU/Heatsink
6:Optical Drive
7:Hard Drive
8:Motherboard
1:PCIe Power Connector
2:CrossFire Bridge
3:SATA Connector
4:20+4 Pin Power Connector

Image Acknowledgement

- Intel i7 980x die – http://maximumpc.com
- Intel i7 980x size reference – http://thecoolgadgets.com
- CPU Heatsink – http://computershopper.com
- Mugen 2 vs Stock Heatsink – http://s23.photobucket.com/home/malveaux
- Hard drive parts – http://seagate.com
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- S-Video Port - http://tell.fll.purdue.edu
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- WiFi PCI Card – http://techreaders.com
- Sound PCIe Card – http://creative.com
- USB/FireWire PCI Card – http://topmedia.nl
- Storage Controller PCIe Card – http://computertarget.com.au
- TV Tuner PCIe Card – http://advanced2000.com
- Budget PC – http://jamesthebard.net
- Gaming PC – http://s149.photobucket.com/home/williamh1978

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