A STEP-BY-STEP, ILLUSTRATED GUIDE FROM THE EXPERTS AT MAXIMUM PC

# PC HOW-TO GUIDE

## MAKE YOUR *ULTIMATE* CUSTOM PC


**45 PAGES OF HANDS-ON PROJECTS**



**CHOOSE THE BEST!**

10 graphics cards and 10 motherboards tested

Volume 01 2016

Future

Graham Barlow

# WELCOME

**THERE'S A LOT OF INNOVATION** and exciting new releases in the world of PC components right now, which makes it the perfect time to build a rig of your own. If you're looking for inspiration, then we've got you covered here. In this special *PC How-To* guide, we show you how the experts here at *Maximum PC* set about building their own PCs, and guide you through the ever-changing landscape of PC components, so that you can be sure you're choosing the right parts.

Skylake, the eagerly awaited new processor architecture from Intel, has finally arrived, and along with it, a slew of 100-series motherboards has hit the market. It's important that you choose the right one, because more than anything else, your motherboard dictates what's going to be possible with your rig. There are some exciting new GPUs available, too, that come in cards of a variety of shapes and sizes.

So, if you're thinking of building your own PC, there are suddenly a lot of different factors to consider. To help you make the best choice for your next build, we have got roundups of the latest graphics cards (flick to page 12), motherboards (hop over to page 44), and reviews of two new Skylake chips (see page 30). Choosing the right memory for your next project is a factor, too, so we tell you everything you need to know on page 32.

If you're feeling really ambitious, then you might want to make your own water-cooled system. As well as giving you extra speed potential, water-cooling is a great way to make your PC really special. Water-cooled systems are great to look at, and lots of fun to build. So that you're completely armed with the facts, we've got a special guide to water-cooling for you, starting on page 82. Along with water-cooling comes the subject of overclocking, a perennial love for custom PC builders. We discuss the whole subject of overclocking in full, starting on page 74. We cover the hardware, the software, and the know-how you need.

Of course, nothing helps a potential PC builder better than seeing how the experts do it. In this guide we've got five sample builds, starting on page 52, from members of the *Maximum PC* team, which cover five very different types of PC. You'll see the thought processes that went into building each one, and you can see all the components we chose, and our reasoning behind choosing them.

Whatever you decide to do, I wish you luck with your next PC build. Don't forget to send us a picture of it here at *Maximum PC,* because we love to see what our readers are doing. Who knows, if it's crazy good, we might just feature it in the next issue of the magazine. Have fun with your PC projects!

*Graham Barlow is a contributing editor to* Maximum PC, *and has been rebuilding, reformatting, and rebooting PCs, in an endless cycle, for over 20 years now.*

↘ submit your questions to: comments@maximumpc.com

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# inside

## HOW TO 2016

### IN DEPTH



### BUILD IT



### HOW-TO



### FEATURES


06


32

24


40


**06**
**THE FUTURE OF THE GPU**
Make sure your next graphics card is future-proof with our guide to the latest GPUs.

**24**
**SKYLAKE**
They call it the pinnacle of microprocessors, so what's all the fuss about Skylake?

**32**
**UPGRADE YOUR MEMORY**
Looking for the perfect memory upgrade? We've got you covered here.

**40**
**SKYLAKE MOTHERBOARDS**
Let's find out what the new 100-series motherboards offer.


# The Future of the GPU

# It could be the perfect time to upgrade your current graphics card, but what do you need to prepare for the GPU future? By Dave James

**THE GRAPHICS CARD** is the component most responsible for PC gaming performance. Above everything else in your PC. You could have the most powerful, $1,000 octo-core Haswell-E CPU in your rig, but if you've got a weedy GPU backing it up, you're never going to be hitting the graphical heights that today's PC games deserve.

And it's a great time to buy a new graphics card right now. Both the leading lights of GPU development—Nvidia and AMD—have finally released their graphics card lineups for this year, with high-end, ultra-enthusiast GPUs and super-efficient, lower-end offerings. And by the way, for ultra-enthusiast, read: eye-wateringly "wtf-how-much?!" expensive.

While Nvidia has had it pretty much all its own way since the GTX 980 was released almost a year ago, AMD has finally responded with a slew of new—and some not so new—GPUs to try and put it back in the game. Correspondingly, Nvidia has updated its range and dropped the prices here and there. Who wins? We all do, of course. You can now go and bag yourself a quality, high-end graphics card for some pretty reasonable sums of money. Which is why this month we got them all into one room for a GPU battle royale.

If this is the state of play in the graphics card market right now, though, what does the future hold for this pedigree racehorse of components? Are we likely to have genuinely affordable, genuinely capable GPUs delivering the 4K experience on the next generation of high-resolution gaming monitors? And is the end nigh for the classic peripheral component interconnect express (PCIe) interface?

Both Nvidia and AMD are set for big new GPU architectures on incredibly tiny production processes in the next year, having both missed out on the bonanza that 20nm lithography was meant to offer. It's set to be a very intriguing time for the not-so-humble GPU then, and with the rise in screen resolution and the burgeoning VR industry's insatiable thirst for GPU power, it needs to be. Let's do some digging and see if we can figure it out what's going on....

Before we go too far into a future filled with high-bandwidth memory (HBM), new component interconnects, and new GPU architectures, there are still a few holes to be plugged in AMD and Nvidia's respective graphics card lineups.

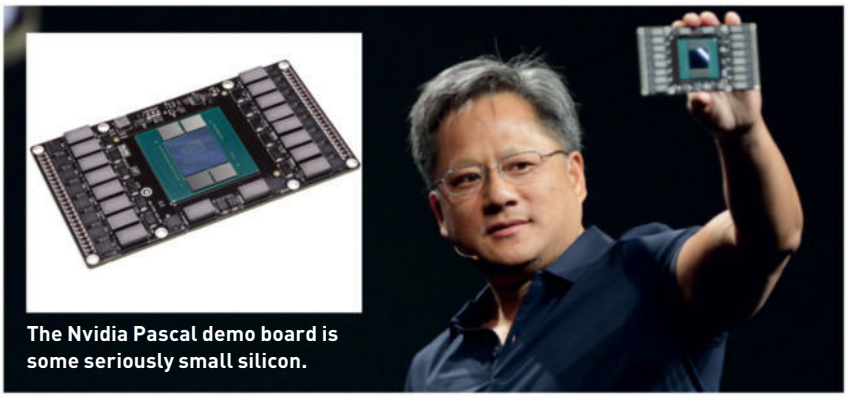
By the time you read this, the GTX 950 will be Nvidia's new entry-level gaming card. The 950 (see "First Look," page 93) sports a slightly cropped version of the GM 206 GPU found in the current GTX 960. It offers impressive power efficiency and 1080p gaming performance.

Interestingly, the GTX 750 Ti will continue to coexist with the GTX 900 cards, with prices now hovering just above $100. Where the 950, and above, all require a 6-pin PEG connection, the 750 Ti is able to draw all the power it needs from the motherboard.

To counter it, AMD is looking to try and spoil the low-end GPU party with its own Radeon 370X, a Trinidad GPU–powered card aiming squarely at the same price point as the GTX 950 Ti. It will essentially be using the same Pitcairn GPU that AMD filled out the R9 270X with, and it will be interesting to see who comes out on top in the battle at the bottom of the market.

There are also rumors that AMD is hard at work putting together a full range of HBM-supported graphics cards to follow the Fiji model used in the Fury cards. Whether that will be as part of an interim refresh of the current chips isn't known, but that's probably unlikely. We expect the current lineup to last until the next AMD GPU architecture drops next year.

With the Maxwell GPU architecture having been around for a good long while now—since early 2014 with the GTX 750 Ti from last September with the full-fat GTX 980 cores—it's time to start thinking about what's coming next.



The Nvidia Pascal demo board is some seriously small silicon.

The next gen of graphics cards from both Nvidia and AMD is going to see a major cut in the production process. This is the big news from the next round of architecture updates, and the reason for this current gen being slightly different to what we expected.

> **Pascal will be the first Nvidia cards to offer 3D memory; it's set to use HBM 2.0 to achieve a purported 32GB max frame buffer.**

When the two companies first started talking about their Maxwell and Pirate Islands GPU ranges, it was largely expected that these would be the first chips to hit the market rocking the new 20nm production process. And it wasn't just us expecting that, either; both the GPU makers thought they'd be making the move.

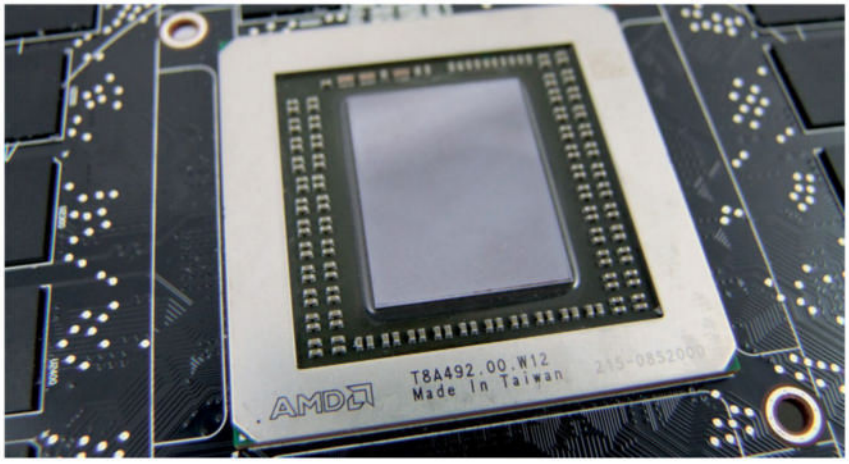
However, the 20nm process turned out to be a nightmare for the silicon makers to produce chips with at a consistent yield, without losing a bunch to defective parts in the baking process. This made the whole 20nm lithography seriously expensive. Tied to the fact that it wasn't actually delivering much in the way of performance or efficiency gains, it isn't surprising that the switch wasn't deemed worth it.

So, Nvidia and AMD have been stuck on the existing 28nm process for at least one generation longer than either really expected. Nvidia, however, seemed to see the writing on the wall, and, with the already-efficient Maxwell architecture, it was still able to deliver improved GPUs. AMD, on the other hand, has stuck with its existing architecture and simply piled more and more silicon into the design to boost performance.

## BLAISE OF GLORY

But the new 2016 GPU architectures from AMD and Nvidia won't be on the 20nm process either. That ship has sailed. We're now expecting both companies to move their chip production process to the new 16nm FinFET (similar to Intel's Tri-Gate 3D transistors) lithography. This will allow far more transistors to be packed into the same, or smaller, die size, and yield greater efficiency gains, too.

On the Nvidia side, we're looking at an architecture called Pascal—named after the French physicist Blaise Pascal—and the rumor that the successor to the full-fat GM 200 GPU could have as many as




Sticking with a 28nm GCN chip requires some serious cooling.

The next step for AMD's GPUs is to drop to the 16nm lithography.

**The upcoming GTX 950 Ti could well come passively cooled.**

double the transistor count. That would give it somewhere upward of 16 billion transistors. That phrase needs to be read in your head one more time, with Carl Sagan's wondrous tones.

The Pascal GPU will be the first of Nvidia's cards to offer 3D memory and is set to use the second-generation HBM 2.0 to achieve the purported 32GB maximum frame buffer. One of the struggles with the current HBM tech used on AMD's Fiji cards is that it has a limit of 2Gb per DRAM die, making a maximum of 1GB in a stack, and only four memory stacks per GPU interposer. That's why the Fury cards have a slightly miserly, though speedy, 4GB frame buffer.

HBM 2.0, though, is designed to massively boost that upper limit with a limit of 8Gb per die, and stacks offering four or eight dies on top of each other. That will give each stack either 4GB or 8GB in capacity. With four of those stacks arrayed on the interposer around the GPU itself, you're looking at either 16GB or 32GB frame buffers, depending on the SKU.

Pascal is looking to unify its memory, too, making it available to both CPU and GPU. In traditional interfaces, that would introduce latency issues across the PCIe connection when communicating between CPU and GPU. But with Pascal, Nvidia is introducing a new interface called NVLink. On our PCs, however, NVLink-proper still looks a while off (see "Is NVLink the end for PCIe?," right).

## AMD ADVANCES

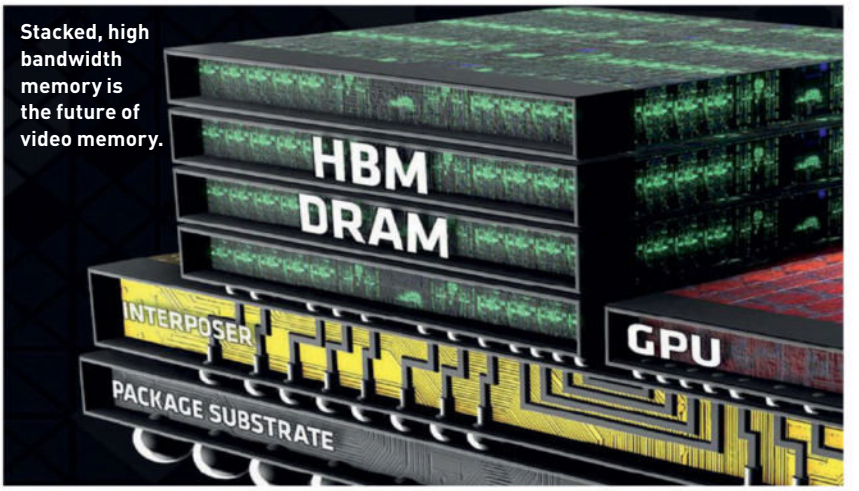
AMD's Arctic Islands architecture—also due in 2016—could be AMD's first new GPU architecture since the inception of the Graphics Core Next design at the beginning of 2012. It has mentioned a doubling of the performance-per-watt efficiency of its high-performance range of GPUs.

It's unlikely to be too radical a departure from the current GCN architecture though, especially given mixing a new production process with a brand-new architecture can be a recipe for disaster. Though that is also the route that Nvidia happens to be taking with Pascal....

What we do know is that the successor to the top Fiji GPU of today will have the Greenland codename and will sport the same second-gen memory architecture as the Nvidia cards: HBM 2.0. That will mean huge potential frame buffers all around. The Arctic Islands range will also utilize the 16nm FinFET technology, which is arguably how it's going to be able to nail the 2x perf-per-watt target that AMD has set itself.

With the introduction of the new lithography and the promise of HBM being used throughout the GPU stack, we're pretty confident that Arctic Islands won't suffer from the same rebrand-a-thon woes that have somewhat blighted the current Southern Islands/R300 series release.

All in all, 2016 looks to be a seriously exciting year in terms of graphics cards. The efficiency gains from the 16nm lithography will keep things highly chilled in the midrange, but also allow for some absolute monster GPUs at the top end. Hell, we could be looking toward 8K gaming by then, guys and gals.




**Stacked, high bandwidth memory is the future of video memory.**

# Is NVLink the end for PCIe?

**ALONG WITH** the announcement of the Pascal architecture, Nvidia CEO Jen-Hsun Huang also introduced the world to NVLink, an interconnect for its GPUs that could potentially offer between five and 12 times the bandwidth of the current PCIe 3.0 connection.

Nvidia's talking about NVLink offering DRAM-class speed and latency, which will allow for the use of Pascal's unified memory across the entire PC. It will also improve performance between GPUs, so multi-GPU systems could end up getting a far more linear scaling in terms of gaming speed.

As well as the NVLink connection on the GPU itself, it will also require dedicated silicon in the CPU if it wants to bypass the PCIe interface completely. From the outset though, that looks likely to be restricted to supercomputer-class high-performance computing (HPC); Intel is unlikely to start dropping Nvidia silicon into its designs.

But if there's no path to the CPU, NVLink can just dedicate all its available bandwidth to GPU-to-GPU connections, which is what will potentially enable it to bear fruit in our gaming PCs.

Right now, we're a fair way off saturating the available PCIe bandwidth on our rigs. The current interconnect is fine for our present-day needs, but boosting SLI scaling could be a real bonus. In terms of HPC applications, however, there are times when programs are doing large pro-level processing on the GPU—such as image processing for astronomy or seismic processing—and the PCIe interface becomes a serious bottleneck.

For our machines, that's not going to be a problem, and AMD shows no sign of wanting to shift interfaces, either. We can't see PCIe going dodo anytime soon, at least not in the next couple of years.


# Nvidia GTX Titan X

## Not winning this clash of cards

**NVIDIA'S GTX TITAN X** is the pinnacle of today's graphics card technology, a position it's likely to maintain until Pascal tips up, waving its 16nm transistors all up in the GM 200 GPU's silicon face. But that doesn't make it the best card around.

At launch, the $999 price tag seemed insanely, almost offensively, high. Sure, it was the first time we'd seen the much-vaunted GM 200 GPU appear in a form we could cram into our desktop machines, and it is most definitely head and shoulders above the GTX 980 in terms of gaming performance, but it didn't have the same feel as the original Titan.

It lacked the supercomputer, double-precision capabilities for a start, and we never warmed to the black shroud of the "X," either. The big problem, however, is that card sitting nonchalantly to its right: the GTX 980 Ti.

It was always going to happen. GPU history has taught us that much. But the release of the GTX 980 Ti has rendered the Titan X almost entirely irrelevant. The higher clock speeds of most iterations of its younger sibling made the difference between core count vanish, and often delivers the GTX 980 Ti a performance lead.

And yet, the Titan X is still $200 more expensive, only buying you an extra 6GB on top of the 980 Ti's frame buffer. By the time you need 12GB of graphics memory, the next generation of midrange GPU tech may well be making this ol' ultra enthusiast card look tired.

### SPECIFICATIONS

| | |
|---|---|
| GPU | GM 200 |
| CUDA Cores | 3,072 |
| Memory Capacity | 12GB GDDR5 |

VERDICT **7**

**Nvidia GTX Titan X**

- **TITAN** Huge frame buffer; overclockable.
- **TITCH** No double precision; doesn't offer value at super-expensive price.

$999, www.geforce.com

# Zotac 980 Ti Arctic Storm

## Chilling with the fastest GPU

**ANYTHING YOU CAN DO,** I can do better, says Zotac's super-chilled GTX 980 Ti, waving its water-cooling block in the Fury X's general direction. This is one of the finest examples of the Titan-killing GTX 980 Ti and shows AMD a thing or two about high-end GPUs.

Rocking almost the same GM 200 GPU as the Titan X, the GTX 980 Ti is missing only 256 CUDA cores and a 6GB chunk of VRAM, but has the same number of ROPs and 336-bit memory bus. Coupled with that beast of a GPU, Nvidia has let each manufacturer put their own stamp on the GTX 980 Ti, too. Most cards you see will be factory-boosted units with new cooling arrays bolted on.

That means cards like this Zotac one here really put the Titan X in its place. It also sits well above AMD's R9 Fury X; its closest rival from the red side. The issue with factory-overclocked cards, however, is that they have a hefty price premium attached, though you can still get more affordable GTX 980 Ti's that give the Titan and Fury X-ers a bloody nose for under $650. With this card you can get genuinely playable frame rates from the likes of *GTA V* and *Shadow of Mordor*, even at the most strenuous of 4K settings (if not quite maxed out).

This still feels like a ludicrous amount of money to spend on a new graphics card, but for value, it beats the Titan X hands-down. The high-end 4K performance you get with this GPU makes it a mightily tempting proposition and a very aspirational card.

### SPECIFICATIONS

| | |
|---|---|
| GPU | GM 200 |
| CUDA Cores | 2,816 |
| Memory Capacity | 6GB GDDR5 |

VERDICT **9** KICK ASS!

**Zotac GeForce GTX 980 Ti Arctic Storm**

- **CHILLING** Super-speedy; cool; Titan-killer.
- **COLD FISH** Still expensive; not much faster than other 980 Ti's.

$780, www.zotac.com


# AMD Radeon R9 Fury X

## Full of sound and fury

**WE GENUINELY HAD HIGH HOPES** for the Fiji GPU in the latest Pirate Islands range of flagship AMD graphics cards. And then the tantalizing promise of the first sub-28nm GPU vanished, along with the 20nm process it was supposed to use, leaving us with just the hopes that high bandwidth memory (HBM) might lift this new Radeon high enough to compete with Nvidia's finest.

The struggle with Fiji is that, to all intents and purposes, it represents very little advancement from the previous generation of Graphics Core Next chips. It's just got a lot more logic inside. If that had been paired with the die-shrink, things might have been rosy. As it is, the 28nm GPU generates a lot of heat (note the water cooler on the vanilla reference board). Even with the huge 4,096 Radeon cores inside, it can't perform as well as the slightly more expensive reference GTX 980 Ti.

It has got the first generation of HBM in there—that's allowed for the smaller form factor, but seemingly little else at the top resolution. At 1440p and 1080p, you get a nice uplift over the old Tahiti-powered R9 290X, but when you hit 4K, that 4GB frame buffer just runs out. Because of the limits of first-gen HBM, AMD could only fit 4GB onto the Fiji GPU.

With hugely detailed games such as *Middle-earth: Shadow of Mordor*, *Total War: Attila*, and *GTA V* demanding well above that limit, the Fury X quickly bumps into its performance ceiling.

**SPECIFICATIONS**

| | |
|---|---|
| **GPU** | Fiji XT |
| **CUDA Cores** | 4,096 |
| **Memory Capacity** | 4GB HBM |

**VERDICT 7**

**AMD Radeon R9 Fury X**

**XPERT** Water cooled; next-gen memory.

**FURIOUS** Can't catch the GTX 980 Ti; only 4GB frame buffer; relatively expensive.

$649, www.amd.com


# Sapphire R9 Fury Tri-X

## Fast and a little furious

**SUCH IS THE WAY** with AMD graphics cards—they will almost always arrive two-by-two. When AMD creates a class of GPU, it will generally offer a higher-end XT version and a slightly cut-down Pro version.

The R9 Fury then is the slightly cut-down Pro version of the Fiji XT in the Fury X. The Fiji Pro has 512 fewer Radeon cores than its bigger brother, and a 50MHz drop in base clock, but is happily sporting the same 4GB of HBM for a super-speed frame buffer. It's also almost $100 cheaper than the Fury X.

Which leaves us scratching our heads. This Sapphire, Tri-X-cooled version of the Fury actually clocks just 10MHz behind the Fury X and yields almost identical gaming frame rates as the more expensive, water-cooled reference card. Yes, the air-cooled card inevitably runs hotter—by around 15 degrees—but when you're dropping only a few fps on average, but saving $100, it becomes a bit of a no-brainer.

It's still over $550 for effectively a third-tier graphics card, but it will deliver excellent gaming performance and, if you're not going 4K yet, will make your 1440p screen sing. The Fury also goes toe-to-toe with the GTX 980, often taking a performance lead. That has led to some price drops on the older card though, so you can find °great deals on the Nvidia side now. But when the price is close, we'd recommend staying with the more-advanced card that's rocking HBM if you're chasing a purchase.

**SPECIFICATIONS**

| | |
|---|---|
| **GPU** | Fiji Pro |
| **CUDA Cores** | 3,584 |
| **Memory Capacity** | 4GB HBM |

**VERDICT 9**

**Sapphire Radeon R9 Fury Tri-X**

**TRUSTY** Almost as quick as the Fury X; decent cooling.

**TRIXSY** Expensive; only just faster than 980.

$563, www.sapphiretech.com


# MSI GTX 980 Gaming

## Bon anniversaire, old friend

**IT SEEMS FUNNY TO THINK** the GTX 980 is almost a year old. It doesn't seem that long since we first plugged the big Maxwell chip into our test rig and were blown away by the unprecedented mix of performance and efficiency.

Despite still being built of the same 28nm transistors as the Kepler generation of graphics cards, Nvidia had managed to tweak its architecture enough that you effectively got all of the benefits of a die-shrink, without having one. Imagine what it would've been like had Maxwell hit the 20nm lithography we expected. Imagine what Pascal is going to be like when it arrives next year.

A year down the line, the 980 is still a great card, especially since the release of the Fury and Fury X has encouraged its first real price drop. With this outstanding card being almost $100 cheaper than the Fury—and a great deal less than the Fury X—it's a fantastic GPU for your 1440p gaming rig.

The GPU here is seriously overclocked, as the GTX 980 is generally capable of, and comes with a 0dB cooler that only really needs to kick in at peak gaming performance.

Right now though, 1440p is the limit of the 4GB frame buffer the GTX 980 sports. So 4K gaming is possible, but too much of a compromise for this card. It's a toss-up between this and the Fury, and in the end it's going to come down to finances and personal preference. The Fury is quicker and has superior memory tech, but the GTX 980 is cheaper and less power hungry.

### SPECIFICATIONS

| | |
|---|---|
| **GPU** | GM 204 |
| **CUDA Cores** | 2,048 |
| **Memory Capacity** | 4GB GDDR5 |

**VERDICT 8**

**MSI GTX 980 Gaming**

**GAME ON** Still a great GPU; quality cooling; sterling 1440p perf.

**GAME OVER** Not a 4K gamer, with that 4GB VRAM.

$470, www.msi.com


# XFX Radeon R9 390X

## Deserving of a new name?

**IT'S REALLY EASY** to get caught whining about feeling misled about this generation of AMD cards. The Fury cards and their Fiji GPUs are the only new graphics silicon AMD has really put the time into for this year's launch. Everything else is essentially a rebranded version of the last-gen option, with a few light tweaks here and there.

But those tweaks have made a real difference. While this Grenada XT GPU is little more than the Hawaii XT chip from the ol' R9 290X, AMD has squeezed a little more speed from its clocks—an extra 50MHz—and doubled the memory. Whether that's enough to mean the GPU deserves a new name is neither here nor there.

While the R9 390X is a lot quicker than the R9 290X it's replacing, it's also effectively the same price. Now, before we get ahead of ourselves, that 8GB frame buffer isn't going to suddenly deliver 4K gaming performance for this aging architecture—there's almost no difference between the 290X and 390X at the highest resolution—but it does deliver performance improvements almost across the board at lower levels.

Almost... because we did experience some weird issues with this card and *GRID 2*. But for everything else, even the demanding *GTA V*, it delivered impressive performance figures. Most obviously in the minimum frame rates, especially with Rockstar's modern classic.

But its li'l brother, the straight R9 390, is the issue here. It's practically as good, with a notable saving, too.

### SPECIFICATIONS

| | |
|---|---|
| **GPU** | Grenada XT |
| **CUDA Cores** | 2,816 |
| **Memory Capacity** | 8GB GDDR5 |

**VERDICT 7**

**XFX Radeon R9 390X**

**GRENADA** Hefty frame buffer; quality 1440p performance.

**GRENADE** Re-branded GPU; R9 390 is almost as good.

$435, www.xfxforce.com

# Sapphire R9 390 Nitro

## Hawaii Pro, with added nitrous

**AMD ALWAYS SEEMS** to pull off the same trick; release two cards based on very slightly different GPUs, with very slightly different performance numbers, and demand a lot more for one than the other.

Inevitably, we then look at the lower-spec card with almost the same gaming prowess and question why anyone would pick the pricier option. Such is the way with the Fury and Fury X. Such is the way with the 290 and 290X. And so it is with the 390 and 390X.

And when you throw into the mix that this new Sapphire Nitro branding means this overclocked card gets a Tri-X cooler attached to it, you know things aren't looking too good for the 390X. Couple all that with the fact the 390 also performs better than the top AMD GPU of the last generation and we have a great midranger on our hands.

With most games, you'll get excellent 1440p performance out of it, and for a pretty impressive price, too. That Sapphire cooler on this version means it maintains a chilled disposition even in the most aggressive of gaming arenas, and the 8GB frame buffer means it can take every high-res texture that *GTA V* or *Shadow of Mordor* cares to toss its way.

It may be another exercise in rebadging GPUs for AMD, but the little tweaks the team has made to this card's silicon have made it very much worth the effort. We may not be hugely impressed with the Fury X, but the work it has done on the 390 almost makes up for it.

### SPECIFICATIONS

| | |
|---|---|
| **GPU** | Grenada Pro |
| **CUDA Cores** | 2,560 |
| **Memory Capacity** | 8GB GDDR5 |

**VERDICT** 9

**Sapphire R9 390 Nitro**

**NITROUS** Faster than the 290X; almost as quick as the 390X; enormo-buffer.

**NOXIOUS** Old architecture; drops frames to the 970.

$340, www.sapphiretech.com

# Gigabyte GTX 970 G1 Gaming

## Ignore the shenanigans

**THERE'S GENUINELY** a lot to like about the GTX 970, despite all the grumbling surrounding its offset frame buffer. It's a good gamer and comes at a decent price, too.

The issue is that Nvidia didn't disclose the smart work it had done with the GPU and the VRAM. To ensure it kept more of the actual GPU logic, Nvidia's engineers did some clever stuff splitting the frame buffer. Had it not done so, the chip would have lost a lot more of the good stuff. Unfortunately, it didn't disclose this and we saw games using over 3.5GB of VRAM struggling on the GTX 970.

But then this isn't a GPU you'd use for seriously taxing 4K gaming, anyway. You can get up there in the VRAM stakes with gaming at 1440p—*GTA V* and *Mordor*'s texture packs do that—but elsewhere, the GTX 970 really fits the bill for a midrange graphics card.

And Gigabyte's version comes with the excellent triple-fan Windforce cooler, which allows this card to be seriously overclocked without melting a hole in your motherboard. Even at its hottest, it doesn't top 64 C.

Its biggest rival is that impressive R9 390. These two GPUs trade blows across most of our benchmarking suite, with AMD taking the lead in one test and Nvidia winning others. Where the 390 does win though is in the more modern games, which need over and above the 4GB frame buffer this card is sporting, even at 1440p. That, and the fact the AMD card is often slightly cheaper, means we give the nod to the 390 here.

### SPECIFICATIONS

| | |
|---|---|
| **GPU** | GM 204 |
| **CUDA Cores** | 1,664 |
| **Memory Capacity** | 3.5 + 0.5GB GDDR5 |

**VERDICT** 8

**Gigabyte GTX 970 G1 Gaming**

**G1** Cool 'n' quick; decent price.

**M25** Pricier than the 390; suffers at top settings in modern games; frame buffer-gate.

$359, www.gigabyte.com

# Asus GTX 960 STRIX

## 2GB just ain't enough any more

**THE GTX 960 IS PRETTY MUCH** the bottom of the ladder when it comes to the modern Maxwell lineup, until the GTX 950 arrives to replace the ol' GTX 750 GPUs, at any rate. And what that means is we're talking about a resolutely 1080p gamer's card.

You can, of course, run a 4K monitor from this GPU, but even at 1440p settings, you'll struggle to play the latest games at top settings with any semblance of buttery smooth gaming. Throw this Asus STRIX card at anything running on a 1080p screen, though, and that's exactly what you'll get. *BF4* runs like a dream at top settings and you can get great performance out of *GTA V*, too. *Shadow of Mordor*'s texture pack, though, is still seriously demanding, even at 1080p, so we only saw 36fps on average, which is still just about acceptable.

The big issue with this card is that 2GB frame buffer. Where once that was plenty, in this brave new resolution-heavy world of ours, it's simply not enough for the most demanding of games and is likely to leave you wanting when new titles drop in the big gamegasm this fall.

But when it's coated in Asus's STRIX armor, it's still a tempting $200 GPU. The 0dB cooler only spins up when you get up to gaming speeds and even then this card stays seriously cool and quiet. At this end of the market though, AMD has got it sewn up again. The competing R9 380 is similarly priced and rocks that 4GB frame buffer to give it some much-needed longevity.

### SPECIFICATIONS

| | |
|---|---|
| **GPU** | GM 206 |
| **CUDA Cores** | 1,024 |
| **Memory Capacity** | 2GB GDDR5 |

**VERDICT** 7

**Asus GTX 960 STRIX**

**STRIX** Low-powered; decent at 1080p.

**STRUCK OUT** Weedy frame buffer; fails at 1440p top settings; the 380 takes it.

$201, www.asus.com

# MSI R9 380 Gaming 4G

## Something old, something new

**WE'VE GIVEN AMD** a little bit of grief for the whole rebranding thing with this current generation of GPUs. And it does feel a little like the company is treading water until either TSMC or Global Foundaries get their 16nm acts together and provide it with a production process for the future. Which is all to say the R9 380 is another old-school GPU; though this is actually the second-most modern after the Fiji chips.

The Antigua GPU at the heart of the R9 380 is essentially the Tonga chip from the previous generation. That means it's got the latest class of GCN architecture, rocking the same 256-bit memory bus as the R9 285 because of the lossless color-compression tech boosting its memory performance.

That's some modern AMD goodness that's missing from the higher-end 390 cards. The real big win for this card is—and we know we keep harping on about it—the chunky memory buffer. With 4GB on this relatively low-end GPU, you're getting a quality 1080p gaming card that's more than capable of mixing it with the most graphically demanding games of now and tomorrow.

The 2GB buffer of the GTX 960 is what's holding it back, but with double that capacity, the R9 380 is a far more capable gamer, even offering very playable performance at 1440p, too. Where you do need to be careful though is with the 2GB versions of the R9 380 that are floating around. Those are definitely to be avoided.

### SPECIFICATIONS

| | |
|---|---|
| **GPU** | Antigua |
| **CUDA Cores** | 1,792 |
| **Memory Capacity** | 4GB GDDR5 |

**VERDICT** 8

**MSI R9 380 Gaming 4G**

**GAMING** Beefy buffer; decent at 1080p; great MSI cooler.

**SHAMING** Avoid the 2GB; 4GB is pricey.

$240, www.msi.com

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# HOW WE TESTED

Our test bed comprises an Intel Core i7-5960X in an Asus X99-Deluxe motherboard with 16GB of 2,133MHz DDR4 memory under Windows 8.1. All of the graphics cards are tested with the latest release drivers on the same benchmark settings to ensure a fair test. We've included the minimum frame rate results as well as the overall average to indicate how smooth an experience you're getting from each graphics card.

## SPECIFICATIONS

| | Website | Price | GPU | Cores | Memory Bus | TDP | Peak Temp (˚C) | Score |
|---|---|---|---|---|---|---|---|---|
| **Nvidia GTX Titan X** | www.geforce.com | $999 | GM 200 | 3,072 | 384-bit | 250W | 83 | 7 |
| **Zotac 980 Ti Arctic Storm** | www.zotac.com | $780 | GM 200 | 2,816 | 384-bit | 250W | 68 | 9 |
| **AMD R9 Fury X** | www.amd.com | $649 | Fiji XT | 4,096 | 4,096-bit | 275W | 64 | 7 |
| **Sapphire R9 Fury Tri-X** | www.sapphiretech.com | $563 | Fiji Pro | 3,584 | 4,096-bit | 275W | 79 | 8 |
| **MSI GTX 980 Gaming** | www.msi.com | $470 | GM 204 | 2,048 | 256-bit | 165W | 75 | 8 |
| **XFX R9 390X** | www.xfxforce.com | $435 | Grenada XT | 2,816 | 512-bit | 275W | 80 | 7 |
| **Sapphire R9 390 Nitro** | www.sapphiretech.com | $340 | Grenada Pro | 2,560 | 512-bit | 275W | 71 | 9 |
| **Gigabyte GTX 970 G1 Gaming** | www.gigabyte.com | $359 | GM 204 | 1,664 | 256-bit | 145W | 64 | 8 |
| **Asus GTX 960 STRIX** | www.asus.com | $201 | GM 206 | 1,024 | 128-bit | 120W | 64 | 7 |
| **MSI R9 380 Gaming 4G** | www.msi.com | $240 | Antigua | 1,792 | 256-bit | 190W | 78 | 8 |

## 1920 X 1080 BENCHMARKS (1080p)

| | Battlefield 4 | Total War: Attila | GRID 2 | GTA V | Shadow of Mordor |
|---|---|---|---|---|---|
| **Nvidia GTX Titan X** | 64 / 122 | 21 / 43 | **132 / 180** | 12 / 103 | 49 / 108 |
| **Zotac 980 Ti Arctic Storm** | **87 / 134** | **36 / 45** | 121 / 177 | **8 / 115** | **48 / 123** |
| **AMD R9 Fury X** | 60 / 100 | 29 / 39 | 114 / 146 | 10 / 88 | 47 / 98 |
| **Sapphire R9 Fury Tri-X** | 61 / 97 | 28 / 37 | 100 / 134 | 31 / 85 | 29 / 93 |
| **MSI GTX 980 Gaming** | 62 / 113 | 23 / 36 | 129 / 162 | 21 / 87 | 42 / 89 |
| **XFX R9 390X** | 48 / 90 | 18 / 31 | 62 / 77 | 21 / 78 | 40 / 83 |
| **Sapphire R9 390 Nitro** | 47 / 82 | 21 / 30 | 91 / 118 | 20 / 74 | 38 / 79 |
| **Gigabyte GTX 970 G1 Gaming** | 47 / 90 | 21 / 30 | 104 / 131 | 21 / 75 | 50 / 74 |
| **Asus GTX 960 STRIX** | 31 / 55 | 9 / 18 | 71 / 88 | 9 / 49 | 17 / 36 |
| **MSI R9 380 Gaming 4G** | 34 / 53 | 11 / 18 | 73 / 87 | 12 / 48 | 18 / 45 |

## 2560 X 1600 BENCHMARKS (1600p)

| | Heaven | Battlefield 4 | Total War: Attila | GRID 2 | GTA V | Shadow of Mordor |
|---|---|---|---|---|---|---|
| Nvidia GTX Titan X | 19.8 / 60.4 | 46 / 83 | 19 / 28 | 105 / 138 | **7 / 70** | 48 / 74 |
| **Zotac 980 Ti Arctic Storm** | **19.6 / 70.7** | **64 / 99** | **20 / 32** | **118 / 157** | **7 / 70** | **50 / 85** |
| AMD R9 Fury X | 19.4 / 49.9 | 36 / 73 | 18 / 27 | 90 / 111 | 10 / 62 | 35 / 71 |
| Sapphire R9 Fury Tri-X | 19.8 / 46.9 | 40 / 69 | 18 / 25 | 82 / 105 | 16 / 61 | 32 / 67 |
| MSI GTX 980 Gaming | 18.2 / 48.6 | 42 / 73 | 13 / 23 | 93 / 118 | 16 / 57 | 36 / 61 |
| XFX R9 390X | 16.7 / 38.8 | 35 / 61 | 14 / 21 | 62 / 77 | 17 / 55 | 29 / 58 |
| Sapphire R9 390 Nitro | 15.9 / 37.8 | 34 / 58 | 13 / 20 | 70 / 88 | 15 / 52 | 28 / 56 |
| Gigabyte GTX 970 G1 Gaming | 15.4 / 38.4 | 34 / 57 | 13 / 19 | 76 / 96 | 19 / 49 | 38 / 51 |
| Asus GTX 960 STRIX | 10.5 / 23.1 | 23 / 37 | 6 / 11 | 48 / 59 | 6 / 31 | 14 / 24 |
| MSI R9 380 Gaming 4G | 11 / 23.6 | 25 / 39 | 7 / 12 | 46 / 57 | 11 / 34 | 10 / 35 |

## 3840 X 2160 BENCHMARKS (4K)

| | Heaven | Battlefield 4 | Total War: Attila | GRID 2 | GTA V | Shadow of Mordor |
|---|---|---|---|---|---|---|
| Nvidia GTX Titan X | 17.5 / 26.5 | 25 / 43 | 6 / 14 | 59 / 78 | 11 / 36 | 29 / 38 |
| **Zotac 980 Ti Arctic Storm** | **13.3 / 29.3** | **30 / 49** | **9 / 17** | **71 / 91** | **9 / 41** | **35 / 46** |
| AMD R9 Fury X | 11.6 / 22.7 | 21 / 40 | 3 / 12 | 57 / 70 | 3 / 35 | 18 / 38 |
| Sapphire R9 Fury Tri-X | 10.8 / 21.3 | 23 / 38 | 7 / 12 | 50 / 66 | 1 / 33 | 14 / 36 |
| MSI GTX 980 Gaming | 10.3 / 20.6 | 23 / 38 | 6 / 11 | 46 / 67 | 6 / 23 | 26 / 33 |
| XFX R9 390X | 9.5 / 17.3 | 19 / 31 | 6 / 10 | 44 / 55 | 12 / 28 | 22 / 31 |
| Sapphire R9 390 Nitro | 9.3 / 16.4 | 17 / 30 | 6 / 10 | 41 / 52 | 12 / 26 | 17 / 31 |
| Gigabyte GTX 970 G1 Gaming | 9.2 / 16.2 | 17 / 29 | 4 / 9 | 39 / 54 | 12 / 24 | 19 / 27 |
| Asus GTX 960 STRIX | 5.8 / 9.6 | 6 / 12 | 1 / 4 | 27 / 35 | 2 / 8 | 6 / 12 |
| MSI R9 380 Gaming 4G | 7 / 11.1 | 10 / 19 | 1 / 6 | 29 / 36 | 4 / 11 | 8 / 20 |

Best scores are bolded. Overall winner is highlighted. Game results are all minimum/average fps.

And the winner is...

# Zotac GTX 980 Ti Arctic Storm

**WE'RE AT A WEIRD MOMENT** in the history of graphics cards. On the one hand, it's a fantastic time to go out and buy a new GPU because there's simply never been this amount of polygon processing power available at any price.

On the other hand, though, you've got a vast number of cards still rocking aging graphics architectures with potentially hugely updated versions on the way. That means, of the cards we've got in our test this month, only a few of them could genuinely be recommended for purchase right now.

The top-end of the market is the toughest, mostly because, and we can probably all agree on this, pricing has become utterly insane. At the top of the pile is Nvidia's GTX Titan X, at $999. Crazy. And now it's not even the fastest card, only holding its 12GB frame buffer over the rest of the graphics market.

Then we've got AMD's only genuinely new GPUs of this latest, late generation. The top Radeon Fury X simply doesn't do enough to make it worthwhile. It is cheaper than the top Nvidia cards, but it loses out in the performance stakes, despite having that brand new memory technology. The Fury and Fury X only have 4GB each as well, and that's simply too little to expect to hit high-res gaming speeds in the future of gaming.

## CHAMPION CARD

Up top then—and probably overall—the GTX 980 Ti is the only high-performance card worth spending money on right now. The 6GB frame buffer and exceptional gaming performance will mean that, even when the 16nm GPU revolution happens next year, it will still be able to hold its head up high in the performance stakes.

Nvidia's old GTX 980 could still be worth a go if you can find it for closer to $400—again, it's not going to cope well with the 4K future with its older GPU and 4GB frame buffer, but it's an absolute rock at 1440p. Many versions come super-quiet and super-cool.

Surprisingly, the rebranded Hawaii cards, specifically the excellent R9 390, have made themselves more worthy than we initially expected. The 390X is impressive for the fact it outperforms its 290X forebear. But then, so does the straight 390, and for considerably less cash.

And that 8GB memory capacity means the 390 is going to still be gaming happily at 1440p for a good while to come, even when the Arctic Islands and Pascal GPUs arrive sometime next year. This Sapphire R9 390 Nitro is the other bright spot in our supertest, and is the one we'd recommend for a midrange card.

Down at the bottom of the pile, the much-maligned GTX 970 still has some skills, but with the performance of the 390 and its hefty frame buffer, the GTX 970 is not going to be able to stand out against the AMD card.

And propping things up at the real budget end, where the GTX 960 goes head-to-head with the R9 380, we've again got to hand the glory to the Radeon offering. And yet again, that's down to the additional frame buffer. The 4GB capacity of the R9 380 isn't going to mean you can suddenly nail super-high resolutions, but it does mean that at a more standard resolution, it's going to cope with even the most demanding of future titles.

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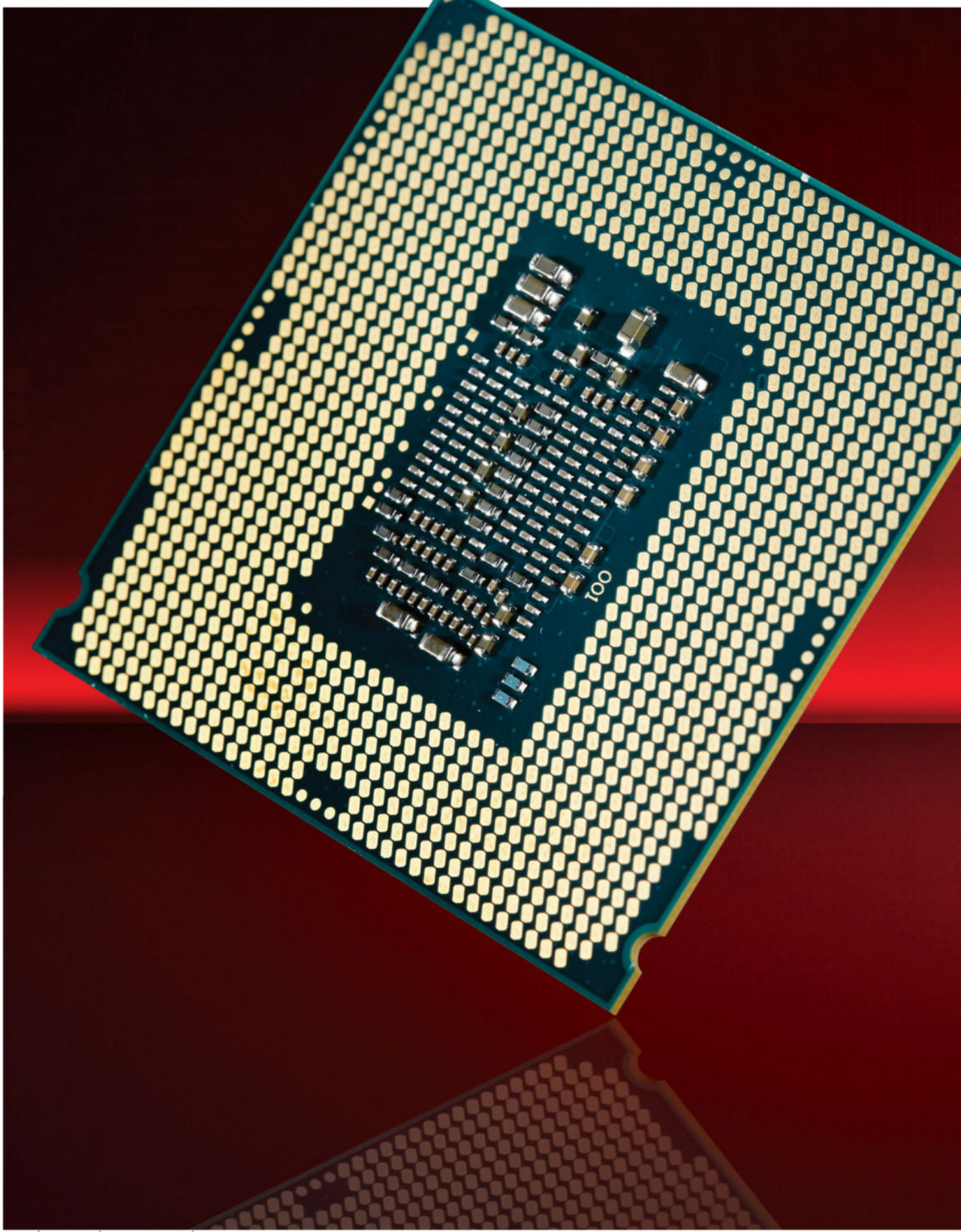


# Skylake Deep Dive

## Intel's latest architecture is finally here, so we got investigating

By Zak Storey

Well, here you have it folks. Skylake hath cometh to the people, and with it comes the absolute pinnacle of Intel's micro-processing technology. Let's just forget about Broadwell. Its short lifetime has been invaluable to us PC enthusiasts, but alas, it was never meant to be.

Taking us from that blasted 22nm architecture down to 14nm was an incredible feat. But it was too little, too late. Ultimately, the little chip paid the price, doomed to retire to an early death. A victim of its own architecture's difficult production methods.

Broadwell's glorious sacrifice, however, has given us one phenomenal gem: Skylake. If the X99 chipset and Haswell-E was the premium-grade reboot that PC enthusiasts needed, it's safe to say that Z170 and Skylake is about to do the same for the rest of us lowly four-core lovers. And let's face it, we've sorely needed it. The last three generations of Intel CPUs have hardly seen a vast improvement over the original Sandy Bridge chips, and it's about time we were given CPUs that mopped the floor with that dusty old dog. Yes, Intel's cores may generally run rings around the competition when it comes to compute performance, but a 5 percent performance increase and 10 percent power reduction, year after year, just isn't exciting enough to warrant tattooing the Intel logo on the inside of our thighs. Not just yet.

Intel needs to knock this one out of the park. And although it's pretty much cemented itself in the world of enthusiast-grade CPUs, another 5 percent performance boost just isn't that interesting, especially when most games currently struggle to utilize anything more than four cores anyway. Hell, we'd still recommend the i5-2500K if it were still available for sale.

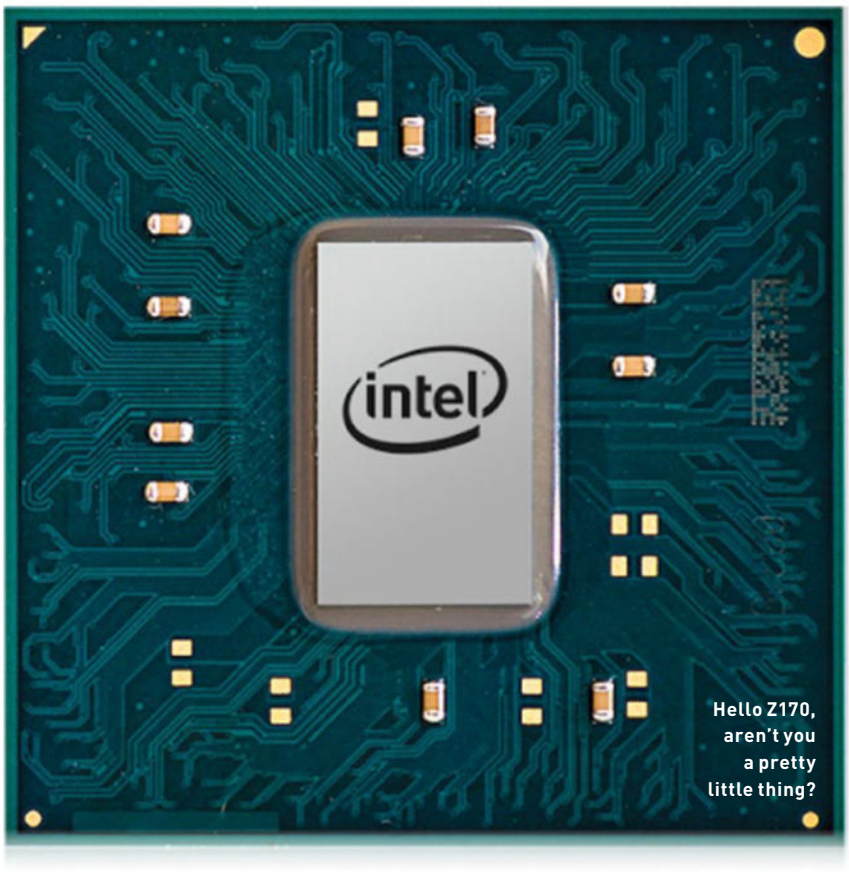
So, what was it that kept Intel behind for so long? What do these chips represent to us? And what shiny new features will it bring to the table? Read on to find out what we discover in our in-depth report (and then turn to page 30 for our full review).

# Skylake and the Z170 Chipset

Let's start with the basics. At this point, we have the Intel Core i5-6600K and the Core i7-6700K—the premium overclocking CPUs for enthusiast users. These are the flagship models of Intel's consumer brand. Processors that, by their very nature, are designed to be pushed to the limits in the hunt for number-crunching, benchmark-rendering, overclocking perfection.

But what does Skylake bring to the table that Haswell didn't? Well, a 14nm processor for starters. Similar to the now-redundant Broadwell, yet a lot more promising. Intel has dropped the FIVR (Fully Integrated Voltage Regulator) from the CPU die and left voltage control entirely up to to the motherboard manufacturers. This allows aftermarket partners to control how they supply power to each individual voltage controller located onboard the chip. What's exciting about this is how much variance we may start to see in the motherboard market once again. It's an area where, for a long time, it's been very difficult to differentiate between or even justify the cost of a $300 board over a $150 one. It might make choosing your motherboard about more than just buying the prettiest one for your budget. And that's fantastic, especially for competition's sake.

On top of all this loveliness, the Z170 chipset has a vastly expanded array of storage options—including Intel's new U.2 PCI Express connector, an additional 12 PCIe lanes to allow greater performance when running NVMe, and PCIe M.2 drives (an upgrade from gen2 to gen3). There's also continued support for six SATA 6Gb/s devices, up to 10 USB 3.0 ports, and 14 USB 2.0 ports. Rather surprisingly, however, there isn't any native support for USB 3.1 (both Type A and Type C). Intel has stated that it's banking on Thunderbolt 3 being the more appealing solution for this particular platform. Although this seems a little short-sighted going forward, only time will tell whether that will hold true. Who knows, maybe 3D Xpoint memory sticks will be powered by Thunderbolt and Intel will become our silicon overlord.



Hello Z170, aren't you a pretty little thing?

But the biggest and most exciting feature by far is the support for DDR4 RAM, the final advancement beyond the limited 2,400MHz DDR3 band. Z170 motherboards will support up to 64GB of memory, from 2,400MHz all the way up to 4,000MHz and beyond, advancing the aging platform far past that of its Broadwell and Haswell cousins.

## MEMORY MUSCLE

But don't fret if DDR4 prices are still a little too steep, and you have a few DDR3L RAM sticks kicking around, Skylake is backward compatible, albeit only with the low-voltage economy version, as opposed to the last platform's DDR3 offerings. That means that if you'd rather just use a DDR3L-enabled motherboard, you can do just that. That said, these motherboards do seem to be few and far between. The only manufacturer we know of that has boards with this feature for the foreseeable future is Biostar, a company that scored a miserable four—for its Z97W Gaming mobo—last time it graced the pages of *Maximum PC* (September issue, "Motherboard Supertest," page 34).

If you're considering the outlay to build a new rig, you really should be looking at DDR4. Prices have dropped by roughly half since it was launched in October last year, which means you're now paying hardly any

**SPECIFICATIONS**

| | Intel Core i7-6700K | Intel Core i7-4790K |
|---|---|---|
| **Lithography** | 14nm | 22nm |
| **Frequency** | 4GHz (Turbo to 4.2GHz) | 4GHz (Turbo to 4.4GHz) |
| **Cores/Threads** | 4/8 | 4/8 |
| **Cache** | 8MB | 8MB |
| **TDP** | 91W | 88W |
| **DDR Support** | DDR4/DDR3L, 64GB Max | DDR3/DDR3L, 32GB Max |
| **PCIe Configuration** | 1x 16, 2x 8, 1x 8, 2x 4 (Gen3) | 1x 16, 2x 8, 1x 8, 2x 4 (Gen3) |
| **Intel Graphics** | Intel HD Graphics 530 | Intel HD Graphics 4600 |

extra for the same capacity of RAM at a far higher frequency than you once were.

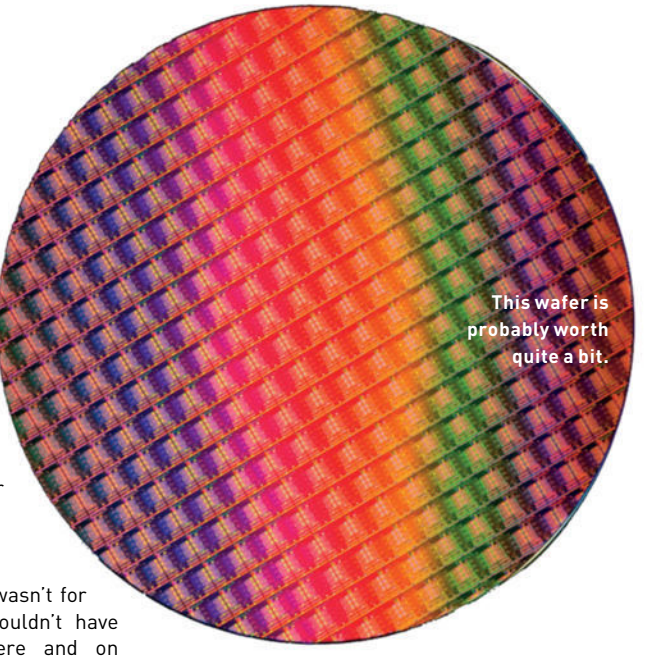
Still not interested? Consider yourself a bit of a speed freak, but memory just doesn't float your boat? Well, ladies and gents, we have one last nugget of juicy information for you—that's the inclusion of PCIe RAID 0, 1, and 5 support, allowing end users to RAID multiple NVMe drives together.

This has the potential to increase transfer read and write speeds all the way up to 3,500MB/s and beyond, approximately six times faster than a traditional SSD.

**SPECIFICATIONS**

| | Z170 Chipset | Z97 Chipset |
|---|---|---|
| **PCIe Lanes** | 20 lanes Gen3.0 | 8 Lanes Gen2.0 |
| **SATA Connectivity** | 6x SATA Ports / eSATA | 6x SATA Ports / eSATA |
| **USB Support** | 10x USB 3.0 / 14x USB 2.0 | 6x USB 3.0 / 8x USB 2.0 |
| **Ethernet** | 10/100/1000 MAC | 10/100/1000 MAC |

# A New Architecture



This wafer is probably worth quite a bit.

Skylake's new architecture has been painstakingly woven from Intel's manufacturing plants and engineering genius. Having to drop Broadwell, even just to make its production deadlines, Skylake is the first widely available 14nm CPU microarchitecture.

It's a chip that's situated in the brand-spanking-new 1151 socket (yes, one whole extra pin), alongside the Z170 chipset. Although not the consumer's first access to a 14nm chip, it'll be the most commonly sought-after processor line going forward, the go-to buy for us PC enthusiasts, overclockers, and system builders looking for the best midrange processors for our towers of power.

To build a processor like Skylake, you have to start from the ground up, and that's with the silicon. Essentially, a wafer-thin slice of computing crystalline goodness, silicon provides the basis for what the CPU will become, before it's cut out and embedded into the CPU superstructure that we're all so familiar with. Utilizing a 193nm ArF lithography (basically a high-powered laser), Intel has to etch in all of the details for each and every processor, from each transistor upward, essentially crafting every detail that makes a CPU a CPU.

The difficulty lies in the lithography itself. The laser in its most minute form is 193nm wide. To put that into perspective, the width of a human hair is 75,000nm across. So, to get that tiny beam of light small enough to even create one single transistor, it's necessary to utilize a variety of different technologies and optics to split the beam into even more ridiculous molecular sizes without necessarily losing any of the additional power that comes from the original beam. The smaller you go, the more difficult it becomes to split the laser down further. Ultimately, this is why it's taken Intel so long to go from the 22nm die size to 14nm, and thus why Broadwell has had such a brief (and rather unexciting) shelf life. We can only hope that this will not be the case for the 10nm chips.

## PRICE POINTS

But alas, not all is lost. If it wasn't for Broadwell's sacrifice, we wouldn't have Skylake. Thankfully, it's here and on schedule, ensuring Intel's latest flagship dodged a similar fate. We can only speculate about release dates at this point, but rumor has it the full desktop lineup should be available by the end of this year, with mobile laptop processors making it to market by early 2016. Again, speculation and rumor on our part.

DDR4 memory is a crucial part of Intel's marketing strategy here. Although it's the next natural progression, the launch price was more than enough to put most people off their dinner. Fortunately, kits have been around since October 2014 and have slowly dropped in price since then with the launch of the extreme-edition processors. With Skylake's release (and dual-channel support) comes a wide variety of dual-channel kits at almost a comparable price point to DDR3. If you're still unsure what memory to choose, however, don't worry. Intel has you covered. Memory kits from the likes of Crucial, Corsair, G. Skill, Patriot, Kingston, and Adata have all been approved by Intel, just to give you peace of mind.

The Z170 motherboards, on the other hand, have been making the rounds for quite some time now, debuting with a wide variety of manufacturers showing off their long-awaited products at Computex, back in June. And man, do they look good! Most mainstream motherboard partners have had these things ready since last Christmas (or thereabouts), so if you really must have the latest hardware, or are thinking it's about time for an upgrade, you'll be more than spoiled for choice.

**The biggest and most exciting feature is the support for DDR4 RAM, the final advancement beyond 2,400MHz DDR3.**

DirectX 12 could well be a game changer, literally.

# Power and Performance

So, how does Skylake actually perform? Well, it isn't the absolute be-all-and-end-all of chip advancements. If you're only one generation behind, with Devil's Canyon, you'll only see around a 10–15 percent improvement in benchmarks and rendering times, clock for clock.

In Cinebench, we saw an outright 11 percent increase in performance over Intel's Core i7-4790K. Not too shabby to say the least, but not exactly beyond the realm of what we expected.

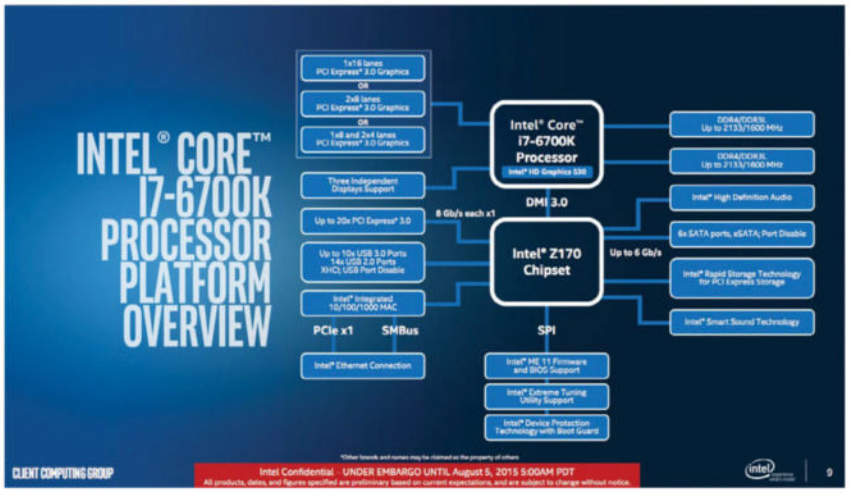
What is interesting is how far we can push the powerful four-core. Skylake's overclocking potential is well documented as being far greater than that of its last three predecessors. And once we cranked our chip all the way up to 4.8GHz, we actually managed to push this core to perform just a little under that of an i7-5820K extreme-edition processor at stock. Interested? You should be. It's unlikely to be impossible to get this processor even higher than that. We achieved these benchmarks on an entry-level Asus motherboard.

## EFFICIENCY DRIVE

All in all, this chip provides us with a very unique insight into what the 14nm processor series can do. But let's cut to the chase. Why is 11 percent good? Is it really worth it? Well, consider it this way. If it's 10 percent better than an i7-4790K, it'll be roughly 20 percent better than a 4770K, and 30 percent better than a 3770K, and so on.

If you're still stuck on the ever-faithful Sandy Bridge architecture [like some of our editors here are... *cough*], then this might be the perfect time for you to upgrade that CPU and take advantage of all of those additional chipset features and processing power.

When it comes to power consumption, Skylake stands comfortably head and shoulders above the competition. We decided to build a basic test system to give the new girl a run for her money. The test bed consisted of an Nvidia GeForce GTX 980, four sticks of Kingston HyperX memory, one 240GB Samsung EVO, and a more traditional 2TB Seagate something or other. Under load (Prime 95 & Furmark), the rig pulled a total of 340W from the wall, utilizing only half of the 750W power supply we had it running on. If nothing else, these chips will be fantastic for small form factor builds and Steam Machines. Hell, if you really wanted to, you could run SLI on a 750W power supply with little-to-no worries at all.




With features galore, it could be time for an upgrade.

## INTEGRATED GRAPHICS

The biggest area of improvement for Intel has been in the integrated graphics department. That may not mean much for those of you buying into the K-line processors, as you'll probably also be investing in a dedicated GPU. However, utilizing DirectX 12 to leverage the CPU effectively could improve frame rates considerably in games.

That may not be so beneficial for Twitch and streaming enthusiasts, but it harks back to what AMD was trying to implement with its Mantle API, allowing Intel to carefully leverage the processing power for what computational tasks each core is better suited to handling.

# Overclocking Potential

Inherently, this generation of chips is vastly different than Haswell and the Devil's Canyon offering that we received last year. Primarily, this is up to Intel's decision to remove the FIVR from the chip design.

The FIVR, or Fully Integrated Voltage Regulator, was a component piece of the CPU found in any previous generation of Intel processor. Its sole purpose was to regulate and control the overall voltage that went directly into each part of the compute portion of the CPU, such as the DRAM controller, and the VCore. By removing this, Intel has handed voltage control to the motherboard manufacturers. This means that, instead of a standardized level of voltage operating across the entire platform, it's now possible for board partners to implement specific voltages for each of those compute portions we mentioned earlier.


**The Core i7 still rules the roost when it comes to overclocking potential.**

## BASE CLOCK BATTLES

But are they cooler than Devil's Canyon? Skylake is quite cold, no doubt partly due to the removal of the FIVR we mentioned earlier. This enables you to ramp up the core clock frequency considerably, without worrying about thermally throttling the chip. But you're still going to need an aftermarket cooler for the majority of your overclocking attempts, as it will provide a great deal more headroom when trying to achieve those higher clock speeds.

In our testing, we found the Core i7-6700K to be a solid 3–4 degrees Celsius cooler than the Devil's Canyon refresh under load. And although Intel has promised to reimplement the FIVR, this doesn't seem likely to happen until the iteration after Kaby Lake, known as Ice Lake. All in all though, we're not too sure whether losing the FIVR is a bad thing.

Another change that's come with Skylake is the ability to alter the base clock frequency in 1MHz increments. The base clock frequencies are currently 100/125/166MHz on Devil's Canyon. However, Skylake scraps the ratio-based system entirely, allowing higher overall overclocks for those willing to eke out every millimeter of power from their otherwise beastly new CPU.

It's important to note, however, that you'll need to adjust the core ratio to coincide with what target clock speed you're attempting to achieve. For example, if you change the base clock to 300MHz and leave the core ratio at default, you'll end up trying to achieve a 12GHz overclock. Which, we think, is theoretically impossible at this point in time.

# Conclusion

So, what does Skylake mean to PC enthusiasts like us? Well, probably that if you're a few generations behind, or building a new rig, Skylake should be a strong consideration. Intel is still top dog when it comes to single- and multithreaded processor performance, and this looks unlikely to change anytime soon.

Hopefully, AMD will bring back some competition via the Zen cores, but who knows when that will be. What these K-series processors have shown us, however, is that Intel's famously weak integrated graphical horsepower has been upped considerably.

Although those running overclockable chips are hardly likely to be utilizing integrated graphics alone, this does give us insight into the capability of the more mainstream chips being released later this year, which is especially interesting for those running laptops and other Intel-powered mobile devices. As much as Skylake is still incredibly competitive, however, it still doesn't hold pace with Haswell-E. The extreme-edition CPUs benefit hugely from the extra cores, and no amount of Hyper-Threading or core performance will beat that for the time being.

What we did find during testing was that, if overclocked up to 4.8GHz, the CPU actually matched performance with that of the entry-level model i7-5820K at stock. For an enthusiast-grade chip, that's one hell of an achievement.


## PROMISING FUTURE

Over the next few years, we'll no doubt see some incredible advancements when it comes to computational power. If Intel keeps up this progress, 10nm processors might not be as far away as many may think. And with 3D Xpoint landing next year, the next phase may change how we look at the world entirely. It's an exciting time to be a tech enthusiast, that's for sure. Don't forget to check out our review of the Skylake chips, over the page.

# Intel Core i7-6700K and Core i5-6600K

## Welcome to Skylake, lifejackets optional


Skylake is more about features than pure performance; it's a good choice if you're building a new PC.

**SKYLAKE.** The name invokes images of a serene outdoor setting, with clear water surrounded by forests and blue skies overhead—a peaceful place where all your hopes and dreams come true. You can go swimming, fishing, water skiing, or any other number of activities. Skylake is also the name of Intel's sixth-generation Core series of processors, conjuring visions of higher performance and improved efficiency. Which makes us wonder: If CPUs were boats, which one would you buy?

Intel has launched two desktop processor updates in as many months. June brought us Broadwell for Desktops, aka fifth-generation Core, and the desktop parts boast Intel's fastest Iris Pro 6200 Graphics, coupled with lower clock speeds and a 128MB eDRAM/L4 cache. Skylake is more like Haswell: no eDRAM, Intel HD Graphics 530, and clock speeds similar to Haswell... sort of. The i5-6600K is clocked the same as i5-4690K, while i7-6700K is clocked at 4GHz–4.2GHz, just shy of i7-4790K's 4.4GHz turbo clock. Architectural changes make up for any deficit, and the result is that Skylake continues Intel's slow but steady performance improvements—the same story we've heard since the second-generation Sandy Bridge parts.

Determining which processor is "best" comes down to intended use. If you're just floating around on a lake and enjoying the scenery, there's no need for a giant yacht or a fast speedboat, and if you're not doing some serious number crunching, just about any modern CPU is "fast enough"—it's why laptops have been gaining ground. Desktops are still faster, but not everyone needs all that performance.

As our charts show, Skylake doesn't radically alter the landscape. Haswell-E remains the performance-focused consumer platform, and enthusiasts can overclock the six or eight cores to 4.5GHz (hello, Dream Machine 2015). It's more power hungry and costs more, but there's no beating the performance.

## TIME TO BUY A BOAT

Skylake, meanwhile, is only 10–20 percent faster than Haswell, and 5–10 percent faster than Devil's Canyon. Processor graphics performance is up 20 percent as well, but that won't matter for anyone with a graphics card. Overclocking is a bit more interesting, as Skylake is hitting 4.6GHz–4.8GHz—around 200MHz higher than Haswell—but it's still only a minor bump in performance. Also note that Skylake doesn't include a cooler, presumably because overclockers will have their own.

The more interesting aspect of Skylake isn't even the CPU; it's the chipset. For the past several generations of CPUs, Intel has used a DMI 2.0 interface that provides effectively 16Gb/s of bidirectional bandwidth between the CPU and the PCH; considering the PCH has multiple USB 3.0 ports, SATA 6Gb/s ports, and now M.2 PCIe and SATA Express, that ends up being a big bottleneck. Enter DMI 3.0.

Skylake and the Z170 chipset use a DMI 3.0 link with an effective 32Gb/s bandwidth, bidirectional. Putting the added bandwidth to good use, Intel has dramatically increased the features of the Z170 compared to Z97. Z170 supports 10 USB 3.0 ports, plus USB 2.0 and SATA, and it has 20 PCIe 3.0 lanes (compared to eight PCIe 2.0 lanes on Z97). We've seen Z170 motherboards with multiple M.2 PCIe ports, and four-way SLI/CrossFire with x8 connections on all cards is possible. And while Skylake supports DDR3L and DDR4 memory, most boards are going the DDR4 route—not necessarily for performance, but because DDR4 allows for higher-density DIMMs.

Those who like a calm and peaceful existence will appreciate Skylake, as it doesn't rock the boat. If you're planning on building a new midrange desktop ($1,500), Skylake is a great choice, but if you bought such a PC in the past several years (Ivy Bridge or later), or if you're running Haswell-E, there's no rush to upgrade. Skylake and the Z170 platform have some nice features that might entice you, but unless you're after multiple M.2 NVMe SSDs or USB 3.1 ports, Haswell owners can just sit back and relax. **–JARRED WALTON**

### BENCHMARKS

| | Core i7-4790K | Core i7- 5775C | Core i5-6600K | Core i7-6700K |
|---|---|---|---|---|
| CB15 1CPU | 173 | 155 | 161 | **174** |
| CB15 SMP | 833 | 767 | 582 | **866** |
| x264 5.0 2nd (fps) | 18.06 | 16.16 | 14.53 | **19.55** |
| ProShow Producer 5 (sec) | **1,296** | 1,497 | 1,618 | 1,408 |
| Premiere Pro CS6 (sec) | 1,088 | 1,139 | 1,405 | **1,064** |
| Stich.Efx (sec) | 770 | 850 | 902 | **655** |
| PCMark 8 Home | 3,508 | **4,359** | 3,890 | 4,172 |
| PCMark 8 Creative | 4,863 | **5,966** | 4,983 | 5,098 |
| PCMark 8 Work | 4,561 | 4,871 | 4,788 | **5,206** |
| GTA V (fps) | 61.4 | **64.3** | 60.5 | 63.1 |
| Metro: Last Light (fps) | 106.9 | **110.6** | 100.7 | 110.4 |
| Shadow of Mordor (fps) | 113.8 | 119 | 116.3 | **120** |
| The Witcher 3 (fps) | 55.2 | **55.9** | 54.2 | 54.7 |
| 3DMark FireStrike Ultra | 3,944 | **3,956** | 3,770 | 3,891 |

Best scores are bolded. Our test systems used 2x 8GB DDR3 or DDR4 G.Skill memory, Samsung 850 Pro 1TB SSD, GTX Titan X, with be quiet!'s Dark Rock 3, Silent Base 800, and Dark Power Pro 11 850W.

VERDICT **9**

**Intel Core i7-6700K and Intel Core i5-6600K**

**+ SPEED BOATS** Good performance; overclocks well; Z170 platform offers new features.

**– TUG BOATS** Requires purchase of aftermarket heatsink; needs new motherboard and RAM; Haswell-E still has more cores and higher performance.

$339 (Core i7), $242 (Core i5), www.intel.com

### SPECIFICATIONS

| | Core i7-6700K | Core i5-6600K |
|---|---|---|
| Base Clock Speed | 4GHz | 3.5GHz |
| Maximum Turbo Clock | 4.2GHz | 3.9GHz |
| Cores/ Threads | 4/8 | 4/4 |
| L3 Cache | 8MB | 6MB |
| Graphics | HD Graphics 530 | HD Graphics 530 |
| Graphics Clock | 350–1,150MHz | 350–1,150MHz |
| TDP | 91W | 91W |

# UPGRADE YOUR MEMORY

## Looking for the perfect memory upgrade? We've got your back

*BY ALAN DEXTER AND ZAK STOREY*

**LET'S FACE IT, MEMORY** isn't the sexiest component in your computer. It's not a beautiful polygon-rendering graphics card from the metallurgic factories of AMD or Nvidia. It's not a gigahertz-crunching, hair-tingling, multithreaded CPU. Nor is it a speed-freak of a PCIe SSD solution—M.2 or otherwise. It's memory. RAM. And if we're honest, while it's without doubt one of the most important cornerstones currently fixed within every PC system on the planet, it's simply not that exciting, nor particularly easy to understand—beyond the concept of capacity, of course.

That said, the questions we are asked here in the *Maximum PC* office most often tend to revolve around that volatile yet thought-provoking component. "How much RAM do I need?" and "What's the best upgrade for me?" Well, that's what we're here to find out.

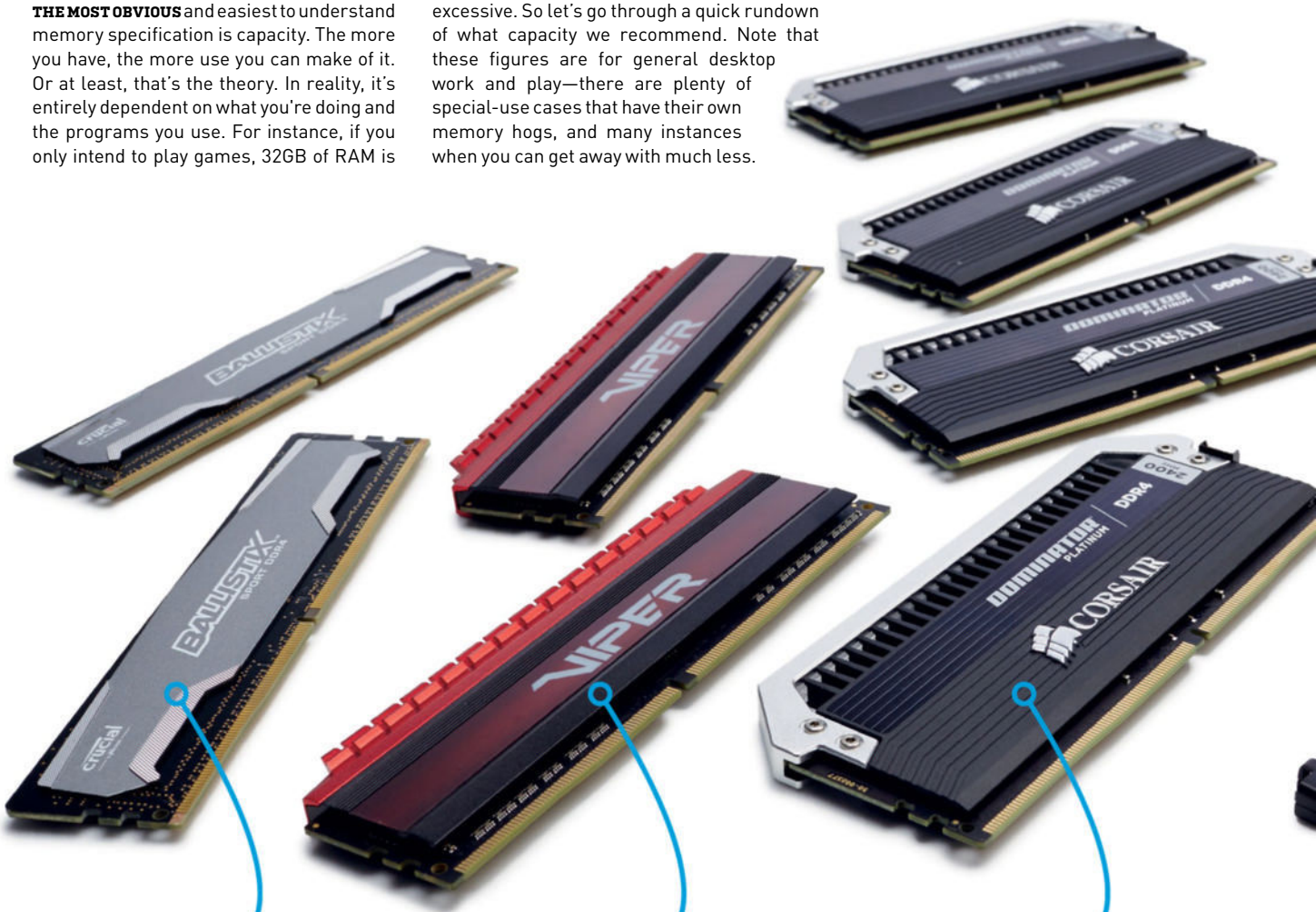
RAM is by far the most over-hyped, confusing thing to get your head around when it comes to PC components. If you didn't know any better, marketing teams across the globe would have you believe that higher frequency memory is what you need. Similar to CPUs and GPUs, surely the faster your memory clock, the more powerful your PC? Couple that with the belief that more capacity equals better, and you're all set to throw yourself into the black abyss of wasting your hard-earned dollars on the wrong setup.

At long last, with the launch of Skylake, we've finally seen the full integration of DDR4 into the custom PC environment, both at consumer and pro-grade levels. And although this new generation of RAM has much higher frequencies and far lower power consumption as standard, the overall performance advantages in comparison to DDR3 pale into insignificance next to the improvements we saw when advancing from DDR to DDR2.

So what is it that makes memory tick? What should you be looking out for? And what does all that jargon mean? Read on....

# CAPACITY COMPLICATIONS

**THE MOST OBVIOUS** and easiest to understand memory specification is capacity. The more you have, the more use you can make of it. Or at least, that's the theory. In reality, it's entirely dependent on what you're doing and the programs you use. For instance, if you only intend to play games, 32GB of RAM is excessive. So let's go through a quick rundown of what capacity we recommend. Note that these figures are for general desktop work and play—there are plenty of special-use cases that have their own memory hogs, and many instances when you can get away with much less.




## 8GB

We now see this as the bare minimum for your average PC. If you want to build a solid gaming system, 8GB is plenty for pretty much every title out there, even at maximum settings. The vast majority of game rendering is done inside the GPU's dedicated VRAM, so having more than 8GB just for gaming is not worth it. If your requirements are more sober, 8GB also happens to be great for office PCs and basic workstations as well—we're talking Adobe Premiere Pro and Photoshop levels here. If you're opening massive Excel spreadsheets and 10 to 20 Google Chrome tabs at a time, 8GB goes a long way to securing a trouble-free PC experience. Of course, you can use any of these applications with less than this—4GB would technically be OK for a light office PC, but we'd be surprised if you can even find 4GB kits for sale.

## 16GB

This is the sweet spot for streamers, YouTubers, and more serious digital artists. Admittedly, you can still do most of that on an 8GB setup, but if you're massively into gaming, and fancy delving into the murky world of online entertainment, or just gorging yourself on more than enough memory for your super-large artworks, this is the place to start. We recommend 16GB for the likes of Adobe After Effects and Premiere Pro, using 4K footage or videos longer than one hour. Out of Adobe's suite, these tend to be the more storage-intensive applications, After Effects more so than Premiere—though it's still rare to see it use more than 16GB of memory. That said, you should make sure you have the processing power to back it up. An Intel Core i7-6700K or 5820K, for example, will be plenty to sate your YouTubing ambitions.

## 32GB

Once you reach these capacities, unless you're heavily into 3D modeling, you're honestly not going to gain much out of it. 32GB and beyond is great for massive 3D renders in Cinema 4D or 3DS Max, but anything else? Honestly? Probably not. The only other solution you could apply to this quantity of memory is to utilize half of it as a RAM disk. Programs such as Asus's RAM Cache or ASRock's RAMDisk help store temporary files, the scratch disk, and other speed-sensitive data on your DIMMs, instead of the primary storage solution in your system, allowing far faster reads and writes. Admittedly, it is great to have this additional space for video rendering, but unless you're profiting from your work, at this price point you'd be better off dumping more funds into other more system-critical components, such as the CPU or the GPU.

# TIMINGS AND LATENCY


## 64/128GB

At this point, you're just satisfying your epeen. It's true, 128GB of memory is commercially available—in fact, Corsair sells both Vengeance LPX and Dominator Platinum kits at this capacity—but it is years and years ahead of any mainstream desktop application or process that we have available to date. We can't even pretend it's viable for future-proofing yourself, because by the time programs begin to use this amount of memory, we'll have moved on to far more impressive memory standards. Ultimately, even if you were to run nine virtual machines on a daily basis, you still wouldn't be able to justify the cost. And if you're thinking of using this to run simulations, you'd be far better off using a couple of Xeon cores and some ECC-registered DIMMs. Mostly server structure technology, as opposed to a dedicated workstation, anyway.

**CAPACITY ASIDE,** there are two figures you need to consider when choosing a new memory kit: its operating speed and the latency of those modules. It's easy to assume a lot from these figures individually, but you need to consider them together to get a true picture of what they are capable of. Roughly speaking, you want fast modules and low latencies, but neither is worth pursuing to extremes—as we'll see.

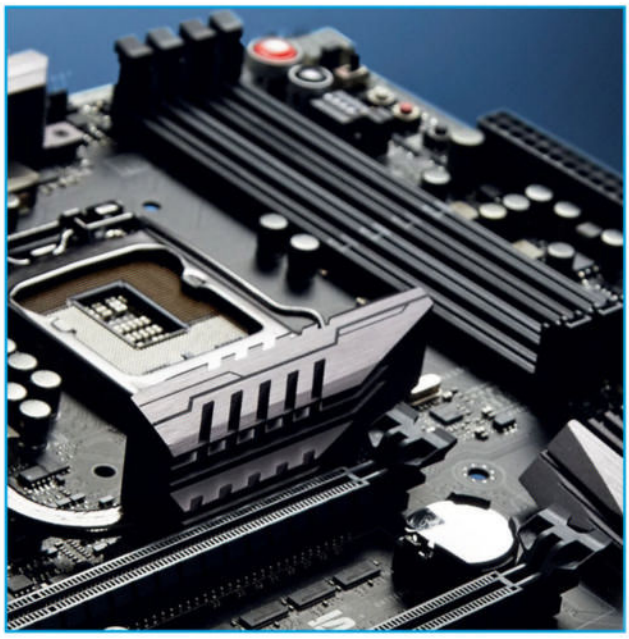
When talking about latency, there is a whole bunch of numbers that define how fast any given stick of memory operates, but the most useful one to highlight is the module's CAS latency. This tends to be advertised after the module's frequency, even if you're not immediately given all of the latency settings (it's always the first if they are fully listed). Standing for Column Address Strobe (or Common Address Strobe, depending on who you talk to), this figure tells you how many clock cycles it takes the module to access a particular memory location and get the output ready for transfer. For modern DDR4 DIMMs, you can expect these latencies to be in the range of 15–20 clock cycles.

The latency on its own doesn't actually tell you that much, at least not without knowing the speed at which the modules are running. And even here it can be a bit confusing, partly because DDR4 transfers several memory requests at the same time, and also because how manufacturers label RAM has gone through a lot of changes over the years. The end result is that you'll rarely see the actual operating frequency of memory quoted in MHz, with million transfers per second (MT/s) being the preferred measurement. Once you do have your CAS latency and your transfer speeds, you can ascertain the module's latency in


**You need to configure any RAM you add to your PC using the CMOS configuration tool.**

**RAM LATENCIES**

| Technology | Transfer Rate (MT/s) | CAS Latency | Real Latency (ns) |
|---|---|---|---|
| SDR | 100 | 2 | 20.00 |
| SDR | 166 | 3 | 18.07 |
| DDR | 200 | 2.5 | 25.00 |
| DDR | 400 | 3 | 15.00 |
| DDR2 | 400 | 5 | 25.00 |
| DDR2 | 800 | 5 | 12.50 |
| DDR3 | 800 | 9 | 22.50 |
| DDR3 | 2,400 | 11 | 9.17 |
| DDR4 | 2,133 | 15 | 14.06 |
| DDR4 | 3,200 | 16 | 10.00 |



Intel's Z170 chipset supports dual-channel memory access.

Above: Mobos based on the X99 chipset support quad-channel access. Left: The memory controller is in the CPU.

real-world terms (lower is better), by using the formula:

**Latency = 2,000/RAM speed x CL**

Note that for DDR4, you can ascertain the transfer rate from the module's label—you're looking for something similar to PC4-2400. When you've got the transfer speed and have found the latency, you can work out the real-world latency in seconds. So, for example, if you were to take a PC4-2400 module with a CAS latency of 14, you'd get:

**Latency = 2,000/2,400 x 14 = 11.67ns**

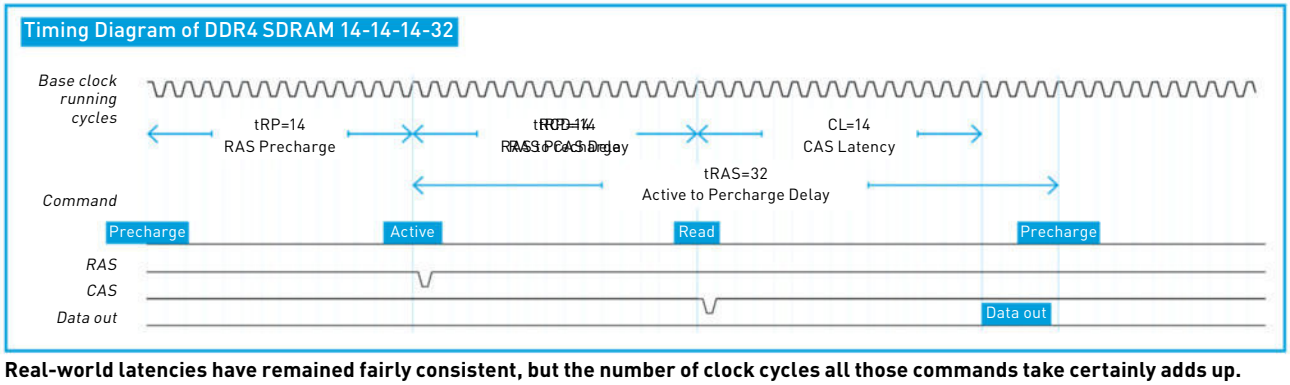
It's worth doing these calculations to see how various memory kits compare, as it isn't always obvious. It's also interesting to see how timings have changed over the years—take a look at the table on the previous page. This covers the various technologies that have underpinned consumer memory since standard SDRAM. Note that as speeds have increased, so the real-world latencies have continued to drop.

Speaking of hertz, it's important to understand that every single component in your machine operates at a specific frequency. Rather like the cycling of a clock, these frequencies tick and tock with a negative and a positive downstroke or upstroke.

Way back in the early days of personal computing, SDRAM only registered data transfers on the rising pulse of each clock cycle. Double data rate SDRAM (DDR SDRAM), however, changed this by operating on both the rise and fall of the clock pulse, increasing standard performance two-fold at the time. This technology has underpinned computer memory timings ever since.

Even here, things aren't quite as straightforward as they could be, and this is due to how we report frequencies. Back before we made the move to DDR (double data rate) RAM, the quoted frequency was legitimate. In order to show that DDR was faster, though, manufacturers often doubled the quoted frequencies, which was somewhat confusing, and not strictly true. Even now, some websites will report DDR4 modules running at 3,000MHz, when in truth the memory clock actually runs at half that speed.

If you've been building your own computers for a while now, you'll be aware that when a new memory technology is released, the transfer speeds tend to be fairly low, while the latencies tend to be higher. This is why the outgoing memory standard tends to offer better speeds than the newer, often more expensive, technology. It doesn't take long for this to even out, though, and that's where we are with the latest DDR4 modules. Now is a good time to buy, in other words.




Real-world latencies have remained fairly consistent, but the number of clock cycles all those commands take certainly adds up.

# STANDARDS

**ANY STICK OF RAM** can operate at a number of frequencies and latencies, depending on the platform you use it on. Which settings it uses is defined in your UEFI/BIOS configuration utility, although in order to get your system up and running, your motherboard should default to the settings defined by a small chip on the RAM, called the serial presence detect (SPD for short). These settings adhere to the JEDEC standard, and don't necessarily set your memory as fast as it can go, although they should ensure that it boots fine. JEDEC defines the standards for memory performance, and ensures that there's common ground for RAM manufacturers and motherboard makers to adhere to. The problem is, JEDEC errs on the safe side a little too much for the more enthusiast-level memory makers. The table below shows the JEDEC specifications for DDR4, and it's hardly redefining speed. To be fair, though, that isn't really its job. It's there to ensure compatibility first and foremost.

If you do have some high-speed memory, you'll need to pop into your BIOS to ensure that your memory is operating at the right speed. For Intel platforms, the timings for the memory are defined by the XMP settings for that memory, while the AMD alternative is AMP. These basically set the timing and frequency settings for your memory, and you need to pick the quickest setting for your platform. You can configure the settings yourself as well, if you'd prefer. How you do this depends on your motherboard so, as always, check the manual for details.

Now you know how to read memory labels, pick the right amount of RAM for your system, and understand latencies, we can look at which sticks are worth considering. Turn the page to find your perfect RAM kit.

**JEDEC STANDARDS FOR DDR4 MODULES**

| Standard Name | Data Rate (MT/s) | Module Names | CAS Latency | Real Latency (ns) |
|---|---|---|---|---|
| DDR4-1600J | 1,600 | PC4-1600 | 10 | 12.50 |
| DDR4-1600K | | | 11 | 13.75 |
| DDR4-1600L | | | 12 | 15.00 |
| DDR4-1866L | 1,866 | PC4-1866 | 12 | 12.86 |
| DDR4-1866M | | | 13 | 13.93 |
| DDR4-1866N | | | 14 | 15.01 |
| DDR4-2133N | 2,133 | PC4-2133 | 14 | 13.13 |
| DDR4-2133P | | | 15 | 14.06 |
| DDR4-2133R | | | 16 | 15.00 |
| DDR4-2400P | 2,400 | PC4-2400 | 15 | 12.50 |
| DDR4-2400R | | | 16 | 13.33 |
| DDR4-2400U | | | 18 | 15.00 |

# CHANNEL LIMITING

**THE NUMBER** of memory channels supported by a processor's memory controller dictates the overall bandwidth available. All modern APUs and CPUs support at least dual-channel memory access, while Intel's "enthusiast" chips (we're looking at you, Haswell-E powered Core i7-5960X) double that up to quad-channel configurations. Multiple memory channels enable the processor to read and write to several DIMMs at the same time, increasing the overall memory bandwidth available. In order to hit the optimal performance, you need to actually populate those channels, though, and that isn't always the case—particularly at the budget end of the spectrum. All too often, we see the most-affordable machines and laptops ship with a single DIMM (or SoDIMM), thus limiting the potential performance available. To paint a silver lining to this cloud, though, it does mean that any memory upgrade you do perform will improve throughput and responsiveness significantly.

**SISOFT SANDRA BENCHMARKS**

| Channels | Bandwidth |
|---|---|
| Quad-Channel | 45.4GB/s |
| Dual-Channel | 28.5GB/s |
| Single-Channel | 14.5GB/s |

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- Hardware Raid 0,1 Function capable
- Full sized Keyboard with color LED backlight
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- Built-in 2.0M FHD Camera & Fingerprint Reader
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- Sound Blaster® X-Fi™ MB5 Sound System

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- Hardware Raid 0,1 Function capable
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- Full sized Keyboard with white-LED backlight
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MOTHERBOARDS ON TEST


ASRock Fatal1ty B150 Gaming K4/D3


MSI B150 Gaming M3


MSI Z170A Tomahawk


Asus Z170i Pro Gaming


Gigabyte GA-170X-Gaming 5


MSI Z170A Gaming Pro Carbon


Gigabyte GA-Z170X-Gaming 7


MSI Z170A Gaming M7

# SKYLAKE Motherboards

## The 100-series motherboards have matured beautifully, but which should you build your next rig around?

*By Dave James*

The motherboard may not be the sexiest of components, but it's the part of your PC that you build your system around. It dictates more about the rest of your rig than anything else, so making the right decision about your motherboard is arguably the most important choice you make when building or upgrading.

With Intel's latest 6th Generation Core processors, code-named Skylake, we've shifted from the 9-series motherboards of Haswell and Broadwell, to the new 100-series. And that's partly because we're also talking about a whole new socket design—a move from the previous LGA 1150 socket to the new LGA 1151 design. Yeah, a whole extra pin.

But the new 100-series boards offer more than a subtle new socket design; there are important new features across all the different iterations of the 100-series. And, like the previous generations, these ranges are directly comparable to what's come before. There are six new chipsets available for Skylake—H110, H170, B150, Z170, Q170, and Q150—though we only really need concern ourselves with half of them.

The H110 is the lowest of the low-end boards, while the Q-series is aimed 100 percent at the business market, with a focus on Intel's Small Business Advantage and Intel Stable Image Platform features.

For us, then, the Z170, H170, and B150 are the boards we're more interested in, catering to the high-end, midrange, and the budget sections of the components market. But what do you get for your money with each of the new chipsets, and which should you commit to building your next rig around? These are vital questions, so aren't you lucky you've got us to help make your decision easier?

Asus Maximus VIII Formula

Asus Maximus VIII Extreme

The switch to the 14nm Skylake processors has brought some notable new features for its motherboard companions. The most prominent are support for DDR4, the move to PCIe 3.0 connections from the chipset, and the chipset offering a much greater number of those lanes.

That's in addition to the 16 lanes of PCIe 3.0 that you've had in the last few generations of Intel processors. This shows the increasing reliance on PCI Express as an interconnect, not just for graphics but for next-gen storage, too. Intel introduced DDR4 and vast numbers of PCIe lanes with its Haswell-E processors, but the X99 chipset still only supports eight last-gen PCIe 2.0 lanes.

So the 100-series chipsets are the most advanced consumer motherboard silicon Intel has produced. The top end of the Skylake mobo spectrum is the Intel Z170 chipset. It's the logical successor to the Z97 used for the Haswell and Broadwell generations, and as such incorporates everything the 100-series can offer.

Of the consumer-focused mobos—as opposed to the business-centric Q-series—the Z170 contains the largest number of PCIe 3.0 connections, featuring 20 lanes from the chipset itself. Compared to the relatively miserly eight PCIe 2.0 lanes offered on the old Z97 and the high-end X99 chipsets, that's quite a boost for the multi-GPU faithful, as well as the NVMe aficionado; and means you can now use both together.

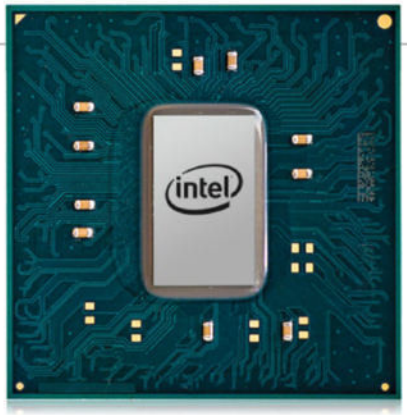
The 20 lanes are split up over five x4 controllers, enabling you to run them as x1, x2, or x4 lanes. Three of the controllers will be covered by the Intel Rapid Storage Technology (RST)—which maximizes performance, especially in solid-state drives—so you could add up to three PCIe SSDs covered by RST without taking away any of the lanes for your graphics array.

That will take up all the SATA ports supported by the chipset itself, though. So if you were to go down that storage path—and your motherboard doesn't have a third-party SATA controller—you'd need to find a separate SATA controller if you still wanted to use some legacy storage.

So in extreme cases, there will still need to be some PCIe juggling, such as when lots of GPUs and PCIe-based SSDs are installed, but nowhere near what the serious enthusiast had to deal with before.

## DDR4 options

DDR4 memory support doesn't actually come from the motherboard chipset per se—the memory controllers are baked into the processors themselves—but different levels of motherboard offer different memory configurations.




**The top-spec Z170 chipset represents the full goodness of the Skylake platform.**

The most straightforward part is that they're all dual-channel, but the Skylake architecture gives the CPUs both DDR4 and DDR3L memory controllers. That means you can get Skylake boards with either DDR4 or DDR3L, and some manufacturers are even creating boards with both.

Thankfully, it's mostly shaking out that the Z170 chipset, as the high-end offering, is going to be pretty much 100 percent DDR4, at least for the current boards.

This means that as well as a CPU and motherboard upgrade, you're also going to have to factor in a memory upgrade. Luckily, the price premium on DDR4 over DDR3 has dropped considerably recently, now that it's become more mainstream.

## Midrange step down

The step down from the top-end Z170 chipset is the H170. It loses out compared to its smarter sibling in the numbers game, having only 16 PCIe lanes attached to the chipset as opposed to the Z170's 20. Linked to that, you only get Intel's RST on a pair of the x4 PCIe controllers, instead of three.

Those 16 lanes still represent twice the capacity of the top chipset from the last generation of Intel silicon, however, making the H170 still a very worthy consideration.

Elsewhere, the H170 only supports eight USB 3.0 connections compared to the 10 of the Z170 boards, and only has four native SATA 6Gbps connections, too.

The H170 chipset also restricts the CPU's PCIe lanes to only running at x16, rather than being able to split into x8/x8, or x8/x4/x4, as with the Z170. That will make the majority of H170 motherboards sub-optimal for budget multi-GPU solutions.

## Business up-front, LAN party behind

Ostensibly, the B150 chipset is more geared toward business users, though the ASRock board in this month's roundup attests to the fact that it's still going to be used by manufacturers as a budget gaming option.

The chipset itself is again cut-down compared to the H170 and Z170 silicon,

# Z170 PCI Express Lanes

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | USB 3 #1 *(Capable of OTG)* | | | | | |
| 2 | USB 3 #2 | | | | | |
| 3 | USB 3 #3 | | | | | |
| 4 | USB 3 #4 | | | | | |
| 5 | USB 3 #5 | | | | | |
| 6 | USB 3 #6 | | | | | |
| 7 | USB 3 #7 | PCIe #1 | | x4 | x2 | |
| 8 | USB 3 #8 | PCIe #2 | | | x2 | |
| 9 | USB 3 #9 | PCIe #3 | | | | |
| 10 | USB 3 #10 | PCIe #4 | GbE | | | |
| 11 | PCIe #5 | | GbE | x4 | x2 | |
| 12 | PCIe #6 | | | | x2 | |
| 13 | PCIe #7 | | | | | |
| 14 | PCIe #8 | | | | | |
| 15 | PCIe #9 | SATA #0 | GbE | x4 | x2 | Intel PCIe storage device #1 |
| 16 | PCIe #10 | SATA #1 | | | | |
| 17 | PCIe #11 | | | | x2 | |
| 18 | PCIe #12 | | GbE | | | |
| 19 | PCIe #13 | SATA #0 | GbE | x4 | x2 | Intel PCIe storage device #2 |
| 20 | PCIe #14 | SATA #1 | | | | |
| 21 | PCIe #15 | SATA #2 | | | x2 | |
| 22 | PCIe #16 | SATA #3 | | | | |
| 23 | PCIe #17 | SATA #4 | | x4 | x2 | Intel PCIe storage device #3 |
| 24 | PCIe #18 | SATA #5 | | | | |
| 25 | PCIe #19 | SATA #6 *(Server only)* | | | x2 | |
| 26 | PCIe #20 | SATA #7 *(Server only)* | | | | |

with only eight PCIe lanes, and a maximum of six USB 3.0 connections. It does up the game in terms of SATA connections, though, retaining the six 6Gbps of the Z170.

In terms of memory, the B150 and H170 boards are where you'll see DDR3 and DDR3L support make an appearance.

### Overclocking

The elephant in the room is overclocking support. The hard and fast rule with Skylake is that if it isn't on a Z170 chipset, it isn't getting overclocked. Though that's what Intel said with previous generations, before every manufacturer let you boost K-series clocks across the board.

Things are different with Skylake, though, and despite the fact that you can baseclock boost non-K-series processors on the Z170, you can't mess with the multipliers on most H170 or B150 boards. Although manufacturers can provide a modicum of support for CPU overclocking, it will generally come at the expense of Hyper-Threading and C-States.

If you're rocking a Core i5, that's not an issue, and you'll be able to pick up an ASRock board with a modified H170 chipset and make good with the overclocking. But those with an i3 or i7 are going to struggle—any overclocked boost will be negated by losing out on Intel's Hyper-Threading tech.

So that's the basic overview of the chipsets, but how different are the motherboards within those brackets? We've collected 10 boards, from all the major manufacturers, to find out who comes out on top with Skylake.

## Broadwell's Back

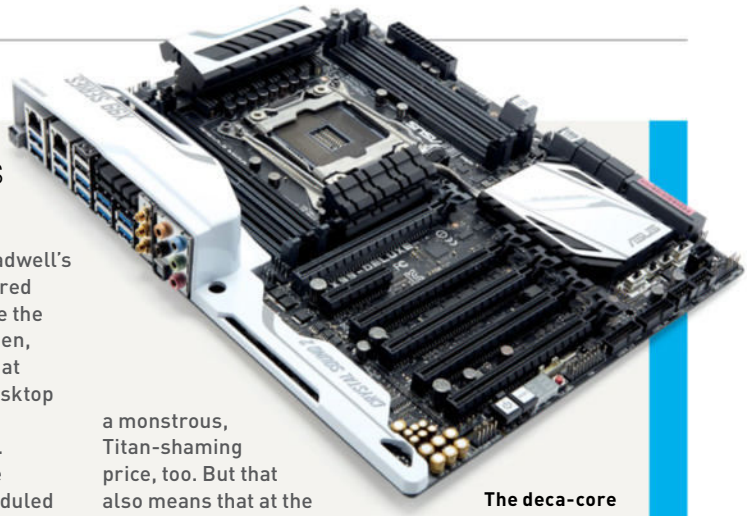
If you thought Broadwell's pair of mostly ignored desktop chips were the last gasp for that gen, you've forgotten that Intel's high-end desktop parts are always a generation behind.

So next we have Broadwell-E, scheduled for the second quarter of this year. As you might expect, Broadwell-E is the 14nm die shrink of the Haswell-E processors, cribbed from the high-end Xeon server parts of the range. As such, it's all about multi-core performance, and this is where Intel has continued its core push, leaving the standard desktop chips to stagnate at four cores.

Haswell-E brought the first straight eight-core consumer CPU from Intel, and Broadwell-E is set to deliver us a 10-core/20-thread monster in the Core i7-6950X—reportedly for a monstrous, Titan-shaming price, too. But that also means that at the other end of this four-CPU range will be a "low-end" Core i7-6800K, offering a six-core/12-thread alternative for just $400.

However, thanks to the fact it's essentially just die-shrunk Haswell-E, Broadwell-E will drop right into the LGA 2011 v3 socket of pretty much any X99 motherboard... so long as the BIOS gets an update first. Manufacturers are likely to bring out special-edition boards to coincide with the launch of the first deca-core consumer chip, but there should also be some mature, reasonably priced X99 boards just waiting for that cheaper six-core CPU.

You can bet that Broadwell-E won't drop if Skylake is still doing decent numbers; there's little chance Intel will want to risk the $400 i7-6800K taking any of the shine off the $390 i7-6700K. Despite going back generationally, the enthusiast is going to look at those two platforms and be tempted to go for the hexa-core version, even if the motherboard is potentially going to be a touch more expensive.



**The deca-core Broadwell-E will apparently be $1,500.**

# Intel 100 Series Chipsets

| | Feature/Capability | Q170 | Q150 | B150 | H110 | H170 | Z170 |
|---|---|---|---|---|---|---|---|
| Chipset I/O | PCI Express Gen 3 Lanes | Up to 20 | 10 | 8 | 6 (Gen 2 only) | Up to 16 | Up to 20 |
| | SATA Gen 3 | Up to 6 | Up to 6 | Up to 6 | 4 | Up to 6 | Up to 6 |
| | USB 3.0 | Up to 10 | Up to 8 | 6 | 4 | Up to 8 | Up to 10 |
| | Total USB Ports (USB 2.0 & 3.0) | 14 | 14 | 12 | 10 | 14 | 14 |
| | SATA Express Capable Ports (x2) | Up to 3 | Up to 1 | Up to 1 | 0 | Up to 2 | Up to 3 |
| | Intel RST for PCIe Storage Ports (x4 M.2 or x2 SATA Express) | Up to 3 | 0 | 0 | 0 | Up to 2 | Up to 3 |
| | Enhanced SPI | Yes | Yes | Yes | Yes | Yes | Yes |
| CPU | PCI Express Gen 3 1 x16 Port | x4, x8, x16 | 1 x16 | 1 x16 | 1 x16 | 1 x16 | x4, x8, x16 |

# ASRock Fatal1ty B150 Gaming K4/D3

## Odd upgrade decisions

**WE DON'T UNDERSTAND** ASRock's naming scheme. Fatal one ty? What's that? Well, it's a brand that's proudly paraded as the gamer's motherboard of choice from this particular company. But how does it compare with the world of Skylake, particularly with the B150 chipset?

You'll notice that this model is backward compatible with the aging yet dependable DDR3 standard. Of course, if you choose that path, you'll lose out on the additional bandwidth, lower voltages, and higher capacities of DDR4.

That choice aside, this motherboard's a little too thin on features. There's a total of six SATA 6Gb/s ports, support for DDR3 at 1,866MT/s, Killer LAN, and a fancy audio solution, but that's about it. In fact, the PCB appears to be a stripped-down version of the B150's more sophisticated Z170 brother—even the M.2 slot retains signs of where it was to be soldered in.

As far as performance goes, the B150 chipset has very limited overclocking capabilities. By "limited" we mean none. There's no support for XMP profiles either. Otherwise it performs as you'd expect. There's very little deviation from the other test results, except in the overclocked benchmarks and memory bandwidth. It's also worth noting that although the BIOS states that Intel's Turbo technology is enabled, we only ever saw our Core i7-6700K top out at 4GHz, as opposed to its 4.2GHz max.

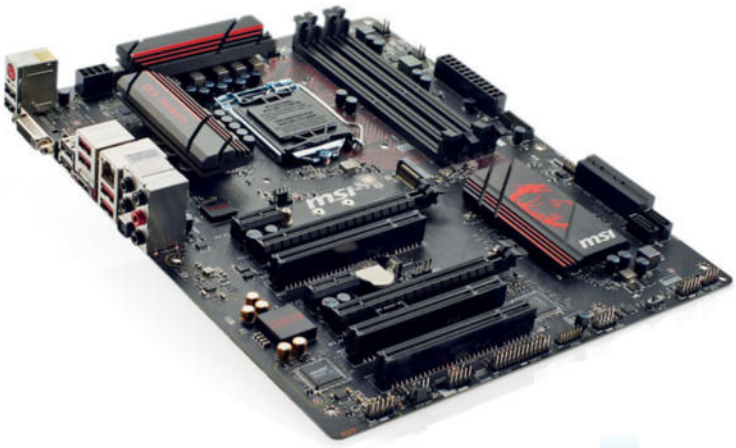
If you're only interested in a small upgrade to a Core i5-6600, with a better audio solution and support for two-way Crossfire/SLI, this board is ideal. However, if you're still on Devil's Canyon, Haswell, or even Ivy Bridge, certainly for gaming, you're not going to get a lot more out of it. Short of additional USB support, and an upgrade to 8x PCIe 3.0 lanes over Z97's 8x PCIe 2.0 lanes, that's all there is to it.

VERDICT **6**

**ASRock Fatal1ty B150 Gaming K4/D3**

- **KILLING SPREE** Affordable; acceptable stock performance.
- **FATALONETY** Lackluster feature set; B150 is a tad tame; not much different from Z97; turbo is a lame duck.

$100, www.asrock.com



# MSI B150 Gaming M3

## B150 done right

**THIS IS HOW B150** should be put together. A clean, slick, black-and-red gaming motherboard, with just enough bells and whistles to keep you happy. No doubt you're still going to lose out compared to the likes of the Tomahawk and its Z170 chipset, but if you're putting together an entry-level gaming PC, this may well be your best bet.

For $110, you get two PCIe 3.0 16x slots, support for up to 64GB of DDR4 at a maximum of 2,800MT/s, six SATA 6Gb/s, one SATA Express port, and one M.2 slot, although not of the PCIe x4 variety, so no super-fast speeds for you. On top of that, you get a separate PCB for audio, Killer Gigabit LAN, plenty of USB 3.0 ports, and the heady software package that comes with it, including Nahimic's audio enhancer, and MSI's desktop software package.

Performance wise, we're delighted to inform you that, again, it's almost exactly the same as the others. Short of reduced potential in CineBench and rendering tasks, (due to the lack of suitable turbo headroom or overclock potential), that's all there is to it. Fortunately, it doesn't suffer from the ASRock's lack of memory bandwidth, and the power draw is well within reasonable levels—in fact, it pulled less from the wall than any other board.

Think of it as a mix of Z97 with Z170, leaning more toward the last generation of motherboards. It's a stepping stone for those making a jump from something like Z77, intending to purchase a more powerful, well-equipped system at a later date. Buy this board, a Core i5-6600, and 16GB of DDR4, and you have a cheap and easy solution. Throw in your old GPU, and you're good to enjoy Skylake's additional processing power. Wait three to four months and some new GPU will surface, buy a new Z170 mobo and a fancy GPU, and wham, you're all up to speed, without having to break the bank in one go.

VERDICT **8**

**MSI B150 Gaming M3**

- **MIGHTY** Upgrade potential; good price; DDR4 support; better than Z97.
- **MILD** M.2 not PCIe; PCI slots.

$110, www.msi.com

# MSI Z170A Tomahawk

## Value king

**MSI'S Z170A TOMAHAWK** comes in at a very affordable $150. At that price, you'd probably expect a very basic, very stripped-down Z170 feature set to match. But short of a few aesthetic features, that's not the case.

The Tomahawk comes with two PCIe x16 slots, one M.2 PCIe x4 slot, six SATA 6Gb/s ports, two SATA Express ports, and support for DDR4 up to 3,400MT/s. Couple that with integrated Wi-Fi and Bluetooth, and you're looking at a capable setup for this little board, to say the least.

As far as aesthetics go, you may not get the gorgeous finish littering the heatsinks and rear I/O cover of the likes of the Gaming M series, nor do you get the reinforced backplates. But the styling still looks pretty snazzy—if you want to extra bling, you're going to have to pay for it.

The MSI Z170A Tomahawk performed as well as all of its competitors, maxing out our CPU at 4.9GHz, and netting the highest PC Mark 8 score out of the lot, at 4,153. Any downsides? Well, memory bandwidth suffered by 2GB/s, and overall overclocked performance in CineBench did seem a little low compared to some of the others in this test, but not enough to warrant concern, that's for sure.

Ultimately, this is the pinnacle of budget Z170 in our eyes. It's aimed at those not looking to break the bank when putting together a machine. Those wanting to make the most out of their cash. Those that don't need the LEDs, or the option to LN2 cool their boards—it's all about making a system that performs admirably, and dumping as much money as they can into the GPU and CPU portions of their builds. On top of that, it's the perfect board for anyone looking to advance early and upgrade later. The addition of an M.2 slot ensures you can stay up to speed with some of the best storage potential out there, and the overclocking capacity is nothing to ignore either.

VERDICT **9**

**MSI Z170A Tomahawk**

**BATTLEAX** Strong feature set; good performance; great price; expandability.

**AXFACE** Aesthetically uninspiring.

$150, www.msi.com

# Asus Z170i Pro Gaming

## Who needs ATX anyway?

**2016 IS THE YEAR** of the ITX chassis. Just take this motherboard—there's no reason why you couldn't throw in a Core i7 clocked at 5GHz, 32GB of 3,000MT/s DDR4, AMD's R9 Fury X, a Samsung 950 Pro 512GB, and a separate RAID 0 array. Enough said.

So, what does this 6.7-inch square provide? You've got the standard 8-pin and 24-pin power, a solid overclocking VRM solution, support for DDR4 at 4,000MT/s, four SATA 6Gb/s ports, one SATA Express port, dual-band Wi-Fi and Bluetooth 4.1, and a full complement of premium audio capacitors, DAC, and headphone amplifier.

The most interesting part of this tiny mobo, however, is the M.2 slot. Space is always going to be a precious commodity for an ITX system, and ultimately something has to give—usually, it's M.2. Fortunately, Asus disagrees, and has placed the M.2 slot on the underside of the PCB. Where its out of sight and cooler that it would be on top. This way, ITX enthusiasts—yes, they do exist—get to take advantage of those PCIe storage speeds we all love.

As far as performance goes, it's a similar affair across the board. CineBench did see a slight drop in stock performance here, but it still outperformed a fair few of its thuggish competitors in the Tech ARP's x264 benchmark. What really blew us away was how well it overclocked. With a quick and easy bump up to 1.41V, the Z170i Pro Gaming managed what has almost become our benchmark of 4.9GHz on our i7-6700K, with no problem.

This motherboard aims to please two groups: those looking for a budget Z170 mobo, and those looking to pack all of Skylake's features into ITX. And it's achieved this admirably, with very little in the way of problems.

VERDICT **8**

**Asus Z170i Pro Gaming**

**PRO** Great price; strong feature set; intuitive M.2 implementation; strong performer.

**SLOW** Aimed at a niche demographic; no rear I/O cover; no angled USB header.

$165, www.asus.com

# Gigabyte GA-170X-Gaming 5

## Best budget board?

**GIGABYTE HAS ALWAYS** had a flair for design, and Z170 is no exception. In a PC gaming world dominated by black and red, it's a nice change to see a manufacturer try to stand out from the herd. The Gaming 5 is stylish mix of black, red, white, and silver—it looks great in a windowed case.

At its heart, you'll find that trusty and well-armed Z170 chipset, supporting three PCIe 16x slots, three SATA Express connectors, six SATA 6Gb/s connectors, a plethora of onboard USB support, and two PCIe x4 M.2 slots, both capable of supporting RAID 0 among other arrays. That's pretty rare in itself, and for a board at this price, it's damn impressive.

Performance-wise, it's one of the better boards at this price point. In our rendering tests, the GA-Z170X-Gaming 5 shone through the muddy battlefield of our motherboard supertest and came out, more often than not, near the top three in almost every scenario. And somehow it managed to do all this while maintaining an exceedingly low power draw, meaning in the long run, it'll make less of an impact on your wallet—impressive work.

Gigabyte's BIOS, on the other hand—well, that's another story. It's one of the least intuitive UEFI BIOSes we've ever had to work with. Even getting Intel's Turbo speedstep tech to work took us four attempts. Seriously, Gigabyte, it's 2016—we understand that it's not a super-integral part of a system, but a clean, swanky BIOS makes life so much nicer. That said, once we did manage to kick the little chip into overdrive, the benchmarks truly let rip.

The Gigabyte GA-Z170X-Gaming 5 is a fantastic motherboard, filled to the brim with more features than you could want, certainly for the price. For those looking to step into the rich world of Skylake's Z170 chipset, you could do a lot worse than snap up this lovely little board.

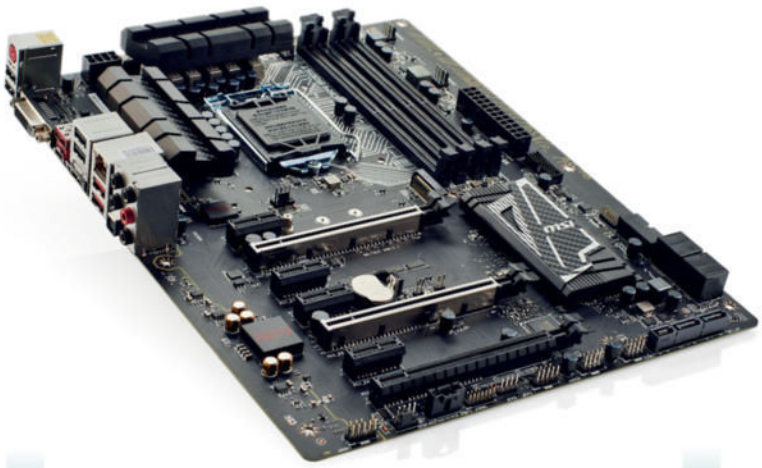
VERDICT **8**

**Gigabyte GA-170X-Gaming 5**

**GIGABYTE** Performance; alternate design; aggressively priced.

**GIGABIT** BIOS; Turbo disabled by default.

$167, www.gigabyte.com



# MSI Z170A Gaming Pro Carbon

## Carbon-fiber gaming confirmed

**MSI HAS PROVIDED MILITARY CLASS** motherboards for as long as we can remember but this is possibly the first time we've ever seen carbon fiber on a motherboard. Or rather, carbon-fiber styling. The Z170A Gaming Pro Carbon is similar in a lot of ways to Asus's Maximus VIII Formula. It's a sophisticated development in the line of Z170 chipsets.

Interestingly, MSI only ever released one RGB-lit Z170 motherboard—the Carbon's older brother, the Gaming Pro—but it was criticized for color clashing. So now we have the Gaming Pro Carbon, a black and gray variant of this entry level gaming motherboard.

So what does 170 bucks buy you? Other than those flashy lights, you get a PCIe x4 M.2 port, six SATA 6Gb/s ports, one SATA Express port, many USB 3.0 options (including our favorite, a right-angled header), three PCIe slots, and support for DDR4 up to 3,600MT/s OC.

How did it perform? Very similarly to the other boards. The highest overclock we managed was 4.9GHz, just like the rest of them, bar the B150s and Asus's Maximus VIII Extreme. Otherwise it was almost identical across the board, short of a slight slump in memory bandwidth.

Using the Gaming Pro Carbon was a dream. The BIOS, although not as intuitive as some, is more than capable of holding its own, and the software suite is great. The inclusion of Nahimic's audio processing software is awesome, and couple that with dual headphone amps, and you're in for a fun experience in game. The RGB lighting is kinda cool, though it might come across as a bit cheesy.

When it's down to the wire, the Gaming Pro Carbon is a solid choice. It has a few niggles, mostly due to its aesthetics and a lack of support options, but otherwise that's all we can really say about it. Smooth as a whistle.

VERDICT **8**

**MSI Z170A Gaming Pro Carbon**

**MCLAREN** RGB lighting; performance is solid; great power draw at peak.

**COAL** No secondary M.2 slot; board is bare; carbon finish not to everyone's taste.

$170, www.msi.com

# Gigabyte GA-Z170X-Gaming 7

## So much swagger

**LOOK AT THAT WHITE REAR** I/O cover. Go on, take a peek. It's stunning. We mentioned earlier how Gigabyte is breaking the mold with its new board designs, and nowhere is this more apparent than with the Gaming 7. The white rear I/O cover draws your attention faster than Kanye West can make a fool out of himself. And wow—does it look good.

What else is interesting about the GA-Z170X-Gaming 7? Beside the dual PCIe x4 M.2 slots, Thunderbolt 3 support, upgradeable OP-AMPs, noise-canceling power design, integrated HDMI 2.0—that spec AMD doesn't yet support on its current GPUs—dual networking solutions, and the elegant RGB lighting embedded into the rear I/O cover? Well, it does support DDR4—that's pretty cool, right? The number of features here is nigh-on incredible.

As usual, our testing found the Gigabyte Gaming 7 to be as strong as all the others. In almost every benchmark it did just as well, short of a small hiccup with memory bandwidth. You do still have to deal with that awful BIOS, but it's a far smoother experience overclocking and tweaking it than with the Gaming 5.

Ultimately, we had no problems with the Gaming 7. It's a feature-rich board, designed to draw your attention. The rear I/O cover is divine, and the RGB lighting—although somewhat confusing, because of the color implemented into the design of the board—is a smart touch.

Does it add much in the way of performance? Well, no, not really for the vast majority of us. If you can't afford to buy a pre-binned CPU, you're not going to get much more out of any of these motherboards. But, the feature set will always be king, and this is something that Gigabyte has nailed, with the Gaming 7. This motherboard is an incredibly compelling proposition.

VERDICT **9** KICK ASS!

**Gigabyte GA-Z170X-Gaming 7**

**GIGAJOULE** Radical design; strong performance; aggressive price; good audio; intuitive lighting; HDMI 2.0.

**JOULE** RGB lighting can clash; clunky BIOS.

$210, www.gigabyte.com

# MSI Z170A Gaming M7

## Premium, thy name is M7

**AT $220, WE START** to enter territory inhabited by additional features and aesthetic choices that really do make you go, "Ooooh!" The M7 is a prime example. One of the first MSI boards to feature a full rear I/O cover, it is a stunning example of black and red done right. The metallic finish across the heatsinks gives the board just enough pop to stand out. But that's not all this beastie can muster.

You have access to six SATA 6Gb/s ports, two SATA Express, two M.2 slots (but no RAID 0), three PCIe 16x slots, protected by the ever-popular steel reinforced brackets, and full support for DDR4 up to 3,600MT/s, if extra-voltage DDR4 is your thing. Fortunately, there's no garish RGB lighting, and the audio solution is quite the little number, supported by Nahimic's software suite.

One of the biggest features MSI is pushing with this board is its auto-overclock dial. Although it sounds great, in reality it is a little dubious. It acts as a BIOS profile button, guessing how much voltage need be applied to your Skylake processor, ramping up the multiplier in situ. Is it any good? Sort of. The thing is, if—like any sane person—you've installed this motherboard in a case, you're never going to have access to that little dial.

And performance? We're starting to feel like a stuck record. We achieved a maximum overclock of 4.9GHz, and all the other benchmarks were within less than 6 percent of one another in almost all cases, short of power consumption. The M7 did well overall, with a PC Mark 8 score above 4,000, but there really is little difference here.

Ultimately, it depends on your chip, how you like your motherboard to look, and whether the audio is any good. Fortunately for the M7, the latter two work incredibly well in its favor. But if you're after a performance motherboard? Well, you might want to think again.

VERDICT **8**

**MSI Z170A Gaming M7**

**MAYHEM** Stunning looks; strong feature set; great all-round performance.

**MEH** Still pricey; game boost impractical.

$220, www.msi.com

# Asus Maximus VIII Formula

## Is this the king of mobos?

**SKYLAKE INTRODUCED** one of the most controversial features ever to grace the world of motherboards: RGB lighting. At first, ill-advisedly, manufacturers simply threw those little LEDs into their boards without much consideration for the potential color clash.

Fortunately, the Formula avoided such a fate. Thanks to a later release cycle, Asus took the opportunity to strip the motherboard of its color, leaving a very sharp, black-and-gray base for those LEDs to complement.

Benchmarking was, as ever, a smooth process. We achieved our maximum overclock of 4.9GHz with relative ease, and all our other benchmarks were in line with what we expected. Leaving us in no doubt that, beyond included features and software suites, there's not enough on the board at this point to make a considerable difference.

That aside, the Maximus VIII Formula includes a redesigned thermal armor and reinforcing backplate, the ability to hide an M.2 SSD south of the chipset, a fully integrated EKWB VRM heatsink, and an Intel U.2 port.

If only we could end here. However, we came across a small problem with all of the Asus motherboards. Recently, while updating our CPU benchmarks, we noticed that, at stock, our Intel Core i7-6700K performed far better than on competing boards—however, at 4.9GHz, the little chip lost around 5-6fps in game. Odd, to say the least. This ended up being a result of Asus's enhanced turbo settings, enabled in BIOS by default. Great at stock, less so for overclocking.

Ultimately, the Formula is a stunning piece of design. Although the RGB lighting isn't for everyone, the performance is there, and at the very least, the black and gray styling, and the feature set, should appeal to those looking to build a top-of-the-line system.

VERDICT **9**

**Asus Maximus VIII Formula**

**CHAMPION** Great design; reiterated lighting; strong performer; balanced price.

**CHUMP** A bit plasticky.

$400, www.asus.com

# Asus Maximus VIII Extreme

## The pinnacle of overclocking?

**THE MAXIMUS EXTREME** lineup has always revolved around one particular pastime: overclocking. If you look at the number of records broken by that fabled name, you'll realize there's more to these boards than mere marketing propaganda. The Maximus VIII Extreme has already broken six world records in overclocking competitions.

This is a motherboard designed to push Skylake to the limit. We're talking overclocks well above the 6GHz mark. But not everyone has a processor (or a cooling solution) capable of such high frequencies. So does that make this board useless for anyone else? Not entirely.

For the money, you get eight SATA 6Gb/s ports, two SATA Express ports, one M.2 slot, one of Intel's prestigious U.2 ports, support for DDR4 up to 3,866MT/s, and no fewer than four PCIe 3.0 x16 slots. Then there's the audio solution, including headphone amplifiers, Nichicon capacitors, a high-precision clock, and an ESS-ES9023P DAC. You get the point.

We pushed our CPU beyond its silicon limit. Increasing the core voltage to 1.425V, and with clever adjustments to the base clock, we achieved a stable overclock of 4.95GHz. Of course, that's only 50MHz more than we got on almost all of our other boards. And our consistency performance tests fell in line with the rest, too.

Aesthetically the Maximus VIII Extreme is stunning. Admittedly, putting RGB lighting on a motherboard with red accents doesn't make much sense, but it's there.

So who is this motherboard for? Overclockers. Those willing to test all of the CPUs out there in the hunt for those record-breaking numbers. It's a well-equipped board, looks stunning, and performs admirably. But in reality, does that make it any better than, say, the Maximus VIII Hero? For the vast majority, probably not.

VERDICT **8**

**Asus Maximus VIII Extreme**

**MAXIMUM** Extreme OC potential; stunning design; rich feature set; U.2 port.

**MINIMUM** Price; RGB lighting; niche product.

$485, www.asus.com

# HOW WE TESTED

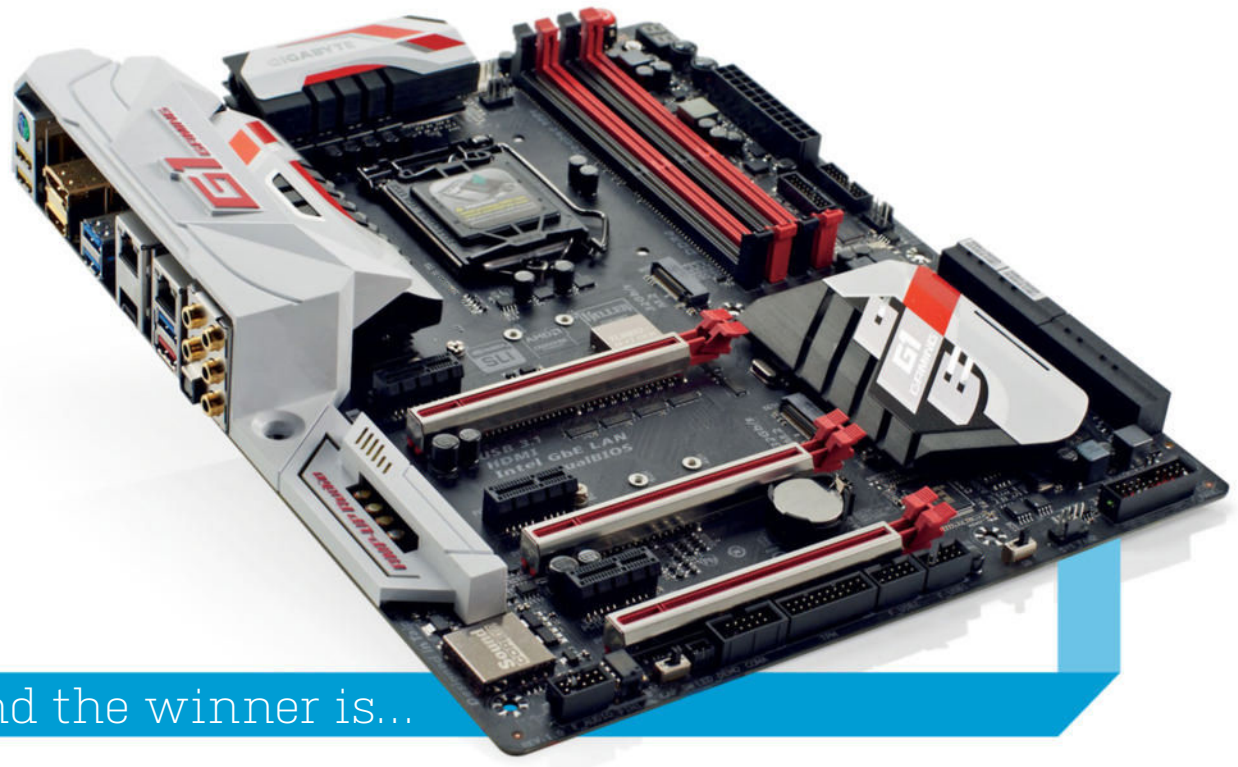
All of our motherboards were tested using 16GB of either DDR4 or DDR3 where appropriate, an Intel Core i7-6700K, a GeForce GTX 980, a Samsung 850 Evo 500GB SSD, a Samsung 850 Pro 2TB SSD, and a Be Quiet! Dark Rock Power Pro 1,200W PSU. All benchmarks were performed for their full duration, repeated three times for consistency, and the average calculated. Best scores are in bold type.

## SPECIFICATIONS

| | Chipset | Form Factor | Memory Support | Storage | PCIe x16 | LAN | Price |
|---|---|---|---|---|---|---|---|
| **ASRock Fatal1ty B150 Gaming K4/D3** | B150 | ATX | DDR3 1866 | 6x SATA 6Gb/s | 2 | 1x Killer E2400 Gigabit | $100 |
| **MSI B150 Gaming M3** | B150 | ATX | DDR4 2133 | 6x SATA 6Gb/s, 1x SATAe, 1x M.2 | 2 | 1x Killer E2400 Gigabit | $110 |
| **MSI Z170A Tomahawk** | Z170 | ATX | DDR4 3600 | 6x SATA 6Gb/s, 2x M.2 PCIe | 2 | 1x Realtek RTL8111H Gigabit | $150 |
| **Asus Z170i Pro Gaming** | Z170 | ITX | DDR4 4000 | 4x SATA 6Gb/s, 1x SATAe, 1x M.2 PCIe | 1 | 1x Intel I219-V Gigabit | $165 |
| **Gigabyte GA-Z170X-Gaming 5** | Z170 | ATX | DDR4 3466 | 6x SATA 6Gb/s, 3x SATAe, 2x M.2 PCIe | 3 | 1x Intel Gigabit, 1x Killer E2201 Gigabit | $167 |
| **MSI Z170A Gaming Pro Carbon** | Z170 | ATX | DDR4 3600 | 6x SATA 6Gb/s, 1x SATAe, 1x M.2 PCIe | 3 | 1x Intel i219 Gigabit | $170 |
| **Gigabyte GA-Z170X-Gaming 7** | Z170 | ATX | DDR4 3866 | 6x SATA 6Gb/s, 3x SATAe, 2x M.2 PCIe | 3 | 1x Intel Gigabit, 1x Killer E2400 Gigabit | $210 |
| **MSI Z170A Gaming M7** | Z170 | ATX | DDR4 3600 | 6x SATA 6Gb/s, 2x SATAe, 2x M.2 PCIe | 3 | 1x Killer E2400 Gigabit | $220 |
| **Asus Maximus VIII Formula** | Z170 | ATX | DDR4 3733 | 6x SATA 6Gb/s, 2x SATAe, 1x M.2 PCIe, 1x U.2 PCIe | 3 | 1x Intel I219-V Gigabit | $400 |
| **Asus Maximus VIII Extreme** | Z170 | EATX | DDR4 3866 | 6x SATA 6Gb/s, 2x SATAe, 1x M.2 PCIe, 1x U.2 PCIe | 4 | 1x Intel I219-V Gigabit | $485 |

## BENCHMARKS

| | CineBench R15 | Tech ARP x264 V5.0.1 | Memory Bandwidth | AS SSD Sequential Read/Write | PC Mark Score | Maximum Overclock | CineBench R15 @ OC | Power Draw Idle/Peak |
|---|---|---|---|---|---|---|---|---|
| **ASRock Fatal1ty B150 Gaming K4/D3** | 859 | 19fps | 17GB/s | 493/474MB/s | 3,779 | 4.0GHz | 859 | **42**/297W |
| **MSI B150 Gaming M3** | 874 | 19fps | 26GB/s | **494**/473MB/s | 3,978 | 4.0GHz | 874 | 48/**288**W |
| **MSI Z170A Tomahawk** | 922 | **20fps** | 27GB/s | 491/475MB/s | **4,153** | 4.9GHz | 1,008 | 50/346W |
| **Asus Z170i Pro Gaming** | 891 | **20fps** | **30GB/s** | 492/**477**MB/s | 4,080 | 4.9GHz | 1,058 | 48/297W |
| **Gigabyte GA-Z170X-Gaming 5** | 915 | **20fps** | 26GB/s | **494**/472MB/s | 3,907 | 4.9GHz | 1,060 | 43/312W |
| **MSI Z170A Gaming Pro Carbon** | 914 | 19fps | 27GB/s | 493/476MB/s | 3,925 | 4.9GHz | **1,072** | 51/296W |
| **Gigabyte GA-Z170X-Gaming 7** | 918 | 19fps | 26GB/s | 493/471MB/s | 4,073 | 4.9GHz | 1,059 | 45/334W |
| **MSI Z170A Gaming M7** | 923 | **20fps** | **30GB/s** | **494**/476MB/s | 4,028 | 4.9GHz | 1,064 | 84/318W |
| **Asus Maximus VIII Formula** | **931** | **20fps** | **30GB/s** | 493/476MB/s | 4,004 | 4.9GHz | 1,061 | 56/324W |
| **Asus Maximus VIII Extreme** | 907 | **20fps** | 29GB/s | 490/**477**MB/s | 4,053 | **4.95GHz** | 1,035 | 56/355W |



## And the winner is...

# Gigabyte GA-Z170X-Gaming 7

**AS YOU CAN PROBABLY TELL** by our extensive benchmarks table, the variance in performance between these mighty mobos was almost non-existent. Don't get us wrong—it's still there, and you can notice it in places, but at most it only ever amounted to 3 or 4 percent. In reality, you're just not going to notice a difference that small outside of benchmarking or particularly lengthy simulations, at which point, these kinds of motherboards just wouldn't even be considered.

So what are the criteria that really differentiate a winner from the rest here? Well, it's all down to feature set, ease of use, and style, with feature set being the more important of the three. After all, what use is a Z170 motherboard if you can't take advantage of all that the chipset has to offer, including the vast extension on the number of PCIe lanes available? For those reasons alone, and despite Gigabyte's often-cumbersome BIOS, the GA-Z170X-Gaming 7 came out as the winner.

## BUILD ON SUCCESS

The overall look and feel of the board is outstanding. The rear I/O cover and intuitively integrated LED lighting work exceptionally well together. Couple that with a radical color scheme, and we're immediately out on top here. It's simply exceptional. We're a big fan of colorful builds here at *Maximum PC,* and these Gigabyte boards have some serious build potential.

But we get it—not everyone is interested in what your system will look like. A good proportion of you simply won't care about the LEDs dotted around that mobo. For those who are going to throw this straight into a windowless chassis, it's the feature set that really matters. Let's put it this way: In theory, you could run two M.2 PCIe NVMe drives in RAID 0 on this board, and two- or three-way SLI/Crossfire, and not even have to worry about it. On top of that, you have access to HDMI 2.0, USB 3.1 Type C, and dual Ethernet connectors, plus a fantastic audio solution. It's simply brilliant in pretty much every regard. OK, there's no U.2 slot on here, or one our favorites, the right-angled USB 3.0 header, but that's not enough for us to mark this one down a notch.

That said, there's still a lot of great motherboards in this group test, and a lot of value options for those looking to dip their toes into the Skylake water. MSI's Z170A Tomahawk, Gigabyte's GA-Z170X-Gaming 5, and Asus's Z170i Pro Gaming—all are fantastic offerings, designed to cater to different audiences, while still taking advantage of the Z170 chipset.

So what have we learnt from all of this? Well, price really doesn't dictate performance. For the vast majority of us, the CPU is going to be the biggest limiting factor. Those thermally stable VRM solutions and power phase designs will undoubtedly not matter for processors under the 5.5GHz mark, and as that's well above 95 percent of CPUs, your best bet is to pick a motherboard that is best accommodated by your build, boasts the features you want, and is one that you like the look of. Perhaps one day we'll see a motherboard that reaches beyond software suites and empowered audio solutions, and when that day comes, the benchmarks may matter again.

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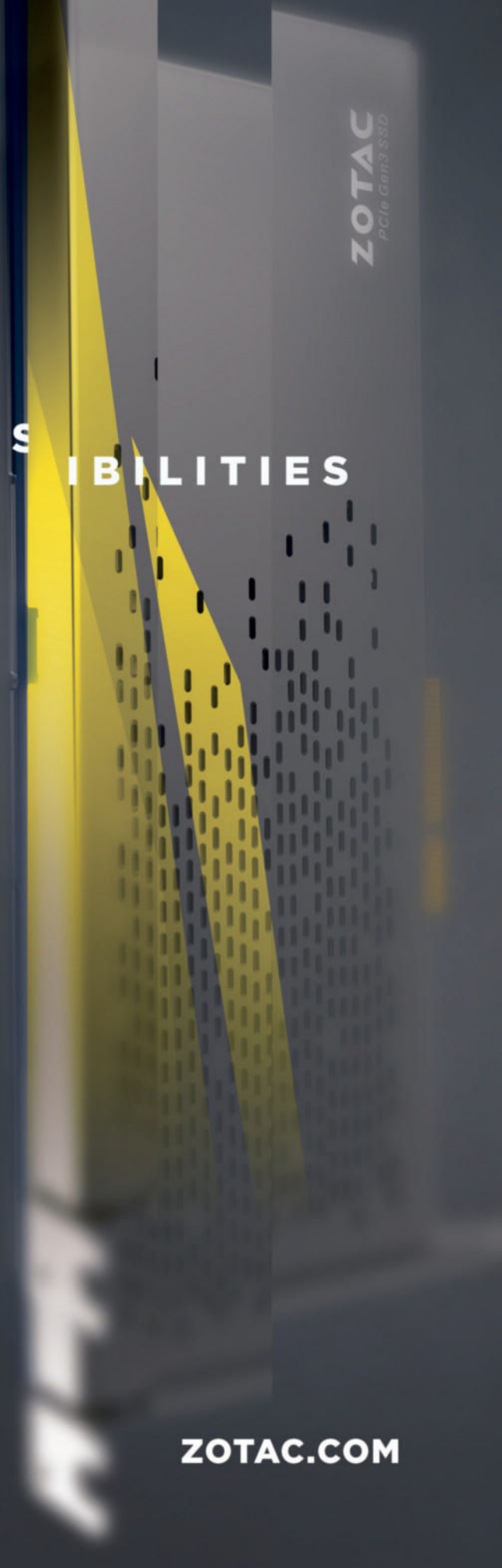




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BUILD IT

ALEX CAMPBELL **ASSOCIATE EDITOR**

# A Home-Brewed Steam Machine

Bringing PC power to the living room

LENGTH OF TIME: **1.5 HOURS** | LEVEL OF DIFFICULTY: **EASY**

## THE MISSION

**THERE ARE A FEW THINGS** that set apart the people who game on PCs from the folks who use consoles. For one, PC gamers often choose keyboards and mice, while console gamers just love their controllers (and usually have little choice in the matter). A PC can offer a lot more power and upgradability, while a console is stuck as-is. The biggest thing to note is where people play their games: PC gamers play at desks (mostly), while consoles rule the living room. That's what Steam machines are looking to change.

There are a few Steam machines available for sale already, and surely more to come. But as a PC builder, one must ask: Why buy one when you can build your own? Some of the prebuilt Steam machines out there aren't too different from consoles in that their hardware can't be changed. If you decide to brew your own, the world is your oyster when it comes to hardware and cases.

Steam machines also come in two flavors: SteamOS and Windows. The Windows machines come with Windows and Steam pre-installed, and aren't too different from a normal Windows desktop PC. SteamOS, on the other hand, is Valve's Linux-based OS offering. It basically runs Steam in Big Picture Mode on top of Debian 8. (Ubuntu, Valve's stated "favorite" Linux distribution, is based on Debian.)

We decided to test out Valve's OS by building a Steam machine that would run SteamOS. That means no Windows "tax," and no worrying about antivirus software annoying you with popups (or scheduled scans) while you're in-game. We couldn't resist trying it out with our own parts.

## SHOVELING COAL

**COMMERCIALLY AVAILABLE** Steam machines tend to be a little conservative when it comes to power. The reason is simple: cost. As games will probably be running on a 1080p TV, there's no need to splurge in an attempt to chase the 4K gold at the end of the rainbow, and there's less overhead from the OS and other applications.

We chose many of the same components as we had in the Summer 2015 Budget Gamer build we made for our quarterly web version of Blueprints. That rig laid the foundation with an Asus Z97I-Plus mobo and an Intel Core i5-4590, with 8GB of Corsair Vengeance DDR3 RAM. Their new home is a slim SilverStone ML08 mini-ITX case. We also used a SilverStone SFX PSU to power the little rig, and dug up a Asus GeForce GTX 960 Strix for our video workhorse.

While the Z97 board is a little overkill considering we're going with a locked CPU, it offers plenty of options in the BIOS (as well as PWM connectors). The mobo also includes a mini-PCIe Wi-Fi card, essential for a rig is designed to run in the living room.

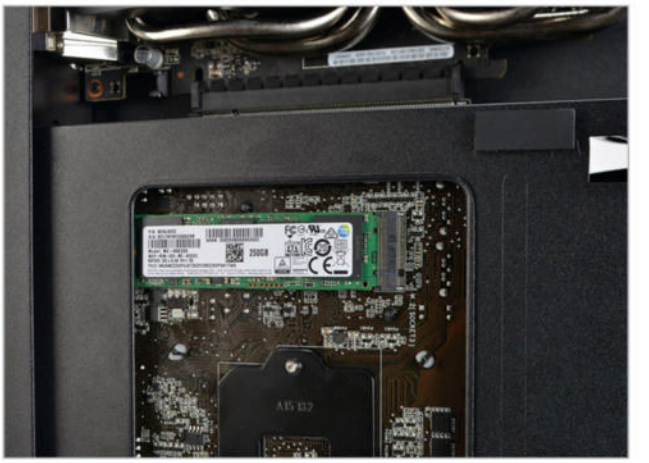
At the time of writing, the Z97I-Plus was hard to find (and thus dearer than its original price). If you can't find it in stock, we recommend an H97I or similar H-class board instead of the Z-class (unless you plan to pick up a K-model CPU). There are a lot of options when it comes to mini-ITX motherboards. And a Skylake-based system won't cost you much more than a Haswell one.

**INGREDIENTS**

| PART | | STREET PRICE |
|---|---|---|
| CPU | Intel Core i5-4590 Haswell | $185 |
| GPU | Asus GeForce GTX 960 Strix 4GB | $240 |
| Mobo | Asus Z97I-Plus | $153 *(Now available for $300)* |
| Memory | 8GB (2x 4GB) Corsair Vengeance DDR3 1600 | $45 |
| Case | SilverStone ML08B-H | $85 |
| PSU | SilverStone SX500 500W SFX (80 Plus Gold) | $110 |
| SSD | 250GB Samsung 850 EVO M.2 | $105 |
| Total | | $923 |

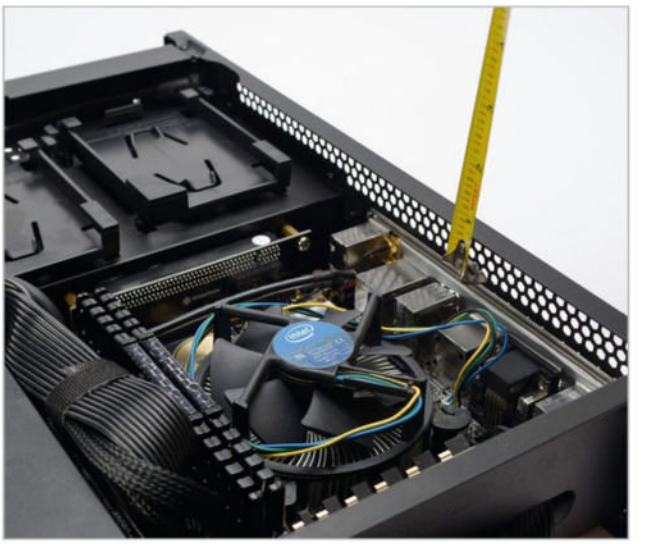
## 1 DON'T FORGET THE BOILER

**IF THERE'S ONE BIG GOTCHA** about using M.2 with mini-ITX, it's that the mount point is often on the underside of the mobo—we felt really stupid when we had everything in except the SSD. D'oh! While we've established M.2 SATA SSDs as our preferred form factor (as long as prices are on par with 2.5-inch models), the decision to go with M.2 in mini-ITX builds really pays off. Mini-ITX form factors can be hellish when it comes to airflow. With M.2, there's one less cable to route, and if it is your only storage drive, one less power cable. The only problem is that M.2 SSDs are topped out at 500GB at time of writing. Larger capacity SSDs are still pricey, and 250GB is plenty for the slim SteamOS and a decent game library. If the need arises, you could add 2.5-inch SSDs or HDDs.



## 2 BOYLE'S LAW

**THERE ISN'T A LOT** of room for CPU coolers in the ML08—there's only about three-quarters of an inch of clearance from the top of the cooler to the side panel. As we went with a fixed-clock i5-4590, we weren't too worried about the use of a stock cooler. However, if you want to go with K-model CPUs, you may want to get a better cooler for overclocking. There are few small-form-factor (SFF) coolers that would be short enough. SilverStone's Argon series is designed to work with the ML08. Corsair recently released an SFF closed-loop cooler, the Hydro Series H5, but even that could prove too thick (at 2.25 inches). If you feel the need for speed in this case, keep a close eye on your temps, as you won't have the thermal headroom you might enjoy in a bigger case. On the bright side, the side panel has a vent above the motherboard, so airflow to the CPU is unobstructed.



## 3 THE ELBOW PIECE

**BECAUSE THE ML08** is so slim, the video card can't be mounted in the typical position, perpendicular to the motherboard. However, you can't really move the PCIe slot, so Stone supplied a hard ribbon piece that turns the slot at a right angle for you. The L-shaped hard ribbon secures in place with a pair of screws, so there's no worry about wobble wreaking havoc on your motherboard. The other thing that this piece does is allow for the two-bay design. Locating the GPU in a separate bay from the CPU and motherboard keeps their heat and cooling separate. Warm air from the GPU isn't pumped over your CPU, and vice versa. Cable management is also cleaner, because you don't have to route things around a big video card. USB, audio, and power cables are easily routed and plugged in, without concern for obstructing the video card.

## 4 VIDEO TURBINES

**THE FIRST THING TO NOTICE** about the GTX 960 Strix is that it looks so small in its bay. Indeed, we could fit a full-sized GPU—such as a GTX 900 series or R9 300 series—in here if we wanted. You'd just have to keep an eye out for big aftermarket cooling solutions. While there's room for reference model cards, mounting a card sporting three fans wouldn't work. To mount the card, there's an extra riser piece that inserts into the L-shaped PCIe ribbon. It's easy to miss, and if you don't use it, the card won't seat into the two slots properly. On the other end of the card, a cutout allows for PCIe power cables to cross the partition into the video card bay. We recommend using ribbon-style cables or individually sheathed cables, as rounded sheathing would be ungainly. This bay is also the only place to mount a 3.5-inch HDD. If you crave multiple terabytes of storage, you need a video card that's shorter than the 960 Strix.

## 5 CONCEALED COPPER

**THE ML08 IS A SLIM CASE.** As a result, we need a slim power supply. We installed SilverStone's 500W SFX model, which gives our rig more than enough juice. The SX500 is fully modular, so we were able to keep cabling to a minimum by going with an M.2 SSD. We used flat ribbon cables, as opposed to rounded sheathed. While rounded sheathed cables help airflow in an ATX case, flat ribbon cables are a boon for the small form factor. We folded our cables over themselves, and positioned them flat against the side of the PSU, keeping them out of the way. There was one more gotcha, though: The power supply's plug isn't exposed to the outside of the case. This means there's no way to externally switch the PSU on or off, so before you close up the case, be sure to switch it on.

## 6 HOT HANDLES

**ONE THING THAT'S HANDY** on a case is, well, a handle. It makes transportation much easier. The ML087 comes with a handle that is attached to the case with four screws, or left off if preferred. The cool feature is that the handle can be attached to either side of the case, as the side panels are symmetrical. This means there is no true "top" or "bottom" to the case, though we feel that the "right way up" has the video card bay on top. If we could improve on one thing in this case, it would be the handle. It's made of plastic that feels strong enough to support the weight of a small system, but the molding isn't the kindest shape on hands. Carrying this thing on the train and across town (yes, we tried that) leaves indentations on the fingers, and prompted us to switch hands often. This could be fixed by rubberizing the grip.


**1** This mounting bracket and area allows for the addition of a slim DVD or Blu-ray drive. Adding such a drive isn't necessary for a Steam machine, though it would be nice if SteamOS would allow the playing of DVDs.

**2** The main mounting points for storage is a pair of 2.5-inch brackets for SSDs or laptop HDDs. By going with an M.2 SSD, we could leave these brackets empty, though using a pair of HDDs in RAID 1 wouldn't be a bad idea for backing up games.

**3** Of course, Wi-Fi is essential for an internet-connected device destined for the living room. While wired Ethernet is always best, the 802.11AC card makes sure that the Wi-Fi connection is as good as it can be.

**4** A slim opening at the bottom of the video card bay is just big enough for a SATA power and data connector to attach to a 3.5-inch drive. If your video card is too long, say goodbye to the 3.5-inch HDD.

# LOW ON PRESSURE

**BUILDING THIS LITTLE RIG** was a blast, and went by much faster than other small form factor builds we've worked on. Installing the SteamOS is easy as well, as long as you look out for a couple of things.

First of all, you need to set the Secure Boot option to "Other OS" in the BIOS. SteamOS and most other Linux distributions aren't able to supply certificates to motherboard vendors. Without a signed certificate, the BIOS will refuse to boot the OS unless you disable Secure Boot.

When we tried the automatic installation for SteamOS, the installer couldn't partition the SSD, for whatever reason. When we tried the "advanced" installation (it really isn't that advanced, as Linux installations go), everything worked just fine.

There's a dark side to playing games on Linux. The vast majority of games available on Steam are for Windows and use DirectX. Of the games for SteamOS and Linux, only a few are developed with Linux in mind, or use OpenGL as their native API. Thus, many games that are ported have to translate DirectX instructions to OpenGL equivalents somehow. That translation, coupled with slightly lower performance of Linux drivers for GPUs, can amount to big performance hits.

At every turn, the better components in this build spanked the little Alienware Steam Machine. When we compared these results to the Windows-based Alienware Alpha, the margins seemed to thin out. The frame rate in *Bioshock: Infinite* was actually lower than what the Alpha pulled off with its 860M.

SteamOS is still in its infancy. The number of titles available to SteamOS will increase, as will support for Linux if the OS starts to gain steam, so to speak. For now, building a SteamOS box is a fun experiment, but don't expect it to replace your desktop rig just yet.

## BENCHMARKS

| | Alienware Alpha | Alienware Steam Machine | |
|---|---|---|---|
| Bioshock: Infinite (fps) | 69.5 | 48.1 | 67.8 -2.4% (Alpha) +41% (Steam) |
| Talos Principle (fps) | 48.1 | 37.8 | 51.2 +6.4% (Alpha) +35.4% (Steam) |
| Half-Life 2: Lost Coast (fps) | 236 | 231 | 254 +7.6% (Alpha) +10% (Steam) |
| Shadow of Mordor (fps) | 50.7 | 35.4 | 64 +26.2% (Alpha) +81% (Steam) |

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our desktop zero-point PC uses a 5960X CPU, three GTX 980s, and 16GB of RAM. *Arkham City* tested at 2560x1440 max settings with PhysX off. *Tomb Raider* at Ultimate settings. *Shadow of Mordor* at Max settings.

# BUILD IT

ALEX CAMPBELL **ASSOCIATE EDITOR**

# The Poor Man's NAS Setup

What do you do with all your old components when you upgrade? Turn them into a NAS

LENGTH OF TIME: **1–3 HOURS** | LEVEL OF DIFFICULTY: **EASY**

## HOME-BREWED NETWORK-ATTACHED STORAGE

**IT CAN BE TEMPTING** to keep revisiting the same theme in a build. After all, most of the PCs we put together are geared toward games, games, and more games. Most of the money we see in a build goes toward graphics cards and CPUs.

But not every computer you build needs to be a super-wicked-awesome gaming rig that warps space-time with eight cores and SLI. Sometimes, you just need somewhere to store your stuff.

When you upgrade your PC's CPU, a new motherboard is often in the works as well. From there, it's easy to simply go ahead and upgrade all of the core components. What you have left is basically an unused PC. But what if you could give those old components a second lease of life? FreeNAS is an operating system that offers just that.

The FreeNAS OS is built on the foundation of FreeBSD, a free software implementation of UNIX. We took some of the recommendations of FreeNAS into consideration when we scrounged together some parts lying around the Maximum PC Lab to create a low-power, quiet PC that we could use to store and serve up files.

## SCAVENGING FOR PARTS

**WHEN WE WENT LOOKING FOR PARTS,** we had a good selection to choose from. However, most of our parts are high-octane, fire-breathing performance cards and processors. We wanted to make this build a low-power machine, because it would be on all the time.

The other challenge was finding parts that fit FreeNAS's recommended specs. We found an old LGA-1156 Celeron that we were hoping to use for its ultra-low power consumption, but the single core fell below the spec set by FreeNAS. Instead, we laid our eyes on an LGA-1150 Pentium G3258. The G3258 is a conflict-free dual-core processor with a TDP of just 53W. That's more than the Celeron would have been, but we had to use what we had.

We matched this with a Gigabyte micro-ATX Z97 board we weren't using. The motherboard is overpowered for the CPU it's paired with, but we liked the fact it had 6Gb/s SATA3 connections, instead of the old SATA2 we'd have been stuck with had we gone with the Celeron.

For storage, we grabbed four 7,200 RPM 6TB WD Blacks that we used for the Dream Machine. While these aren't the best to use in a NAS, they are large capacity and come with a five-year warranty. For RAM, we went with 8GB of Corsair XMS 3 DDR3-1600.

We stuck everything into the Fractal Design R4 mid-tower. We chose this for its soundproofing features, and because it offered plenty of space for four drives, and was languishing away in our lab.

### INGREDIENTS

| PART | | STREET PRICE |
|---|---|---|
| Case | Fractal Design R4 (Arctic White) | $110 |
| Motherboard | Gigabyte Z97M-D3H | $109 |
| CPU | Intel Pentium G3258 | $60 |
| Memory | 8GB (4x 2GB) Corsair XMS3 DDR3-1333 | $70 |
| HDD | 4x 6TB WD Black 7,200 RPM | $1,120 |
| PSU | Enermax Revolution X't 530W 80Plus Gold | $80 |
| USB Flash | 16GB PNY Attaché USB 2.0 flash drive | $6 |
| ODD | Plextor PX-LB950SA Blu-ray writer | $160 |
| Total | | $1,715 |

## 1 A SMART APPLIANCE

**AS WE USED** a little dual-core Pentium, and overclocking wasn't planned, a stock heatsink and fan were fine. The low profile of the fan improves the airflow of the case.

If you're building this at home, an old Core i3 or i5 would work well. If you've got an AMD board, using an FX CPU or A-series APU will work, too, even though FreeNAS recommends going with Intel. If you're rolling with team red, just try to use a CPU or APU with the lowest TDP you can, as this machine will be on all night and day. Your CPU usage is unlikely to max out, so power draw will be a small percentage of the processor's maximum draw.

The DIMMs are Corsair XMS3 DDR3-1333. We had a 6GB kit (three 2GB sticks), so we checked model numbers before throwing them together for a total of 8GB.

## 2 RACK 'EM UP, PACK 'EM IN

**IF THERE'S ONE ESSENTIAL** feature of a NAS, it's large-capacity hard drives. We took four 6TB WD Blacks and mounted them up front, next to a fan to keep them cool.

If you can, we recommend going with enterprise-grade HGST drives, though they're pricier than their consumer desktop counterparts. It's good practice when using RAID to use identical models and capacities.

FreeNAS implements RAID through software in ZFS, and refers to it as RAIDZ. To take advantage of RAID, you need a minimum of two drives for RAID 0 or 1, three for RAID 5, and four for RAID 6 or 10 (or 0+1). Keep in mind that RAID is not the same as a backup; it simply protects you against a physical drive failure. If you use cheaper desktop drives, you have to replace them more often.

One more thing: FreeNAS doesn't recommend using a hardware RAID controller.

## 3 THE BARE MINIMUM

**WHEN LOOKING FOR A MOTHERBOARD,** it can be tempting to use just any board. However, there's a gotcha that could be easily overlooked if your old boards have been used for gaming: Whatever board you use, make sure it has video output.

While you're checking out the back panel, take note of what connections are there. Does it have HDMI? DVI? VGA? Make sure whatever is there matches up with what monitor(s) you have. While a NAS won't need an attached monitor for day-to-day operation, you'll need one to install the OS. It's really annoying to feel like you're all set up, just to find out you need to go to the local electronics store for a video adapter.

Other connections such as eSATA, FireWire (IEEE-1394), and USB 3.0 are nice, but not critical. With those, you can expand the NAS's storage (or transfer data) by attaching removable drives.

## 4 THE MEMORY REMAINS

**ONE OF THE GREAT THINGS** about building a home-brewed NAS is that the cable management is so much easier than the kind of mess you'll find in a gaming PC. That is, if you use a modular power supply.

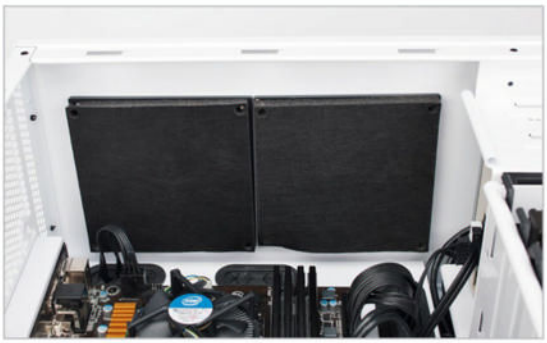
If you've got a modular power supply, take the PCIe power cables and store them in a box somewhere. All we're worried about is the SATA, ATX, and CPU power cables. Connecting your SATA power should be a breeze, and as long as you employ some sanity, you shouldn't need more than one (or two, depending on your vendor) for an array of four drives. In our build, we included a Blu-ray drive for good measure, and had to run a SATA power cable to it. Our other SATA cable had four connections on it, which was enough to power our four WD Blacks with one run.

## 5 ENTER NINJA MODE

**THE MAIN REASON** we chose the R4 was that it had been designed with acoustics in mind. For a machine that's intended to be always-on, noise can be an issue, especially if you place it in a guest room or near a bedroom. While you may be fine with the whirring of fans, spouses, significant others, and visiting in-laws may not be so understanding.

As you don't want to have to turn off the NAS because of your mother-in-law, mitigating noise can be a priority. The padding inside the R4 absorbs a lot of sound, while offering options for airflow with top and side mounts for fans. We prioritized placing fans in the front to cool the hard drives.

Making sure the case doesn't have LED lighting you can see from space is a big plus, too. A home NAS should be like a data ninja: neither seen nor heard, yet highly effective.

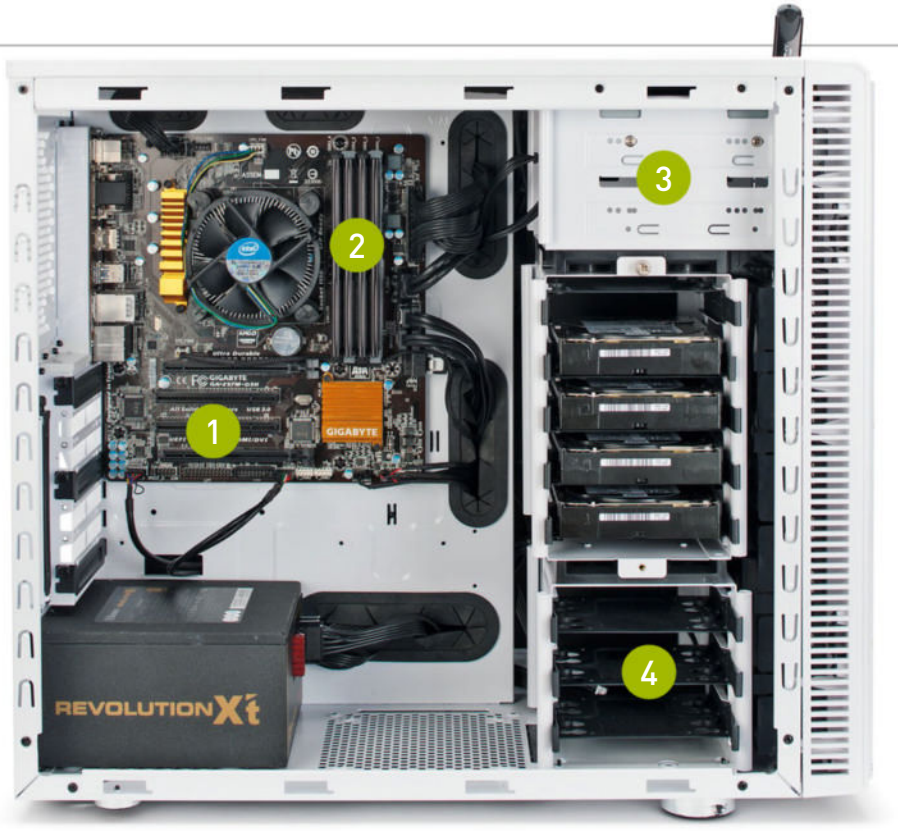


## 6 ONE KEY TO RULE THEM ALL

**FREENAS RECOMMENDS** you install the OS on a removable USB thumb drive. Your NAS doesn't need constant access to a speedy SSD; all the storage is going to your RAID array. As the OS is headless, there's no need to store bulky graphical assets for the OS or expensive graphics libraries. Boot times are irrelevant, as the NAS is meant to stay on.

Also, FreeNAS can encrypt the filesystem on your hard drives. To decrypt the files, the OS needs access to key files, which it has to store somewhere. By putting the OS on the USB key, you can render the hard drive array unintelligible by removing the USB key. If the decryption keys can't be recovered, the encrypted data is basically destroyed.

The second stick is for installing the OS. If you use a USB drive instead of an SSD, the stick you put the installation files on can't be the same stick you install the OS on.




1 **The lack of a graphics card makes this desktop motherboard look barren. That's not all bad, because the PCIe slots can be used to add additional network interfaces or SATA connections.**

2 **We used 8GB of non-ECC RAM in this build. FreeNAS recommends 16GB of ECC RAM for more demanding business applications, but 8GB is good enough to start with for home applications.**

3 **While you don't really need one, we went ahead and included a Blu-ray writer for good measure. This can be handy if you want to make optical disc backups.**

4 **We used a USB stick to house the OS, but you can always install it on an SSD or small HDD if you feel like it. Or you can use the empty spots in the cage for more hard drives.**

# ALL THE FINE PRINT

**IT'S ONE THING** to build a home file server from recovered parts; it's another to build the most optimized system for the job. With regards to FreeNAS, there are several considerations when it comes to picking the choicest parts.

First, servers aren't the same as desktops. A lot of server applications can run on desktop hardware but they run best on server hardware. In the case of FreeNAS, an ideal system would make use of a Xeon processor, ECC RAM, and enterprise-grade hard drives.

If you plan on making your NAS do a lot of computational heavy-lifting, it pays to use a more powerful CPU. We got away with our little Pentium because we didn't expect a big CPU load. We also preferred low power consumption over performance. But if you want to do a lot of transcoding and other operations on the NAS, use a beefier CPU.

When it comes to RAM, there are long discussions online about the potential dangers of using non-ECC RAM. ECC RAM differs from non-ECC RAM in that it performs self-checking of bit integrity. The fear of using non-ECC RAM is that bad bits could be written to disk, and scrubs (processes that keep a ZFS pool healthy) could exacerbate bad bits, potentially corrupting the whole filesystem, resulting in losing the pool altogether. In effect, there is a danger that non-ECC RAM could cause something that's meant to be a protective feature of ZFS to be its downfall.

This is enough to scare anyone into thinking that ECC RAM is the only way to go, but there are important considerations. First, ECC RAM is much, much more expensive than non-ECC RAM. Secondly, there's very little chance that your desktop motherboard supports ECC RAM. Thirdly, your CPU needs to support ECC RAM in order to use it. See where this is going?

Matthew Ahrens, one of the co-founders of the ZFS project (he currently contributes code to ZFS for Delphix), dispelled fears that non-ECC RAM would bring your FreeNAS pools crashing down. In an Ars Technica forum post he said, "There's nothing special about ZFS that requires/encourages the use of ECC RAM more than any other file system." He continued to say that using non-ECC RAM with any other filesystem (such as NTFS, Ext3, or others) has about the same amount of risk of destruction as using non-ECC memory with ZFS.

Extrapolating from Ahrens' post, the danger of loss of your ZFS pool is likely the same as the random loss of the data on your desktop due to RAM errors. That danger is slim, but enough to make ECC a must for mission-critical applications. But your DVD collection isn't mission-critical (unless you really can't live without *Animal House).* For home use where cost is a consideration, non-ECC RAM is fine. If you're building a business on your NAS, the cost of ECC RAM is a cost of keeping the business up and running.

If the sky would burn red hot like the pits of hell if you lost your data, it probably warrants a backup. A NAS is a handy appliance to have. It keeps your data accessible and frees you from concerns that you'll always need to pack extra gigabytes of free storage on your device. But it's not a backup, unless it's backing up another NAS.

Finally, we have hard drives. We used WD Blacks, but many desktop hard drives aren't built with NAS applications in mind. This is part of the reason the 3TB Seagate Barracuda got a lot of flak. The cloud storage provider BackBlaze collected statistics and found that 3TB Barracudas failed at a higher rate (26.7 percent) than other drives it used.

The 3TB Barracudas' average age was about 2.5 years. As it turns out, the 3TB Barracuda only has a two-year warranty. On top of that, the Seagate Barracuda isn't meant for enterprise server and NAS applications. (Neither are the WD Blacks we used.) And remember, a cloud provider is going to have way, way more I/O hits than your home NAS.

The biggest cost of the system will likely be the hard drives. Look for hard drives with high capacity and a good, long lifespan. (The length of the warranty is a good indicator.) HGST offers great, reliable NAS and server drives, but they also cost more. Cheaper drives such as the Barracuda can get the job done, but will have a higher replacement rate.

Even though this build topped the $1,700 mark, we still like to think of it as a poor man's NAS, since we used parts that were past their prime or languishing in a corner. By keeping true to the core requirements (multicore CPU, 8GB RAM), you can build a home FreeNAS box out of just about any hardware you can scrounge together. Go ahead—give those old parts a new lease on life.

# BUILD IT

ALEX CAMPBELL **ASSOCIATE EDITOR**

# Team Red Comes Back in Black

We took some high-end AMD parts and put them into this darkly beautiful rig

LENGTH OF TIME: **1–3 HOURS** | LEVEL OF DIFFICULTY: **EASY**

## CHECK ONE, TWO

**SOMETIMES IT CAN BE** incredibly tempting to go with what's familiar. For us, Intel tends to be our preference when we look for a performance CPU. But we asked ourselves: What if we went full-on Team Red?

Sure, AMD doesn't make a part that can compare to the Core i7-5960X, but that doesn't mean it doesn't offer some good CPUs. And on the upside, you generally pay less for an AMD CPU, which means that gamers or builders on a budget can still have a good experience without as much of a hit to the wallet. After all, the 5960X is $1,000.

We also wanted to find an excuse to build into the NZXT Noctis 450 that had been sitting in our office for a few months. Once we opened the box, we wondered why we hadn't built into it earlier. The Team Red theme went together with the black and red accents of the case perfectly.

We feel like this build is a great example of what you can do with the darker, redder side of the PC parts market. Combined with the red accents on our GPU and RAM, this build really shines as one of our favorites in terms of aesthetics.

## THE SET LIST

**WHEN WE STARTED** piecing together this rig, we went hunting around our lab for AMD parts we had to hand. We happened upon the foundations of what would make our build: an eight-core AMD FX 9370 and an ASRock Fatal1ty 990FX Killer mobo.

The FX 9370 makes use of AMD's Vishera core, which is a little on the thirsty side. With a TDP of 220W, we had to make sure we cooled it if we wanted to keep it stable, so we grabbed a Cooler Master Nepton 280L, with its big 280mm radiator.

As for video, we couldn't resist using our Asus R9 Fury Strix. Although it's not AMD's biggest, baddest GPU (the 9370 isn't the top of AMD's offerings either), the Fury holds its own. Think of the Fury and the Fury X in the same terms you would the 980Ti and Titan X.

As for the rest, we nabbed 8GB of Corsair Vengeance RAM to fill two of the four DIMM slots on our 990FX mobo. And keeping with our theme, the RAM had to be red. For storage, we went with a 250GB M.2 Samsung 850 EVO and a 3TB Seagate Barracuda spinning drive.

The power supply was tricky. As we were in the midst of moving office, we had a hard time finding a PSU that would be a good match. We eventually found a Corsair RM650, which worked well. However, if you want to overclock this GPU or CPU, go find a PSU rated at least 750W. The 650W unit got our benchmarks done without a problem, but we'd really like the extra headroom for overclocking.

### INGREDIENTS

| PART | | STREET PRICE |
|---|---|---|
| Case | NZXT Noctis 450 | $140 |
| Motherboard | ASRock Fatal1ty 990FX Killer | $120 |
| CPU | AMD FX-9370 Vishera | $210 |
| Memory | 8GB Corsair Vengeance DDR3 1600 (red) | $47 |
| GPU | Asus Radeon R9 Fury Strix | $570 |
| PSU | Corsair RM650 (80 Plus Gold) | $107 |
| HDD | 3TB Seagate Barracuda | $90 |
| SSD | 250GB Samsung 850 EVO M.2 | $108 |
| CPU Cooler | Cooler Master Nepton 280L | $120 |
| Total | | $1,512 |

## 1 FLYING HIGH AGAIN

**THE NEPTON 280L** kept us cool during tests, but before we could run them, we had to mount the big radiator somewhere. The Noctis 450 is a midtower, so there's not much room inside. But there's plenty of room up top.

With a little effort making sure to release all the round catches at the top of the inside of the case, you can release the whole top plastic molding in one piece. We found that if you put it in just the right spot, you can place the big 280mm radiator on top of the fan mounts and still get the top to attach properly. This is a big space saver, and also helps support the big radiator.

Luckily, this case isn't built with 5.25-inch optical drive bays in mind, so we could snake the tubing for our cooler in the "drive bay" where the ODDs would normally go.

## 2 ROCK YOU LIKE A HURRICANE

**MOST BUILDERS** know that AMD parts can get toasty under load, so good cooling is essential. As we had our CPU covered with a 280mm radiator, we needed to make sure our R9 Fury got all the airflow it could handle.

The Noctis 4509 comes with four case fans: one up front, two up top, and one in the rear. Since we wanted to place our CPU cooler up top, we moved those two fans to the front to help keep the Fury fed with fresh air.

We also mounted our radiator with a pushing exhaust configuration, so making sure we had enough cool air for the radiator was a must.

When we snapped the front panel back on, there were no lights from the fans or front of the case, which made for a sleek black matte look that really impressed. You don't need LEDs on all your parts. Even if we had LED fans up front, we doubt we'd be able to see them.

## 3 NO SHELTER

**WE'VE BECOME BIG FANS** of using an M.2 form factor SSD whenever possible. This Samsung 850 EVO is no exception.

Don't expect NVMe speeds here: This SSD runs pure SATA mode and offers the same speed as a 2.5-inch model. But both the 2.5-inch and the M.2 are about the same price, so why not go M.2? It saves on cabling mess and improves our airflow.

The only downside to installing an M.2 SSD is you have to install it before your video card. The other upside is that when you finally do want to upgrade to NVMe, you've got the platform to do so. On most motherboards, the switch from SATA to NVMe mode can be made with the help of a simple BIOS option.

Of course, another downside to using M.2 is that your storage isn't shielded behind a plastic or aluminum casing. It's exposed to mishaps and damage if you're not careful.


## 4 THE MEMORY REMAINS

**WHEN WE INSTALLED** our 3TB Barracuda, we realized you can't see the drive easily from the "front" with the panel off. NZXT decided to build a partition in the Noctis 450 that makes the drive inaccessible from the front. Instead, you have to take off the "back" panel to add or remove hard drives. This can be a pain in the butt when your cable management makes it difficult to get the back panel closed in the first place.

As much as that can be an annoyance, there is a bit of logic: By mounting drives this way and keeping that partition, the build looks cleaner with the "front" panel taken off. It also helps channel air from the fans toward the PCIe slots and CPU, as opposed to letting it fly about everywhere.

We just recommend steering away from the idea of using this case if you'll be swapping out hard drives often; opening the back panel is rarely fun.

## 5 THE PATIENT

**WORKING ON A PC** can feel like working in an operating room. In this build, one of the more hairy parts was trying to install the GPU. Just as that hard drive partition makes life painful when messing with your hard drives, it also made things interesting when installing our R9 Fury Strix.

At 11.8 inches long, the R9 Fury Strix needs a lot of space in a case. The space was there in the Noctis 450, but it took a bit of wiggling to get the GPU put in place. To do it, we had to back the card into the hard drive cage partition before moving it forward to insert and seat it in its rightful slot. This wasn't difficult, but it did require a bit of patience.

If we wanted to add a card to use in Crossfire, it would be interesting to try to fit it in. On the plus side, the GPU looks handsome, while conforming to our black-and-red theme.


## 6 UNDER THE SURFACE

**ONE OF THE REASONS** this build looks so clean is the power supply partition that NZXT built into the Noctis 450.

Such partitions are often underestimated, but they help the build stay organized. If you don't have a modular PSU, spare cables can be coiled and zip-tied away inside the partition. The loose end of SATA and power cables, too, can find a home there. The partition also allows for dedicated airflow for the PSU (and more optimized airflow for the motherboard compartment), and can keep heat contained.

The downside is that installing your PSU is not as straightforward. You can't just plop it in place. Instead, you have to slide the PSU into position, often by removing a bracket, where you see the PSU mounting screw holes. And you have to mount the PSU with the fan facing downward, as there isn't a lot of room for efficient intake from the top.


1 **While we probably had enough room to mount the radiator below the bracket, keeping it up top gave us more space and kept things from looking cluttered.**

2 **The bevel line you see creates a channel for stowing big cables, keeping cable bulge to a minimum.**

3 **Using the cutouts in the top of the PSU partition makes routing audio and USB connections much cleaner.**

4 **While it would look gaudy on other cases, the underglow effect is nice because it's the only external LED lighting on the all-black case, save for a red LED behind the power button.**

# THE SOLO AND BREAKDOWN

**WHEN WE WERE ALL FINISHED,** this was one of our favorite builds in terms of looks. The interior looks clean, and the red-and-black theme has a darkly evil appeal reminiscent of *Command and Conquer*'s Brotherhood of Nod. But looks aren't everything.

When we ran our graphics benchmarks, we couldn't really expect a single Fury to stand up to the wrath of three GTX 980s. However, this system did offer some promising marks.

The *Shadow of Mordor* benchmark returned a score of 44.2 frames per second on average at 2160p. That's enough to make it into the playable realm at 4K, no easy feat.

*Tomb Raider* didn't fare as well at 4K, with 38.5fps. That's too close to 30fps for our blood. However, if you really want to play *Tomb Raider* at 4K, turning down (or off) antialiasing could bump up the frame rate. With these marks, playing at 1440p would be just fine.

In *Batman: Arkham City,* we saw what this card could do at 1440p. Again, the marks aren't as high as a 980Ti would be, at 89fps, but they are playable. With a FreeSync monitor, playing at that resolution would be enjoyable.

Remember that these benchmarks are stress tests with all (non-GPU-specific) settings maxed out. Turning down settings can yield dozens of extra frames per second.

When we fired up 3DMark Fire Strike Ultra, we saw our rig get a respectable score of 3,515, comfortably above the Oculus Rift recommended spec score of 2,596.

Our CPU benchmarks returned much lower scores than the i7-5960X in our zero-point. Though the Vishera's octa-core offered more than a quad-core, the 5960X's Hyper-Threading, smaller process (22nm versus 32nm), and higher L3 cache (20MB versus 8MB) produced a faster machine. But the 5960X is a $1,000 CPU. The FX-9370 is $210.

The single-threaded benchmarks returned a much smaller delta than the corresponding difference in price. Considering that the FX-9370 costs 79 percent less than the 5960X, a delta of about 40 percent in Stitch and 23 percent in ProShow isn't all that bad.

Once we got into our multithreaded benchmark, the performance gap widened to canyon-size. The 5960X has more L3 cache and Hyper-Threading, so instead of eight logical CPUs, it has 16. That's twice what the Vishera offered, and the FX-9370 fell behind.

On the bright side, the CPU stayed cool with the help of the Nepton 280L. During the CPU-intensive x264 encoding test, we saw a peak CPU temp of 52 C. Likewise, Fire Strike Ultra only topped out at 48 C. That leaves plenty of thermal headroom for overclocking. Speaking of which, if there is one thing we could have done differently it would be the power supply. Going with a 750- or 800-watt PSU would give you all the headroom you need to overclock safely. We weren't comfortable with the idea with only 650 watts to work with.

## BENCHMARKS

| | ZERO-POINT | |
|---|---|---|
| Stitch.Efx 2.0 (sec) | 806 | 1,087 (-34.9%) |
| ProShow Producer 5.0 (sec) | 1,472 | 1,814 (-23.2%) |
| x264 HD 5.0 (fps) | 33.8 | 13.3 (-60.7%) |
| Batman: Arkham City 1440p (fps) | 204 | 89 (-56.4%) |
| Tomb Raider 2160p (fps) | 87.5 | 38.5 (-56%) |
| Shadow of Mordor 2160p (fps) | 70.1 | 44.2 (-36.9%) |
| 3DMark Fire Strike Ultra | 8,016 | 3,515 (-56.1%) |

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our desktop zero-point PC uses a 5960X CPU, three GTX 980s, and 16GB of RAM. *Arkham City* tested at 2560x1440 max settings with PhysX off. *Tomb Raider* at Ultimate settings. *Shadow of Mordor* at Max settings.

# BUILD IT

ALEX CAMPBELL **ASSOCIATE EDITOR**

# Caged Power: All on Display

If you've spent loads of cash on cool components, why hide them away in an enclosed case?

LENGTH OF TIME: **2 HOURS** | LEVEL OF DIFFICULTY: **MEDIUM**

## ASSEMBLING THE CAGE

**HAVING THE INSIDES OF YOUR PC** on display might not be for everyone, but if you want a PC that looks a little different then it can set your computer apart from the crowd. It helped that Max, from our video team, wanted to build a new rig into an open-air case by In Win that he'd bought. So we figured: Why not? This is the Holiday issue, after all, so we decided to get into the spirit.

Most of the time, our builds end up in PC cases that enclose the guts on all six sides. Even if there is a side panel window, five out of six sides remain mostly or totally opaque. That means that the case is on display, not the parts inside. Seeing as the case costs only a fraction of the price of the PC, it's a shame to hide all those parts away behind sheets of black steel and aluminum.

We wanted to try out this open-air case because it gives us a chance to look at those parts that are too often hidden away. But with beauty comes pain. An open-air case like this one presented some unique challenges for our build.

Even with those challenges, we were happy with the final result, and hope that Max isn't too upset when we have to take back some of the parts and keep them in our lab. Sorry, Max.

## ROUNDING UP THE PARTS

**WHEN WE SET OUT** to do this build, we wanted to include some shiny, new parts. This, of course, meant we had to go with Skylake; we've been overdue for a build that used Intel's latest architecture. For graphics, though, we had a choice: We could go lower-end with the recently released GTX 950, or go bigger with the AMD's R9 Nano.

Guess which way we went. More power is sexier, so we chose the Nano, which fitted well in this mini-ITX build. The CPU and GPU found a home on the Gigabyte GA-Z170N motherboard, which supports DDR4 and offers wireless networking too, with its mini-PCIe Wi-Fi card. We had an EVGA Z170 board, but the included Wi-Fi was a good reason to pick this board over the other. We just wish that the mobo came with on-board power and reset buttons, like the EVGA model. As this is a Z170 board, we had to go with DDR4 memory. We got a couple of 8GB sticks of 2,666MHz Corsair Dominator.

All of our parts found a comfy, airy home in the In Win D-Frame Mini. While Max chose the orange and blue frame, it also comes in black and red. The cool thing about it is that there's no clear top or bottom; you only need to worry about access to ports and buttons.

The 750W power supply is plenty for the parts we chose, and as mini-ITX is limited to one GPU, there's no need to worry about extra headroom for SLI or Crossfire. However, the extra wattage does allow for single-GPU upgrades, or the addition of spinning drives.

### INGREDIENTS

| PART | | STREET PRICE |
|---|---|---|
| Case | In Win D-Frame Mini (orange) | $250 |
| Motherboard | Gigabyte GA-Z170N | $165 |
| CPU | Intel Core i7-6700K | $360 |
| Memory | 16GB (2x 8GB) Corsair Dominator Platinum DDR4 2666 | $170 |
| GPU | AMD Radeon R9 Nano | $650 |
| PSU | BitFenix Fury 750G 80 Plus Gold | $121 |
| SSD | Samsung 850 EVO 2TB | $800 |
| CPU Cooler | Deepcool Maelstrom 240 | $177 |
| Total | | $2,693 |

## 1 HOT STUFF

**THE RADEON R9 NANO** is quite a powerful GPU, given its tiny form factor. However, we noticed that it got pretty toasty when we ran our graphics benchmarks. While normal closed cases could solve this by channeling air through the case, we were low on options because there was no way to effectively push extra air over the card. The air coming from our CPU radiator was nice and cool, but the slight offset of the motherboard meant that the Nano wouldn't get any of the cool breezes. Placing the "front" glass panel on the case helped a little bit, but the Nano breathes best with a little extra air flow from a case fan.

If we were to redesign the case, we'd like to see an extra removable bracket for a case fan, just below the GPU mount. This would better support the use of extra-toasty GPUs, which would usually have more forced air, to stay a little cooler under load.


## 2 SIDE MOUNTED

**THE PSU** is the heaviest component in nearly any build, so mounting it on the side of the case might seem counter-intuitive. Not so, with the D-Frame. The PSU happily occupies a bracket on the side of the cage, but doesn't make the cage feel off-balance.

To make things neater, we went with individually sheathed cables, which are easier to manipulate. Routing the cables was a bit tricky with a smooth aluminum plate, instead of a motherboard tray rife with cable-management tie loops. Luckily, the cage came with a few accessories that helped.

We used a modular power supply, so there's no need to stash unused cables. That's a big deal in a case where there are no hiding places for your cabling.

## 3 USB 3.0 WOES

**IF THERE WAS ONE BEEF** we had with this motherboard, it was the positioning of the USB 3.0 front panel connection. After you figure in the presence of a GPU, it became clear that there was no sexy, clean way to attach the cable.

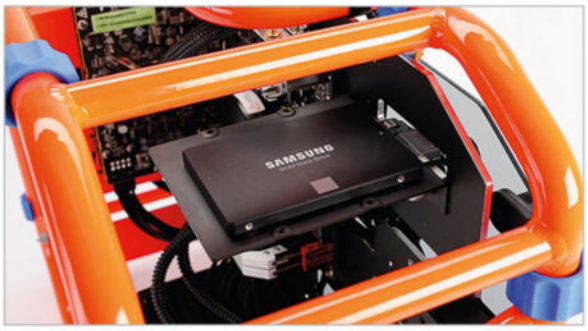
To the left, you have the R9 Nano, and routing under the GPU between the PCIe slot and the "back" panel was too tight a squeeze. If we came from below, the cable would have routed across the memory and CPU. We decided to run the cable over the "top," which places it over a pair of USB ports and the Wi-Fi antenna connectors. The result was the best of a bunch of less-than-ideal options. If there's an upside, it's that the USB cable is braided, which makes it at least look good, even if it is in the way. Then again, some may like the appearance of cables jutting out of the mobo, giving it a cybernetic look. We won't judge.


## 4 SILENT STORAGE

**WITH THE RECENT RELEASE** of the 2TB Samsung 850 EVO, we thought it would be perfect for a mini-ITX build. Having two whole terabytes available on an SSD is pricey, but it has its advantages: It eliminates the need for a small HDD for Steam games or media files, and there's one less moving part to fail from frequent moves to and from LAN parties or events.

It's easy to forget that an enclosed case muffles the sound of fans, and hard drives searching for, reading, and writing data. The high-speed clicks of the hard drive disappear when using an SSD, leaving only the CPU cooler and GPU as noise sources.

The black finish on the 850 EVO is similar to the finish of the aluminum mount of the D-Frame, which makes the slim SSD seem to disappear. The downside is that the drive is a little too far from the edge of the plate (two or three millimeters), which made it a bit hairy when we tried using an L-shaped SATA cable.




## 5 DOMINATING THE CAGE

**WHEN WE LOOKED** for memory, we wanted to go big on capacity but we noticed that most of our DDR4 kits are 16GB, but in 4x 4GB kits. Bummer. As we searched, we remembered: We had a machine that could donate a few sticks. We grabbed two 8GB sticks of Corsair Dominator RAM from our 2015 Dream Machine, and used them.

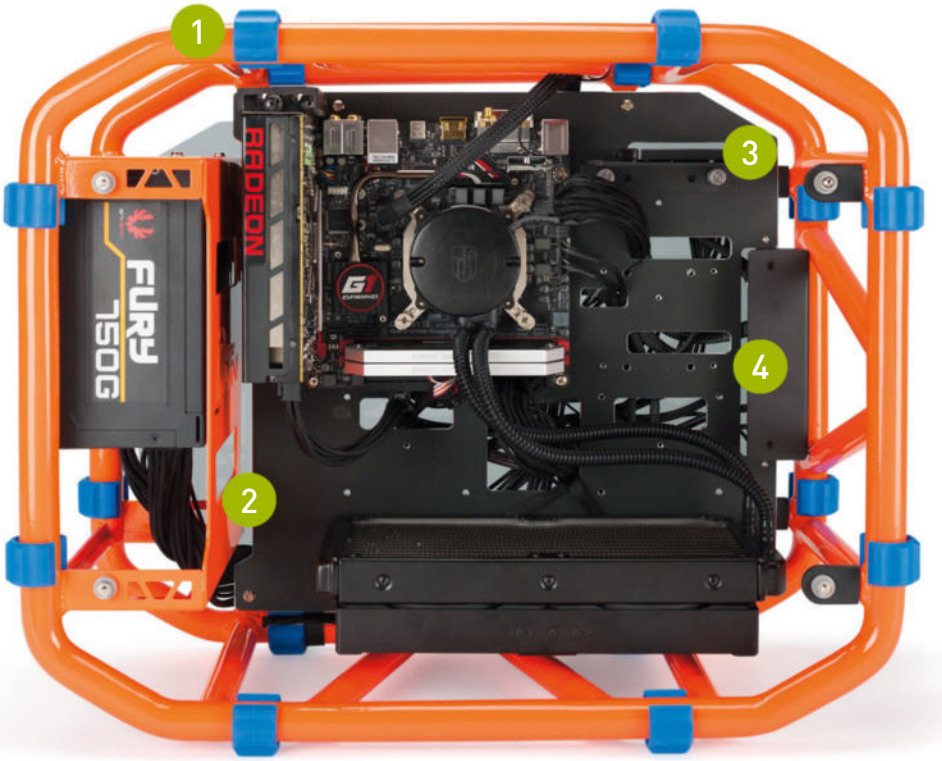
As with most X99 systems, our Z170 board from Gigabyte defaulted to setting the RAM clocks of the 2,666MHz sticks at 2,133MHz. The problem was solved by upping the multiplier for the RAM clock. Leaving it at 2,133MHz wouldn't have hurt performance much, as RAM clocks are rarely a bottleneck now. In other mini-ITX builds, going with 2,133MHz DDR4 RAM would be fine in most cases, and you'll save a little coin by forgoing higher RAM clocks.


## 6 ONE COOL CAGE

**ONE OF THE NEAT THINGS** about this build was the way the cage accommodated our cooling solution. It comes with a bracket for a 240mm closed-loop cooler, which sits out of the way at the "bottom" of the cage. We were able to get our Deepcool Maelstrom 240 snugly in the bracket, with nary a screw to secure it in place. Other coolers might not stay put with friction alone, so the eight screw holes can be used.

The Deepcool chiller was our backup choice, though. We tried using a bigger cooler, but for some reason it wouldn't have good enough contact with our CPU, which resulted in some problems booting.

The main gripe we had using a 240mm cooler with this mobo was the lack of PWN pinouts. There's no CPU_OPT or second case fan pinout, meaning we had to do something to get three PWM connectors fit on two pinouts.




1 **The blue rubber bumpers on the D-Frame Mini enable you to position the cage in any orientation you like. They also stop the case from sliding around in your car's trunk on the way to a LAN party.**

2 **The extra room below the PCIe slot allows for full-length video cards. In our build, the Nano leaves this area sparse and clear.**

3 **Thumb screws allow for the attachment and removal of hard drive and cooler brackets, for tons of modularity.**

4 **The "front panel" is a bit of a misnomer in this cage, where there is no clear front, back, up, or down.**

# BREAKING OUT

**THROWING ALL OF THESE PARTS** together in a cage was a lot of fun and was quite a different building experience. Such a build requires you to think more about the aesthetics of the build's entirety, since there's no hiding of cables or extraneous accessories here.

Like we said, though, an open-air case build is not without its challenges. One of those was the cooling system. We started off with a larger cooler that ended up not maintaining good contact with our CPU for some reason, so we had to go with the Deepcool we had on standby. Once we had the radiator and pump in place, we had three PWM connectors to plug in, but only two pinouts to work with.

We solved this in a roundabout way. First, we plugged the two fans for the radiator into the CPU and case fan pinouts. We then connected the pump to a two-pin Molex-to-PWM adapter. This had two consequences, which we weren't fond of. First, the two fans ran at different speeds, since each PWM pinout runs as a function of a different temperature sensor. The CPU fan is a function of CPU temps, as you'd expect, but the case fan takes temps from the motherboard itself. While we stayed at acceptably cool temperatures due to the large radiator, we wouldn't do this when overclocking, as the fan plugged into the case fan connector wouldn't rev up as temperatures increase. Not good.

The other side effect was that the water pump runs at full speed while connected to the two-pin adapter. Normally, you'd connect the pump to a four-pin pinout for the same reason you'd attach the radiator fans to them. However, we needed the pump to work, so we put up with this while we ran our benchmarks.

Our caged rig did pretty well in some aspects, while relatively poorly in others. In the single-threaded CPU benchmarks, the i7-6700K Skylake performed well, outpacing the i7-5960X in our zero-point. With a 240mm cooling setup, we believe this CPU could score even higher with overclocking. When we reviewed the CPU, the 6700K got a 17 percent boost from overclocking. Not bad at all.

When it came to the 3D application benchmarks, the little R9 Nano put up a good fight. Considering our beefy zero-point machine has three GTX 980s in SLI, a single GPU can hardly expect to beat it.

Despite having less than half the 3DMark score in Fire Strike Ultra, the Nano delivered playable frame rates in *Tomb Raider* and *Shadow of Mordor* at 4K. In *Batman: Arkham City* at 1440p, the 92fps means that there's plenty of power there to keep a FreeSync 1440p monitor synced and happy at 60Hz.

In the multithreaded test, x.264, the octa-core 5960X still reigns supreme, but for most gamers and enthusiasts who don't encode video all day, this build would perform nicely. And with its portable, unique form factor, it can be quite the conversation starter.

## BENCHMARKS

| | ZERO-POINT | |
|---|---|---|
| Stitch.Efx 2.0 (sec) | 806 | 781 (3.1%) |
| ProShow Producer 5.0 (sec) | 1,472 | 1,442 (2.0%) |
| x264 HD 5.0 (fps) | 33.8 | 19.54 (-42.9%) |
| Batman: Arkham City 1440p (fps) | 204 | 92 (-54.9%) |
| Tomb Raider 2160p (fps) | 87.5 | 36.6 (-58.2%) |
| Shadow of Mordor 2160p (fps) | 70.1 | 40.2 (-42.7%) |
| 3DMark FireStrike Ultra | 8,016 | 3,362 (-58.1%) |

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our desktop zero-point PC uses a 5960X CPU, three GTX 980s, and 16GB of RAM. *Arkham City* tested at 2560x1440 max settings with PhysX off. *Tomb Raider* at Ultimate settings. *Shadow of Mordor* at Max settings.

BUILD IT

ALEX CAMPBELL **ASSOCIATE EDITOR**

# What Gloriousness Really Looks Like

A build based on a poll published by reddit.com/r/PCMasterRace

LENGTH OF TIME: **1½ HOURS** | LEVEL OF DIFFICULTY: **EASY**


## THE MISSION

**THERE ARE PLENTY** of places on the web where PC enthusiasts congregate. Countless forums, social media accounts, and blogs abound with folks showing off their PC builds and talking about hardware. You'd better believe www.reddit.com/r/PCMasterRace is one such place .

Even though the words "Master Race" may make some uneasy (and for very good reason), you can rest assured the vast majority of the subreddit's members are just PC enthusiasts who love to build and use PCs. The subreddit derives the name from the belief that PCs are inherently superior to consoles. In many ways, we can get behind that idea. The forum is full of stories about console users ascending to join the ranks of PC users.

The thing is, the title "Master Race" may suggest that all the members of such a forum have high-end PCs that would warp space-time or have conveyor belts that make bacon grilled cheese sandwiches all day. As it turns out, this isn't always the case—though if someone has a PC that has a grilled cheese maker built into it, we want to see it yesterday.

We found an infographic posted on the subreddit that was based on a poll of the members of PCMR. The infographic showed the percentage of users who used different kinds of parts, e.g., air versus water cooling, and a host of other specs. We thought it would be interesting to find out what the "master race" rig actually looked like, so we set out to build one based on the most common features, as described by the infographic.

## A MASTER CASE FOR THE MASTER RACE

**ONE THING WE NOTICED** when we set out to build our PCMR machine was that the common specs are strikingly similar to the recommended specs for Oculus Rift. As a result, we were able to reuse some of the parts Jarred used for his Oculus Rift build in our September issue. We plucked the short Asus GTX 970 and ASRock Z97 mobo out of that build and put together a rig using parts from around our lab.

One of the new impressive pieces of gear that went into the build was Cooler Master's conveniently named Master Case 5. This midtower case is fully modular, and most elements come off with an easy-to-reach tab or thumb screw. We also have a box full of "extras" for the case, but we decided to stick with the "stock" version. The parts we chose all fit well within the midtower chassis, without overdue effort from us.

For the brains of this build, we went with the Core i5-4590, which is also the recommended CPU for Oculus Rift. For memory, we pulled the two Patriot Viper 3 DDR3 modules from last month's upgrade build and pressed them back into service.

### INGREDIENTS

| PART | | STREET PRICE |
|---|---|---|
| CPU | Intel Core i5-4590 | $200 |
| Motherboard | ASRock Z97 | $170 |
| GPU | Asus GTX 970 DCMOC | $355 |
| Memory | Patriot Viper 3 8GB DDR3 1600 | $50 |
| PSU | EVGA Nex750G 80 Plus Gold | $105 |
| Case | Cooler Master Master Case 5 Midtower | $109 |
| HDD | WD Black 1TB | $71 |
| SSD | Samsung 850 EVO M.2 250GB | $109 |
| Fan | 3x Corsair AF140 White | $51 |
| Total | | $1,220 |

## 1 PLUS FIVE INTELLIGENCE

**WHEN IT COMES TO CPUS**, PCMR is pretty damned clear about what the preferred chips are. Eighty percent of PCMR builds use Intel processors. The survey also broke down what the preferred processor lines were. The subreddit chose the Core i5, with 41.1 percent of the vote, over the Core i7 (32.4 percent) and AMD FX (13.1 percent). Only 36.3 percent of ascended members overclocked.

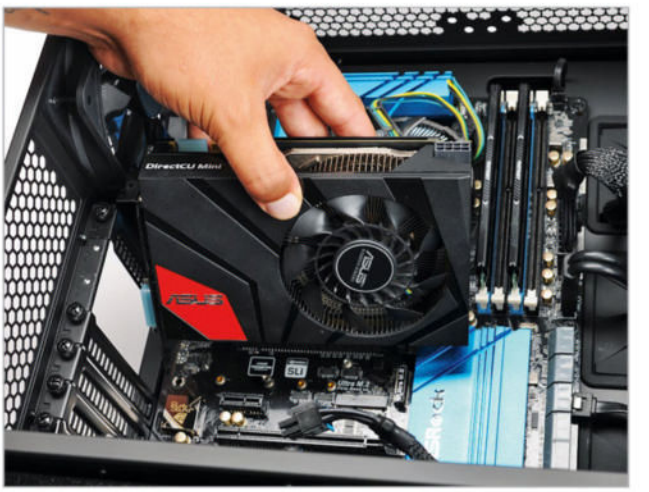
We chose the Core i5-4590 as our CPU. While it's not unlocked, this quad-core has plenty of power for most applications. The CPU is also fairly inexpensive, and coupled with a Z97 board, allows for future upgrades.

A quick look at Intel ARK reveals that the 4590 is made with conflict-free materials. That little added bonus means that this CPU, while less beefy than its bigger cousins, can give you the warm fuzzies while you blast your foes to bits with a rocket launcher.


## 2 HEART OF A WARRIOR

**WHEN THE PCMR** flexes its muscles, it prefers green to red by a wide margin. Nvidia claimed 67.7 percent of the vote while AMD only clutched 28.9 percent. Intel's integrated graphics made a small showing with 3.4 percent of the vote.

Most respondents also preferred a "high-end" videocard (one that costs between $300 and $500). The short version of the GTX 970 by Asus that we chose falls squarely in that price range at $355. We left the GPU at stock clocks too, as only 38 percent of the ascended said they overclocked their GPU. Even if we had overclocked the GPU, this little card had plenty of room to breathe in this case. Nvidia's next step up, the GTX 980, falls into the survey's "flagship" category at $550.



## 3 NEVER FORGET

**WHEN WE LOOKED** at what PCMR members used for storage solutions, we found that 55 percent do the same thing we do in most of our builds: use an SSD for the OS and apps and regulate media files and other storage to spinning hard drives.

For our SSD, we went with an M.2 version of the Samsung 850 EVO. The read and write performance of the M.2 model is about the same as the SATA version, as is the price at a little over $100. This particular motherboard had two M.2 slots to fill, so we figured: hey, why not? For the spinning drive, the 1TB WD Black gives us enough archive space to start out with at a decent price ($71). The flexibility of the Master Case lets us put the drive almost anywhere forward of the motherboard, but we opted to keep it at the bottom of the mounting rail to optimize airflow to the CPU and GPU.

## 4 ADVANCED MENTAL CAPACITY

**MEMORY IS ONE OF THOSE THINGS** that can differ greatly depending on the application of the machine. Games tend to not need a whole lot of RAM, but big data-heavy design applications do. When it comes to the ranks of the PCMR, about half (51.3 percent) of users only need 8GB of RAM. Meanwhile, 33.7 percent made the jump to 16GB.

The overwhelming majority use DDR3. The RAM data gave us another interesting insight: Since only a small minority of respondents (9 percent) are using DDR4, we can derive that not a whole lot of people are sporting X99 Haswell-E systems. We love our Haswell-E systems here in our lab, but in the wild, they're clearly not as widespread.

## 5 THE SOURCE OF POWER

**TO KEEP THINGS COOL,** a case needs air flow. With the Master Case, the included single 140mm front case fan just didn't cut it with us. We replaced the single fan with a trio of Corsair's AF140 white LED fans.

We tend to go with closed-loop water cooling to chill out our CPUs for overclocking, but it turns out only 36.3 percent of PCMR overclock their CPUs, and nearly 70 percent use air cooling. That let us justify keeping Intel's stock CPU fan, while also pushing a bunch of air through the case.

The ASRock Z97 Extreme has four PWM case fan pinouts. We stacked the three fans up front to push a wall of air toward the GPU, CPU, memory, and mobo. The stock side panel of the Master Case lacks a window, which means that the three fans won't create too-big glowy light leaks.

## 6 CABLE NIGHTMARE

**IMMEDIATELY OBVIOUS** with this case was the utter lack of cable management. In terms of PC cabling, this is the stuff of nightmares. What seems like an obvious route for cables—over the horizontal rail and behind the drive bays—is made impossible by a side panel that has an inward (inward!) bevel. When we tried to keep cabling tucked behind the mobo tray, we felt like the case was making fun of us. "Oh, that's cute," it would say. "I bet you'd just love an extra centimeter. Tough luck."

Coupled with the woefully insufficient zip ties that came with the PSU, this cable job could have you waking up in cold sweats. We had to stuff the cables behind the drive cage, doing our best to keep them out of the way of the front fan's air flow. The wiring still looks like a mess.


1 **Using a Z97 board is a bit overkill for the locked i5-4590 we chose for our CPU. However, using a Z97 board opens the door for future upgrades to K-model CPUs.**

2 **The Master Case 5 only has USB 3.0 ports on the front panel, so there was no need to snake USB 2.0 connections to other parts of the board.**

3 **Since the Master Case 5's drive bays are fully modular, we removed the front-facing 5.25-inch cage to improve air flow.**

4 **Having cable passthroughs with rubber grommets on the case's horizontal partition helps keep unsightly cross-motherboard cable reaches to a minimum.**

# ASCENSION

**WHEN IT COMES RIGHT DOWN TO IT**, gaming PCs come in all calibers. To members and readers of /r/PCMasterRace, the most important thing is to prefer gaming on the PC to gaming on a console. As we found out, that PC doesn't need to be a Dream Machine.

Even though the average PCMR specs are modest compared to the stuff we usually build and review, the i5-4590 is still a good CPU. While we often use the GTX 980 as the yardstick by which to judge other GPUs, the GTX 970 is still plenty powerful, and offers great performance for the price.

When it comes to the time, single-threaded benchmark tests, the Core i5-4590 wasn't far behind the Core i7-5960X. Considering that the i5-4590 is only a fifth of the price of the 5960X, its performance is actually quite impressive.

Once we ran our multithreaded x264 benchmark, the octa-core 5960X left the little quad-core 4590 in the dust. While you can cut, slice, and encode video, we'd definitely go for a hexa-core CPU if you have the budget for it. Even if you can't go that high, the clocks of an i7-4790K Devil's Canyon will get things done much quicker than the i5 can.

Since we transplanted the GTX 970 from last month's upgrade build, our video benchmarks remained about the same. A single GTX 970 versus three 980s in SLI isn't really a fair fight in any sense of the term, but that doesn't mean that the 970 is a weakling. The GTX 970 performs well at 1440p, and is the recommended GPU for Oculus Rift.

Audiophiles make up a minority of the PCMR, since only about 21 percent of respondents used a sound card (10.7 percent), digital-to-analog converter (8.5 percent), or a digital audio workstation-grade setup (1.8 percent). About 79 percent settled for onboard audio, so we did, too. This time.

Building a PC can be intimidating. Helping others with their first rig is a chance to help spread the joy of building PCs. After all, we've all had our moments of peasantry where we break down and play a game or two in the living room, too, console controller in hand. But for PC enthusiasts, a mouse, keyboard, and a wicked-fast and sharp gaming experience will always reign supreme.

## BENCHMARKS

| | ZERO-POINT | |
|---|---|---|
| Stitch.Efx 2.0 (sec) | 806 | 871 (-8%) |
| ProShow Producer 5.0 (sec) | 1,472 | 1,554 (-5.6%) |
| x264 HD 5.0 (fps) | 33.8 | 13.52 (-60%) |
| Batman: Arkham City 1440p (fps) | 204 | 72 (-64.7%) |
| Tomb Raider 2160p (fps) | 87.5 | 28.3 (-67.7%) |
| Shadow of Mordor 2160p (fps) | 70.1 | 30.6 (-56.3%) |
| 3DMark FireStrike Ultra | 8,016 | 2,479 (-69.1%) |

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our desktop zero-point PC uses a 5960X CPU, three GTX 980s, and 16GB of RAM. *Arkham City* tested at 2560x1440 max settings with PhysX off; *Tomb Raider* tested at Ultimate settings; *Shadow of Mordor* at Max settings.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# HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

## INSIDE




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FREE SPEED!

# OVERCLOCKING MASTERCLASS

## The hardware, software, and know-how you need to get the most from your PC

By Zak Storey

Overclocking. It's long been a part of a PC enthusiast's toolkit when it comes to wringing every last ounce of power from our beloved machines. Whether you've opted to run AMD or Intel, overclocking has been a staple food group of the techie's diet for as long as there have been chips in PCs. The basic principle is very simple: Add more voltage to the component part, provide it with sufficient cooling, either through water or air (or Ln2 for the more adventurous among us), and increase the Hz output of the hardware you're trying to improve.

But this doesn't come without risk. While we've come a long way in the world of overclocking, it is still possible to fry your CPU, GPU, RAM, or motherboard to the point where it's more charred than your old man's best barbecued sausages. So, the first question you should always be asking yourself is whether it's worth the risk. The answer, generally (and, ahem, unhelpfully), is sort of.

As proven time and again by Intel's latest and greatest chips, a good-quality CPU core often outstrips an increase in gigahertz. On the flip side, however, increasing the performance of a two-year-old core so that it can keep pace with the newer generation can save you a pretty penny, and possibly put off that upgrade for another year or more. So read on for step-by-step guides to overclocking your CPU, RAM, and GPU.

# Overclocking Your CPU

## Learn to fulfill your processor's potential in 10 simple steps

Before crossing the start line, there are a few basic principles to get your head around. The first one is heat. Inevitably, the more voltage you add to your components, the more heat that component is going to output. Second, the higher the clock speed you're trying to achieve, the more voltage you will need to power that attempt. And third, there's only so much voltage your PC part can take before you start to see detrimental effects. These could be a drop in frame rates for GPUs, corrupting processes on the CPU, or even a failure to boot at all. These, essentially, are the basic limits of overclocking.

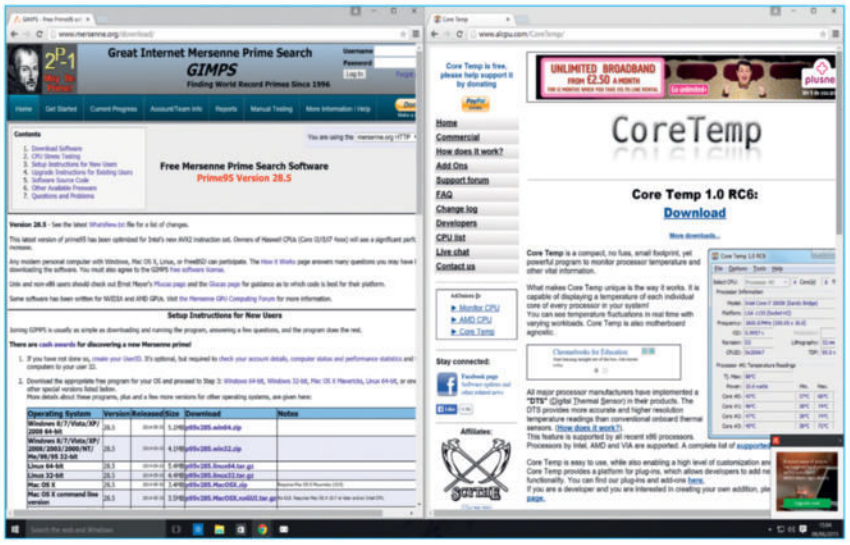
All chips are born equal, but some are more equal than others. You'll often hear overclockers talk of "The Silicon Lottery." In short, this is to do with the manufacturing process with each and every processor. Small imperfections in the application of the silicon lead to a variance in how well the chips perform, both in stability with an increase in voltage, and how much heat they produce at max load. You might get lucky with yours, or you might not. It can equate from anywhere between 0.2GHz difference to, in some cases, up to 1GHz in overclocking potential.

So, assuming you've got an aftermarket cooler of some description (see "Picking a Cooler," on page 46), that you have a processor or component that's capable of overclocking (K/X series for Intel and any AMD chip), and that you understand how to get into your BIOS, here's how to get going.

### 1 CHECKING CPU STABILITY

To ensure a successful overclock, we'll need to know that the CPU is stable at both idle and max load. To do this, we'll be using a free piece of software that's called Prime95, from http://bit.ly/1kVNJZh.

You'll also want to download a program to accurately monitor the temperatures your CPU is outputting. For this, we'll use Core Temp, from www.alcpu.com/CoreTemp/, as this works with both AMD and Intel cores. There are alternatives out there—Corsair and NZXT have proprietary software that works with their AIOs, plus most motherboards have viewable temperature controls that you can use from the desktop. If you don't want to install anything on your rig, then Real Temp GT is your guy.




**Prime95 is a key overclocking tool, with its stress tests being a major part of the process.**


**Default profiles limit potential, but are often safer than manually entering them.**

### 2 CORE TEMP

Once those programs are extracted or installed, load Core Temp to begin monitoring your CPU's temperature. Always look at the lowest core temperature to give yourself a good understanding of how hot your CPU is running.

### 3 STRESS TESTS

Now we'll want to benchmark your CPU, at stock, to see how hot it runs at 100 percent. Start Prime95, select "Just stress testing," and then you'll be given a list of options as to which stress test you'd like to perform. Choose "Blend Test" and press "OK."

### 4 INTO THE BIOS

After about 5–10 minutes, once your temperatures have stabilized, go into Prime95. Select "Test" on the top bar and hit "Stop," then restart your PC and mash that Delete key to get into your BIOS. In this test, we're using an ASRock Z97 Extreme 4 motherboard, so the UEFI could be a little different in comparison to some of the other manufacturers you'll find out there, but the base settings will essentially be the same.

### 5 AUTO-OVERCLOCK

Once inside your BIOS, find the overclocking tab. In ours, it's named "OC Tweaker." Once in, you have several options. The easiest way to overclock your CPU is to let the motherboard do the majority of the work. Most manufacturers will include overclock profiles, usually ranging from 4GHz to 4.8GHz, depending on the CPU installed.

Setting the motherboard to run one of these profiles will allow it to attempt to overclock the chip to that frequency without any user input. This can be a quick solution, especially if you're only dialing in


**This looks like it'll be stable.**

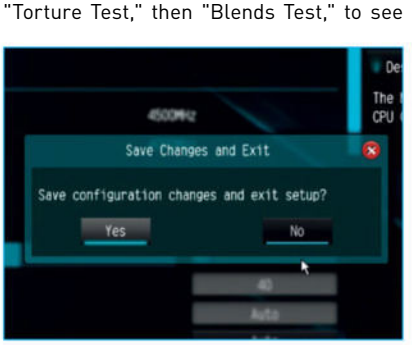
a conservative overclock (3.5GHz to 4GHz, for example), but this isn't conducive if you want to push beyond that 4.8GHz barrier, or if you can't reach that frequency through the automated profiles.

## 6 CHANGING THE MULTIPLIER

More adept users will find manual control a lot more comprehensive in regard to what true overclocking is all about. To keep it simple, you want to be changing the CPU ratio, or multiplier, for all cores to the target number you wish to achieve. That's 35 in this case. The multiplier then works with the cores' BCLK frequency (usually 100) to create that final figure of 3.5GHz. In this tutorial, we're going to attempt to overclock our CPU, just to start with, from 3.5GHz to 4GHz, simply by changing the multiplier.

## 7 TEST AT MAXIMUM LOAD

Once you've changed the CPU ratio multiplier to 40, save changes and exit the BIOS. Boot into Windows, open Core Temp to monitor your CPU temperature, then open Prime95 and select "Options," "Torture Test," then "Blends Test," to see how your chip fairs at maximum load. If it's stable for at least five minutes, we can then begin to up the multiplier to try to achieve a higher overclock.




**This process can be a bit repetitve, but it's definitely worth it.**

## 8 FINDING THE LIMIT

At this point, you'll want to increase the multiplier by one and repeat the process of stress testing in Windows each time, until you reach the point where you initially either blue screen or your CPU begins to thermally throttle itself. Ideally, you want to blue screen before you reach your thermal limit.

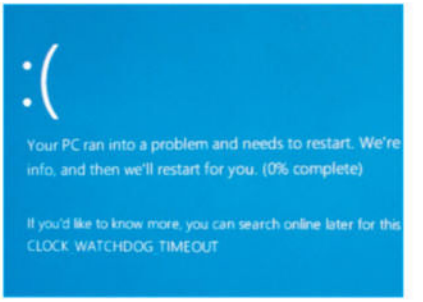
## 9 INCREASING THE VOLTAGE

To overcome the blue screen issue, we need to start working with the Vcore voltage. Back in the BIOS, you want to find CPU Vcore Voltage Mode. Change this to "Fixed." At this point, you may need to do some research as to what stock Vcore level your CPU takes, and what people are suggesting for overclocking. You'll want to begin increasing the voltage by 0.01 volts each time, until you can successfully boot, stress test, and maintain stability at your target frequency. Once you get a little more comfortable overclocking, you'll find yourself increasing voltages by 0.05 or 0.1 at a time. It's more about learning how your CPU responds to different amounts of voltage at this point.

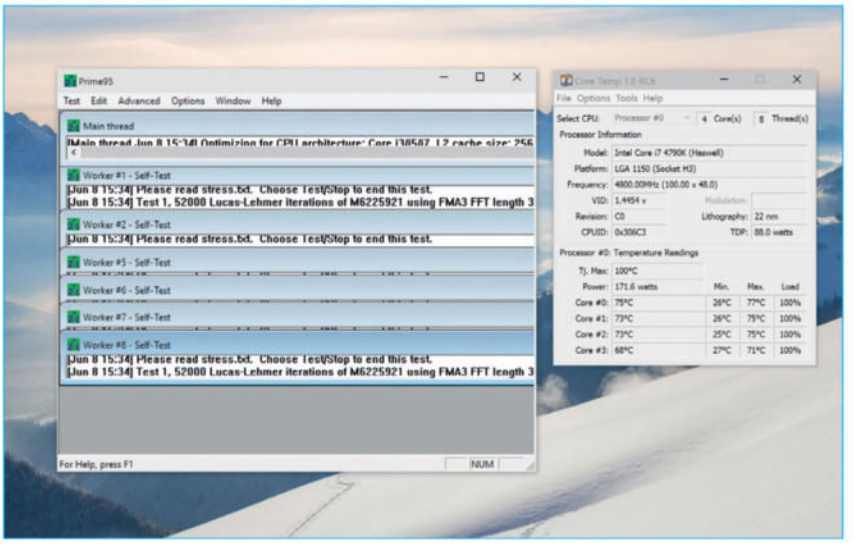
Eventually, you'll reach a point where you cannot reach that next frequency, regardless of how much voltage you throw at it. This is when you want to dial back your overclock by 0.1GHz and drop the Vcore voltage back to the last stable settings for that frequency and maintain it there, as this is your final overclock.

## 10 BACK TO BENCHMARKING

To ensure a stable overclock, you should now benchmark using Prime95 and CoreTemp for as long as you feel is appropriate. This can be anywhere from an hour to a full day, depending on how patient you are.




**Welcome to the blue screen of death. It's time to start playing with the voltage.**




**Always stress test your CPU before overclocking, to get a good reference point.**

# PICKING A COOLER

The first thing to consider after you've decided on overclocking is what you'll use to cool your components. To put it bluntly, the stock coolers that AMD and Intel provide simply won't cut it when it comes to dissipating the excess heat that comes from adding more voltage. They're designed to deal with what the processor can output at stock frequencies, and not a lot more.



## AIR

The more traditional, easier solution would be to rely on air cooling for your CPU. There's a huge list of air coolers out there, but it's vital that you consider the size of the cooler versus the height of your RAM and the size of your case. The last thing you want is to buy a new heatsink for your shiny new i7-4790K, only to discover it won't fit over the top of your Corsair Dominator GTs. The Dark Rock Pro 3 is a particular favorite of ours—it's silent, yet can relieve your CPU of over 250W of TDP, plus it'll keep your bacon cool.

## AIO WATER COOLING

The second option, and one we all prefer here at *Maximum PC*, is an all-in-one water-cooling loop. You've probably seen a lot of these kicking about, Corsair's Hydro H100i being the more famous of the bunch. These are a quick and easy solution, and often provide a great deal more cooling than a single air cooler, due to their increased surface area. They're also a lot less tricky to install (providing you have the radiator support), and can clean up your rig quite nicely while allowing you to swap out components with relative ease.

## CUSTOM-LOOP COOLING

Finally, the fully custom loop. It's the dream, the crème de la crème, and the aspiration of every tech enthusiast starting out on the bumpy road to a successful overclock. It's also something that's become increasingly easy to build in recent years. Although certainly the most effective of the three, due to the ability to expand on your loop by adding more radiators, and cool more components, it can become very rigid, especially if you want to change out a graphics card, for example. It's definitely something that needs to be researched fully before committing to, if only because it can easily add up to $500 to your costs. And that's without the real premium components. But wow, does it look good when you're done. The Parvum Titanfall rig is a prime example of this.

# MOBOS AND PSUs

Once you've got your cooling sorted out, you'll want to make sure you've got the best possible components that you can budget for in regard to stability. That means two items in particular—the power supply unit (PSU) and the motherboard. They are both imperatively important when it comes to overclocking. Perhaps most obvious is buying a motherboard that supports overclocking. For Intel, that's any motherboard with the Z97 chipset. For AMD users, it's currently any FM2 or AM3+ board.

Concerning power supplies, you want to be looking at a PSU that has at least 20 percent spare capacity, in terms of wattage, over what your system requires. Preferably, push as much money as you can into it. The higher-end power supplies not only feature better surge protection, but also provide a more consistent flow of electricity between the wall and your PC parts. This should result in longer life and more stability, both when overclocking and through everyday usage.

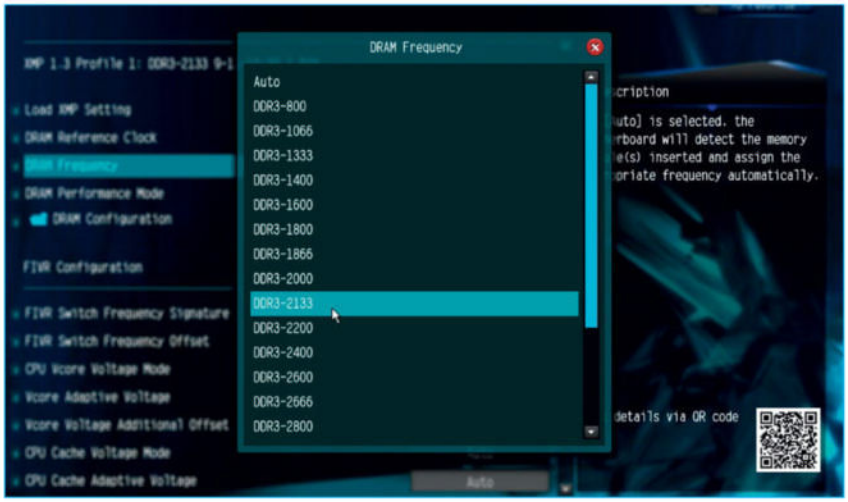
# Overclocking Your RAM


## Wait! There's more! Overclocking isn't limited to just your processor

Yes. It's true. Overclocking doesn't just mean tinkering with your CPU. Other avenues exist if you're keen to shove the boat out a little bit more.

RAM speeds over the course of the last few years have almost tripled in frequency, meaning performance can be improved quite dramatically in certain computational programs. It's important to bear in mind, however, that the higher you push your RAM frequency, the more your CPU will suffer. In other words, it might mean an overall lower final overclock for your little powerhouse.

On the other hand, AMD's APUs, despite being a lower-end graphics solution, will benefit hugely from an increase in those same frequencies. So, what does all this come down to?



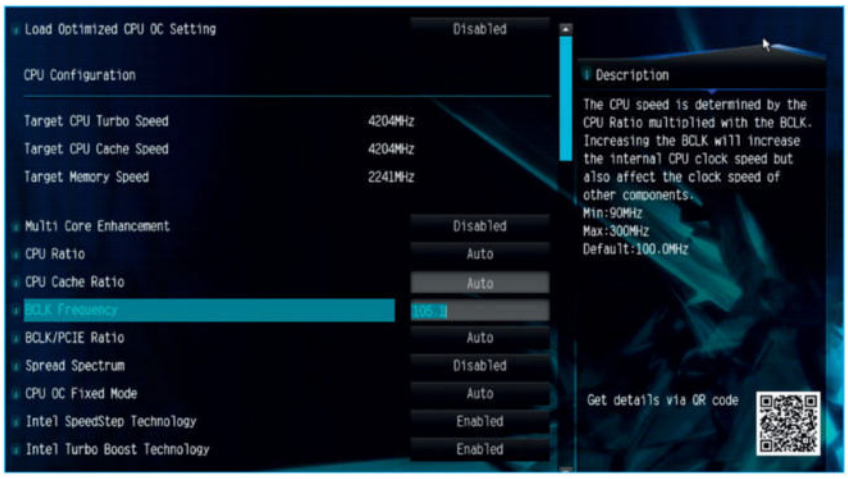

**Motherboard support may vary here.**

### 1 WHAT'S THE FREQUENCY?

Identifying the frequency of your RAM on purchase is crucial. We wouldn't go for anything less than 1,600MHz as a minimum if building a rig today. With Skylake and DDR4 around the corner, we'd be tempted to hold off a little and wait for that, as the price of the next generation of memory is still continuing to plummet.

### 2 THE PROFILE SETUP

We're using a pair of Corsair Dominator Platinums, clocked at a stock speed of 2,133MHz. To take advantage of any potential additional clock speed, you'll need to set up the memory with the correct profile on install. So, either Intel's XMP profiles or AMD's AMP profiles. This is exactly what we'll be using, just to do a slight overclock of the memory.




**Pushing your CPU and RAM to the max.**

### 3 UPPING THE FREQUENCY

Enter your BIOS by again headbutting the Delete key. Make sure you have either your XMP profile or your AMP profile selected, then change the memory frequency to one frequency higher than your memory's stock frequency. In all likelihood, your RAM should be able to manage and maintain that frequency, regardless of what the stock speeds say.

### 4 ABOVE AND BEYOND

If you want to take it further, this time we'll change the BCLK frequency, instead of adjusting a RAM multiplier. You can up this in very small increments. But it also ups your CPU's basic overclock, so if you've already OCed your chip to the absolute max, it's unlikely you'll be able to push the memory or the CPU any further.

# Overclocking Your GPU

## Last, but certainly not least, the final hurrah of overclocking

With DirectX 11, at least, OCing the GPU is the area of most benefit to gamers. But it's also where overclocking has most dramatically changed. That's because, with Nvidia's GPU Boost and AMD's Power Tune, it's no longer possible to simply up the voltage and in turn increase cards' core clock speeds.

It's now often better to ignore the voltage and let the proprietary software do its own thing. This way, you can avoid reaching the artificial power limits set by our GPU overlords—cores won't throttle themselves in an attempt to control imaginary temperatures, that may or may not be present, even if they're running on an aftermarket cooler, or water.

Sounds ridiculous, right? You're not wrong. Still, we'll show you how far you can go with these cards.

### 1 GET THE SOFTWARE

Unlike CPU overclocking, we need to download some proprietary software to use within Windows to overclock our cards. It's usually most beneficial to download whichever manufacturer's software your card's PCB is based upon. GPU Tweak for Asus, Afterburner for MSI, Precision for EVGA, and so on. In this case, we're using a reference cooler on our GTX 980, so we're using MSI's Afterburner, as it provides us with frame monitoring for benchmarking, a customizable display, and in-game overlays to monitor how well these cards perform in comparison to their stock speeds.

### 2 ENABLE MONITORING

Once Afterburner is installed, the first thing we want to do is enable in-game overlay, and frame rate monitoring, followed by (for us at least) changing the skin to something a little more workable.


**Afterburner's in-game overlay makes it easy to monitor how your GPU is doing.**

### 3 TEST STOCK SPEEDS

Next, you'll want to get a clear understanding of how your card performs at stock speeds. We're using *Total War: Rome II*'s benchmarking software, at maximum settings, at 2560x1440. We achieved a minimum frame rate of 19, a maximum of 61, and, more importantly, an average of 44.7.

### 4 INCREASE THE POWER LIMIT

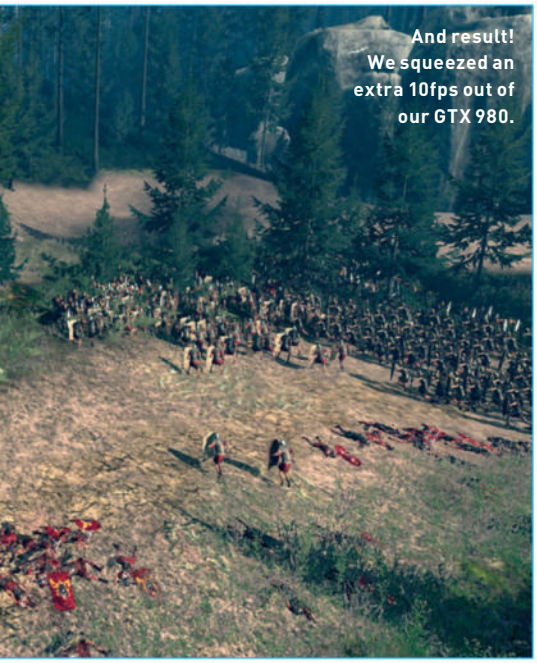
With the benchmarks and stock speeds out of the way, it's now time to get into the overclocking side of things. Head back to the desktop and open MSI Afterburner again. The first thing we're going to increase is the power limit. Move the slider to as high as it will go (usually 110 percent). This should allow our card to use absolutely every inch of power we can get, beyond Nvidia's recommended stock settings, meaning the card can run all the way up to 91 degrees Celsius, as opposed to the stock 79 C.

### 5 UP THE CLOCK SPEED

Start by increasing the clock speed. Research what's most suitable for your card. In our case, a healthy overclock for the core clock should be an extra 225–275MHz offset, so we go for 240MHz.

### 6 NOW, THE MEMORY CLOCK SPEED

Lastly, we're going to increase the memory clock speed. After research, we can see that the community,



And result! We squeezed an extra 10fps out of our GTX 980.


***Total War: Rome II*'s benchmark tools are a lifesaver.**

on average, is aiming for around 450MHz. We'll try that and see how it goes, leaving Nvidia's GPU Boost to calculate exactly how much voltage we need for everything. All that's left to do is press "Apply" and go back into the benchmark to see how well the card now performs.

Remember, if something goes wrong, a quick reboot of the system will reset all of your overclock settings to default.

In the *Total War: Rome II* benchmark, we achieved a minimum frame rate of 17 at overclock, a maximum of 67, and, more importantly, an average of 53.6. That's an increase of almost 9fps for the average. Granted, the delta between the minimum and the average is considerably greater than the stockclocked version, but who can argue with free performance?

## CPU BENCHMARKS

| | Core i5-4670K Turbo to 3.8GHz | Core i5-4670K OC to 4.5GHz | Core i7-4790K Turbo to 4.4GHz | Core i7-4790K OC to 4.8GHz |
|---|---|---|---|---|
| Idle Temp (°C) | 29 | 29 | 27 | 31 |
| Load Temp (°C) | 71 | 84 | 62 | 70 |
| Cinebench | 566 | 667 | 877 | 943 |
| Total War: Rome II (min/avg/max fps) | 19/40/59 | 16/40/53 | 16/42/58 | 17/42/57 |
| Vcore | N/A | 1.385 | N/A | 1.445 |

Tests carried out on max settings/shader model 4.1/1440p.

## GPU BENCHMARKS

| | Stockclocked GTX 980 | Overclocked GTX 980 |
|---|---|---|
| Total War: Rome II Minimum fps | 17 | 17 |
| Total War: Rome II Average fps | 45 | 54 |
| Total War: Rome II Maximum fps | 57 | 67 |
| 3D Mark Firestrike Extreme | 5,654 | 6,558 |

Tests carried out on max settings/shader model 4.1/1440p.

## TEST BENCH SPECIFICATIONS

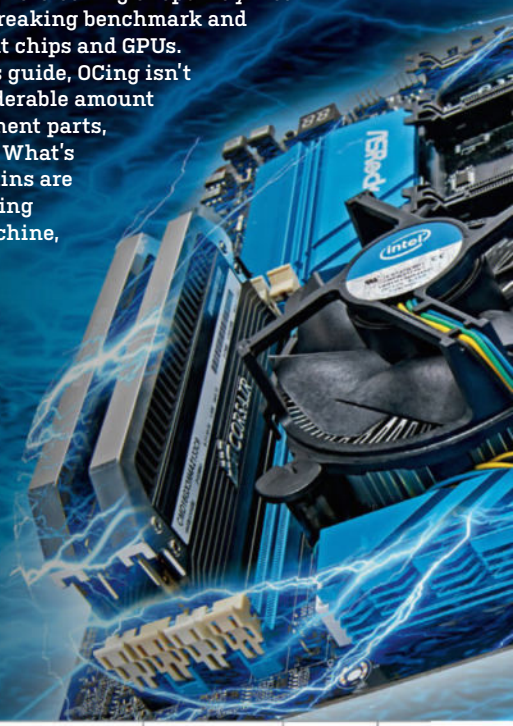
| | |
|---|---|
| CPU | Intel i5-4670K / Intel i7-4790K |
| Motherboard | ASRock Z97 Extreme4 |
| Memory | Corsair Dominator Platinum (2x 4GB) 2,133MHz |
| Graphics | Nvidia Geforce GTX 980 |
| SSD | OCZ Arc 100 (240GB) |
| Power Supply | BitFenix Fury 750W |

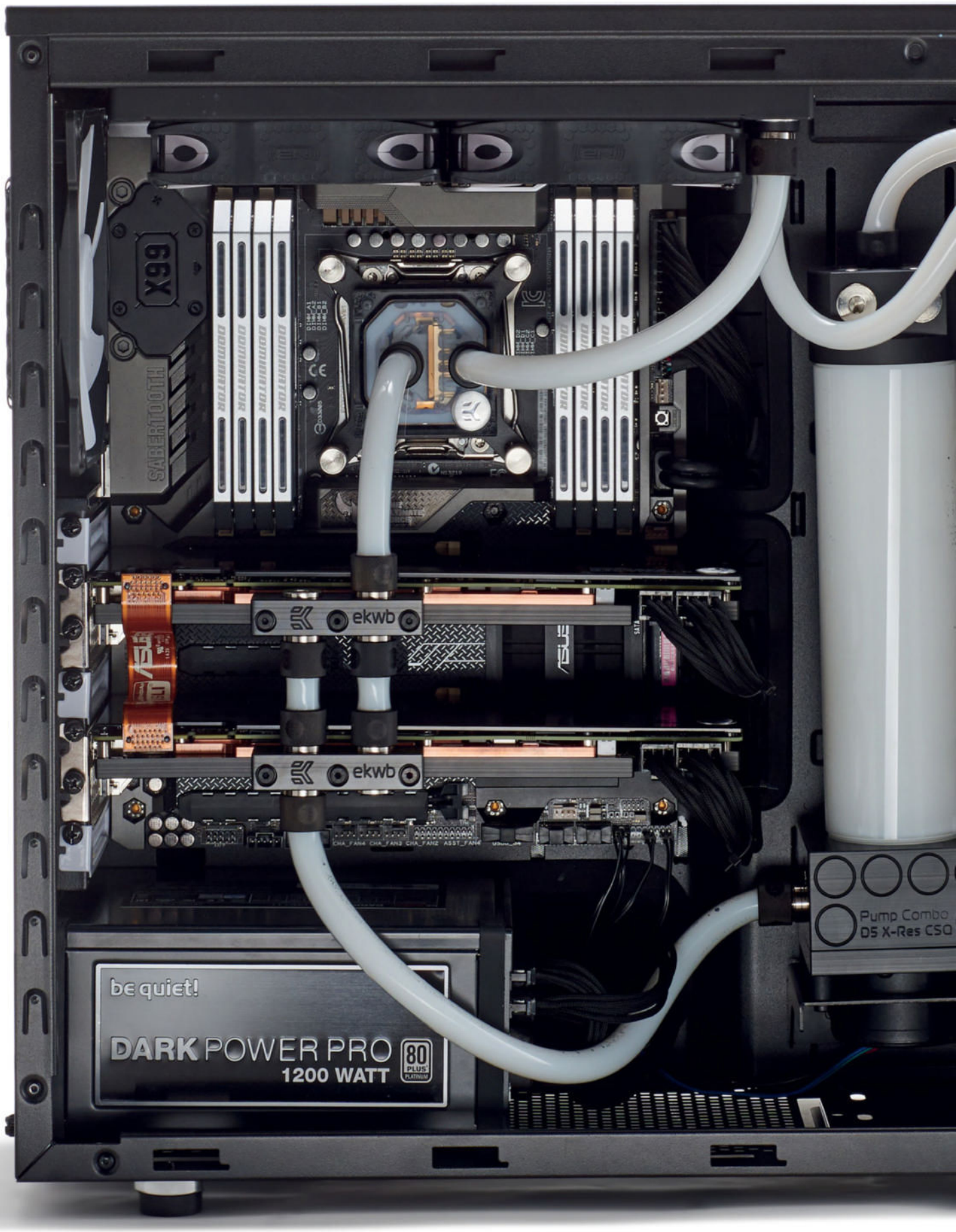
# CONCLUSION

Welcome to the world of overclocking, a place where dreams are realized, and where having just enough of those overclocking chops may mean the difference between a world record–breaking benchmark and a night of crying into a pile of burned-out chips and GPUs.

As mentioned at the beginning of this guide, OCing isn't for the faint-hearted. You can do a considerable amount of damage to your CPU and other component parts, so it's not something to be taken lightly. What's more, in some cases, the performance gains are negligible. But, if you're interested in eking every last ounce of power from your machine, this is definitely the hobby for you.

It's something the vast majority of PC users will shy away from, and it's understandable why—the thought of placing extra strain on any of your components for the sake of a few more points in Cinebench hardly seems worth it at times. But when you're sitting there, in front of a stable 5GHz overclock on an ITX motherboard, with a chip being cooled by a single 120mm rad outperforming cores half its age, there's an odd sense of pride about it all. A bond between man and chip. Yes, we went there.





# WATER COOLING 101

## Don't overheat—become a water-cooling master

*By Zak Storey*

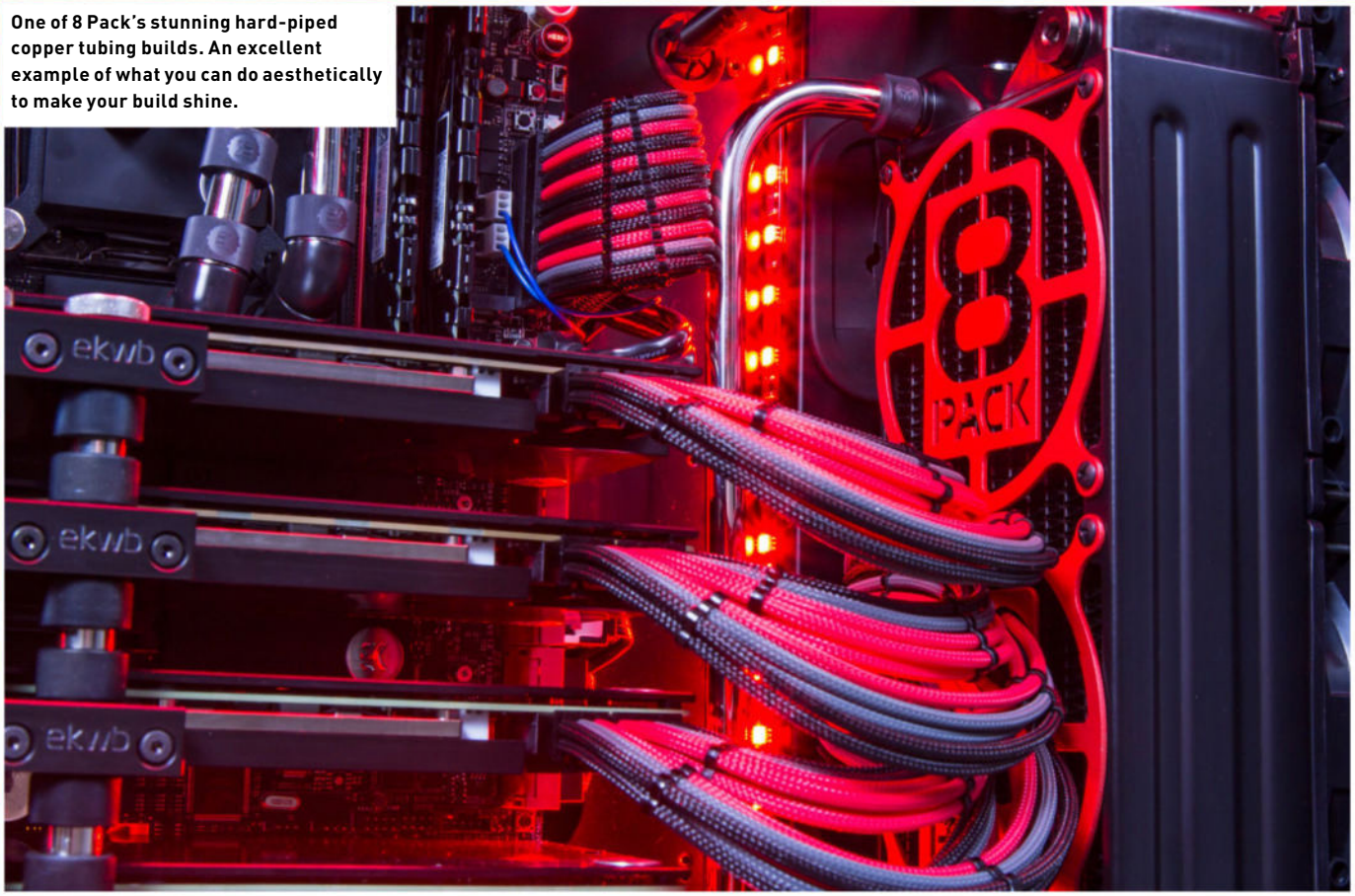
For much of recent history, water cooling has been shunned. Only a select few could afford to merrily dance with computing death, taking their chances with water-cooling hardware and components that weren't even designed to work in the silicon environment. They'd graft plumbing fittings onto hardware and hand-mill various water blocks, all in the hope of creating a leak-proof, watertight system that could efficiently and effectively transfer heat away from their component parts, to a far greater degree than traditional air coolers ever could.

That was back in the times when the average PC enthusiast was less concerned about how a PC looked. More important was how many frames per second they could squeeze from their beige box of dominance in *Unreal Tournament*. It was a terrifying time. But over the last five years, the situation has changed dramatically.

Water-cooling manufacturers and modding companies—such as EKWB, XSPC, Primochill, Bitspower, and E22—have come to the forefront in far greater numbers. This is when water cooling really began to take center stage. Indeed, today you'd be hard-pressed to find a high-end system that's not running some form of all-in-one CPU cooler or a custom loop. Hell, all of us here at the *Maximum PC* office would run hard-piped builds if we could, and there isn't one of us still stuck on the retail cooler, or even an air cooler for that matter.

So, what is it that attracts people to water cooling? Why is it so much better than traditional air cooling? Essentially, all forms of cooling work on the same basic principles. You might have heard of them, they're part of the laws of thermal and fluid dynamics. No matter whether you have an air cooler or a full custom-loop setup, you're transferring heat from one point to the other. It then cools and circulates back around again to transfer that heat out of the system to the outside environment again and again.

All very fancy, right? Air cooling technically isn't an accurate description of that cooling method, and neither is water cooling—they




**One of 8 Pack's stunning hard-piped copper tubing builds. An excellent example of what you can do aesthetically to make your build shine.**

both essentially require a fan and a radiator to expel that heat. So, is water cooling for you? Should you dive into the murky depths of $H_2O$ nirvana? Maybe you'll discover something about yourself along the way. Read on to find out.

## WHY WATER COOL?

Let's cut straight to it. Primarily, water cooling is done to enhance the aesthetic beauty of a build. Don't get us wrong, the heat-reducing properties of multiple radiators and fans cooling your internal components is fantastic and highly efficient. But if you're looking for the most effective price-to-performance ratios, a good AIO cooler for your CPU and a triple-fan GPU cooler would be more than enough to ensure you never hit any of the thermal limits dictated to us by our silicon-inducing overlords. And in today's technological climate, you're far more likely to encounter hardware-based limits, rather than temperature-based ones, in your overclock attempts.

One of the biggest benefits of water cooling, besides looking better than Gabe Newell's monthly bank statements, is the noise reduction. Simply put, noise control is all about effective fan control. It's not necessarily how many fans you have, but how fast they're spinning. Ultimately, the lower the RPM, the lower the noise output. For instance, if you take five 120mm fans and run them at 1,200rpm, and then take two separate 120mm fans and run them at 3,000rpm, we can guarantee the two fans will be creating more audible noise than the five.

## AESTHETICS

Water cooling is primarily about enhancing the look of your build, ensuring your silicon shrapnel stands out from the crowd and looks as good as it possibly can. There are multiple ways of doing this with water cooling. By all means, we're not saying that air-cooled builds can't look good—there are some seriously stunning rigs out there that run on simple old air coolers. But water cooling sits at the centre of the modding community. It's responsible for most of the innovations we've seen in this area of the market. Whether that's braided cables, windowed-side panels, or LED lighting, you can assume that the vast majority of these ideas originated from some modder out there grafting an idea onto one of their builds, and then showing it off to the masses.

So, you have four options in total when it comes to liquefying your machine. First, you could simply just use an all-in-one cooler. This way, you avoid the hassle of setting up any kind of crazy system, you're covered by a warranty, and still gain the benefits of having a water-cooled CPU. Your second option is to go with a soft tubing loop, utilizing flexible colored or clear tubing. This is one of the most adaptable water-cooling methods as the tubing is flexible and easy to use.

The third and currently most popular option is to use acrylic tubing, most notably PETG tubing. This non-fragile, highly robust hard piping creates an entirely different look for a build, utilizing straight lines and angles to really make your rig pop. And then, finally, there's copper tubing. It's identical in almost every way to acrylic tubing, except it's far easier to bend and a lot cheaper. Copper provides a good base to either nickel or chrome plate or even powder coat as well, though it's opaque. Whichever way you choose, you'll still benefit from the reduced noise and the far-superior cooling capacity that water cooling provides.

## WATER-COOLING COMPONENTS

If you thought that building a custom PC was tricky enough, then we've got some bad news for you. Here's a quick rundown of what you'll have to consider purchasing on top of your standard build. You'll

EK's Supremacy Evo CPU block provides incredible cooling with a simple mounting mechanism. We went transparent to show off our snazzy white pastel coolant.

need: a case, tubing, radiator(s), a CPU block, GPU block(s), GPU backplate(s), memory block(s), reservoir(s), pump(s), compression fittings, angled fittings, bulkhead fittings, stop valves, coolant, and fans. Once you've decided how you want to cool your rig and what chassis you want to cool your build in, then it's a simple matter of pricing your choices, throwing it all in the basket, and breaking your wallet in two as you fork out for an expensive exercise in modding.

### CPU BLOCK

By far the most obvious component to cool your rig. You'll need to make sure you buy a CPU block that's compatible with the chip you're trying to cool. More often than not, this is just a simple choice between Intel and AMD, as processor sizes don't tend to vary greatly.

### GPU BLOCK

Predictably, GPUs experience the greatest deal of variance. Both in the design of the PCB and in which graphics processor you choose as well. You'll need to make sure you buy a compatible block for your card. Some manufacturers, such as EKWB, will often include specific water blocks designed to work with aftermarket cards such as Gigabyte's Windforce, MSI's Lightning, or the Asus STRIX series of cards. This may extend as far as the backplate as well, so always double check.

### MEMORY BLOCK

Whether or not you decide to cool the RAM with your custom loop is entirely up to you. The modules certainly do output heat. But really, it just looks more awesome than anything else. Besides, nobody will penalize you if all you're looking for is to cool your CPU and GPU. You'll also need compatible RAM modules that match up with your water blocks.

# DISPELLING THE MYTHS

## MANY FICTIONS CLOUD THE WORLD OF WATER COOLING, SO WE'VE SIFTED THE REALITY FROM THE RUMOR

### MYTH 1

**If I use deionized water in my loop, then leaks won't matter or cause any damage.**

**Answer** Unfortunately, no. As soon as the water is introduced to the system, it will begin making contact with the various metals inside of the water blocks. It will soon be picking up positive ions, meaning it'll be conductive within a couple of hours, at the very least.

### MYTH 2

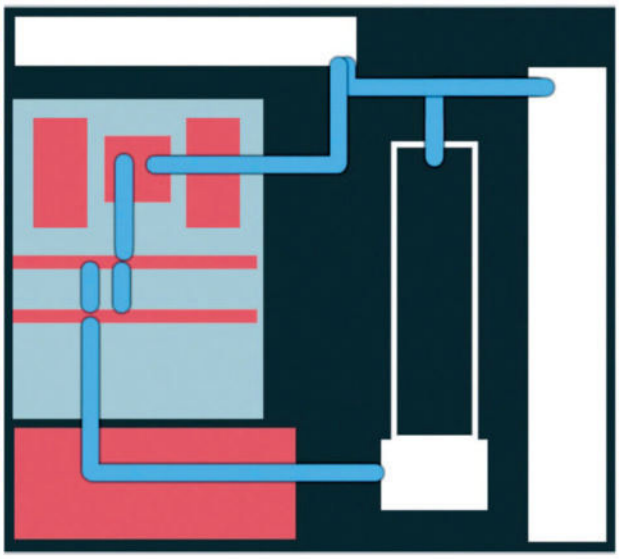
**What If I blow it up when I switch it on? What if there's an instant leak?**

**Answer** Honestly, you're not going to damage anything. The best way to fill and test a loop is to make sure everything's unpowered by using a PSU bridge. By using this bridge, you can switch on just the pump and that's it. Leave this on for 24–48 hours to see if you have any leaks.

### MYTH 3

**If I water cool my PC and add more fans, it's going to cool down my room right?**

**Answer** Definitely not. In fact, it's more than likely that the opposite will occur. Your hardware may run cooler, but you'll still be outputting the same amount of heat (or maybe even more if you're ramping up that overclock), out of the same radiators. If anything, your room will become warmer as you'll have more fans pushing more heat out of those radiators.



Even if it's just a shoddy Photoshop design, planning your build visually will save you time when it comes to figuring out how many fittings you're going to need and how best to run your cooling loops.

Making sure you've got enough space to work inside of your chassis is vital for having a stress-free, easy build.

## FITTINGS

Some of the most important parts of your build are the fittings you choose to use. Depending on what tubing you decide to use, you'll need either compression fittings or acrylic fittings. Although acrylic fittings are still technically compression fittings, they're designed to work around hard tubing by not crushing the acrylic as much, unlike traditional compression fittings, which tend to have a greater pinch to them. If you're looking for a basic build, you can usually get away with just the standard fittings.

However, if you're looking at designing a build with cleaner lines and a little more flare, you may want to invest in some angled fittings as well, usually stipulated at 45 or 90 degrees. Additionally, a stop valve might come in handy for loop maintenance.

## PUMP / RESERVOIRS

Technically, you don't need to buy a reservoir to successfully run a water-cooled loop. However, they do look rather impressive, and make it a lot easier to fill a water-cooled system than using other methods. You will, however, always need a pump to ensure that the fluid within your system is flowing, and pulling heat away from your core components and out to the radiators. Additionally, you should always have your pump gravity fed (meaning fluid should always be flowing down into it).

## RADIATORS AND STATIC PRESSURE

At this point, you need to look at how you're going to output that heat. The only option you have is to use radiators. You can do this however you like, either by using separate loops for your GPUs and CPUs or by combining the two together into one single loop. But you'll still need radiators to get rid of all of that heat, and accompanying fans to reduce this per loop.

Once you've decided what space your case has for radiators and how many you're going to use, you need to take a closer look at the FPI and thickness of the radiators you'll be using. FPI stands for fins per inch. Essentially, the higher the FPI, the higher the static pressure you're going to need to effectively move cool air through that radiator. For instance, if you have a radiator with an FPI of 38, you'll probably want static pressure optimised fans. However, if you have deeper radiators with a lower FPI of 16, you won't see any comparable difference between static pressure fans or airflow fans. In fact, in these cases, you're often better off equipping them with airflow fans instead.

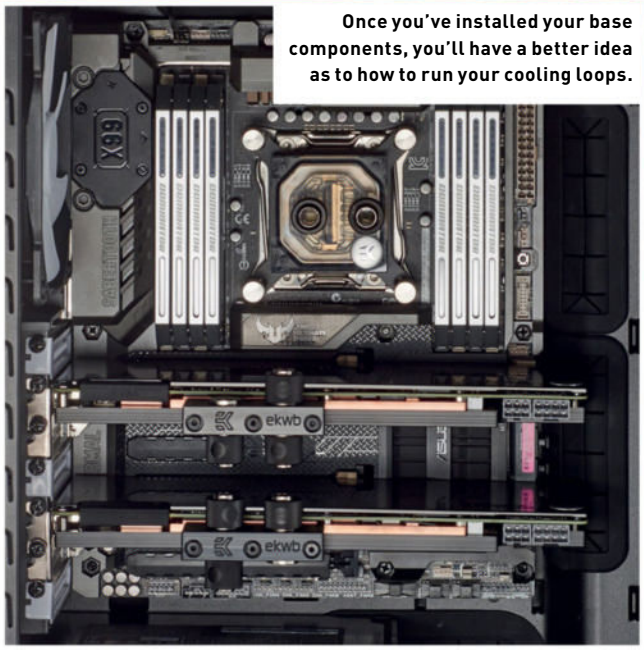
## WHERE TO BUY?

There isn't a fantastic array of places where you can buy a lot of these components in the United States. But one of the largest water-cooling specialists in the country is Frozen CPU (www.frozencpu.com), which has a vast selection. Additionally, if you're a little more patient and want to ensure you're getting EKWB directly from the source, you can buy straight from EKWB's site (www.ekwb.com). Also, here's a special shout out for EKWB, without whom there simply wouldn't have been any way to provide this first look into water-cooling for y'all.

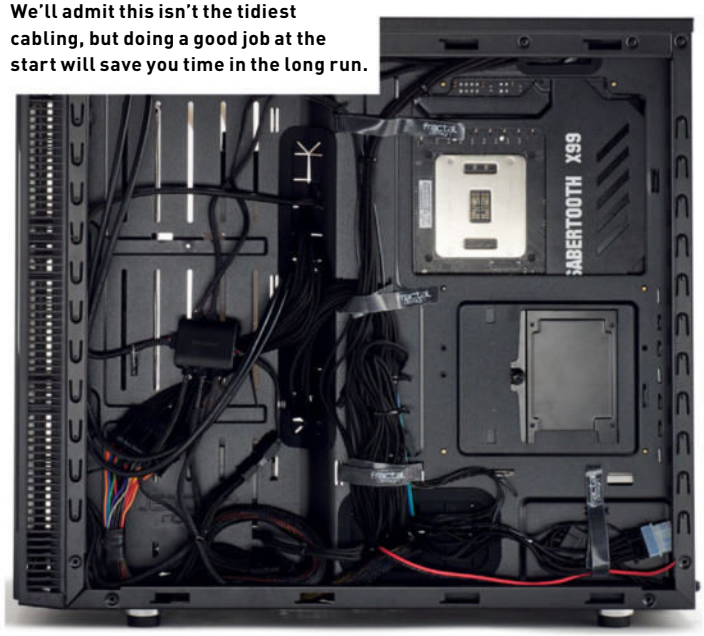
## PLANNING YOUR LOOP

So, at this point, you should be well aware of all the hardware you'll need to consider. Next, you want to research which case is best. There's a huge variety out there. In fact, you'll find there are water-cooling cases from Mini-ITX chassis all the way up to full E-ATX super towers. Once you've found your case, check what radiators it can support for water cooling. Then you need to think about your tubing and how you're going to cool it—a single loop or dual loops. Once you have all these decisions nailed down, your best bet is to sketch out how you want to run your loop, and how many fittings you'll need for all your hardware. Usually, you'll need two fittings per water cooling item—one in and one out.

For us, the choice was pretty simple. We'd use the Fractal Define S, a case designed from the ground up for easy water-cooling installation. A dual radiator at the top and a triple rad at the front. On




Once you've installed your base components, you'll have a better idea as to how to run your cooling loops.




We'll admit this isn't the tidiest cabling, but doing a good job at the start will save you time in the long run.

top of this, we'd be using a single closed loop to cool both of the EVGA Superclocked GTX 980 Ti cards and the Intel Core i7-5820K. Then it was a matter of tallying up how many fittings we needed, taking into account we'd be using soft tubing and a pump/res combo, as well as planning how our build would look. We'd be using an Asus X99 Sabertooth TUF mobo—stunningly gorgeous and covered in black-and-grey-plated armor. On top of this, we managed to get hold of a mixture of black water blocks and fittings. We'd use white coolant to add a little contrast.

## CHOOSING THE CHASSIS

Picking the right case can be a tricky business, especially when you're looking to do a water-cooled mod such as this. The best way to do this is to look out for cases designed particularly for water cooling, or by companies who revolve around it. Parvum, Phanteks, Corsair, Caselabs, and Fractal are all fantastic case firms that provide some excellent chassis to work and build in, making it easy to create a stunning work of art.

Selecting the right case is undoubtedly the biggest consideration you have to make. It will dictate where your reservoir goes, how many radiators fit and what thickness they are, plus how your tubing runs will work. For instance, we tried to build this particular setup inside the Phanteks Enthoo Evolv, but we'd already pre-ordered the water-cooling components for a different chassis and they ended up being incompatible with the Phanteks, even though that's a huge case to work in.

## FITTINGS AND LOOPS

And so begins the building process. Of course, like with our regular builds, we advise that you build all your PCs outside of the case first, just to see if they work. We individually tested both our GPUs, the memory, and the CPU with traditional coolers, before throwing water blocks on any of it.

Then we began the internal build process, stripping the chassis of any unwanted components, such as hard drive bays and cages, and continued to install the motherboard, the memory, and the GPUs, securing them firmly to ensure that nothing would fall out or become damaged over the course of our build. We also took this opportunity to install the radiators and plug in the fans where they were necessary. It's also time to attach the reservoir, and install all of the fittings.

## CABLE MANAGEMENT

In a build like this, cable management needs to be flawless. The last thing you want is excess, untidy cables cluttering up your rig. Not only will they get in the way of the tubing, they'll also restrict airflow and generally make your tubing routes that little bit more difficult. Cablemod (www.cablemod.com) provides custom-sleeved cables for Be Quiet!, Cooler Master, Corsair, EVGA, and Seasonic power supplies. These should spruce up your build quite nicely. Alternatively, it's not impossible to sleeve the cables yourself. This takes a lot more time and patience, but you can include cable combs to keep the cables tidy, plus vary your color schemes.

Additionally, we used the Phanteks PWM Fan Hub. Threading all five Noiseblocker fans through one fan controller means we can control how much power they receive directly from the CPU fan header, meaning the system will ramp up or down dependent on CPU temperature (which, admittedly, will be quite low for this build).

## BUILDING AND PRIMING THE LOOP

At this point, it's time to start your tubing runs. Line up a stretch of tubing between the two points you wish to connect, then cut a little more off than you think you'll need. It's better to have too much than too little—you can always shorten the runs later. Next, unscrew one of the fittings, wiggle your tubing onto the fitting, and thread the other end of the compression fitting onto the unattached end. Then screw it down, compressing the tubing in place.

If you're struggling to fit the tubing on, use a pair of needle-nosed pliers. Gently insert them into the end of the tubing and carefully stretch the tubing slightly, so it's easier to work. Then you'll need to take the sleeve off the other fitting, pre-attach that to your new tube and do the same with the other end. It's then simply a case of running all of the tubes to their correct lines. It doesn't matter which tube goes where, as long as it creates a loop. Once the system is sealed off and pressurised, the temperature of the water will be consistent around the entirety of the loop, regardless of which component goes to which first. Thanks, physics!

You're now at the scary part—priming your loop. Ensuring that the reservoir is gravity feeding the pump (in other words, it's above), attach one last fitting with a length of tubing onto the top of the reservoir (depending on how you have your reservoir set up, it might



**It will take time to get your loops right (it took us three attempts to master the bridge between our GPUs). But once it feels snug and secure, you can start filling your loop. Throw paper towels underneath everything—they're a good indicator of a leak.**

be advisable to get a multi-port top adapter). Then use a funnel to carefully pour your coolant into the loop. In our case, we like to use a plastic ketchup bottle to fill our loop.

Before doing any of this, you want to make sure that everything on your motherboard is unpowered. Ensure that your CPU power, your motherboard ATX power, and any power cables heading to your graphics card are all unplugged, either at the power supply end or the hardware's end. Then you'll want to either bridge the two power points on the ATX power with a paper clip, or use a specially designed bridge connector. Then it's simply a case of switching the power on every time you fill the reservoir, until the entire loop is filled. Just remember not to do this until after your reservoir/pump has fluid inside of it.

## CONCLUSION

As you've probably already spotted, the build looks great. Matching the black EK water blocks with the Asus X99 TUF Sabertooth worked out really well, and the white provides a brilliant contrast to the overall style and look.

The temperatures are where we expected them to be. We clocked the Core i7-5820K up to 4.4GHz and recorded temperatures at 55 degrees Celsius under load. The GPUs remained at around 60 degrees under full load and we maintained the fans at a constant 20 percent speed throughout the system.

As for performance, we couldn't really get much more out of either the GPUs or the CPU, as they were already at their hardware limits. But either way, the performance was still outstanding, and the fact that it remained so quiet even while under high load is really something else.

A worthy mention here is definitely the coolant. We used EK White Pastel coolant to fill our loop and it looks fantastic, even with a soft tubing loop. Our leak test went without a hitch. Although we could only test it for around 45 minutes during the shoot, there was absolutely no spillage. The EK compression fittings ensured an incredibly tight seal around all of the components. That is, as long as you haven't damaged the tubing in the process (especially if you're lazy like us and use scissors). Generally speaking, you should always run a leak test for 24 hours minimum before powering any of the components on, but in our case, we simply didn't have time.

In hindsight, we'd have loved to have gone with hard tubing. It's all the rage at the moment, and rightly so—it's some of the nicest-looking water-cooled work you can do. A larger case would have also been good. One of Caselabs's Magnum SM8s or Parvum's ATX chassis would've been excellent—going up to two 360mm radiators


instead of just the one and a dual radiator would have been great for additional cooling.

A different chip would have also been nice, just to see if we could push beyond the silicon limits on ours. Thermally, there's no issue with our 5820K, it just won't clock beyond 4.4GHz, but that could have been a different story if we'd gone beyond the 4.7GHz boundary. Additionally, running two loops would've looked stunning. One in black and one in white, separating the GPU and the CPU.

Should *you* be water cooling, though? That was the original question. It depends on your budget. As with any build, hard cash is ultimately what it always comes down to. If you're looking for the best bang for your buck, water cooling with a custom loop just isn't for you. Even if you do it on the relative cheap, you'll still be looking at somewhere around the region of $600, minimum, on top of everything else.

Water cooling is for those looking to build a beautiful and quiet workstation capable of destroying benchmarks and running any task you can throw at it with absolute silent ease. It's not for the faint hearted, and although water cooling has come a long way since the first attempts way back yonder, it's still filled with danger and possible hardware failure. But then, we don't know of any aspect of the PC enthusiast's arsenal that isn't.

**SPECIFICATIONS**

| | |
|---|---|
| **CPU** | Intel Core i7-5820K @ 4.4GHz |
| **Motherboard** | Asus Sabertooth X99 |
| **Memory** | 64GB Corsair Dominator Platinum (8x 8GB) @ 2,666MHz |
| **Graphics** | 2x EVGA GeForce GTX 980 Ti Superclocked ACX 2.0+ |
| **Storage** | 2x Samsung 850 EVO 500GB SSD |
| **Case** | Fractal Define S |
| **Power supply** | Be Quiet Dark Power Pro 11 1,200W – Platinum |
| **Fans** | 5x Noise Blocker NB-eloop B12-2 120mm fans |

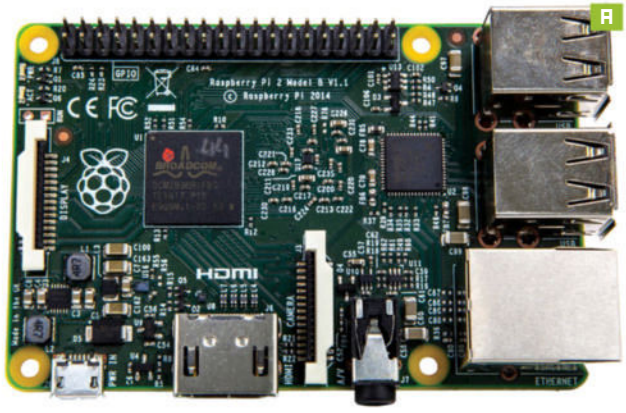
# Raspberry Pi as a Wireless Print Server

## YOU'LL NEED THIS

**RASPBERRY Pi 2**
The brilliant mini-computer costs under $45. See www.raspberrypi.org.

**A PRINTER ISN'T THE MOST CONVENIENT OF PERIPHERALS.** They look out of place on most desks and create a racket when spitting out pages. You could throw a few hundred dollars on a snazzy new network printer that sits in a corner somewhere, and can receive print orders from any computer on the local network. Or you could just hook up your regular USB printer to the Raspberry Pi and enjoy the same conveniences offered by top-of-the-line network printers.

If you haven't already used your printer on Linux, head to www.openprinting.org/printers to check whether your printer is compatible with the CUPS printing server software. If your printer is listed, hook it up to the Raspberry Pi using one of the USB ports. For this project, we're using the Raspbian distro, and the Pi is connected to the local network via a compatible wireless adapter. However, you can also hook the Pi up to your network via the wired Ethernet port. –MAYANK SHARMA




### 1 ACCESS YOUR RASPBERRY PI

You can follow the instructions in this tutorial by accessing the Raspberry Pi [Image A] remotely from any other computer on the network. Just make sure that the SSH server inside Raspbian is enabled by using the raspi-config tool. It's also a good idea to assign a fixed IP address to the Pi. You can do this easily from within your router's admin page. For this tutorial, we'll assume that the IP address of your PI is 192.168.3.111. You can now access the Pi from within Windows using the PuTTY client, or from any Linux distro with the SSH CLI command, such as:

```
$ sudo ssh pi@192.168.3.111
```

### 2 INSTALL CUPS

Once you're inside Raspbian, update the repositories with:

```
$ sudo apt-get update
```

and then install any updates with:

```
$ sudo apt-get upgrade
```

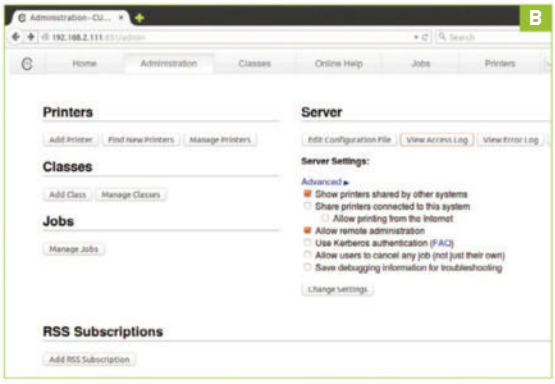
Now pull in the CUPS print server with:

```
$ sudo apt-get install cups
```

» When it's installed, add your user to the group created by CUPS called "lpadmin" that has access to the printer queue. Unless you have created a custom user, the default user on Raspbian is named "pi." Use the following command to allow it to interact with the printer:

```
$ sudo usermod -a -G lpadmin pi
```

» Here we use the usermod tool to add ("-a") the pi user to the lpadmin group ("-G"). By default, CUPS can only be configured from the local computer that it's installed on. Because that doesn't work in our case, we need to edit its configuration file to allow us to make changes to the server from a remote computer.




### 3 ALLOW REMOTE CONNECTIONS

First of all, you need to create a backup of the original configuration file with:

```
$ sudo cp /etc/cups/cupsd.conf /etc/cups/cupsd.conf.orig
```

» Then open the file with the nano text editor:

```
$ sudo nano /etc/cups/cupsd.conf
```

» Inside the file, scroll down to the following section:

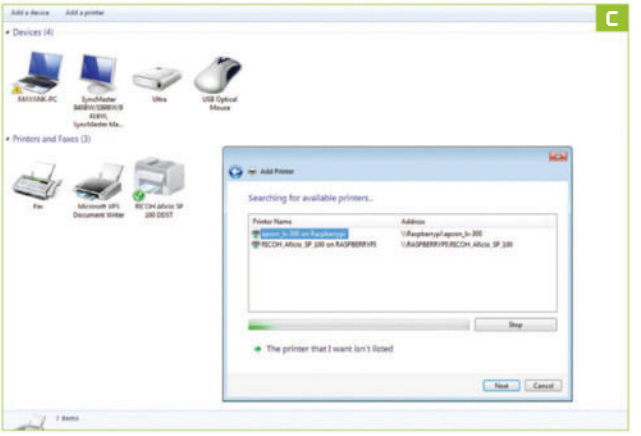
```
# Only listen for connections from the local machine
Listen localhost:631
```

» Comment out that line and add another to ask CUPS to accept connections from any computer on the network. Make sure the section looks like this:

```
# Only listen for connections from the local machine
# Listen localhost:631
Port 631
```

» Then scroll a bit further down in the config file until you reach the "<Location>" sections, and add a new line that reads "Allow @local" just before the close of the section. The section with the appended line should now read like this:

```
<Location />
# Restrict access to the server
Order allow,deny
```



```
Allow @local
</Location>
```

» Now add the "Allow @local" line to the other two "Location" sections: "<Location /admin>" and "<Location /admin/conf>." Save the file and restart the CUPS server with:

```
$ sudo /etc/init.d/cups restart
```

» You should now be able to access the CUPS administration panel [**Image B**] via any computer on your local network by pointing the web browser to your Pi. Then follow the four-step walkthrough over the page to add your printer to CUPS.

## 4 TWEAK THE FIREWALL

Some Linux distributions ship with a restrictive iptables firewall policy that doesn't allow connections via the CUPS ports. Even if Raspbian doesn't have any such restrictions, make sure it doesn't throw up any unexpected errors by punching holes in the firewall with:

```
$ sudo iptables -A INPUT -i wlan0 -p tcp -m tcp --dport 631 -j ACCEPT
$ sudo iptables -A INPUT -i wlan0 -p udp -m udp --dport 631 -j ACCEPT
```

» If you connect to the Pi via Ethernet instead of a wireless adapter, modify the command and replace "wlan0" with "eth0."

## 5 NETWORK-WIDE ACCESS

When you are through setting up your printer using the CUPS administration panel, it's time to make it accessible to the other machines on your network. While Linux distributions will have no trouble detecting your new network printer, making them visible to Windows and Apple devices requires a couple of additional steps.

» For Windows, install the Samba server on the Pi with:

```
$ sudo apt-get install samba
```

» Then open its configuration file ("/etc/samba/smb.conf") in the nano text editor, hunt for the section labeled "[printers]," and make sure it contains the following line:

```
guest ok = yes
```

» Then scroll down to the "[print$]" section and change its path to the following:

```
path = /usr/share/cups/drivers
```

» Now scroll up to the "Global Settings" section at the top of the configuration file. Modify the workgroup parameter within to point to the name of your workgroup, which by default is named "WORKGROUP." Also enable the wins support by adding the following line:

```
wins support = yes
```

» Now save the file and restart Samba with:

```
$ sudo /etc/init.d/samba restart
```

## 6 CONFIGURE WINDOWS AND APPLE DEVICES

Then head over to the Windows machine, launch the "Add New Printer" wizard, and click the option to install a network printer. Thanks to the modified Samba configuration, the wizard detects and lists any printers hooked up to the Pi [**Image C**]. If you have Apple devices, you can enable support for Apple's AirPrint system, which allows you to print from the iPad and iPhone. For this, just install the Avahi daemon with "sudo apt-get install avahi-daemon" on the Pi, which will then make the connected printer visible to AirPrint-compatible devices.

## 7 PRINT FROM PYTHON

In addition to the ability to use our network printer from within graphical apps across all platforms, we can also use it to print from the command-line interface. Furthermore, we can also interact with the printer using the Python programming language.

» The CUPS printing server installs a bunch of command-line tools (see box below) for interacting with the server and any connected printers. You can send files to the printer using the "lp" command, such as:

```
$ lp ~/docs/a_text_file.txt
```

» If you have multiple printers, you can print to a particular printer by specifying its name, such as:

```
$ lp ~/docs/another-text.txt -d EPSON_LX-300
```

# CUPS COMMAND-LINE UTILITIES

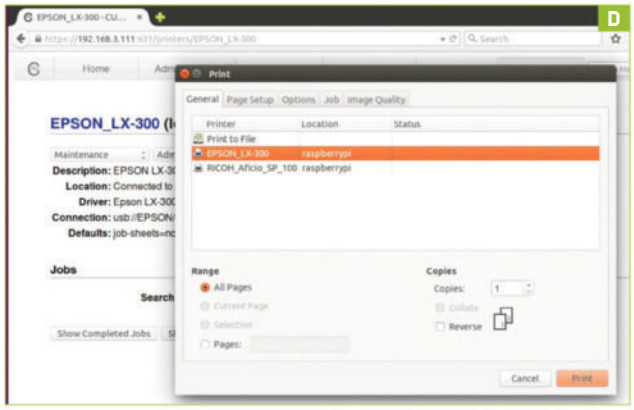
The CUPS printing system ships with a number of nifty little command-line utilities. In fact, you can set up and configure all aspects of your printer from the CLI. Let's run through some of the most useful commands that will help you manage the printer better.

We've already seen the "lp" command, which queues a file for printing on the default printer. The default printer is specified in the "PRINTER" variable. You can specify it with the command "export PRINTER=printer-name" where "printer-name" is the name of the printer you specify in Step 2 of the walkthrough over the page.

If you have multiple printers, use the "-d" option to specify the printer you wish to print to. For example, "lp -d HP-printer file.txt" prints the file on the HP printer, which isn't set as the default.

To influence the characteristics of the printed output, use the "-o" option to specify a variety of options. For example, "lp -o landscape -o fit-to-page -o media A4 file.jpg" fits the image into A4 size specifications, and prints it in landscape. Refer to the CUPS documentation (www.cups.org/documentation.php/options.html#OPTIONS) for a list of options.

If you mistakenly print a large file and want to stop the print job before you waste too much paper, you can use the "lpq" command to print a list of all the print jobs currently in the queue. The command also lists the file that each job is printing and its size, so you can easily identify the job ID assigned to each. Make note of it because you need it to cancel the print job. For instance, the command "cancel 2" cancels the job with the ID 2.




## 8 USING PYTHON

When you use the commands with a PDF or image file, CUPS converts the files using the printer drivers. You can also use Python to generate printer-friendly content. This is best done with the PyCups library, which provides Python bindings for the CUPS server. Install the library with:

```
$ sudo apt-get install python-cups.
```

» Then create an example.py Python script with:

```
import cups
conn = cups.Connection()
printers = conn.getPrinters ()
for printer in printers:
print printer, printers[printer]["device-uri"]
```

» The script fetches details about all the printers managed by CUPS and prints their name and device address to the screen. When you execute the script, it produces an output like this:

```
EPSON_LX-300 usb://EPSON/LX-300+?serial=L010209081
RICOH_Aficio_SP_100 usb://RICOH/Aficio?serial=T382M977983
```

» You can also print files from the Python script using the "printFile" function, by specifying them in the format:

```
$ printFile (name of the printer, filename to print, job
title,options)
```

## 9 MODIFY EXAMPLE.PY

Open the previous example.py script and add:

```
file = "/home/pi/testfile.txt"
printer_name=printers.keys()[0]
conn.printFile (printer_name, file, "Project Report", {})
```

» The first line saves the name of the file you wish to print inside a variable named "file." The second fetches the list of printers and saves the first name, which is the default printer inside a variable named "printer_name." The third line uses the first two variables and prints the file in the specified format.

» A more interesting example is to use the wkHTMLtoPDF toolkit to convert HTML pages into PDFs and pass them on to the printer, from within a Python script.

» Before you can install the toolkit, install the required components and a set of fonts to process the web pages:

```
$ sudo apt-get install xvfb xfonts-100dpi xfonts-75dpi
xfonts-scalable xfonts-cyrillic
```

» Then install the tool with "sudo apt-get install wkhtmltopdf" before installing the Python wrapper with:

```
$ sudo pip install git+https://github.com/qoda/python-
wkhtmltopdf.git
```

» You can now use the following to convert a web page into a PDF file:

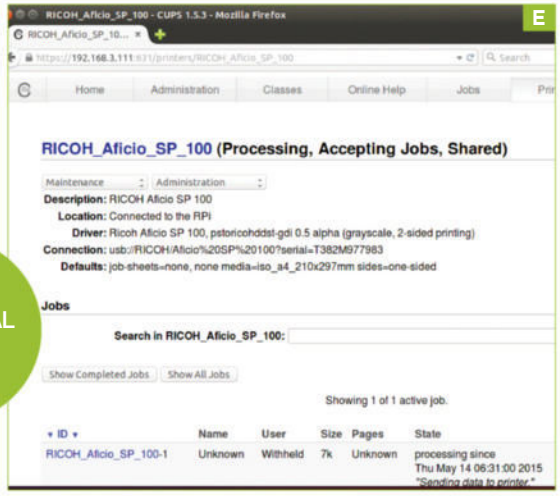
```
from wkhtmltopdf import WKHtmlToPdf

wkhtmltopdf = WKHtmlToPdf (
  url='http://www.maximumpc.com',
  output_file='/home/pi/docs/mpc.pdf',
)
wkhtmltopdf.render()
```

» The code saves the main page of the *Maximum PC* website as a PDF in the "/home/pi/docs" directory.

ANOTHER PI TUTORIAL NEXT MONTH

## 10 PUT IT ALL TOGETHER

Refer to the following code to see how the pieces fit together—it converts a page into a PDF and




# ADMINISTERING CUPS

In addition to adding printers, the CUPS web interface provides access to various other useful settings. You can administer most of the printing tasks from the "Administration" tab, which houses settings under various categories. Under the "Server" section, for instance, you can find options to tweak the configuration of the server, as well as view various types of access and error logs.

Using the "Manage Printers" button under "Printers," you can control the settings for individual printers. Every printer's page has options under two pull-down menus labeled "Maintenance" and "Administration" [**Image E**]. From under the "Maintenance" menu, you can print a test page, a self-test page, clean print heads, and manage print jobs.

To customize the behavior of the printer, use the "Administration" menu to tweak its default options, set it as the default printer, restrict user access, modify its settings, or delete it from the CUPS server altogether. Beside the "Administration" tab, there's a couple of other important tabs we should mention as well.

For starters, you need to switch to the "Classes" tab for printer class management. A class is a collection of several printers. When you send a print job to a class, CUPS automatically assigns the job to the next available printer, instead of waiting for a specific printer to be ready.

Then there's the "Jobs" tab, which enables you to view and manage all print jobs that are currently in the print queue.

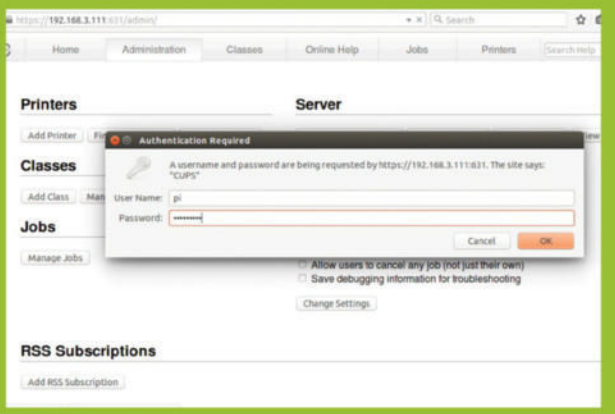
prints it out.

```
#!/usr/bin/env python
import cups
from wkhtmltopdf import WKHtmlToPdf
wkhtmltopdf = WKHtmlToPdf(
  url='http://www.maximumpc.com',
  output_file='/home/pi/maxpc.pdf',
)
wkhtmltopdf.render()
conn = cups.Connection()
printers = conn.getPrinters()
for printer in printers:
    print printer, printers[printer]["device-uri"]
file="/home/pi/tuxradar.pdf"
printer_name=printers.keys()[0]
conn.printFile (printer_name, file, "PDF Print", {})
```

» The script first converts the homepage of www.maximumpc.com into a PDF. It then connects to CUPS, prints a list of attached and configured printers on the screen, and uses the default printer to print the PDF. The PyCups library is full of methods (https://pythonhosted.org/pycups/) to control all aspects of CUPS.

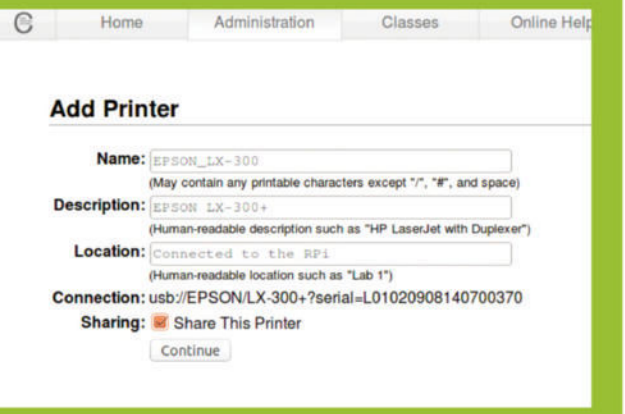
» Note: All distros can access the USB printers connected to the Pi without tweaks [**Image D**]. Happy printing!

# ADD A PRINTER



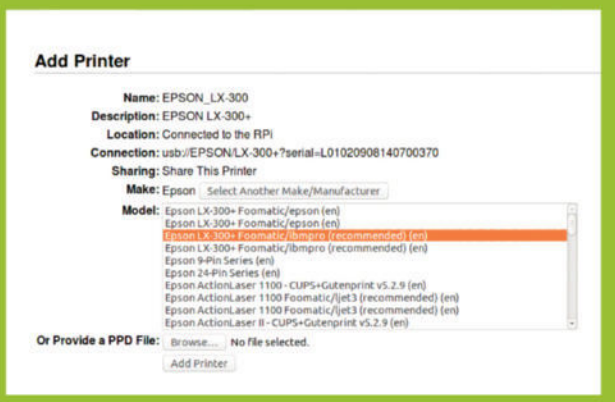

**1. THE CUPS DASHBOARD**

The CUPS print server includes a built-in web server that powers its configuration panel. It's running on port 631 on the Raspberry Pi, which in our case is 192.168.3.111:631. Access the address from any browser on the network. You have to accept its security certificate, and then log in to the interface using the credentials of the user you've added to the "lpadmin" group, which in our case is the "pi" user.



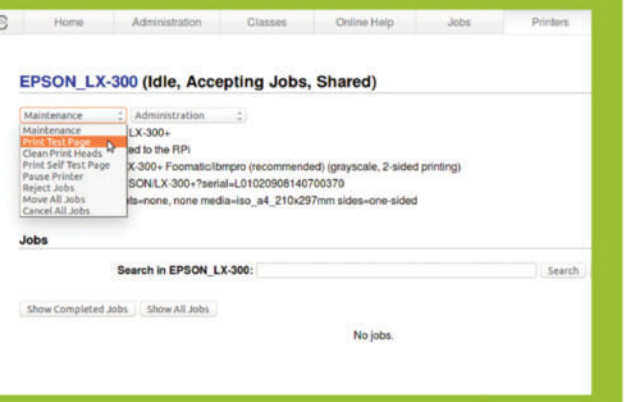

**2. ADD A PRINTER**

Once logged in, switch to the "Administration" tab, and click the "Add Printer" button, which brings up a list of printers. Toggle the radio button next to your printer, and head to the next step. Here you're asked to add or edit the name, description, and location of the printer. Make sure you enable the "Share This Printer" option to make the printer accessible all over the network.




**3. SELECT A DRIVER**

You're asked to choose a driver for the selected printer. CUPS shows you a list of drivers based on the make of printer. Chances are that several of the drivers are marked "Recommended." However, scroll through the list until you find the driver for your exact model. Alternatively, if you have a PPD file for the printer's driver, click the "Browse" button and navigate to it.




**4. SET DEFAULT OPTIONS**

In the final step, CUPS enables you to set some generic print settings, such as page size and source. The options vary from one printer to another, and might spread over several sections. When you've finished, click "Set Default Options." You're then taken to the main administration page for that printer. Use the "Maintenance" pull-down menu to print a test page.

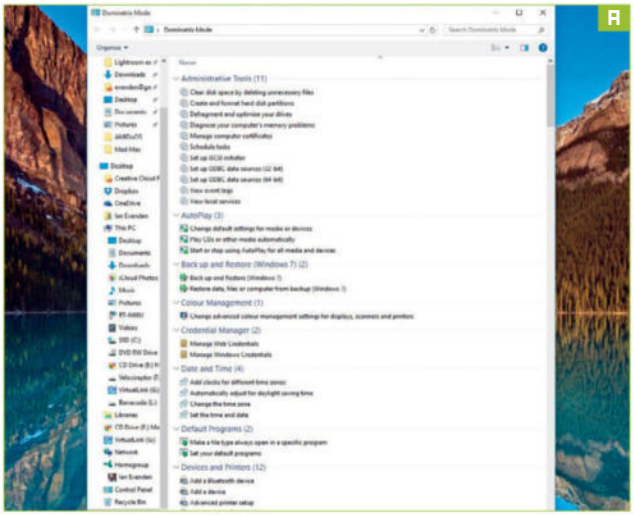
# Become a Windows God

**YOU'LL NEED THIS**

**WINDOWS 10**
Though you'll find this equally useful if you're still using Windows 8.

**ANYONE WHO'S BEEN USING WINDOWS 10** for a while will know the pain of trying to find a particular setting. Anything more involved than changing the screen wallpaper, or turning Wi-Fi on and off again, can be done in any of three places. And the Control Panel, despite its new stripped-back white minimalist loveliness, isn't always completely helpful when it comes to pointing you toward the settings you need. Wouldn't it be great, then, if you could gather all the settings together, like cattle in a Texas corral? A single place where you could look for troubleshome system settings or motherboard properties. Well, you can.

Once you've created the God Mode folder, you'll find more than 200 entries for settings and preferences from across your PC. While Windows 10 streamlined the locations of its various settings, anyone still using Windows 8 will find this especially useful, because they still live under the tyranny of the Charms bar. **–IAN EVENDEN**


A

## 1 CREATE A GOD MODE FOLDER

Unfortunately, the code is a bit more complex than "IDDQD." Create a new folder (right-click and choose "New→Folder"), and name it "GodMode.{ED7BA470-8E54-465E-825C-99712043E01C}." Find it online and copy and paste—it's easier—although the first word (or words, with spaces) before the period, which becomes the name of the folder, can be whatever you want [Image A]. "Dominion," maybe. Or "Divine Right Of Kings." "Exploit The Tweak." Whatever you choose, a folder with that name appears on your desktop. We've chosen "Dominatrix Mode" because we're children who still feel funny when we think about *WOW*'s Succubus.

## 2 OPEN THE FOLDER

The folder's icon should change to that of the Control Panel. Double-click to open it, and you'll find something not dissimilar to the Control Panel—except there are many more options. Over 200, in fact.

## 3 WHAT'S INSIDE?

There's nothing here that you won't find elsewhere, scattered across Windows' myriad settings and preference panes. The beauty of God Mode is that it gathers them in one place, so you don't have to go searching for the setting you need, or play the fun Control Panel Guessing Game about which category what you need will be found in. The folder is simply organized from A to Z, with a search box at the top.

## 4 ADMIN TOOLS

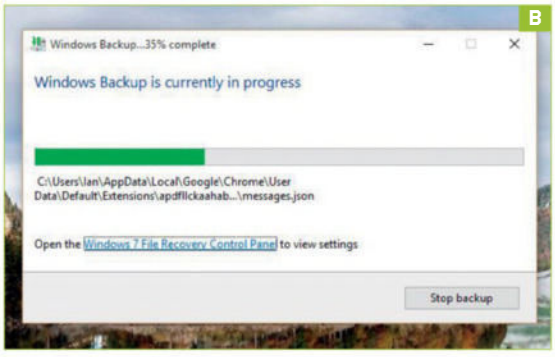
First up are the Admin tools, including defragging for improving the performance of cluttered non-SSD drives, the creation and formatting of drive partitions, and the Task Scheduler, for making your friend's PC play Slipknot at 3 a.m.

## 5 AUTOPLAY

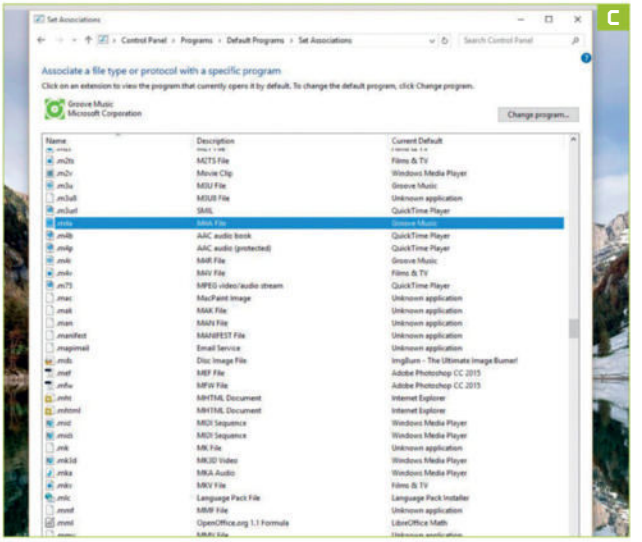
Slightly more interesting is the next section, "Autoplay," which enables you to change settings that usually only appear when you plug a new removable drive into the PC. Double-click the first option, "Change default settings," and you can alter how your PC reacts to all kinds of removable media, including turning Autoplay off altogether if it's getting too much.

## 6 BACKUP

"B" is for "Backup," and that's the next item on the list. It may say Windows 7 after it, but this backup utility works in Windows 10, after its sad removal from Windows 8.1. Click it, pick a target drive with lots of free space, allow Windows to manage your backups, and... off it goes [Image B]. You can choose to manually select what is



B



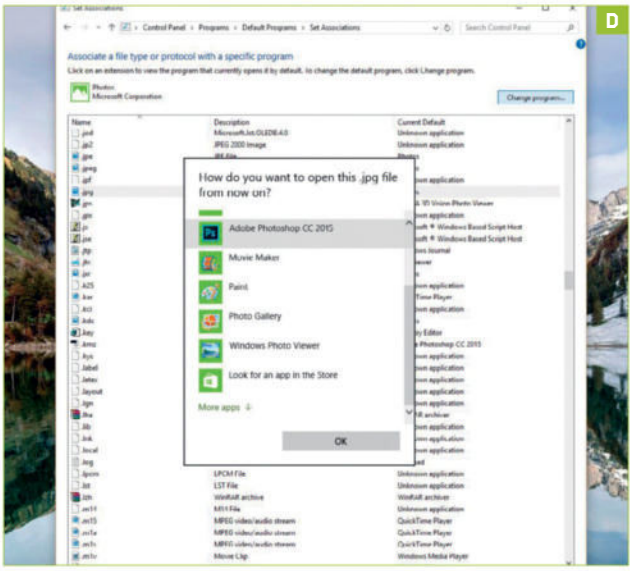

and isn't backed up if you like, but Windows does a pretty good job, and knows where all the important stuff is.

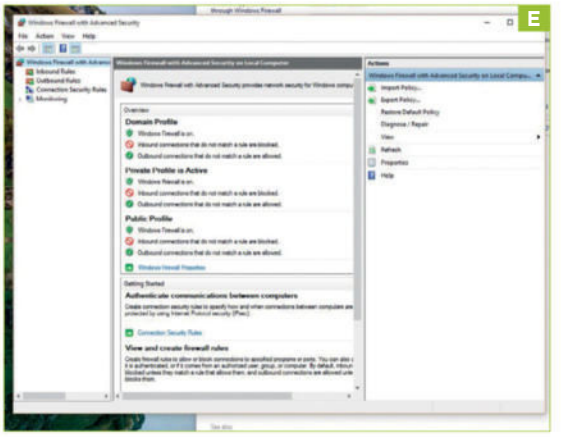
## 7 FILE DEFAULTS

Default programs are the ones that launch automatically when you double-click a folder [**Image C**]. For a Word document, you may well want Word, but if you open a JPEG, would you prefer Photoshop rather than Windows Picture Viewer [**Image D**]? This is where you change it. Select the .jpg file extension from the enormous list, click the "Change Program" button at the top, and a list appears of programs Windows thinks may be able to open the file. Choose the program you want to use—if it's not on the list, click "More apps." Still not there? Click "Look for another app on this PC," which lets you browse to the app of your choice.

## 8 EASE OF ACCESS

Further down the list, past the arcane mysteries of Bluetooth and Printers (whatever they are), you'll find the Ease of Access Center for useful things like turning off animations if they give you motion sickness, or the on-screen keyboard for those times you only take a mouse to the couch to watch Netflix, and can't be bothered to get up again. The Internet Options are a




little further on, so you can delete cookies, enable pop-up blocking, or clear those embarrassing Netflix movies from your history. *Breast Men* (1997) is a fine example of celluloid art, but perhaps not something you should admit to watching while around your mother. And you know she looks at your internet history.

## 9 MORE OPTIONS

Anyway, further down the list, past "Mouse Options" and something called a "modem," we find our old friend "Add and Remove Programs"—something the *Maximum PC* team is always having to use the Control Panel search to find. Remote access is just below it, and below that is "Security and Maintenance," where you'll find actually-important stuff, like user account controls and error reports. Further on, there's text-to-speech and speech recognition settings, too, for those who like to think we're on the bridge of the *Enterprise*.

## 10 SYSTEM SETTINGS

Finally—well, almost finally—there's "System." From here you can check your processor speed, tweak performance, fiddle with virtual memory, and access the Task Manager to kill errant processes that won't close by any other means. Windows Defender and Windows Firewall live right at the bottom of the list [**Image E**], two things that are generally just switched on and left alone. You might need to access the firewall if you're messing with an app that needs internet access but isn't on Microsoft's list, however.

## MICROSOFT'S CUSTOMER IMPROVEMENT PROGRAM

If privacy is important to you, you might want to opt out of Microsoft's Customer Improvement Program—it's under "Security and Maintenance" in the God Mode folder. This background process collects anonymous information about your PC as you work, and sends it to Microsoft. It does this with a scheduled task, which should run at a time you're not using your PC. Under Windows 7, however, it was noted that disabling it improved performance—so there's no reason to leave it running if you want to squeeze every drop of juice out of your current build. Or, if you're feeling philanthropic, you could leave it on and help Microsoft improve the features of Windows, based on your usage.

# Protect Windows 10

**YOU'LL NEED THIS**

**WINDOWS 10**
There are solutions for other versions of Windows.

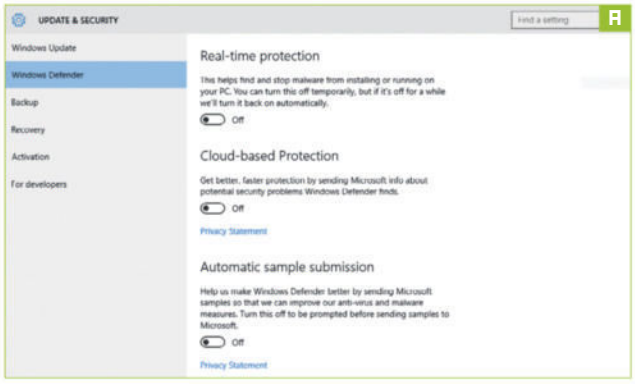
**WHEN YOU'RE A PC,** everything is out to get you. You need to learn how to shut the door on malicious software, and clean it out if it does take hold.

We already know that you don't browse movie streaming sites, frequent dating services populated by young ladies from the former Soviet Union who occasionally use stock photos as profile pictures, or merrily execute every .exe attachment you discover in your email spam folder—but even though you're a paragon of online virtue, there are still things you can do to protect your PC.

As a responsible Windows 10 user, you're probably already doing them. You chose "Express Settings" at install or flicked the button marked "Help protect your PC," and allowed Windows to download and install updates.

There are also third-party applications you can install to help protect against and remove malware should it somehow become resident on your PC. However, the old advice against having two antivirus apps installed at the same time still holds: They can clash, and report each other as potentially unwanted programs.

The best way to keep your PC clean is to be careful where you point your browser. In fact, never go on the Internet again, like your mother told you. **–IAN EVENDEN**




## 1 SWITCH ON WINDOWS DEFENDER

If you used Express Settings when you installed Windows 10, or bought your PC with the OS already installed, then Windows Defender is probably already switched on. To check, click "Control Panel → Update & Security → Windows Defender," and if it looks like [**Image A**], panic and switch all three options on. If you've got concerns about what Microsoft is doing with your data—maybe you have something terrible to hide—then only switch on the top option. The other two send data about malware threats on your PC to MS, and enroll you in the program now known as Microsoft Active Protection Service, which was renamed possibly because its previous name of Microsoft SpyNet was too terrifying.

## 2 UPDATE DEFENDER

Keeping Windows Defender updated is important. The malware definitions should update automatically, but if you open Windows Defender and it warns you it's out of date, click the "Update" tab, and hit "Update Definitions" to start the process.

## 3 SCAN YOUR PC

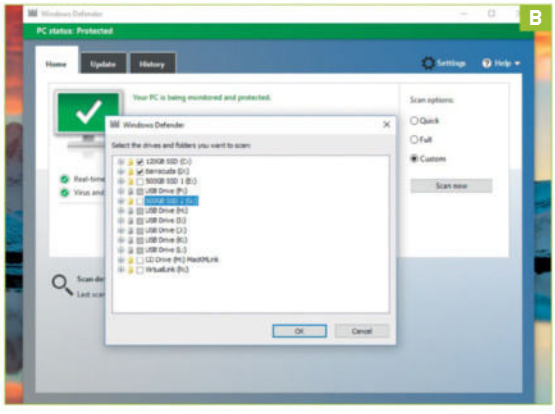
Using Windows Defender to run a scan every now and then doesn't hurt, and you have a choice of three kinds. Quick is the scan you should do most often. It only looks in places malware is likely to be found, and doesn't take up too much time. A Full scan looks everywhere, and is most often used after an infestation has been taken care of, to mop up any stragglers. Custom [**Image B**] enables you to specify which drives and folders are scanned. We struggle to think of a reason why you'd want to do this—maybe if you've got some files that are notorious for giving false-positive results, or you have a lot of data that's known to be clean, and you want to save time. Either way, the option is there if you need it.

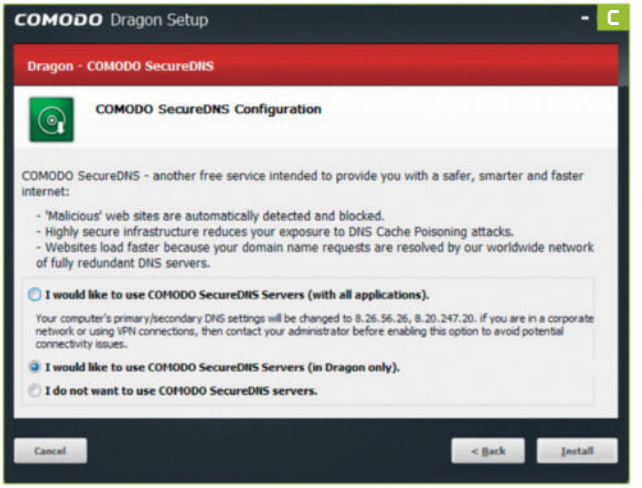
## 4 CHOOSE YOUR BROWSER

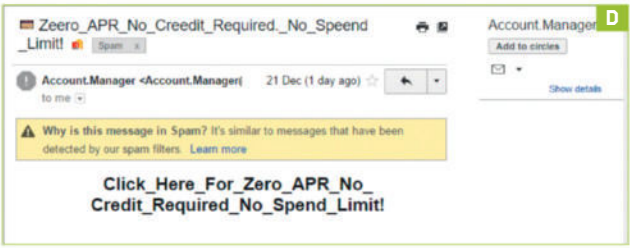
Even when Windows Defender is switched on, there's still no excuse for not following a few best-practice rules when killing time on the Internet. Use a modern browser that's kept up to date—the Edge browser that ships with Windows 10 is actually very good in terms of security, justifying the break with Internet Explorer's security-risk-riddled legacy. Google's Chrome browser is a good choice, and has an offshoot—the Epic Privacy Browser (www.epicbrowser.com)—which blocks pretty much everything.

## 5 A SECURE ALTERNATIVE

Another option, and another Chrome-a-like, is online security company Comodo's Dragon browser (there's an Ice Dragon variant based on Firefox if you prefer). Comodo maintains its own DNS system, which you can choose to use either for just the browser or for your whole PC when you install Dragon [**Image C**]. Comodo's DNS filters out the addresses of known malware providers, but there's another feature that makes Dragon even more secure: Virtual Mode. Entering this means





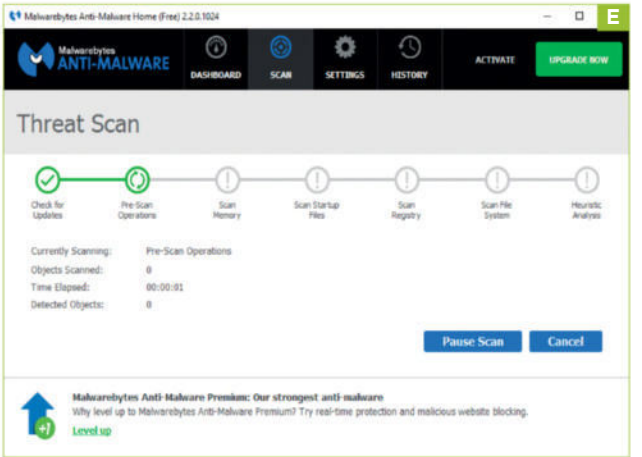

installing Comodo's Internet security package, which you may not want to do, but once it's there, you can run a browser that's isolated from the rest of your system—no matter where you choose to stick it, no harm can come to the rest of your PC.

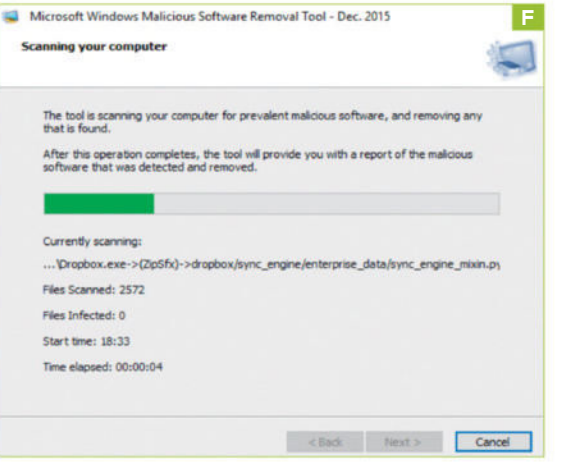
## 6 CHECK QUARANTINED FILES

If the worst does happen, and that beguiling email from a dating site you don't remember signing up to turns out to be too good to be true [Image D], a Windows Defender scan will flag the attachment you downloaded as infected and quarantine it. Quarantined files are viewed from the History tab, from where you can choose to delete them or, if you're sure they really contain the pictures they claim to, allow them to run.

## 7 GET A SECOND OPINION

Malwarebytes (www.malwarebytes.org) is a program that will run happily alongside Windows Defender, and is well worth having. There's a free version, which will, of course, bug




you to upgrade to the paid version, which offers real-time protection like Windows Defender [Image E]. If Windows is acting up and Defender can't find anything, a scan with a second application can sometimes turn up the culprit.

## 8 RUN A MALWAREBYTES SCAN

Once installed, Malwarebytes will update itself and then ask you to run a scan—this took less than four minutes on our test PC with 3TB of storage on board, but it may take a little longer if you have a lot of data for it to sort through.

## 9 REMOVE MALICIOUS SOFTWARE

There's one more Microsoft solution if you're sure your computer is infected and you need something to clean it out—the Malicious Software Removal Tool (http://bit.ly/1YuQBRE) [Image F]. MS sneakily attempts to add a script to change your default search engine to Bing with the download, but uncheck that and the 50MB file can be downloaded. In action, the tool looks a lot like Windows Defender, with options for Quick, Full, or Custom scans.

## 10 ALL SET

Rather than block malicious programs from running, the MSRT deletes them once they're installed, so is a way of fighting back rather than a defense. If you follow the advice in *Maximum PC,* and don't trust every link and email attachment you come across, you shouldn't need to use it.

## FALSE POSITIVES

A false-positive result occurs when an anti-malware app thinks a file is malicious when it isn't. A common trick to infect the unwary is to claim a download is innocuous but will trigger a false positive, and this is almost always a lie. The best advice is to not run a file unless you are completely sure of its origin and trust the source.

The detection of malicious files through their actions is known as "heuristics," and Malwarebytes includes it in its scans. Heuristics is most useful for detecting unusual activity, say a supposed image file that contains executable code. If you've got a script that makes changes to your system that uses the same methods as a known virus, a heuristic analysis could flag it as malicious.

# Give Photos a Vintage Look

### YOU'LL NEED THIS

**VINTAGER**
Give your photos a classic, old-fashioned feel with this free, third-party tool. Download it at http://bit.ly/1EX1mku.

**NOSTALGIA REALLY ISN'T WHAT IT USED TO BE,** particularly where photos are concerned. Dig out old pictures, and the signs of aging all add extra charm and ambience to the scenes they portray. Modern digital photos aren't subject to the ravages of time, but thanks to a great free tool, called Vintager, you can inject some nostalgia into your recent snaps, and see how they might have aged had they been shot on film.

It's simple to use: Vintager gives you a choice of 17 filters to try. Many apply different colored filters to inject some age and washed-out ambience, such as Blossom, Coconut, or Mint. Others go further. Candela adds a layer of artificial scratches, while Billie ages the photo by darkening it. You can then fine-tune these settings to get the perfect shot. Read on to find out how. –NICK PEERS

### 1 SELECT PHOTOS TO AGE

Point your browser at www.exeone.com/vintager to download and install Vintager. Once installed, leave "Launch Vintager" ticked, and click "Finish." When the main window opens, click the folder button next to "Image," to pick the photo or photos you want to edit. If editing multiple photos, hold Ctrl as you select each one. Click "Open" when you're done.

### 2 CROP, ROTATE, RESIZE

The first of your selected photos will appear in the preview window. Use the "Crop" tab to select part of the photo if you want to focus on a specific part of the image. Use the "Rotate" tab to spin or flip the image, and finally the "Resize" tab to shrink the size of the finished photo. Click the anchor button before you begin to preserve its aspect ratio.

### 3 APPLY EFFECT

Now click one of the five preset buttons beneath the editing controls to apply an aging effect—more effects are hidden away, so use the arrow to the right of the preset to navigate between them all. Once you've found an effect you like, use the Color adjustment tab's "Brightness" and "Contrast" sliders to fine-tune.

### 4 FRAME AND APPLY

Switch back to the first tab. Use the "Depth of Field" menu to lighten or darken the edges of your picture, and the "Frame" menu, if you want to pick your own frame, rather than go with the "Use predefined frames" option. Click "Apply." Copies will be saved to the same folder as the originals, unless you've ticked "Overwrite old files."

## GOING OLD-SCHOOL

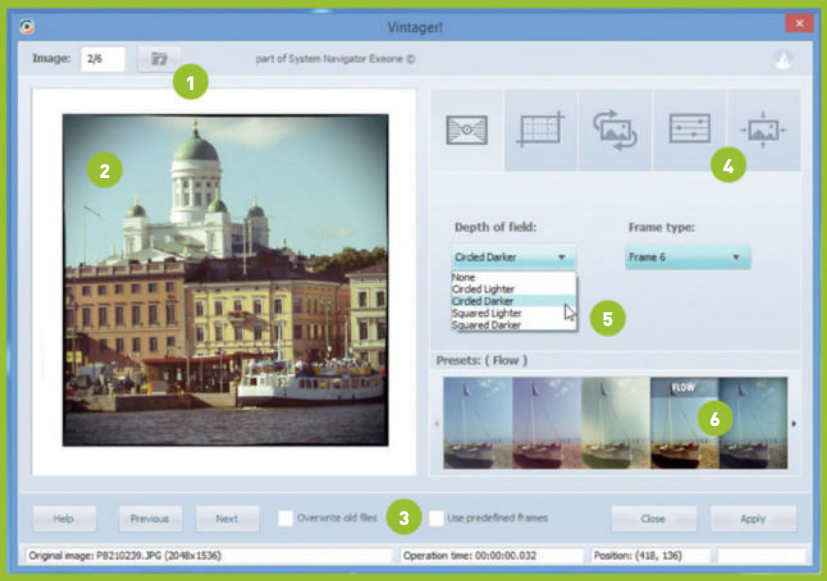
**1. SELECT PHOTOS**
Click this button to discard the currently loaded images and choose a new photo, or set of photos.

**2. PREVIEW WINDOW**
Use this window to crop your image, plus preview the effects and image edits as you select them.

**3. USE PREDEFINED FRAMES**
Each preset comes with a recommended frame. Use it, rather than select your own, by ticking this box.

**4. EDITING CONTROLS**
Options for editing your photo are hidden behind five tabs: Effects, Crop, Rotate, Color Adjustment, and Resize.

**5. TAB CONTROLS**
This area displays different options (or instructions, when Crop tab is selected), depending on which tab you have selected.




**6. PRESET EFFECTS**
Vintager has 17 different aging and coloring effects. Click one to apply it to the photo. Fine-tune until you're happy.

msi

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# Vortex

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