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Welcome

Custom PC Issue 193

/ FROM THE EDITOR

Super Zen

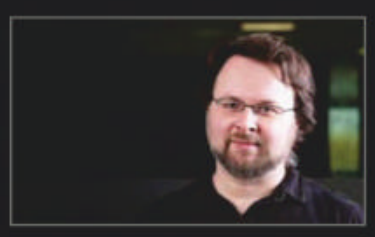
There's been a veritable avalanche of new silicon plummeting into the PC valley at high speed over the last few weeks, and this issue of Custom PC is largely dedicated to making sense of it, and showing what you can do with it. For starters, there's our main build feature on p76, which shows that you don't need to spend a ridiculous amount of money on building a new PC with all the latest tech.

It's not a budget rig, but it does get you all the exciting new gear, including an AMD Zen 2 CPU, a 1TB PCI-E 4 SSD, an Nvidia GeForce RTX 2060 Super GPU and an X570 motherboard for under £1,500 inc VAT. In addition, we've also reviewed Nvidia's new RTX 2060 and 2070 Super GPUs, and compared them with AMD's Radeon RX 5700 and 5700 XT on p16. Now that the dust has settled, we can confidently tell you which mid-range GPU you should buy for your budget. Meanwhile, there's a full Labs test of X570 motherboards on p42, and a review of AMD's new Ryzen 5 3600X on p22.

My favourite feature of this issue, however, is Rys Sommefeldt's deep dive into AMD's new RDNA GPU architecture on p86. As some of you may have noticed since the Raspberry Pi takeover, we've been regularly devoting a feature each month to showing you how the technology in your PC works.

Some of these features go deeper than others, and this month's feature gets right into the nitty-gritty of how RDNA works in games. If you find it a bit too technical, then don't worry, because next month we're planning to run a further deep dive feature that explains how modern GPUs work. If you don't know your front end from your rear end, then next month's issue will give you a primer to help you really understand your graphics hardware.

Sadly, we've also had to remove the Retro tech section from this month's issue, to make way for all the features at the back of the mag. However, I assure you this is only temporary – Retro tech will be back next issue as normal. CPC



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CUSTOM PC

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ISSUE 193

ISSUE 193
SUBSCRIBERS EDITION

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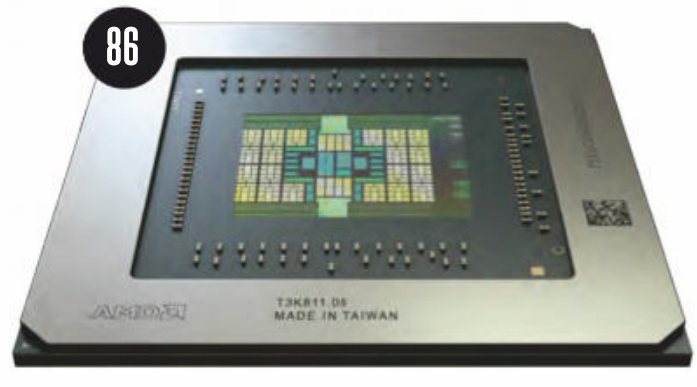

Cover guide

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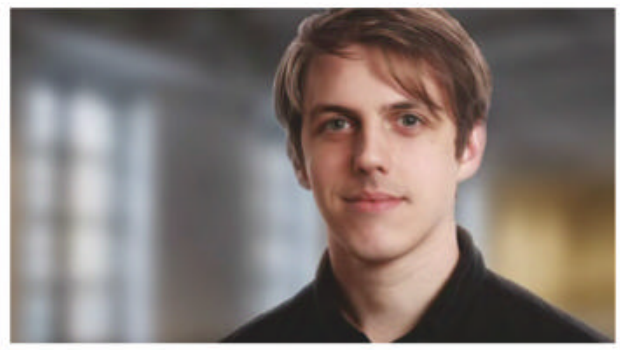

RICHARD SWINBURNE / VIEW FROM TAIWAN

ROADMAPS AND DEAD ENDS

Intel's leaked 2020 CPU plans looks good for AMD, says Richard Swinburne

I will preface this column by reminding readers that leaked road maps aren't officially confirmed by Intel. This column is based on a number of leaks of Intel's plans for 2020, which have been published separately in various places online.

Intel has already publicly announced that its Core i9-9900KS will be arriving later this year. It's the same 8-core CPU as the i9-9900K/KF, but with a 5GHz all-core clock that should bring some performance advantages. Ultimately, though, AMD's 16-core behemoth – the 3950X – is going to add far more advantages when it launches around the same time. The scheduling of the i9-9900KS tells us that Intel's 300-series platforms (Z390 and so on) will remain with us until at least the end of the year. That's unusual not only because it means a delay in Intel's annual update of its desktop platform, but also because it's at a time when AMD is at its most competitive.

The leaked Intel 2020 road maps detail a new LGA socket with 1,200 pins, which is reportedly due to be announced around this coming December/January. After ten years of LGA115x, it's finally buh-bye. The new socket is apparently set to receive new Comet Lake-S processors with TDPs going up to 125W.

This would mark the first time since Intel split its desktop platforms into mainstream and HEDT line-ups that the standard platform has exceeded 100W CPUs. Of course, these TDP numbers are pretty meaningless these days because boost clocks often push power draw well above 200W anyway. The reason for the uptick is, supposedly, that Intel is planning a 10-core 20-thread processor as its next-gen high-end chip, still made on a 14nm process!

Intel's first Ice Lake processors, featuring Intel's next big microarchitecture update are reportedly coming this year, but only for laptops. Comet Lake-S chips, however, remain in the Skylake generation. As Intel is very unlikely to discontinue a new platform in under a year, we can expect the Comet Lake-S platform and old Skylake-class architecture to cover most of 2020.

Comet Lake-S is reportedly also limited to PCI-E 3, and its official DDR4 speeds are below 3GHz. In fact, the only update appears to be that it features the latest silicon-baked security mitigations to Spectre and Meltdown vulnerabilities, but then again, so does AMD's Zen 2.

Not only is AMD winning reviews and performance benchmarks now, but by the time next summer hits, AMD will be launching its Zen 3 CPUs, with an updated microarchitecture and 2nd-gen 7nm+ process. Even if Zen 3 is only a modest update, its 12 and 16-core chips should breeze into a dominating position, again versus Intel's 10-core competitor.

> If Intel's premium brand position is hurting now, it looks set to have a worse time next year

Intel's X series 'update' appears to be even more lethargic, being *yet another* X299 refresh. The Cascade Lake-X refresh CPUs are likely to offer some turbo-boost performance tweaks to make them more competitive, as well as the new silicon-baked security mitigations. However, this platform looks set to continue using 14nm transistors, while only supporting PCI-E 3 and CPUs with up to 18 cores. If that's true, it will sit in a poor market spot, where it's more expensive than X570 systems, while offering far fewer cores than AMD's Threadripper CPUs.

From here, we have to wonder how this will affect Intel's first Xe GPU launch next year? Without leading CPU performance and PCI-E 4 graphics, it won't have the best launch scenario. If Intel's premium brand position is hurting now, it looks set to have a worse time next year. CPC

Richard has worked in tech for over a decade, as a UK journalist, on Asus' ROG team and now as an industry analyst based in Taiwan @ricswi

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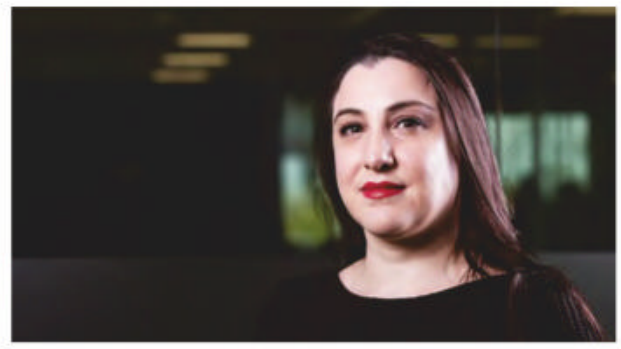

TRACY KING / SCEPTICAL ANALYSIS

DO GAMES HAVE TO BE FUN?

After chairing a panel on gaming as a force for good, Tracy King challenges the notion that games have to be fun

I was recently asked to chair a panel at Manchester International Festival discussing gaming as a force for good. My panellists were Paloma Dawkins, a game designer in the USA; Hardeep Pandhar, an artist who had created an extraordinary installation exploring gamergate; and Dan Hett, a games writer and developer.

Dan's brother Martyn died in the Manchester Arena bombing in May 2017. Losing someone in a terrorist attack is an unimaginable pain, but Dan has tried to create at least a small bit of good in response. He channels his grief into making games. As I played Dan's interactive fiction game 'C ya laterrr' – named after the final text his brother sent – in preparation for the panel, I experienced his loss, and the panic of that final evening, along with him. It was heartbreaking.

This is unusual for a gaming experience. Games are meant to be fun, right? Even the scary, abstract or overtly political games – from Silent Hill to Flower to Papers, Please – give you a fun mechanic with the message. But Dan's games defy being called fun.

Likewise, Paloma Dawkins' game Songs of the Lost isn't exactly a pleasant experience. I watched a playthrough video in which the guy playing exclaimed, 'Hey I thought this was meant to be fun!' But it isn't a horror game, it's just weird, new and unsettling. Despite the not-fun-ness, he played through to the end. He had a satisfying gaming experience, maybe even a good one, but not one he necessarily considered fun.

As indie platforms such as itch.io have gained popularity, so has the concept of experiential gaming. The availability of open source software such as Twine has opened up the writing and developing of games to non-developers, and helped to push the boundary away from just 'profitable and fun!' and into 'artistic expression'. Plus, like all art forms, the end result can vary across different people. As someone who has personal experience of grief, I had a different response to Dan Hett's work than someone who hasn't. Both responses are valid, but it was interesting to suddenly notice that I'd brought some emotional baggage into a game.

I can't call that fun, and yet I can't bring myself to dislike it either. There was a sort of catharsis in letting my own experiences, emotions and personal politics inform my response to a game, when normally I'd just be button-mashing or clicking impatiently to get to the enjoyable bit. Dan's next game is about extremism, which again doesn't sound fun, but I'm looking forward to being challenged by it.

If you'd asked me last month what makes a game, I'd have said that fun is an essential component (or at least the intention to be fun – side-eye to games that are meant to be fun but aren't even close). What would be the point of a game if it isn't fun? Even when games deal with themes of loss and death (such as Everybody's Gone to the Rapture, and Firewatch), it's just subtext via a fun experience.

But I no longer think games have to be fun, any more than I think novels or films have to be fun. I'll still use games for escapism and relaxation, but I'll also be seeking out games that challenge me in other ways. It's a brave, new, un-fun world. And that's a good thing. CPC

Gamer and science enthusiast Tracy King dissects the evidence and statistics behind popular media stories surrounding tech and gaming @tkingdot

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Incoming

PREVIEW

NVIDIA GEFORCE RTX 2080 SUPER / £669 inc VAT

SUPPLIER nvidia.com

The summer hardware flurry isn't over yet – Nvidia has launched another GPU in its Super series, and we managed to get our mitts on our sample just before this issue went to the printers. The GeForce RTX 2080 Super finally enables all the parts on Nvidia's TU104 GPU, giving you 48 streaming multiprocessors (SMs). That gives you 3,072 stream processors, 48 RT cores and 384 Tensor cores.

It's a bit of a miniscule boost compared with the other two Super GPUs. The RTX 2060 Super and 2070 Super (see p16) each get 256 more stream processors than their predecessors, but the RTX 2080 Super only has 128 more stream processors and two more RTX cores than the original 2080.

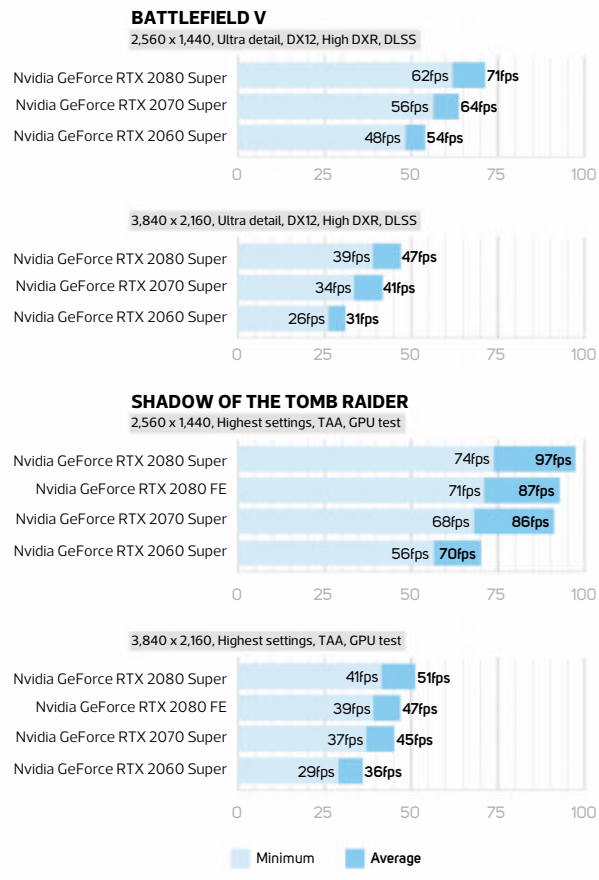
Clock speeds have also been improved, with the base and boost clocks sitting at 1650MHz and 1815MHz respectively, compared to 1515MHz and 1800MHz on the original RTX 2080 Founders Edition. The RTX 2080 Super also has a higher memory frequency, with its 8GB of GDDR6 RAM clocked at 15.5GHz (effective), compared to 14GHz for all the RTX cards below it.

Sadly, first impressions are a bit on the 'meh' side. In terms of performance, the jump from the 2070 Super to the 2080 Super is smaller than the jump from the 2060 Super to the 2070 Super. It's also only slightly faster than the original 2080. That's not surprising given the spec of the GPU, but it makes it hard to justify costing nearly £200 more than the 2070 Super, especially when only £100 separates the 2060 Super from the 2070 Super.

What the RTX 2080 Super does achieve is a solid Battlefield V frame rate at 2,560 x 1,440 with ray tracing on High, staying above 60fps in our test.

Its 4K minimum of 39fps at these settings is also pretty good considering the work it's doing. If you really want decent frame rates at 4K, though, the RTX 2080 Ti is still the only GPU that manages it. Look out for a full review of the GeForce RTX 2080 in Issue 194.

BEN HARDWIDGE



HyperX £80 wireless headset

HyperX has announced a new wireless headset for just £80 inc VAT. The Cloud Stinger has a 2.4GHz wireless connection and a 17-hour battery life, while keeping the weight down to 270g. The volume controls are built onto the earcups, and the microphone has noise cancelling and a swivel-to-mute system. The unit has a range of around 12m, and the ear cups rotate as well.

The circumaural, closed-back earcups contain 50mm directional drivers with neodymium magnets, and HyperX says the headset is 'built on the comfort and sound DNA of previous Cloud headsets.' The HyperX Cloud Alpha has been on our Elite list for over 18 months, so we'll be interested to try it for ourselves. The Cloud Stinger is available now.

PHIL HARTUP

New Sound Blasters

Creative is celebrating the 30th birthday of the Sound Blaster line-up with two new cards, the Sound Blaster AE-9 and AE-7. The former uses audiophile-grade components, and is aimed both at gamers who want to hear precisely what's about to kill them, and people looking to use a home PC as a serious music and media setup.

The hardware sounds impressive, with an ESS 9038 SABRE-class reference DAC delivering up to 129dB SNR and 32-bit 384kHz sampling. The AE-9 also packs CleanLine Technology, which is designed to improve the quality of the microphone path for voice communication. Meanwhile, the AE-7 has an ESS 9018 SABRE-class DAC with 127dB DNR, 32-bit 384 kHz sampling and DSD64 playback. Look out for a full review of the AE-9 in our next issue.

PHIL HARTUP

WORTH £230

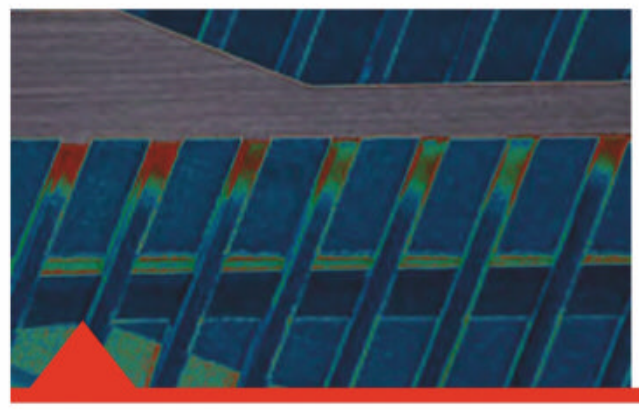
WIN!

A be quiet! DARK BASE PRO 900 CASE!

What's that?

.193

Our pals at be quiet! are offering a Dark Base Pro 900 Rev. 2 Silver case to one **Custom PC** reader. The image below is a distorted close-up of a piece of hardware in this issue. If you identify it, email the name and page number of the product to competition@custompcmag.org.uk, with 'What's that? 193' in the Subject field.



.192

Last month we mistakenly reprinted the same 'What's that?' image as the month before, so we're going to run that competition for another month. If you can spot the image below anywhere in Issue 192, email the product's name and page number to competition@custompcmag.org.uk, with 'What's that? 192' in the Subject field.

Issue 191 winner

The winner from our Issue 191 competition was Stephen Rolph, who correctly identified the MSI Radeon RX 570 Armor from p19. Congratulations Stephen! We'll be in touch to sort out getting your prize sent to you.

Terms & conditions
Please see p103 for our competition terms and conditions.

Letters

Please send us your feedback and correspondence to
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Extra terrestrial

I've been a subscriber pretty well from the start, and always enjoy the regular PC build features. I wonder if it would be possible to build a media PC to replace my aging Panasonic hard disk recorder. It has a DVD writer in it, so that material can be archived from hard disk to removable media. It also has SCART/composite video inputs, so that I can copy material from my Sky hard disk recorder onto the Panasonic.

New machines with these features no longer seem to be available, possibly due to digital rights issues, and the prevalence of streaming media. I have Amazon Prime video, but nothing beats being able to have the material to hand on DVD, in my opinion.

I wonder about the feasibility of building a media PC that could accomplish the above, and what hardware and software would be required? I'd need a Freeview TV card, DVD writer, a suitable hard disk or large SSD etc, RGB video input and so on. Possible build feature in the magazine?

RICHARD PITMAN

Ben: Thanks for being a loyal subscriber, Richard! I think an analogue video capture machine is a little too niche for a dedicated full build feature, but it's certainly something we could look at as part of a general media PC feature. I used to have a similar setup to the one you describe, up until a few years ago, using a TBS DVB-T2 Freeview card, an SSD, a large hard drive and a Startech analogue capture cable – a USB dongle with a composite input and left and right stereo inputs.

I used Windows 8 with Windows Media Center at the time, but I'd probably use Kodi today. I reckon you could probably build a similar setup – the parts are still available, and an AMD APU would have enough processing power. That said, after doggedly avoiding it for years, I've pretty much joined the streaming club now. While you don't get the satisfaction of owning physical media, it's massively more convenient!

Twitter highlights

Follow us on Twitter at @CustomPCmag

@2dgamemania Some people say 2080 Ti, Titan or the latest card is probably 'too' powerful. Whenever I hear comments like this, I never understand it. Imagine if you have an RTX-capable game, and a 2k 144Hz monitor. Would it run the game at 144fps? Unlikely.

@itsDenkimon No such thing as 'too' powerful. The 2080 Ti is today the best card for high-end gaming such as you described (without ray tracing enabled). I've got a 1080 Ti and it's not really good enough for 1440p at 144fps.

Ben: *Well, quite. People who say these GPUs are 'too powerful' are likely not looking at use scenarios outside of their own. They might be overkill for playing games at 1080p, but I have a 4K monitor and the RTX 2080 Ti is pretty much the only card that will consistently give me fast frame rates at that resolution (and certainly not at 144fps!). Alas, I can't afford one. Maybe not too powerful, but arguably too expensive.*

Is the GeForce RTX 2080 Ti too powerful?

@elanstreaming It'll get there eventually, but it's not appealing right now.

@achunt The emperor's new reason to up-shift the price point of new video cards. Sorry, but video card prices have gone far beyond the hardware costs and now it's just gouging the consumer with a 'how much can we get away with?' pricing policy. They could halve the price and still profit.

@Indi3Gam3r Realistically, does anyone really care about anything other than @CyberpunkGame at this point?

Custom PC asks
Is ray tracing the wave of the future or a lot of fuss about nothing?

What do you think of ray tracing and GPU prices? Let us know at **letters@custompcmag.org.uk**

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Reviews

Nvidia GeForce RTX Super vs AMD Radeon RX 5700

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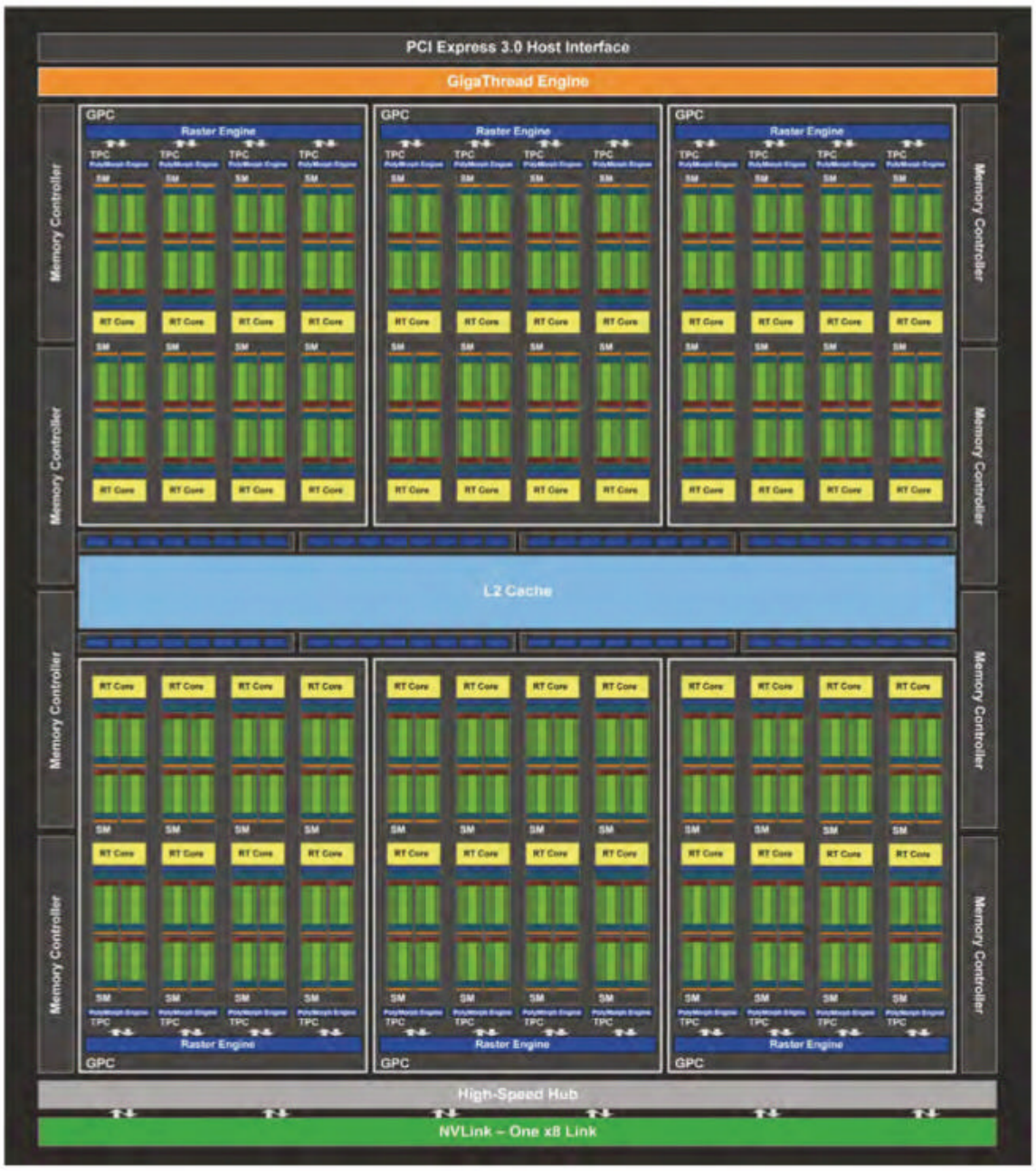
After the utter chaos that's just unfolded in the graphics card world, it feels like we need a bit of a recap in order to put Nvidia's Super RTX GPUs in context. Last month, AMD released the first graphics cards based on its new RDNA architecture (see p86), the Radeon RX 5700 and 5700 XT. Nvidia, with spectacular timing, also marched in like a party-pooping parent, launching its first competing RTX Super products, with review embargoes expiring a week before the AMD launch.



Nvidia's TU104 chip has all its parts enabled in the RTX 2080 Super. Remove eight SMs and you get the RTX 2070 Super

It's a situation that made reviews difficult at **Custom PC**, as we had a print deadline at the same time. We had time to test the AMD GPUs, but didn't get any RTX Super samples in time for full review last month. We ended up not being able to give scores to the AMD GPUs until we'd tested the Nvidia competition, and since then AMD has also announced price cuts, while the price of pre-Super RTX GPUs has dropped a bit. Are you following? Good.

Thankfully, the dust is now starting to settle, and we're now at a point where we can properly put the RTX 2060 and 2070 Super through their paces, and also make some recommendations. Over the next few pages, we'll take you through the new Super GPUs, and recommend which GPU you should buy for your budget.

What's so super?

There's essentially nothing new in the 'Super' RTX GPUs. They're based on the same 445mm^2 TU106 and 545mm^2 TU104 chips we saw in last year's RTX graphics cards, but the model numbers have shuffled along a bit, with different numbers of streaming multiprocessors enabled on the various chips.

Let's start with the RTX 2060 Super; like the original RTX 2060, it's based on the same TU106 GPU as the RTX 2070. However, the RTX 2060 Super is much closer to the original RTX 2070 in terms of spec. It has 34 of its SMs enabled, giving it 2,176 stream processors, 34 RT cores for hardware ray tracing and 272 Tensor cores for Nvidia's deep learning features, such as its DLSS anti-aliasing mode.

Comparatively, the original RTX 2060 only has 1,920 stream processors, 30 RT cores and 240 Tensor cores, while the RTX 2070 is only a small step up, with 2,304 stream processors, 36 RT cores and 288 Tensor cores.

Just as importantly, the RTX 2060 Super now comes with 8GB of 14GHz (effective) GDDR6 memory, unlike the 6GB of its predecessor. What's more, it's attached to a 256-bit interface, rather than its predecessors 192-bit interface, and it has the full count of 64 ROPs, rather than 48. This move brings the RTX 2060 Super into line with its three bigger siblings, with a total memory bandwidth of 448GB/sec, compared to just 336GB/sec for the RTX 2060.

Another result of this move is that board manufacturers don't necessarily need to make a new PCB for the RTX 2060 Super – the ones for their RTX 2070 cards should be fine. It's a situation that effectively means the RTX 2060 Super is much more practical to water-cool than its predecessor, as Antony Leather discusses on p106. Clock speeds have also changed slightly, with a 1470MHz base clock and 1650MHz boost clock, compared to 1365MHz and 1680MHz respectively for the original RTX 2060.

Next up is the RTX 2070 Super, which moves from the TU106 GPU of its predecessor to the TU104 GPU used by the RTX 2080. You can think of it as a bit like the GTX 1070 Ti in that respect. The newly announced RTX 2080 Super (see p12) has all 48 of the TU104 chip's SMs enabled, giving it 3,072 stream processors, a small step up from the original RTX 2080's 46 SMs containing 2,944 stream processors.

The RTX 2070 Super has 40 of the TU104 GPU's SMs enabled, giving it 2,560 stream processors, 40 RT cores and 320 Tensor cores.

SUPER MAN

+ 2060 Super handles 2,560 x 1,440 ray tracing
+ 2070 Super is extremely fast
+ Futureproofing

SUPER HANS

– RX 5700 XT quicker than 2060 Super
– Expensive
– Palit Game Rock card is massive

That's a healthy count of 256 more stream processors than its predecessor. Clock speeds have also increased. The original RTX 2070 has base and boost clocks of 1410MHz and 1620MHz respectively (1710MHz for the latter on the Founders Edition), but the RTX 2070 runs at base and boost clocks of 1605MHz and 1770MHz. Finally, unlike the original RTX 2070, the 2070 Super can also be used in 2-way SLI configurations.

The cards

We've received two cards from board partners to test for this review. First up is Zotac's GeForce RTX 2060 Super Mini, a small card that costs £380 inc VAT (the same price as the RTX 2060 Founders Edition on **nvidia.com**). It has a width of just 210mm – 18mm shorter than the Founders Edition's 228mm. It's a basic card, with no RGB lighting and stock clock speeds, but it does have a wraparound backplate that covers the rear of the PCB and folds round to cover the front of the card too. It takes up the space of two expansion slots, and it has two fans shifting air through the heatsink's heatpipe-assisted aluminium fins.

Meanwhile, our RTX 2070 Super sample comes from Palit, and it's the company's high-end Game Rock model. It's a large card, measuring 292mm wide (compared to 267MHz for Nvidia's Founders Edition). Its cooling is assisted by massive copper heatpipes that you can see poking out beyond the PCB, along with two large fans and a chunky backplate.

There's also some lighting on the front of the card, but not on the edge, which seems like a missed opportunity – you're unlikely to want to put this 2.75-slot card in a vertical GPU mount next to a glass side panel, as it will restrict airflow.

Two 8-pin PCI-E power connectors sit on the edge of the card, and Palit has also given the GPU an overclock, with the boost clock rising to 1830MHz on our sample.

Performance

Both the RTX 2060 Super and 2070 Super perform in line with expectations. The biggest jump is seen between the original RTX 2060 and RTX 2060 Super. When we first tested the former in Battlefield V with High DXR ray tracing enabled, it dropped right down to 22fps. We haven't included that result in our graphs, as we did that test before DLSS was enabled in Battlefield V, so the results aren't comparable.

Even with DLSS, however, we've still seen the RTX 2060 struggling with ray tracing at decent settings at 2,560 x 1,440. That changes with the RTX 2060 Super, which handled our Battlefield V High DXR test with a solid minimum of 48fps. The RTX 2060 Super also storms through the rest of our benchmarks, staying above 50fps in all our 2,560 x 1,440 tests.

It's up against some serious competition here now though. AMD's Radeon RX 5700 XT is a fair bit quicker than the RTX 2060 Super across the board, never dropping below 60fps in Shadow of the Tomb Raider.

Nvidia's TU106 chip has all its parts used in the RTX 2070. Remove two SMs and you get the RTX 2060 Super

In fact, if you run Battlefield V in DirectX 11, even AMD's much cheaper Radeon RX 5700 beats the RTX 2060 Super. The new AMD GPUs might not have hardware ray tracing, but they're seriously fast at rasterisation tasks.

Where the RTX 2060 Super really impressed us, however, is with its power efficiency. At peak GPU load, our system only drew 248W from the mains, compared to 295W for the Radeon RX 5700 XT. Also, the coolers on both the Founders Edition and the Zotac Mini card are massively quieter than the noisy blower coolers on AMD's latest cards. The Zotac's fans do audibly spin up when the GPU is running at full pelt, but at least the noise isn't irritating.

Meanwhile, the RTX 2070 Super is the new sub-£500 king. We tested the Palit card at both its overclocked speed, and the Nvidia stock speed, to gauge performance.

With the exception of Battlefield V in DX11 mode, the RTX 2070 Super tops all the performance charts in our tests. It's brilliant for gaming at 2,560 x 1,440, never dropping below 60fps in any of our 2,560 x 1,440 non-ray-traced tests. It can even handle a bit of 4K gaming if you're happy for your frame rate to drop down to the mid-30s. It can even handle Battlefield V with High DXR at 4K with this level of frame rate.

The boost on the Palit card also gives it a few extra frames per second here and there, pushing the Battlefield V minimum up to 59fps at 2,560 x 1,440 with High DXR. Like the Zotac card, the Palit Game Rock card did get noticeably noisy under load, although the noise is nowhere near as irritating as the racket from AMD's blower coolers. It's not particularly power-frugal, though, with our system drawing 324W from the mains with the Palit card installed.

Overclocking

Finally, we wanted to see if we could eke even more performance out of the RTX Super cards, and found that there's some room for manoeuvring here. In particular, there's plenty of headroom to overclock the memory. The Zotac card was happy to have an extra 1GHz (effective) added to the memory clock, while the Palit card could have another 800MHz (effective) added to the memory frequency.

There was some room to push up the GPU clock speed too – we could add another 50MHz to the Palit's already overclocked 1830MHz boost clock, and another 120MHz to the Zotac GPU's boost clock. These tweaks gave us a bit more performance, with the Zotac card now hitting a 60fps minimum in Shadow of the Tomb Raider at 2,560 x 1,440 (a 4fps boost), and the Palit card's minimum rising from 70fps to 73fps in the same game.

BEN HARDWIDGE

SPEC
ZOTAC GEFORCE RTX 2060 SUPER MINI

Graphics processor Nvidia GeForce RTX 2060 Super, 1470MHz base clock, 1650MHz boost clock

Pipeline 2,176 stream processors, 64 ROPs

RT cores 37

Tensor cores 272

Memory 8GB GDDR6, 14GHz effective

Memory interface 256-bit

Bandwidth 448GB/sec

Outputs/inputs 3 x DisplayPort 1.4, 1 x HDMI 2b

Power connections 1 x 8-pin

Card width 210mm

SPEC
PALIT GEFORCE RTX 2070 SUPER GAME ROCK

Graphics processor Nvidia GeForce RTX 2070 Super, 1605MHz base clock, 1830MHz boost clock

Pipeline 2,560 stream processors, 64 ROPs

RT cores 40

Tensor cores 320

Memory 8GB GDDR6, 14GHz effective

Memory interface 256-bit

Bandwidth 448GB/sec

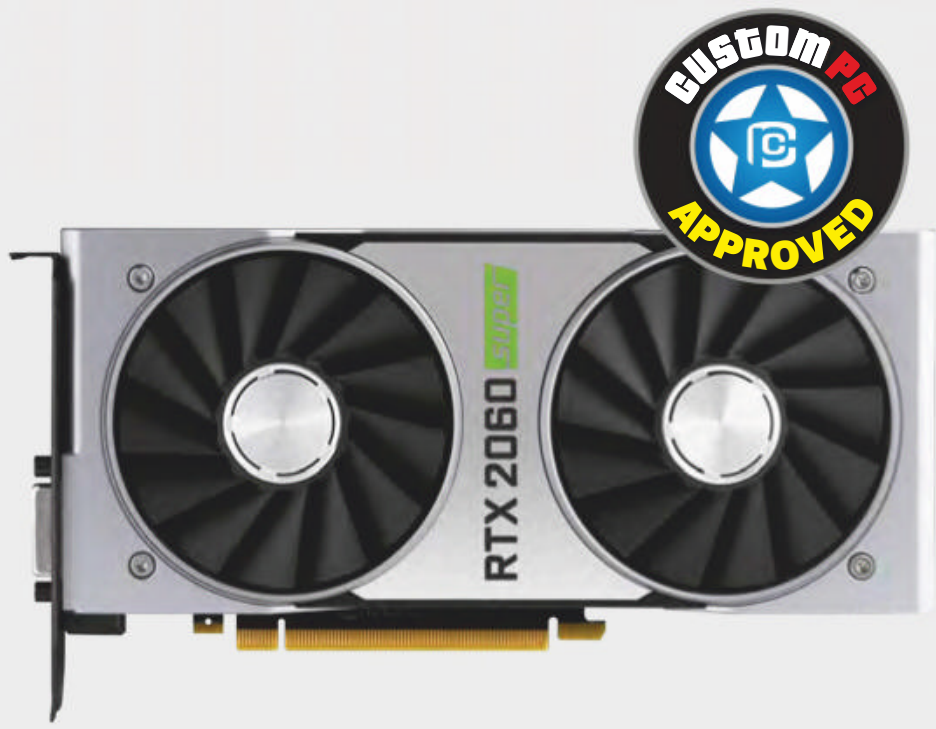
Outputs/inputs 3 x DisplayPort 1.4, 1 x HDMI 2b, 1 x USB Type-C VirtualLink, 2-way NVLink

Power connections 2 x 8-pin

Card width 210mm

Which card should I buy?

Now that we've got a good snapshot of the graphics card landscape, here are Custom PC's graphics card recommendations for various budgets



Zotac GeForce RTX 2060 Super Mini

PERFORMANCE 33/40

FEATURES 17/20

VALUE 34/40

OVERALL SCORE 84%

£351–£400
Nvidia GeForce RTX 2060 Super
/ £380 inc VAT

SUPPLIER scan.co.uk

This is where the water starts to get muddy. AMD's Radeon RX 5700 XT is undoubtedly faster than the RTX 2060 Super in most games, and it costs the same amount of money. However, at this price we expect some futureproofing, and AMD's lack of hardware ray tracing hurts it here. When Cyberpunk 2077 comes out next year, we're going to want to play it with ray tracing enabled.

That said, the line is very thin here, and we've given both GPUs the same score. If your priority is getting the fastest frame rates possible, AMD's Radeon RX 5700 XT is a better buy although, as with the RX 5700, we recommend holding out for third-party cards with quieter coolers. If you want the best graphical eye candy, though, the RTX 2060 Super is the card of choice. Unlike its predecessor, it can handle ray tracing at 2,560 x 1,440, and it's still plenty fast enough in games at 2,560 x 1,440, even if it can't quite catch the AMD competition.

Nvidia's Founders Edition, as used in our build this month (see p76), is our card of choice here for the money, although the similarly-priced Zotac Mini card also holds up well if the Founders Edition is out of stock, or if you want a smaller card.

AMD Radeon RX 5700

PERFORMANCE 32/40

FEATURES 12/20

VALUE 39/40

OVERALL SCORE 83%

£300–£350
AMD Radeon RX 5700
/ £320 inc VAT

SUPPLIER overclockers.co.uk

AMD is back with a bang! The Radeon RX 5700 is significantly quicker than the original GeForce RTX 2060 in almost every test, and it hardly consumes any more power either. It can't do hardware ray tracing, but then the RTX 2060 can only realistically do it at 1080p anyway. However, the blower coolers on the first Radeon RX 5700 cards are horribly noisy – we recommend holding out for third-party cards with quieter coolers before purchasing.

£401–£500
Nvidia GeForce RTX 2070 Super

Interestingly, the RTX 2060 Super and Radeon RX 5700 XT have basically made the original RTX 2070 redundant. You can get faster performance for less money from the AMD card, and there's little you can do with the RTX 2070 that you can't now do with the RTX 2060 Super. That means there's now a £100 gap between budgets before you get an appreciable difference for your money.

As such, the current king of the sub-£500 price league is clearly the RTX 2070 Super. It races through games at 2,560 x 1,440, and it can even handle 4K gaming if you don't mind dropping to frame rates in the mid-30s. Most importantly, it also has plenty of ray-tracing power, nearly hitting a 60fps minimum in Battlefield V with High DXR at 2,560 x 1,440.

We recommend buying Nvidia's Founders Edition of this card, which costs £475 inc VAT. Nvidia's cooler is superb, and the small overclock on the Palit Game Rock card doesn't do enough to justify the price difference. The Game Rock card is also needlessly massive. CPC

Palit GeForce RTX 2070 Super Game Rock

PERFORMANCE 39/40

FEATURES 17/20

VALUE 22/40

OVERALL SCORE 78%

AMD Radeon RX 5700 XT

PERFORMANCE 35/40

FEATURES 12/20

VALUE 37/40

OVERALL SCORE 84%

Nvidia GeForce RTX 2070 Super

PERFORMANCE 38/40

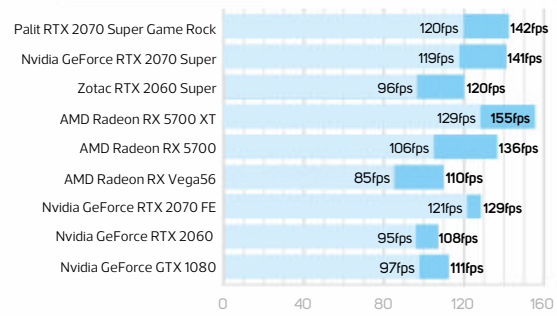
FEATURES 17/20

VALUE 26/40

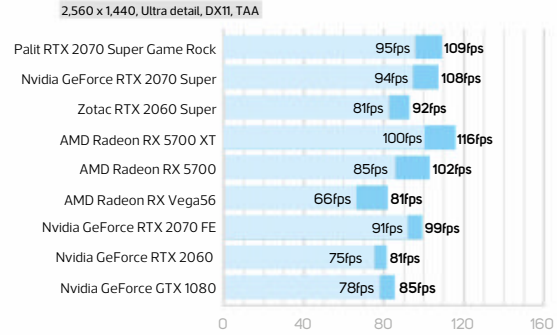
OVERALL SCORE 81%

BATTLEFIELD V

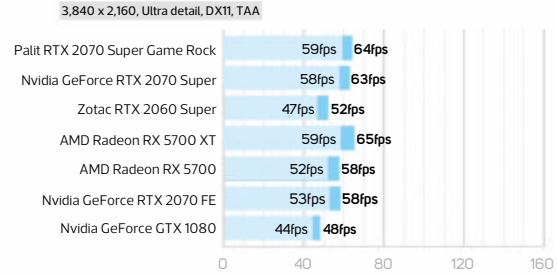
1,920 x 1,080, Ultra detail, DX11, TAA



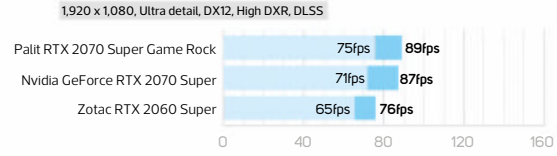
2,560 x 1,440, Ultra detail, DX11, TAA



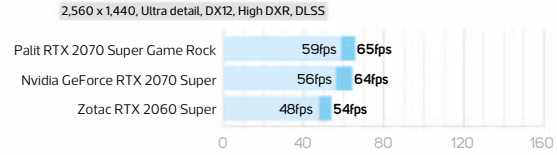
3,840 x 2,160, Ultra detail, DX11, TAA



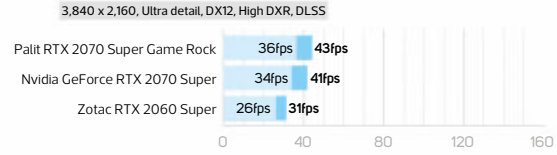
1,920 x 1,080, Ultra detail, DX12, High DXR, DLSS



2,560 x 1,440, Ultra detail, DX12, High DXR, DLSS

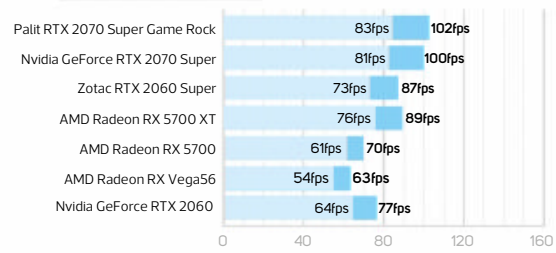


3,840 x 2,160, Ultra detail, DX12, High DXR, DLSS

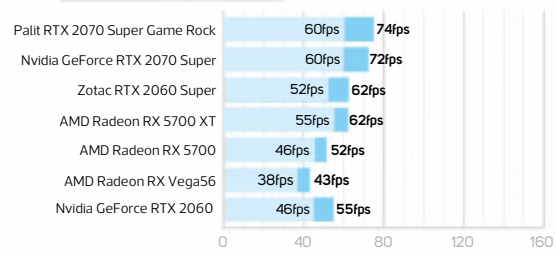


TOTAL WAR: WARHAMMER II

1,920 x 1,080, Ultra detail, DX11, TAA

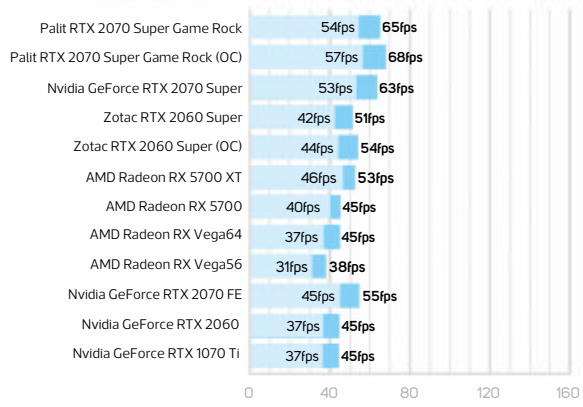


2,560 x 1,440, Ultra settings, FXAA, DX11



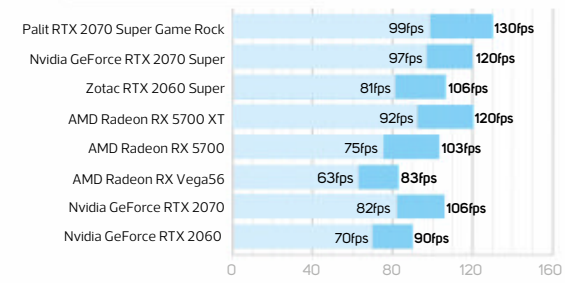
UNIGINE SUPERPOSITION BENCHMARK

4K Optimized, DirectX

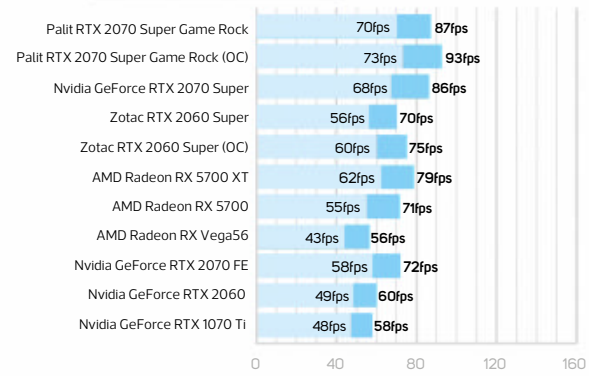


SHADOW OF THE TOMB RAIDER

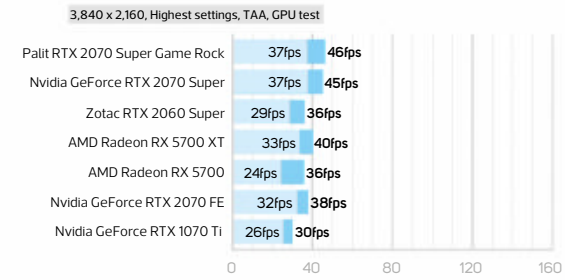
1,920 x 1,080, Highest settings, TAA, GPU test



2,560 x 1,440, Highest settings, TAA, GPU test

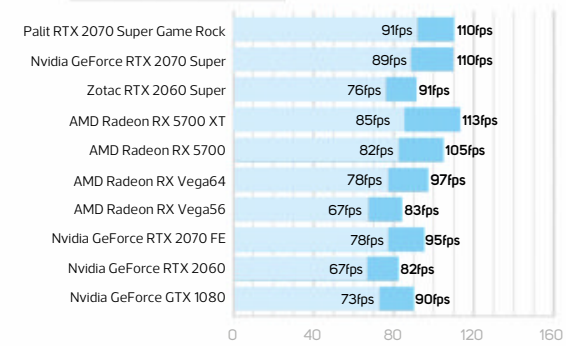


3,840 x 2,160, Highest settings, TAA, GPU test

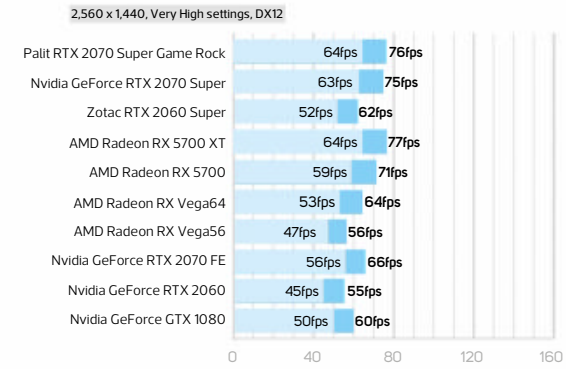


DEUS EX: MANKIND DIVIDED

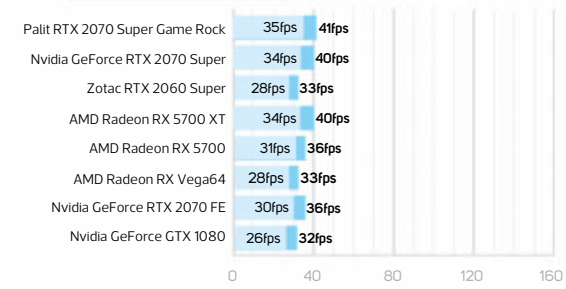
1,920 x 1,080, Very High settings, DX12



2,560 x 1,440, Very High settings, DX12

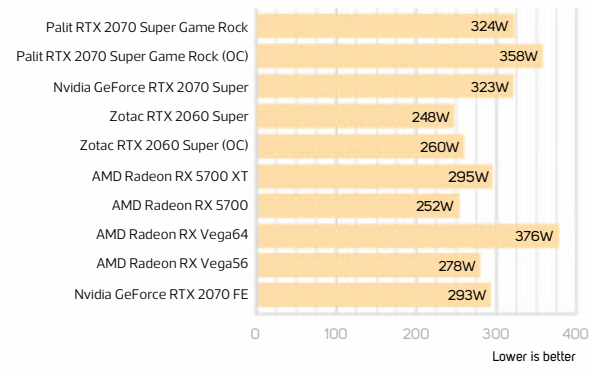


3,840 x 2,160, Very High settings, DX12



TOTAL SYSTEM LOAD POWER CONSUMPTION

Unigine Superposition Benchmark, 4K Optimized, DirectX



SOCKET AM4 PROCESSOR

AMD RYZEN 5 3600X

/ £240 inc VAT

SUPPLIER overclockers.co.uk

While AMD's 12-core Ryzen 9 3900X is undeniably awesome, the rest of the 3rd-gen Ryzen stack is no less important. After all, the Ryzen 5 2600 and Ryzen 5 2600X outstripped every other desktop CPU in terms of sales according to several retailers, and the Ryzen 5 1600 and Ryzen 5 1600X offered superb multi-threaded performance for the cash as well. As a result, the Ryzen 5 3600X's price is a key battleground for AMD.

In terms of price, the competition comprises just one CPU – Intel's Core i5-9600K, which sits £20 below the Ryzen 5 3600. The next step up is the Core i7-9700K, which will set you back around £120 more, highlighting the huge gap in Intel's current 9th-gen product stack. The AMD chip has a couple of sizeable advantages over the Intel one too.

The biggest one is the addition of Simultaneous Multithreading (SMT), giving the Ryzen 5 3600X 12 threads compared to the Core i5-9600K's six threads. Secondly, the AMD CPU comes equipped with a Wraith Spire cooler; while modest, this is more than up to the task of dealing with this 6-core CPU at stock speed, whereas you'll need to invest in a cooler to get started with the Intel CPU.

The deeper specifications paint a fairly rosy picture for AMD too. The Ryzen 5 3600X has a massive 32MB of L3 cache and, due to a pair of cores being disabled on one of if its quad-core CCX modules, it has just 1MB less total cache than the Ryzen 7 3700X. Even better, AMD has given it the same 4.4GHz maximum boost frequency of the Ryzen 7 3700X.

Interestingly, the Ryzen 5's base frequency is 200MHz higher, which points at the reason why its TDP is higher too, at 95W compared to just 65W for the Ryzen 7 3700X. The latter also had an all-core boost frequency of 4GHz, but the Ryzen 5 3600X often hits 4.1GHz in multi-threaded workloads when all six cores were under load.

Compared with its predecessors, the Ryzen 5 3600X continues to give the Ryzen 5 series a 200MHz per-generation bump to the maximum boost frequency, starting with 4GHz for the 14nm Zen Ryzen 5 1600X, 4.2GHz with the 12nm Zen+ Ryzen 5 2600X and finally 4.4GHz with the new 7nm Zen 2 CPU.

Both its predecessors only offered 16MB L3 cache as well, and there are other benefits from the Zen 2 CPU, as we covered in Issue 192. The result is a slightly higher launch price, with the Ryzen 3 3600C costing £240 inc VAT, compared to the Ryzen 5 2600C's £210.

SPEC

Base frequency
3.8GHz

Max boost frequency
4.4GHz

Core
Zen 2

Manufacturing process
7nm

Number of cores
6 x physical (12 threads)

IGP
None

Simultaneous Multithreading (SMT)
Yes

Cache
32MB L3 cache, 3MB L2 cache

Memory controller
Dual-channel DDR4, up to 3200MHz

Packaging
AMD Socket AM4

Thermal design power (TDP)
95W

Features
Precision Boost 2, Precision Boost Overdrive, FMA3, F16C, SHA, BMI / BMI1 + BMI2, AVX2, AVX, AES, SSE4a, SSE4, SSE3, SSE2, SSE

Performance

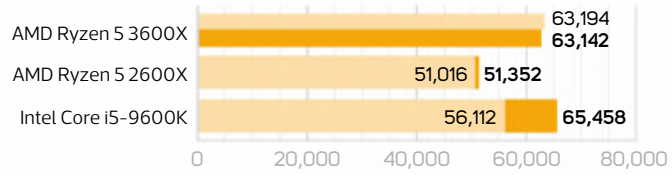
Despite its similarities to the Ryzen 7 3700X, we couldn't quite hit the same manual all-core overclock of 4.3GHz with the Ryzen 5 3600X. That was at our usual AM4 vcore of 1.425V, but even increasing this vcore to 1.44V didn't yield any benefits. In the, end we took a step down to 4.25GHz where it was perfectly stable, but that's a little disappointing given that we managed 4.2GHz with the Ryzen 5 2600X.

The new CPU's stock speed performance was stellar, though, making the IPC gains from the new architecture clear. We saw a 24 per cent boost to the single-threaded image editing test compared with the Ryzen 5 2600X – a score of 63,194 versus just 51,016. AMD also added big gains in the video encoding test too, with the score rising from 424,790 with the old Zen+ CPU to 484,128 on the new chip.

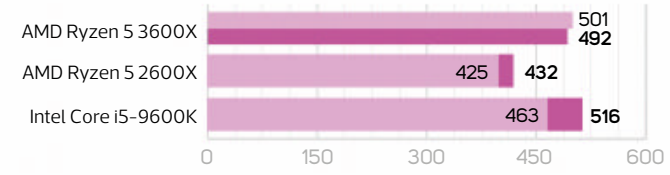
Multi-tasking was also much improved, with a 27 per cent boost over the Ryzen 5 2600X's score. The 3600X's final stock speed system score of 202,642 is in a different league to the Ryzen 5 2600X's 173,016.

BENCHMARK RESULTS

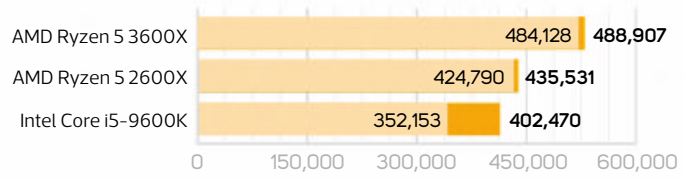
GIMP IMAGE EDITING



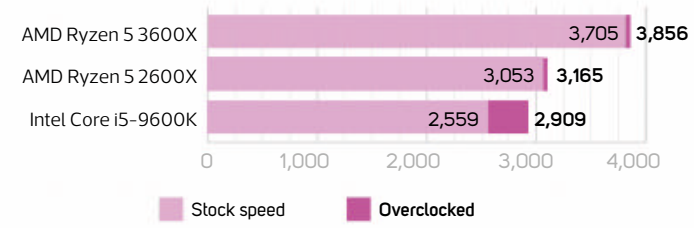
CINEBENCH R20 SINGLE-THREADED



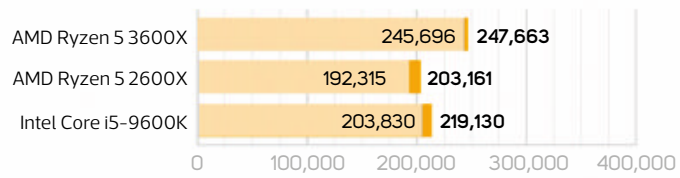
HANDBRAKE H.264 VIDEO ENCODING



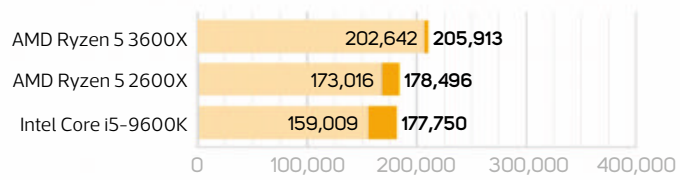
SYSTEM SCORE



HEAVY MULTI-TASKING

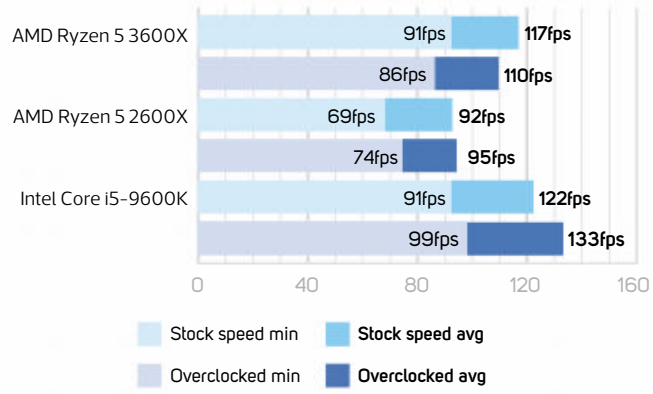


SYSTEM SCORE

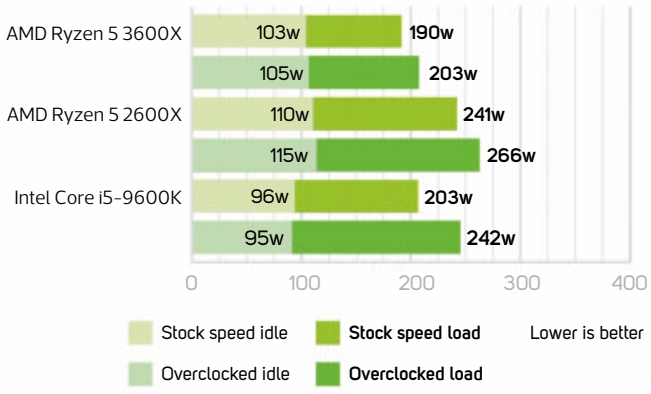


FAR CRY 5

1,920 x 1,080, Ultra settings



TOTAL SYSTEM POWER CONSUMPTION STOCK SPEED



Far Cry 5 was another night and day increase, with the minimum frame rate rising from 69fps to 91fps, all while consuming over 50W less under load. Sadly, overclocking yielded little extra performance, and the 150MHz maximum frequency deficit compared with the stock speed boost saw slower numbers in Cinebench's single-threaded test, as well as our image editing test.

Compared with the Core i5-9600K, the Ryzen 5 3600X was more than a match at stock speed, outdoing the Intel CPU in every Realbench test by huge margins. It was a similar situation in Cinebench where it even battered the Intel CPU in the single-threaded test.

At stock speed, the AMD CPU was only slightly adrift in Far Cry 5, although the Intel CPU edged out a bigger lead once overclocked to 4.9GHz. This still wasn't enough to get close to the Ryzen 5 3600X in Cinebench's multi-threaded test, or our heavily multi-threaded video encoding test though.

In these tests, the AMD CPU held a sizeable lead, although once overclocked, the Core i5-9600K is a little quicker in our image editing test and Cinebench's single-threaded test.

Conclusion

Unless you massively overclock the Core i5-9600K, Intel's offering is simply no match for the Ryzen 5 3600X, which was nearly as fast in Far Cry 5 and held massive leads in every other test. The only downside is overclocking, with the AMD CPU barely able to better its stock speed all-core boost, leading to single-threaded benchmarks being noticeably slower than the Intel chip, thanks to the AMD CPU's maximum frequency being well below its peak stock speed boost.

As a result, the 3600X is definitely a CPU that will respond better to Precision Boost Overdrive than manual overclocking. For a pure gaming system, the Intel CPU can be a little faster in some titles once overclocked, but as soon as you step outside games, the Ryzen 5 3600X tramples all over it, while it completely destroys the Ryzen 5 2600X too. The Ryzen 5 3600X is a potent all-rounder for the cash.

ANTONY LEATHER

VERDICT

A superb multi-purpose CPU and a worthy successor to the Ryzen 5 2600X.

RAGE AGAINST THE MACHINE

- \+ Excellent value
- \+ Significantly faster than 2600X
- \+ Power-frugal

RAGE QUIT

- – Overclocked Intel CPUs faster in some games
- – Little overclocking headroom

PERFORMANCE 41/50

FEATURES 15/15

VALUE 33/35

OVERALL SCORE 89%

ATX CASE

CORSAIR ICUE 220T RGB AIRFLOW / £100 inc VAT

SUPPLIER scan.co.uk

Corsair has just added another case to its arsenal of RGB-equipped models, but rather than offer yet another premium model that won't leave you with much change from £200, Corsair's iCUE 220T RGB Airflow costs just £100 inc VAT. It has solid build quality, it's available in black or white and it includes a trio of the company's SP120 RGB Pro 120mm fans.

As its name suggests, the iCUE 220T RGB Airflow isn't another tempered-glass-clad case. It offers a glass side panel, but the top and roof are ventilated, with the front section easily popping off to provide access to the filter and fans. The front panel isn't quite as open as other high-airflow cases we've seen, but the snazzy design cut into it certainly offers better airflow than a solid panel. The downside is that the trio of RGB fans in the front aren't quite as visible as they would be in a glass-fronted case, but they still glow brightly through the perforations.

The most obvious issue with the iCUE 220T RGB Airflow, though, is the lack of a rear exhaust fan. Corsair might assume you'll be adding one of its liquid coolers to this slot, but given the case's price (and name), the majority of potential owners will probably be looking at air coolers, where the lack of a rear fan will be a hindrance.

Meanwhile, the included RGB fans are already hooked up to a Lighting Node Core RGB controller, which offers control of up to six fans, with the ability to use a motherboard USB 2 header to communicate with Corsair's iCUE software. Each fan has eight individually controllable RGB LEDs, which can link to a number of lighting effects, synchronising across all the fans in series if required, while you can also manually set each LED to a specific colour.

Other components, such as RGB memory, can join the party too and, unlike Kolink's Observatory, the fans come with 3-pin connectors, so you can also control them using your motherboard. Given Corsair's prowess in the software fan and lighting control arena, you might argue the lack of integration with iCUE and the fans is disappointing, but it's fine for a case at this price. Besides, most motherboards offer excellent fan control these days anyway.

Back to the chassis itself, the iCUE 220T RGB Airflow is relatively small, not quite stretching to 40cm deep, while standing 45cm tall and 21cm wide. Even so, there's space for a 360mm or 280mm radiator in the front panel, and a 240mm model in the roof, so there's plenty of room to expand your cooling if you fancy some upgrades. However, if you do add a rear fan, only 120mm models are supported in this location. The width also means there's limited height clearance for CPU coolers, but standard-sized coolers, such as Deepcool's Gammaxx GT BK and ARCTIC's Freezer 34 Esports Duo, will fit with a few millimetres to spare.

Your typical PC enthusiast won't find much lacking with the iCUE 220T RGB Airflow. It has a fairly typical front panel, offering two USB 3 ports, an audio jack, plus power and reset buttons. Meanwhile, inside there's space for two hard disks and a pair of 2.5in SSDs, although the latter lack tool-free mounts, unlike the hard disks. Dust filters are present in the base, front and roof of the case, and all are easily accessible too.

SPEC

Dimensions (mm)
210 x 395 x 450 (W x D x H)

Material
Steel, plastic, tempered glass

Available colours
Black, white

Weight
6.5kg

Front panel
Power, reset, 2 x USB 3, headphone/mic

Drive bays
2 x 3.5in, 2 x 2.5in

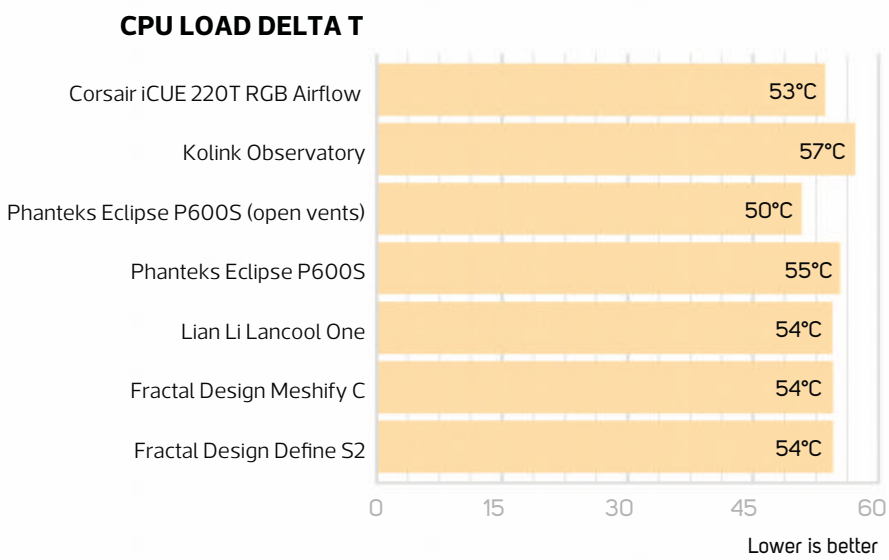
Form factor(s)
ATX, micro-ATX, mini-ITX

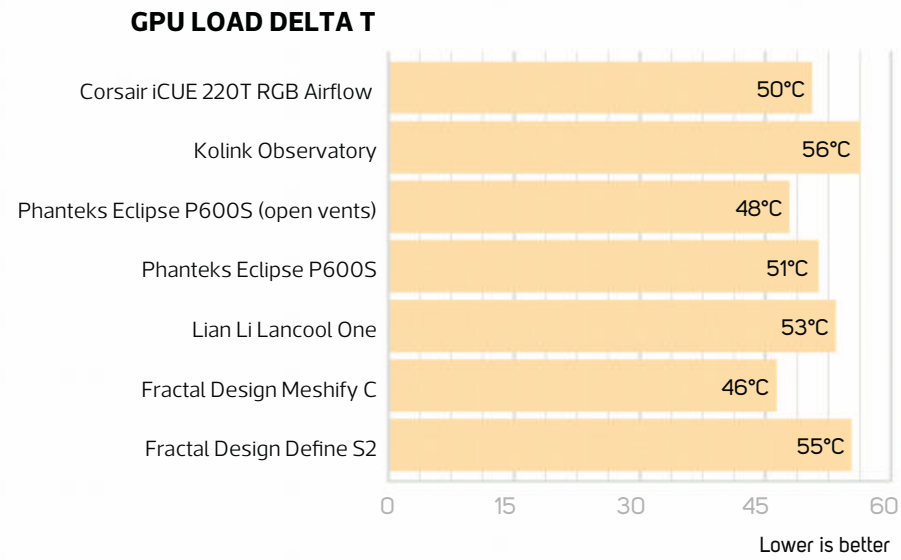
Cooling
3 x 120/2 x 140mm front fan mounts (3 x 120mm fans included), 2 x 120mm/140mm roof fan mounts (fan not included) 1 x 120mm rear fan mounts (fan not included

CPU cooler clearance
160mm

Maximum graphics card length
300mm

TEMPERATURE RESULTS





Meanwhile, a full-length PSU cover means cables can be tucked in front of your PSU, but there's also an excellent array of cable tie anchor points and cable-routing holes. The lower chamber's hard disk cage is fairly basic, with pull-out, tool-free trays, but it does the job. However, it will need to be removed if you want to mount a 360mm radiator in the front. One notable omission, though, is the lack of a vertical graphics card mount, which is included with some of Corsair's other ATX towers, such as the Obsidian 500D.

Performance

Corsair's SP120 RGB Pro 120mm fans are reasonably powerful at their full 1,400rpm speed, but are fairly restrained when it comes to dishing out decibels. However, thanks to the case's porous front end, if you're noise-sensitive, you'll definitely want to tune down the fans using your motherboard when temperatures are low enough. The three included fans and vented front end certainly seemed to help the iCUE 220T RGB Airflow deal with our test gear, with the CPU delta T of 53°C being 1°C cooler than the Fractal Design Meshify C.

The Phanteks Eclipse P600S shows what a proper vented front end and rear exhaust fan can do, though, as it knocked a further 3°C off that temperature with its front vent open. The Corsair's GPU delta T of 50°C comes close to matching the Phanteks case, though, and it's better than the results from closed-front cases, such as the Kolink Observatory and Fractal Design Define S2. However, the Fractal Design Meshify C was a couple of degrees cooler.

Conclusion

If you want a case that offers decent cooling as well as RGB lighting for £100 or less, the Corsair iCUE 220T RGB Airflow makes a strong argument for pointing your wallet in its direction. It's a solid-feeling case with most of the usual conveniences you'd expect from an enthusiast case in this price bracket, and its unique front panel sets it apart from the usual black boxes.

However, the same can also be said of the Lian Li Lancool One Digital, which costs the same and adds aluminium and USB Type-C ports to the mix, as well as better water-cooling support, although it can't quite match the Corsair cases' thermals. We'd opt for the Lancool One Digital as our case of choice in this price bracket, but the iCUE 220T RGB Airflow still comes recommended if airflow is a top priority for you.

ANTONY LEATHER

VERDICT

Great cooling and a snazzy front panel for a fair price, although it's up against some strong competition.

AIR FORCE

+ Good value
+ Full digital RGB lighting
+ Decent cooling

AIR BED

- No exhaust fan
- No USB Type-C ports
- Limited CPU cooler clearance

COOLING 26/30

FEATURES 14/20

DESIGN 25/30

VALUE 18/20

OVERALL SCORE 83%

PCI-E 4 NVME SSD

CORSAIR MP600

/ £250 inc VAT

SUPPLIER scan.co.uk

IOPS

+ Supremely fast
+ Heatsink keeps temperatures in check
+ Not much more expensive than PCI-E 3 SSDs

EYE OPS

- Unlikely to see many real-world benefits
- PCI-E 4 speed requires X570 motherboard

When M.2 hit the scene a few years ago, we were thankful for this brilliant interface that cuts cable clutter, and it's made storage one of the focal points of cutting-edge hardware. Nowhere more so, in fact, than with AMD's new X570 motherboards, which support PCI-E 4. What's more, the storage industry has managed to galvanise the production of PCI-E 4 NVMe SSDs to launch at the same time, partly thanks to a $15 million US investment from AMD. That's just as well, because there are precious few other reasons to opt for an X570 motherboard, apart from some admittedly very fancy board designs.

This month we're looking at one of a handful of PCI-E 4 SSDs to already hit the market, and Corsair was one of several companies to hit the ground running, with its MP600 added to AMD's 3rd-gen Ryzen press packs. It looks minimally attractive too, with its big black heatsinks being more likely to complement a motherboard than the stark bare copper on the similar Aorus product we saw last month (see Issue 192, p20).

It's available in 1TB and 2TB capacities – sadly, no capacities south of 1TB seem to be on offer yet. Like most of the other PCI-E 4 SSDs on sale, it uses the Phison PS5016-E16 controller, combined with a DRAM cache and 3D TLC NAND. With four PCI-E lanes available, PCI-E 3 has a theoretical maximum bandwidth of 4GB/sec (32Gb/sec), but PCI-E 4 boosts this figure to 8GB/sec (64Gb/sec).

In terms of claimed speeds, Corsair states up to 4,950MB/sec for reads and 4,250MB/sec for writes, with respective IOPS figures of 680,000 and 600,000. The former might suggest a reason for the large combined top and bottom heatsinks included with these new SSDs, but in fact, power consumption has been shown to be roughly in line with PCI-E 3 models, and it's the X570 chipset that's the cause of the higher power consumption figures people have reported. Our model stayed between 50-60°C under load using the included heatsink. Corsair also states an endurance figure of 1,800TBW, which is three times that of Samsung's 1TB 970 Evo Plus.

Using CrystalDiskMark, our 1TB version of the Corsair MP600 dished out a peak read and write speed of 5,008MB/sec and 4,268MB/sec respectively – clearly blisteringly quick performance for those big file transfers, and numbers that stand around 40 per cent higher than your typical PCI-E 3 NVMe M.2 SSD. The 4K random QD32 test was significantly faster too, with read and write figures of 1,666MB/sec (406K IOPS) and 1,489MB/sec (364K IOPS). That compares to 1,281MB/sec and 1,238MB/sec for Samsung's 970 Pro 512GB.

Conclusion

We're clearly dealing with a step change in performance with PCI-E 4 SSDs and, to AMD's credit, drives such as the Corsair MP600 help to offer that extra level of excitement that will no doubt tempt affluent enthusiasts over to its X570 platform. If you're not intending on opting for an X570 motherboard, though, the likes of Samsung's 970 Evo Plus costs around £40 less for the same capacity

Also, bear in mind that the extra performance on offer from the MP600 is unlikely to be noticeable in real-world use outside of large file transfers. However, seeing as you get 40 per cent extra performance in these scenarios for not much more money, we'd pay the extra cash if we were building an X570 rig.

ANTONY LEATHER

PERFORMANCE 48/50

FEATURES 18/20

VALUE 23/30

OVERALL SCORE 89%

VERDICT

A ludicrously fast SSD, although you'll only really use the extra performance in large file transfers.

NEW

Wireframe

Join us as we lift the lid on video games

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PCI-E 3 NVME SSD

SEAGATE FIRECUDA 510 / £225 inc VAT

SUPPLIER overclockers.co.uk

Hard drive behemoth Seagate has recently returned to the SSD market, with its new Firecuda NVME drives available in capacities of 1TB or 2TB, with stated maximum sequential read and write speeds of 3,450MB/sec and 3,200MB/sec respectively.

You can also get lower-capacity versions of essentially the same drive, but Seagate has branded these drives with the Barracuda name, in line with the reduction in performance that comes with lower capacities. Available in 256GB and 512GB models, they offer almost the same stated read speed of 3,400MB/sec, but the write speed drops to 2,180MB/sec on the 512GB model and just 1,050MB/sec on the 256GB version.

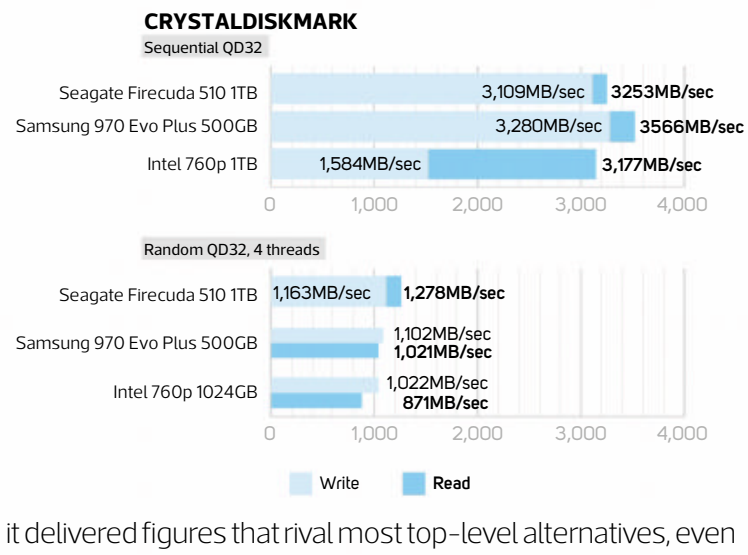
The drives are governed by a Phison E12 NVMe controller, which has four cores and features up to eight NAND channels and 32 NAND chip-enable (CE) lines. While we've seen the introduction of PCI-E 4 with AMD's X570 platform, as well as supporting drives (see p26), the Phison E12 is a PCI-E 3 controller. It's partnered with Toshiba's latest 64-layer 3D TLC NAND, with four modules used to create this 1TB drive. Unlike some M.2 SSDs, these modules are mounted on both sides of the drive, although this shouldn't affect any PC installations.

For each 1TB of storage, the drives use 1MB of DRAM cache. The use of TLC NAND also necessitates using some of the NAND function as an SLC cache to maintain high write speeds. This cache is dynamic, so your exact sustained write speed will depend on how much data is stored on the drive, but its base level is 28GB, which is plenty for most sustained write operations.

Of course, the use of TLC NAND also marks this drive as being not entirely suited to sustained seriously heavy workloads. However, that's not a concern outside of very specialist heavy-duty scenarios. There's also no hardware encryption. On the plus side, Seagate states a plentiful write endurance of 1,300 total terabytes written (TBW) and the drive has a five-year warranty.

However, when it comes to performance, the Firecuda 510 impresses. In CrystalDiskMark, it was just a little shy of Seagate's performance claims for sequential speeds, but still essentially maxed out the limitations of PCI-E 3. Likewise, in AS-SSD, it delivered figures that rival most top-level alternatives, even if it couldn't quite catch the Samsung SSD 970 Evo Plus.

As for random read/write performance, it also kept pace with other high-end rivals, even outperforming the Samsung 970 Evo Plus. During a sustained write test, the dynamic SLC cache held up well, delivering a consistent 1.8GB/sec speed for a 200GB write.



SPEC

Form factor
M.2 2280

Interface
4x PCI-E 3

Connection standard
NVMe

NAND
Toshiba 64-layer 3D TLC

Controller
Phison PS5012-E12

Write endurance
1,300TBW

Warranty
Five years

Capacities
1TB, 2TB

Conclusion

When it comes to performance, this drive doesn't disappoint, although its reliance on PCI-E 3 already puts it behind the very latest competition. There are also no extras, or hardware encryption, all of which makes it difficult to justify the price – the 1TB Samsung 970 Evo Plus currently goes for £200 inc VAT, and faster PCI-E 4 drives only go for £250 inc VAT now. The Firecuda 510 is good, but it needs to be cheaper in this highly competitive field.

EDWARD CHESTER

VERDICT

Competitive PCI-E 3 performance, but the price is too high.

TOASTY

+ Great performance
+ Clever dynamic write caches

TEPID

– Overpriced
– No hardware encryption

PERFORMANCE 40/50

FEATURES 16/20

VALUE 19/30

OVERALL SCORE 75%

GAMING MONITOR

MSI OPTIX MAG321CURV

/ £449 inc VAT

SUPPLIER amazon.co.uk

Measuring 31.5in from corner to corner, MSI's Optix MAG321CURV is large enough that you can just about use the screen at its native 4K resolution without using Windows scaling options. If that's a stretch too far, you can also get away with scaling it up by just 125 per cent, or you can enjoy a large, easy-to-read experience running at its default scaling level of 150 per cent.

MSI has equipped this monitor with a VA-type LCD panel, which provides it with a high native contrast ratio of 2,500:1. This contrast ratio, combined with the large screen size, makes it particularly well suited for sitting back and enjoying video or playing certain games.

Add support for an extended colour range (81 per cent DCI-P3), and the MSI can deliver a form of HDR. It's not the most dazzling HDR mode we've ever seen, but the extended colour range does add a bit of extra zip. Crucially, MSI hasn't made the mistake of having the screen run at its extended colour range all the time, unlike some HDR displays. As such, when you're using the display for non-HDR software, colours still look correct and not overly saturated.

Indeed, overall image quality from this display is surprisingly good, although not perfect. The contrast exceeds the figure quoted by MSI – the colour temperature only deviated from the ideal 6,500K figure by 78 (dropping to 41 when calibrated), and the average delta E 2000 figure of 0.2 shows solid colour accuracy. The Colour balance is all but perfect, plus the gamma measurement of 0.01 is close to ideal too. However, there's a slightly washed-out look to the image, particularly when the display is corrected with calibration software, resulting in compressed, patchy-looking colours. It's fine for general use but not ideal for image and video editing.

MSI has done an excellent job with most other aspects of the screen. It looks smart, with its gently curved display, incredibly thin bezels and elegant metal stand, and it offers plenty of features too. You get one DisplayPort input, two HDMI ports and even USB Type-C for video inputs, along with a two-port USB hub on the back. The stand also offers height, rotation and tilt adjustment, so it's easy to get the display set up. Meanwhile, the on-screen display system is easy to navigate, via a single mini-joystick on the back of the display, and it has all the options you'll need.

So far, so good, but there's one major downside to this display, which is that it's limited to a refresh rate of just 60Hz. The addition of FreeSync helps to keep frame rates smooth when used with AMD graphics cards, but there aren't many AMD GPUs that can handle 4K gaming (G-Sync support would be more useful here), and the overall responsiveness of the screen isn't great. It's fine for slower-paced games but not for competitive players of fast-paced first-person shooters.

SPEC

Screen size
31.5in

Resolution
3,840 x 2,160

Panel technology
VA

Maximum refresh rate
60Hz

Stated response time
4ms

Stated contrast ratio
2,500:1

Display inputs
1 x DisplayPort 1.2, 2 x HDMI 2, 1 x USB Type C

Audio
No

Stand adjustment
Height, rotation, tilt

Extras
Rear RGB lighting

VISION

+ Good price
+ Decent overall image quality
+ Great balance of resolution and size

DERISION

– No G-Sync support
– Basic gaming performance
– HDR underwhelming

Conclusion

The Optix MAG321CURV is a decent-quality screen for a competitive price. It's particularly good if you just want a big panel to sit back and enjoy watching video, or for playing slower-paced games in full 4K detail. However, the 60Hz refresh rate and lack of G-Sync support means it's limited as a true gaming screen, while other monitors are better for professional use.

EDWARD CHESTER

VERDICT

A big 4K monitor at a great price, but it comes with compromises.

IMAGE QUALITY
20/30

GAME PERFORMANCE
24/30

FEATURES
14/20

VALUE
17/20

OVERALL SCORE
75%

PC Specialist recommends Windows

Windows 10

PROTEUS VI RTX

15.6" Matte Full HD IPS Screen
Intel® Core™ i7-8750H
16GB Corsair 2133MHz
8GB GeForce RTX 2070
1TB SEAGATE 7mm SATA HDD (7,200)
Genuine Windows 10 Home

This spec from
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VORTEX ELITE

PCS 6003B BLACK GAMING CASE
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ASUS® H310M-A
8GB Corsair VENGEANCE 2400MHz
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15.6" Matte Full HD IPS 144Hz Screen
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8GB GeForce RTX 2070 Max-Q
1TB SEAGATE 7mm SATA HDD (7,200)
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CORSAIR OBSIDIAN 500D RGB
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ASUS® PRIME A320M-K
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VR GAMING HEADSET

OCULUS QUEST

/ £399 inc VAT (64GB) **/ £499** inc VAT (128GB)

SUPPLIER oculus.com

Virtual Reality represents the pinnacle of full-immersion gaming, but its practicalities have stymied Neuromancer-like fantasies of literally stepping into Cyberspace. The necessity to plug your headset into a powerful PC, and own large spare room for regular VR gaming, has limited its appeal. One solution is the Oculus Quest, an entirely standalone headset that essentially acts as a portable console you wear on your face.

There are no cables tethering you to your PC, no external sensors to set up around your room. It's the closest VR has come to 'pick-up-and-play' yet – a liberating and greatly improved experience that ,while not quite revolutionary, demonstrates the future VR must embrace if it's to become a standard mode of play.

Specs

While the Quest's design focus is usability, the headset also provides greater visual clarity than the original Rift. Chiefly, its OLED display panel operates at a resolution of 1,440 x 1,600 per-eye, compared to the Rift's 1,080 x 1,200 pixels per eye. The Quest has a slower refresh rate, however, at 72Hz compared to the Rift's 90Hz.

A Qualcomm Snapdragon 835 system-on-chip (SoC) is built into the headset, incorporating four Kryo 280 Gold cores running at 2.45GHz, and four Kryo 280 Silver cores running at 1.9GHz – both core types are based on the ARM Cortex-A73 microarchitecture. The SoC also includes an Adreno 540 GPU (Adreno is Qualcomm's name for the Imageon tech it bought from AMD) with a unified shader architecture and 256 ALUs. Integrated speakers also replace the Rift's built-in, flip-down headphones.

There's a 64GB version and a 128GB version, the latter of which, at £500, costs £100 more than the 64GB. This isn't much money, but as VR games tend to be small, and you only need up to 12 games on the system at any one time – the 64GB version is still fine.

Clearly, the Quest is less powerful than any headset that connects directly to a PC, but the added visual quality of the displays (at least when compared with the Rift) compensates for that lack of graphical prowess. The Quest is also the first VR headset with six degrees of freedom for both head and hand tracking. Rather than using external sensors, the Quest tracks motion through four on-board, wide-angle cameras placed at each corner of the headset.

Setup

The Quest arrives in a small box containing the headset, two redesigned Oculus Touch controllers, a USB-charging cable and attachable plug, plus four AA batteries for the Touch controllers, two of which are spares. The Quest must be charged out of the box, although the cable is long enough to enable use while charging.

Set up is performed mainly through the Oculus smartphone app, which connects via Bluetooth. The process takes you through system updates, pairing the controllers, calibrating your floor height and drawing the boundaries of your play space. The latter is achieved by viewing your room through the headset cameras and using the controllers to 'paint' the boundary.

You'll be ready to play in around 20 minutes, although you still need to download your games, and you may have to wait closer to an hour if you want a fully charged battery, Nonetheless, the lack of external sensors makes it a pain-free process.

Wearing the device

The Quest is 100g heavier than the Rift, but that's a small increase given the additional hardware. Plus, unlike the Rift, the Quest doesn't have a heavy cable pulling down on the left side of your head. The HMD's frame system is similar to that of the Rift. It distributes the weight across the entire head and can be adjusted with Velcro straps at the temples and crown.

Its size is similar to the Rift, but the Quest is aesthetically sleeker, with a surface coated in soft fabric and a smooth, more rounded eyeplate.

The Quest is generally comfortable to wear, although it does make you sweat around the eyes. One small problem is that the seal isn't perfect. There is a small but noticeable gap at the base that lets light into your vision.

The redesigned Touch controllers are 30g lighter than the Rift ones. The distinctive circular band no longer wraps around your hand, instead encircling your thumb over the controller's buttons and analogue stick. There's a textured grip along the back of the handle, while the 'grip' button – used mainly for picking up objects – has been moved to a more natural 'gripping' position. The decreased weight is welcome, but we found the controllers less intuitive in the hand. Moreover, the new vinyl safety straps are fiddly compared with the string cords of the originals.

Entering VR

Upon entering VR , the first noticeable difference compared with the Rift is the clearer picture. The 'screen-dooring' effect that plagued 1st-gen headsets is now hardly an issue, while in-game objects remain sharp at short and medium-range distances (long-distance objects can still look a little blurry).

The other notable difference is the sense of liberation. With no external sensors, there's no risk of stepping outside the sensors' vision and suddenly finding yourself paralysed in VR-space, or your vision clipping as the device becomes unable to read your direction. There's an additional benefit, which is that the Quest is portable. As long as your games are installed, you can set up and play in any room, or even outdoors.

You just need to redraw the boundaries of your play area.

All told, it's a smooth, seamless experience, offering all the immersive magic of VR with far fewer limitations or frustrations. The only real negative is that the battery lasts only two hours. You can play it while it's charging, but that negates the benefit of being completely wireless.

Conclusions

The Quest represents a marked step forward for VR, despite the lack of PC hardware. The convenience is great, and the high-resolution display is sharp.
The new Touch controllers are less intuitive than those of the Rift, but the reduced weight makes them easier to use over longer periods.

However, the Quest's gaming library is currently quite limited, especially if you already own a Rift. Most of the best games are the same as those on the Rift, and many, such as Superhot and Job Simulator, aren't cross-buy enabled, so you have to buy them again to play them on the Quest. There are more Quest apps coming, but it will be a while before the device has a library to match the Rift.

If you're already a VR enthusiast with a dedicated play space, the Quest isn't really a worthwhile investment. If, however, you don't own a VR headset yet, the Quest offers a good balance of price, accessibility and power.

RICK LANE

QUEST

+ Simple setup
+ Wireless VR is transformative
+ Improved picture clarity

ERRAND

− Short battery life
− New controllers less intuitive
− Not enough new games at launch

VERDICT

The most accessible VR gaming platform yet, the Quest frees players from the shackles of wires and sensors, while still providing an immersive experience.

OVERALL SCORE

85%

GAMING PC

SCAN 3XS VENGEANCE RTX TI / £3,199 inc VAT

SUPPLIER scan.co.uk

Scan's 3XS Vengeance RTX Ti is expensive and imposing, which is no surprise considering the hardware inside. The 3XS is built around AMD's flagship Ryzen 9 3900X. It's a formidable chip based on AMD's Zen 2 microarchitecture, and built on a 7nm manufacturing process. It has 12 cores (and 24 threads via SMT), and a mighty 64MB of L3 cache.

It ordinarily runs at 3.8GHz, but Scan has overclocked the chip across all cores to 4.3GHz. That's below the 4.6GHz boost achieved on some cores, but it's better than the CPU's all-core boost peak of around 4.1GHz. AMD's new chip competes with Intel's top chips, such as the 8-core i9-9900K.

That CPU last appeared in the £3,300 Overclockers UK Radiance Pro (see Issue 191, p38), which overclocked that CPU to 5GHz.

Scan has locked the 3900X inside an Asus ROG Strix X570-F Gaming motherboard. The inclusion of AMD's newest X570 chipset means you get PCI-E 4 support, and the board is stocked with large heatsinks, RGB LEDs, plenty of USB connections and spare SATA and M.2 connectors. There's SLI support and enough bandwidth to add a second GPU too.

On the I/O backplate, you'll find five USB 3.1 Gen 1 ports, a Type-C port and a BIOS flashback button. Overall, the board isn't missing much – there are no on-board buttons or Wi-Fi, but that's it. The high-end hardware continues elsewhere. There's no hard disk – instead, Scan has made full use of the X570 chipset's PCI-E 4 support by deploying a 2TB Corsair MP600 (see p26 for our review of the 1TB version).

Meanwhile, the CPU is paired with 32GB of memory clocked to 3200MHz, and the Corsair power supply serves up 1,000W of power – ideal for adding a second GPU, a solid 80 Plus Gold rating and modular design.

It's a killer spec for heavily multi-threaded content creation work, but Scan's Ryzen-based rig is also able to handle high-end gaming. An EVGA GeForce RTX 2080 Ti card pairs the usual 4,352 stream processors and 11GB of memory with Nvidia's 1545MHz boost clock. It's Nvidia's top-spec gaming GPU, and it should make this machine very fast in games.

The hardware is packed inside a vast Corsair Crystal 680X RGB case. Its width of 344mm makes it nearly 150mm wider than most enclosures. It looks superb, with tempered glass side, front and roof panels, and there are synchronised RGB LEDs on the fans, memory, graphics card and CPU cooler.

The Corsair's width enables a dual-chamber design. The PSU is installed vertically behind the motherboard tray, and the extra space means the Corsair has tool-free cages for three 3.5in drives and four 2.5in drives. Scan has kept the whole interior neat, and the extra space means plenty of room to work.

Plus, as usual, you get Scan's excellent warranty, which includes a full three years of parts and labour coverage, complete with a year of on-site service.

SPEC

CPU
3.8GHz AMD Ryzen 9 3900X overclocked to 4.3GHz

Motherboard
Asus ROG Strix X570-F Gaming

Memory
32GB Corsair Vengeance RGB Pro 3200MHz DDR4

Graphics
EVGA GeForce RTX 2080 Ti

Storage
2TB Corsair MP600 M.2 SSD

Case
Corsair Crystal 680X RGB

Cooling
CPU: Corsair Hydro H100i RGB Platinum with 2 x 120mm fans; GPU: 2 x 90mm fans; front: 3 x 120mm fans; rear: 1 x 120mm fan

PSU
Corsair RM1000x

Ports
Front: 2 x USB 3.1, 1 x USB 3.1 Type-C, 2 x audio; rear: 4 x USB 3.1 Gen 1, 2 x USB 3.1 Gen 2, 1 x USB 3.1 Gen 2 Type-C, 1 x Gigabit Ethernet, 1 x optical S/PDIF, 5 x audio

Operating system
Microsoft Windows 10 Home 64-bit

Warranty
Three years parts and labour. First year on site, then return to base

Performance

The Ryzen 9 3900X is tremendous. In our heavily multi-threaded Handbrake video-encoding test, its score of 813,573 was more than 200,000 points beyond the Core i9-9900K in the aforementioned Overclockers PC, and the Scan's overall system score of 293,352 is nearly 60,000 points beyond the same machine.

AMD has a clear advantage over Intel in multi-threaded apps, so the Scan will be far better with work applications and creative software. It's just as quick as Intel in single-threaded tasks and gaming. Impressively, the overclocked Scan also beat the Intel-based Overclockers machine in our

BENCHMARK RESULTS

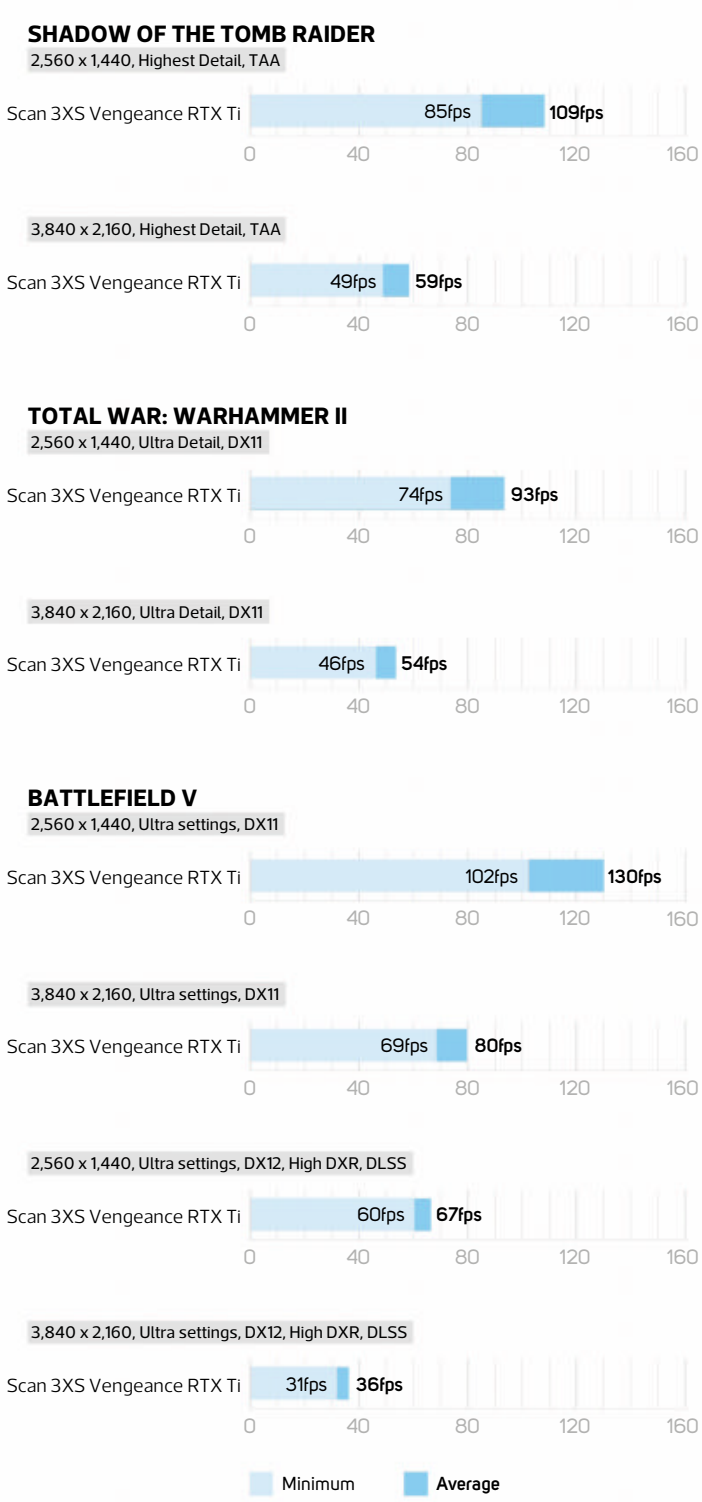
60,379 GIMP IMAGE EDITING

813,573 HANDBRAKE H.264 VIDEO ENCODING

152,528 LUXMARK OPENCL

268,594 HEAVY MULTI-TASKING

293,352 SYSTEM SCORE



single-threaded image editing test. With its RTX 2080 Ti GPU, it also ripped through our gaming benchmarks.

It never drops below 60fps in any of our tests at 2,560 x 1,440, even if you run Battlefield V with ray tracing enabled and set to High. It drops down to a 31fps minimum with these settings at 4K, which is borderline playable, but the rest of its 4K frame rates are superb.

Meanwhile, the Corsair PCI-E 4 SSD delivered read and write speeds of 4,906MB/sec and 4,178MB/sec respectively. That's incredible speed – more than 1,000MB/sec faster than the best PCI-E 3 SSDs, although you're only likely to see it in large file transfers.

However, thermal performance is mixed. The Scan's GPU delta T of 50°C is fine, but the CPU load delta T of 66°C is very high, even if it technically meant the CPU was just within thermal limits. It's not quiet either. The Corsair Hydro H100i cooler produces more noise than most other machines when idle at Scan's settings, and it steps up further when gaming, or in a full-system stress test.

Headsets and speakers might cover the noise during a gaming session, but the Scan is never quiet and could prove irritating if you want a quiet PC – you'll at least want to put it under your desk rather than on top of it.

Conclusion

Still, this PC isn't designed for subtlety. The AMD CPU delivers amazing multi-threaded power, and the gaming performance is amazing. Likewise, the 2TB PCI-E 4 SSD is huge and fearsomely quick, the memory is excellent, and the motherboard and PSU are great. The case has loads of space for spare storage too.

The noise is irritating, though, and this specification is also overkill for many people. If you just want a PC for gaming, you don't need to spend extra on a 12-core CPU. If you want a PC that does it all, though, this is a fast PC with a top-tier spec.

MIKE JENNINGS

ZEN

+ Incredible CPU pace
+ Solid gaming abilities
+ Record-breaking PCI-E 4 SSD

CHAOS

- Irritating noise
- Expensive
- Overkill for many people

PERFORMANCE 24/25

DESIGN 21/25

HARDWARE 22/25

VALUE 19/25

OVERALL SCORE 86%

VERDICT

Enormous speed for both content creation in gaming, but it makes a fair bit of noise.

GAMING PC

CYBERPOWER ULTRA 5 SUPER / £1,179 inc VAT

SUPPLIER cyberpowersystem.co.uk

CyberPower's Ultra 5 Super is the first PC we've seen with a new Nvidia RTX 2060 Super GPU (see p16), which is designed to provide a significant boost over the previous RTX 2060. It has 2,176 stream processors, compared to the original GPU's 1,920, and the 2,304 in the original RTX 2070. The Founders Edition card in the CyberPower. It also comes with 8GB of memory, rather than 6GB.

The card in the CyberPower is an Nvidia Founders Edition, with a 1470MHz base clock and 1650MHz boost frequency. The RTX 2060 Super also compares well with the AMD Radeon RX 5700, which has comparable performance for the money but no hardware ray-tracing abilities.

The RTX 2060 Super isn't the CyberPower's only new silicon either – this machine also has a Ryzen 5 3600, which has six SMT-enabled cores (giving it a total of 12 threads – alongside base and boost clocks of 3.6GHz and 4.2GHz. It's a core spec that compares well with Novatech's £1,349 Reign Sentry MKI (see Issue 192, p40), which had a Core i5-9600K with no Hyper-Threading, as well as a standard RTX 2060 graphics card.

The CPU slots inside an MSI B450-A Pro. It's not an X570 motherboard, but that's no surprise at this price. The older chipset means you lose out on PCI-E 4, but you can still run the new CPUs fine. Elsewhere, the MSI is a modest board though. It has two spare memory slots and some free 1x PCI-E slots, but its sole M.2 connector is occupied and its second 16x PCI-E slot only runs at 4x speed.

It has entry-level Realtek ALC892 audio and no Wi-Fi either, although CyberPower has thoughtfully added a separate card for the latter. At the rear you get pairs of USB 3.1 Gen 1 and Gen 2 ports, but no Type-C ports and no optical S/PDIF either.

Elsewhere, CyberPower has installed 16GB of 3000MHz DDR4 memory, and you also get a 2TB hard drive and a 512GB Intel 600p SSD. The latter is a PCI-E 3 NVMe drive that's much quicker than a SATA drive, but no match for Samsung's 970 Evo Plus drives, or the latest PCI-E 4 drives for that matter.

Meanwhile, power comes from a 600W Cooler Master unit. It's not modular, and it only has entry-level 80 Plus certification, but it has more than enough power for the spec. CyberPower's case comes from Cooler Master too. It's a MasterBox MB511, and it looks conventional: it has a meshed front panel with three 120mm fans, a magnetic dust filter on the roof and a see-through side panel.

SPEC

CPU
3.6GHz AMD Ryzen 5 3600

Motherboard
MSI B450-A Pro

Memory
16GB Corsair Vengeance LPX 3000MHz DDR4

Graphics
Nvidia GeForce RTX 2060 Super 8GB

Storage
512GB Intel 600p M.2 SSD, 2TB Seagate Barracuda hard disk

Case
Cooler Master MasterBox MB511

Cooling
CPU: Cooler Master MasterLiquid Lite 120 with 1 x 120mm fan; GPU: 2 x 90mm fans; front: 3 x 120mm fans

PSU
Cooler Master MasterWatt Lite 600W

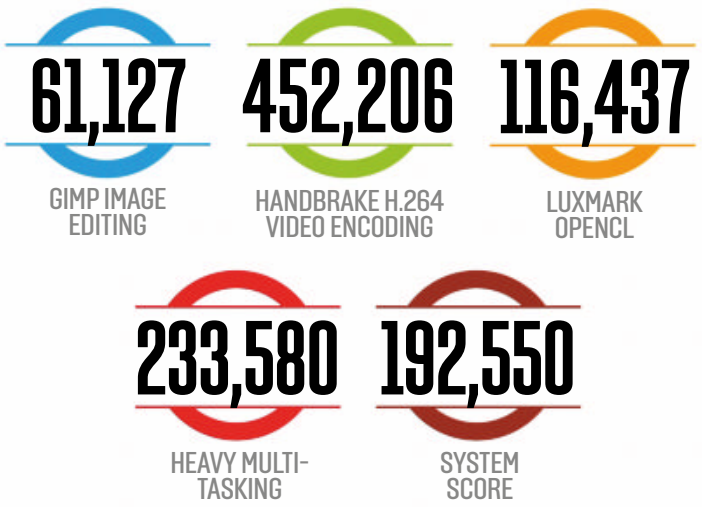
Networking
Gigabit Ethernet, dual-band 802.11ac Wi-Fi

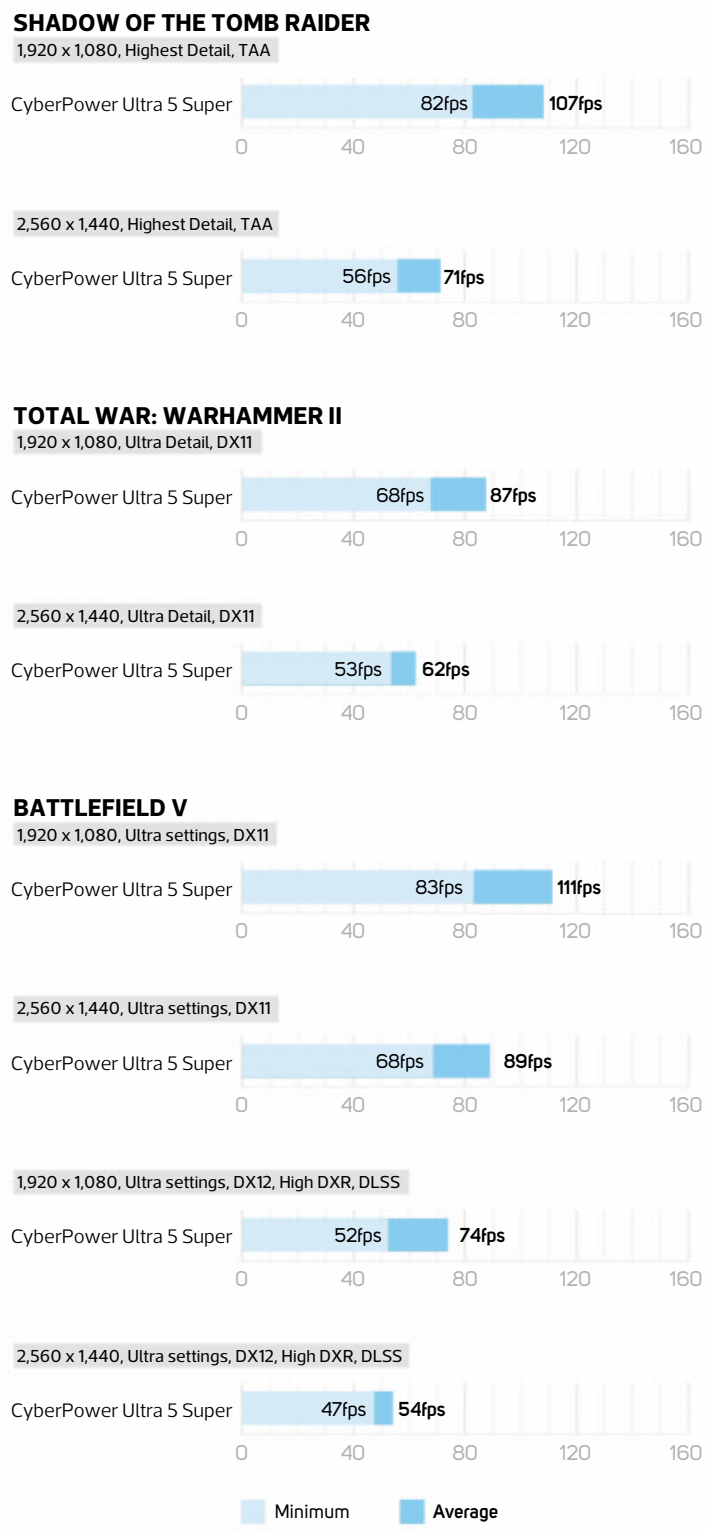
Ports
Front: 2 x USB 3, 2 x audio; rear: 2 x USB 3.1 Gen 2, 2 x USB 3.1 Gen 1, 2 x USB 2, 1 x Gigabit Ethernet, 1 x PS/2, 6 x audio

Operating system
Microsoft Windows 10 Home 64-bit

Warranty
Two years parts and labour, plus one year labour only. Six months collect end return, then return to base

BENCHMARK RESULTS





It's a low-cost case, though, so the side panel isn't made of tempered glass – it's plastic. It's bare on the inside too, with a plain PSU shroud, no rubber grommets and mediocre cable tidying. There's also room for a single hard disk and three 2.5in drives. The aforementioned Novatech is better here – its NZXT H500 is smarter and smaller, with a neater interior and a tempered-glass side panel.

Finally, the CyberPower has a three year labour warranty with two years of parts coverage, and six months of collect and return service. That's a good deal for a system at this price.

Performance

The CyberPower's RTX 2060 Super easily outpaced the RTX 2060. In Shadow of the Tomb Raider, its 82fps minimum at 1080p was 10fps better than the Novatech with its RTX 2060. It even maintained a 30fps minimum in this game at 4K. Likewise, in Total War: Warhammer II, the CyberPower's 68fps minimum at 1080p was 22fps ahead of the Novatech. It zipped through Battlefield V with a 9fps lead, and it managed playable frame rates in Battlefield V with High ray tracing enabled at 2,560 x 1,440 as well – a feat the normal RTX 2060 couldn't manage.

Similarly, the new AMD CPU impressed, cutting out a modest lead over the Novatech's i5-9600K in our single-threaded image editing test, and getting a huge advantages in our heavily multi-threaded Handbrake video encoding test. Its overall score of 192,550 is miles ahead of the Novatech's Core i5. The accompanying SSD also delivered fine read and write speeds of 1,825MB/sec and 981MB/sec respectively.

The CPU is topped with a Cooler Master MasterLiquid Lite, and it cools effectively – the CPU's peak delta T of 56°C is fine. Similarly, the GPU's delta T of 49°C isn't a problem. This machine produces noticeable fan noise when idle and gaming, though, so it's no good if you want a near-silent experience – you'll want to keep it under your desk. At least the noise level is consistent, without any sudden modulations.

Conclusion

The CyberPower Ultra 5 Super concentrates on performance rather than finesse, and it delivers. The RTX 2060 Super and Ryzen 5 3600 outpace the pricier Novatech, which means more gaming pace and processing versatility throughout. Elsewhere, though, the budget bites. CyberPower's motherboard and case are basic, and this PC produces persistent noise.

If you're happy to make those sacrifices, though, and you want the best performance possible for the money, it's a tempting trade-off. If you're not fussed about looks and noise, and want the maximum speed for the minimum outlay, the CyberPower is a great budget option.

MIKE JENNINGS

VERDICT

It might lack sophistication, but this low-cost rig delivers a huge amount of CPU and GPU power.

RYZEN

+ Superb gaming power
+ Plenty of CPU ability
+ Low price

FALLING

- Underwhelming motherboard
- Basic enclosure
- Persistent noise

PERFORMANCE **23/25**

DESIGN **18/25**

HARDWARE **20/25**

VALUE **24/25**

OVERALL SCORE **85%**

Custom Kit

Phil Hartup checks out the latest gadgets, gizmos and geek toys

ICLEVER SOLAR CHARGER / £21.99 inc VAT

SUPPLIER amazon.co.uk

The theory here is solid enough – a robust power bank that you can take on your travels and recharge on the fly using the light of the sun. The implementation is at best half-baked though. The half that is properly ready for prime time is the 10,000mAh bank itself, with its rubbery casing and sealed ports giving it an IP67 waterproof rating. This rating guarantees immersion in shallow water for up to half an hour, covering you for low-key outdoorsy misadventures, soaked luggage and sudden downpours when you've left it outside to catch some rays.

The flaw is the solar panel itself, which isn't up to the task. Even in blazing sunshine, trying to fill up the power bank is like trying to satisfy a hungry elephant by throwing it peanuts one at a time from 30m away. With a decent capacity and rugged construction, the iClever has some good qualities, but a solar charger that can't charge off the sun is pretty useless.

Jack-of-all-trades ●○○○○ **Master of sun**

STRIKER MAGNETIC LIGHT MINE / £5.99 inc VAT

SUPPLIER amazon.co.uk

The Striker Magnetic Light Mine is a small but helpful gizmo designed to provide a hands-free light for people working in dark places with nearby magnetic surfaces. The shape mimics an old-fashioned underwater mine, with the protrusions capped with neodymium magnets. Nestled among these magnetic arms is a small (but quite powerful) light, while on the opposite side sits the On switch, which is a little fiddly but gets the job done. You switch on the Striker, stick it to a nearby surface aimed at your work area, and it provides light without you having to hold a torch in your teeth like a rubbish pirate, or propping your phone up on something – it's particularly handy for working inside PC cases.

Thine ●●●●○ **Mine**

STAGEEK MOUSE CORD CONTROLLER / £14.99 inc VAT

SUPPLIER amazon.co.uk

The usual approach to keeping a mouse cable under control is a bungee that lifts it off the tabletop and keeps it out the way. The Stageek Mouse Cord Controller goes in an entirely different direction, instead working like an anchor. The controller is held together by magnets; you take off the top and feed the cable through it. Then, thanks to the sheer weight of the unit and its sticky bottom layer, it keeps your excess mouse cable under control.

The main difference in feel compared with a mouse bungee is that a bungee-style cable controller usually has some flex in it, hence the name, allowing for some extra movement. Conversely, the Stageek sticks well enough for it to feel distinctly jarring when you first try to move it. Nevertheless, you can get used to the lack of flex, and the Stageek also looks very neat and tidy – it's well worth considering if making your cables look less messy is a priority.

Style ●●●●○ **Substance**

JOBY GRIPTIGHT ONE / £38.960 inc VAT

SUPPLIER amazon.co.uk

The Joby Griptight ONE is a small phone tripod with flexible legs, a detachable Bluetooth shutter control and magnetic feet, so you can position your camera in normally inaccessible places. As well as holding a phone to take pictures or video, the Griptight can also be used as a stand. The magnetic feet are the unique selling point of the Griptight, and while at first they seem inadequate and conjure images of phones falling, if you find the right surface and respect the obvious limitations of three small magnets taking on gravity, they do the job.

Having Bluetooth control for the camera is good too, as it means you don't have to prod the camera to take the shot. The flaws lie in a combination of awkwardness and the limitations of the magnets. It's not particularly easy get the Griptight to sit just so, especially because you need to angle the legs in order to aim the camera, rather than pivoting the camera yourself at the top. If the magnets were stronger, this process would be easier. Getting it to sit and remain steady on a vertical surface is just about doable, but getting it to remain steady *and* pointed exactly where you want it can be vexing.

Jobby ●●●○○ **Joby**

GIM RGB GAMING MOUSEPAD / £16.58 inc VAT

SUPPLIER amazon.co.uk

The GIM RGB is a supersized 800 x 400mm mousepad with an illuminated outer border. After all, a really big illuminated mousepad *must* be better than a standard illuminated mousepad. This theory almost holds; having a great big mousepad to act as a surface for your keyboard, mouse and any other bits with a coloured border is pretty good, but the pad itself isn't quite up to par.

First off, the size isn't ideal for what it's trying to achieve – as a regular mousepad, it's way too long and lacking enough height; as a full gaming area pad, it feels like it should be longer and broader. Secondly, the material doesn't lie completely flat. Eventually, if you work at it, you can flatten it out, but having to do it is annoying and unnecessary. On the plus side, the lighting is good, and you can press a button on the pad to change between 13 different colours, which is ideal if you want to coordinate it with other lighting in your setup. There's definitely a space in the market for a massive RGB mousepad, but this one isn't it.

Argy-bargy ●●○○○ **RGB**

Seen something worthy of appearing in Custom Kit? Send your suggestions to phil.hartup@gmail.com

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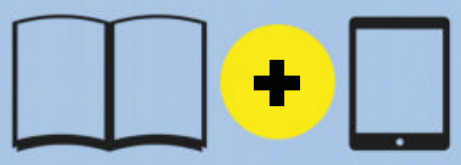

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LABS TEST

Board game

Antony Leather tests six motherboards based on AMD's latest X570 chipset for 3rd-gen Ryzen CPUs

How we test

While you don't need an X570 motherboard to take advantage of AMD's stunning new 3rd-gen Ryzen CPUs, there are several good reasons to consider one. You get PCI-E 4 support for starters, which allows you to run the latest generation of SSDs at speeds of over 5,000MB/sec. Some of the new boards also sport power circuitry that may better suit AMD's 12-core and 16-core CPUs too. There are some fantastic designs out there, with feature sets that could give any Intel-based motherboard a run for its money.

As well as looking into each board's features and design, we test each motherboard's prowess in raw performance. Our test kit includes a Ryzen 9 3900X CPU, 16GB of 3466MHz Corsair Vengeance RGB Pro RAM, an EKWB EK-MLC Phoenix all-in-one liquid cooler, an Nvidia RTX 2070 Super graphics card and Windows 10 with the 1903 update.

We also use a 2TB Samsung 970 Pro SSD, along with a Corsair 1TB MP600 PCI-E 4 SSD, to test the speed of M.2 ports as well as heatsink performance, tapping into the SSDs' internal temperature sensors during back-to-back runs of CrystalDiskMark's entire battery of tests.

To test the on-board audio, we use RightMark's Audio Analyzer software to measure the dynamic range, noise level and total harmonic distortion. Other tests include our RealBench suite of benchmarks, Far Cry 5, Cinebench R20's single and multi-threaded tests and power consumption at both stock and overclocked speeds. Our scores are based on a weighted calculation including performance, features and value, with the overall score being the sum of those three values.

Contents

ASROCK X570 TAICHI / £335 inc VAT

SUPPLIER scan.co.uk

The X570 Taichi's price tag lands in the middle of the pack this month, adding £30 to the price of the Asus ROG Strix X570-E Gaming, so it's up against some stiff competition. It looks great, and it also has the full range of PCI-E 4 support, spanning all three M.2 ports and all its PCI-E slots.

There are eight SATA 6Gbps ports too, making the Taichi one of the most storage and bandwidth-focused boards on test, and it will happily run SATA and PCI-E 3 SSDs in those M.2 slots too. The ASRock also takes on the Asus ROG Strix X570-E Gaming in terms of overclocking and testing tools, with the Taichi including power and reset buttons, a clear-CMOS button, an LED POST code display and USB BIOS Flashback.

However, the ASRock's chipset fan made a horrible whining din at first, since for some reason, ASRock set the fan profile to Performance mode in its latest BIOS. Switching it to Quiet mode improved this fan noise, but it was still just noticeable when the system was idle – you'll hear it if the rest of your system is super-quiet. The EFI system (and ASRock's software) is also a bit basic compared with the competition, with not much beyond the bare essentials.

All three M.2 slots sit under a large heatsink, but the 62°C load temperature of our Corsair PCI-E 4 SSD was the second warmest result on test, likely due to the lack of fins on the heatsink and the fact it cools all three slots, so it was also cooling our Samsung 970 Evo with our OS on it. The large heatsink means you'll need to remove all your PCI-E devices in order to access your M.2 SSDs as well, which isn't ideal.

Meanwhile, two large, heatpipe-equipped heatsinks cool the 14-phase power delivery system, and the VRMs seemed to hover at 60°C under load at stock speed using our IR laser probe, which is reasonable.

Meanwhile, the rear I/O panel offers seven Type-A USB ports, although only a pair of USB 3.1 Gen ports. The board also lacks the faster LAN ports of some boards on test too, but it does at least include 802.11ax Wi-Fi.

In terms of performance, the X570 Taichi performed well, with decent results across our benchmarks and chart-topping numbers in Far Cry 5 and the Cinebench R20 single-threaded test too. We managed to overclock our Ryzen 9 3900X to 4.3GHz on it with a 1.425V vcore, which wasn't the best on test but equal to most of the other boards. This overclock saw the system score rise from 298,064 to 302,525, and while the M.2 SSD was a little on the warm side, it still posted read and write speeds of 4,981MB/sec and 4,267MB/sec respectively.

Conclusion

The X570 Taichi is a decent X570 motherboard, but the Asus ROG Strix X570-E Gaming just pips it to the post, thanks to a quieter chipset fan, similar features and performance, and a lower price.

VERDICT

A solid effort, but there's a couple of niggles and slightly cheaper alternatives.

SPEC

Chipset AMD X570

CPU socket AMD Socket AM4 (Zen+, Zen 2)

Memory support 4 slots: max 128GB DDR4 (up to 4666MHz)

Expansion slots Three 16x PCI-E 4, two 1x PCI-E 4

Sound 8-channel Realtek ALC1220

Networking Intel Gigabit Ethernet, 802.11ax Wi-Fi

Overclocking Base clock 100-200MHz, CPU multiplier 23-63x; max voltages: CPU 1.6V, RAM 1.8V

Ports 8 x SATA 6Gbps 3 x M.2 PCI-E 4, 1 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 6 x USB 3, 3 x surround audio out

Dimensions (mm) 305 x 244

MARTIAL ART

- \+ Solid performance
- \+ Plenty of storage options
- \+ Attractive design

MARTIAL LAW

- – Noisy chipset fan
- – M.2 SSDs hard to access
- – Sub-par EFI and software

PERFORMANCE 33/35

FEATURES 26/35

VALUE 22/30

OVERALL SCORE 81%

ASUS ROG CROSSHAIR VIII FORMULA / **£589** inc VAT

SUPPLIER overclockers.co.uk

Asus' Formula boards have won many top awards at **Custom PC** over the years, but this one is a bit different. Rather than retailing for a (still wallet-smarting) couple of hundred pounds, the ROG Crosshair VIII Formula won't leave you with much change from £600. This tops the prices of Asus' recent HEDT ROG boards for X299 and X399 chipsets, so we're interested to see if this board can justify it.

The obvious extra feature is a large waterblock that spans all the VRMs with a single inlet and outlet. Bought separately, this block would likely add over £100 to the price, although the board still managed to maintain VRM temperatures below 50°C under load at stock speed, even without water cooling. The Formula is certainly attractive too, especially once its tasteful RGB lighting fires up, plus it has a quartet of RGB headers to expand your lighting with 4-pin or 3-pin addressable RGB LED strips.

SPEC

Chipset AMD X570

CPU socket AMD Socket AM4 (Zen+, Zen 2)

Memory support 4 slots: max 128GB DDR4 (up to 4800MHz)

Expansion slots Two 16x PCI-E 4, one 16x PCI-E 3, one 1x PCI-E 4

Sound 8-channel Realtek ALC1220

Networking Intel Gigabit Ethernet, Aquantia 5 Gigabit Ethernet, 802.11ax Wi-Fi

Overclocking Base clock N/A, CPU multiplier 23-65x; max voltages: CPU 2V, RAM 2V

Ports 6 x SATA 6Gbps 4 x M.2 PCI-E 4, 7 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 4 x USB 3, 3 x surround audio out

Dimensions (mm) 305 x 244

FORMULA 1

+ Integrated water cooling
+ Quiet chipset fan
+ Extensive RGB lighting

FORMULAIC

- Lacks stand-out features
- Not as interesting as other ROG boards
- Extremely expensive

You get a pair of PCI-E 4 M.2 ports and, unlike some of the boards on test, they're both housed under a single long heatsink at the bottom of the PCB. As a result, you don't need to remove your graphics card to access them, which is particularly handy if your system is water-cooled. Asus includes the full complement of overclocking and testing tools as well, although the ASRock X570 Taichi's fully formed, larger buttons are better. Thankfully, the chipset fan, while constantly spinning, was inaudible to our ears.

The Reset button here can be configured to perform other tasks, which extreme overclockers might find useful. Likewise, there's also a Slow mode switch, as well as a Retry button, for overclockers, and the ROG Crosshair VIII Formula offers a mass of features for water-cooled systems as well.

There's a single 3A/36W header that offers more than enough power for water-cooling pumps, for example, along with nine fan headers, plus water-cooling flow and temperature sensors. Asus includes an armada of USB ports on the rear I/O panel too, with seven Type-A USB 3.1 Gen 2 ports and a Type-C port as well. You also get a 5 Gigabit LAN port and integrated 802.11ax Wi-Fi, all crammed into an ATX PCB.

Sadly, in terms of performance, the ROG Crosshair VIII Formula seemed to lag a little behind the best-performing boards on test, and didn't top any charts. We also failed to match the 4.35GHz achieved when overclocking the MSI Prestige X570 Creation, managing a tamer 4.3GHz that saw our Handbrake video encoding score rise from 795,276 to 859,909.

Conclusion

For this price, we expected more from ROG Crosshair VIII Formula given the excellent ROG boards we've seen over the past 12 months. However, it lacks unique or killer features – the likes of the MSI Prestige X570 Creation offer cheaper, but still lustworthy homes for your 3rd-gen Ryzen CPU.

VERDICT

A great feature set and a quiet chipset fan, but the Formula gets nowhere near to justifying its huge price.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
32/35	33/35	13/30	78%

ASUS ROG STRIX X570-E GAMING / £270 inc VAT

SUPPLIER ebuyer.com

X570 boards might cost a fair amount more than their X470 predecessors, but at £270 inc VAT Asus' ROG Strix X570-E Gaming has price on its side compared with most of the competition this month. It also ticks a number of boxes when it comes to acting as the foundation for a powerful 3rd-gen Ryzen system.

That, said, there's a few omissions and cutbacks. There are no power or reset buttons, and you don't even get a clear-CMOS button either. The button on the rear I/O panel is actually tied to the BIOS Flashback function – even the £100 cheaper MSI X570-A Pro has a clear-CMOS button.

The rest of the specification is bang on though. You get a 2.5 Gigabit Ethernet port, as well as an Intel Gigabit port, plus 802.11ax Wi-Fi. The rear I/O panel is also awash with the latest USB tech, with a total of seven USB 3.1 Gen 2 Type-A ports and a Type-C port – you get a full-fat Gen 2 Type-C header for compatible cases too.

There's a generous count of eight SATA 6Gbps ports, and Asus has reined in one of the M.2 slots to only offer PCI-E 3 support, while the other offers full PCI-E 4 bandwidth. There's a hefty total of 16 power phases too, and while the board doesn't have a VRM temperature sensor, we measured the VRM top and rear areas remotely using an IR laser probe as hovering around 50°C, which was only a little warmer than the ROG Crosshair VIII Formula. The board is undoubtedly helped by the huge 8mm heatpipe connecting the two large VRM heatsinks, which is one of the biggest we've ever seen on a motherboard.

Meanwhile, the EFI was up to Asus' usual standards, although it's now firmly in second place when it comes to fan control, with both Gigabyte and MSI offering more control of your fans. On the plus side, the Strix's chipset fan is completely inaudible, unlike some of the competition. Meanwhile, Asus' AI Suite software has a great overclocking section, although the fan control is again limited.

We managed to hit the usual 4.3GHz frequency with our Ryzen 9 3900X using a 1.425V vcore – that's not as good as the frequency we hit with the MSI Prestige X570 Creation, but a match for every other board on test, although the Strix was one of the more power-hungry boards at both stock and overclocked speeds. Our overclock saw the RealBench System score rise from 295,640 to 309,847, with the video encoding score rising by 8 per cent too.

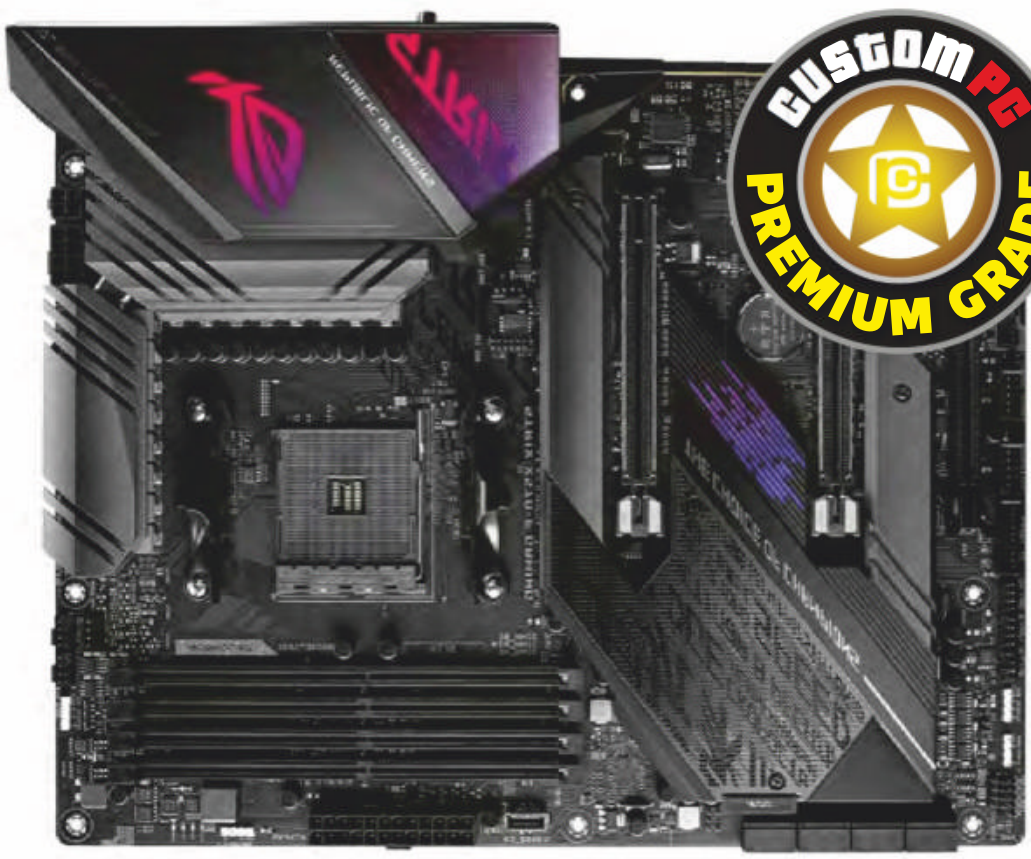
Conclusion

While it's still the costs the best part of £300, the ROG Strix X570-E Gaming coped well in our tests and handled our overclocked 12-core CPU with ease and, unlike the cheaper MSI X570-A Pro, it's a potential partner for AMD's 16-core Ryzen 9 3950X too. The MSI Prestige X570 Creation and Gigabyte X570 Aorus Master have more features, but if £300 is your limit, this quiet, well-featured board is the one to get.

VERDICT

A solid overclocker and all-rounder with sensible features and reasonable price tag.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
33/35	27/35	24/30	84%



SPEC

Chipset AMD X570

CPU socket AMD Socket AM4 (Zen+, Zen 2)

Memory support 4 slots: max 128GB DDR4 (up to 4400MHz)

Expansion slots Three 16x PCI-E 4, two 1x PCI-E 4

Sound 8-channel SupremeFX S1120A

Networking 1 x Realtek 2.5 Gigabit LAN, 1 x Intel Gigabit LAN, 802.11ax Wi-Fi

Overclocking Base clock 96-118MHz, CPU multiplier 28-64x; max voltages: CPU 2V, RAM 1.8V

Ports 8 x SATA 6Gbps 1 x M.2 PCI-E 4, 1 x M.2 PCI-E 3, 7 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 3 x surround audio out

Dimensions (mm) 305 x 244

STRIX

+ Good value
+ Quiet chipset fan
+ Decent features for the price

STRICTLY

– Few overclocking and testing tools
– No VRM temperature monitor
– Only one PCI-E 4 M.2 port

GIGABYTE X570 AORUS MASTER / £390 inc VAT

SUPPLIER overclockers.co.uk

We're pleased to report that the Gigabyte X570 Aorus Master has received several BIOS revisions since last issue, bringing control of the chipset fan to the EFI, and allowing it to spin down when it should do so.

Unlike some of the boards on test this month, the Gigabyte has individual single-slot M.2 heatsinks, rather than a large one to cover its trio of PCI-E 4 M.2 slots. This arrangement enables you to access each SSD without needing to remove graphics cards and other PCI-E devices, but the small heatsinks did mean the board had the highest M.2 SSD temperature on test using our Corsair MP600 SSD, which was actually a little cooler using its own heatsink. Despite the separated heatsinks, the board is definitely one of the best-looking on test, and the subtle RGB lighting adds some pizzazz to the otherwise black and silver colour scheme too.

The Gigabyte X570 Aorus Master sits in the middle of the pack in terms of prize, but it actually offers a few extreme overclocking features, such as PROBELT voltage measuring points and dual BIOS switches.

SPEC

Chipset AMD X570

CPU socket AMD Socket AM4 (Zen+, Zen 2)

Memory support 4 slots: max 128GB DDR4 (up to 4400MHz)

Expansion slots Three 16x PCI-E 4, one 1x PCI-E 4

Sound 8-channel Realtek ALC1220

Networking 1x Intel Gigabit LAN, 1x Realtek 2.5 Gigabit LAN, 802.11ax Wi-Fi

Overclocking Base clock 100-300MHz, CPU multiplier 8-64x; max voltages, CPU 1.8V, RAM 2V

Ports 6 x SATA 6Gbps, 3 x M.2 PCI-E 4, 3 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 2 x USB 3, 4 x USB 2, 3 x surround audio out

Dimensions (mm) 305 x 244

GIGABYTE

+ Plenty of premium features
+ Excellent fan control
+ Plenty of expansion possibilities

BYTE

- Average M.2 heatsinks
- Expensive
- Average overall performance

Meanwhile, its power and reset buttons, a clear-CMOS button and LED POST code display will be handy for any out-of-the-case testing, overclocking and benchmarking that comes its way.

There are 14 power phases, and the VRMs are cooled by large, finned heatsinks rather than blocks of metal, which Gigabyte claims improves cooling. The temperatures of the VRMs were reported to be 59°C at stock speed under load, which is higher than some results this month, but still offers decent headroom for overclocking and hopefully dealing with AMD's Ryzen 9 3950X too.

In terms of networking, there's a Realtek 2.5 Gigabit port, Intel Gigabit LAN and 802.11ax Wi-Fi. All of the X570 Aorus Master's PCI-E slots and M.2 ports are PCI-E 4, and all its M.2 ports support SATA SSDs too, which makes up for only having six SATA ports compared to the eight on several other boards this month.

Meanwhile, Gigabyte's EFI fan control section and Windows software are excellent, and while it generally isn't as snazzy as MSI or Asus' efforts, we still hit the usual 4.3GHz with a vcore of 1.425V. This overclock saw the RealBench system score rise from 306,884 to 315,214 and the video encoding score go from 835,226 to 848,107, although the board already exhibited excellent lightly threaded performance in the image editing test and Cinebench R20 single-thread test. The Gigabyte is also relatively power-frugal.

Conclusion

The Gigabyte includes a lot of features, and while it does cost a lot more money than the likes of the Asus ROG Strix X570-E Gaming, it largely justifies the extra outlay if you really need those extra overclocking features and support for lots of PCI-E 4 SSDs. It's great to see Gigabyte has fixed the annoying chipset fan too. For most people, though, we recommend opting for the Asus board and spending the extra cash elsewhere.

VERDICT

A decent array of premium features that leaves some more expensive boards wanting, but it's up against hefty competition.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
33/35	29/35	19/30	81%

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MSI PRESTIGE X570 CREATION / £450 inc VAT

SUPPLIER overclockers.co.uk

As the second most expensive board on test, the MSI Prestige X570 Creation needs to justify its price, although a quick sift through the box reveals some exciting goodies. You get a beefy M.2 Xpander-Z Gen 4 card that adds two PCI-E 4 M.2 ports, complete with heatsinks and a fan, along with a sturdy desktop Wi-Fi antenna, three thermal probe cables, RGB extension cables, and cabling to hook up various Corsair RGB components.

The board itself is the only E-ATX example on test, and it makes good use of the extra space. It has a huge cooling array, with a heatpipe connecting the VRM heatsinks and chipset heatsink, evening out the heatload and allowing the larger-than-average chipset fan to also cool the 17-stage power delivery and VRMs. Thankfully, the fan rarely needs to spin up, and it's inaudible when it does.

The main niggle here, though, is that the single-piece M.2 heatsink prevents you from accessing your M.2 SSDs while a graphics card is installed. Otherwise, the layout is excellent, with angled 24-pin ATX, SATA 6Gbps and USB 3 headers. You only get six SATA ports, rather than eight, but that's still plenty for most people.

Every M.2 port and PCI-E slot supports PCI-E 4, and you get a generous total of nine 4-pin fan headers to take advantage of MSI's tweaked EFI, which now matches Gigabyte's efforts when it comes to fan control. There's also a massive count of 13 Type-A USB ports on the rear, although only one of them is USB 3.1 Gen 2, while there's a Type-C port with the same speeds too.

The premium features continue with a 10 Gigabit Aquantia Ethernet controller, power and reset buttons, a clear-CMOS switch and LED POST code display. There are also four 1x PCI-E slots and a smattering of RGB lighting, with three additional RGB headers included.

The Prestige X570 Creation offered exceptional cooling of our Corsair MP600 M.2 SSD in its Xpander-Z Gen 4 card, although the fan is best switched off as it's noisy. Even the board's own M.2 heatsink was better than most of the competition, but the real star in the results was the audio performance, where the dynamic range of 118dBA and noise level of -118dBA are exceptional.

What's more, it managed to get our Ryzen 9 3900X CPU to a stable 4.35GHz clock using a 1.425V vcore – the highest result we've seen so far, while still maintaining super-low power draw. However, due to the variations in CPU boosting we've seen so far from early EFI versions, this overclock didn't lead to chart-topping results.

Conclusion

If you plan on getting AMD's 12 or 16-core 3rd-gen Ryzen CPUs, we have no doubt MSI's Prestige X570 Creation is an excellent tool for the job. It's dripping with super-premium features and is a match for many high-end desktop boards we've seen. There are certainly cheaper options, but if you'll make use of some of its cutting-edge technology and have the funds, it's a highly desirable board.

VERDICT

A super-premium motherboard that's begging for a 16-core Ryzen CPU.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
33/35	34/35	18/30	85%

SPEC

Chipset AMD X570

CPU socket AMD Socket AM4 (Zen+, Zen 2)

Memory support 4 slots: max 128GB DDR4 (up to 4600MHz)

Expansion slots Three 16x PCI-E 4, four 1x PCI-E 4

Sound 8-channel Realtek ALC1220

Networking Intel Gigabit LAN, Aquantia 10 Gigabit LAN, 802.11ax Wi-Fi

Overclocking Base clock N/A, CPU multiplier 23-65x; max voltages: CPU 2V, RAM 2V

Ports 6 x SATA 6Gbps 4 x M.2 PCI-E 4, 1x USB 3.1 Type-A, 1x USB 3.1 Type-C, 10 x USB 3, 2 x USB 2, 3 x surround audio out

Dimensions (mm) 305 x 244

IRON MAN

+ Super-premium features
+ Excellent overclocker
+ Superb cooling

IRON AGE

- Expensive
- Some features are overkill
- Not the best-looking board

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MSI X570-A PRO

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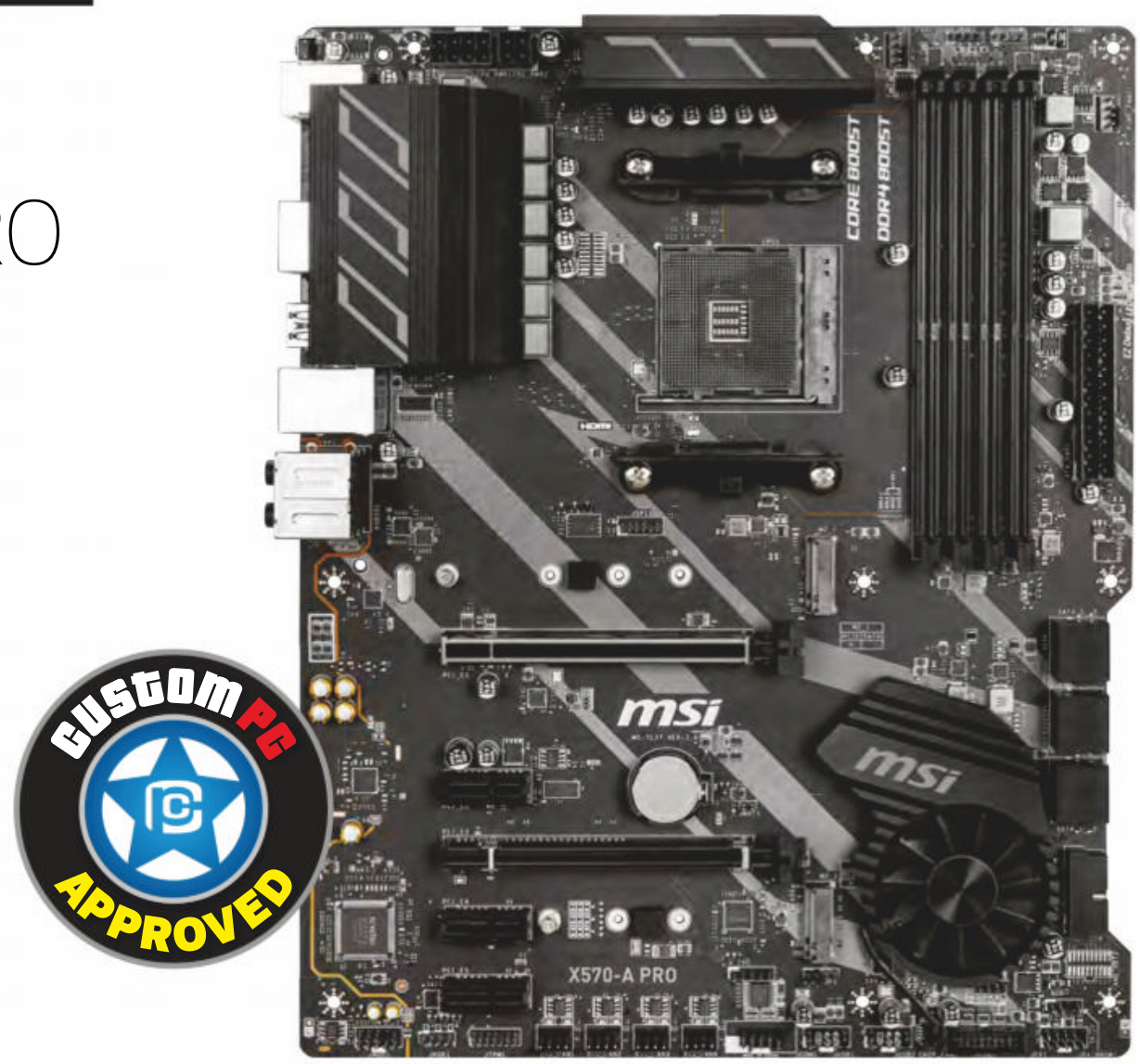
SUPPLIER box.co.uk



With its comparatively low price, the MSI X570-A Pro is undeniably rather spartan-looking compared with all the other boards on test, with no M.2 heatsinks and only modest-sized VRM heatsinks; there's no heatpipe to link them and spread the heatload. Underneath them are ten power phases, but just eight of them handle the CPU, so this board is by far the least well-equipped in terms of power delivery on test.

There's also no lavish cooling array, with the chipset heatsink and fan left to fend for themselves. Thankfully, the fan is very quiet. As well as omitting heatsinks from the M.2 ports, only one of them offers full PCI-E 4 support, but given the likelihood of the board being purchased with more limited budgets in mind, it's unlikely owners will be gunning for two PCI-E 4 SSDs anyway.

SPEC

Chipset AMD X570

CPU socket AMD Socket AM4 (Zen+, Zen 2)

Memory support 4 slots: max 128GB DDR4 (up to 4400MHz)

Expansion slots Two 16x PCI-E 4, three 1x PCI-E 3

Sound 8-channel Realtek ALC1220

Networking Intel Gigabit LAN, 802.11ax Wi-Fi

Overclocking Base clock N/A, CPU multiplier 23-65x; max voltages: CPU 2V, RAM 2V

Ports 6 x SATA 6Gbps 1 x M.2 PCI-E 4, 1 x M.2 PCI-E 3, 1 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 4 x USB 3, 2 x USB 2, 3 x surround audio out

Dimensions (mm) 305 x 244

PRO

- \+ Superb value
- \+ PCI-E 4 for under £200
- \+ Decent overclocker

AMATEUR

- – VRMs on the toasty side
- – Not many PCI-E 4 ports and slots
- – Lacks features

That second M.2 slot also supports SATA M.2 SSDs so, along with its six SATA 6Gbps ports, the MSI X570-A Pro is fairly flexible when it comes to storage. You even get USB 3.1 Gen 2 Type-A and Type-C ports on the rear I/O panel, albeit just one of each, although there's no Type-C header on the PCB.

Despite the price, however, MSI has included Realtek's ALC1220 audio codec, and you get the full six audio ports, including an optical port, so you gain little by stepping up in price as far as audio quality is concerned. The rear I/O panel also reveals a small button that we initially thought was a clear-CMOS button, but it's actually for USB BIOS Flashback, which allows you to update the EFI without a CPU in the socket.

Meanwhile, layout is generally okay, although there are no fan headers near the rear of the case, so you might need to invest in a fan extension cable for your rear exhaust fan to reach a system fan header.

VRM temperatures were also the highest on test, at a software-reported 78°C after a ten-minute load test, but this temperature didn't have an impact on benchmarks. We also hit the same 4.3GHz clock with a 1.425V vcore as most of the other boards on test, which boosted the video encoding score from 812,360 to 821,208. The board was on the money in terms of audio and storage performance too, with the only niggle being high overclocked power consumption. MSI's EFI is also excellent, especially the fan control section.

Conclusion

We suspect that our overclocked Ryzen 9 3900X is approaching the MSI X570-A Pro's limits in terms of power delivery and cooling, but realistically, this CPU is the toughest customer it's likely to face. MSI has struck a good balance of features too, maintaining flexible storage options and decent audio capabilities, as well as offering baseline PCI-E 4 support for graphics cards and SSDs. If you want to jump on the X570 bandwagon without spending a fortune, it's a great choice, although it's not an ideal partner for AMD's Ryzen 9 CPUs.

VERDICT

Despite a few shortcomings, this board offers superb value for money, proving that PCI-E 4 support doesn't need to cost a fortune.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
32/35	19/35	30/30	81%

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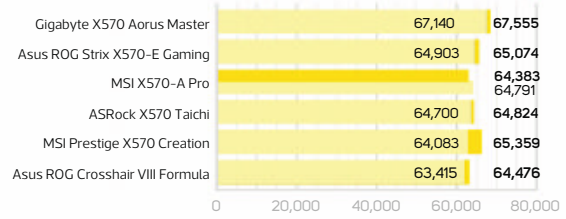
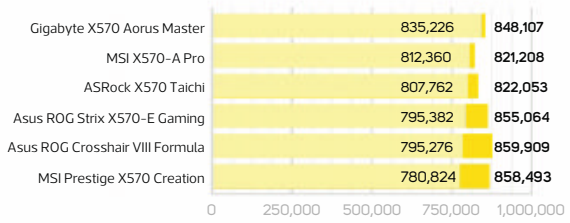
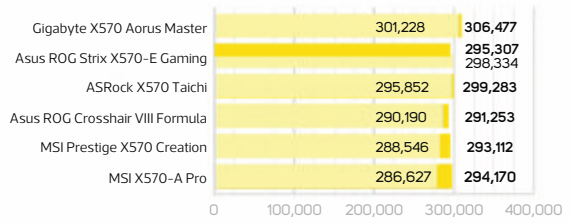
GIMP IMAGE EDITING



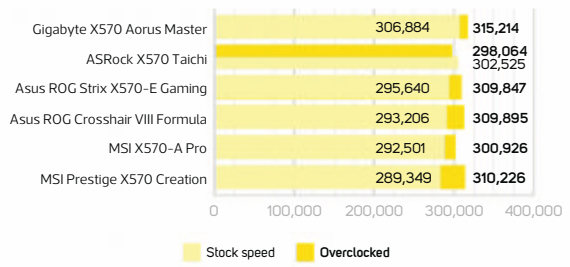
HANDBRAKE H.264 VIDEO ENCODING



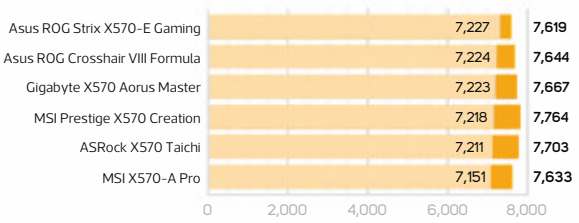
HEAVY MULTI-TASKING



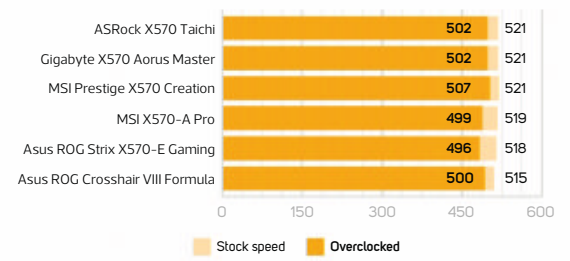
SYSTEM SCORE



CINEBENCH R20 MULTI-THREADED

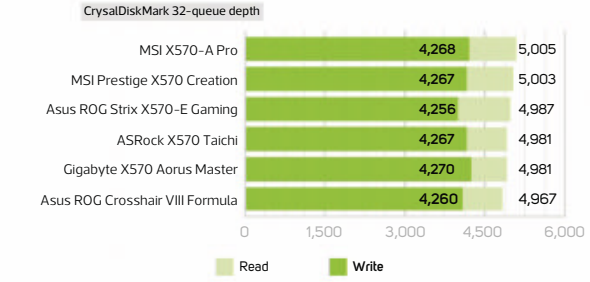


CINEBENCH R20 SINGLE-THREADED



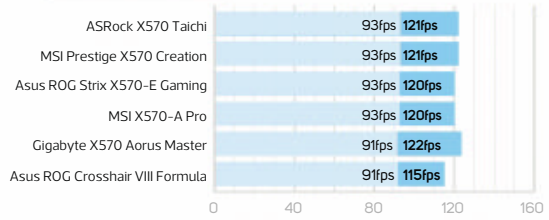
M.2 SPEED (MB/SEC)

CrysalDiskMark 32-queue depth



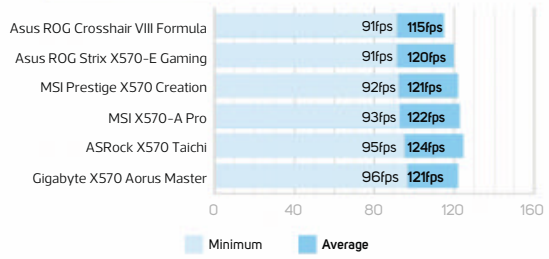
STOCK SPEED FAR CRY 5 (FPS)

1,920 x 1,080, Ultra settings



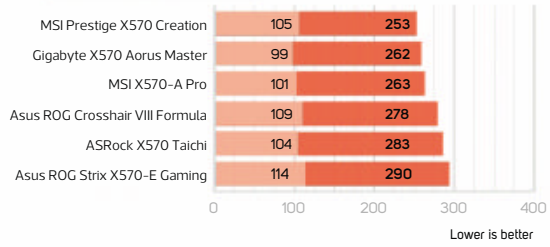
OVERCLOCKED FAR CRY 5 (FPS)

1,920 x 1,080, Ultra settings



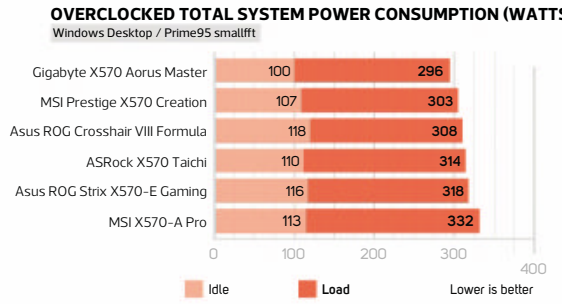
STOCK SPEED TOTAL SYSTEM POWER CONSUMPTION (WATTS)

Windows Desktop / Prime95 smallfft



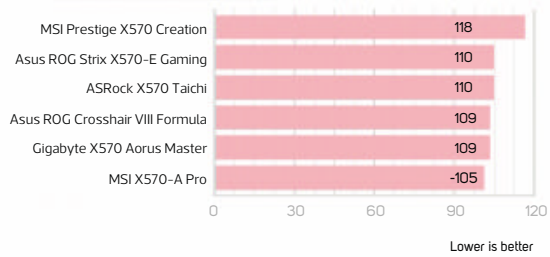
OVERCLOCKED TOTAL SYSTEM POWER CONSUMPTION (WATTS)

Windows Desktop / Prime95 smallfft



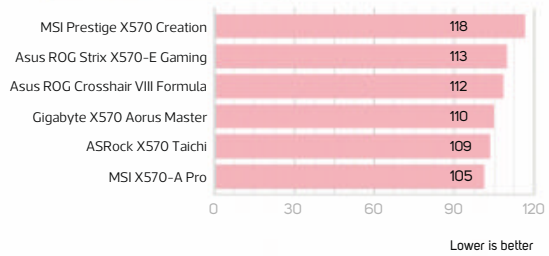
NOISE LEVEL (DBA)

RightMark Audio Analyzer 24-bit, 192KHz



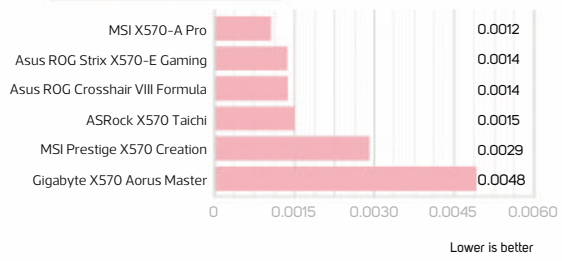
DYNAMIC RANGE (DBA)

RightMark Audio Analyzer 24-bit, 192KHz



TOTAL HARMONIC DISTORTION

RightMark Audio Analyzer 24-bit, 192KHz



LABS TEST

Mechanical advantage

Edward Chester puts the latest high-end mechanical gaming keyboards to the test

How we test

Mechanical gaming keyboards are now the established premium option for gamers. Just a few years ago, it was enough for a keyboard maker to slap a few dozen Cherry MX keyswitches on a base and call it done, but these days there are far more options.

The likes of Logitech and Razer now produce their own keyswitches, while cheaper copies of Cherry MX switches are available too. Sticking with Cherry MX provides the greatest versatility, as keycaps (and potentially keyswitches as well) can easily be replaced. We've also seen low-profile switches arrive, for those that prefer a lower typing angle, as well as quiet and high-speed options.

RGB lighting is, of course, also a big factor on high-end keyboard these days, with full lighting customisation being an extra bonus. It's also handy to have a few extra keys, for controlling media, adjusting the audio volume or other desktop functions, as well as providing extra functionality in games.

To test this batch of mechanical gaming keyboards, we first put them through their paces through typing duties, with each review being written on its respective keyboard. We also tested each keyboard in games to judge their responsiveness. We then looked at the styling and build quality of the keyboards, as well as their customisation options and extra features.

Contents

ASUS ROG STRIX FLARE / £120 inc VAT

SUPPLIER game.co.uk

Asus' Strix brand is all about RGB, and sure enough, the Flare provides the requisite RGB backlighting to its keys. However, this is a pretty standard feature on premium keyboards these days, so Asus has had to ramp it up a notch.

In the top-right corner is an RGB-illuminated clear plastic plate with an Asus ROG logo painted on it. On its own, it isn't a compelling extra feature, but the plastic plate can be removed and swapped for an included unmarked plate, allowing you to add you own little illuminated logo to the keyboard. You also get underlighting on the sides of the keyboard, creating some attractive washes of colour on the side of our test mouse.

The big downside here, though, is that while the lighting might be quite cool, the styling and design could be better. From the angled brushed finish, through the right side of the plastic top plate, to the slightly lopsided feel created by the multimedia controls being bunched up on the left, it feels like it needed more time on the drawing board. To our eyes, the stylised angular font on the keys cheapens the appearance too, although that's mainly down to personal taste.

Onto more practical considerations, the multimedia keys are certainly welcome. You get a rather stiff volume wheel, playback controls, a button for disabling the Windows key and a button for cycling through the lighting modes. Around the back there's also a USB passthrough port. A wrist rest is also included, but it's a solid plastic affair with no cushioning, so it doesn't offer the support of some more premium alternatives.

BENQ ZOWIE CELERITAS II

/ £110 inc VAT

SUPPLIER scan.co.uk

Optical keyswitches are the big feature of the Celeritas II. BenQ Zowie has teamed up with Flaretech, which makes a new type of keyswitch that relies on a light beam being blocked and unblocked, rather than a metal contact plate.

One upside to these switches is a longer lifespan – they're rated to 100 million keystrokes, compared to the 50 million of most mechanical keyswitches. They also have a shorter actuation point and there's far less debounce delay. The firmware needs to allow a short period of time before sending a signal, to ensure that the key has been pressed properly and the contacts aren't bouncing around. This delay is just 0.03ms, compared to 5ms on normal keyswitches.

In most scenarios, this delay isn't likely to make much difference, but there could be the odd occasion where that fast response is crucial. In our use we didn't notice any significant difference, but the typing and gaming experience was still excellent. Also, a big bonus with these optical switches, compared with Razer's ones, is that they're compatible with Cherry MX keycaps, so you can swap out your keycaps too.

Elsewhere, though, the Celeritas is less convincing. The Zowie brand has long aimed at providing no-frills gaming tools, so it's no surprise the Celeritas isn't packed with features but, for the price, it's notable just how many features are missing. There's no RGB backlighting, no software programmability, no USB passthrough and no extra keys, although you do get multimedia control via secondary functions on the F keys. You also miss out on a wrist rest.

An intriguing addition is a PS/2 adaptor, which allows you to set the keyboard to repeat keystrokes automatically.

A big plus point of this keyboard is the use of standard Cherry MX keyswitches, so you get reliable quality and it's easy to swap out keycaps too. The overall typing experience is also excellent, and Asus' software offers full customisation of the lighting and function of each key.

Conclusion

An intriguing swappable clear RGB plate adds some fun customisation options to this keyboard, and it's a solid option with proper Cherry MX keys. However, its basic design needs some work if it wants to compete in this crowded market.

VERDICT

Loads of RGB lighting, but the basic design needs some more work.

DESIGN	FEATURES	OVERALL SCORE
12/20	16/20	72%
PERFORMANCE	**VALUE**	
23/30	21/30	

It's a niche feature that may be useful to pro Starcraft players, but it's not particularly useful for the rest of us. As for design, the Celeritas is simple but reasonably effective, plus it's built like a tank, weighing in at 1.89kg.

Conclusion

The BenQ Zowie Celeritas II is a reliable workhorse that's built to last. It also offers an excellent typing and gaming experience with keycaps that can be easily replaced. However, there's no denying it's a bare bones offering for its price.

VERDICT

Excellent performance, but severely lacking features compared with the competition.

DESIGN	FEATURES	OVERALL SCORE
12/20	12/20	70%
PERFORMANCE	**VALUE**	
24/30	22/30	

COOLER MASTER MK850 / £160 inc VAT

SUPPLIER overclockers.co.uk

For all the innovations we've seen across the other keyboards on test, there's only one keyboard that features a truly potentially game-changing innovation: the Cooler Master MK850. It includes eight keys (QWERASDF) that don't just offer the digital single-action response of a normal key, but can provide an analogue signal too. Press the key deeper, and it sends a high signal, press it lightly and it sends a lower signal.

The idea is that this extra Aimpad control can, primarily, be used to emulate the input provided by the analogue sticks of a gamepad/controller. Racing games, flight sims and other games where fine control is required could benefit. The keys work by using an infrared light set alongside the normal Cherry MX keyswitches, which tracks the distance of the keycap to produce the analogue signal.

Despite the relatively small range of motion of the keys, the switches work surprisingly well. The most obvious application is racing games, where the ability to have analogue steering, acceleration and braking makes the experience far more realistic and nuanced. However, there are some serious caveats to the technology.

For a start, you have to switch the keyboard into a different mode to enable the analogue feature, which turns off the normal key function. You also have to regularly calibrate the keys, which is a faff.

Perhaps most importantly, it's just not as pleasant to use as a gamepad's analogue stick. There's a handful of games where having analogue control and mouse movement is beneficial, but often games are optimised for one or the other.

Thankfully, there's plenty to like about this keyboard elsewhere. It looks fantastic, thanks in large part to its aluminium top plate, and it has plenty of other features, including a comfortable soft wrist rest, an extra row of gaming keys down the left edge and a couple of what Cooler Master calls precision wheels. These wheels can be assigned to control obvious tasks such as volume, but also mouse DPI, backlight brightness and more.

There are also separate multimedia controls along the top row, the cable is detachable and uses USB Type-C, plus you get two USB passthrough ports.

Conclusion

The Cooler Master MK850 is a tour de force of modern mechanical gaming keyboards. It's stylish, packed with features and uses standard Cherry MX switches, so it's easy to customise. We're not entirely convinced its headline Aimpad technology is the next big thing, but it's a welcome addition that doesn't detract from the rest of this impressive bit of kit.

VERDICT

Not a complete replacement for your gamepad, but still a great keyboard.

DESIGN	FEATURES	OVERALL SCORE
18/20	20/20	82%
PERFORMANCE	**VALUE**	
24/30	20/30	

CORSAIR K70 MK.2 LOW PROFILE / £160 inc VAT

SUPPLIER scan.co.uk

I found myself muttering, 'Oh that's lovely, properly lovely,' the moment I set this keyboard down on my desk. Corsair has long led the charge for smart-looking mechanical keyboards, and much of this keyboard's appeal comes down to Corsair's tried and tested design. There's the brushed aluminium top plate on which the keys are mounted and the all-black livery, but the pièce de résistance is the new low-profile keys.

Corsair keyboards that use standard Cherry MX switches have keys that stand so proud of the base that they look a bit gangly and cluttered. With these new low—profile switches, though, the whole unit sits tightly together, making for a more elegant look. What's more, Corsair has really made the most of the low-profile switches, with the keyboard measuring just 22mm to the top of the front keys. Most other mechanical keyboards measure nearly 10mm taller, and even the Roccat Vulcan 120 measures 26mm tall.

This low height allows your wrists to sit at a lower angle than normal, making long-term use more comfortable. The shorter throw of the switches can also make them easier to use. The overall typing experience of this keyboard is fantastic, although getting used to it might take time if you're a diehard fan of full-height mechanical switches.

Also, we did find a problem with the '2' key erroneously repeating key presses, a hardware fault we've never encountered before on a new mechanical keyboard, but one that's hopefully only limited to our review sample.

The rest of the keyboard delivers the goods too. You get multimedia controls in the top right, and profile, brightness and Windows key lock buttons in the top left. On the back edge there's also a USB passthrough, and of course you get RGB lighting. Corsair's software also provides full-key illumination and control,

DUCKY SHINE 7 / £170 inc VAT

SUPPLIER overclockers.co.uk

Ducky has been making highly regarded mechanical keyboards for a long while, and the Shine 7 is its top model. It sports RGB backlighting, double-shot PBT keycaps and a beautiful zinc alloy top plate.

The latter surrounds the keys and bends down the sides. It looks great, and the material is apparently three times stronger than aluminium, although it's debatable if there's much benefit when it's only used to make the top plate. The plate surrounds the keys, rather than the keys being mounted directly to it, which creates a clean look and allows for an even backlight, thanks to the white plastic layer diffusing the light beneath the keys.

Flip over the keyboard and it has a standard plastic base, with static rubber front feet and two-stage, flip-down rear feet. The 1.6m USB cable is also handily removable thanks to a USB Type-C connection. There's an intriguing row of DIP switches on the underside too, allowing you to swap the left-Ctrl and Caps Lock keys or the left-Alt and left-Windows key. They can also disable the Windows keys and switch between N-Key rollover and 6-Key rollover.

You get four extra buttons on the top right, providing mute and volume control, along with a shortcut for the calculator app. Below them sit four annoyingly bright indicator lights for the lock keys. Otherwise, there are no other secondary functions or extra keys.

You can program keys and macros manually through a convoluted sequence of button presses, but there's no software to do it quickly. You do get software for programming the RGB lighting, however, with extensive options for effects, although you can't fully program individual keys.

Keyswitches are the usual selection of Cherry MX models, and they're as good as ever. Meanwhile, the fancy double-shot keycaps use a two-step injection moulding process,

and the company's extensive range of other RGB components means it's easy to manage all your PC's lighting from one place.

Conclusion

It's not cheap, but the K70 Mk.2 Low Profile is fantastic. It looks amazing, it's well built, the low-profile design feels lovely and it has a wide range of features. Assuming the problematic keyswitch we experienced is an isolated incident, we can't recommend this keyboard highly enough.

VERDICT

With its low-riding style and great feature set, the K70 Mk.2 is our top keyboard pick.

DESIGN	FEATURES	OVERALL SCORE
20/20	18/20	84%
PERFORMANCE	VALUE	
24/30	22/30	

which means the labelling on each key isn't just printed but runs throughout the depth of the key, making them very durable. However, the clarity of the labelling, particularly on keys with finer writing, such as Home and PgUp, isn't great.

Conclusion

The Shine 7 is a fantastic premium mechanical keyboard with a smart design, top-notch build quality and a good balance of features. However, the overly bright lock key lights are surprisingly distracting, and the lack of software programmability is a shame, especially for the high price.

VERDICT

Top build quality sets this keyboard apart, but it's not good enough to justify its price.

DESIGN	FEATURES	OVERALL SCORE
16/20	16/20	76%
PERFORMANCE	VALUE	
24/30	20/30	

LOGITECH G513 CARBON

/ £105 inc VAT

SUPPLIER amazon.co.uk

The Logitech G513 Carbon is a departure from the company's previous gaming keyboards. The angular, plasticky, gimmicky feel of the G910 is gone, and instead we have a sleek, almost minimalist keyboard that oozes quality.

The fanciest feature is the aluminium top plate. It's not an original addition, with Corsair long being associated with the look, but it's a tried and tested route towards a more premium-feeling product. In fact, it works better than with many other keyboards, as Logitech's in-house Romer-G keyswitches don't spill their backlighting out all over the aluminium plate, making for a tidy overall look.

On the flipside, the metal used isn't as thick as on Corsair's keyboards, and the G513 feels relatively lightweight and flexible for a mechanical keyboard. The minimalist feel also impacts on some practical aspects though. You miss out on any extra gaming keys, for example, and there are no dedicated multimedia controls.

Meanwhile, several of the F keys have secondary functions that are activated via the right Fn key, but they aren't much use for gaming. F5-F12 are pre-programmed, while F1-F4 can be given extra functions via Logitech's software. You can also use this software to assign macros to these keys, but you can't program any other keys. Tap Fn+F8 and the keyboard will enter a game mode that deactivates the Windows keys, plus you can set it to deactivate other keys.

A welcome addition is a pleather-covered memory foam wrist rest. Oddly, it doesn't attach to the keyboard, but just rests on its own six rubber feet, although that makes it versatile too, plus it feels great. The lengthy 1.8m cable is braided and quite thick, so it should stand the test of time, although it's rather stiff and arrives rather kinked. A USB passthrough can be found on the rear.

As for the overall typing/gaming experience, the clear labelling and RGB backlighting makes it easy to see what's going on, and Logitech's Romer-G keys feel essentially as good as Cherry MX equivalent in action. A unique keycaps fitting means you can't easily replace keycaps though.

Conclusion

The G513 Carbon is a stylish keyboard with great backlighting and a lovely, comfortable wrist rest. However, it lacks a few features, its configurability is basic and its keycaps can't easily be replaced with generic ones.

VERDICT

A stylish, quality keyboard for a competitive price, although it's lacking some notable features.

DESIGN	FEATURES	OVERALL SCORE
16/20	12/20	74%
PERFORMANCE	VALUE	
22/30	24/30	

MSI VIGOR GK60 / **£83** inc VAT

SUPPLIER scan.co.uk

The GK60 is MSI's second-tier mechanical gaming keyboard, after the flagship GK80. As such, you miss out on a few flagship features such as a USB passthrough and RGB backlighting. However, you do get an affordable keyboard with an even red backlight that's easy on the eye. Often, RGB lighting has a slight shimmering quality, possibly down to the way the LEDs regulate their brightness and mix of colours.

There also isn't much light leaking from the sides of the MSI's keyswitches, making for a clean overall look.

The aluminium top plate helps too. Its anodised dark grey colour, combined with a slightly reflective brushed finish, looks good in isolation and provides an attractive backdrop for the backlighting. It's also more pleasant to touch than the heavily brushed finish of Corsair's keyboards.

The angular shape, dragon logos and font on the keys are all a bit over the top. The top row of number keys is also problematic, as the numbers are quite small and difficult to read at a glance. Thankfully, the use of standard Cherry MX Red switches means it's easy to swap out the keycaps, plus the typing experience and action in games is, of course, excellent.

In terms of extra features, there's not much of note here. There are no extra keys, no multimedia buttons, no USB passthrough and no wrist rest. The USB cable is tethered and doesn't have a braided outer, although it's a plentiful 2m metres long. You get multimedia secondary functions on the F keys but that's your lot. However, that's also why this keyboard is so much cheaper than the other models on test.

RAZER HUNTSMAN ELITE / **£200** inc VAT

SUPPLIER Razer.com

Opto-mechanical keyswitches are the Huntsman Elite's big selling point. Instead of using an electrical contact to trigger a signal, the keys open and close a light path. Because the signal actuation isn't physical, you don't get a worn contact point as with traditional mechanical switches. As such, Razer can claim a durability of 100 million clicks, compared to around 50 million for most mechanical switches.

Razer has also aligned the actuation point with the point at which you hear and feel the click of the key – yes, Razer's opto-mechanical switches are only available in clicky varieties for now. There's also almost no debounce delay – the signal is sent the second the key is hit. They're much like the optical switches of the BenQ Zowie Celerita II (see p54), but Razer has also made the keyswitch more stable than typical Cherry MX-style switches, resulting in less key wobble.

We were sceptical about some of the claims, but the keys feel really great in action. They're just that little bit more precise, even more than Cherry MX Blue switches. The only downside is the lack of compatibility with readily available replacement keycaps.

The rest of the keyboard is a delight too. Razer has always had an eye for design, and the Huntsman Elite looks fantastic. Its all-black livery is an ideal backdrop to the wonderfully executed, fully customisable RGB lighting. The RGB strip runs around the outside of the keyboard and perfectly squishy wrist rest – it's a brilliant finishing touch. It easily takes the crown as the best-looking keyboard on test. It's also sturdily built and topped by an elegant, smooth aluminium top.

For extra features, you get dedicated multimedia controls in the top right, including a swish volume wheel, but no extra gaming keys.

Meanwhile, you can adjust the backlighting via secondary functions, and with MSI's Mystic Light software. However, the brightness adjustment shortcut didn't work, and even the software can't apply per-key lighting – you can only adjust the brightness or choose a set lighting pattern.

Conclusion

The MSI GK60 provides a solid balance of affordability and quality. For well under £90, you get a keyboard with an aluminium top plate, real Cherry MX keyswitches and a generally quality feel. It's not loaded with features, and the styling isn't quite to our liking, but it's a dependable option for a good price.

VERDICT

Cheap and mostly cheerful, the MK60 is a quality keyboard for a good price.

DESIGN	FEATURES	OVERALL SCORE
16/20	10/20	77%
PERFORMANCE	**VALUE**	
22/30	29/30	

The keyboard is fully programmable, though, so you can assign just about any function to any key. The lighting customisation is also fantastic, and the lighting looks great. Razer's Synapse software can control all your other Razer peripheral backlighting, as well as that of some other manufacturers' products and even Philips Hue light bulbs.

Conclusion

We expected the Razer Huntsman Elite to feel more like a gimmick than a gaming essential, but we're rather won over. The opto-mechanical switches feel fantastic and the design and features are top-notch. It's a superb keyboard if you can afford it.

VERDICT

Elite by name and price, and thankfully by nature too.

DESIGN	FEATURES	OVERALL SCORE
20/20	18/20	82%
PERFORMANCE	**VALUE**	
25/30	19/30	

ROCCAT VULCAN 120 AIMO / £115 inc VAT

SUPPLIER cclonline.com

Roccat has boldly chosen to develop its own low-profile Titan switches for this keyboard. They use a traditional electronic trigger but apparently provide a 20 per cent faster debounce response. The switches are also stabilised, for less key wobble, and have a very short 1.8mm actuation point. Meanwhile, the low-profile caps are 50 per cent lighter than typical Cherry MX-style ones.

While most switches allow the keycaps to cover the switches as they're pressed, on the Roccat the sides are always on view. This situation enables Roccat to make the RGB backlighting shine out evenly from all round the switches. It makes for a far more dazzling display than most keyboards, although it will be a bit garish for some tastes.

The other key benefit of low-profile switches is, of course, that they allow for a lower keyboard and typing angle, with this keyboard's keys sitting around 5mm lower than on most other mechanical keyboards. We found the lower wrist angle this provides made it noticeably more comfortable for typing than taller mechanical keyboard designs. It's a shame the included wrist rest is just a thin plastic affair, so it doesn't make the most of this benefit.

The rest of the keyboard's design is a bit of a mixed bag. An aluminium plate tops the keyboard, providing a premium feel, but the simple, clean lines that make the Logitech G513 or Razer Huntsman so appealing are missing.

You get a volume wheel and three disappointingly cheap-feeling extra buttons in the top right of the keyboard, but no other extra gaming keys.

Instead, all the F-keys have default secondary functions while Roccat's software allows you to completely customise the layout and lighting. We particularly like the AIMO lighting system that automatically changes the lighting scheme depending on what you're doing. As for overall performance experience, the combination of the low key height and responsive, stabilised keyswitches makes typing and gaming a joy.

Conclusion

Roccat has sold us on the benefits of a low-profile mechanical keyboard, as the Vulcan 120 AIMO is really comfortable for typing. However, we're not convinced by the exposed switch sides and the feature set is a mixed bag. Corsair K70 Mk.2 Low Profile (see p56) does a better all-round job, but the Roccat is a good-value alternative.

VERDICT

A low price and a comfortable typing experience, although the feature set is a mixed bag.

DESIGN	FEATURES	OVERALL SCORE
14/20	16/20	80%
PERFORMANCE	**VALUE**	
22/30	28/30	

How we test

MOTHERBOARDS

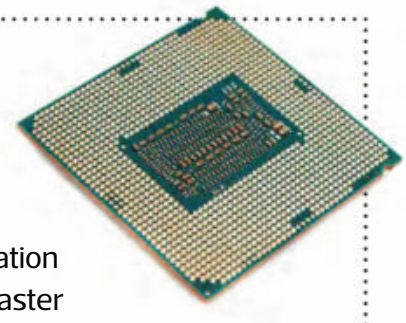
TEST PROCESSORS

- **Intel LGA1151** Intel Core i9-9900K
- **Intel LGA2066** Intel Core i9-7900X
- **AMD AM4** AMD Ryzen 9 3900X
- **AMD TR4** AMD Threadripper 2950X

We otherwise use the same core spec for each motherboard. Our test gear comprises an Nvidia GeForce RTX 2070 Super Founders Edition graphics card and a 2TB Samsung 970 Pro SSD. We also use Corsair Vengeance RGB 3466MHz DDR4 RAM – a 16GB dual-channel kit for mainstream systems, and a 32GB quad-channel kit for HEDT systems.

We use **Custom PC**'s own RealBench suite, and Far Cry 5 installed on Windows 10 Home 64-bit to test basic performance. We also test the board's SATA and M.2 ports, and record the noise level and dynamic range of the integrated audio using RightMark Audio Analyzer. We also try to overclock our test CPU to its maximum air-cooled level on each motherboard, and record the performance results.

PROCESSORS



TEST MOTHERBOARDS

- **Intel LGA1151** MSI MEG Z90 ACE
- **Intel LGA2066** MSI MEG X299 Creation
- **AMD AM4** Gigabyte X570 Aorus Master
- **AMD TR4** MSI MEG X399 Creation

We otherwise use the same core spec to test each CPU. Our test gear comprises an Nvidia GeForce RTX 2070 Super Founders Edition graphics card and a 2TB Samsung 970 Pro SSD. We also use Corsair Vengeance RGB 3466MHz DDR4 memory – a 16GB dual-channel kit for mainstream desktop systems, and a 32GB quad-channel kit for HEDT systems.

We use **Custom PC**'s own RealBench suite, Cinebench and Far Cry 5, installed on Windows 10 Home 64-bit, and record the power draw of the test PC. These tests cover a broad range of performance characteristics, including image editing, gaming, video encoding and 3D rendering. We run all tests at stock speed and at the CPU's highest overclocked frequency.

MONITORS

We test image quality with an Xrite iDisplay Pro colorimeter and DisplayCal software to check for colour accuracy, contrast and gamma, while assessing more subjective details such as pixel density and viewing angles by eye. We also run games on them to assess their responsiveness, and to see how well any active sync tech works, and to gauge their performance at high refresh rates.

CPU COOLERS

We measure the CPU temperature with CoreTemp, and subtract the ambient air temperature to give a delta T result, enabling us to test in a lab that isn't temperature controlled. We load the CPU with Prime95's smallfft test and take the reading after ten minutes.

TEST KIT

Fractal Design Meshify C case, 3000MHz Corsair Vengeance LPX memory, 256GB Crucial MX100 SSD, be quiet! System Power 9 500W PSU, Windows 10 64-bit.

INTEL LGA1151

Intel Core i5-9600K CPU overclocked to 4.6GHz with 1.2V vcore, MSI Z370 PC Pro motherboard.

INTEL LGA2066

Intel Core i9-7900X overclocked to 4.2GHz with 1.15V vcore, MSI X299M Gaming Pro Carbon AC motherboard.

AMD AM4

AMD Ryzen 7 1700 overclocked to 3.9GHz with 1.425V vcore, Asus ROG Strix B350-F Gaming motherboard.

AMD TR4

AMD Threadripper 2950X overclocked to 4.1GHz with 1.425V vcore, AMD Threadripper 2990WX overclocked to 4GHz with 1.3375V vcore, ASRock X399M motherboard.

GRAPHICS CARDS

We mainly evaluate graphics cards on the performance they offer for the price. However, we also consider the efficacy and noise of the cooler, as well as the GPU's support for new gaming features, such as real-time ray tracing. Every graphics card is tested in the same PC, so all the results are directly comparable. Each test is run three times, and we report the average of those results.

We test graphics cards at 1,920 x 1,080, 2,560 x 1,440 and 3,840 x 2,160, although we omit the latter resolution on cheaper cards that are unable to produce playable frame rates at this setting. We also try to overclock every graphics card we test to assess the performance impact.

TEST KIT

Intel Core i7-8700K overclocked to 4.7GHz on all cores, 16GB Corsair Vengeance LED 3000MHz DDR4 memory, Gigabyte Z370 Aorus motherboard, Cooler Master MasterLiquid 240 CPU cooler, Corsair HX750 PSU, Cooler Master MasterCase H500M case, Windows 10 Home 64-bit.

GAME TESTS

Battlefield V Tested in DirectX 11 at Ultra settings on every card. If a GPU also supports real-time ray tracing, we then test it in DirectX 12 with DXR enabled on Low and High settings. We run through a one-minute custom benchmark in the 'Under No Flag' War Story, recording the frame rate with Fraps.

Shadow of the Tomb Raider Tested at the Highest settings preset, with TAA. We run the built-in benchmark, and record the frame rate from the GPU test.

Total War: Warhammer II Tested in DirectX 11, as the DirectX 12 beta currently causes stuttering issues on some GPUs. We test at Ultra settings with FXAA, and run the built-in 'Battle' benchmark.

Deus Ex: Mankind Divided Tested at the Very High preset in DirectX 12, running the built-in benchmark.

POWER CONSUMPTION

We run Unigine Superposition at 4K Optimized DirectX settings. We measure the power consumption of our whole graphics test rig at the mains during the test, and record the peak power draw. Bear in mind that this result is for the whole system, not the graphics card alone.

CUSTOM PC AWARDS

EXTREME ULTRA

Some products are gloriously over the top. They don't always offer amazing value, but they're outstanding if you have money to spend.

PREMIUM GRADE

Premium Grade products are utterly desirable, offering a superb balance of performance and features without an over-the-top price.

PROFESSIONAL

These products might not be appropriate for a gaming rig, but they'll do an ace job at workstation tasks.

APPROVED

Approved products do a great job for the money; they're the canny purchase for a great PC setup.

CUSTOM KIT

For those gadgets and gizmos that really impress us, or that we can't live without, there's the Custom Kit award.

CUSTOM PC REALBENCH

Our own benchmark suite, co-developed with Asus, is designed to gauge a PC's performance in several key areas, using open source software.

GIMP IMAGE EDITING

We use GIMP to open and edit large images, heavily stressing one CPU core to gauge single-threaded performance. This test responds well to increases in CPU clock speed.

HANDBRAKE H.264 VIDEO ENCODING

Our heavily multi-threaded Handbrake H.264 video encoding test takes full advantage of many CPU cores, pushing them to 100 per cent load.

LUXMARK OPENCL

This LuxRender-based test shows a GPU's compute performance. As this is a niche area, the result from this test has just a quarter of the weighting of the other tests in the final system score.

HEAVY MULTI-TASKING

This test plays a full-screen 1080p video, while running a Handbrake H.264 video encode in the background.

Elite

Our choice of the best hardware available

Core component bundles

The fundamental specifications we recommend for various types of PC. Just add your preferred case and power supply, and double-check there's room in your case for your chosen components, especially the GPU cooler and graphics card. We've largely stopped reviewing power supplies, as the 80 Plus certification scheme has now effectively eliminated unstable PSUs. Instead, we've recommended the wattage and minimum 80 Plus certification you should consider for each component bundle. You can then choose whether you want a PSU with modular or captive cables.

Budget system with integrated graphics

Quad-core CPU, basic gaming

Needs a micro-ATX or ATX case.
We recommend a 350W 80 Plus power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 3 2200G	scan.co.uk	**#176** p22	£80
CPU COOLER	AMD Wraith air cooler included with CPU	N/A	**#176** p80	£0
GRAPHICS CARD	AMD Radeon RX Vega 8 integrated into CPU	N/A	**#176** p22	£0
MEMORY	8GB (2 x 4GB) Corsair Vengeance LPX 3000MHz (CMK8GX4M2A 3000C16)	scan.co.uk	**#176** p80	£50
MOTHERBOARD	MSI B450M Mortar (micro-ATX)	scan.co.uk	**#182** p50	£93
STORAGE	500GB WD Blue SN500 (M.2 NVMe)	ebuyer.com	**#191** p78	£70
	Total £293			

UPGRADES

SWAP CPU	AMD Ryzen 5 2400G (slightly faster CPU and GPU performance)	ebuyer.com	**#189** p45	£120

Budget gaming system

Quad-core CPU, 1080p gaming

Needs a micro-ATX case. We recommend a 450W 80 Plus power supply. See Issue 191, p78, for an example build guide.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i3-8100	overclockers.co.uk	**#191** p78	£125
CPU COOLER	Raijintek Juno Pro RBW	overclockers.co.uk	**#191** p78	£12
GRAPHICS CARD	Palit GeForce GTX 1660 StormX 6GB	cclonline.com	**#191** p78	£198
MEMORY	16GB (2 x8 GB) Corsair Vengeance LPX 3000MHz (CMK16GX4 M2A2666C16)	scan.co.uk	**#191** p78	£76
MOTHERBOARD	Gigabyte B360M DS3H (micro-ATX)	cclonline.com	**#191** p78	£73
STORAGE	500GB WD Blue SN500 (M.2 NVMe)	ebuyer.com	**#191** p78	£70
	Total £554			

UPGRADES

SWAP GRAPHICS CARD	AMD Radeon RX Vega 56	ebuyer.com	**#190** p47	£236

Mid-range all-purpose system

6-core CPU, 2,560 x 1,440 gaming

Needs an ATX case. We recommend using a 550W power supply with 80 Plus Bronze certification. See p76 for a similar example build guide.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 3600X	overclockers.co.uk	**#193** p22	£240
CPU COOLER	AMD Wraith Prism air cooler included with CPU	N/A	-	£0
GRAPHICS CARD	AMD Radeon RX 5700	overclockers.co.uk	**#192** p24	£320
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB 3466MHz (CMW16GX4 M2C3466C16)	scan.co.uk	**#192** p21	£118
MOTHERBOARD	MSI X570-A Pro (ATX)	box.co.uk	**#193** p48	£170
STORAGE	1TB Corsair MP600	scan.co.uk	**#193** p26	£250
		Total £1,098		

UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 2060 Super (adds real-time ray tracing abilities)	scan.co.uk	**#193** p16	£380
ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	**#166** p54	£93
UPGRADE CPU COOLER	Deepcool Gammaxx GT BK	scan.co.uk	**#192** p52	£30

Mid-range gaming system

8-core CPU, 2,560 x 1,440 gaming with real-time ray tracing

Needs an ATX case with room for a 240mm all-in-one liquid cooler. We recommend a 600W 80 Plus Bronze power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 3700X	overclockers.co.uk	**#192** p14	£320
CPU COOLER	Corsair H100i Pro RGB (240mm AIO liquid cooler)	ebuyer.com	**#183** p50	£111
GRAPHICS CARD	Nvidia GeForce RTX 2070 Super	nvidia.com	**#193** p16	£475
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB 3466MHz (CMW16GX4 M2C3466C16)	scan.co.uk	**#192** p21	£118
MOTHERBOARD	Asus ROG Strix X570-E Gaming (ATX)	ebuyer.com	**#193** p44	£270
STORAGE	1TB Corsair MP600	scan.co.uk	**#193** p26	£250
		Total £1,544		

UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	**#166** p54	£105

Core component bundles cont ...

4K gaming system

12-core CPU, 4K gaming with real-time ray-tracing abilities

Needs an E-ATX case with room for a 240mm all-in-one liquid cooler. We recommend a 650W 80 Plus Gold power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 9 3900X	overclockers.co.uk	**#192** p14	£500
CPU COOLER	Corsair H100i RGB Platinum (240mm AIO liquid cooler)	scan.co.uk	**#175** p20	£140
GRAPHICS CARD	Nvidia GeForce RTX 2080 Ti	scan.co.uk	**#189** p20	£990
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB 3466MHz (CMW16GX4 M2C3466C16)	scan.co.uk	**#192** p21	£118
MOTHERBOARD	MSI Prestige X570 Creation (E-ATX)	overclockers.co.uk	**#193** p48	£450
STORAGE	1TB Corsair MP600	scan.co.uk	**#193** p26	£250
	Total £2,448			
UPGRADES				
ADD SECONDARY STORAGE	4TB Western Digital Blue	overclockers.co.uk	**#166** p54	£93

Heavy multi-threading workstation

Serious multi-threaded power, 1080p gaming

Needs an ATX case with room for a 240mm all-in-one liquid cooler. We recommend a 700W 80 Plus Gold power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Threadripper 2950X	overclockers.co.uk	**#182** p23	£800
CPU COOLER	Enermax Liqtech II TR4 240 (240mm AIO liquid cooler)	overclockers.co.uk	**#186** p44	£130
GRAPHICS CARD	Zotac Gaming GeForce GTX 1660 6GB	ebuyer.com	**#190** p44	£205
MEMORY	32GB Corsair Dominator Platinum RGB 3200MHz (CMT32GX 4M4C3200C16)	scan.co.uk	**#188** p19	£250
MOTHERBOARD	ASRock X399 Taichi (ATX)	cclonline.com	**#170** p47	£322
STORAGE	1TB Samsung 970 Evo Plus (M.2 NVMe)	ebuyer.com	**#188** p51	£210
	Total £1,917			
UPGRADES				
SWAP GRAPHICS CARD	Nvidia GeForce RTX 2070 Super (2,560 x 1,440 gaming with ray tracing, and some 4K gaming)	nvidia.com	**#193** p16	£475
SWAP CPU	AMD Threadripper 2990WX (faster in some heavily multi-threaded software, not recommended for gaming)	scan.co.uk	**#182** p24	£1,600
ADD SECONDARY STORAGE	6TB Seagate BarraCuda Pro	overclockers.co.uk	**#166** p50	£215

Mini PCs

Our favourite components for building a micro-ATX or mini-ITX PC. Always double-check how much room is available in your chosen case before buying your components. Some mini-ITX cases don't have room for large all-in-one liquid coolers, for example, or tall heatsinks. You'll also need to check that there's room for your chosen graphics card. We've also recommended a small PSU and a low-profile CPU cooler, if your chosen case requires them.

Mini-ITX

Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Intel Z390 (LGA1151)	ASRock Z390 Phantom Gaming-ITX/ac	scan.co.uk	**#185** p50	£182
Intel X299 (LGA2066)	ASRock X299E-ITX/ac	scan.co.uk	**#174** p26	£396
AMD X470 (AM4)	Asus ROG Strix X470-i Gaming	scan.co.uk	**#181** p22	£185

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Fractal Design Define Nano S	scan.co.uk	**#153** p22	£60
PREMIUM	NZXT H200i	scan.co.uk	**#187** p41	£100

CPU coolers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
LOW-PROFILE	Noctua NH-D9L	amazon.co.uk	**#143** p17	£44

Power supplies

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
800W SFX	SilverStone Strider SX800-LTI	scan.co.uk	**#185** p82	£161

ATX Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Phanteks Eclipse P300 Glass	overclockers.co.uk	**#176** p28	£55
SUB-£75	NZXT H500	scan.co.uk	**#178** p26	£70
SUB-£100	Lian Li Lancool One Digital	overclockers.co.uk	**#184** p32	£95
MID-RANGE	Phanteks Eclipse P600S	overclockers.co.uk	**#187** p24	£128
HIGH-END	Phanteks Enthoo Evolv X	overclockers.co.uk	**#187** p24	£200
LUXURY	Cooler Master Cosmos C700M	scan.co.uk	**#183** p28	£390

Micro-ATX

Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Intel Z390 (LGA1151)	Asus ROG Maximus XI Gene	overclockers.co.uk	**#189** p28	£309
Intel X299 (LGA2066)	MSI X299M Gaming Pro Carbon AC	cclonline.com	**#174** p24	£255
AMD X399 (TR4)	ASRock X399M Taichi	scan.co.uk	**#179** p28	£336
AMD B450 (AM4)	MSI B450M Mortar	scan.co.uk	**#182** p50	£93

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Fractal Design Focus G Mini	overclockers.co.uk	**#180** p46	£47
MID-RANGE	Fractal Design Define Mini C	scan.co.uk	**#161** p26	£70
PREMIUM	NZXT H400i	overclockers.co.uk	**#175** p32	£90

Networking

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ROUTER	Linksys EA9500 Max-Stream	amazon.co.uk	**#182** p58	£250
PREMIUM ROUTER	Asus ROG Rapture GT-AC5300	overclockers.co.uk	**#170** p35	£308
MESH NETWORK (requires existing router)	BT Whole Home Wi-Fi Triple Pack	currys.co.uk	**#172** p54	£160
PREMIUM MESH ROUTER	Netgear Orbi 2-Pack (RBK50)	amazon.co.uk	**#172** p57	£241
WI-FI ADAPTOR	Asus PCE-AC68	scan.co.uk	**#128** p88	£58
SINGLE-BAY NAS BOX	Synology DS118	box.co.uk	**#174** p34	£154
DUAL-BAY MEDIA NAS BOX	Synology DS218play	box.co.uk	**#174** p34	£204

Monitors

AMD FreeSync

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN BUDGET 1,920 X 1,080	AOC G2460VQ6	amazon.co.uk	**#174** p52	£125
24IN MID-RANGE 1,920 X 1,080	AOC C24G1	cclonline.com	**#191** p28	£178
24IN 240Hz ESPORTS 1,920 X 1,080	AOC AGON AG251FZ	overclockers.co.uk	**#187** p48	£290
27IN 2,560 X 1,440	Samsung C27HG70	ebuyer.com	**#171** p28	£460

Nvidia G-Sync

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN 2,560 X 1,440	AOC AGON AG241QG	box.co.uk	**#169** p55	£378
27IN 2,560 X 1,440	Asus ROG Swift PG279Q	scan.co.uk	**#155** p48	£640
35IN ULTRA-WIDE 3,440 X 1,440	AOC AGON AG352UCG6	box.co.uk	**#180** p52	£650
27IN 4K PREMIUM	Asus ROG Swift PG27UQ	box.co.uk	**#181** p31	£1,799

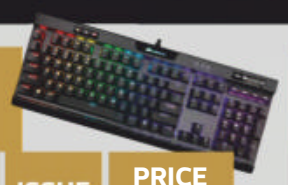
AMD FreeSync and Nvidia G-Sync

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN BUDGET 1,920 X 1,080	AOC G2590FX	overclockers.co.uk	**#190** p53	£200
25IN MID-RANGE 1,920 X 1,080	Asus VG258QR	overclockers.co.uk	**#190** p54	£280

Non-gaming

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN 5,120 X 2,880	Iiyama ProLite XB2779QQS	scan.co.uk	**#179** p34	£695

Peripherals and audio



Gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
MEMBRANE	Corsair K55 RGB	overclockers.co.uk	**#176** p52	£55
MECHANICAL	Corsair K68	ebuyer.com	**#181** p53	£80
MECHANICAL MMO	Corsair K95 RGB Platinum	ebuyer.com	**#164** p26	£170
PREMIUM MECHANICAL	Corsair K70 Mk.2 Low Profile	scan.co.uk	**#193** p56	£160
LUXURY MECHANICAL	Razer Hunstman Elite	razer.com	**#193** p59	£200

Gaming mice

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
FIRST-PERSON SHOOTER	SteelSeries Rival 600	scan.co.uk	**#184** p59	£74
MMO	Roccat Nyth	amazon.co.uk	**#186** p53	£65
AMBIDEXTROUS	Razer Lancehead Tournament Edition	scan.co.uk	**#177** p53	£65

Peripherals and audio cont ...

Game controllers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
STEERING WHEEL & PEDALS	Logitech G920 Driving Force	currys.co.uk	**#159** p55	£200
GAMEPAD	Microsoft Xbox One Wireless Controller	game.co.uk	**#191** p56	£44

Speakers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
STEREO	Edifier R1280DB	amazon.co.uk	**#192** p57	£120

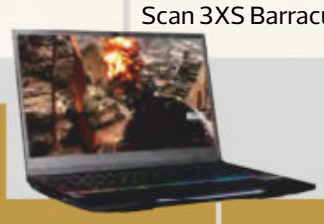
Gaming headsets

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
STEREO	HyperX Cloud Alpha	currys.co.uk	**#173** p50	£83
SURROUND	Asus ROG Centurion	ccdonline.com	**#163** p49	£216
WIRELESS	SteelSeries Arctis 7	amazon.co.uk	**#178** p58	£119
PREMIUM WIRELESS	SteelSeries Arctis Pro + GameDAC	scan.co.uk	**#179** p31	£213

PCs and laptops

Pre-built PC systems

CATEGORY	NAME	CPU	GPU	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET PC WITH INTEGRATED GRAPHICS	Falcon Raptor RX	AMD Ryzen 5 2400G stock speed	AMD Radeon RX Vega 11	falconcomputers.co.uk	**#176** p52	£450
SUB-£1,000 GAMING	Chillblast Fusion Ryzen 5 GTX 1660 Ti	AMD Ryzen 5 2600 stock speed	Nvidia GeForce GTX 1660 Ti	chillblast.com	**#189** p58	£999
ENTRY-LEVEL RAY TRACING	CyberPower Ultra 5 Super	AMD Ryzen 5 3600 stock speed	Nvidia GeForce RTX 2060 Super	cyberpowersystem.co.uk	**#193** p36	£1,179
GEFORCE RTX 2070 SUPER GAMING	PC Specialist Vulcan S2	Intel Core i7-9700F stock speed	Nvidia GeForce RTX 2070 Super	pcspecialist.com	**#192** p38	£1,606
GEFORCE RTX 2080 GAMING	Chillblast Fusion Juggernaut 2080	Intel Core i5-9600K OC to 4.6GHz	Nvidia GeForce RTX 2080	chillblast.com	**#183** p62	£2,060
PREMIUM MINI-ITX	Corsair One i160	Intel Core i9-9900K stock speed	Nvidia GeForce RTX 2080 Ti	corsair.com	**#190** p32	£3,399
DREAM PC	Scan 3XS Barracuda	Intel Core i9-9900X OC to 4.4GHz	2 x Nvidia GeForce RTX 2080 Ti	scan.co.uk	**#145** p58	£10,143



Laptops

CATEGORY	NAME	CPU	GPU	SCREEN	SUPPLIER	ISSUE	PRICE (inc VAT)
GAMING	PC Specialist Recoil III RTX 17.3in	Intel Core i7-9750H stock speed	Nvidia GeForce RTX 2070	17.3in 1,920 x 1,080 IPS 144Hz	pcspecialist.com	**#188** p32	£1,665
THIN AND LIGHT GAMING	Scan 3XS Vengeance GL 2070	Intel Core i7-8750H stock speed	Nvidia GeForce RTX 2070 Max-Q	15.6in 1,920 x 1,080 IPS 144Hz	scan.co.uk	**#189** p34	£1,737
PREMIUM GAMING	Asus ROG Zephyrus S GX701GX	Intel Core i7-8750H stock speed	Nvidia GeForce RTX 2080 Max-Q	17.3in 1,920 x 1,080 IPS 144Hz G-Sync	amazon.co.uk	**#190** p28	£3,100

RICK LANE / INVERSE LOOK

IN PRAISE OF CHARACTERS

Rick Lane analyses the importance of character when games tell stories

I was originally going to title this column: 'To tell better stories, games need better characters.' It's true, but it implies that games don't tell compelling stories right now, and that's unfair. There's a wide array of games that have weaved wonderfully entertaining tales, from the BioShock and Portal games, to BioWare's unique and brilliant Mass Effect trilogy.

More recently, Telltale's adventure games have added to the pile of fantastic story-driven experiences, and there are innumerable indie titles, such as To the Moon and Kentucky Route Zero, which are majestically written and plotted. Even the story of this year's Wolfenstein, a game about shooting Nazi robot dogs with laser guns, punched above its weight.

All these games share the same reason behind their storytelling success – characters, which are crucial to any story. Thankfully, strong, memorable characters are becoming more commonplace, and that's worth highlighting. Games weren't always this way, and it would be easy to slip backwards into bad habits.

For a long time, games viewed stories mechanically. Writing was designed to fit within a particular set of levels or missions, and narratives were objective-driven. You can even see this approach in a game such as Thief, where the story accommodates the mission setting. The difference with Thief, of course, is that it introduced Garrett, and Garrett's character sustains our interest over the plot.

You can still see this style of storytelling today, most obviously in Call of Duty. These games follow the exact same plot structure as Thief, except they're devoid of any interesting characters. That's why it's impossible to care about their world-saving missions, and why the now traditional 'death of a comrade' scene going into the third act has become so ineffective. Compare it with a game such as Portal, which is arguably the epitome of this level-based narrative, but brings it together through the magnificent GLaDOS.

BioShock did a lot to finish that storytelling style. It featured great characters, but it also used, abused and inverted the traditional structure so masterfully that it couldn't really be bettered, forcing games to try a different tack. Consequently, games have moved on even further – they're not simply making themselves interesting through good characters, but being driven by characters.

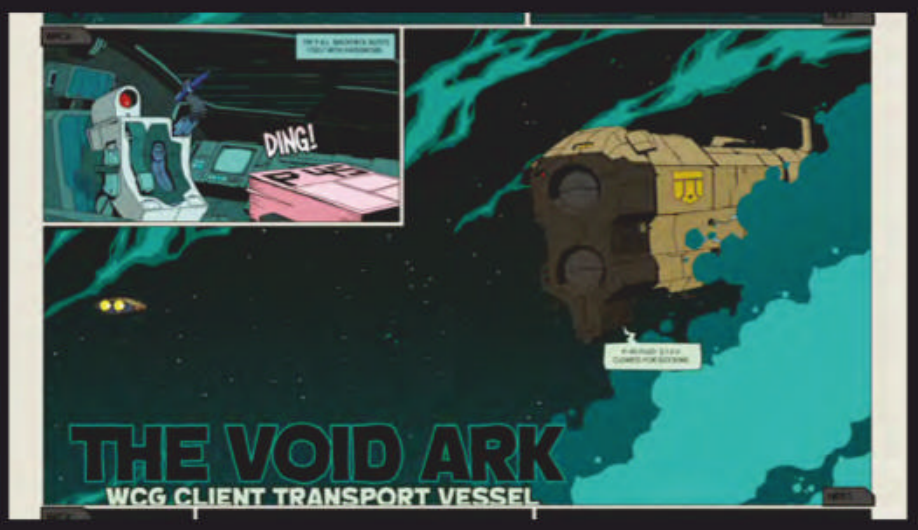
> The importance of character in creating meaningful and relatable games can't be underestimated

Mass Effect 2 is my favourite example, a game that spends many hours establishing relationships between you and your crew, earning their 'loyalty' for the sake of undertaking an extremely dangerous mission. Then, when that mission comes, it isn't the objective that interests you, but simply trying to keep your friends alive. The Walking Dead took this approach even further, creating a game that's entirely about characters.

We're even at the stage where character can play a vital role in games without a scripted story. Strategy games such as Crusader Kings and XCOM are made vastly more interesting by letting you control recognisable individuals rather than entire armies or nations – individuals who grow, change, live and die, depending on your actions.

The importance of character in creating meaningful and relatable games can't be underestimated. The industry is slowly realising this fact, but we need to ensure it continues down this route by being aware of the difference good characterisation can make to a game, and praising it where we see it. CPC

Rick Lane is Custom PC's games editor @Rick_Lane



Void Bastards / £24.99 inc VAT

DEVELOPER Blue Manchu / **PUBLISHER** Humble Bundle

Created by former System Shock 2 designers, Void Bastards is about exploring derelict spaceships, scavenging what you can find and avoiding being murdered by horribly mutated Northerners. You're a randomly selected prisoner en route to a penal colony on a giant prison ship when it becomes trapped in a gigantic spaceship graveyard. Your ship doesn't have the necessary parts to escape, so you're up for early release ... into the dark void of space.

Although completing the game requires you to achieve set goals, for the most part you'll be looking for items that get you to the next ship across the graveyard, such as more fuel for your little scout-pod, or gadgets to build new weapons and equipment.

You navigate the graveyard via a 2D, FTL-like interface. When you board a ship, however, the game switches to a 3D, first-person perspective. The derelicts have different classes that affect the rooms and items you're likely to find. Medical frigates have healing bays and plentiful staples for your ad hoc shotgun, while luxury cruise liners are usually stuffed with food.

However, your spacesuit only has a limited supply of oxygen, while each ship has its own colourful and deadly threats. The mutants range from blob-like Tourists, who explode when close to you, to thuggish Juves, who fire telekinetic orbs at you while turning the air a distinctly Mancunian shade of blue. In addition, there's a range of potential environmental hazards, including fires, radiation pools and deadly security systems.

The condition of each ship is procedurally generated with its own unique puzzle – how you attempt to solve it is up to you. You could head straight to the Bridge to download item and enemy locations, for example, or you could go to the other end of the ship and grab some fuel. The equipment you bring on board, also affects your tactics – whether you go in guns blazing, or use wandering 'Kittybots' to distract enemies.

The vivid comic-book art style and Douglas Adams-style humour lend Void Bastards a unique tone without compromising the atmosphere of exploring those eerie derelicts. Unfortunately, though, only around half the enemies are fun to fight. Others are best avoided, but higher-level ships are often so crammed with enemies that avoidance is near impossible.

Although the algorithms that drive Void Bastards can frustrate at times, it's hard to resist the appeal of delving into another spaceship to see what surprises it contains. If procedural System Shock with added jokes sounds like your cup of tea, it's worth doing some time with Void Bastards.

RICK LANE

VOID

+ Stylish visuals
+ Fun tactical exploration
+ Good humour

AVOID

− Some annoying enemies
− Too many enemies on higher-level ships

/ VERDICT

The combat may stumble, but Void Bastards' whip-smart aesthetics and compelling systems still make it worth playing.

OVERALL SCORE

80%

Total War: Three Kingdoms / £39.99 inc VAT

DEVELOPER Creative Assembly / **PUBLISHER** Sega

Total War has always dealt in the broad tides of conflict, seeing you control great empires such as Rome or nation states such as Medieval France. Yet in its sweeping strategy campaigns and massive, spectacular battles, people are often reduced to statistics in one of your vast armies. Even your most significant faction members, your generals and spies, are chess pieces, their individualism becoming significant if they're knocked off the board.

Total War: Three Kingdoms changes this situation. Taking inspiration from Paradox's Crusader Kings series, it turns your faceless generals, faction leaders, government administrators and espionage agents into recognisable characters with their own distinct personalities. These characters exist within a complex social hierarchy that relates both to your faction and those surrounding you. It's one of several major changes that makes Three Kingdoms the most innovative Total War game in years, and comfortably the best instalment since Shogun 2.

Set in ancient China, a game of Three Kingdoms commences with players selecting one of 12 warlords.

Your goal is to progress through the ranks of the aristocracy, starting as a noble and climbing to become a marquis, duke, king and eventually Emperor of China. You do this by earning 'prestige', gained by building and upgrading cities, and/or winning battles.

Each of the 12 warlords has a unique ability that shapes the course of their campaign. Cao Cao, for example, is a master strategist, able to incite proxy wars between rival factions and take advantage of the chaos. Liu Bei, meanwhile, can use the strength of his personality to help unify China's crumbling Han Empire, annexing its territories into his own faction without spilling a drop of blood.

All warlords and their retainers are subject to Guanxi – the new system that drives the relationship between characters. Unlike previous Total War games, characters have no fixed role. You can assign them to be generals, court administrators, government officials and spies as you see fit. However, a character will form a relationship with every other character they encounter, which can have a drastic impact on every facet of the game. For example, generals will establish a bond with one another, which might be friendly or unfriendly.

TOTAL WAR

- \+ Excellent diplomacy
- \+ Guanxi brings character to the fore
- \+ Battles nearly always a significant event

TOTAL BORE

- – Some superfluous systems
- – UI not always easy to read

If it's friendly, they might eventually become blood brothers, gaining a mutual defensive bonus when fighting. If one of them is killed, however, the remaining general might fall into an uncontrollable rage, charging at the enemy heedless of your orders. On the other hand, a frictional relationship might sound like a problem, but it can encourage your generals to fight harder, if only to spite their rival.

Guanxi pervades almost every system in the game, but it's particularly important in two areas. The first is your government. As you progress up the ranks of aristocracy, more government positions become available in your dynasty. Ideally, you want to staff those positions with capable individuals, but you also want to keep your faction members happy. If a character's satisfaction level drops too low, they might eventually leave your faction, potentially joining one of your enemies. Sometimes a little nepotism goes a long way.

The second area is diplomacy. With Three Kingdoms, this has never been more significant (and enjoyable). Securing your borders with strong alliances is important to prevent you from being overwhelmed in the early game. However, maintaining these alliances means keeping them happy, and because everybody interrelates with everybody else, you need to think very carefully about the characters with which you can go to war, sue for peace and trade. It's absolutely superb – an ever-shifting chess game that encourages genuine strategy rather than simply deploying overwhelming force.

One final area of Three Kingdoms that's been completely overhauled is espionage. You no longer recruit spies and move them around the board. Instead, you pick a character with the espionage trait, and assign them to infiltrate a specific faction. At this point, that character will enter their recruitment pool, and if successfully recruited, they can begin performing covert operations. The longer they're in that faction, the higher the rank they'll attain, to the point where they can potentially end up leading that faction to hand the entire dynasty over to you.

The changes to armies and battles are subtler, but equally significant. As in Total War: Thrones of Britannia, you don't recruit entire units at cities. Instead, units appear instantly in the retinue of one of your generals, but take several turns to reach full strength. Meanwhile, each warlord has a limited number of armies they can field relative to their aristocratic rank. A noble can only control one army, for example, while a marquis gets two or three.

The result is that battles are less frequent, but more important. Most armies won't engage in a fight unless they're near full strength, and consequently almost every battle is a major spectacle that could go either way. Meanwhile, your tactical opportunities are expanded with new 'hybrid' units, such as cavalry that can hold a front line, or infantry that can fire short-range missiles. Additionally, if you play on the new Romance mode, your generals become ancient Chinese superheroes, able to take on entire units by themselves and deploy special abilities that can reshape the battle.

The resulting Total War is both more flexible and less predictable than its predecessors, where diplomacy and espionage are now equally important to your martial capabilities, and where personal stories and relationships are threaded through your victories, in battle and on the campaign map.

Of course, it isn't perfect. The Ancillaries, special weapons and armour with which you can equip your characters, is one system too many. As your faction expands, constantly fiddling with character equipment becomes too much busywork. Also, the UI, while incredibly stylish, isn't the easiest to read, with some important buttons (such as the button for seeking out a spouse) tucked away in places you might not think to look.

Overall, however, Three Kingdoms is by far the best Total War game in years. Its reworked systems enabled far more subtle and nuanced strategic possibilities, while the character relationships conjure stories that will surprise and shock you in equal measure.

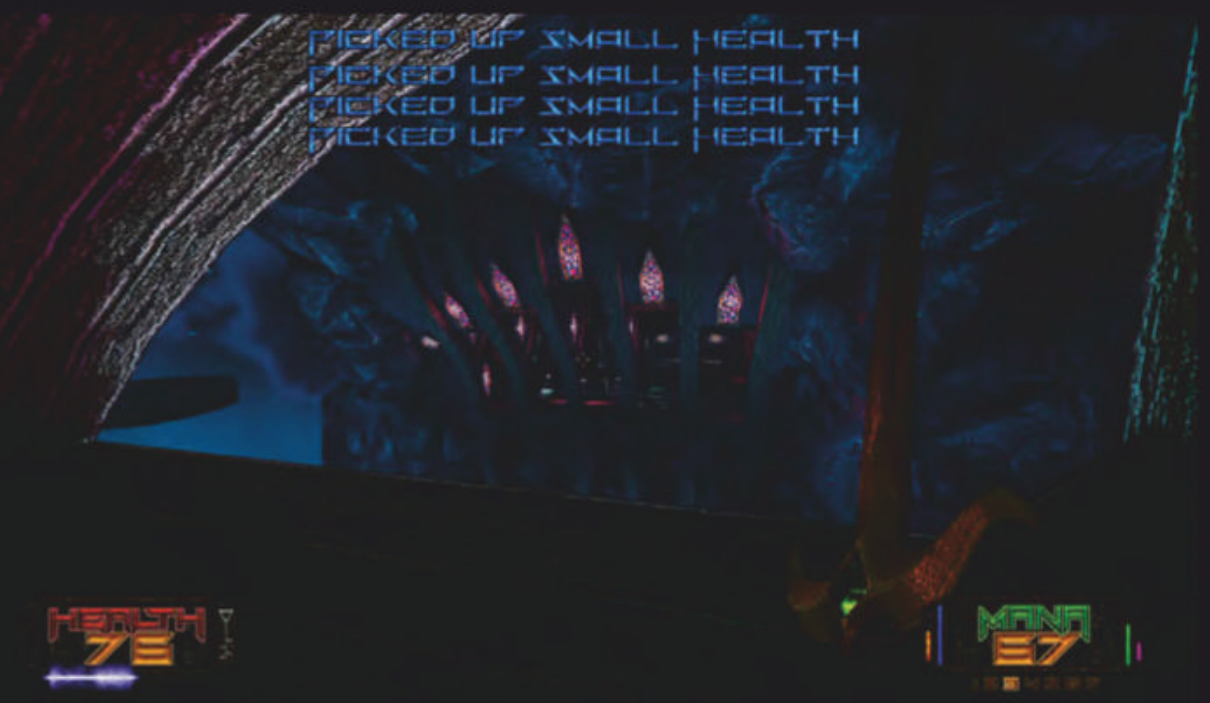
RICK LANE

/VERDICT

A stunning reinvention of the long-running strategy series, Three Kingdoms' bevy of smart ideas makes it the best Total War game in ages.

OVERALL SCORE

90%



Amid Evil / **£12.49** inc VAT

DEVELOPER Indefatigable / **PUBLISHER** The New Bloods Interactive

HERETIC

- Thrilling combat
- Amazing weapons
- Great level design

HERE-CROSS

- Enemy pacing could be better
- Some fiddly platforming
- Underwater bits

/VERDICT

Amid Evil flings itself to greatness with its fast pace, cleverly constructed levels and a weapon roster that's downright sacrilegious.

OVERALL SCORE

90%

Amid Evil is a 'first-person slinger', a fantasy FPS that situates itself within the proud, albeit brief, tradition of games such as Heretic, Hexen: Beyond Heretic and, er, Hexen 2. It's a relentless metaphysical thrill ride with some of the most imaginative level and weapon design we've seen. The premise is delightfully simple. You're a nameless warrior chosen to rid the universe of a mysterious evil spreading its tendrils through a bunch of different fantasy realms. That's it. Now hurry up and get smiting.

And what smiting! Your weapons aren't shotguns and rocket launchers, but staffs, swords and tridents, each of which works differently, and you won't know how until you press the left mouse button for that first, glorious time. The Whisper's Edge snicker-snacks a stripe of green light at enemies, while the Voltride fires a sustained electrical charge that, if focused on one enemy long enough, causes them to burst into smithereens, along with any nearby opponent.

Special mention goes to the Star of Torment, which fires a cluster of crystal shards that will impale an enemy on any surface, or, if there's no surface, shoot them off the map entirely. It's the most satisfying new weapon we've encountered in an FPS since the Drillbit launcher from Bulletstorm.

Similar credit goes to Amid Evil's level design. The game takes you from sun-soaked ancient temples, to a corrupted fairy-tale kingdom, to a kaleidoscopic wizard's lair suspended in the sky. All these levels are beautifully constructed, abstract and puzzle-like, yet they maintain astonishing forwards momentum. The design of the last level, which takes place in a formless purple void, is remarkable.

The game isn't entirely flaw-free. Each weapon has a powerful alt-fire that you can activate once you collect enough 'souls', but it rarely feels like there's a need to use it, an issue that some more careful enemy placement could resolve. In addition, the boss battles that cap off every stage are rather underwhelming. Also, while the game smartly avoids many irritating quirks of old shooters, such as fall damage, there are still lots of precarious ledges from which it's easy to fall, and trying to get out of water is like watching a fish try to climb a ladder.

Nonetheless, Amid Evil is an enthralling eight to ten hours of furious fantasy action. Its level design often matches the mighty DUSK, and its selection of weapons eclipses that of quite a few big-budget shooters. If you're a fan of running fast and killing enemies from a distance, Amid Evil does both very well indeed.

RICK LANE

Outer Wilds / £19.99 inc VAT

DEVELOPER Mobius Digital/ **PUBLISHER** Annapurna Interactive

Space exploration games don't get much better than Outer Wilds. You play the latest recruit of Outer Wilds Ventures, the space program of the folksy planet Timber Hearth. You're given your own spaceship and tasked with investigating the farthest reaches of Timber Hearth's star system.

Unlike most space games, which emphasise the scale of the great and inky void, Outer Wilds takes place in a single star system. Within those boundaries are several planets, a handful of moons and a roving comet known as the Interloper. What's more, you only have 20 minutes before the star at the centre of your system explodes, killing you and – due to mysterious circumstances we won't spoil – cascading you back to the moment you first awoke prior to climbing into your ship.

Many modern space games use procedural generation to flesh out their millions of planets, but each body in Outer Wilds has been painstakingly designed by hand, and they're far from typical balls of rock. Brittle Hollow, Timber Hearth's nearest planetary neighbour, is a giant purple eggshell riddled with ancient ruins on the underside of its crust. It has a black hole at its core, and it's orbited by a lava-spewing moon called Hollow's Lantern. As you explore, globules of lava from the Lantern crash onto the planet's surface, breaking off huge chunks of the crust, which collapse into the black hole and vanish.

In this single planet, Outer Wilds communicates the weirdness, danger and awe of space exploration. Every object in the system is a cosmic wonder that would be the star attraction of any other game. They're also highly dynamic, with the topography dramatically shifting and changing in the countdown to the supernova.

There's more to this dynamism than simple visual spectacle. Outer Wilds is one giant clockwork puzzle, where certain events happen at specific moments, and sometimes you need to take advantage of these moments to progress. You'll gradually piece together a story relating to an ancient civilisation that preceded your own, which built vast probe cannons and great machines that function via quantum mechanics.

Knowing you have limited time pushes you forward, making you bolder and more curious. Indeed, you'll rarely see that bright blue supernova. You'll be crushed by islands, fall off planets, be struck by moons and tumble into stars. However, you'll awake moments later, and you can return to your last living location within two minutes.

Outer Wilds isn't perfect. The spaceship flight controls can be frustrating, and conversations with fellow travellers are rather undercooked. However, the visual spectacle and environmental puzzling more than make up for these minimal shortcomings.

RICK LANE

WILD

- \+ Astonishing space exploration
- \+ Great story
- \+ Clever time loop concept

MILD

- – Frustrating flight controls
- – Dialogue could be better

/ VERDICT

One of the finest space exploration games ever, Outer Wilds dazzles with its mind-bending experiences and ingenious time loop concept.

OVERALL SCORE

90%

REALITY CHECK

It's all a bit spacey in Rick Lane's VR roundup this month

REVIEW

STAR WARS: VADER IMMORTAL: EPISODE ONE / £7.99 inc VAT

DEVELOPER ILMxLAB / **PUBLISHER** Disney Interactive Studio

Star Wars: Vader Immortal is roughly one hour of pure Star Wars wish-fulfilment. It lets you watch a Star Destroyer loom over your puny spacecraft, wield a lightsaber and deflect blaster bolts at Stormtroopers. Plus, of course, it lets you stand nose to chest with one of the most iconic baddies in cinema history. It's lavishly produced and utterly captivating, although it skimps on its best features just a little too much.

Written by David S Goyer (who co-wrote The Dark Knight), Vader Immortal tells the story of a young smuggler who is intercepted by a Star Destroyer near the lava planet of Mustafar, abducted and imprisoned inside Vader's Castle. You then discover you're a latent Force-wielder, and Vader has been searching particularly hard for you. Aided by your trusty droid companion, you escape into the bowels of Vader's castle.

It's almost worth the price to simply stand in the Star Wars world. To look out of a starship window into the great inky void, watch Stormtroopers march around from an elevated gantry in Vader's Castle and experience Darth Vader's height and ability to intimidate.

But there's a game here too, albeit a relatively simple and prescribed one. The most significant aspect of Vader Immortal is how it lets you wield a lightsaber. Once acquired around the middle of the game, the saber is attached to your belt. You draw it with your hand and ignite it with a push of one of the Oculus Touch controller's buttons.

Although you don't get to battle Vader himself, you square off against various types of saber-wielding droids. It's a straightforward matter of swinging your arms, although it takes a while to perfect holding the light saber two-handed. Combat is simple, but effective and utterly thrilling, particularly the final battle, which sees you fighting enemies from multiple angles. Our only complaint is that the lightsaber doesn't cut properly – it's understandable that Disney might want to limit dismemberment, but surely it could allow players to lop off the limbs of a droid or two.

Beyond saber combat, you scout around the bowels of Vader's castle, climbing ladders, navigating perilous ledges and solving simple mechanical puzzles. One of the more understated joys of Vader Immortal is interacting with many of the interfaces seen from the films, opening doors with a hydrospanner, pulling the lever of a starship to enter hyperspace, and so on.

Vader Immortal only takes around an hour to complete, but that's reflected in its price, and it's bundled with a Jedi training Dojo where you can hone your saber skills against laser-spitting remotes. It would be better if the first episode involved a bit more action and less standing while people talk to you, even if that person is often Darth Vader. However, it's a solid start for this three-episode series, and we can't wait for the next instalment.

OVERALL SCORE

80%

NEWS

FLY THE TARDIS

VR is great for wish fulfilment. We've already seen games that let you dodge bullets like Neo and swing a lightsaber like Luke Skywalker (see opposite). Now the BBC hopes to fulfil the wishes of every British sci-Fi fan, with a Doctor Who game that lets you fly the TARDIS.

Doctor Who: The Edge of Time is being developed in conjunction with Maze Theory. It's a 'feature length' VR game that puts you in the shoes of the Doctor's latest companion, as the Time Lord embarks on another adventure across space and time, with Jodie Whitaker lending her voice to her virtual self.

The main draw here, however, is the opportunity to get hands on with one of sci-fi's most iconic vehicles. To this effect, Maze Theory claims to have put '12,000 hours' into its replication of the current BBC TARDIS set, based on hundreds of photos taken by members of the team. Moreover, the intention is not merely to recreate the look of the TARDIS, but also its function, ensuring that every knob and dial on its alien dashboard is functional and interactive. Doctor Who: The Edge of Time will phase onto all the major PC VR headsets (and the Quest) in September.

OPINION

SIZE ISN'T EVERYTHING

One of the perceived limitations of VR is the brevity of the experiences it offers. Most VR games last only a few hours, while those that offer longer experiences, such as Fallout 4 or Elite Dangerous, tend to be standard games adapted for VR. However, VR also offers an opportunity for us to get out of some bad gaming habits.

Most modern games are far too long, to the point where finishing any game from a major publisher can dominate your evenings for weeks, even months on end. What's more, very few of these games justify that size, with many revolving around the same handful of half-hour feedback loops repeated ad nauseum.

Now imagine that, rather than lying on the sofa with a controller for 30-40 hours, you have to stand up, wave your arms around, clamber over objects, physically dodge sword strikes and gunshots. Playing in VR makes you sweaty and tired. It isn't built for life-absorbing games. It makes sense for VR experiences to last as long as you can keep up with them.

And that's good! Games should be built to fit into our lives, not monopolise them. Why spend 40 hours doing one activity over and over again, when you could do three or four for approximately the same price? As long as VR games don't overestimate their value, their shorter runtimes could provide a valuable opportunity to adjust our expectations.

NEWS

EXPLORING THE COSMOS

Back in January, HTC announced its newest headset, the Vive Cosmos, but the announcement was light on details. We knew the Cosmos would use an inside-out tracking system similar to the Oculus Quest (but with six cameras instead of four), and we knew that it would cost round £700, but that was it.

Now, HTC has shed more light on the headset's specs. The Cosmos' display will include a combined resolution of 2,800 x 1,700 (1,440 x 1,700 per eye) – an 88 per cent increase over the original Vive. It will also run at the same 90Hz refresh rate as the Vive. A big change is that the Cosmos will use RGB LCDs instead of the more popular OLED displays used by most other headsets. The general drive is to reduce the screen-door effect as much as possible, which HTC claims the Vive does by around 40 per cent, although we don't know how HTC has arrived at that figure.

The Cosmos' display puts it above every other headset currently on the market, including the Valve Index, which runs at 1,440 x 1,600 per eye. The Cosmos is due for release this autumn. CPC

BUILD AN 8-CORE GAMING PC

Antony Leather shows you how to assemble a 3rd-gen Ryzen gaming rig, complete with PCI-E 4 SSD, Nvidia RTX 2060 Super GPU, X570 motherboard and liquid cooling

FOR £1,495

AMD's new 3rd-gen Ryzen CPUs blew us away last month, offering amazing performance for surprisingly low prices, so this month we've built an X570-based gaming PC to show you how it's done. We'll be using AMD's 8-core Ryzen 7 3700X, along with Corsair's 1TB MP600 PCI-E 4 SSD and Nvidia's RTX 2060 Super GPU, while throwing in some liquid cooling and Phanteks' awesome P600S case in a fantastic sub-£1,500 gaming rig.

As usual, we'll be offering tips, tricks and tweaking advice, as well as alternative products for budgets above and below our example, depending on your own needs. We'll also be taking a look at the best ways to overclock your PC and set it up for the best performance, depending on whether you need maximum multi-threaded grunt for content creation, or the highest frame rates in games.

SHOPPING LIST

CPU

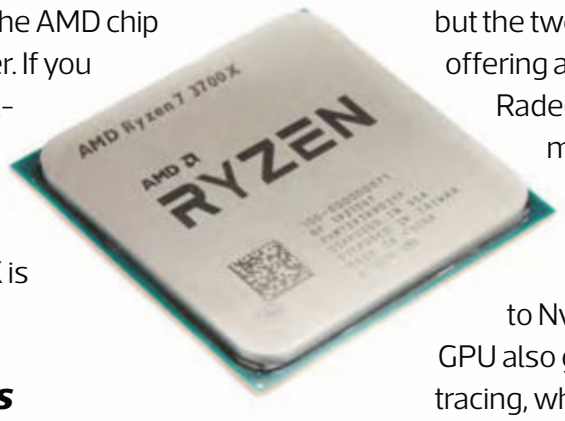
AMD Ryzen 7 3700X

£320 inc VAT

overclockers.co.uk

The 3rd-gen Ryzen sweet spot for great performance in games, as well as content creation, is the Ryzen 7 3700X. It has a peak boost frequency of 4.4GHz and a massive 32MB L3 cache. Plus, with its eight cores and 16 threads, it's a monster in multi-threaded content creation workloads too.

It's also an easy customer for our chosen motherboard with its 65W TDP, and even when overclocked, you don't need to spend a fortune on cooling hardware for it. Intel still has a small lead in some games, but the list of titles where this happens is now smaller, as are the differences. Plus, in some games, the AMD chip is actually faster. If you need a great all-round CPU for around £300, the Ryzen 7 3700X is a great choice.



Alternatives

Despite recent price cuts, Intel's Core i7-9700K still costs around £50 more than the Ryzen 7 3700X and is rarely much faster in games, especially above 1080p. It also gets a bloody nose from the AMD CPU in multi-threaded workloads, as the Intel CPU lacks Hyper-Threading.

If you're building a PC purely for 1080p gaming, though, the Core i5-9600K and Core i7-9700K are still viable options that offer slightly better frame rates in some (but not all) games. Also, thanks to increased competition, prices for them and Intel's other 9th-gen CPUs continue to fall. It's also worth waiting to see how the Ryzen 7 3800X performs, since it has a higher boost frequency that could offer better performance in games, while the Ryzen 5 3600X (see p22) is cheaper and still offers plenty of multi-threaded grunt compared with Intel CPUs.

Graphics card

Nvidia GeForce RTX 2060 Super Founders Edition

£379 inc VAT

nvidia.com

The surprise boost to Nvidia's RTX range last month took some wind out of the sails of AMD's Navi launch, but the two GPUs are still closely matched, offering advantages in different areas. The Radeon RX 5700 XT is a good card and mostly on a par with the RTX 2060 Super, but the latter is currently much quieter when gaming, as well as cooler-running, thanks to Nvidia's dual-fan design. The RTX GPU also gets you support for hardware ray tracing, which isn't supported on the AMD GPU. The Nvidia card gets our vote in this price league – it's a great choice for 2,560 x 1,440 gaming at decent frame rates.

Alternatives

AMD's Radeon RX 5700 XT is slightly faster in some titles at lower resolutions, so if you're not too fussed about fan noise, it can be a slightly better alternative. If you have your heart set on frame rates above 60fps at 2,560 x 1,440, then the RTX 2070 Super is a great option too, although you'll need to spend an extra £100 or so. If you still want the benefits of ray tracing and DLSS, but can't stretch to the RTX 2060 Super, then the RTX 2060 can be had for around £300 and also offers smooth frame rates at 2,560 x 1,440, although it struggles with ray tracing above 1,920 x 1,080.

Motherboard

MSI X570-A Pro

£170 inc VAT

box.co.uk

Despite equivalent X470 and Z390 motherboards retailing for a lot less money than their X570 counterparts, there are still affordable X570 boards, including MSI's X570-A Pro (see p50). It offers PCI-E 4 support, so it can push the latest SSDs to their limits. It also handled our Ryzen 9 3900X with ease this month, plus its chipset fan is quiet. If you're after a basic X570 board that still offers the key perks of AMD's new chipset, though, it's a great choice.

Alternatives

For an extra £100, you can get the Asus ROG Strix X570-E Gaming (see p45), which has better power circuitry and cooling, making it a better home for an overclocked 12 or 16-core 3rd-gen Ryzen CPU, as well as offering a more lavish set of features and better looks.

It's worth remembering that X570 motherboards aren't direct replacements for X470 and B450 motherboards, but are instead designed to offer a premium platform that sits above them, with PCI-E 4 support and other new features, such as 802.11ax Wi-Fi and LAN speeds in

SHOPPING LIST CONT

excess of 1Gb. Many also offer more capable cooling and power circuitry than their last-gen counterparts. However, there's nothing wrong with using a B450 or X470 chipset motherboard with 3rd-gen Ryzen CPUs, and AMD has stated that these CPUs should work just as well in them too.

If you currently own an X470 motherboard, there's not much reason to upgrade unless you're dead set on owning one of the ludicrously fast PCI-E 4 SSDs that are hitting the shelves. If you just want to take advantage of the new CPUs' better performance, you're good to go. There are a couple of caveats, though, with the most important being that 400-series chipset boards will require a BIOS update to work with 3rd-gen Ryzen CPUs. That's fine if you still have an older Ryzen CPU or can borrow one from a friend, but without one, you won't be able to update the BIOS.

The exceptions here are boards that were equipped with a BIOS Flashback feature, which allows you to update the BIOS without a CPU being installed. Some of our previous Socket AM4 favourites, such as the MSI B450M Mortar, offer this feature. If you pick up one new or second-hand, it won't matter if it has an old BIOS – you can update it even if you have no CPU to hand.

However, even if your board lacks this feature and you have no way to update the BIOS, all is not lost. AMD has revived its processor loan service (**custompc.co.uk/AMDLoan**), where it will send you an older CPU, allowing you to update the BIOS on your motherboard, before returning the CPU to AMD – all free of charge.

Memory

16GB (2 x 8GB) Corsair Vengeance LPX 3466MHz

£118 inc VAT

scan.co.uk

AMD's 3rd-gen Ryzen CPUs support memory up to 3600MHz in a 1:1 ratio with Infinity Fabric, all with no extra tweaking required. Above this frequency, you need to delve into some fairly complicated overclocking and dividers, for limited benefits, so we recommend sticking to 3600MHz as your limit. However, we found there to be only modest gains above 3466MHz, as well as noticeably higher costs. Our tip is to opt for a dual-channel CAS16 3466MHz kit, such as Corsair's Vengeance LPX one, and simply overclock it to 3600MHz – it's an easy tweak that gives you a little extra performance for free.

Alternatives

If you want to add RGB lighting to the equation, Corsair's Vengeance RGB Pro with the same spec costs around £20 more, while its luscious Dominator Platinum RGB kit costs an additional £40.

Power supply

Corsair CX450M

£46 inc VAT

scan.co.uk

Modern systems rarely draw more than 400W from the wall, even if you fully load an overclocked CPU and graphics card at the same time, which is unlikely to happen in either games or content creation software. Firing up Prime95 and 3DMark TimeSpy's graphics test at the same time for a worst-case scenario, our PC drew less than 400W when overclocked even when fully loaded, and in games and content creation, you'll be looking at around 100W less than this figure.

Therefore, there's not much point opting for much more than 450W for our PC. We've chosen Corsair's CX450M semi-modular power supply, as it offers plenty of headroom for our PC, as well as the benefit of some modular cables, so you can ditch those unused Molex cables to make your cable tidying a little easier.

Alternatives

If you need a little more headroom, Corsair's CX550M offers 100W more headroom, which would allow for more scope with future upgrades, especially if you want to use a more powerful CPU than we've chosen, or if a move to a 4K-capable GPU might be on the cards. It costs another £10, while stumping up another £35 will bag you the RM550X, which also sports 550W of power, but with a completely modular cable set. The latter allows you to replace the stock cables with a set braided in specific colours – great if you want to add a personal touch.

Solid state drive

Corsair 1TB MP600

£250 inc VAT

scan.co.uk

There's not much point in opting for an X570 system and not investing in a PCI-E 4 SSD. Most of them come with heatsinks, which is great for out heatsink-less motherboard, but they can also be cooled effectively by motherboard heatsinks too. We've picked Corsair's 1TB MP600 (see p26), which is fast and offers enough space for most people to ditch their hard disk too, giving you a single volume of ultra-fast storage.

Alternatives

If you need more space for a monster game library and 4K content creation, there's a 2TB version of the MP600, although it will set you back £470. If you're sticking with an X470 motherboard, it's not essential to fork out for a PCI-E 4 SSD. The 1TB version

THE P600S IS OUR FAVOURITE CASE AT THIS PRICE

CPU cooler

Alphacool Eisbaer 120 LT

£77 inc VAT

aquatuning.co.uk

With the Ryzen 7 3700X's TDP sitting at just 65W, there's little need to invest heavily in CPU cooling, even if you're overclocking. We've chosen Alphacool's Eisbaer 120 LT liquid cooler, as it's quiet and sports two 120mm fans that can ramp up when needed to keep the CPU in check. It's also expandable should you wish to add a GPU waterblock or custom reservoir, and has plenty of cooling power to deal with our 8-core CPU.

Alternatives

AMD's 3rd-gen Ryzen CPUs do respond to lower temperatures, especially if you tap into Precision Boost Overdrive. If your budget can stretch a little further, Corsair's H10i Pro RGB offers superb cooling with its 240mm radiator and powerful fans for around £20 more.

If you have a more limited budget, Deepcool's Gammaxx GT BK offers decent cooling on Socket AM4 for just £35. You can save even more cash, though, by using the included Wraith Prism RGB cooler. It's not particularly quiet or capable of dealing with overclocks, but if you're running at stock speed and would prefer to put more cash towards your graphics card, it's definitely an option.

of WD's Black SN750 costs under £200 and still dishes out over 3,000MB/sec. You can also consider a smaller capacity, as the 500GB version of WD's Black SN750 only costs around £100. If you have terabytes of data to store, though, hard disks are still the most cost-effective way to house it, especially as you can bag 2TB hard disks for around £50 now

Case

Phanteks Eclipse P600S

£135 inc VAT

overclockers.co.uk

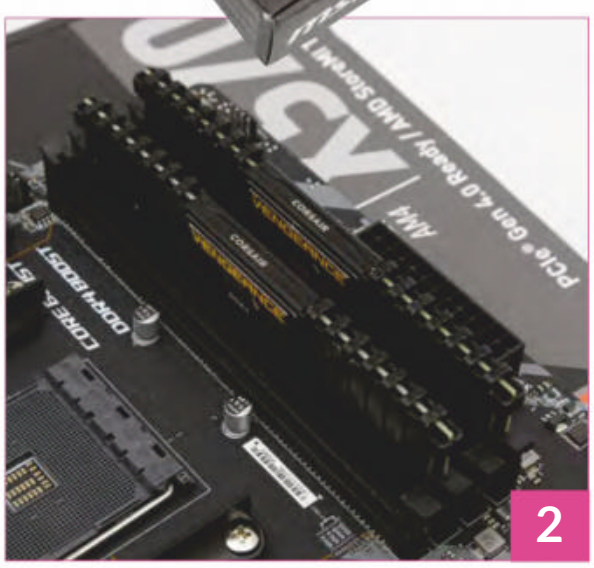
With great air cooling as well as water-cooling support, a flexible layout and superb features, the Eclipse P600S is easily our favourite case in this price league. It's nearly identical to Phanteks' much pricier Evolv X, and the black and white version here looks great as well. While we won't be using any internal storage mounts, its flexibility includes space for up to four hard disks and three SSDs, as well as the largest all-in-one liquid coolers.

Alternatives

Phanteks has some strong offerings lower down the budget spectrum too. The Eclipse P300 is a great-looking option, with a fair few less features than the Eclipse P600S, but for a budget-friendly price tag of just £50. For a cheaper high-airflow alternative, the Fractal Design Meshify C is a great choice that costs under £100.

BUILDING THE PC

1



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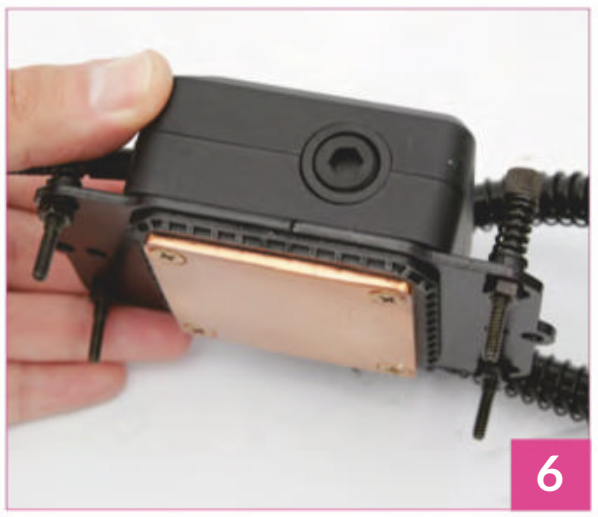


6

1 Test hardware

Test your hardware first to check for faulty components. It's unlikely, but if your motherboard is faulty, it will be less hassle to find out now than when your hardware is installed into the case. Use your CPU's stock cooler, connect the PSU's power cables and connect the case's front panel power connector to your motherboard, or short out the two power button pins at the bottom of the motherboard using a screwdriver to boot the PC. If you see the POST screen on your monitor, you're good to go. This only takes a few minutes but it's worth doing.

2 Install memory

Start by installing the memory. With our two-module kit, put them in the second and fourth slots to enable dual-channel mode.

3 Install CPU

Ryzen CPUs have pins on the underside, and while they aren't as delicate as the socket pins on Intel motherboards, they can still be bent if dropped. Handle the CPU with care and never lift it more than a few centimetres above a surface in case you drop it. If you do manage to bend a pin, use a small precision screwdriver or knife tip to bend it back to vertical. Be careful when you install the CPU too. Lift the latch up, align the triangular mark on the CPU with the similar marking on the socket, and the CPU should drop straight in without any force.

4 Remove CPU socket brackets

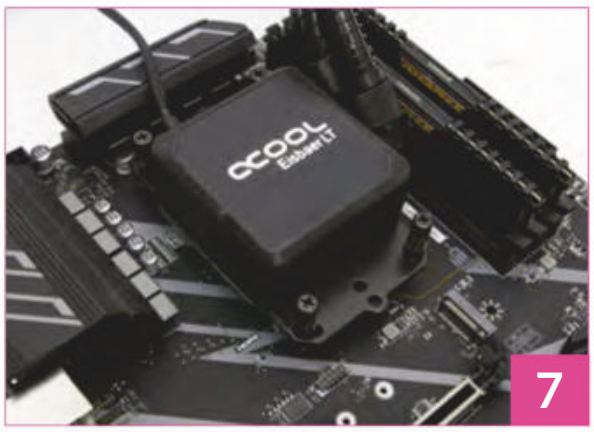
Our cooler uses the standard AM4 socket backplate, but not the socket brackets. Use a screwdriver to remove them, and place the brackets and the screws into your motherboard box for safe keeping.

5 Apply thermal paste

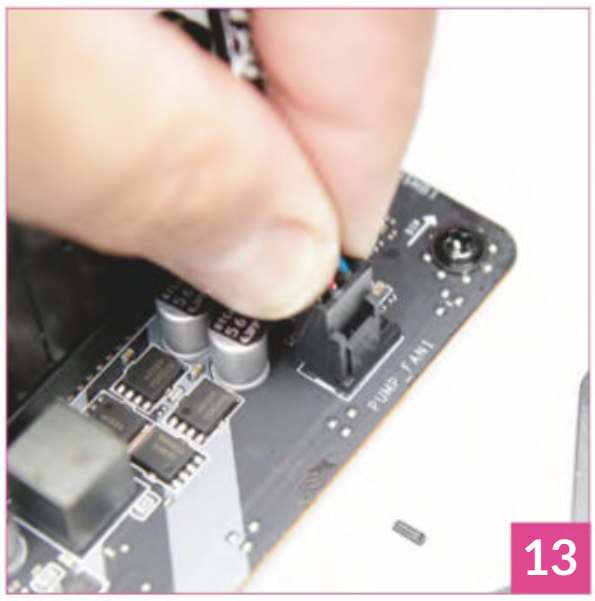
Clean any thermal paste residue from testing your hardware in the first step with TIM cleaner (such as ArctiClean) or isopropyl alcohol, and a lint-free cloth. Apply the included thermal paste in a cross shape of thin lines 2-3mm thick. This will allow the paste to spread over the CPU evenly once the cooler is clamped down.

6 Attach AM4 mounting hardware

The cooler is equipped with a range of mounting kits – we're using the Socket AM4 kit. This includes brackets, screws and springs that you need to attach to the pump section according to the instructions.



PLACE THE RADIATOR IN THE REAR FAN MOUNT



7 Install pump

As you need to hold the backplate to the motherboard in order to install the pump, it's far easier to do this step with the motherboard out of the case. Lay the motherboard on a flat surface with the socket backplate in its normal position, then secure the pump to the backplate.

8 Fit I/O shield

Some motherboards include integrated I/O shields, so if you choose a different motherboard to ours, be sure to check. If it's not, install the bracket in the back of your case, now as you don't want to have to remove your motherboard later.

9 Remove rear case fan

It's best to place the Alphacool radiator in the rear fan mount. Remove the existing fan in the case to make room for it. We'll relocate it later, so keep it and its screws to hand.

10 Fit front fan to radiator

Now install the front fan to the radiator. Its open end should face the same way as the tubing, so it blows air through the radiator. It's best to have the fans exhausting hot air from the case.

11 Install motherboard

Lay your case on its side, and carefully lift the motherboard into the case, onto the metal standoffs. At the same time, carefully lay the radiator inside the case. Secure the motherboard using the screws provided with the case.

12 Fit radiator to case

Place the second radiator fan with its open end facing the radiator, then use the included screws to secure it to the vacant fan mount in the rear of the case. Orientate the fans so that their cables sit on the motherboard side, hiding the cables.

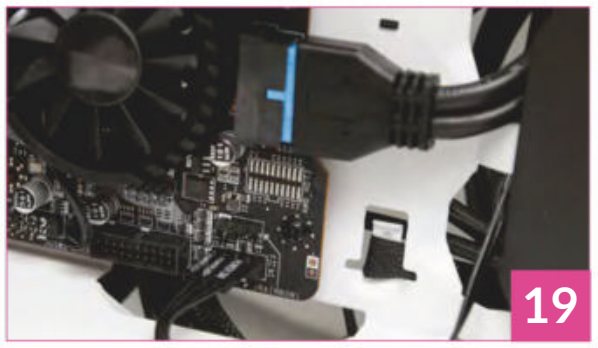
13 Connect pump power cable

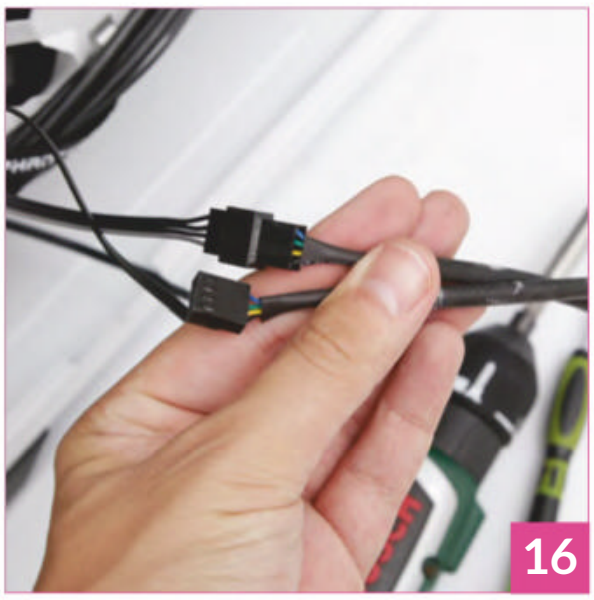
The pump section has its own power cable, which needs to be connected to the dedicated header on the motherboard to the right of the memory modules.

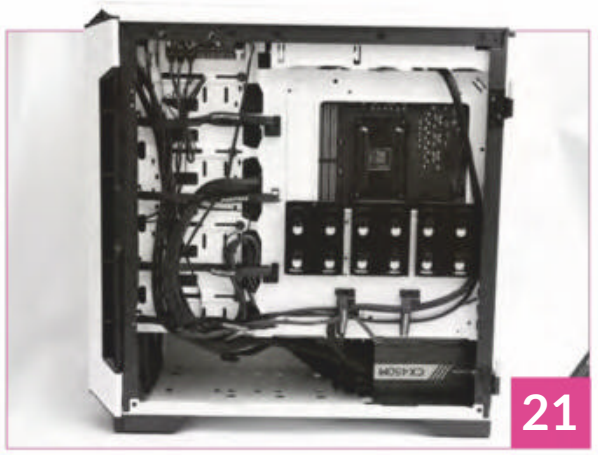
14 Connect fan cables

The cooler includes a 4-pin splitter cable, allowing you to connect both fans to a single fan header. Connect the fans to this splitter, then plug the cable into the CPU fan header.

BUILDING THE PC CONT







15 Reinstall rear case fan

Pop off the front fascia from the case and reinstall the rear case fan here to add some extra cooling. You'll need to shift the existing pair of intake fans up to accommodate it. Check that all three fans are connected to the fan hub to the side of the case.

OPTIONAL

16 Use fan extension cable

The fan hub can power the three front case fans at full speed by default, but it does include a PWM cable should you want to control the fans using your motherboard. One snag with our motherboard is that its system fan headers are all at the bottom of the motherboard and the included cable doesn't reach. If you want to control the case fans, you'll need a 30cm PWM extension cable – they cost under £3 from **amazon.co.uk**

17 Install PSU

To install the PSU, remove the rear bracket at the bottom of the case, secure it to the PSU, feed its cables into the PC and then reinstall the bracket on the PSU mount.

18 Connect 24-pin and 8-pin power connectors

Slide the case's black cable covers open, and feed the cables you need through them to the appropriate places on the motherboard, before sliding the covers back again. Connect the 24-pin connector to the motherboard through the middle cable cover, and then run the 8-pin CPU power connector over the top of the motherboard tray, and plug it into the socket on the top left of the motherboard.

19 Connect front panel cables

Now connect your case's front panel audio cable, USB 3 cable, plus the power and front panel LED connectors, to the appropriate pins on the bottom of your motherboard. If you're not sure which cable goes where, consult your motherboard's manual.

20 Connect fan hub power cable

The fan hub requires a SATA power connector, so we'll have to add a SATA cable to our PSU and then connect it to the fan hub around the back.

21 Tidy cables

The Eclipse P600S is a fabulously easy case to keep tidy. Use the Velcro cable ties to gather the cables together and lock them out of the way. At this point, you can install the SSD (see step 24), secure your graphics card in the top 16x PCI-E slot, connect a 6-pin PCI-E connector from your PSU to the graphics card (see step 26) and you'll be ready to go. However, if you're prepared to spend a little more money, you can follow the next few

22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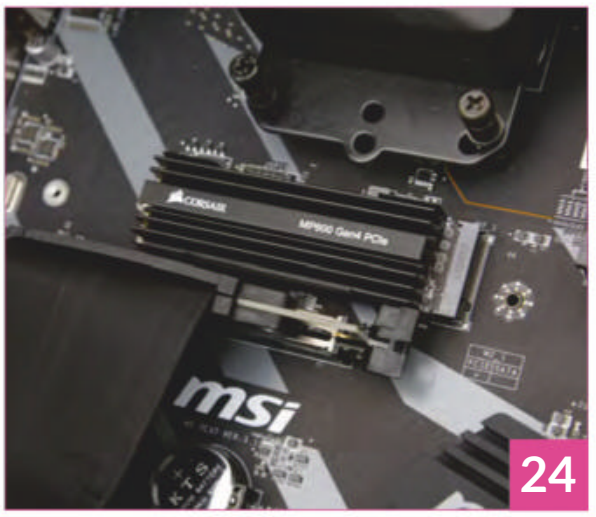

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28

USE THE VELCRO TIES TO GATHER THE CABLES TOGETHER

steps with some optional extras to add some visual pizzazz to your system.

OPTIONAL

22 Insert PCI-E riser cable

Our first optional extra is a vertical graphics card mount. The mount itself is included with the case, but you'll also need a 90-degree Phanteks PCI-E riser cable, which is available separately for £30 inc VAT from **overclockers.co.uk**. Insert the riser cable into the primary 16x PCI-E slot. The case offsets the graphics card by several inches away from the side panel, so it will still get enough airflow, unlike in some cases where the clearance is a bit tighter.

23 Attach cable to vertical mounting bracket

Secure the cable's graphics card slot to the included plastic case mount that comes with the case.

24 Install M.2 SSD

Usually the M.2 SSD is best placed at the bottom of the motherboard for better cooling, but on this board, that lowest slot isn't PCI-E 4-compatible, so use the top one. Thankfully, here it's also visible above our vertical graphics card mount that would otherwise hide it.

25 Install graphics card and bracket

Secure the mount to the case, install the graphics card into it and screw the card's rear I/O panel into the vertical PCI-E slots at the rear of the case.

26 Connect GPU power connector

Finally, connect your power supply's 6-pin PCI-E power connector to the graphics card, routing it through the bottom PSU cover as shown and moving the cable cover back as far as it will go.

27 Install LED strips

We've also added a dynamic RGB lighting setup to our case, courtesy of Phanteks' digital RGB LED starter kit (£37 inc VAT from **overclockers.co.uk**), which includes all the gear you need, including two 40cm RGB LED strips and a controller. The strips are magnetic and stick well to the case and PSU cover.

28 Install fan lights

Finally, we've also added a trio of Phanteks Halos 140mm digital RGB LED fan frames to our front fans (£11 inc VAT each from **overclockers.co.uk**). These frames sit between the fans and case and include extra-long fan screws for the purpose.

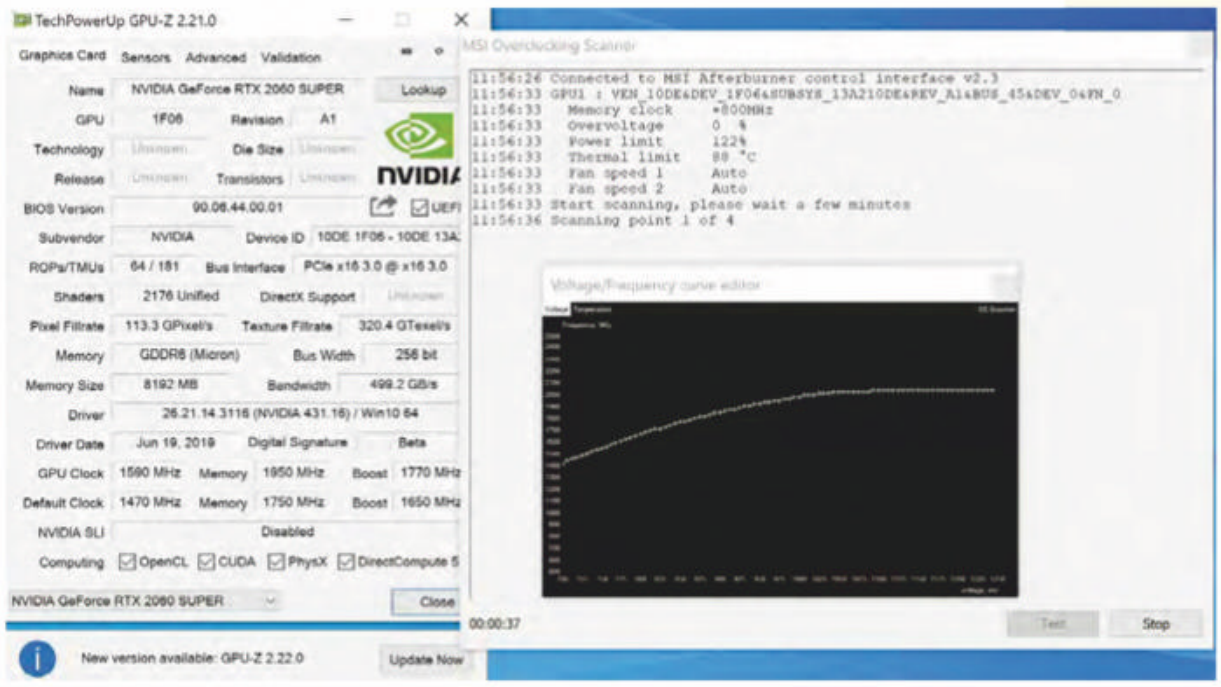
FINAL SETUP

Overclock your graphics card

The Nvidia RTX 2060 Super Founders Edition is an excellent overclocker, and it's simple to get some extra performance. Download GPU-Z (**techpowerup.com**) and MSI Afterburner (**guru3d.com**), increase the temperature and power limits to maximum in the latter, and then locate the small three-bar button next to Core Clock.

In the window that appears, hit OC Scanner in the top right, then select Scan. This will begin to automatically overclock and test your graphics card and is normally fairly accurate in obtaining a core frequency reasonably close to what you'd achieve manually. You'll see the core frequency in GPU-Z leap around as the programs runs.

When the test has finished, close the window and click the option that says Curve to the right of Core Clock. This will apply the best stable frequency from the scanner. Finally, add 800MHz to the memory frequency. The fruits of our efforts increased the GPU boost frequency from 1650MHz to 1813MHz, and the memory from 14GHz (effective) to 15.6GHz (effective). These figures should be stable on an RTX 2060 Super card, but to be sure, head into some games and watch for screen artefacts or stability issues. If any appear, dial back the memory by 50MHz and the core by 25MHz, then try again.

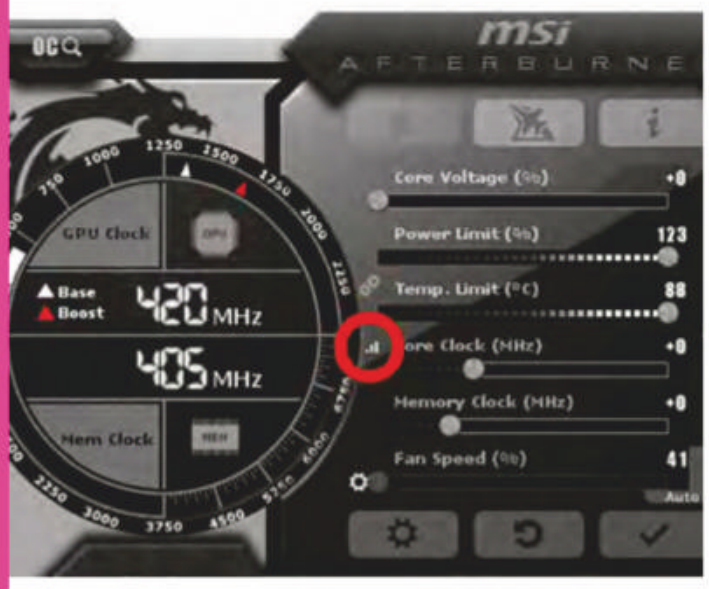


MSI's OC Scanner is great for finding a stable overclocked core frequency

Set up your memory

Start by applying the memory XMP profile in the EFI, which will set the correct speed, timings and voltage. If you're up for overclocking your memory to 3600MHz, do it now and head into Windows for a stress test – don't perform a memory and CPU overclock at the same time, as it can make stability testing harder. To overclock your memory, apply the XMP profile, head down to the DRAM Frequency option and select 3600MHz from the list. Now grab the latest version of Prime95 (**mersenne.org**) in Windows and run the large FFTs test. If all is well after ten minutes, you can consider your memory overclock a success.

In Afterburner, locate the small three-bar button next to Core Clock



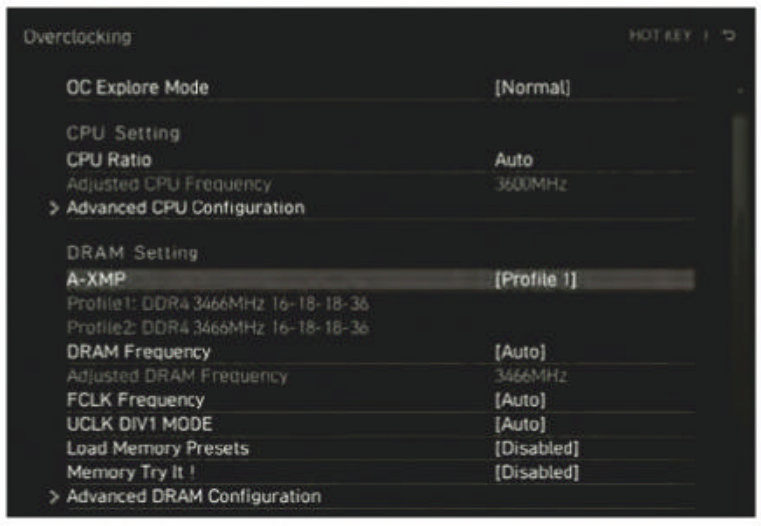
CPU overclocking

AMD's latest CPUs aren't straightforward when it comes to overclocking. Their all-core overclock headroom is fairly limited, sitting at just 4.3GHz on our Ryzen 7 3700X despite its 4.4GHz maximum boost frequency. While you'll gain a couple of hundred megahertz in an all-core boost from around 4GHz at stock speed, you'll lose the ability for the CPU to drop back under low loads. You'll also reduce its lightly threaded performance, as its stock speed boosting will be disabled too.

People who prioritise multi-threaded content creation performance are better-suited to a manual overclock to 4.3GHz. To do that, dial in a vcore of 1.425V and multiplier of 43x, then reduce the voltage until a run through Prime95's smallfft test becomes unstable (be sure to disable AVX instructions in the program).

However, for our gaming system, we've gone with maximum single-threaded performance and used AMD's Precision Boost Overdrive feature to increase boost frequencies, while retaining the maximum

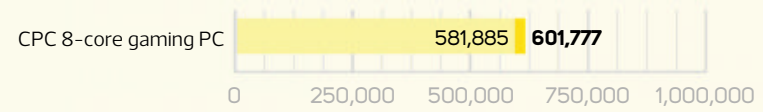
Apply the memory XMP profile in the EFI to set the correct speed, timings and voltage



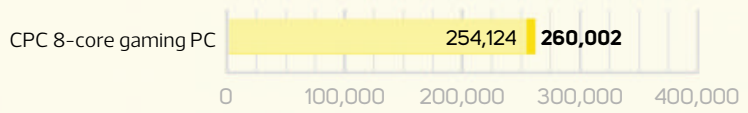
PERFORMANCE

GIMP IMAGE EDITING

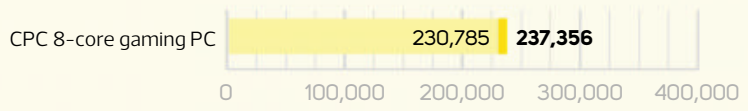
HANDBRAKE H.264 VIDEO ENCODING



HEAVY MULTI-TASKING

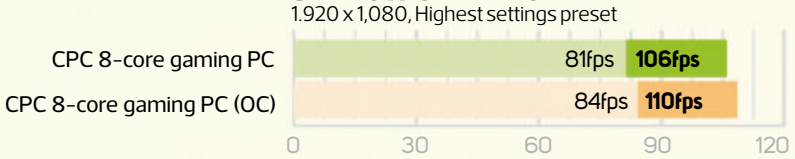


SYSTEM SCORE

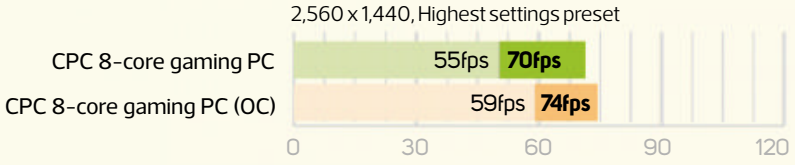


SHADOW OF THE TOMB RAIDER

1,920 x 1,080, Highest settings preset

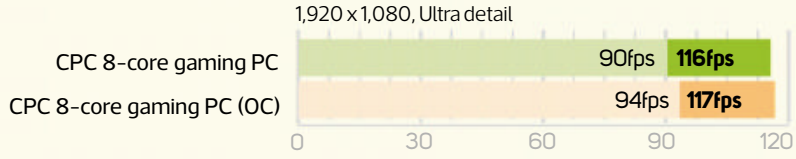


2,560 x 1,440, Highest settings preset

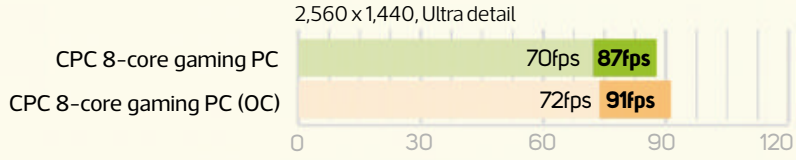


FAR CRY 5

1,920 x 1,080, Ultra detail

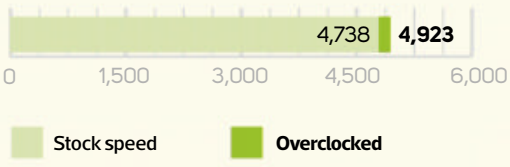


2,560 x 1,440, Ultra detail



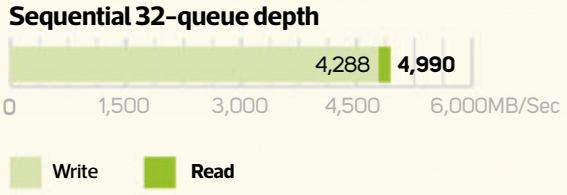
CINEBENCH R20

Multi-threaded test



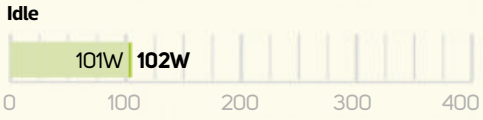
CRYSTALDISKMARK

Sequential 32-queue depth

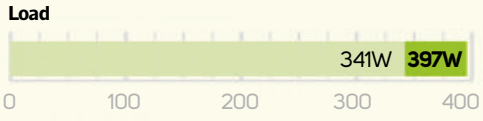


TOTAL SYSTEM POWER CONSUMPTION

Idle



Load



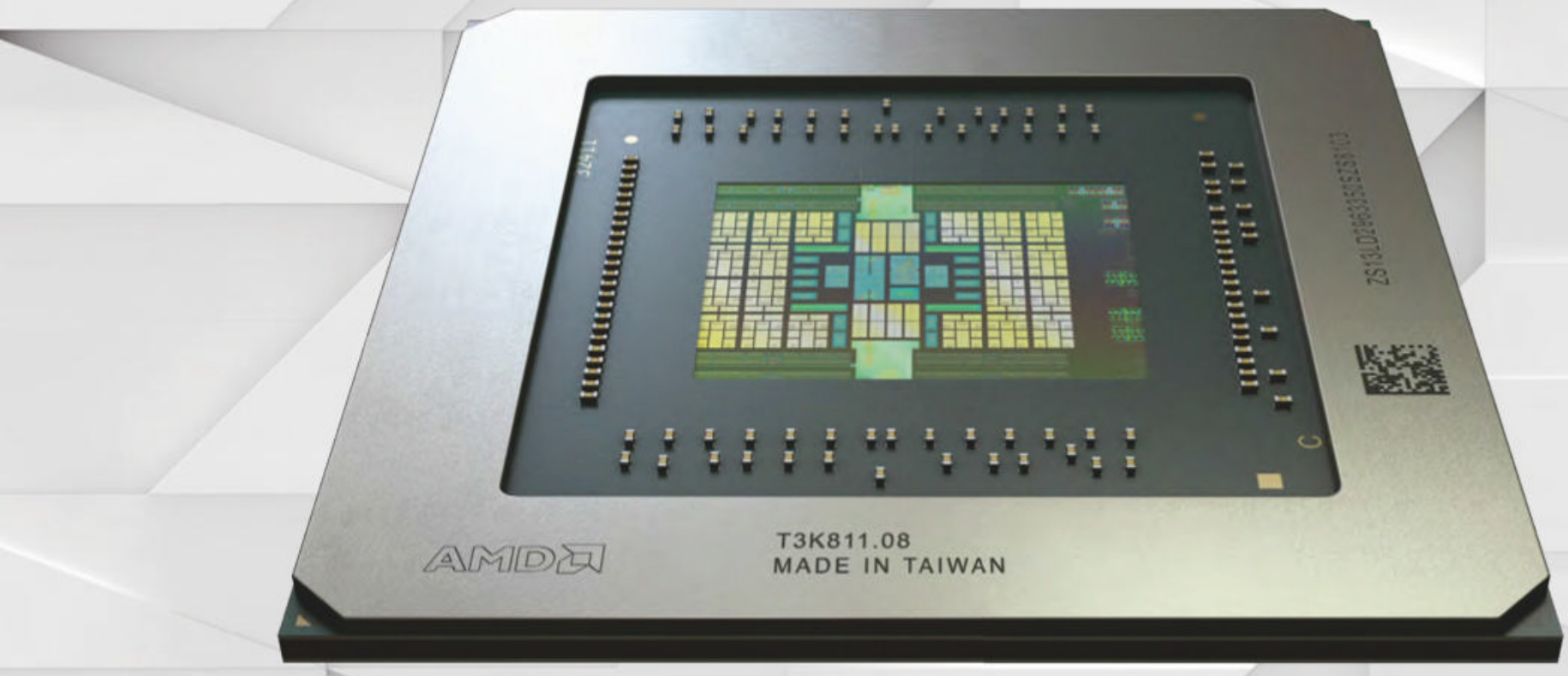
Use AMD's Precision Boost Overdrive software to get a gaming performance boost

4.4GHz boost – this will give us good gaming performance, while reducing power when the system is idle.

Head into the EFI, go to Settings/Advanced/AMD Overclocking, and find the Precision Boost Overdrive option. Select Advanced, set the PBO limits to motherboard, then dial in 200MHz to the maximum CPU boost clock override. We found that, with our setup, the all-core boost increased from between 3.95-4GHz up to 4.15GHz under load.

Our memory overclock and CPU tweaking boosted the RealBench system score from 230,785 to 237,356, and increased the Cinebench R20 multi-threaded score from 4,738 to 4,923. Meanwhile, manual 4.3GHz overclock saw a score of over 5,200 points in the multi-threaded Cinebench test, but a noticeably slower result in the single-threaded test.

These tweaks, combined with our graphics card overclock, increased the minimum frame rate by 2-4fps in Shadow of the Tomb Raider, and they only added 56W to the load power draw of our PC, so it's definitely worth overclocking these components. CPC



AMD RDNA
THE DEEP DIVE

RYS SOMMEFELDT LIFTS THE LID ON AMD's FIRST NEW GPU ARCHITECTURE SINCE 2012

AMD is no longer undergoing a resurgence. Having recently released its new 3rd-gen Ryzen CPUs and Radeon RX 5700-series GPUs, AMD has accelerated past Intel on the processor front and is aggressively renascent when it comes to graphics. The one-two punch of fresh architectural advancements for both CPUs and GPUs, along with mass production on leading-edge foundry technology that's yet to be tapped by its key competitors, has put the firm back on the competitive map.

The Navi10 GPU underneath the RX 5700 Series products is made using TSMC's excellent 7nm process technology, allowing the design to be smaller and consume less power, but with the same performance compared with being made on either 16nm or 12nm nodes.

However, advanced foundry technology isn't the whole story. AMD also made significant changes to the microarchitecture and connected I/O with which Navi10 is built, which AMD calls RDNA. It's been a process of reimagining, rethinking and reimplementing AMD's vision of how a competitive GPU design should look in 2019.

Many years in the making, let's take a trip down the RDNA pipeline to explore what's new, and look at it in the context of AMD's prior GPU design, Vega, to see where the new performance efficiency really comes from.

The basic summary is that AMD remembered that the 'G' in GPU stands for 'graphics' rather than 'general', but where's the fun in reading that without understanding why? Let's dive right in.

The move from HBM to GDDR6 requires a larger PCB, but enables AMD to make substantial cost savings

KNOW YOUR INITIALS

ALU: Arithmetic logic unit

GCN: Graphics Core Next (AMD's GPU microarchitecture from 2012 to 2019)

CU: Compute unit

FMA: Fused multiply add

HBM: High-bandwidth memory

LDS: Local data share

RDNA: AMD's new GPU microarchitecture, introduced in 2019

SFU: Special function unit

SIMD: Single input, multiple data

VGPR: Vector general purpose registers

WGP: Workgroup

PCI-E 4 AND GDDR6

I/O is usually the last bit of a GPU design that anyone discusses, but let's make it the first stop on our tour of what makes RDNA tick. Talking to the outside world is fraught with danger as far as a GPU is concerned because of the latency of doing so. Because a GPU tends to want to work on large chunks of data that need to be fed into and out of the chip as fast as possible, bandwidth is prioritised over latency, which is anathema to how a CPU wants to work.

That also feeds into thinking about GPU parallelism, because high bandwidth tends to mean high latency, for both accesses to the DRAM memory directly connected to the GPU, and accesses over the PCI-E connection to the host CPU. The GPU needs to be able to keep working while those accesses return the data it needs, an ability that GPU designers call latency tolerance. The tolerance is achieved by making the GPU wider and therefore able to do more work in parallel.

AMD chose GDDR6 as the directly connected memory on Navi10, the first implementation of RDNA, and for very good reasons compared with the HBM2 memory used on Vega10 and Vega20, which powered the RX Vega and Radeon VII high-end products – cost. HBM2 achieves its incredibly high bandwidth with a very wide parallel connection to the GPU. The high number of parallel connections, each an individual wire, means HBM2 memory needs to be physically very close to the device to which it's connected.

This setup results in special packaging that uses an interposer — a special silicon chip that acts as the connective substrate between HBM2 memory and whatever it's connected to. The HBM2 stack and interposer are both expensive to make, due to the complexities of manufacturing and packaging the HBM2 stack, and the sheer size of the interposer. Then they have to be physically bonded to each other, along with the GPU, and tested. That extra packaging and testing work adds hundreds of dollars to the cost of any HBM2 product, and it's why, despite its technical brilliance, you don't see it used everywhere that high performance memory is required.

In order to bring down costs to sensible levels, AMD turned instead to a 256-bit-wide GDDR6 interface for Navi10. GDDR6 provides bandwidth in the same ballpark as HBM2 — almost 450GB/sec in a Radeon RX 5700 XT across its 256-bit bus — without the extra packaging and test costs.

The PCB for the product becomes larger, because the GDDR6 memory chips can't live as close to the GPU as with HBM2, but the cost savings for AMD are substantial and allow the company to sell the Radeon RX 5700 XT for just £380 inc VAT and still make a healthy profit. Fun fact: AMD not only uses GDDR6, but also contributed significantly to inventing it; AMD Product CTO, Joe Macri, is a founding father of the JEDEC standards process that created, fostered and popularised graphics-specific GDDR memory, as well as HBM.

AMD HAS ACCELERATED PAST INTEL ON THE PROCESSOR FRONT AND IS AGGRESSIVELY RENASCENT WHEN IT COMES TO GRAPHICS

As for getting data into those GDDR6 memory chips, the CPU sends it across a PCI-E 4 bus on Navi10, and you can expect AMD to use that brand-new version of PCI-E for every other standalone consumer graphics

product based on RDNA for the foreseeable future. In fact, Navi10 and the Radeon RX 5700-series product line are the first consumer PCI-E 4 graphics products on the market. Support for it is also required on the PC side if you want the full bandwidth, which today means Ryzen 3000-series processors plugged into AMD X570 mainboards.

Compared with PCI-E 3, the new standard offers double the bandwidth per pin, which means the same number of pins and the same 16x slot size. That also means compatibility - plug a Radeon RX 5700 XT into a system that supports an older version of the standard and it will work just fine, just slower — and only a tiny bit slower in practice in today's games. Still, it's a solid bit of futureproofing from AMD on the I/O side, and befits the advanced technologies found in the rest of RDNA-based designs.

Now that we know how RDNA gets data from the host to the GDDR6 memory to work on while rendering, let's look at what happens inside the microarchitecture as it does so, starting with the first part of the design that gets to work during graphics rendering: the front end.

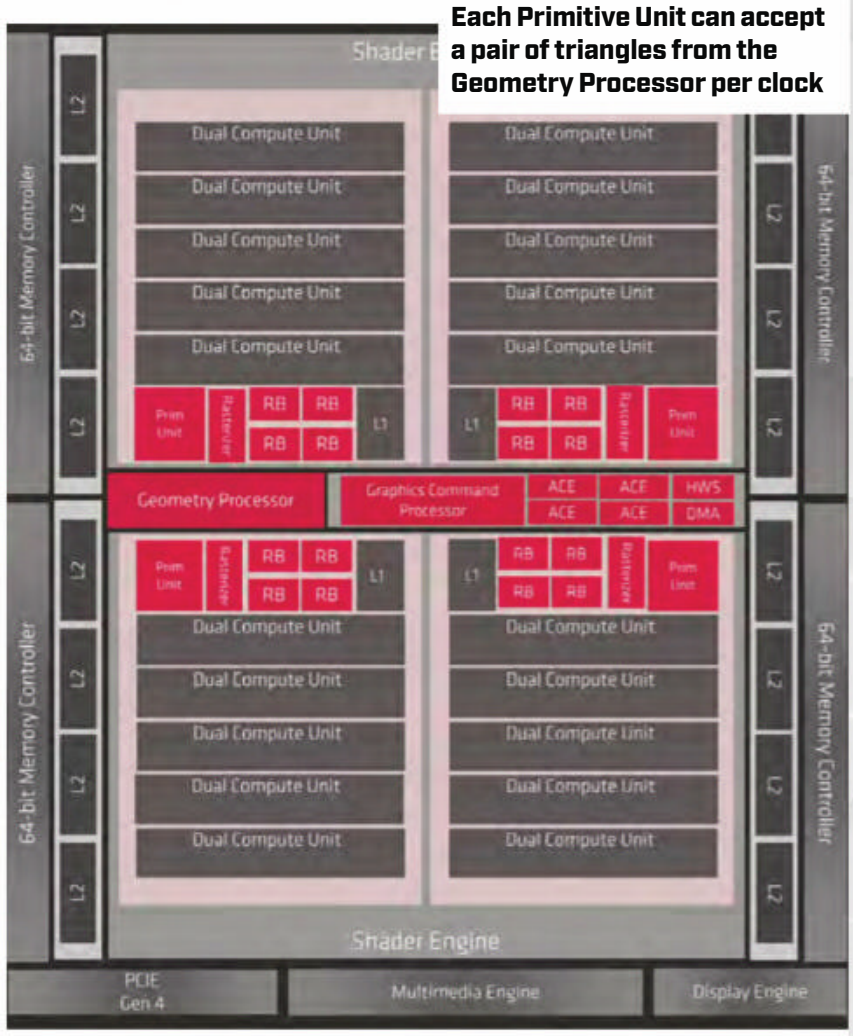
RDNA FRONT END

In any GPU, the first task for the design is to work on processing input geometry in the form of triangles. Everything you can see on the screen during normal rasterised rendering is made up of them, and with game vendors pushing the boundaries of visual fidelity every year, the count and density of geometry sent to the GPU only increases. You need a front end that can process them at a high rate, and get them sent down the pipeline to the rasteriser for onward processing with as few bottlenecks as possible.

AMD has been diligently working on improvements to that aspect of the design in order to improve throughput through the front end, and RDNA bears the first truly visible fruits of that labour. Through a combination of hardware changes and compiler-heavy lifting, depending on what your game asks from the GPU, you can now see some significant performance increases compared with prior AMD GPU architectures. RDNA's front end architecture tries to exploit the fact that, on average, not every triangle will end up visible on the screen.

For example, some will end up outside the visible boundaries of the screen and can therefore be culled, or some will end up back-facing, where the shaded side of the triangle is away from the screen and so doesn't need to be processed. In addition, some will end up without any visible area to rasterise, even if they're on-screen or front-facing.

The hardware and software for RDNA work in tandem to process triangles together to exploit those properties of some triangles, in order to identify if they don't contribute to on-screen pixels, and then cull them more efficiently. The central Geometry Processor handles the guts of that work in hardware, coordinating with the pair of Primitive Units that reside inside each Shader Engine, which is the top-level building block of any RDNA-based GPU. We'll come back to that at the end, when we tie up RDNA to create the full picture of how it's put together.



Each Primitive Unit can accept a pair of triangles from the Geometry Processor per clock

WHEREAS GCN WAS A 64-WIDE MACHINE, MEANING IT EXECUTED A 64-WIDE WAVE OF THREADS, RDNA IS A 32-WIDE MACHINE AT ITS HEART

Each Primitive Unit can accept a pair of triangles from the Geometry Processor per clock, and then output a single one for further processing by the rest of the design. That 2:1 throughput is designed to match a rough 50 per cent cull rate for incoming geometry, which, broadly speaking anyway, is what games tend to send to the hardware to be drawn. The aggregate onward triangle rate for Navi10, which has two Shader Engines and consequently four Primitive Units, is four triangles per clock.

RASTERISATION

There's not that much to say when it comes to the rasterisers in RDNA compared with Graphics Core Next (GCN) and Vega, and we may as well refer to both GCN and Vega as GCN here, because in practice, Vega is very similar. There's a pair of rasterisers per Shader Engine in RDNA, and each one is capable of accepting a single triangle per clock, which it then rasterises at a rate of 16 outgoing pixels per clock.

The type of rasterisation that RDNA uses, and GCN before it, is called scan conversion. The implementation detail of how that works is reasonably complex in hardware, but conceptually straightforward for us to imagine. The hardware computes the interior area of the triangle given its coordinates on the screen, and scans along that inside area – in terms of the horizontal row of pixels the triangle covers – line by line.

NEW SHADER CORE

AMD doesn't change the shader core architecture of its GPUs very often. In fact, the new shading microarchitecture in RDNA is only AMD's fourth completely new programmable shader core design since 2001. Some of you may remember the ATI Radeon 9700 Pro, the first GPU in ATI's history with a programmable shader architecture. That card didn't hit the market until the second half of 2002, almost

17 years ago, and when AMD acquired the company in 2006, that architectural generation was still the one on the market.

RDNA is one such infrequent generational change for the company. Each of the improvements makes good sense in isolation, but it's only when we tie them all up at the end of the explanation that the whole theme of the design becomes clear. Before we start, though, let's run through a quick refresher on shaders.

Triangles sent to the GPU are transformed and animated to be on the screen in the right place according to a program that's run for each vertex of the triangle, called a vertex shader. Those triangles are processed to work out the pixels they'll touch on the screen, and then those pixel samples are individually painted according to a program that's run for each one, called a pixel shader. There's a third common type of program that operates on general data, called the compute shader.

All those shader programs are executed across sets of vertices or pixels in a highly parallel nature by the GPU, which is called SIMD (single instruction, multiple data) execution. For each piece of data in the set, it runs the same instruction on it in parallel.

The name for a set of either vertices or pixels that executes in SIMD fashion (and in practice, there are some other types of parallel-processed data too) changes depending on who you talk to. That makes it difficult to unify the terminology, but they're all talking about the same group of work, whether you see people referring to it as a warp, grid, wavefront, wave, workgroup, task, thread group and so on. We'll use 'wave' from this point onwards.

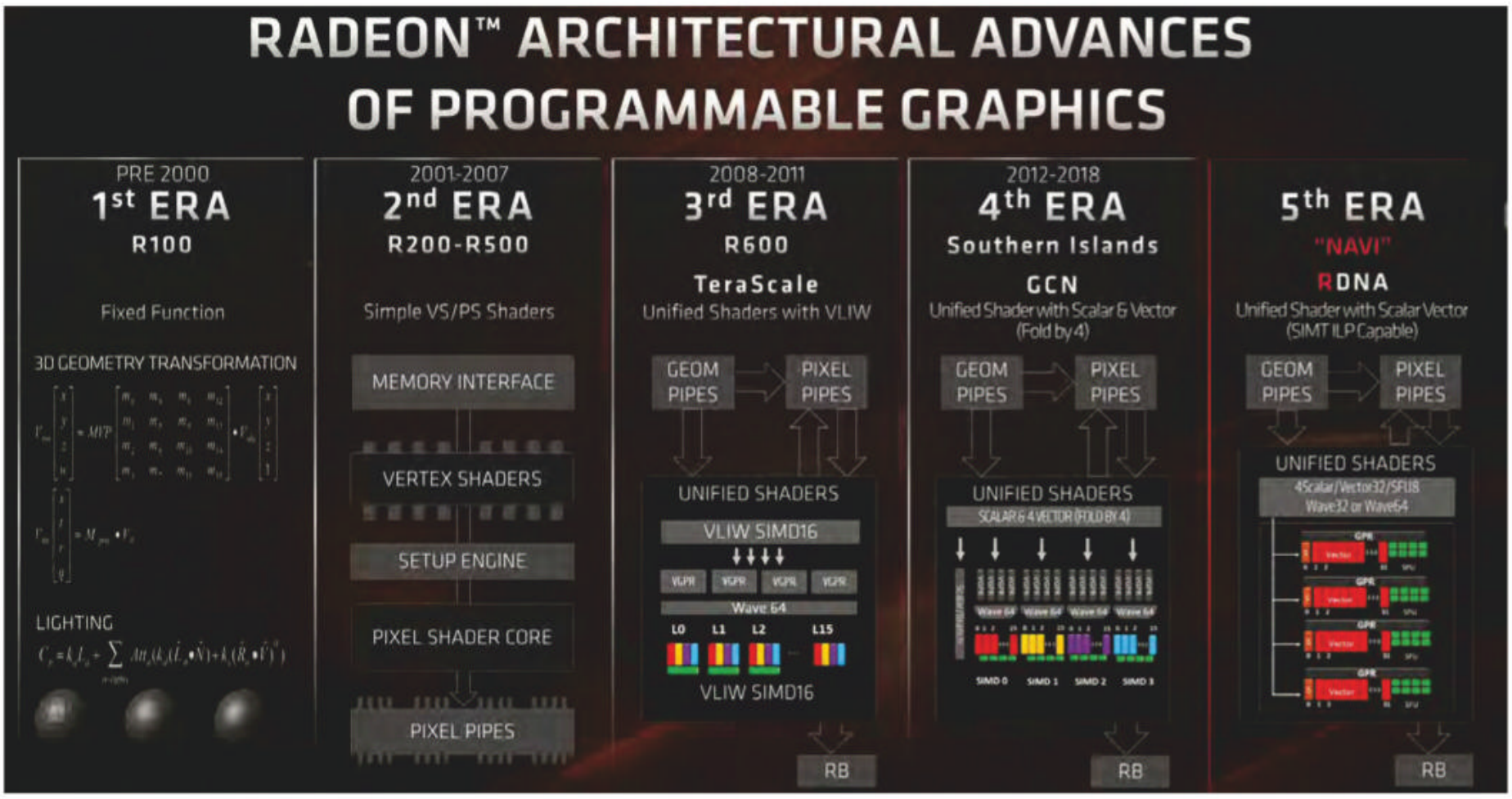
IT PROVIDES A VERY HEALTHY SPEED-UP IN MODERN SHADER CODE JUST FROM THOSE CHANGES

The 'width' of the SIMD aspect of the machine is really important, because shader programs can have branches in them. Imagine a pixel shader that needs to decide which texture to apply based on some property of the renderer. Maybe it's applying a shiny material – some pixels in the wave might take one branch, some might take another. The way it works is the GPU still runs that pixel shader for all pixels in the wave, and just masks out the results from those that didn't take the current branch.

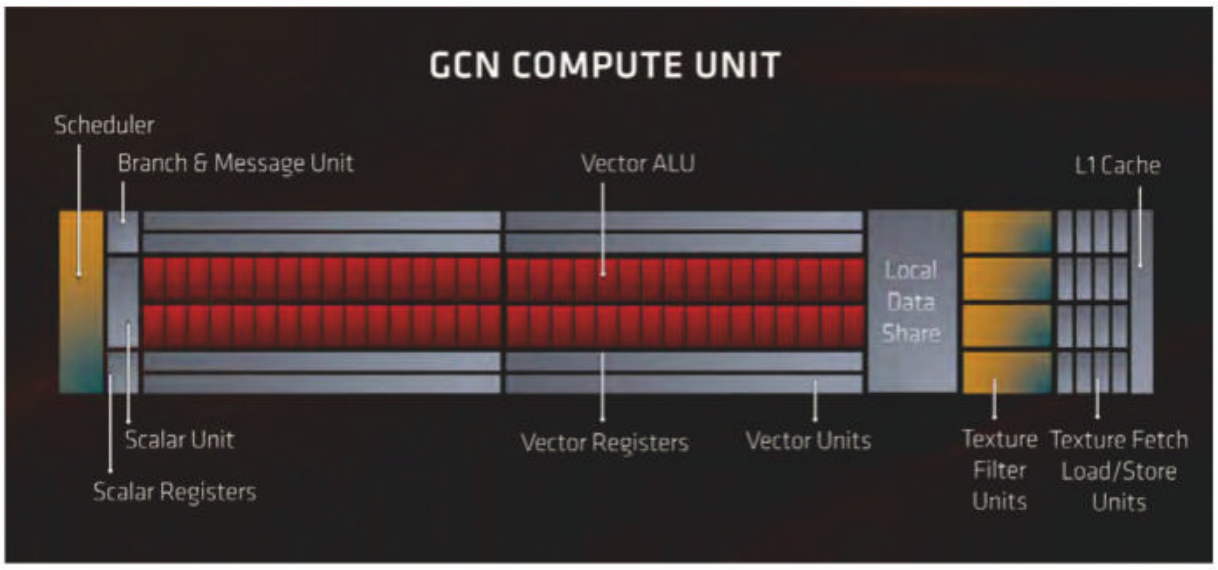
Imagine your GPU can run a single 64-wide wave, and that just one of the pixels in the wave took the current branch. The machine runs at 1/64th the potential peak performance for that branch, which is potentially hundreds or thousands of cycles long. SIMD width is therefore a trade-off for the GPU designer to make. Making it wider is simpler in hardware, which usually means less area and power, but it also means there's a performance penalty for lightly taken branches is higher.

The most apparent change to RDNA is in the SIMD width. Whereas GCN was a 64-wide machine, meaning it executed a 64-wide wave of threads, RDNA is a 32-wide machine at its heart. On top of that, GCN ran each 64-wide wave over four clock cycles on a 16-wide SIMD unit. RDNA runs each 32-wide wave in a single cycle on a 32-wide SIMD unit.

RDNA also changes how work is distributed across a collection of those SIMD units. GCN distributes work across groups of four 16-wide SIMD units at a time in a collective block it calls the Compute Unit (CU). In comparison, RDNA distributes its work across a pair of 32-wide SIMD units in a collective block it calls the Workgroup



The new shading microarchitecture in RDNA is only AMD's fourth completely new programmable shader core design since 2001



GCN distributes work across groups of four 16-wide SIMD units in a collective block it calls the Compute Unit (CU)

Processor (WGP). We'll consider RDNA at that level now, in collections of WGPs, with the CU arrangement of GCN as our context.

That pair of profound changes in the microarchitecture achieves two key goals: reducing the inefficiency of branchy code, and getting a higher aggregate throughput for smaller waves. Let's work through a short but illustrative example.

Imagine a 64-thread wave dispatch to each machine. GCN accepts that into a CU, and because it runs the CU as a collection of four 16-wide SIMDs that run over four clocks, all 64 threads have to go to one of those four SIMDs in the CU. The dispatch takes four cycles to execute and leaves three of the four SIMDs idle. RDNA accepts the dispatch into a WGP, and because the SIMDs only take one clock to run a wave, and there's a separate decoder and issue path for each SIMD, the work is distributed across both and the work finishes in a single clock with no idle SIMDs.

The end result is that, for smaller dispatches, which actually make up a surprising amount of modern rendering, RDNA can work on them more efficiently than GCN.

It provides a very healthy speed-up in modern shader code just from those changes alone, but RDNA doesn't stop there.

SCALAR PERFORMANCE

Whereas the SIMDs in a GCN CU shared a single scalar arithmetic logic unit (ALU), which is useful for any task that only needs to be executed once for any given wave, RDNA has a pair of those same scalar ALUs per WGP, one assigned to each SIMD. The scalar-to-SIMD ratio is effectively doubled in RDNA as a result, including the scalar register space and scalar cache, which AMD call the K-cache (K$).

BECAUSE THERE ARE FEWER SIMDS COMPETING FOR LDS USAGE, THE EFFECTIVE BANDWIDTH DOUBLES

Because those scalar units work on behalf of the SIMDs in AMD GPU designs, to feed them data, they form an important part of the processing chain in the shader core. While it was rare for it to happen in GCN, in RDNA the scalar unit physically can't be a bottleneck for the SIMD hardware.

DOUBLED VGPR AND LDS BANDWIDTH

Each RDNA WGP has 256KB of vector general purpose registers (VGPRs) to use for intermediate storage as it runs shader programs. Like almost all programmable GPU architectures since they were invented, the maximum number of waves in flight on the machine being processed is bound by the number of available registers to run them.

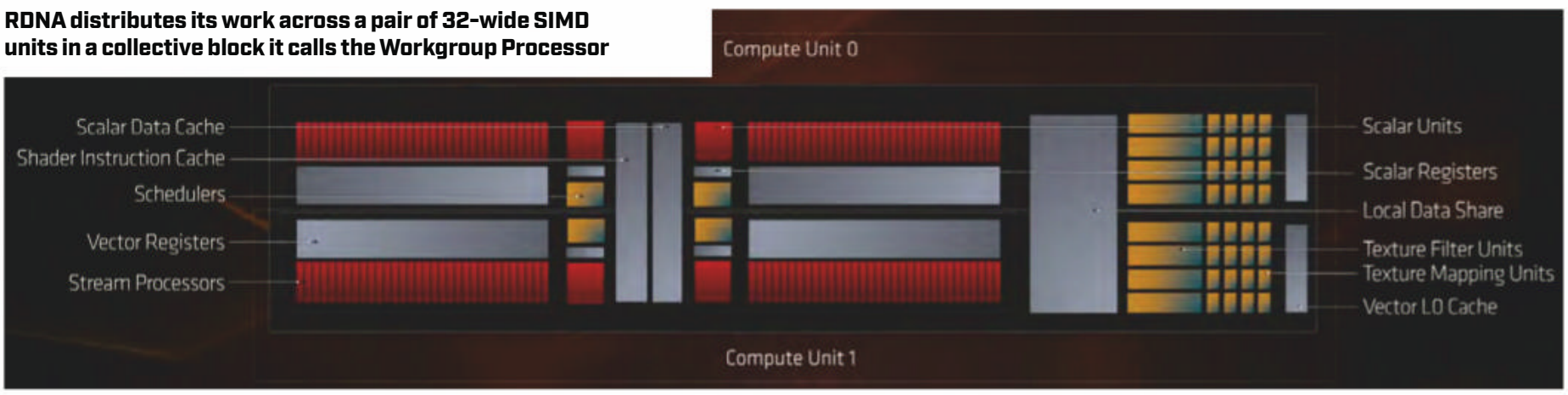
Say that your shader program needs ten registers and your machine has 20 available. You can run two waves of threads, each consuming ten of 20 registers. That basic principle applies to modern GPUs, just with much bigger numbers: RDNA has 256KB of VGPRs per WGP. Each VGPR is 32 x 32-bits in size (so 128B), giving you 2,048 (262,144 / 128) VGPRs per WGP. Even with ten waves in flight on the WGP, that's still roughly 200 VGPRs per wave. Contrast that with the architectural limit of modern x86-64, which has just 16 registers available for programs to use (under the hood there are more, but still!); GPUs are just completely different beasts.

Lastly, let's talk about Local Data Share (LDS), which is a special, very fast, very flexible local memory shared among the SIMDs in a WGP or CU. It's no bigger in RDNA compared with GCN at 64KB, but because there are fewer SIMDs competing for its usage, the effective bandwidth doubles for the aggregate WGP structure compared with a GCN CU. It's the same tactic AMD took with the scalar ALU and its resources, and the VGPR pool sizing: keep it as before but share it between less SIMD hardware.

DOING MORE PER CLOCK IN THE WGP

We've now established the new WGP structure and new basic execution model,

RDNA distributes its work across a pair of 32-wide SIMD units in a collective block it calls the Workgroup Processor



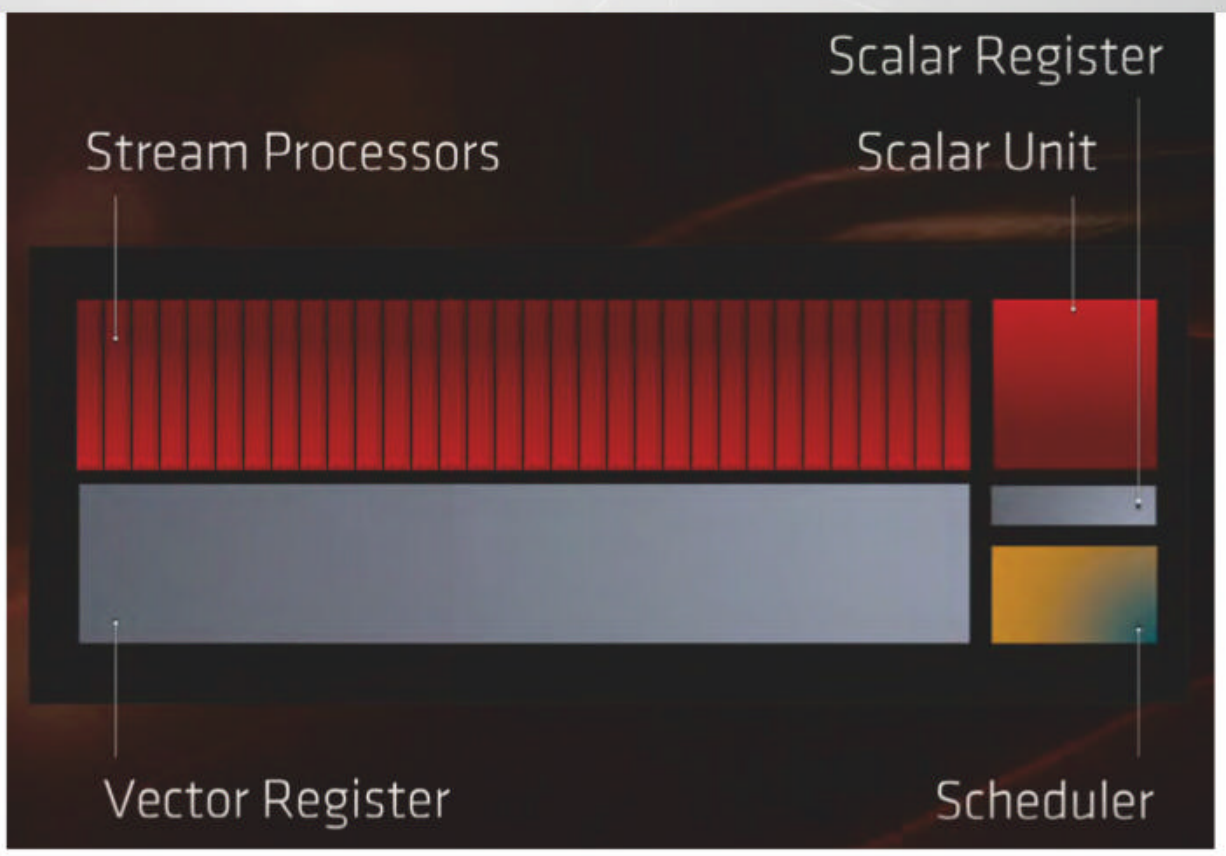
and how it more efficiently shares available per-WGP resources, such as the VGPR pool, LDS and the scalar hardware that assists the WGP's SIMDs in their work. AMD could have reasonably signed off the WGP design there and called it done, but it also took a close look at the kinds of shader programs that modern games ask the hardware to execute, across the full spectrum of vertex, pixel, compute and tessellation. It also took the compiler-driven way of executing the new geometry pipeline into account.

A special function unit (SFU) lives alongside the main SIMD hardware in the CU in GCN, and its job is to efficiently run special kinds of arithmetic instructions that don't tend to come up too often in shader programs and, because of how the hardware needs to implement them, shouldn't really be a part of the primary arithmetic pipeline in the SIMD.

The primary SIMD pipeline in RDNA runs floating point at IEEE754-spec single precision, just like a modern CPU, including support for weird floating-point numbers that affect how you execute, such as denormals (numbers very close to, but not quite, zero). It implements that with support for a fused multiply-add (FMA) instruction. That 2-op instruction runs both the multiply and the add part of the arithmetic in a single cycle. It's also capable of just executing a multiply or an add if that's all that's needed. But that's pretty much all it does, at least for floating point.

There's no support for the aforementioned special functions, such as sin, cos, log, pow, exp, and other similar arithmetic instructions, which tend to have a much longer latency than one cycle at their target accuracy. Because the latency to generate the right result for those functions can be long and variable, support for those essential but special functions has always been separate in AMD GPU architectures, and indeed those from almost all other GPU makers too.

In GCN, to issue an instruction to the SFU, you steal an instruction slot in the instruction stream that you're running, so you can't issue to the main SIMD while you're issuing to the SFU, and you wait for the SFU result to come back before you can do more main SIMD work. That's easy to implement, but kind of sucks because it takes issue slots away from the main SIMD hardware, which is almost always more commonly needed in normal shader programs. The innovation in RDNA is to catch up with competing architectures and still take an issue slot away from the SIMD hardware, but to then run the SFU in parallel.



In RDNA, the SFU takes four cycles to return the result of a particular op. In GCN that would block the main SIMD hardware for all four clocks. In RDNA, it only blocks for one clock, and the main SIMD can get back to work for the three other clocks that are left before the SFU comes back with its result. If the compiler can find work to do in those three clocks, then RDNA gets (much) more efficient at running those co-issuable FMA + SFU opportunities that sometimes crop up in modern shaders. It's doable for the compiler, especially because it's not a huge instruction window to fill up before the SFU will come back with any result.

RDNA ALSO CHANGES HOW WORK IS DISTRIBUTED ACROSS A COLLECTION OF THOSE SIMD UNITS

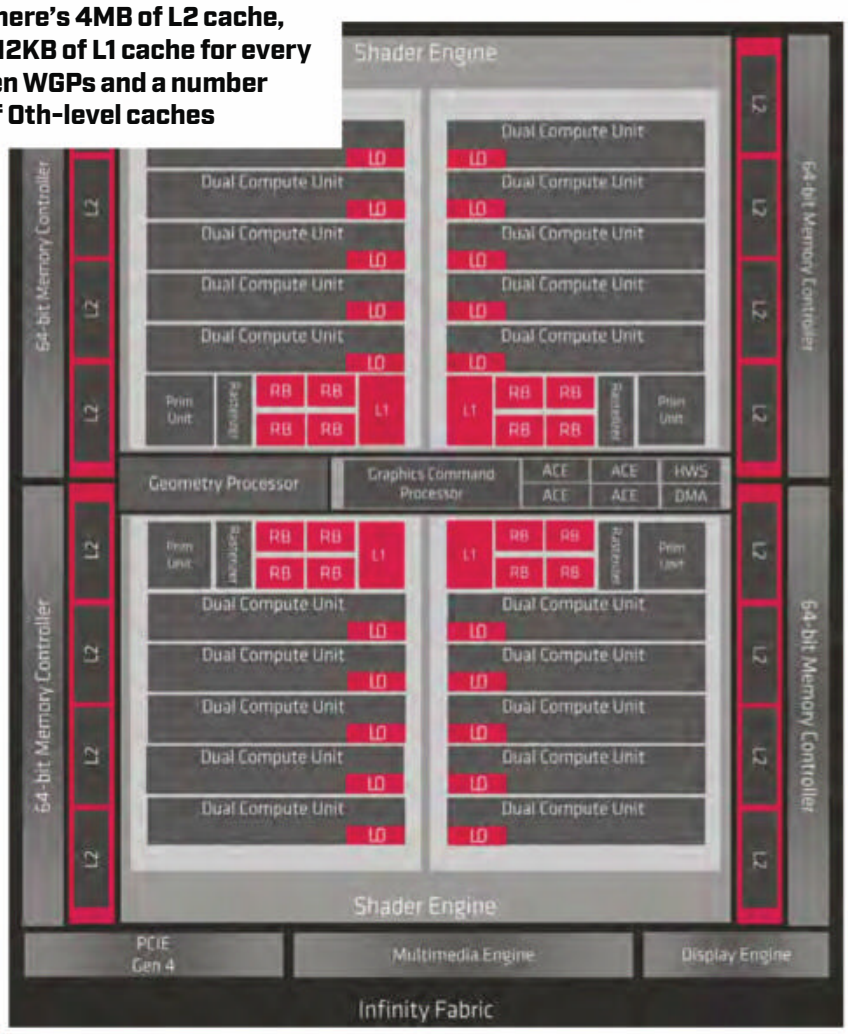
TEXTURE HARDWARE CHANGES, FP16 AND WAVE64

The only texture hardware change of note in RDNA that we can see is that the design is now capable of full-rate 64 bits per pixel (bpp) and BC6H format bilinear filtering, which is twice the performance in Vega. Commonly requested by game developers over the last few years, AMD upped its texture performance ante and made its sampler hardware full-rate for basically all surface formats you might want to filter in common graphics workloads now. It's a great future-looking change to the texture hardware design in response to strong developer demand.

Whereas the SIMDs in a GCN CU shared a single scalar ALU, RDNA has one assigned to each SIMD

Shader programs in modern games, especially pixel shaders, have plenty of opportunity for executing parts of the shader program in reduced precision, typically 16-bit floating point (FP16). Like GCN, RDNA still supports executing FP16 at double rate for some instructions (and 16-bit integer too, but that's less common) by running those instructions on two halves of a packed 32-bit VGPR. Put one 16-bit value in the top half of the register, and one in the bottom half, and the hardware can run a dual-rate instruction for a decent subset of the SIMD's arithmetic instruction capability. Competing architectures can do a similar process now too.

Lastly, before we can move on from the new WGP that makes up the shader core, AMD made a point of telling the public that RDNA can also operate in a special mode it calls Wave64. As we figured out earlier, GPUs have choices when it comes to wave size and how many clocks over which to run the wave. In RDNA, Wave64 mode is a 64-wide wave that runs over two cycles on the 32-wide SIMDs that make up the WGP.



There's 4MB of L2 cache, 512KB of L1 cache for every ten WGPs and a number of 0th-level caches

While AMD's compiler could dynamically and transparently select between the native Wave32 mode and Wave64 execution mode for some shaders, for performance, we reckon it's mostly there for backwards compatibility with GCN, which runs in its own effective 'Wave64' mode over four cycles all the time. Some AMD customers highly value a measure of backwards compatibility, so it makes sense for it to be an operating mode of the RDNA microarchitecture, while still being a feature AMD can use in PC GPUs, such as the Radeon RX 5700 series, and future RDNA-based designs.

CACHE AND MEMORY

All these core microarchitectural changes in RDNA are backed up by some fresh thinking in the caches and memory hierarchy compared to GCN. First up, cache sizes: each RDNA implementation is free to choose its own sizes for the main caches, so we can only really talk about what's in Navi10. It has 4MB of Level 2 (L2) cache, which is the last cache on the chip before the external GDDR6 memory and the PCI-E 4 buses, depending on which one the GPU needs to talk to. All the blocks in the total design are clients of the L2 cache, so they all talk to the outside world through that cache.

Then there's a 512KB of L1 cache for every ten WGPs in the Navi10 Shader Engine. Each Shader Engine in Navi10 has two of those ten WGP sets, so there's 1MB of total L1 cache per Shader Engine, or 2MB for the whole chip. Then there are a number of 0th-level caches below those L1 caches, one each for the SIMDs (the V$ L0), instruction fetch and issue hardware (the I$ L0), and the scalar K-cache (the K$ L0). AMD doesn't disclose the size of the L0 caches in RDNA unfortunately, so we can't tell you what they are, but they're likely in the 8-32KB range.

AMD also doubled the amount of bandwidth from the L0 cache hierarchy into the shader core, so the WGPs can make better use of those caches when they hit. AMD also reduced the amount of clock cycles it takes to talk to each level of the cache hierarchy. That's been a traditional deficit for very cache-sensitive programs running on AMD GPU designs when compared with competing architectures. AMD recognised that situation and addressed it in RDNA, heavily reducing access latency to L2 cache by up to 24 per cent. Access latency to the GDDR6 memory through the external memory fabric after the L2 cache is also reduced by up to 7 per cent.

There's also a sweet change to how the cache hierarchy can respond to both requests and misses. Each kind of main request to the GDDR6 memory by the hardware, be it a general load, store or texture sample, now has its own request queue in the hardware.

Compared with the shared queue in GCN, that lets RDNA's memory system respond more efficiently to mixed request loads and service them separately, without any heavy accesses of any one type starving the others. It's rare to hear about improvements in the memory system in a GPU, with vendors mainly focusing on the compute ability or other aspects, but that's a great improvement for RDNA – it really helps general graphics workloads that tend to have a solid mix of both load/store memory activity and texture accesses.

Finally for this section, there's a change to how the L2 cache can work if a request from the rest of the GPU misses in the L2 cache and needs to go out to the memory fabric and either GDDR6 or the PCI-E machinery.

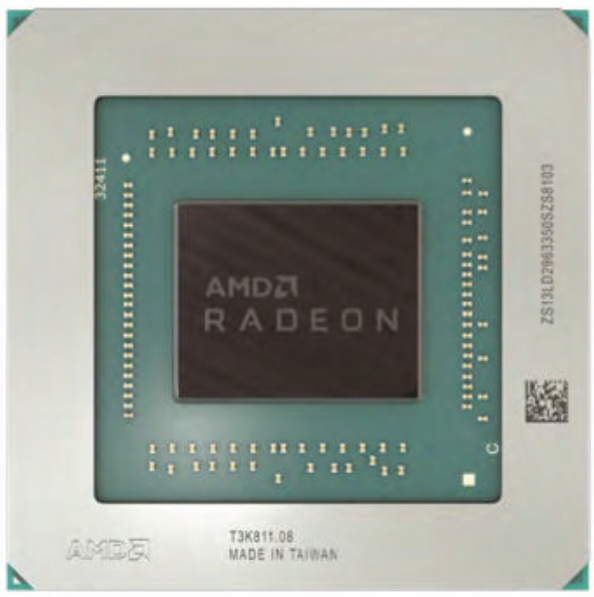
In GCN, a miss would block subsequent L2 accesses, even if they might hit and be able to return immediately, rather than wait for the request to come back through the last level fabric.

In RDNA the L2 system now supports hit-under-miss. As the name suggests, any hit that happens under an in-flight miss can be serviced by the L2 system and return data to the GPU so it can keep going. Best of all, continued L2 hits can also return, which allows RDNA to be blocked less by L2 miss transactions and keep working.

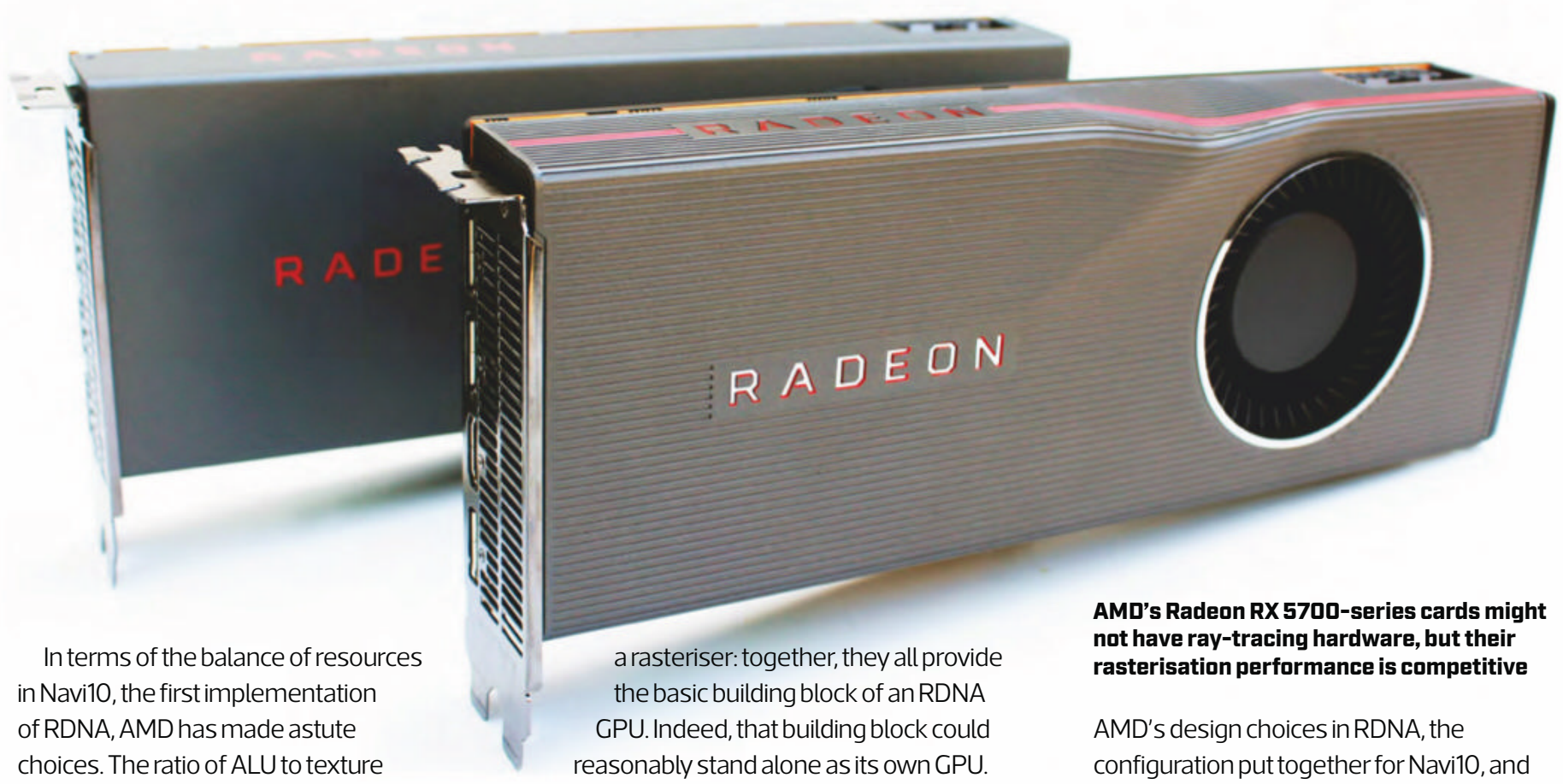
REBALANCING RDNA GPUs

The vast majority of differences described in RDNA so far have been in service of graphics workloads first and foremost. From co-issue of FMA and SFU, to reworking the entire WGP structure to be more efficient with smaller, short-lived and/or branchy dispatches — work that's less common in typical GPGPU workloads — to giving load, store and sampler accesses their own queues into the memory system, all the way to the really fast 64bpp bilinear sampling rate in the texture hardware.

There's no way to look at RDNA and not realise that AMD's focus is graphics acceleration in games. All of that would be lost, though, if AMD decided to scope out RDNA-based designs as inappropriately wide as the biggest Vega GPUs in terms of the new shader core.



Navi10 has 2,560 SIMD lanes, 80 scalar ALUs and 40 high-performance four-sample-per-clock texture units



AMD's Radeon RX 5700-series cards might not have ray-tracing hardware, but their rasterisation performance is competitive

In terms of the balance of resources in Navi10, the first implementation of RDNA, AMD has made astute choices. The ratio of ALU to texture operations remains solid at 16:1, which is fine and in line with other competitive designs from other vendors. The ratio of ALU to back-end pixel export resources, which blend and then move pixels out of the core into the GDDR6 memory at the end of pixel shading, is down to 40:1, from 64:1 in Vega.

That means there's a higher back-end export rate to service finished pixels and get them out of the core, so that more can be flushed through. That leads to less back pressure in the memory system, and less stalling as the hardware waits for export grants to be given so that old pixels can make way for new ones.

Lastly, that focus on the new front-end geometry performance in RDNA has resulted in a 320:1 ALU:triangle ratio, down from 1,024:1 in Vega. That means there's comparatively much more front-end performance to feed the new WGP-based shader core with useful work to do, keeping the machine busier and better utilised for, again, common gaming graphics workloads.

NAVI10 BY THE NUMBERS

Navi10 is basically a well-balanced 40 WGP part. Each WGP has a new dual 32-wide SIMD structure, and they share access to a pair of beefy scalar ALUs, plenty of local data shares, and a big shared VGPR store. Each group of ten WGPs also shares a big 512KB L1 cache, well-provisioned back-end export hardware, a Primitive Unit and a rasteriser: together, they all provide the basic building block of an RDNA GPU. Indeed, that building block could reasonably stand alone as its own GPU.

Navi10 takes four of those building blocks and amalgamates them into two Shader Engines, all sharing a massive 4MB L2 cache and the main command and control logic needed to drive the design and talk to the CPU. The headline stats therefore run to 2,560 SIMD lanes, 80 scalar ALUs, 40 high-performance four-sample-per-clock texture units, and 64 pixels per clock of export rate.

THERE'S COMPARATIVELY MUCH MORE FRONT-END PERFORMANCE TO FEED THE NEW WGP-BASED SHADER CORE

REMEMBERING HOW TO BUILD A GPU

So what's the end result of this newly balanced GPU? The tested performance of the first RDNA-based GPU, Navi10, and the Radeon RX 5700-series products that it powers, show a solid performance increase at the same power as comparable Vega products, and an even larger increase in measured performance for the same die area, even though some of that benefit comes from the new 7nm process technology AMD is using to make it.

Mostly importantly, Radeon RX 5700-series products compete with Nvidia's equivalents in a way that we haven't seen from AMD for quite a while, and at the right price points.

AMD's design choices in RDNA, the configuration put together for Navi10, and the economics it gets for it from TSMC's 7nm process, plus the pairing with GDDR6 instead of HBM2, mean you get a strongly competitive product based on a reworked and reimagined microarchitecture, on which AMD can continue to build and keep competing.

There are no new rendering features in RDNA compared with Vega, for which some people have criticised the company. There's no hardware ray tracing, no variable rate shading, and no mesh shader support. However, these omissions are likely deliberate – enabling AMD to treat RDNA and Navi10 similarly to the way it treated Zen 1 and the first Summit Ridge-based Ryzen 1000 Series processors – you get strongly competitive products out there with a great technical base, nail the basics in the microarchitecture again, use advanced manufacturing technology to get an extra edge, and then power on towards future products that can really put some pedal to the metal.

That looks like AMD's goal with RDNA: remember how to build great GPUs to lay the foundations for the future, and bring more performance and features to the table next time.

Not having to do everything at once paid dividends for the Zen team, as we've all seen with Zen2 and Ryzen 3000-series products. RDNA and Navi10 is hopefully similar for the graphics team at AMD; more competition in any semiconductor market can only be good for consumers. CPC

PLAYING FOOTSY

Edward Chester investigates how to free up your fingers by adding a gaming foot pedal to your setup

Racing and rudder pedals have been around for years, but other games have been left in the cold

We've long had accelerator and brake pedals for racing games, and rudder pedals for flight sims, but foot pedals have been sadly neglected in the wider gaming world. While we're all used to keyboards and mice festooned with extra buttons, we've been leaving a whole extra set of input devices idle – our feet. Are foot pedals the next revolution in the gaming peripheral world? We did a little digging to find out.

Why do I need a gaming pedal?

The idea and overall benefit of using your feet to add more control to your computer shouldn't take much explaining: you can perform two or more functions with your feet, freeing up your hands and fingers for other tasks. Adding pedals to a racing or flight sim setup may make it feel more authentic, but more importantly, it just makes it easier to use.

Look outside the world of gaming and PCs, and we see this added utility used in all sorts of walks of life. There are sewing machine speed pedals, guitar effects pedals, the pedal keys of an organ, kick drum pedals – the list goes on and on. Heck, even some software comes with pedal control.

Perform a quick search online for PC foot pedals and one of the most common results is pedals designed specifically for use with dictation software. The question shouldn't really be why do you need a gaming pedal, but why on earth do we not all already have them?

The list of possible uses is near endless. Even a single pedal that replicates a single key press could allow you to trigger push-to-talk on your favourite gaming chat app, or bring up your in-game inventory.

Double up on the number of pedals and you could offload the run and crouch keys or use them to lean left and right.

Go all out and you could use multiple pedals to select weapons, fire off macros and much more, all without having to move your fingers from the most important keys and buttons on your keyboard and mouse.

Add analogue pedals into the mix and you have even more potential. Okay, so the uses here may be less game-orientated, but having a pedal that can adjust volume, scrolling speed/direction and so on could certainly be useful.

The options

Considering all this potential, you'd expect gaming peripheral companies to have long since cottoned on to this cash cow and milked it dry. However, not a single well-known peripheral company has got on board yet. It's quite bizarre.

That said, there's still a few options if you're willing to take a punt on an unknown company. Search online for gaming foot pedals, and one of the first options you'll see pop up is the Fragpedal, made by Good Work Systems. Built with gaming in mind, the Fragpedal is available in two-pedal or four-pedal versions and it certainly looks like it has potential. Unfortunately, we weren't able to get hold of one for this feature, as the small US-based company doesn't yet ship to the UK.

With that promising option a no-go, we found just two programmable USB foot pedals that appeared to be widely available round the world. Both appear to be made by a Chinese company called PCsensor (the software for configuring both pedals is made by this company), although they're marketed under all sorts of different names depending on where you buy them.

The first is a 3-in-1 pedal board, which you can find sold under the Sodial brand on **amazon.co.uk** for just £20 inc VAT (it's listed as the FS3 in the PCsensor software). The second can also be found on **amazon.co.uk** under the Docooler brand, with the single-pedal version (FS2016USB1) costing £18 inc VAT and the two-pedal version (FS2016USB2) costing £30 inc VAT.

> The idea and overall benefit of using your feet to add more control to your computer shouldn't take much explaining

Not really knowing what to expect, we ordered one each of the Sodial and the two-pedal Docooler. After a reliably short Amazon delivery time, both pedal boards arrived unscathed – clearly both products were stocked in the UK. A quick download of the configuration software from **PCsensor.com** and we were able to give the pedals a workout.

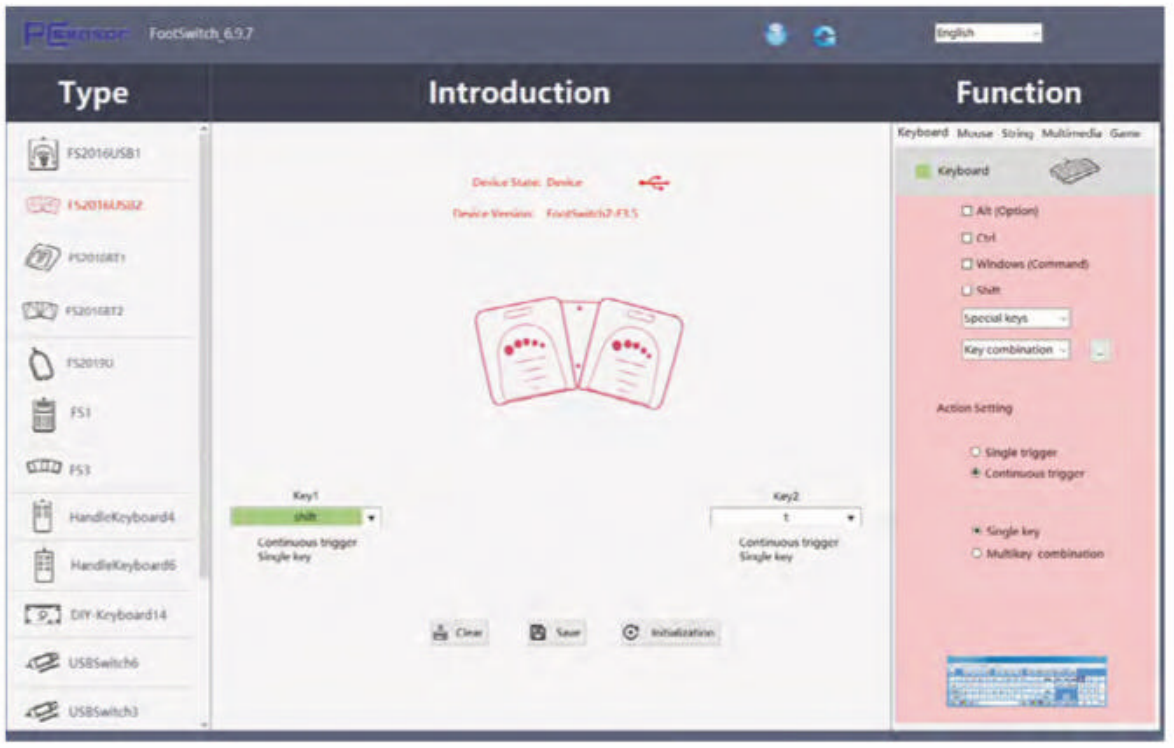
Straightaway, it was obvious that the Docooler pedal was much more robust than the Sodial one. It has a thick metal base that makes the pedals both sturdy and weighty enough not to slide around the floor. The foot switches themselves are also large, heavily sprung and provide a clearly audible click when triggered.

In contrast, the Sodial pedals have a flimsy plastic base, and the pedals are small and much more lightly sprung. They also hinge from the front of the pedal, so it's difficult to press the pedal with just the tip of your foot. This arrangement was annoying enough that we flipped the pedals around and used them with the USB cable directed towards us. The buttons also don't provide any sort of audible or tactile feedback when they're triggered.

Setting up both sets of pedals was really easy though. The software clearly lists all the products it supports down the left side, and it automatically shows which ones are plugged into your PC. Select the device, and you can assign to each pedal either a single key press, a mouse button click, a string of key presses, a multimedia key function or even emulate game controller buttons. You can also opt to have key presses trigger once or continuously.

The Sodial FS3-P is a cheap USB pedalboard with three programmable pedals

The Docooler FS2 is a robust USB foot pedal board with two programmable pedals



The PCsensor software is surprisingly versatile and easy to use

Pedal to the metal

Having established that we much prefer the Docooler pedals, we used them as our main test subject, to see just what the addition of pedals brings to our gaming. We tested them in three main configurations. The first was with the left pedal mapped to push-to-talk and the right pedal assigned to bring up the in-game map. In other words, we only used them for low-level, occasional functions. We tested this configuration across a number of games.

Next, our testing became a bit more game-specific, and we set up the pedals for use in Apex Legends. This game requires you to almost constantly hold down the left Shift key to ensure you're always running, so we offset this one task to the left pedal, to see how well it held up to much more constant use. The right pedal was assigned to push-to-talk.

Finally, we configured the pedals for use in PlayerUnknown's Battlegrounds, where we used them for leaning left and right. If you've ever played a first-person shooter that has leaning control, you'll know it can be difficult to combine full WASD movement, running/walking/crouching control, mouse aiming and leaning. By offsetting the latter to the foot pedals, it should be much easier to get the other movements right.

> With the right hardware properly set up, a foot pedal setup seems like a natural progression in gaming controls

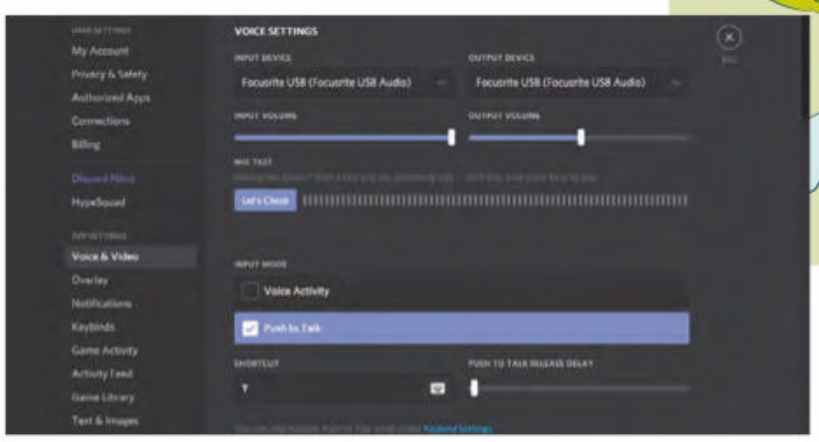
Going back to our first scenario, the pedals easily proved their worth here. Simple, occasional inputs that are non-critical is where it's easy to feel comfortable relying on cheap no-name foot pedals, and you don't need particularly agile feet either.

However, it was immediately clear that having two separate pedals spaced further apart, where they sit more naturally under the feet, would be much more preferable to a single two-pedal board. Unfortunately, by the looks of the PCsensor software, this setup may not be possible as it only lists each pedal once. However, you could perhaps use a combination of an FS2016USB2 and the single-pedal FS2016USB1.

Meanwhile, the second scenario quickly demonstrated that the FS3 pedals weren't up to the job, as the switches just didn't seem to be as reliable when being held down constantly. The FS2016USB2 held up well though.

You can just relax your foot on the pedal and basically never let it go – especially if you opt for the continuous trigger input, which will trigger the key press again, even if an element in the game forces you to stop running. The pedal seemed to hold up to the abuse of prolonged pressing and worked like a charm.

Finally, we come to the leaning challenge, which is where the whole world of foot-pedal use takes on another level of skill and learning – it was also where we most missed having two pedals more spaced out.



Push-to-talk on team chat is one task that's easy to offset onto a foot pedal

Momentary switches can be bought for just a couple of quid each

Using both feet accurately and reliably, and coordinating them with keyboard and mouse movements, took some learning, and we certainly didn't master it in the week or so we tested the pedals. However, we saw the potential. With the right hardware properly set up, a foot pedal setup seems like a natural progression in gaming controls.

Can I make my own?

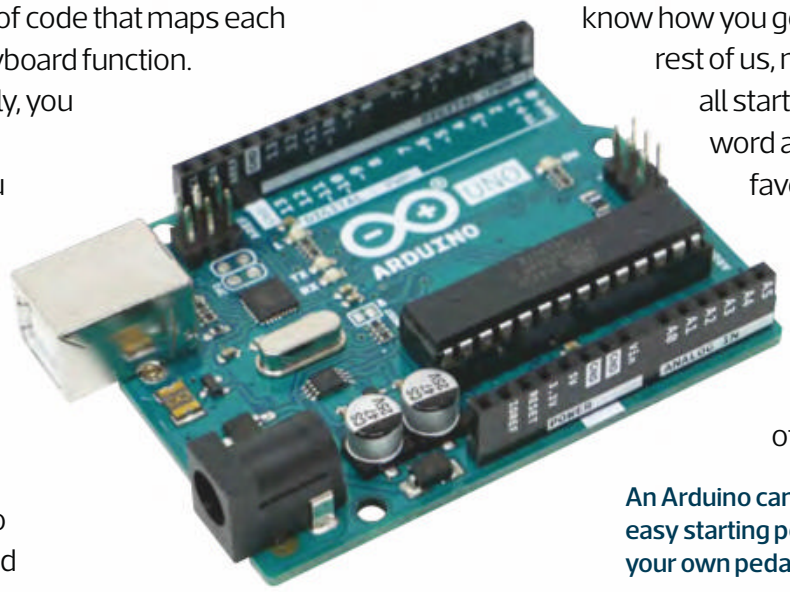
As we've mentioned, none of the big-name brands has become involved in this potentially big market yet, which is perplexing. When we've seen such specialised, expensive gaming mice, keyboards, headsets, steering wheels and joysticks, it's hard to imagine there isn't enough of a niche market for foot pedals too. Either way, though, that's the situation right now. If the above couple of examples don't take your fancy, or you want a more sophisticated pedal setup, the only other option is to make your own.

We're still working on our own DIY pedal board, so we don't have a full build guide yet, but the theory is quite simple. Grab a handful of momentary switches, or premade pedals, mount them on a board, wire them to an Arduino and write a short bit of code that maps each button press to a keyboard function.

If it's done correctly, you shouldn't need any extra power, and you could just run the board from the Arduino's USB power source. We managed to grab four momentary switches, an Arduino and a slab of plywood all for under £40 – you can look for our complete build guide in a later issue.

Leaning in FPS games is tricky to master with just a keyboard and mouse

In the meantime, if you've ever experimented with foot pedals for gaming – or if you've made your own foot pedals – get in touch (letters@custompcmag.org.uk) and let us know how you got on. As for the rest of us, maybe it's time we all started spreading the word and badgering our favourite PC peripheral companies to start investing in controllers that allow us to make the most of all our limbs. CPC



An Arduino can make for an easy starting point for making your own pedal board

GARETH HALFACREE'S

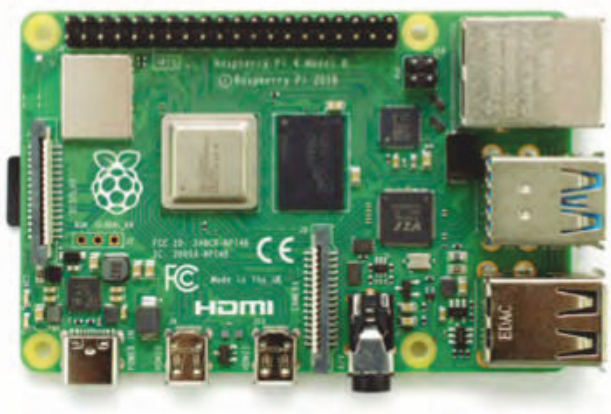
Hobby tech

The latest tips, tricks and news in the world of computer hobbyism, from Raspberry Pi, Arduino and Android to retro computing

REVIEW

Raspberry Pi 4

Although everyone knew it was coming, nobody expected it quite this quickly: the Raspberry Pi is dead, long live the Raspberry Pi. To clarify: as indicated during the launch of the Raspberry Pi 3 Model A+, the 'legacy' Raspberry Pi range has come to a close. Its replacement, looking not wholly dissimilar and going under the name Raspberry Pi 4, is a ground-up re-engineering effort that aims to finally address some of the most long-standing complaints about the low-cost, education-focused single-board computer family.



The layout has been shuffled, with the Ethernet port now at the top

The heart of the effort is a new system-on-chip (SoC), the Broadcom BCM2711B0. The headline-grabbing features are four 1.5GHz ARM Cortex-A72 CPU cores and an all-new VideoCore VI GPU – making it the first Raspberry Pi in history to launch without the aging VideoCore IV.

Inside, there's an even more welcome change. The main bottleneck of the Raspberry Pi design, from the original Model B through to the range-topping Raspberry Pi 3 Model B+, has gone. The SoC now enjoys around 5Gb/sec of bandwidth to connect with external devices, instead of trying to shove everything through a single 480Mb/sec USB lane.

That has a serious impact on the Raspberry Pi's capabilities. Where the four USB 2 ports would previously have shared bandwidth, not only are they now fully independent, but two of them have also been upgraded to USB 3. Likewise, where the 'Gigabit' Ethernet of the Raspberry Pi 3 Model B+ would top out at around 250Mb/sec, the Pi 4's port gets about as close to Gigabit speeds as you could hope.

There's still more to the Pi 4 as well. The shift to an all-new SoC has broken the 1GB

The new BCM2711B0 is the Foundation's first SoC to be built on a 28nm process node

memory barrier, with the Pi 4 launching in 1GB, 2GB and 4GB varieties – and it's all LPDDR4 memory, rather than the older models' LPDDR2. The upgraded GPU now also includes dual-display capabilities, with the board design trading the traditional full-sized HDMI port for a pair of micro-HDMI connectors, each able to drive a 4K display – either a single 4K60 or two 4K30 panels. Plus there's a hardware decoder for HEVC

SPEC

SoC Broadcom BCM2711B0 quad-core A72 (ARMv8-A) 64-bit @ 1.5GHz

GPU Broadcom VideoCore VI

Networking Dual-band 802.11b/g/n/ac Wi-Fi, Gigabit Ethernet

Memory 1GB, 2GB or 4GB LPDDR4 SDRAM

Bluetooth Bluetooth 5, Bluetooth Low Energy (BLE)

GPIO 40-pin GPIO header, populated

Storage Micro-SD

Ports 2 x micro-H DMI 2, 3.5mm analogue audio-video jack, 2 x USB 2, 2 x USB 3, Gigabit Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)

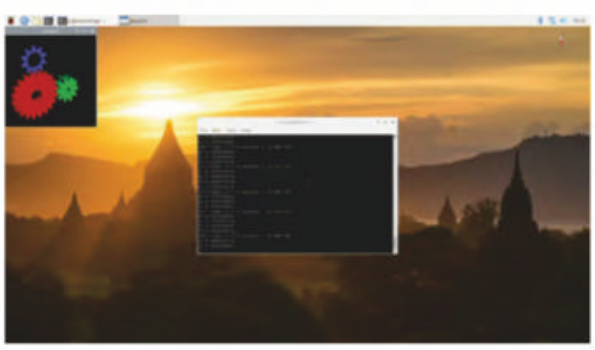
Dimensions (mm) 88 x 58 x 19.5

Weight 46g

Rejoice! There are two USB 3 ports, although they share a single PCI-E lane to the SoC

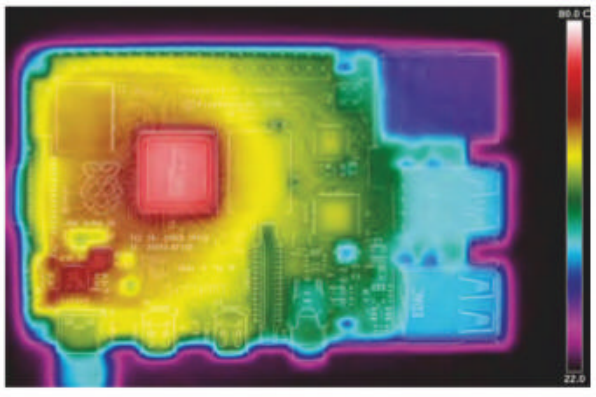
(H.265) content, capable of decoding 4K60 content to boot, although all other formats are limited to lower resolutions.

While the Pi 4 looks superficially similar to its predecessors in terms of layout, there have been considerable shifts. The top pair of USB ports and the bottom Ethernet port have now changed places, there are now two micro-HDMI connectors in place of the single full-sized HDMI port, and the micro-USB power connector is now a USB Type-C connector, boosting the board's maximum input current to 3A.



Even uncased, the Pi hits its thermal throttle point in under five minutes of sustained activity

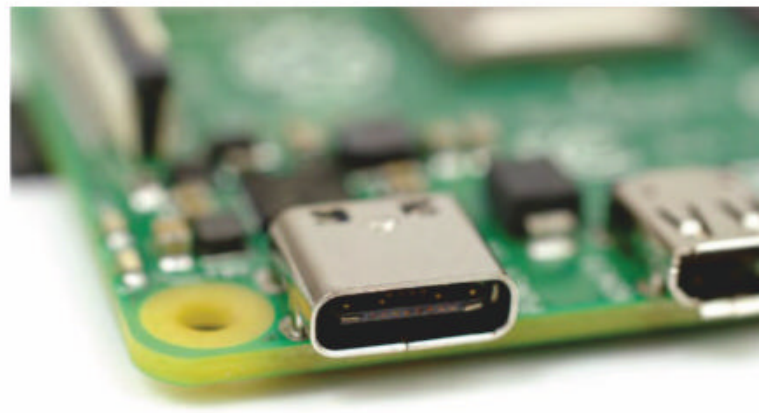
Under load, the Raspberry Pi 4 gets hot enough to hurt



Each port also now sits a little prouder of the board, which means you're unlikely to squeeze a Pi 4 into an existing case without considerable modification.

Surprisingly, though, for all project co-founder Eben Upton warned of a clean-slate plan following the last of the 'legacy' family, compatibility is good. Raspbian 'Buster', released alongside the board, boots on any Raspberry Pi from the Pi 4 going all the way back to the original Model B. The new board is also fully compatible with add-ons adhering to the Hardware Attached on Top (HAT) standard, and accessories such as the Raspberry Pi Touch-Screen Display and Raspberry Pi Camera Module connect without difficulty.

The changes aren't just tick-boxes on a spec sheet either. Processor-wise, the Pi 4 is considerably faster than the Pi 3B+ across a range of workloads. It's around four times faster in the LINPACK benchmark, twice as fast at multi-threaded file compression and around a third faster in a GIMP-driven image editing challenge. The GPU provides a solid boost too, pushing around 50 per cent more frames per second in the OpenArena first-person shooter as its predecessor.



A switch to a USB Type-C connector lets the Raspberry Pi 4 draw up to 3A

It gets interesting in workloads that were previously fighting the USB bottleneck though. The Ethernet throughput has quadrupled from around 240Mb/sec to 943Mb/sec, while USB storage throughput has risen by an order of magnitude from 33.24MB/sec read and 34.1MB/sec write – dropping if you're transferring data over the network at the same time – to 363MB/sec read and 323MB/sec write. Even the micro-SD storage enjoys a boost thanks to the addition of DDR support, going from 23.5MB/sec read and 17.4MB/sec write to 45.7MB/sec read and 27.7MB/sec write.

There's a cost, naturally – power and its friend, heat. The Pi 4 runs hot, with thermal imaging showing heat spreading throughout the board. This heat comes from increased power draw. When idle, the Pi 4 draws 3.4W, compared to the Pi 3B+'s 2.9W, although this figure may fall with post-launch firmware optimisations, while under load it hits 7.6W.

It's a small price to pay, although your wallet will feel the difference in RAM capacities. Pi 4 pricing sits at around £33, £43, and £53 (inc VAT) for the 1GB, 2GB, and 4GB models respectively, from resellers including **pimoroni.com**.

NEWS IN BRIEF

The Pi Hut acquires ModMyPi

Popular Raspberry Pi accessory and customisation outlet ModMyPi has been acquired by rival The Pi Hut, with the promise that ModMyPi's products will remain available under the new ownership. 'The entire ModMyPi range will be available direct from The Pi Hut as soon as humanly possible! Please bear with us, there's a LOT of stuff to move across,' the company confirmed. 'The Pi Hut team will continue to manufacture and distribute ModMyPi's complete range of products, host the entirety of their web content and offer the same range of services our customers have grown to love.'

It's small and colourful, plus there's a lot crammed into its diminutive dimensions

REVIEW

M5Stick-C

While Arduino-branded microcontrollers continue to prove popular, hobbyists on a budget have begun looking at devices based on the ESP family of devices. In particular, the ESP32 and ESP8266, the latter of which redefined what you can expect from a board costing as little as £2 with built-in Wi-Fi and Bluetooth connections.

With the core ESP hardware costing so little money, it's no surprise to see a secondary market of ESP-powered gadgets cropping up, and the M5Stack range may well encompass the most impressive examples. The M5Stick-C, as reviewed, is a microcontroller development kit based around the ESP32, but expanded to tick almost all the boxes anyone could hope to tick.

The core microcontroller is a Tensilica LX6 running at 240MHz, offering 520KB of static RAM (SRAM) and expanded with 4MB of flash storage. As with other devices in the ESP range, it includes integrated 802.11b/g/n 2.4GHz Wi-Fi, as well as both Bluetooth Classic and Bluetooth Low Energy (BLE). It has pulse-width modulation (PWM) on every available GPIO pin, a built-in SD card controller, capacitive touch sensing and a Hall sensor to boot.

So far, so ESP32. Where the M5Stick-C builds on its rivals is by slapping a bootload of extras on top, and in a chassis measuring just 48 x 24 x 14mm. Within those diminutive dimensions is an 80mAh lithium polymer battery for on-the-go use, a USB Type-C port for charging and data, a six-axis inertial measurement unit (IMU), a 0.96in colour 160 x 80 LC, a red LED, an infrared LED, a microphone and a Grove-compatible expansion socket. There's also a general-purpose input/output (GPIO) header with access to 5V in and out, 3.3V, direct battery connection, and three spare GPIOs.

That's already a long list, but there's more. The battery is charged through a power-management integrated circuit (PMIC), which is available for software control, allowing you to query the current charge or discharge rate as well as the temperature. There are even three buttons: one to control the power, a large face button under the M5 logo, and a smaller button on the side as a secondary input. If that weren't enough, M5Stack has even found room for a small magnet that allows the M5Stick-C to

A little chunky, perhaps, but if you want a watch that turns heads, the M5Stick-C could fit the bill

Clever side buttons, plus a single face button, provide some measure of control

Despite its bulk, the M5Stick-C is surprisingly comfortable when fitted to the bundled watch strap

In its 'wearable' bundle form, the M5Stick-C includes a watch strap, wall-mount and Lego-compatible mounting clips

adhere to many metal surfaces without the need for permanent mounting hardware.

In short, the M5Stick-C is a bit of a beast – at least, in microcontroller terms. All the features in the world are useless without the software to back it up, though, and here M5Stack has had a head start over its rivals. The ESP microcontroller family is already popular enough to have had a range of software projects ported across to it, including MicroPython, Arduino and even JavaScript.

Sadly, here's where it starts to fall apart. The hardware side of the M5Stick-C is undeniably impressive, although a little more attention to assembly to avoid the off-centre and bruised display of our review sample would be good to see. The software side, however, is poorly documented and difficult to access.

It gets off to a poor start at the beginning – the documentation on the M5Stack website is available only for Windows and macOS users; people running Linux are left to their own devices. Thankfully, the instructions for adding support for the M5Stick-C to the Arduino-IDE are platform-agnostic, although not labelled as such. Once it's configured, it gives you the usual ESP32 examples plus a range of M5Stick-C specific programs. Code is provided to handle the buttons, LEDs and display, with the latter including projects that draw Spirograph-style images or generate a user-configurable, and just-about-scannable, QR Code.

A handy, though off-centre, sticky label on the bottom marks all the GPIO pins

Not all the projects work, however. What should have been the most notable one, a clone of one-button reaction game Flappy Bird, fails to run correctly and turns what is already a frustrating game into Mission Impossible.

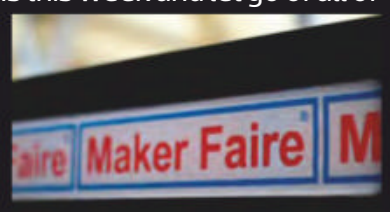
For the educational market, M5Stack has its own block-based visual programming environment, dubbed UIFlow. Using the UIFlow firmware – flashable only from Windows or macOS – it's possible to program the M5Stick-C in a drag-and-drop environment, or switch to Python, directly in the browser. It's an approach borrowed from a range of rival devices, including the BBC micro:bit, but its implementation isn't great: there's little documentation explaining how to get started, and pulling up the required 'API Key' – actually a unique reference code for the M5Stick-C you want to program – could be easier too.

All can be forgiven, however, with a look at the price. Purchased from **m5stack.com**, the M5Stick-C costs just $9.95 US with a bundled USB Type-C cable or $11.95 US with watch strap, wall-mount and Lego-compatible clip as reviewed (around £7.85 and £9.40 respectively exc VAT). Another kit with environment sensor and speaker 'hat' add-ons - no relation to the Raspberry Pi's HAT standard – is available for $15.90 US (around £12.50 exc VAT). At those prices, it's a toy that's hard to turn down.

NEWS IN BRIEF

Maker Media closes its doors

Maker Media, the company behind MAKE: Magazine and the popular Maker Faire series of events (see Issue 155 for a field report from Maker Faire UK 2016), has laid off its staff and ceased operations. 'Maker Media Inc ceased operations this week and let go of all of its employees — about 22 employees,' chief executive Dale Dougherty told TechCrunch of the closure. 'I started this 15 years ago and it's always been a struggle as a business to make this work. Print publishing is not a great business for anybody, but it works, barely. Events are hard. There was a drop-off in corporate sponsorship.'



REVIEW

Zach-Like

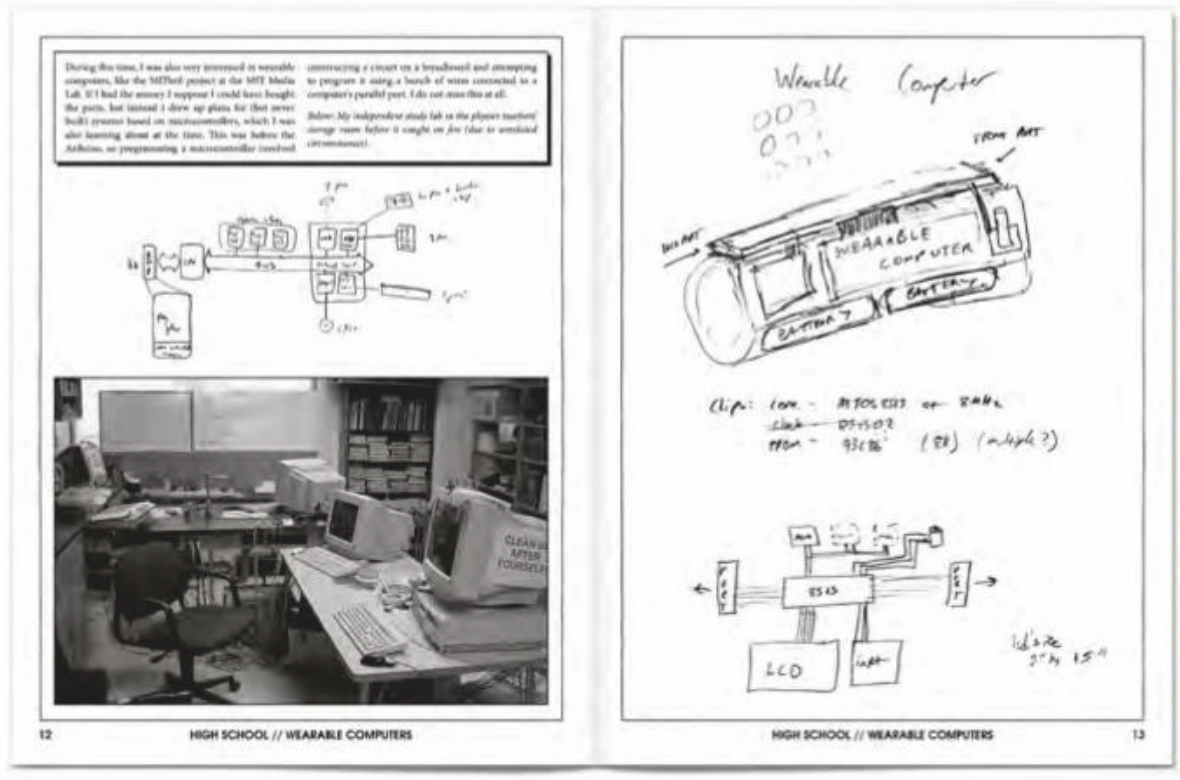
Zachtronics founder Zach Barth took to Kickstarter to crowdfund this book of design documents, and the campaign closed at more than ten times its modest $5,000 (around £4,000) goal.

That's not entirely surprising, given the popularity of Zachtronics' games, including Exapunks (reviewed in Issue 183), Shenzhen I/O (see Issue 161) and TIS-100 (see Issue 156). What is surprising, though, is that the book has now been launched on Steam, along with Barth's entire back catalogue of early games, including never-before-seen prototypes, completely free of charge.

As a printed book, there's a lot to enjoy in Zach-Like. While reproduced in paperback, despite backers' cries for a hardback format, and purely in black and white, the coffee table-style book offers a glimpse at how the sausage gets made. It starts with scans of Barth's middle-school sketches for never-produced games, and a fake assembly language that would later inspire his work in Exapunks.

There's not much narrative. Zach-Like doesn't tell a story; it shows you what makes Zachtronics games the way they are, through a glimpse into the mind of Barth himself. There are blocks of text that attempt to contextualise what you're seeing, but the stars of the book are the design documents themselves. These documents are joined by additional content, including paper-based puzzles and scans of physical extras included with selected titles' limited-edition print runs.

It's almost the exact opposite of the approach taken by Jordan Mechner, who released collections of his diaries journaling the time he was creating Kareteka and Prince of Persia. Mechner's books are near-exclusively written with only the occasional partial scan of a design document as an interstitial between chapters. Barth's approach is far more visual, only using the written word to provide context to the original documentation.



Following a barnstorming crowdfunder, Zach Barth's collection of game design documents is available for free download

No prizes for guessing the inspiration for this little unreleased title, Hack the Planet

The digital version, though, is where the magic really happens. There are two PDF copies of Zach-Like itself – one in standard one-up format and another in two-up format, depending on your preferred reading format. There are also PDF copies of card game Red Tape, turn-based tabletop strategy title Inifintron, a full-colour art book for Ironclad Tactics, and videos of interactive installations Tex-Mechs and Atropros in action. These installations are also properly covered in the design documents found in Zach-Like.

It's not just about reading and watching either. The digital version of Zach-Like includes all Barth's early games, including the infamous Infiniminer – the game that would 'inspire' Markus 'Notch' Persson to create block-'em-up Minecraft. You also get reverse-engineering classic Ruckingenur, as well as Infinifrag, Manufactoid, Gregor Mendel's Pro Botanist 2006 and more.

There are never-before-released prototypes too, including three early builds of Ironclad Tactics and two of Opus Magnum. There's also a hacking game inspired by the fight between Dade 'Zero Cool/Crash Override' Murphy and Kate 'Acid Burn' Libby in 1995 ravewear-fest movie Hackers. Sadly, all these titles are Windows-only, along with the main software launcher, and at the time of writing don't work in Valve's Proton compatibility tool, although they can be manually launched in Linux via Wine.

With an asking price of 'free, gratis, and for nothing', there's no reason not to pick up the digital version of Zach-Like. None of the games in the bundle shows the polish of Barth's more recent creations, but the book is well worth a read for people interested in game design in general, or Barth's approach specifically. The prototypes are an added bonus, and the other games are a welcome distraction if nothing else. Zach-Like is available to download from **store.steampowered.com** CPC

Gareth Halfacree is the news reporter at www.bit-tech.net, and a keen computer hobbyist who likes to tinker with technology. @ghalfacree

WIN

A 27IN IIYAMA RED EAGLE 144Hz GAMING MONITOR

Here's an awesome opportunity to get your hands on a 217in 144Hz FreeSync gaming monitor, courtesy of the lovely folks at Iiyama. One lucky Custom PC reader will get an Iiyama G-Master GB2760QSU monitor sent to their home.

- **27in TN LED panel**
- **FreeSync support**
- **144Hz refresh rate**
- **1ms response time**
- **2,560 x 1,440 resolution**
- **HDMI, DisplayPort and DVI inputs**
- **USB 3 hub**

WORTH **£300**

SUBMIT YOUR ENTRY AT
CUSTOMPC.CO.UK/WIN

Whether you're already a hardcore gamer, or aiming to be one, the 27in G-Master GB2760QSU (known as Red Eagle) offers the competitive edge you need to unleash your full gaming potential. Armed with FreeSync technology, a 144Hz refresh rate and a blistering 1ms response time, you can make split-second decisions and forget about ghosting effects or smearing issues.

The WQHD (2,560 x 1,440) resolution offers 77 per cent more on-screen space than a standard 1,920 x 1,080 full HD monitor. Meanwhile, the ability to adjust brightness and dark shades with the Black Tuner delivers greater viewing performance in shadowed areas. Nothing will skip your attention. You get a triple input setup (DVI, HDMI and DisplayPort), as well as speakers, a headphone connector and a USB 3 as well. No matter which games you prefer – RTS, FPS, MOBA and MMO – with the Red Eagle on your desk, you'll be at the top of the gamer food chain.

ANTONY LEATHER'S

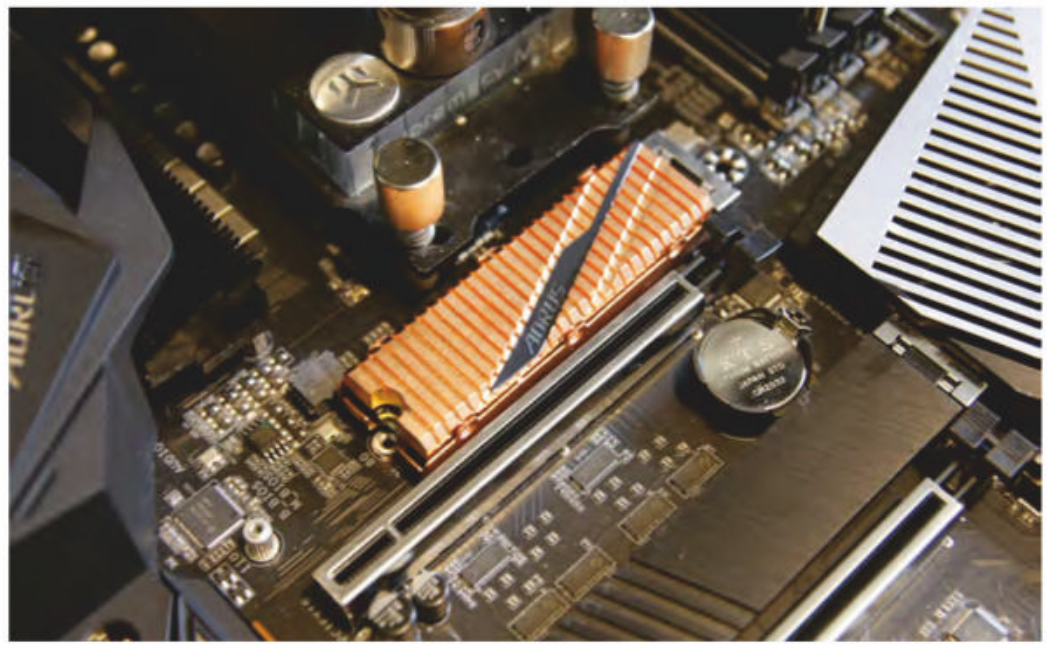
Customised PC

Case mods, tools, water-cooling gear and modding

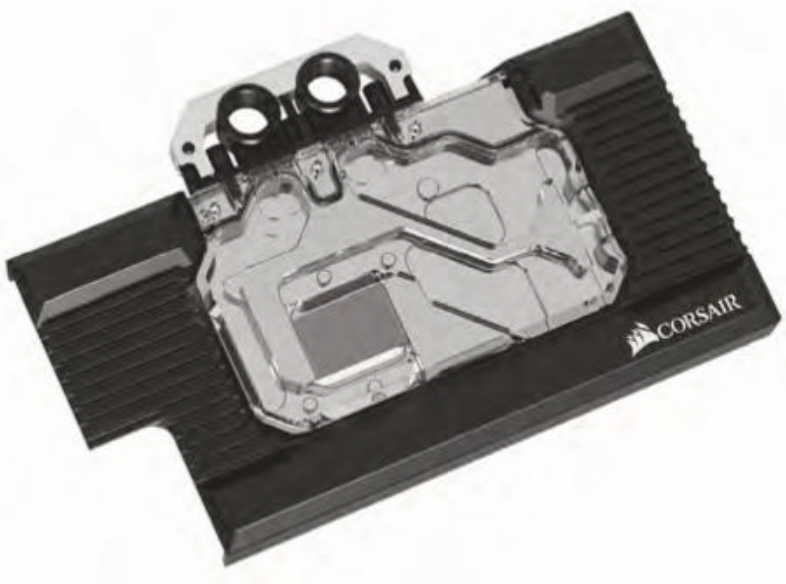
The mid-range likes of Nvidia's GTX 1060 6GB and RTX 2060 might be superb cards that have retailed for significant amounts of cash, but there have been no full-cover waterblocks available for them from reputable manufacturers. The RTX 2060 has been priced between £300 and £400, depending on the model, and it seems bizarre to me that water-cooling a card in that price range is so difficult.

In fact, I've spent far less money on graphics cards with readily available full-cover waterblocks in the past. Given the rise of mini-ITX systems over the past few years, water cooling is an excellent way to keep GPU cooling in check in the tight confines of small cases with meagre airflow.

The large copper heatsink on Aorus' SSD clashes with the colour scheme on some motherboards



Corsair's RTX 2070 FE block also fits on the RTX 2060 Super



That's before we get into the aesthetics of the situation, which is the main reason why many of us water-cool our PCs. I don't think wanting to water-cool a graphics card that costs close to £400 is unreasonable.

The same can't be said for AMD's Vega and Navi cards. Both line-ups have had decent water-cooling support, and the Radeon RX 5700 and RX 5700 XT will both be getting full-cover waterblocks from the likes of EKWB in the very near future. I'll be taking a look at them when they arrive soon, showing you how to water-cool a new Navi card.

There's another kid on the block too, of course – Nvidia's RTX Super series. Given the higher prices for some of these models over their predecessors (with the RTX 2060 Super retailing for closer to £400), my waterblock rage kicked in again. However, rather than being another tricky series of GPUs to water-cool, the RTX Super models are actually much more water-cooling-friendly than their predecessors from the start.

This is thanks to them using similar PCBs to the cards above them in the previous generation. For example, the RTX 2060 Super Founders Edition uses a near-identical PCB to the RTX 2070. Similarly, the RTX 2070 Super is a cut-down RTX 2080 in terms of both spec and physical layout – its PCB is identical to that of its older bigger sibling.

Unlike the original RTX 2060, the Super version can be easily fully water-cooled

That's fantastic news for a couple of reasons. Firstly, the RTX 2070 Super has a waterblock available immediately via existing RTX 2080 waterblocks, although it's worth checking with manufacturers first to be sure the block will fit. When I was writing this article, EKWB and Corsair had confirmed compatibility with their RTX 2080 waterblocks and the new RTX 2070 Super reference or Founders Edition PCBs.

The best news, though, is that the RTX 2060 Super is compatible with reference or Founders Edition RTX 2070 waterblocks, and again EWKB and Corsair have already confirmed compatibility with their existing blocks. Sadly, the original RTX 2060 remains a tricky card to water-cool, but at least the RTX 2060 Super, which is a decent choice in the £350-400 range at the moment, can be water cooled. I've taken a look at how to water-cool your shiny new RTX Super card on p106.

If you have a third-party Super card, it's also worth keeping an eye on the various online configurators and manufacturers' websites to see if your card is compatible with older waterblocks too – this information will start to become available once more PCBs land in the laps of waterblock manufacturers.

Cooling a PCI-E 4 SSD

I've been playing with Aorus' new NVMe M.2 PCI-E 4 SSD for the past few weeks as part of our ongoing 3rd-gen Ryzen coverage and I'm absolutely in awe of its speed. Both Corsair and Gigabyte have added heatsinks to their PCI-E 4 SSDs, as have other manufacturers, which is a great idea. Just in terms of aesthetics, if your motherboard lacks a heatsink, you won't have an unattractive label sticking out like a sore thumb.

I've been advocating SSD heatsinks for a while, and we also conducted a small M.2 heatsink group test a while ago too. The heatsinks included with PCI-E 4 SSDs are heftier than these ones though. The double-sided copper heatsink on the Aorus SSD is huge and weighs a lot too.

However, there are reasons you might want to replace a PCI-E4 SSD heatsink with one of your motherboard's ones, if it has them. For example, some boards, such as MSI's Prestige X570 Creation, integrate the M.2 heatsink into a large single piece that can be cooled by the chipset fan. In terms of looks, I'm also not a big fan of the bare copper seen on the Aorus heatsink, especially if it's sitting on a motherboard that's predominantly black with a splash of chrome.

I was interested to see what happened if I removed the Aorus' stock heatsink and used the motherboard's own heatsinks instead. The heatsink is easily removable, and only thermal pads and screws hold the two sections together. Dropping the Aorus SSD into the MSI Prestige X570 Creation's lowest M.2 port, I set about performing some load tests and was pleased to see that the Aorus SSD sat at exactly the same temperature of 53˚C using the motherboard heatsink as with its own heatsink.

Interestingly, YouTuber Der8auer has also found that PCI-E 4 SSDs don't actually consume more power than their PCI-E 3 counterparts. In a recent video, he demonstrated that it's the chipset, rather than the SSDs, that are power-hungry.

Basically, if your motherboard has a decent M.2 heatsink, there's no reason you can't use it to replace the stock heatsink on your PCI-E 4 SSD. In my testing, they performed the same in terms of both drive temperature and performance during extended load tests.

There are a few extra components on the underside of the PCB, which are admittedly passively cooled by the stock heatsink, and not by the motherboard heatsink, but again, this didn't seem to impact performance or temperature. As far as I can tell, if you do want one of these new PCI-E 4 SSDs based on a Phison controller, a decent motherboard heatsink will still cool it fine. CPC

The latest PCI-E 4 SSDs are based on a Phison controller

Antony Leather is Custom PC's modding editor @antonyleather

How to Water-cool RTX Super cards

Lots of waterblocks are compatible with Nvidia's new Super RTX cards. **Antony Leather** shows you how to fit one

TOTAL PROJECT TIME / 2 HOURS

Until now, water-cooling an RTX 2060 was extremely difficult, as no major waterblock manufacturer offered a full-cover waterblock in the UK. As luck would have it, though, both the RTX 2070 Super and RTX 2060 Super now use PCBs nearly identical to those of the original RTX 2080 and 2070 respectively, both of which are well covered for waterblock compatibility.

As a result, you can use blocks made for Nvidia's reference RTX 2070 PCB on the RTX 2060 Super, bringing easy water cooling to a 2060 model for the first time. Similarly, you can use reference RTX 2080 waterblocks on the RTX 2070 Super, meaning there's no need to wait for compatible waterblocks if you just want to water-cool your new card now and get on with gaming. We look at a couple of compatible waterblocks here, as well as how to install them.

TOOLS YOU'LL NEED

4mm socket for 1/4in wrench
ekwb.com

1/4in wrench or hand tool
Most hardware stores

GPU waterblocks and backplates
overclockers.co.uk

Thermal paste cleaner
overclockers.co.uk

Precision Philips screwdrivers
Most hardware stores

1 / IDENTIFY GRAPHICS CARD

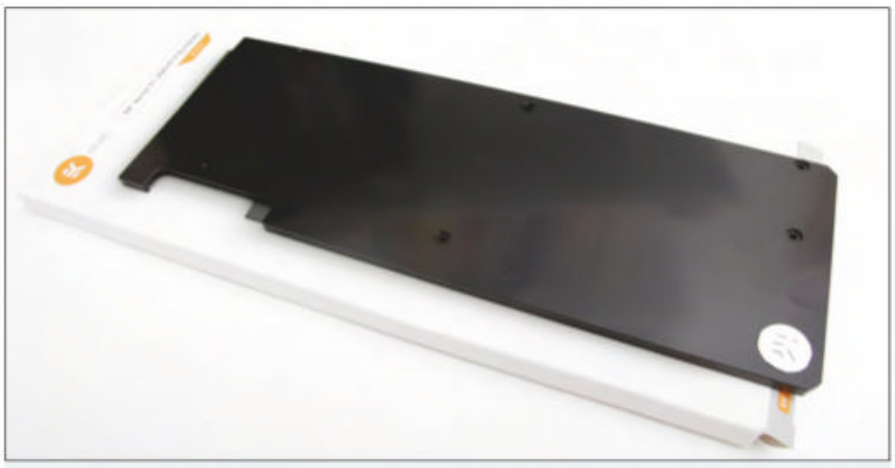
Only reference or Founders Edition cards are compatible with reference design-compatible waterblocks. If you purchased your graphics card from Nvidia, you're good to go. If you bought a third-party card, identify its PCB at **ekwb.com/configurator**, although this site is currently a work in progress.

2 / CHECK COMPATIBILITY

To identify compatible waterblocks, you can use manufacturers' own configurators. As we mentioned above, EKWB has started to list compatible blocks, while Corsair has already added compatible blocks to its website for the RTX 2060 Super and RTX 2070 Super at **corsair.com**

3 / LOCATE HEATSINKS

Find the large heatsinks that run from hotspots to fins in front of a fan. They're often attached using a heatpipe, and usually the whole contraption needs to be removed. There will likely be one for the CPU and one for the GPU if your laptop has one.

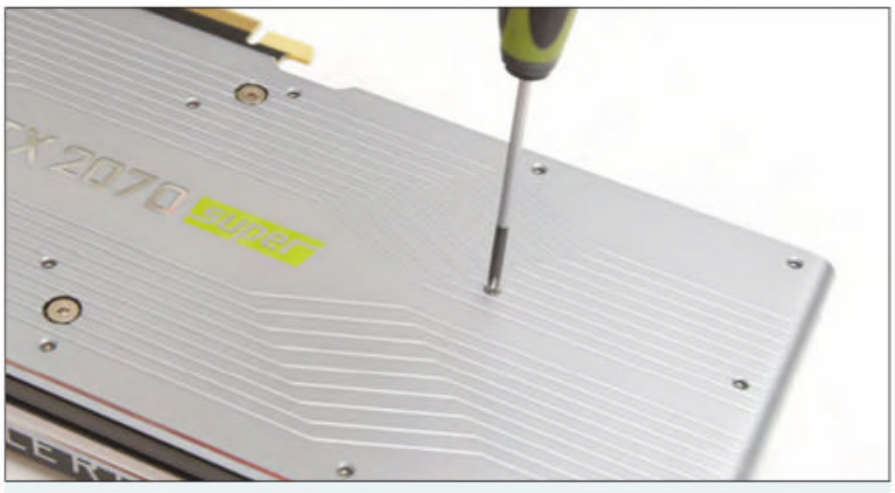


4 / CONSIDER BACKPLATE

Corsair includes a backplate with its waterblocks, but unlike the stock backplates and EKWB's ones, they don't cool the rear of the PCB. If you want the best cooling possible, take a look at EKWB – the company's backplates use thermal pads to help cool the rear of the PCB.

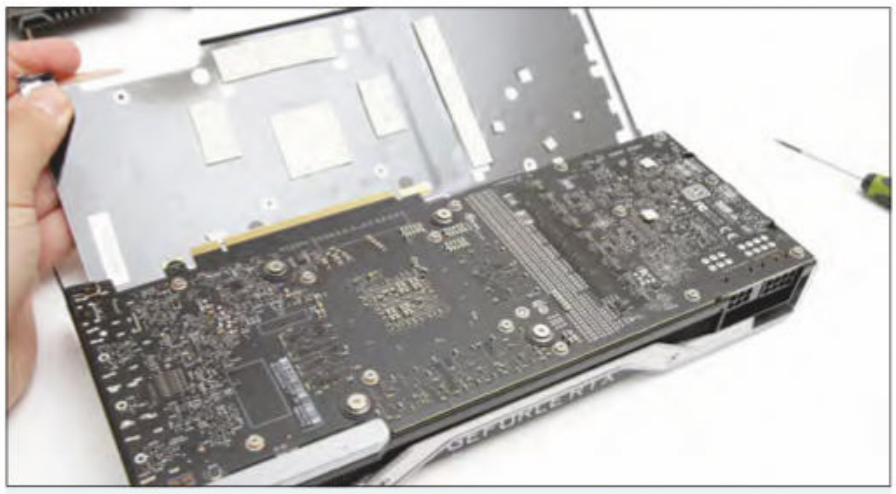
5 / STRESS-TEST

So you can see the impact of your cooling work, grab some air-cooled data using Unigine Superposition (**unigine.com**). Run the 1080p Extreme setting benchmark, and use MSI afterburner (**guru3d.com**) to measure the temperature during the test. Run the test again once you've added the waterblock.



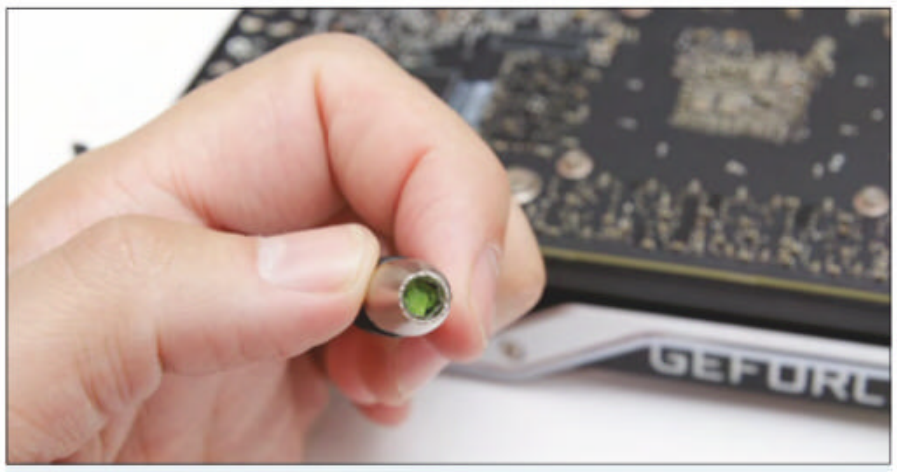
6 / REMOVE BACKPLATE SCREWS

To start, remove the small screws holding the stock backplate in place. Don't remove the larger screws holding the cooler just yet, as you don't want it to fall off.



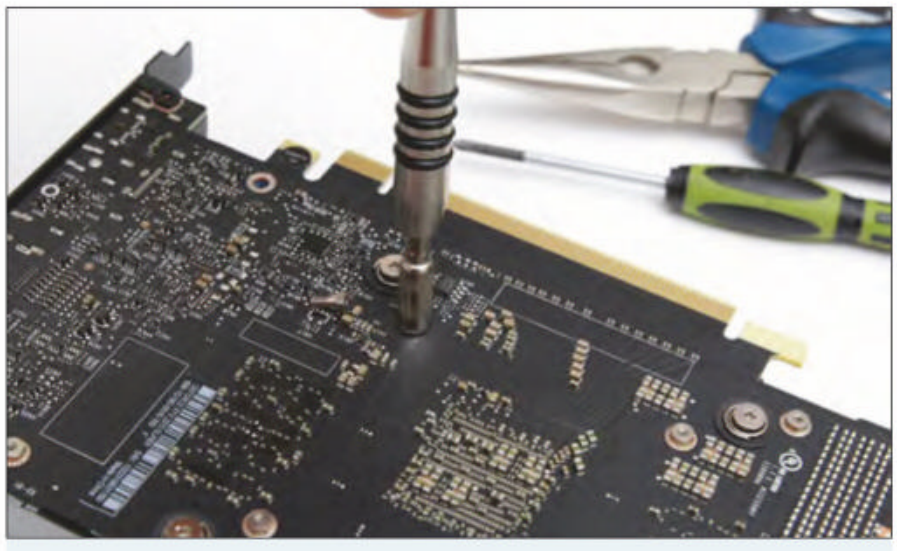
7 / REMOVE BACKPLATE

The backplate should peel off easily, as there will only be thermal pads now holding it in place. Remove it slowly, so you don't risk damaging the pads – they'll need to be in good condition if you want to reinstate your old cooler to sell your card later.



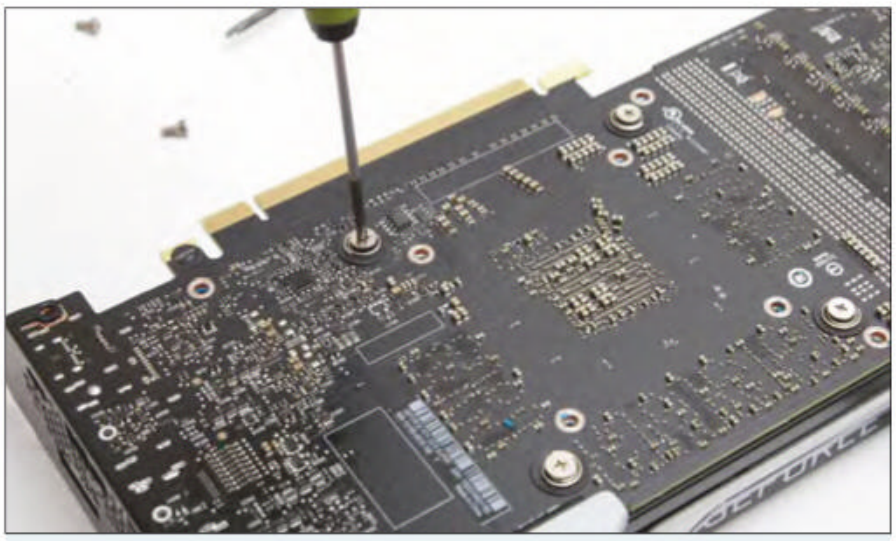
8 / PREPARE HEX TOOL

Four-mm hex nuts make up the majority of screws securing the cooler. You'll need a 4mm socket to remove them. They're often magnetised and can easily trap your nut inside them. Insert some scrunched-up tissue or tape inside the socket, so the nut won't get stuck on the inner magnet and be difficult to remove.



9 / REMOVE HEX NUTS

Insert the socket tool over the nuts and turn them anti-clockwise to undo them. Several of the nuts on our RTX 2070 Super were extremely stiff. We needed to use pliers to add some leverage to our socket tool, but don't be tempted to use pliers on the nut itself, or you risk scratching the PCB.

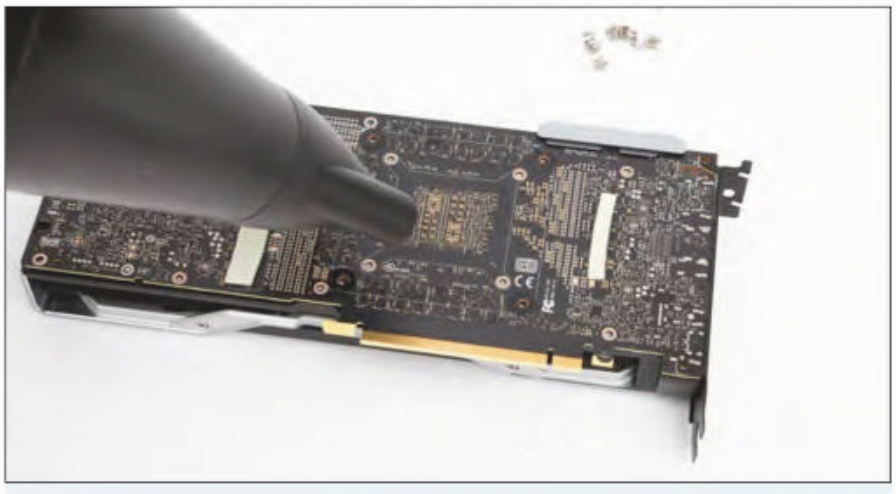


10 / REMOVE REMAINING SCREWS

With the cooler supported from underneath so it won't fall off, remove the remaining screws and keep them safe in a pot so that you don't lose any of them.

11 / REMOVE REAR SCREWS

Finally, you need to deal with the trio of black screws shown here – these sit on the fan side of the expansion slot plate. Leave the one below the DisplayPort connector in place.

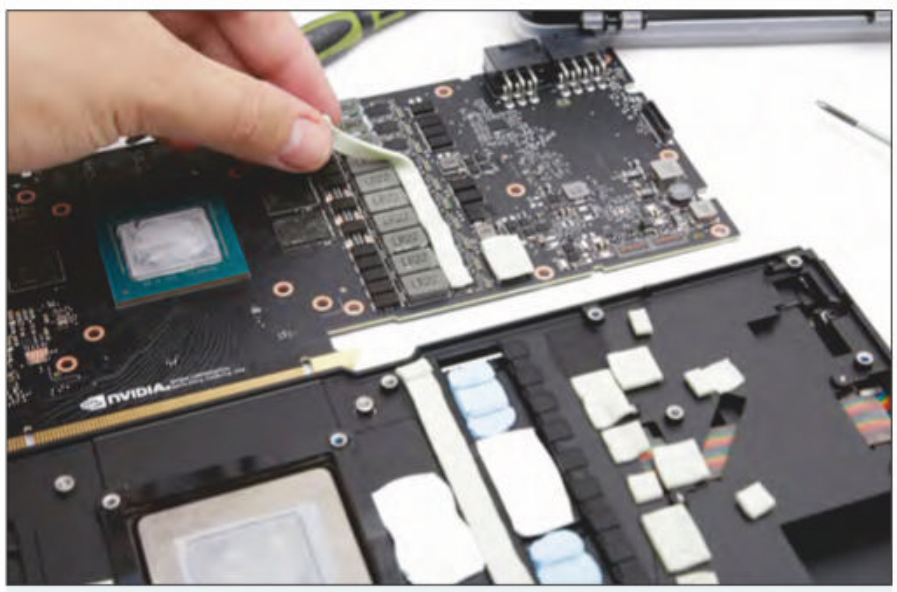


12 / USE HAIRDRYER

If the cooler refuses to budge, it's likely the thermal paste has dried and is holding the PCB and cooler together. Rather than wrenching the two components apart, simply use a hairdryer on the highest setting for 20 seconds to warm the card, which will heat the paste and loosen its grip.

13 / DETACH FAN

There's a single power cable on the RTX Super Founders Edition cards that powers the fan and lighting. This cable needs to be disconnected before you try to completely remove the cooler.

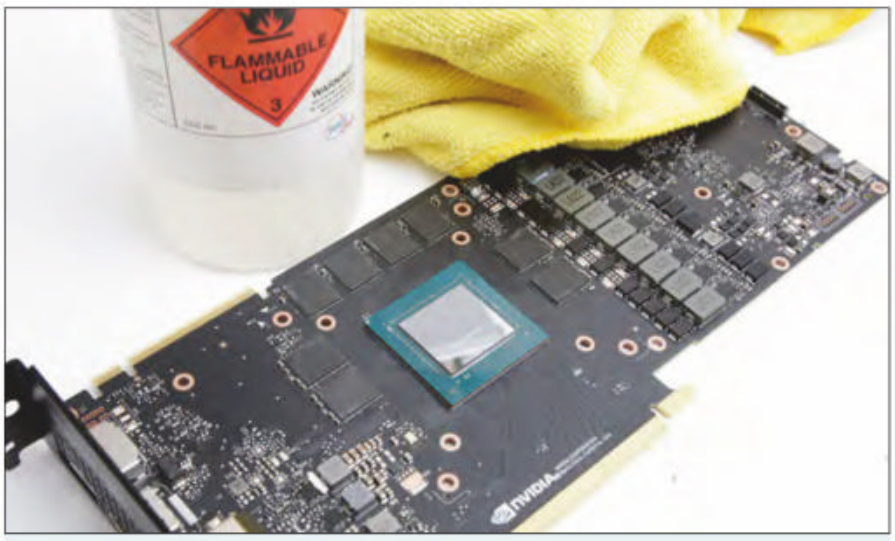


14 / REMOVE THERMAL PADS

If any thermal pads remain attached to the PCB once the cooler is removed, gently lift them off and place them back in the right place on the cooler. You can use a small knife or screwdriver to delicately lift off smaller pads.

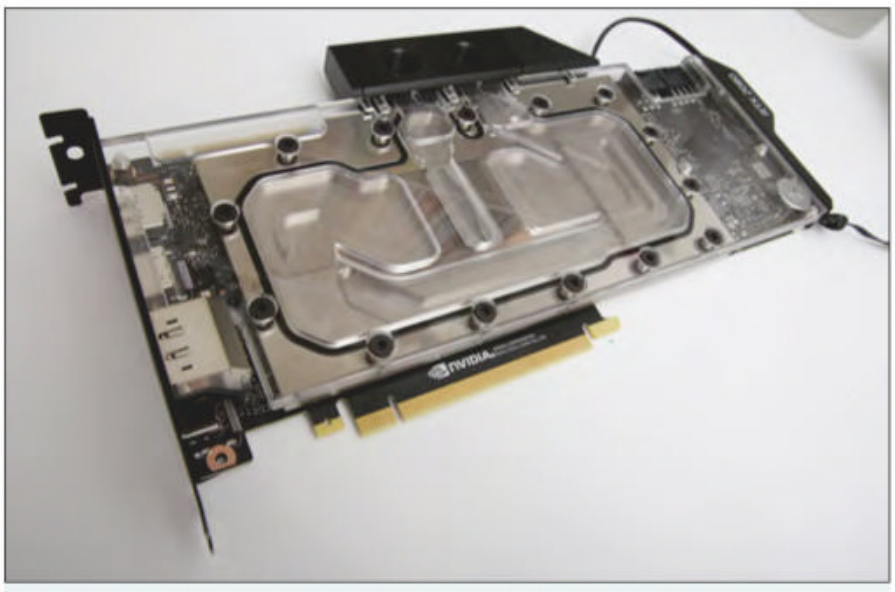
15 / REATTACH SCREWS

A great way to keep all your screws together and remember what went where is to replace the screws back on to the cooler, and loosely fit the back plate to it. You can then place these parts back into your graphics card's box



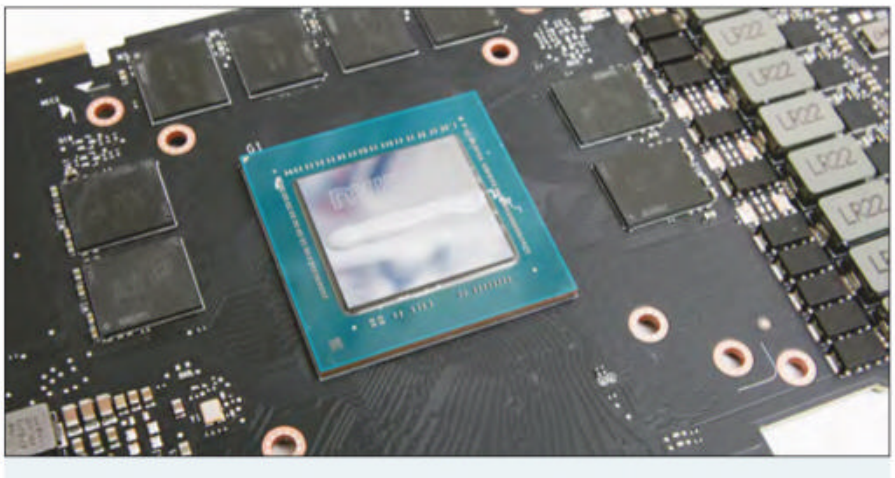
16 / CLEAN RAM AND GPU

Use thermal paste cleaner or isopropyl alcohol to clean the GPU core and memory. The core will have old thermal paste applied, while the RAM will have residue left from the old thermal pads – both materials need to be removed.



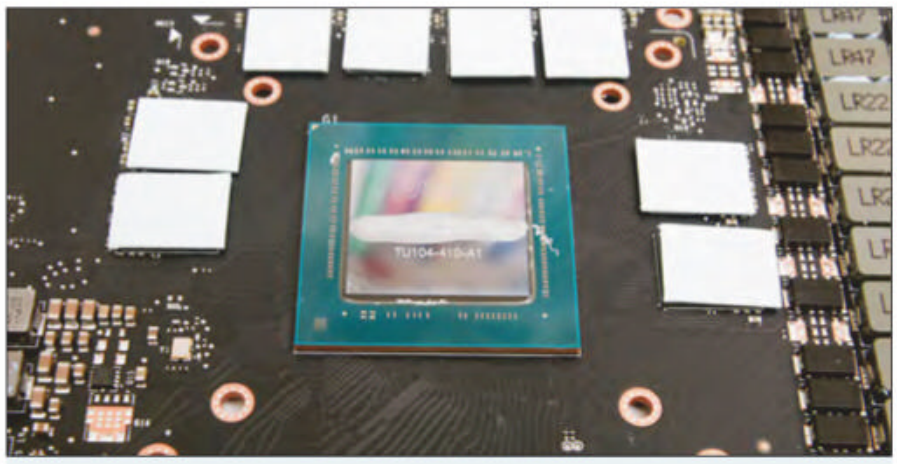
17 / TEST-FIT WATERBLOCK

Before you use the new paste or pads, try the waterblock and make it fit on the card – you can then get a feel for how to mount it. This step can prevent you from accidentally slipping later, spreading thermal paste all over the place and potentially damaging the thermal pads.



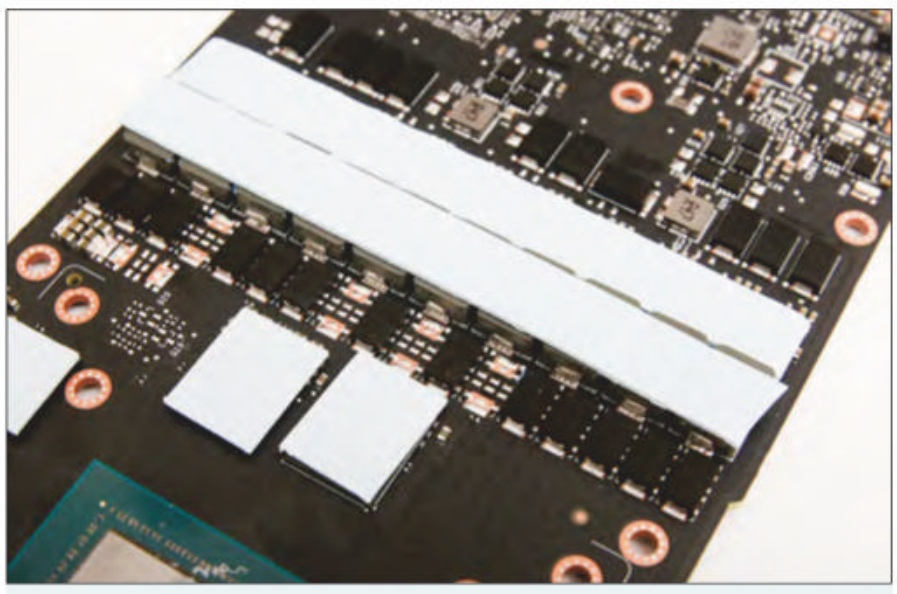
18 / APPLY THERMAL PASTE

The thermal paste is pre-applied on Corsair's waterblocks, but with most other models, you'll need to apply it yourself. Use a thin line, 2-3mm wide from right to left – this line will then spread to cover the chip once the block is fixed in place.



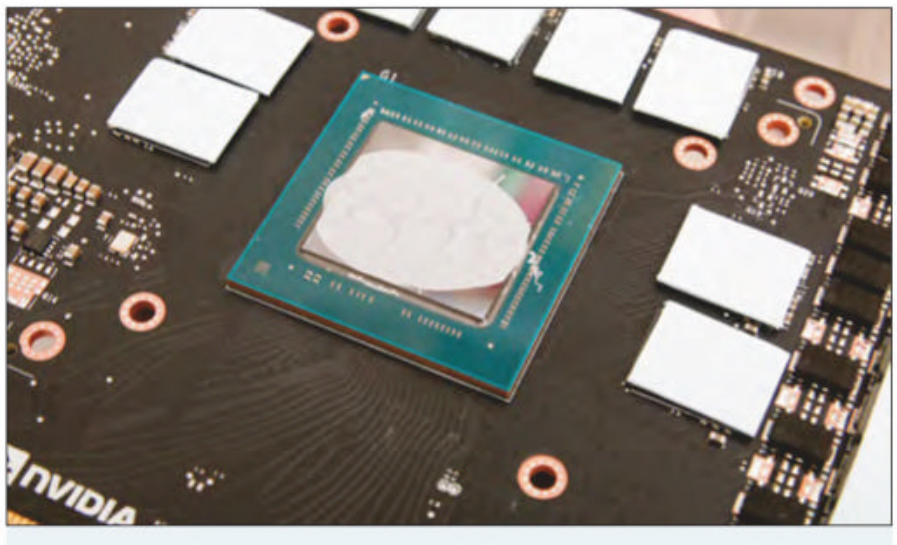
19 / APPLY RAM PADS

With the EKWB block, you need to cut your own thermal pads according to the instructions. Be sure to peel off the rigid plastic layer from one side, as well as the dark blue plastic sheet from the other side.



20 / APPLY MOSFET THERMAL PADS

It's easier to deal with the MOSFET pads, as you just need to cut single strips to the right length. We used two 8mm-wide strips, cutting them to length.

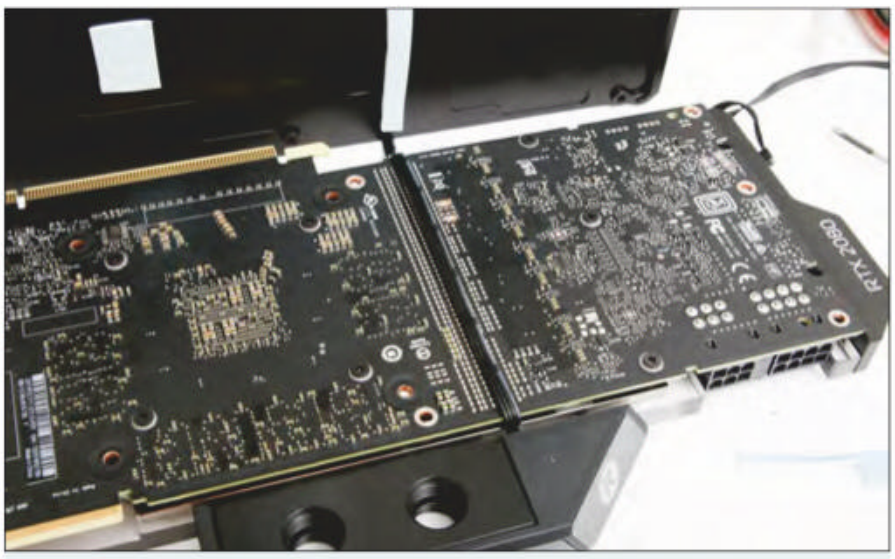


21 / CHECK CONTACT

Install the PCB on the waterblock. If you're not sure the block is making good contact with the paste, remove the block and check the thermal paste has begun to spread. If so, you're clear to secure the block using the screws. If not, try repositioning the block, so the mounting holes line up, and try again.

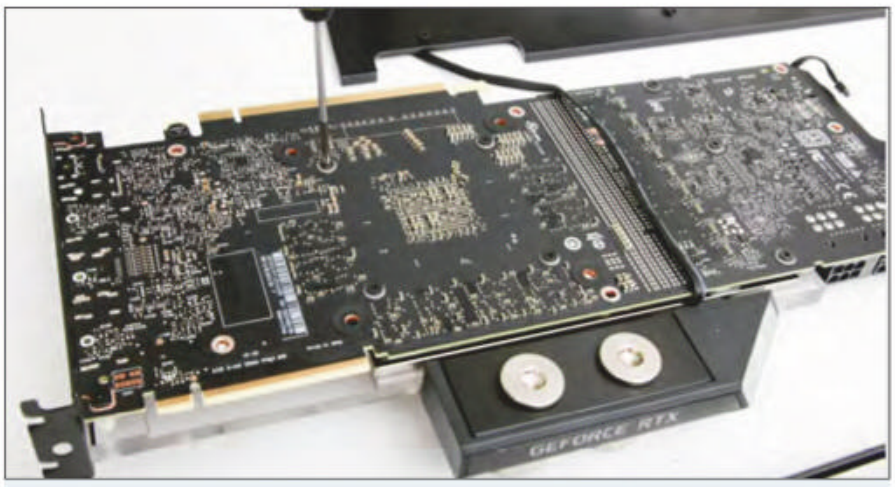
22 / FIT BACKPLATE THERMAL PADS

Corsair's backplate can be installed straight away, while the EKWB model requires thermal pads to be installed first. Apply these pads according to the instructions, making sure you place them on the correct side of the metal backplate.



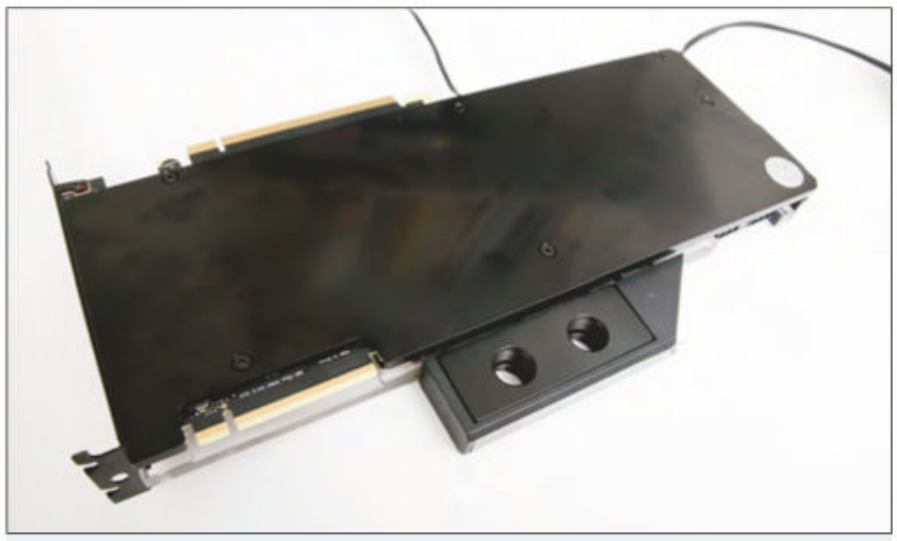
23 / LAY RGB CABLE

One trick you can try with the EKWB model is to lay its RGB cable under the backplate, making for much neater cable tidying. However, you must make sure it lies flat and doesn't sit on any sharp objects or components.



24 / INSTALL WATERBLOCK SCREWS

With the waterblock placed against the PCB from underneath, use the included screws and washers to secure the block to the PCB. With the Corsair block, the backplate can be placed first with all the screws passing through it.



25 / INSTALL BACKPLATE

If you intend to use the EKWB backplate, you need to install certain screws first before installing it. You may need to press down the backplate for the screws to bite, as you'll be compressing the thermal pads and RGB cable first.

26 / INSTALL TUBE FITTINGS

Install your water-cooled graphics card into your PC case and decide on the best way to route your tubing. Most full-cover waterblocks have inlets and outlets on both sides of the block to make routing more flexible.

27 / INSTALL BLANKING PLUGS

Once you've decided which ports to use for the inlet and outlet, place the included port blanking plugs into the unneeded ports. Fit these plugs before you install the graphics card, as it's easier and less likely to put pressure on your graphics card and motherboard. CPC

Readers' Drives

RetroCade

Rich Jones built this custom arcade cabinet PC from scratch, making great use of plywood, Perspex and a load of LEDs. It runs both retro games and current-gen titles on the Core i5 system inside

I first took an interest in custom arcade machines back in 2012, when I spotted Koenig's bar-top design called the Weecade (**koenigs.dk**). I was hooked immediately; I'd always been pretty handy with woodworking and had a wide variety of different tools on hand to make it happen. My son was also coming to an age where I was about to introduce him to gaming, and I wanted him to experience the classics with which I grew up.

By the end of 2012 I'd built my first arcade machine. It was nice, but I felt I could do better. I'd been thinking of building a machine that would show off both my woodworking and PC building skills, as I'd been building my own PCs since the late 1990s.

I decided to design a cabinet that was a different shape to the usual bar-top design. It had to be see-through so I could show off all the components and custom wiring. I wanted it to be powerful enough to play modern PC games on high detail, but not so powerful that getting rid of the heat inside it would be a problem. It was at this point that I decided that 1080p gaming would be enough, and that a 26in monitor would still allow the machine to be portable without needing a trolley jack just to move it.

> By the end of 2012 I'd built my first arcade machine. It was nice, but I felt I could do better

/MEET THY MAKER

Name Rich Jones

Age 41

Occupation Oil and gas industry

Location North Wales

Main uses for PC Current-gen gaming and retro gaming

Likes Anything retro, regularly attending Arcade club in Bury and the excellent new venue in Leeds

Dislikes Loot crates. It's gambling and unfair

Hardware and controls

The build consists of two main parts. The bottom half houses the Asus P8Z68-V Pro motherboard, Intel Core i5 CPU, 16GB of RAM, Corsair CX750M PSU and a slot loading Blu-ray drive. The graphics card is mounted on a flexible riser ribbon cable, with the fan just clearing the components on the motherboard tray. I also stripped down this card, so I could change the colour of the GeForce logo to red.

Meanwhile, the main SSD and one 4TB hard drive are also housed in the bottom section. The top section houses the Dell 26in IPS monitor, four JBL speakers, the amplifier and three more 4TB hard drives, giving me 16TB of storage in total.

The control panel on the front consists of two RGB ball-top Ultimarc joysticks, with six RGB buttons per player on each side. The software allows for each game to light up the required controls and their function for each individual game. I also fitted 'coin addition' buttons, as well as Player 1 and 2 Start buttons. Then there are buttons for exit game, game information, select, and volume up and down. Also housed here are two PacLED64 controllers

SYSTEM SPECS

CPU Intel Core i5-2500K overclocked to 4GHz

Graphics card Nvidia GeForce GTX 780 Ti

Storage 4 x 4TB WD hard drives, 500GB Samsung 850 Evo SSD

Memory 8GB DDR3

Motherboard Asus P8Z68-V Pro

Gaming peripherals and controllers 2 x RGB ball-top Ultimarc joysticks, 2 x PacLED64 LED controllers, Ultimarc I-PAC32 controller interface, JBL speakers

PSU Corsair CX750M

Cooling 2 x Noctua fans and low-profile CPU cooler

for driving the LEDs, and an Ultimarc I-PAC32 interface for converting the button strokes into keyboard presses for the emulators. There are also two wireless Xbox One controllers for more modern games.

Constructing the cabinet

The cabinet itself is made from 18mm plywood. The curved top section is made by kerf-cutting, leaving only the top layer uncut. Each side piece is identical, and they're joined in the middle. Then, once bent, the gaps are filled with resin and the wood is back to full strength.

The Perspex was engraved in a local sign shop, and the front piece was bent with a hot wire bender – it's lit along its edge using 5mm LEDs embedded in the grooved slot in which the Perspex sits. This gives the effect of only the engraving lighting up. In total there are 128 RGB channels in use, 22 of which are used for the engraving and the rest for the buttons and joysticks.

Meanwhile, cooling comes from two Noctua fans – one on each side. The left fan draws in cold air over the CPU and graphics card, and the hot air is then pushed out by the right-hand side fan. The rear Perspex piece originally had no vents cut into it, but I was unhappy with the temperatures inside the machine, so I cut some slots. It runs at nominal temperatures now, even at full load.

That's a wrap

No paint is on the cabinet; instead, it's all coated with decent quality car vinyl. The vinyl is hard-wearing and doesn't rub off like paint over time. Wrapping is relatively easy, but the design needs to incorporate the seams in the wrapping – you have to plan if you want to hide them as best as possible. For example, the T-moulding along the edge was necessary to hide the joint between the two sides of the wrapping.

It wasn't all easy. I ran into some issues with bad interference through the speakers. I was first concerned that the close proximity of all the components in the top section, and the mass of wires I was hiding in there, was the cause, but it turned out to be the cheap amplifier I was using. I also wasted many hours making a custom mirrored Perspex motherboard tray with eight red LEDs embedded into it. The idea was that the underside of the motherboard would reflect back onto the mirror, but you can't even see the tray when it's inside the cabinet.

RetroCade is running Windows 7, mainly for compatibility issues with some of the older emulators; it runs the front-end Hyperspin and uses Rocket Launcher to launch the games. Every game I could want, from Spacewar (1962) to current-gen titles are on there, using up all 16TB of hard drive space. Pressing the game info key will also pause the game and bring up the original manuals, box art, maps, cheats and so on for each game. CPC

No paint is on the cabinet; instead, it's all coated with decent-quality car vinyl

BE A WINNER

To enter your machine for possible inclusion in Readers' Drives, your build needs to be fully working and, ideally, based in the UK. Simply send us a couple of photos on Twitter (**@CustomPCMag**) or Facebook (**CPCMagazine**), or email low-res ones to **editor@custompcmag.org.uk**. Fame isn't the only prize; you'll also get your hands on some fabulous prizes.

Corsair K70 RGB MK.2 SE – Cherry MX Speed

The Corsair K70 RGB MK.2 SE is a premium mechanical gaming keyboard that's built to last. It has a silver anodised brushed aluminium frame, as well as stunning white precision-moulded, double-shot keycaps. It's built to turn heads and withstand a lifetime of gaming. There's a detachable, soft-touch wrist rest too.

Meanwhile, its Cherry MX Speed mechanical keyswitches provide the reliability and accuracy you demand, with blisteringly fast 1.2mm actuation. There's also stunning per-key RGB dynamic backlighting, 100 per cent anti-ghosting with full-key rollover, 8MB of on-board memory, plus dedicated media controls.

Alphacool water-cooling gear

Water-cooling hardware manufacturer Alphacool is offering a choice of £150 worth of gear to every featured Readers' Drives winner. For your prize, you can select from DIY water-cooling kits, the Eiswolf and Eisbaer all-in-one CPU and GPU liquid coolers, as well as a vast range of individual components, including waterblocks (pictured), fittings, reservoirs, pumps and radiators. Alphacool also makes coolant, tubing and fans, as well as modding and water cooling-related tools.

JAMES GORBOLD / HARDWARE ACCELERATED

RYZEN SHINE

AMD's Zen 2 processors are reconditioning the CPU market, and James Gorbold is thankful

Over the past few weeks, the enthusiast PC landscape has seen a seismic shift away from Intel towards AMD. It's not the first time this has happened, but the last time was back in the early noughties when AMD launched Athlon 64. AMD has spent the past few years building towards this moment, with the launch of Zen CPUs in March 2017, and Zen+ in April 2018.

But while Zen was competitive, and Zen+ was good, the new Zen 2 CPUs are truly great, running circles around Intel's Coffee Lake CPUs. What's more, Zen 2 CPUs are aggressively priced – they not only perform better than Intel CPUs, but undercut them too. If you combine a Zen 2 CPU with an X570 motherboard, you also get full support for PCI-E 4 GPUs and SSDs.

There was, of course, overwhelming-positive media coverage of Zen 2, with **Custom PC** being no exception. However, unlike the Zen and Zen+ launches, which did gain AMD some market share but didn't fundamentally change the market, Zen 2 is a real game changer. If the CPU market were using Dungeons & Dragons rules, AMD just rolled a 20 for initiative, 20 to hit and 20 to damage. The only area I'd score AMD down would be 15 for critical damage, because while there was some stock available at launch, the supply situation could have been better.

Even so, AMD has done significant damage, with Zen 2 not just competing with Coffee Lake, but for the first time in many years, an AMD processor range is largely outselling Intel's at Scan. That statement is broadly true across the board, but to take one specific example, the AMD Ryzen 9 3900X has been outselling the Intel Core i9-9900K at a ratio of almost 7:1 at leading resellers.

This seismic shift isn't restricted to the enthusiast market either, as Zen 2 is also starting to build moment with corporate buyers. Sure, it will always take longer for these decision makers to switch brand, but it will happen.

All of which makes me wonder how Intel will respond. In the short term, we already know from Computex that the Core i9 9900KS is coming soon, but while an all-core 5GHz processor is undoubtedly cool in terms of numbers, I can't see it having a massive impact on the market. Looking further ahead, there's plenty of rumours and leaks online about next-gen CPUs and platforms. I can't comment on them officially, but you can see Richard Swinburne's analysis on p8.

> If the CPU market were using Dungeons & Dragons rules, AMD just rolled a 20 for initiative, 20 to hit and 20 to damage

What I can share is my opinion, which is that Intel can't afford to simply continue with its current plans and needs to be more radical. A good start would be recognising that the X platform as it stands has had its day. While lots of PCI-E lanes and quad-channel memory are still desirable on paper, most applications and games, even high-end graphics, barely receive any benefit. As a result, customers simply won't pay the premium that the X platform commands. The move away from X to K started a while back, but Zen 2 will only accelerate that change.

I recognise that it may takes months, if not years, for Intel to truly regain the initiative and overhaul or abandon the X platform, but with a new CEO in place, and intense competition from AMD, serious change is required. In the meantime, AMD can reap the benefits of being on top. CPC

James Gorbold has been building, tweaking and overclocking PCs ever since the 1980s. He now helps Scan Computers to develop new systems.

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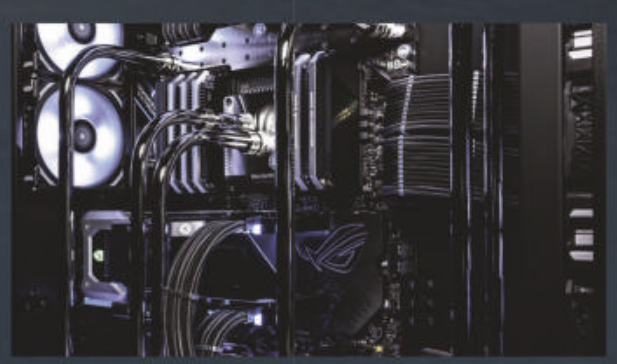
Scan recommends

Windows 10



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