CUSTOM PC

THE BEST-SELLING MAG FOR PC HARDWARE, OVERCLOCKING, GAMING & MODDING / **ISSUE 207**

NVIDIA

NAILS IT

FULL REVIEW OF THE GEFORCE RTX 3080

1 | **4K GAMING AT OVER 200**FPS

2 | **RAY TRACING COMES OF AGE**

3 | **LEAVES RTX 2080 Ti IN THE DUST**

+ | **DEEP DIVE** HOW NVIDIA'S NEW GPU ARCHITECTURE WORKS

RTX 3080

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Welcome

Custom PC Issue 207

/ FROM THE EDITOR

Ray tracing comes of age

Nvidia has plastered itself all over the tech headlines over the past few weeks. Not only has the Green Team has stamped a tremor through the tech industry with its plan to buy Arm (see p12), but the launch of its latest Ampere-based GeForce GPU, the GeForce RTX 3080 (see p16), caused several retailer websites to come crashing down on launch day.

Apparently not even Nvidia was prepared for the ferocious onslaught of sales. 'We expected the best ever demand for the RTX 30-series, but the enthusiasm was overwhelming,' said the company in an online statement. 'We were not prepared for this level, nor were our partners. We apologise for this.'

It's easy to see why so many gamers are clamouring for this new GPU when you look at the benchmark results in our review. The GeForce RTX 3080 costs nearly half the price of Nvidia's previous flagship, the RTX 2080 Ti, but its performance is consistently 10fps in front of it. Ray-traced games can be run at decent settings with smooth frame rates, and non-ray-traced games run significantly faster too, thanks to a substantial boost in the number of CUDA cores.

There have been some substantial changes under the hood to make this level of performance possible, from the 8nm manufacturing process to Nvidia's new streaming multiprocessor design and the use of GDDR6X memory. As such, we didn't just want to tell you about the frame rates, but also what makes the new GPU tick, so we've dissected the innards of the Ampere GeForce architecture in a full feature on p74.

In the meantime, AMD is readying its own ray tracing-capable RDNA 2 GPUs (see p12), with the Red Team's graphics architecture being used by both Sony and Microsoft in their next-gen consoles. Ray tracing in games is about to become big, with all the realistic lighting, reflections and shadows that it brings.

While we loved seeing the first games with ray tracing in 2018, there's no getting away from the fact that Nvidia's first RTX GPUs were a bit underwhelming, with high prices and a lack of game support. That's all changed now. If you can find stock, it's time to upgrade. CPC

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RICHARD SWINBURNE / VIEW FROM TAIWAN

AN ARM AND A LEG

Nvidia goes all-in on a huge gamble, buying Arm for $40 billion US.
Richard Swinburne analyses the implications

In September, Nvidia sealed the biggest deal in semi-conductor history by paying $40 billion US for Arm. The good news is that Nvidia plans to keep Arm's headquarters and IP registered in the UK and is even furthering investment with an AI research and education centre, as well as building an Arm/Nvidia-based AI supercomputer for research. However, there's notably no commitment to keeping or growing UK jobs, as Softbank made when it bought Arm in 2016.

Nvidia is looking to bolster Arm with its own GPU and AI technologies, which is good because Arm's Mali GPU tech isn't exactly held in high regard, and its Ethos NPU series hasn't seen much success. Nvidia also spends over 6x more on R&D in a year than Arm, so this gives Arm a huge shot in the, erm, leg. By owning Arm instead of just licensing from it, Nvidia can take a long-term architectural direction that ties its GPU, AI chip and CPU platforms together innately, in addition to millions of new software developers.

Nvidia has been trying to get hold of CPU IP for nearly two decades. In the early 2000s, when Nvidia began making its own motherboard chipsets, it was in discussion to buy VIA and its x86 CPUs. However, VIA was facing legal trouble from Intel over x86 licensing, so instead Nvidia acquired Stexar in 2006, which made a CPU that converted x86 and later Arm instructions to its own very long instruction word (VLIW) instruction set.

Nvidia launched Denver and Denver 2 using this tech, but ultimately, it was unsuccessful and Nvidia instead used 64-bit Arm CPU cores in its following Tegra chips. With its recent purchase of Mellanox networking, I've no doubt Nvidia will fully focus on the high-end product road map

> Nvidia spends over 6x more on R&D in a year than Arm, so this gives Arm a huge shot in the, erm, leg

with great ambition in the Enterprise market. However, there are exciting opportunities for PCs here too – we could see a new range of derivative CPUs for Windows laptops and PCs, especially for gaming and workstations.

Nvidia states it will retain Arm's open licensing model, but notably, Arm will operate as an Nvidia division, not an independent subsidiary. This means Arm will be subject to more direct oversight than before, which may worry some key Arm partners – Samsung and Qualcomm have been subject to Nvidia legal action over patents before.

Keeping partners happy should be of paramount importance to Nvidia though. The company is now worth 50 per cent more than Intel and it answers to shareholders, so this massive purchase needs to pay off. However, Nvidia's partner relations have been typically defined as a strong-willed, brand-first approach, which is the antithesis of Arm's traditionally open-eared, hands-off working methods. And let's not understate this, the repercussions of this purchase will be immense, as the Arm ecosystem extends to every nook and cranny of the semiconductor ecosystem.

The ripples will reach much further than when AMD bought ATI in 2006. You may not realise this, but there's Arm IP throughout your PC. If you own an AMD Zen-era CPU, it has Arm TrustZone IP and an embedded security processor inside. Arm IP is likely also in your motherboard chipset, Wi-Fi chip, sound chip, and even your mouse and keyboard – anywhere there's an embedded controller will likely have some form of Arm IP inside. Jensen has gone all in and the next few years will be very interesting in every industry that uses Arm IP. **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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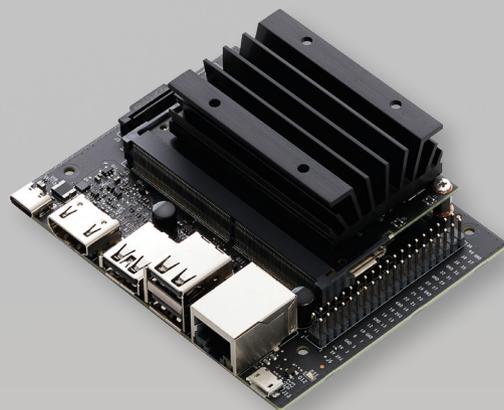
TRACY KING / SCEPTICAL ANALYSIS

CULTURE CLASH

Tracy King explores how different countries' cultures have influenced each other in gaming, and looks to India for the next influence

When I think about gaming mythology, I usually think of Japanese culture. JRPGs have been my preference since early Final Fantasy, and I've played and replayed all sorts of JRPGs, from the Tales Of series through Valkyria Chronicles to Disgaea, and now prefer them. I like the folklore, the philosophy and the character tropes more than American and British equivalents, but it's fair to say those three countries (and therefore their cultures) dominate games.

Surprisingly, Japan has as rich and extensive a PC game development history as the West. The reason we Brits didn't get many Japanese imports in the 1980s golden age of PC gaming was simply down to hardware differences. Early Japanese home computers had to accommodate Japanese text rather than written English, so porting titles for export to Western PCs was like trying to fit a square (Enix) peg into a round hole.

But while those early JRPGs set the gaming tropes that would eventually dominate my own taste, those tropes didn't originate from a single culture. In the early 1980s, Wizardry, an Apple II dungeon-crawler was exported to Japan to great success, kickstarting Japan's own role-playing game development industry. That's not to say a lot wasn't lost in translation (the fourth Wizardry game was a flop in Japan, allegedly because the solutions to the puzzles were based on Western cultural references), but Western and Japanese games have clearly influenced each other over time.

Which brings us to 2020 and the dominant cultures in games. British game developers get a tax break if their titles contain or reflect Britain and British culture. There is literally a culture test for this, run by the British Film Institute, which developers must pass in order to qualify for the tax relief – you may recall from previous columns various controversies about games that seem to have found a way around the rules. While that makes sense for games with a contemporary or wartime setting, it doesn't really stack up for games with mythological lore.

Take the world's most popular PC game, League of Legends. While ostensibly a Western title, its lore is heavily influenced by Ancient Egyptian and Greek myths alongside the work of writers such as HP Lovecraft (who himself was influenced by ancient myths). LoL also borrows from Eastern myths and culture. This inspiration from other cultures' folklore is inevitable in a magical setting (arguments about cultural appropriation aside, magic isn't real, so it's always been ripe for adaptation).

The Yggdrasil Tree often pops up in JRPGs but is mainly Norse in origin. Mana, the magical healing essence, is found in all cultures under different names. I've argued before that care needs to be taken with regionalising – the best practice is to work with someone from the culture being adapted, but perhaps even better practice is to widen the number of cultures that get to make games in the first place. It's time to add some new cultures to the mainstream.

This is why I'm excited by the rise of India in the PC game development scene. Classed as an 'emerging' market, mobile gaming currently dominates India. However, PC gaming is rapidly growing there as access to hardware improves, and India isn't short of skilled developers. I'm keeping a close eye on several Indian PC games, including Raji, an action-adventure game based on Indian mythology and art. I haven't played in that mythological universe before and I'm looking forward to having my gaming horizons broadened. CPC

> This inspiration from other cultures' folklore is inevitable in a magical setting

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

Incoming

RAZER CUTS PERIPHERAL CABLES

Razer has introduced wireless versions of three of its popular gaming peripherals, the DeathAdder mouse, BlackWidow keyboard and BlackShark headset. 'Every time we launch a new product, a lot of fans ask for a wireless version', explained Alvin Cheung, senior vice president of Razer's Peripherals Business Unit.

Razer claims the £180 BlackShark V2 Pro 'delivers lossless immersive audio for low-latency wireless gaming', with quoted 24-hour battery life and 12m range. Meanwhile, the £130 DeathAdder V2 Pro has a stated 120-hour maximum battery life via Bluetooth, or 70 hours using Razer's low-latency HyperSpeed wireless tech. There's also an option to play games with a wired cable while it's charging. The mouse weighs 88g and features eight programmable buttons.

Finally, the £230 BlackWidow V3 Pro keyboard features Razer's own mechanical switches, which also feature transparent housing to really show off the RGB lighting. Again, it can also connect via cable, Bluetooth or Razer's HyperSpeed wireless system. The new peripherals are available to buy now from **razer.com**
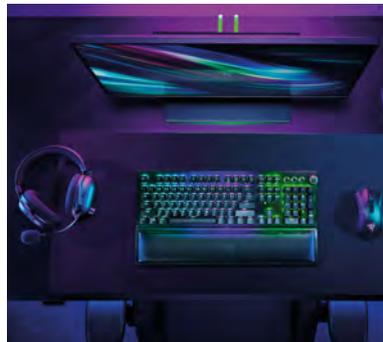
SAMSUNG UNLEASHES FIRST PCI-E 4 SSD

After ruling the solid state seas for years, Samsung fell behind the competition in the PCI-E 4 world, but it's now finally released its first consumer 4x PCI-E 4 NVMe SSD. According to the company, the new 980 Pro can provide sequential read and write speeds of up 7,000MB/sec and 5,000MB/sec respectively, which would put it in front of the other PCI-E 4 SSDs we've tested so far.

Samsung says the development has been a big effort, with all the main components being designed in-house, including the V-NAND, DRAM and Elpis controller. The 980 Pro comes in capacities of 250GB, 500GB and 1TB, with 512MB of LPDDR4 RAM on the 250GB and 500GB drives, and 1GB on the 1TB drive. There's also a 2TB drive waiting in the wings for a future release. All the drives also support AES 256-bit Full Disk Encryption and have a five-year limited warranty.

Prices start from £87 inc VAT for the 250GB model, going to £144 inc VAT for the 500GB drive and £222 inc VAT for the 1TB drive (prices from **scan.co.uk**).

CORSAIR LIGHTS UP PSUs

Corsair has invited its power supplies to the RGB party now, with its new range of CX-F PSUs. Available in both black and white housing, and in capacities of 55W, 650W and 750W, the new PSUs have a 120mm RGB fan with eight addressable RGB LEDs.

A push-button on the back enables you to cycle through nine lighting modes, and eight different colours, and there's also the option to control the lighting via one of Corsair's iCUE RGB lighting controllers, or with a compatible motherboard using the included 5V ARGB adaptor.

The power supplies themselves all have 80 Plus Bronze certification, guaranteeing up to 88 per cent efficiency, as well as a fully modular cable system. Prices start from £73 inc VAT for the 550W model, to £90 inc VAT for the 750W version (prices from **corsair.com**).

NEW AMD CPUs AND GPUs INCOMING

AMD has revealed that it not only plans to launch the first of its forthcoming Zen 3 CPUs in October, but also its first RDNA 2 GPUs, which will feature the Radeon RX 6000-series naming scheme. The Zen 3 CPU launch event is set for 8 October, while the RDNA 2 GPU event is scheduled for 28 October.

The company released a teaser video on social media, which shows a Zen 3 CPU using a similar layout to AMD's Zen 2 chips, with a pair of chiplets and a larger I.O chip, on an AM4 package. The CPU dies will be manufactured on a 7nm process by TSMC. Meanwhile, RDNA 2 is set to be AMD's first GPU design to feature hardware-accelerated ray tracing, meaning the company could potentially compete on key features with Nvidia again.

AMD describes RDNA 2 as a 'breakthrough gaming architecture for PCs and consoles', and it forms the basis of the graphics hardware in the forthcoming PlayStation 5 and Xbox Series X consoles, as well as the firm's new PC GPUs.

NVIDIA RELEASES $59 2GB JETSON KIT

Not content with turning the gaming GPU industry on its head this month, Nvidia is also keeping itself busy in the computer hobbyist and educational markets, releasing a new 2GB Jetson Nano Developer Kit for just £59 US (around £55 inc VAT). The new kit includes an SDK that Nvidia says will install 'everything necessary to begin learning and exploring AI'.

Importantly, the company says the kit will support 'popular cameras, sensors and peripherals' out of the box, without the need for extra drivers. The Jetson Nano's specs list includes a 64-bit quad-core Arm A57 CPU clocked at 1.43GHz, and an Nvidia Maxwell GPU with 128 CUDA cores. There's also support for Gigabit Ethernet, and you can add Wi-Fi support via an external USB dongle.

Meanwhile, connection options include a USB 3 port and a pair of USB 2 ports, as well as a USB 2 Micro-B port, while power is provided via a USB Type-C connector. Storage comes via a micro-SD card slot, although you'll need to provide your own micro-SD card. The board measures 100 x 80 x 29mm (W x D x H), and is available to buy from **okdo.com** now.

NVIDIA TO BUY ARM

Nvidia has shaken up the tech world by announcing its plan to buy Cambridge CPU designer Arm for $40 billion US. 'Arm will remain headquartered in Cambridge,' claims the company.

'We will expand on this great site and build a world-class AI research facility, supporting developments in healthcare, life sciences, robotics, self-driving cars and other fields.' Nvidia also says it plans to 'build a state-of-the-art AI supercomputer, powered by Arm CPUs', adding that 'Arm Cambridge will be a world-class technology centre'.

However, a number of people have expressed concern about the move, including Arm co-founder Hermann Hauser, who has written an open letter to UK Prime Minister, Boris Johnson at **savearm.co.uk**

If the sale is to be allowed, says Hauser, he says it should have legally binding requirements that guarantee UK Arm employees' jobs and ensure that Nvidia doesn't get preferential treatment over other Arm licensees. Hauser also says that 'Britain must get an exemption from the US OFAC regulation, so that UK companies are guaranteed unfettered access to our own microprocessor technology'.

On 13 September, Nvidia said the transaction was expect to 'take place in approximately 18 months'. You can read Richard Swinburne's analysis of this news on p8.

Letters

Please send us your feedback and correspondence to
letters@custompcmag.org.uk

When should I buy?

I love your magazine. As a thrifty PC builder, I'm always on the lookout for bargains and ways to get the most 'bang for my buck'. I suffer from the classic 'hang on until the prices drop' syndrome. It's inevitable while waiting for that to happen, newer products hit the market and I just endlessly wait to avoid buyer's remorse.

Is there a good time of the year to wait for types of parts, or is it possible to have a strategy for getting components for the best prices possible?
DAVID NASH

Ben: If you'd asked this question a few years ago, I could have pointed you towards definite patterns in the industry. Intel used to have a regularly predictable tick-tock cycle of CPUs, and Nvidia and AMD generally launched their new ranges of GPUs half a year apart from each other, with a new line-up or a product refresh once a year.

Those vaguely predictable times have gone now though. Complications with manufacturing as transistors have become smaller have resulted in Intel being stuck at 14nm for several years now, with small refinements to its CPU ranges only being released when the company can do it.

Then, in the GPU arena, AMD hasn't been able to compete with Nvidia at the high end for several years, leaving Nvidia to launch its new GPUs when it wants.

It's all culminated in a very strange couple of months, where AMD is bringing out new CPUs and GPUs, and Nvidia has new GPUs, all at the same time. By the end of this year we'll

When's the next issue out?

CUSTOM PC
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Issue 208
On sale on Thursday, 5 November

know the lay of the land in terms of CPUs and GPUs all in one go, which should have a knock-on effect on the price of older gear. I'd try to pick up some kit at the beginning of 2021.

American aluminum

You're a UK-based magazine, and I love and look forward to each issue. You need to spell aluminium properly, however, not with the US spelling! There were a few typos in this issue – do you need another proofreader?
DAVE GWYTHER

Ben: Your write, wee shood bee abel two spel 'aluminium' wiv al tha leters inn tha rite plaices! I think you're referring to the iPredator Powder mod feature, which was written by someone who doesn't speak English as his native language, and he used the US spelling. We picked up most of the references to 'aluminum' during proofing, but it seems we missed a couple of them. To my shame, I see we missed it on the competition page too.

We do have a proofreader (Julie Birrell), who has been with us since the very beginning of the magazine. She's usually excellent, but sometimes mistakes still slip through the net, particularly at crunch time. Maybe we should just do a simple find-and-replace run on US spelling for these kinds of articles in the future.

Where's my DOS guide?

Issue 205's Retro tech article (In the DOS house) was supposed to be completed in Issue 206, but it's not there – it's nowhere to be found.
DAVID JAMES

Ben: Sorry David, we ran out of space in Issue 206, but it's here in Issue 207. Turn to p106, and you'll find a great guide from K.G. Orphanides on setting up FreeDOS on legacy hardware.

Our DOS setup guide can be found on p106

Costly chipsets

Why are those B550 boards so darn expensive?! It's like an extra £150 for PCI-E 4 plus faster Ethernet.
PAUL NAUGHTON

Ben: I don't think it's as much as £150, but I agree that B550 boards are certainly overpriced for what they offer compared with B450 boards. The latter offer better value for money unless you really want to run a PCI-E 4 SSD.

Mmm, look at all that tasty aluminum

Reviews

GRAPHICS CARD

NVIDIA GEFORCE RTX 3080 FOUNDERS EDITION / **£649** inc VAT

SUPPLIER nvidia.com

Nvidia's GeForce RTX 3080 Founders Edition looks deceptively modest and unassuming when you first unbox it. The packaging doesn't present the card to you on a foam stand when you lift the lid, unlike the RTX 2080 cards, and it's not built like a shiny metal tank with big green lights either. In fact, if you hold this classy black and silver card up to the light, you can see right through the right-hand fan vent, as the PCB is so small.

Behind this humble appearance, though, lies an incredible piece of silicon engineering. We knew it was going to be quicker than the RTX 2080, but we weren't expecting it to well and truly trounce the RTX 2080 Ti for nearly half the price. This GPU really makes ray tracing properly achievable at high settings with decent frame rates, even at 4K in some games.

It's still not cheap, of course. Three years ago we would have been gobsmacked by the £649 and £1,399 prices of the RTX 3080 and 3090 respectively, but they look wholly reasonable in the context of the overpriced RTX 2080-series cards.

They're still expensive, but you get an awful lot more for your money. Also, while the RTX 2080 was kicked at its launch for the lack of supporting software for its new features, we now have ray-tracing options in lots of the latest games, as well as DLSS support, and CyberPunk 2077 is just around the corner.

A new GPU
The beating heart under the RTX 3080's cooler is Nvidia's brand-new GA102 GPU, based on the company's Ampere

GEFORCE RTX GPU COMPARISON

	RTX 3090	RTX 3080	RTX 3070	RTX 2080 Ti	RTX 2080 SUPER	RTX 2070 SUPER
Price (inc VAT)	£1,399	£649	£469	£995	£618	£434
Manufacturing process	Samsung 8nm	Samsung 8nm	Samsung 8nm	TSMC 12nm	TSMC 12nm	TSMC 12nm
CUDA cores	10,496	8,704	5,888	4,352	3,702	2,560
RT cores	82 (2nd-gen)	68 (2nd-gen)	46 (2nd-gen)	68 (1st-gen)	48 (1st-gen)	40 (1st-gen)
Tensor cores	328 (3rd-gen)	272 (3rd-gen)	184 (3rd-gen)	544 (2nd-gen)	384 (2nd-gen)	320 (2nd-gen)
GPU base clock	1395MHz	1440MHz	1500MHz	1350MHz	1650MHz	1605MHz
GPU boost clock	1695MHz	1710MHz	1725MHz	1545MHz	1815MHz	1770MHz
Memory	24GB GDDR6X	10GB GDDR6X	8GB GDDR6	11GB GDDR6	8GB GDDR6	8GB GDDR6
Memory clock (effective)	19.5GHz	19GHz	14GHz	14GHz	15.5GHz	14GHz
Memory interface width	384-bit	320-bit	256-bit	352-bit	256-bit	256-bit
Memory bandwidth	936GB/sec	760GB/sec	448GB/sec	616GB/sec	496GB/sec	448GB/sec

architecture. Built on an 8nm process, it packs 28.3 billion transistors into a 628mm^2 chip. We've explored what makes the new GPUs tick in exquisite detail in our feature on p74, but it's worth going through some of the numbers here too, as they're simply phenomenal.

The RTX 3080 has one graphics processing cluster (GPC) disabled, leaving you with six of them, but the specs are still formidable. Unlike the RTX 20-series, Nvidia hasn't just focused its biggest efforts on ray-tracing performance here, but raw shader performance too. As such, the RTX 3080 has a colossal count of 8,704 stream processors, which Nvidia calls CUDA cores, compared to 4,352 in the RTX 2080 Ti and 3,702 in the RTX 2080 Super.

Both the RT and Tensor cores have also been improved, and there are 68 of the former and 272 of the latter. That's half the number of Tensor cores you'll find in the RTX 2080 Ti, and the same number of RT cores, but Nvidia has refined the way both these processor types work (more details in the full feature on p74).

Another key change is the use of GDDR6X memory, which doubles the per-pin bandwidth of GDDR6 memory at the same clock speed, and it's attached to a 320-bit memory interface. With an effective clock speed of 19GHz, compared to 14GHz for the RTX 2080 Ti, the RTX 3080 has a memory bandwidth of 760GB/sec, compared to 616GB/sec on the RTX 2080 Ti.

The card

Not only has Nvidia introduced a new GPU architecture, but there's also a brand-new cooler design for its Founders Editions. In fact, when you first get it out the box, you might take a second to work out which way up you're holding it. The 'RTX 2080' writing is on what you'd usually expect to be the back of the card, along with a fan on the right. Flip the card over and you'll find another fan on the left side of the card's front.

It's a very different design from usual graphics card coolers, which mount all the fans on the front, with a metal plate on the back. The idea behind this design is that it
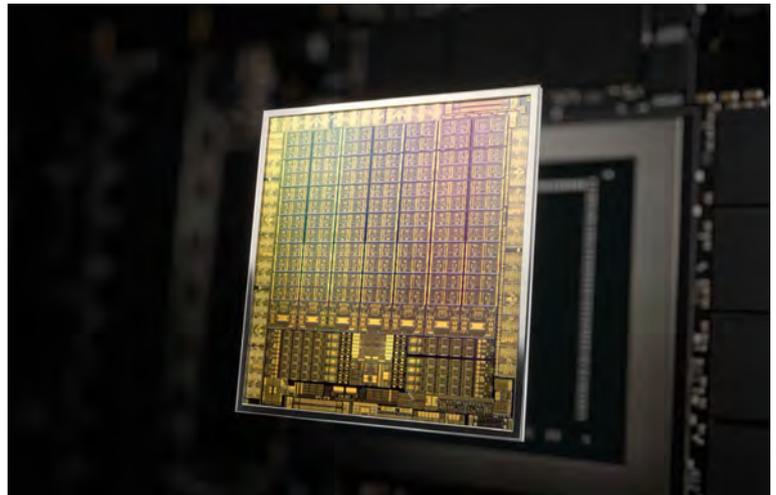
The GA102 packs 28.3 billion transistors into a 628mm^2 chip

works in conjunction with your case's airflow system. Instead of dumping hot air into the bottom right of your case, the card's two fans work to pull cool air from the bottom of your case into the cooler. The fan on the front expels hot air through a vent on the card's expansion slot backplate, while the fan on the back pushes hot air out the top, where it can be effectively pulled out by your exhaust fan.

Meanwhile, the PCB itself is tiny. Rather than making a PCB that extends for the length of the card, the RTX 3080's board is densely packed and has a large triangle cut out of the right-hand side, so the back fan can pull air all the way through the cooler.

It's an innovative design, and it looks classy too. It feels reassuringly solid, but it's also surprisingly light. The only frill is the glowing white light that illuminates the 'GeForce RTX' writing on the edge, as well as shining through the point where the back fan vent meets the cooler's shroud.

Pleasingly, the cooler also works really well. We tested the RTX 2080 Super and 2080 Ti Founders Editions again for this review, and the latter makes a really annoying high-pitched fan noise when you push it hard for a while, and
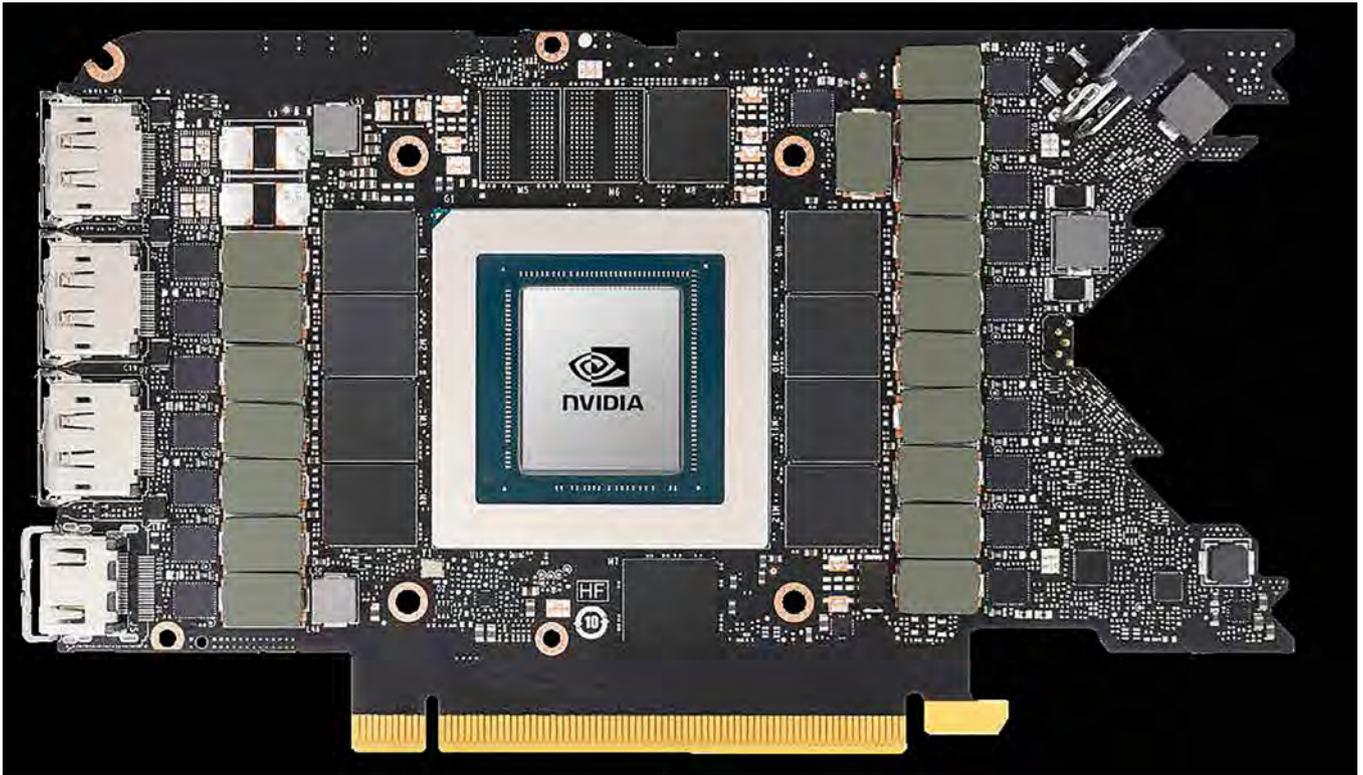
The RTX 3080 Founders Edition has a small, high-density PCB with a cut-out at the end

SPEC

Graphics processor
Nvidia GeForce RTX 3080, 1440MHz base clock, 1710MHz boost clock

Pipeline
8,704 CUDA cores, 96 ROPs

RT cores
68 (2nd-gen)

Tensor cores
272 (3rd-gen)

Memory
10GB GDDR6X, 19GHz effective

Memory interface
320-bit

Card interface
16x PCI-E 4

Bandwidth
760GB/sec

Outputs/inputs
3 x DisplayPort 1.4a, 1 x HDMI 2.1

Power connections
1 x 12-pin (adaptor to 2 x 8-pin included)

Number of slots
2

Card length
285mm

the backplate gets very hot. Comparably, the RTX 3080 was very quiet throughout testing, even when we'd been pushing it hard for hours. The fans don't spin up when it's idle (you can easily see the fan on the back lying still), and while it makes some noise during gaming, it's consistent and not overly loud or irritating.

There are some other surprises too, one of which is the power connector nestled in the middle of the card's top edge. Rather than the usual 6-pin or 8-pin PCI-E power connectors, the RTX 3080 has a new 12-pin connector. Don't worry if your PSU doesn't have a 12-pin plug though – an adaptor that goes to a pair of 8-pin plugs is included in the box. The 12-pin socket is neat, however. The pins are small, and it enables a graphics card to get loads of power from just one cable.

A further surprise comes from the lack of an NVLink SLI connector. The top-end GeForce RTX 3090 is the only card in the new line-up that supports Nvidia's dual-GPU technology, showing that the company is keen to move away from it everywhere except the very top end. There's also no sign of the VirtualLink connectors found on the RTX 20-series cards for VR headsets.

Performance

We decided to tweak our game test suite for this review, in order to better reflect the current gaming landscape, so we've added a couple more test games. The first is Metro Exodus, which is extremely demanding (but also extremely gorgeous!) when you run it at Ultra settings with Ultra ray tracing. In addition to testing frame rates, we're also now using several back-to-back runs of this test to gauge power consumption at full load.

The second new game in our graphics test suite is Doom Eternal, which we run at the very top (Ultra Nightmare) graphics settings. There's no ray tracing in this game, and it's also highly scalable – you can clock up hundreds of frames per second without it becoming CPU limited. This makes it a great test for raw shader power, while also showing performance in a fast-paced first-person shooter where a high frame rate is arguably more important than eye candy.

In addition, we've tweaked our Shadow of the Tomb Raider benchmark so that we test with ray-traced shadows enabled. We're continuing to test with our custom Battlefield V DXR benchmark as well, and we'll likely be adding a CyberPunk 2077 test when it comes out.

Let's start with Doom Eternal, which shows the big jump in raw shader power over Nvidia's previous-gen GPUs. With 8,704 CUDA cores at its disposal, the RTX 3080 averaged a ridiculous 424fps at 1,920 x 1,080 and 362fps at 2,560 x 1,440. Even at 4K, the RTX 3080 had a 99th percentile minimum of 135fps and an average of 212fps, compared to 95fps and 147fps for the RTX 2080 Ti.

The previous-gen cards could already cope with this game well enough anyway, but the RTX 3080 gives you the headroom to run a fast-refresh monitor in sync. Either way, it's clear that there's a decent boost in shader performance between the RTX 2080 cards and the RTX 3080.

Conversely, Metro Exodus with Ultra settings and Ultra ray tracing is the test that really pushes RTX cards to their limit, and the RTX 3080 shows its might here as well. It still doesn't have enough power to cope at 4K without some help from DLSS, but it's consistently 9-12fps in front of the RTX 2080 Ti. If you enable DLSS, you can even get a happily playable 43fps 99th percentile minimum, compared to a borderline playable 33fps on the RTX 2080 Ti, or an unplayable 28fps on the RTX 2080 Super.

Finally, Shadow of the Tomb Raider and Battlefield V again showed the RTX 3080 to be significantly quicker than not only the RTX 2080 Super, but also the RTX 2080 Ti, usually by at least 10fps. As with Metro Exodus, native 4K without DLSS is still a struggle, although it's at least borderline playable (unlike the RTX 2080 cards). Enable DLSS, though, and you can run Battlefield V with High DXR at 4K without dropping below 60fps – that's an amazing feat.

The RTX 3080 is also ideal for gaming at 2,560 x 1,440 with ray-tracing eye candy enabled, even without DLSS. Its 99th percentile minimum of 75fps in Battlefield V at this resolution is a superb result that's well above the RTX 2080 Ti's 58fps, as is the 68fps 99th percentile minimum in Shadow of the Tomb Raider.

Overclocking

If you're prepared to dabble in a bit of tweaking, you can also squeeze a bit more performance out of the RTX 3080 Founders Edition, although our sample didn't have a huge amount of headroom. We managed to add an extra 52MHz to the GPU core clock without any trouble, but going any higher caused instability. We were also able to add 350MHz (700MHz effective) to the memory clock.

Just these tweaks made a noticeable difference, though, with the Metro Exodus frame rate improving by an extra 2fps at 4K and up to 5fps at 2,560 x 1,440. Just as
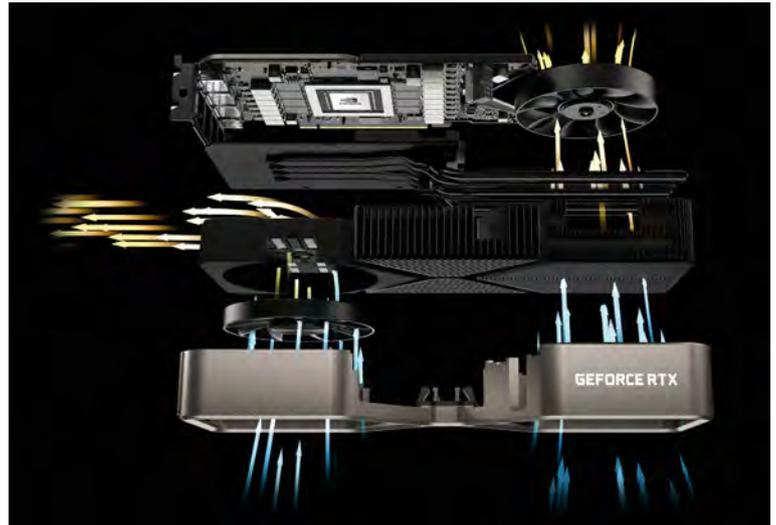
noticeable was the difference between the figures on our wattage meter though.

When overclocked, our test system drew a peak of 508W from the mains with the RTX 3080 installed, compared to 456W at stock speed. Both these figures are also a fair bit higher than the 381W of the RTX 2080 Ti.

Conclusion

Wow. Just, wow. It's fair to say that anyone who bought a full-price GeForce RTX 2080 Ti recently is probably pretty annoyed now. The GeForce RTX 3080 really brings ray-traced gaming to the fore, even in highly demanding games at 4K if you enable DLSS. For close to half the price of the RTX 2080 Ti a few weeks ago, you can now get a card that's not only significantly quicker in ray-traced games, but also when it comes to raw shader power.

Nvidia's Founders Edition is also a superb example, with a stylish new cooler that's both quiet and highly effective. It's expensive, yes, but it's such a big leap from its predecessors that it offers cracking value.

Of course, AMD is also waiting in the wings with its line-up of RDNA 2 GPUs, which will also support ray tracing. We'll be very pleasantly surprised if they can compete with the RTX 3080, though, given AMD's recent history of only competing in the mid-range.

At the moment, we wouldn't hesitate to buy a GeForce RTX 3080 card right now. The only downer is that it's already very hard to find any stock, as our columnist James Gorbold discusses on p114. If you can afford one and find stock, though, this is a truly fantastic graphics card.

BEN HARDWIDGE

VERDICT

A truly incredible piece of graphics engineering. The RTX 3080 trounces the RTX 2080 Ti for nearly half the price, offering significant improvements to both ray tracing and raw shader performance.

PERFORMANCE
36/40

FEATURES
19/20

VALUE
34/40

OVERALL SCORE
89%

BENCHMARK RESULTS

SHADOW OF THE TOMB RAIDER
1,920 x 1,080, Highest settings, High ray-traced shadows, TAA

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	76fps	123fps
Nvidia GeForce RTX 2080 Ti FE	65fps	105fps
Nvidia GeForce RTX 2080 Super FE	61fps	93fps

2,560 x 1,440, Highest settings, High ray-traced shadows, TAA

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	68fps	99fps
Nvidia GeForce RTX 2080 Ti FE	50fps	75fps
Nvidia GeForce RTX 2080 Super FE	42fps	63fps

2,560 x 1,440, Highest settings, High ray-traced shadows, DLSS

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	73fps	111fps
Nvidia GeForce RTX 2080 Ti FE	56fps	89fps
Nvidia GeForce RTX 2080 Super FE	50fps	75fps

3,840 x 2,160, Highest settings, High ray-traced shadows, TAA

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	38fps	54ps
Nvidia GeForce RTX 2080 Ti FE	27fps	40fps
Nvidia GeForce RTX 2080 Super FE	21fps	32fps

3,840 x 2,160, Highest settings, High ray-traced shadows, DLSS

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	52fps	75ps
Nvidia GeForce RTX 2080 Ti FE	42fps	60fps
Nvidia GeForce RTX 2080 Super FE	34fps	49fps

BATTLEFIELD V
1,920 x 1,080, Ultra settings, DX12, High DXR, TAA

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	100fps	125fps
Nvidia GeForce RTX 2080 Ti FE	84fps	100fps
Nvidia GeForce RTX 2080 Super FE	74fps	86fps

2,560 x 1,440, Ultra settings, DX12, High DXR, TAA

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	75fps	91fps
Nvidia GeForce RTX 2080 Ti FE	58fps	71fps
Nvidia GeForce RTX 2080 Super FE	47fps	58fps

3,840 x 2,160, Ultra settings, DX12, High DXR, TAA

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	35fps	50fps
Nvidia GeForce RTX 2080 Ti FE	27fps	37fps
Nvidia GeForce RTX 2080 Super FE	22fps	29fps

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

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	60fps	71fps
Nvidia GeForce RTX 2080 Ti FE	51fps	59fps
Nvidia GeForce RTX 2080 Super FE	41fps	48fps

Legend: 99th percentile / Average

DOOM ETERNAL
1,920 x 1,080, Vulkan, Ultra Nightmare settings

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	309fps	424fps
Nvidia GeForce RTX 2080 Ti FE	244fps	349fps
Nvidia GeForce RTX 2080 Super FE	216fps	327fps

2,560 x 1,440, Vulkan, Ultra Nightmare settings

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	252fps	362fps
Nvidia GeForce RTX 2080 Ti FE	172fps	270fps
Nvidia GeForce RTX 2080 Super FE	157fps	238fps

3,840 x 2,160, Vulkan, Ultra Nightmare settings

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	135fps	212fps
Nvidia GeForce RTX 2080 Ti FE	95fps	147fps
Nvidia GeForce RTX 2080 Super FE	82fps	125fps

METRO EXODUS
1,920 x 1,080, Ultra settings, HairWorks off, Advanced PhysX off, Ultra RT

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	59fps	107fps
Nvidia GeForce RTX 2080 Ti FE	49fps	85fps
Nvidia GeForce RTX 2080 Super FE	41fps	69fps

2,560 x 1,440, Ultra settings, HairWorks off, Advanced PhysX off, Ultra RT

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	49fps	78fps
Nvidia GeForce RTX 3080 10GB FE (OC)	54fps	81fps
Nvidia GeForce RTX 2080 Ti FE	37fps	59fps
Nvidia GeForce RTX 2080 Super FE	30fps	47fps

2,560 x 1,440, Ultra settings, HairWorks off, Advanced PhysX off, Ultra RT, DLSS

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	53fps	91fps
Nvidia GeForce RTX 2080 Ti FE	44fps	72fps
Nvidia GeForce RTX 2080 Super FE	37fps	60fps

3,840 x 2,160, Ultra settings, HairWorks off, Advanced PhysX off, Ultra RT

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	28fps	42fps
Nvidia GeForce RTX 2080 Ti FE	21fps	31fps
Nvidia GeForce RTX 2080 Super FE	16fps	24fps

3,840 x 2,160, Ultra settings, HairWorks off, Advanced PhysX off, Ultra RT, DLSS

Card	99th percentile	Average
Nvidia GeForce RTX 3080 10GB FE	43fps	64fps
Nvidia GeForce RTX 3080 10GB FE (OC)	45fps	66fps
Nvidia GeForce RTX 2080 Ti FE	33fps	49fps
Nvidia GeForce RTX 2080 Super FE	28fps	40fps

TOTAL SYSTEM POWER CONSUMPTION

Card	Idle	Load
Nvidia GeForce RTX 3080 10GB FE	57W	456W
Nvidia GeForce RTX 3080 10GB FE (OC)	62W	508W
Nvidia GeForce RTX 2080 Ti FE	60W	381W
Nvidia GeForce RTX 2080 Super FE	57W	368W

Lower is better

Legend: Idle / Load

GEFORCE RTX 3090

Amazingly, even though the RTX 3080 well and truly knocks the RTX 2080 Ti off its perch, it doesn't represent the pinnacle of Nvidia's new GeForce line-up. That honour goes to the RTX 3090. It uses the same base GA102 chip as the RTX 3080, but it has seven graphics processing clusters (GPCs) enabled.

The result is a colossal count of 10,496 CUDA cores, along with 82 2nd-gen RTX cores and 328 3rd-gen Tensor cores. It also has a 384-bit memory interface, which is wider than the 32-bit interface on the 3080, and it's backed up by a huge 24GB bank of GDDR6X memory. The result of the memory configuration is a huge total memory bandwidth of 936GB/sec, which isn't far off 1TB/sec.

Sadly, our print schedule didn't give us quite enough time to get a GeForce RTX 3090 and working driver in for review this issue, but the kind folks were lucky enough to get an early sample and run a few numbers for us on their own test rig.

Bear in mind that these test results were conducted on a different test rig from our own, and are also run at different settings, with only the average recorded. As such, they're not at all comparable to the results in the main GeForce RTX 3080 review, but they're comparable with each other in the confines of this box. Scan's test rig is based on a Core i9-10900K with 16GB of 3000MHz memory and an Asus ROG Strix Z490-F Gaming motherboard.

That extra GPC clearly gives the GeForce RTX 3090 an edge over the 3080 in these ray-traced game tests, with the 3090's average frame rate consistently being at least 10fps in front of the 3080's results, and sometimes even higher. The result is a card that pushes even further in front of the RTX 2080 Ti, with differences of 20fps and over.

That said, at £1,399 inc VAT, the RTX 3090 does cost double the price of the RTX 3080, and it's clearly a very long way from being twice as fast. We'll hopefully be able to take a proper look at the RTX 3090 in our next issue, but in the meantime, it's fair to say that the RTX 3080 offers much better bang per buck than the 3090, but the latter is the GPU to buy if you have the money and want the smoothest 4K frame rates possible with ray tracing enabled. CPC

AVERAGE FRAME RATES

SHADOW OF THE TOMB RAIDER
2,560 x 1,440, Highest settings, High ray-traced shadows, DLSS
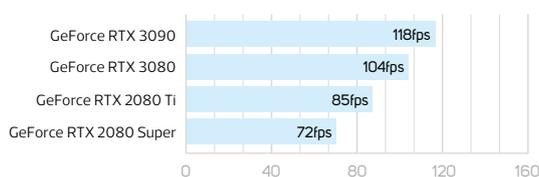
	fps
GeForce RTX 3090	118fps
GeForce RTX 3080	104fps
GeForce RTX 2080 Ti	85fps
GeForce RTX 2080 Super	72fps

3,840 x 2,160, Highest settings, High ray-traced shadows, DLSS

	fps
GeForce RTX 3090	79fps
GeForce RTX 3080	69fps
GeForce RTX 2080 Ti	56fps
GeForce RTX 2080 Super	42fps

METRO EXODUS
2,560 x 1,440, Ultra settings, HairWorks on, Advanced PhysX on, Ultra RT, DLSS

	fps
GeForce RTX 3090	79fps
GeForce RTX 3080	67fps
GeForce RTX 2080 Ti	53fps
GeForce RTX 2080 Super	39fps

3,840 x 2,160, Ultra settings, HairWorks on, Advanced PhysX on, Ultra RT, DLSS

	fps
GeForce RTX 3090	59fps
GeForce RTX 3080	49fps
GeForce RTX 2080 Ti	39fps
GeForce RTX 2080 Super	28fps
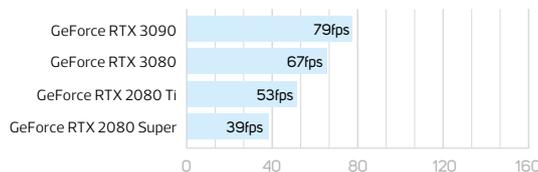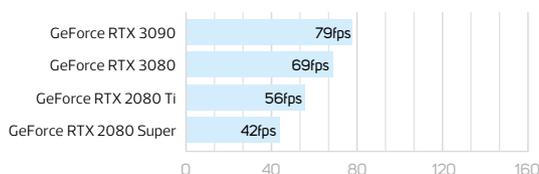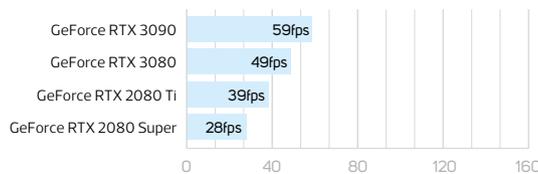
RECOIL III PRO

15.6" Matte Full HD Screen
Intel® Core™ i7-9750H
16GB Corsair 2400MHz
6GB GeForce GTX 1660 Ti
1TB SEAGATE 7mm SATA
HDD (7,200)
Genuine Windows 10 Home

This spec from
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PULSAR ELITE

PCS WRAITH RGB
Intel® Core™ i5-9400F
ASUS® PRIME Z390-P
8GB Corsair VENGEANCE 2400MHz
6GB GEFORCE GTX 1660
Genuine Windows 10 Home

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£849.99

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15.6" Matte Full HD IPS Screen
Intel® Core™ i7-9750H
8GB Corsair 2133MHz
6GB GeForce GTX 1660 Ti
1TB SEAGATE 7mm SATA
HDD (5,400)
Genuine Windows 10 Home

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CORSAIR OBSIDIAN 500D RGB
Intel® Core™ i9-9900K
Gigabyte Z390 AORUS Master
32GB Corsair VENGEANCE 3000MHz
11GB GEFORCE RTX 2080 Ti
Genuine Windows 10 Home

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£2,849.99

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/PCSPECIALIST   **@PCSPECIALIST**

CORSAIR 4000D AIRFLOW / **£80** inc VAT

....
SUPPLIER overclockers.co.uk

The sub-£100 case market is a crowded space, with a large number of models offering a mix of good cooling and pleasing aesthetics. The new Corsair 4000D Airflow, then, finds the odds against it in terms of breaking out from the crowd, but it comes in at a reasonable price of just £80 inc VAT, while promising decent airflow through its vented panel. It's also backed up by two near-identical models that shun the vented front panel of our sample for either a closed front end, or the iCUE model, which is kitted out with tempered glass and includes three AirGuide RGB fans for an extra £30.

The 4000D Airflow includes two 120mm AirGuide fans acting as an intake and an exhaust, and they're positioned to give your CPU cooler and GPU a helping hand. The case is available in black or white, and both models look very clean, with a large, flush, magnetic dust filter on the roof and an attractive, patterned vent in the front panel.

The side panel is made predominantly from tempered glass, but rather than employing an idea akin to Fractal Design's pop-off mechanism, you still need to deal with thumbscrews that are located at the rear of the case to remove it. We also didn't find either side panel to be particularly easy to remove, and both felt a little stiff.

There are some yellow details on the case too, which form a part of Corsair's new aesthetic tweaks, which you'll see on a variety of products. In this case, a small yellow tab helps to lift out the top dust filter, which sits so flush it can be otherwise tricky to remove. The front vented panel also pops off with little effort, revealing a large removable dust filter beneath it, with another on the underside that pulls out from the rear, so maintaining your PC will be fairly easy.

The case offers a single USB 3 port, as well as a full-fat USB Type-C port, which will require a Type-C header on your motherboard to operate correctly. Corsair has introduced a new RapidRoute cable management system too, which offers hefty Velcro anchor points and a single-channel route with 25mm of clearance behind the motherboard tray. However, it can't deal with much more than the 24-pin ATX power cable. The PSU area is also a little tight – fitting our modest modular PSU proved a bit of a squeeze with its cables attached.

The main chamber is well designed, though, with a cover for the main cable-routing holes doing a good job of hiding the spaghetti, and the fan-mount holes are elongated, so you can adjust your fans back and forth too. The case is reasonably compact at 45cm long and 47cm high, but it still has space for a 360mm radiator and three 120mm fans in the front, plus a 280mm radiator and two 140mm fans in the roof, so it has all the potential for housing a high-end water-cooled PC. There are also two dedicated 2.5in trays behind the motherboard tray, and two 2.5in/3.5in trays in a small storage cage under the PSU cover, so there's enough space for a reasonable storage array.

There's a vertical graphics card mount as well, although there's no riser cable included in the box and the mount is

SPEC

Dimensions (mm)
230 x 453 x 466 (W x D x H)

Material
Steel, plastic, glass

Available colours
Black, white

Weight
7.8kg

Front panel
Power, reset, 1 x USB 3, 1 x USB 3.1 Type-C, stereo/mic

Drive bays
2 x 2.5/3.5in, 2 x 2.5in

Form factor(s)
ATX, Micro-ATX

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

CPU cooler clearance
170mm

Maximum graphics card length
360mm

CPU DELTA T

Corsair 4000D Airflow	52°C
be quiet! Pure Base 500DX	50°C
Fractal Design Define 7 Compact	54°C
Phanteks Eclipse P600S (open front)	50°C
Phanteks Eclipse P600S	52°C
Thermaltake H550 TG ARGB	54°C

Lower is better

GPU DELTA T

Corsair 4000D Airflow	43°C
be quiet! Pure Base 500DX	44°C
Fractal Design Define 7 Compact	42°C
Phanteks Eclipse P600S (open front)	44°C
Phanteks Eclipse P600S	45°C
Thermaltake H550 TG ARGB	48°C

Lower is better
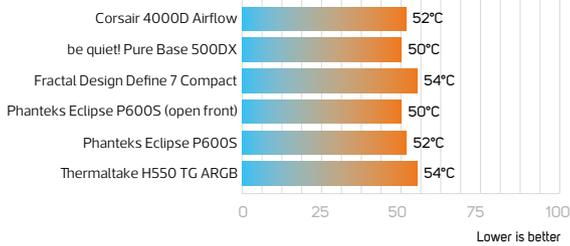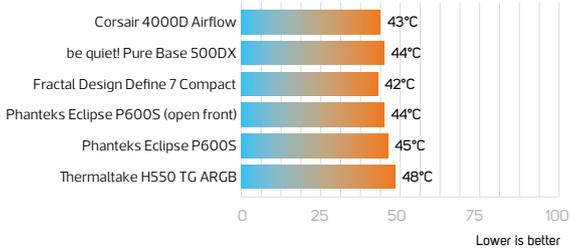
rather close to the side panel, potentially affecting airflow to your GPU cooler. It has to be said that other cases in the sub-£100 price league have more features or are more innovative than the 4000D Airflow. The Fractal Design Define 7 Compact has its open roof design, which makes installing your hardware so much easier, plus it has more USB ports and sound dampening. Cases such as the be quiet! 500DX also have RGB lighting.

Performance

The 4000D Airflow managed to cool our overclocked Ryzen 5 1600 without any problems, with its delta T of 52°C putting it behind the be quiet! Pure Base 500DX, but matching the Phanteks Eclipse P600S and bettering the Fractal Design Define 7 Compact and Thermaltake H550 TG ARGB. Meanwhile, our Palit GeForce GTX 1660 StormX graphics card hit a delta T of 43°C, which is a solid result, bettering the Phanteks Eclipse P600S and Fractal Design Define 7 Compact, and it was supremely quiet under load too.

Conclusion

The 4000D Airflow is a solid effort from Corsair. It looks smart, well-made and makes PC building easy for the most part. It has plenty of room for expansion, although it's rather limited in terms of storage, and the cooling ability is great for just £80. However, while Corsair has priced the case around £10 below its closest competitors, they still offer better value for money and more exciting, useful features.

The Fractal Design Define 7 Compact has more USB ports and an innovative open roof design, for example, while the be quiet! Pure Base 500DX turns heads with its elegant and striking RGB lighting, plus it packs a punch in the cooling department too. If you do want to save yourself a tenner, the 4000D Airflow is still undoubtedly a good choice for those with a budget of £80, particularly if air cooling is a top priority.

However, we'd be sorely tempted to spend the extra cash to pick up one of the two aforementioned cases, which are ultimately a little more desirable, offer slightly better cooling or have a few extra features for just a little extra money.

ANTONY LEATHER

VERDICT

A solid effort from Corsair for a reasonable price, but there's not much wow factor.

RAPID ROUTE
+ Good cooling
+ Low noise
+ Smart exterior

BUS ROUTE
− No stand-out features
− Only one USB 3 port
− Stiff competition for just £10 more

COOLING
25/30

FEATURES
15/20

DESIGN
25/30

VALUE
17/20

OVERALL SCORE
82%

GAMING HEADSET

EPOS | SENNHEISER
GSP 601 / **£199** inc VAT

SUPPLIER eposaudio.com

SONIC BLISS

+ Fantastic clarity
+ Good build quality
+ Easy-to-use mic and volume control
+ Comfortable

KNUCKLES SANDWICH

– A little heavy
– Overly boosted bass and treble
– Expensive for the feature set

The GSP 601 is the latest addition to the newly renamed Epos | Sennheiser line of gaming headsets. It's essentially just a colour-updated version of the GSP 600, but we've not reviewed that headset before, so this is a good chance to take a look.

Despite being nearly all made from plastic, it's a very well-built headset with clear levels of finesse and strength to every part.

Whether it's the lovely smooth matt finish used throughout, the total lack of mould seams on the edges, or the sheer heft and ruggedness, this headset is built to last and feel good. It's also a reasonably comfortable headset to wear. The headband is cleverly split in two, spreading the relatively hefty 395g weight of the headset while still allowing air to flow, although it does still feel heavy on your head.

The earcups are also deep and pleasantly contoured for a cossetted but comfortable fit, thanks to ample, very soft cushioning with a velour covering that provides a surprising amount of grip.

Adding to the comfort is an intriguing adjustable headband. As well as the usual sliding height adjustments on each arm, there are two sliding sections inside the gap between the two parts of the headband. These sliding sections adjust the clamping force of the headset, allowing you to reduce the otherwise strong squeeze on the side of your head. It's a notable improvement over the fixed tension design of the company's previous GAME ZERO headset.

As for those new colour updates we mentioned, you can still get the original all-black GSP 600, this white GSP 601 with copper accents, and the intriguing blue and tan scheme of the GSP 602. The white and copper looks attractive enough, if a little busy.

When it comes to features, the GSP 601 is a simple analogue stereo headset, with no wireless communication, detachable microphone, virtual surround or additional inputs or outputs. You do, however, get a very good-quality microphone that has a class-leading frequency range and a noticeably fuller sound than most gaming headset microphones. It also conveniently folds up and out the way, auto-muting in the process.

There's also an on-headset volume wheel that's satisfyingly large and easy to locate, although it's very stiff to move. This helps to ensure it doesn't get knocked too easily – a problem with the GAME headsets – but it's gone a bit too far the other way in this case. The main audio cable is also detachable and uses the same mini-jack as the GAME headsets.

For sheer power and clarity, the sound quality is impressive, as indicated by its wide 10Hz-30KHz frequency range. However, Epos has fallen into the trap of going for a particularly pronounced 'gamer' sound profile with a massively boosted top and low end. As a result, the high end sounds shrill, the low end is overly prominent and the whole presentation ends up sounding strangely hollow. It works well enough for gaming, but we'd much rather that equalisation was applied via software, leaving the headset to sound better for music and video.

Conclusion

We're generally fans of Epos | Sennheiser's approach to headset design, finding the company's headsets to be comfortable and well built, plus they offer superb sound quality. Largely, that holds true for the GSP 601, but it's heavier than some of the company's previous headsets, it's quite pricey for the features, and its sound is a little heavy on the bass and treble to be useful outside of gaming.

EDWARD CHESTER

VERDICT

High build quality and sound detail make this a worthy high-end headset, but it's expensive for the limited feature set, and its sound won't suit everyone.

SPEC

Audio config
Stereo

Frequency range
10-30,000Hz

Sensitivity / sound pressure
112db PL at 1KHz, 1V RMS

Mic frequency response
10-18,000Hz

Mic sensitivity
–47dBV/Pa

Weight
395g

DESIGN/COMFORT
17/20

FEATURES
13/20

SOUND QUALITY
30/40

VALUE
15/20

OVERALL SCORE
75%

ALPHACOOL EISBAER LT92 / **£68** inc VAT

SUPPLIER aquatuning.co.uk
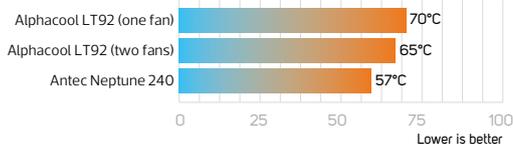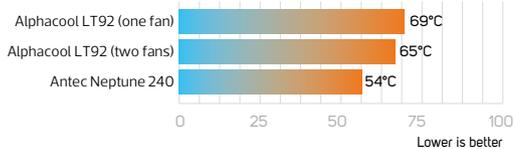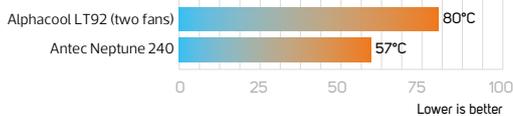
W hile radiators for 120mm and 140mm fans occupy most liquid-cooled setups, they can't fit in every case. Mini-ITX cases sometimes have 120mm fan mounts, but lack the clearance for actual radiators in them. Similarly, pump sections can be too large to squeeze into tight spaces, and long tubes can end up kinking. With these issues in mind, Alphacool has introduced the 92mm Eisbaer LT92.

Its low-profile Eisbaer LT pump is supremely quiet, and its tubes measure just 25cm, so they don't trail through a small case. There are no cumbersome quick-release fittings either.

You can also expand the cooler, as the pump section fittings use standard G1/4in ports. The smaller radiator means it will fit into popular small cases such as the DAN A4 and save space in other cases too. No fans are included, but Alphacool sent us two 1,900rpm 92mm be quiet! Pure Wings fans, which cost £8 each. As such, the cooler will cost close to £90 for the full setup, which is steep given that the cheaper Antec Neptune 240 has RGB lighting and two 120mm fans.

With one 92mm fan, the LT92 struggled with our overclocked Core i5-9600K, reaching a delta T of 69°C – higher than the far cheaper ARCTIC Freezer 7 X. Even with a second fan and a steady flow of warm air blasting out the rear fan, the delta T only fell to 65°C.

We didn't dare use the LT92 on our overclocked Core i9-9980XE with a single fan, but it couldn't cope with two fans either – the CPU temperature went over 100°C, resulting in a delta T of 80°C – you'll only be able to use the LT92 on a stock speed LGA2066 CPU with fewer cores. Our AMD Ryzen 7 1700 wasn't as toasty, though, and its delta T of 65°C with both fans was a match for the ARCTIC Freezer 7X, but again, it performed poorly with one fan.

Conclusion

There are limited situations where the Eisbaer LT92 is useful, given that modest air coolers perform similarly for less money. The reduced radiator size limits cooling, even with a push-pull setup of reasonably powerful fans. It's quieter than the competition, but should only be used as a last resort where larger liquid coolers aren't an option, and there isn't clearance for a decent small air cooler.

ANTONY LEATHER

VERDICT
Niche appeal and limited cooling, but worth considering if space is tight.

WD40
+ Extremely compact
+ Short tubes
+ Low-profile quiet pump

SQUEAKY DOOR
− Average cooling
− No fans included
− Can't handle overclocked LGA2066 CPUs

TEMPERATURE RESULTS (DELTA T)

AMD SOCKET AM4
Alphacool LT92 (one fan)	70°C
Alphacool LT92 (two fans)	65°C
Antec Neptune 240	57°C

Lower is better

INTEL LGA1151
Alphacool LT92 (one fan)	69°C
Alphacool LT92 (two fans)	65°C
Antec Neptune 240	54°C

Lower is better

INTEL LGA2066
Alphacool LT92 (two fans)	80°C
Antec Neptune 240	57°C

Lower is better

SPEC

Compatibility
Intel: LGA115x, LGA1200, LGA2066, LGA2011; AMD: Socket AM4, AM3/+, AM2/+, FM2/+, FM1, TR4, TR4X

Radiator size (mm)
134 x 92 x 30 (W x D x H)

Fans
None

Stated noise
N/A

LGA2066
COOLING
10/40

FEATURES
17/20

DESIGN
14/20

VALUE
08/20

FITTING
Easy

OVERALL SCORE
49%

LGA115x
COOLING
28/40

FEATURES
17/20

DESIGN
17/20

VALUE
11/20

FITTING
Easy

OVERALL SCORE
73%

AM4
COOLING
28/40

FEATURES
17/20

DESIGN
17/20

VALUE
11/20

FITTING
Easy

OVERALL SCORE
73%

GAMING MOUSE

MAD CATZ R.A.T. PRO X3 SUPREME / **£215** inc VAT

SUPPLIER box.co.uk

SUPREME

+ Loads of customisation
+ Great sensor performance
+ Decent buttons

SUB-PAR

− Hugely expensive
− Some minor button issues
− Divisive design

The R.A.T. Pro X3 Supreme has an eye-watering price, but that means you get customisation options that simply aren't possible anywhere else. There are three palm rests, all with adjustable angles, and three scroll wheels with both metal and rubberised options included. The wheel's tension level can be adjusted, and it has analogue tilt control, so finer sideways movement is possible.

There are multiple rest options for your thumb and little finger, and both ceramic and PTFE base plates. It's possible to create more than 100 different hardware combinations, so it's ideal for fine-tuning your peripheral to extremely specific requirements. There are also ten buttons, including a sniper button, a DPI adjuster and a profile-switcher, and the mouse includes a cleaning brush, a carry case and a storage tray.

The specification is high-end on the inside too. The X3 is powered by a Pixart PMW 3389 sensor that can be removed and upgraded. The sensor peaks at 16,000dpi, it has a 0.3ms response time, and it's rated for 400 inches per second of movement and 50g of acceleration.

There's space for ten profiles and they can be customised in Mad Catz' software, although the user interface is dated and awkward. There are a handful of missing features too – the X3 isn't ambidextrous or wireless, the 1.8m braided USB cable can't be detached and there are no customisable weights either – the X3 weighs around 105g, so there's plenty of heavier options.

The result of all this is an outlandish design, even by Mad Catz' standards. The underlying magnesium-alloy frame is visible, and the extra parts use a mix of carbon fibre and gunmetal finishes. There are also gold accents throughout, and a couple of RGB LED zones. It's solid in terms of build quality, but it looks like Optimus Prime at a rave.

We have no complaints about the sensor's performance though. It's smooth, consistent, fast and easily good enough for top-level competition – even if 16,000dpi is overkill for most gamers. The buttons are good too, although their action is a tiny bit too soft at their far ends. The side-mounted buttons are also squashy, and the scroll wheel is buried deeply into the unit, so it can be tricky to move sideways.

The X3 works well with all grip types if you have small or medium-sized hands, but if you have larger paws, it works better with claw and fingertip grips – none of the three palm rests has a long tail, so there's not much rear support. The little-finger rests are also a little cramped.

Then there's the elephant in the room – the astronomical £215 price. If you're willing to eschew the extreme amount of customisation on offer, you can find most of the X3's features for less cash: the Elite-listed Razer Naga Trinity costs £100, and includes customisable side plates with more buttons alongside a 16,000dpi sensor. Corsair's Dark Core RGB Pro is also a £100 wireless favourite that tops out at 18,000dpi.

Conclusion

Ultimately, that's a huge amount of money to spend on market-leading customisation. The X3's fine tuning may appeal to finicky gamers who want to claim every advantage, but most people just don't need this level of tweaking. Elsewhere, the X3 has good performance, a high-end sensor and robust design, but its looks are divisive, its buttons have minor issues and plenty of alternatives are just as good. It's just too expensive and overdesigned for most gamers' needs.

MIKE JENNINGS

SPEC

Weight
105g

Dimensions (mm)
115 x 87 x 38 (W x D x H)

Sensor
16,000dpi Pixart PMW 3389

Buttons
10 (left, right, 3 x scroll wheel, 2 x back/forward, sniper, top DPI, profile switch)

Cable
1.8m braided

Extras
2 x RGB lighting zones, customisable components and sensor, carry case

DESIGN
16/20

FEATURES
18/20

PERFORMANCE
24/30

VALUE
16/30

OVERALL SCORE
74%

VERDICT

Very customisable and a good performer, but a discordant design and high price severely limit its appeal.

GAMING LATOP

DELL G5 15 / **£1,299** inc VAT

SUPPLIER dell.co.uk

There's no shortage of laptops around with RTX 2060 graphics and Intel's Core i7-10750H processor, but the Dell G5 is one of the more affordable options – at £1,299, it's at least £100 cheaper than many machines with similar hardware. It also includes the full-fat version of the RTX 2060, which means its 1,920 stream processors and 6GB of memory are clocked to base and boost speeds of 960MHz and 1200MHz. The Max-Q model has a better base speed but a poorer boost pace alongside slower memory.

Meanwhile, the Comet Lake-based Core i7-10750H has six Hyper-Threaded cores alongside base and boost speeds of 2.6GHz and 5GHz. There are no surprises in the rest of the spec either – the Dell includes 16GB of memory and a 512GB SSD, but no secondary hard disk, while networking is handled by dual-band Wi-Fi 6 and Gigabit Ethernet. Instead, the biggest surprise is found on the outside. The plastic lid is finished in a shade called Interstellar Black, and it's peppered with glitter and has an iridescent logo. It's a bold look, although it won't be to everyone's tastes.

Elsewhere, the Dell has visible seams and large air vents that look dated, and its 2.34kg weight and 25mm body mean it isn't slim or light. There's also some noticeable give in the base and wrist rest, and the single-hinged lid is too easy to move – a protective bag would be a wise investment. Beyond the glittery lid, the chassis is underwhelming, but that's no surprise at this price.

Connection options are limited too. The Dell has one USB 3.2 Gen 1 port and a Type-C connection that supports DisplayPort, but its extra full-sized ports only use USB 2. The power button has a fingerprint reader, but it feels too soft in action, and the 720p webcam is poor quality and has no Windows Hello support.

Likewise, while the keyboard has a decent layout, including a numberpad and four-zone RGB LEDs, the keys don't have enough travel, feeling hollow and unsatisfying. The trackpad isn't much better, with buttons that need too much force to register. The trackpad also sits too far to the left of the machine, which interferes with WASD usage in games.

Dell's machine faces strong competition if you're willing to spend a little more. The MSI GS66 Stealth costs £1,499, and it includes a 240Hz display, better connection options and improved ergonomics inside a slimmer, lighter chassis. Laptops at £1,399 with this specification also serve up better connections and lighter enclosures, and it's possible to find faster AMD CPUs at all comparable price points.

SPEC

CPU
2.6GHz Intel Core i7-10750H

Memory
16GB 2933MHz DDR4

Graphics
Nvidia GeForce RTX 2060

Screen
15.6in 1,920 x 1,080 VA 144Hz

Storage
512GB Toshiba BG4 M.2 SSD

Networking
Dual-band 802.11ax Wi-Fi, Gigabit Ethernet, Bluetooth 5.1

Weight
2.34kg

Ports
1 x USB 3.2 Gen 1, 1 x USB 3.2 Gen 1 Type-C / Thunderbolt 3, 2 x USB 2, 1 x audio, 1 x HDMI, 1 x mini-DisplayPort, 1 x SDXC

Dimensions (mm)
366 x 254 x 25 (W x D x H)

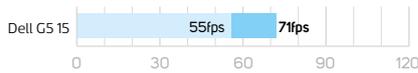**Operating system**
Windows 10 Home 64-bit

Warranty
One year parts and labour return to base

SHADOW OF THE TOMB RAIDER
1,920 x 1,080, Highest Detail, TAA

Dell G5 15 — 55fps / 71fps

(scale: 0 30 60 90 120)

TOTAL WAR: WARHAMMER II
1,920 x 1,080, Ultra Detail, DX11, FXAA

Dell G5 15 — 48fps / 59fps

(scale: 0 30 60 90 120)

BATTLEFIELD V
1,920 x 1,080, Ultra settings, DX12, High DXR, TAA

Dell G5 15 — 33fps / 47fps

(scale: 0 30 60 90 120)

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

Dell G5 15 — 48fps / 60fps

(scale: 0 30 60 90 120)
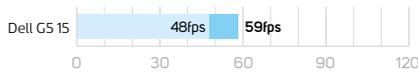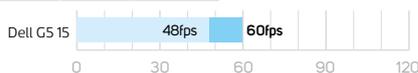
☐ Minimum ☐ Average

46,102 — GIMP IMAGE EDITING

357,445 — HANDBRAKE H.264 VIDEO ENCODING

133,440 — HEAVY MULTI-TASKING

138,428 — SYSTEM SCORE

Performance

The RTX 2060 remains solid for 1080p gaming, with minimums that ranged between 48fps and 55fps in our test games once DLSS was activated in Battlefield V. That's enough pace to handle single-player games at good frame rates – and to play esports titles at frame rates that will complement the 144Hz display without quality compromises. It's noticeably quicker than the RTX 2060 Max-Q.

The Dell's application benchmark score of 138,428 is underwhelming, though, being almost 40,000 points behind the aforementioned MSI, which included the same CPU, and further behind machines with AMD Ryzen 4000-series chips. It's not enough of a drop to cause significant bottlenecks, but it's a concern.

The performance drop can be explained by a closer look at clock speeds – during single and multi-threaded tests, the Dell hardly ever ran at speeds beyond 4.3GHz. That matches the CPU's all-core Turbo speed, but it's a long way short of its theoretical single-core pace of 5GHz. The underperforming processor is paired with SSD speeds of 2,308MB/sec read and 1,270MB/sec write, which are middling results for an NVMe drive.

Sadly, there were also thermal issues. The Dell is never loud, and its internal temperatures are fine, but the base panel and the area above the keyboard both became too hot during testing. It's not an issue if you're at a desk, but it could get uncomfortable if you're using this machine on your lap.

Meanwhile, the Dell's 1080p VA screen has a 144Hz refresh rate but no active sync, although that's not a surprise at this price. The panel's brightness level of 325cd/m^2 and black point of 0.27cd/m^2 are both good too, making for a contrast ratio of 1,204:1. That helps the G5's display deliver good levels of depth and nuance. Sadly, though, the colour temperature of 7,970K is cool, the delta E of 2.63 is middling and the sRGB coverage level of 83.9 per cent is only average, making the display look washed-out despite the decent contrast. It's fine for gaming and general desktop use, but you can get better laptop screens elsewhere.

The speakers offer similar quality. They have ample volume and a good mid-range, but the top end is tinny and the bass is weak. On the plus side, the Dell's battery lasted for two hours during a gaming benchmark and six hours when working, so you'll be able to game on the train.

Conclusion

Dell's G5 is keenly priced when compared with similarly specified rivals, but the lower price manifests itself in several areas. The chassis is bulky and has middling build quality, the screen's colour temperature is cool, the keyboard and trackpad disappoint, and CPU performance levels are reduced. These issues aren't ruinous, and the Dell does fight back with decent gaming performance and battery life for the money, but it leaves the G5 floundering.

If you're searching for an affordable RTX 2060 laptop, it's acceptable, but you only need to spend just a little more and you'll get a slimmer, lighter machine, with a better screen, ergonomics and CPU performance. The G5 is available in pricier configurations, but they make its faults starker – and its more affordable GTX 1660 Ti options are expensive when compared with other laptops with that GPU. The Dell is a reasonable mid-range gaming laptop for the money, but its shortcomings mean it's better to save up for a better machine.

MIKE JENNINGS

VERDICT

Reasonable pace at a decent price, but it has too many shortcomings in key areas for us to recommend.

PLANETARY

+ Cheaper than many rivals
+ Decent mainstream gaming speed
+ Glittery lid design

BLACK HOLE

− Middling build quality and size
− Underwhelming keyboard and trackpad
− Disappointing CPU performance
− Pallid, washed-out screen

PERFORMANCE
18/25

DESIGN
17/25

HARDWARE
17/25

VALUE
18/25

OVERALL SCORE
70%

AMD B550 GAMING PC

FIERCE PC LUMINA LAVA ULTIMATE / **£1,700** inc VAT

SUPPLIER fiercepc.co.uk

Fierce PC's Lumina Lava Ultimate blends mid-range components with the bold design usually associated with more expensive PCs, enabling gamers to get a high-end aesthetic without breaking the bank.

The cooling hardware can be seen through the case's tempered glass panel. The front of the rig houses a Barrow D5 pump and reservoir, and curved tubing transports the coolant between a Black Ice radiator and the CPU's Barrow waterblock. The coolant is orange, and the fans on the radiator, side-mounted intake and 120mm exhaust all match.

More light glows from beneath the CPU block, and the power cables are braided with orange and black material. This rig is built around Fierce PC's Lumina chassis, and its bold faceplate design mimics cracked, red hot magma. RGB LEDs behind the panel make it glow, and it's magnetic – so it can be swapped for the numerous designs that Fierce PC sells separately.

The Lumina is robust and well designed, with a PSU shroud, neat cabling and clean metal throughout. It's 220mm wide and 500mm tall, so there's a decent amount of room to work. The rear is less impressive: it's untidy and cramped, and the fan hub board becomes unstuck from the motherboard tray too easily. Meanwhile, there's space for two 2.5in drives, but the sole 3.5in bay is clogged with cables. It's not perfect, but this chassis is just as good as enclosures available from more recognisable brands in this price league.

Meanwhile, the Asus Evo V2 GeForce RTX 2060 Super graphics card takes the boost clock from 1650MHz boost clock improved to 1695MHz, and Fierce PC has added an extra 100MHz to that figure alongside 30MHz to the memory. Likewise, the AMD Ryzen 5 3600XT CPU has had an all-core overclock from 3.8GHz to 4.5GHz. The rest of the specification is reasonable: there's 16GB of Corsair 3200MHz Vengeance Pro RGB memory, a 500GB Seagate FireCuda 520 NVMe PCI-E 4 SSD, a 1TB hard disk, and a Cooler Master MWE 750 Bronze PSU, which has a fine 80 Plus Bronze certification but a non-modular design.

The Asus ROG Strix B550-F Gaming motherboard does the job too. It has two M.2 connectors, and 2.5Gbps Ethernet, although it only has dual-band 802.11ac Wi-Fi. Meanwhile, the rear I/O panel serves up USB 3.2 Gen 2 Type-A and Type-C connectors alongside four USB 3.2 Gen 1 ports. However, the second 16x PCI-E slot only runs at 4x speed, with no support for Nvidia SLI, and only the top M.2 connector supports PCI-E 4 – the second M.2 slot and all the PCI-E slots below the top 16x one are PCI-E 3. There's no on-board USB 3.2 Gen 2 header either.

When it comes to specs, there's little to choose between the Fierce PC and its rivals. PC Specialist's Magma R2 includes an RTX 2060 Super and a stock-speed Ryzen 5 3600XT in a plain case, for example, but costs considerably less money at £1,199. Indeed, ditching the Lumina's water cooling could save you a lot of cash – for £1,700, it's easy to find PCs with RTX 2070 Super graphics and better CPUs.

SPEC

CPU
3.8GHz AMD Ryzen 5 3600XT overclocked to 4.5GHz

Motherboard
Asus ROG Strix B550-F Gaming

Memory
16GB Corsair Vengeance RGB Pro 3200MHz DDR4

Graphics
Asus GeForce RTX 2060 Super 8GB

Storage
500GB Seagate FireCuda 520 PCI-E 4 M.2 SSD, 1TB Seagate Barracuda HDD

Networking
Gigabit Ethernet, dual-band 802.11ac wireless

Case
Fierce PC Lumina ARGB

Cooling
CPU: Barrow Composite Edition Micro Jet waterblock, Barrow D5 Vario pump and 130mm reservoir, Black Ice Nemesis LS240 radiator with 2 x 120mm fans; GPU: 2 x 90mm fans; side: 2 x 120mm fans; rear: 1 x 120mm fan

PSU
Cooler Master MWE 750 Bronze 750W

Ports
Front: 2 x USB 3.1 Gen 1, 2 x audio; rear: 1 x USB 3.2 Gen 2, 1 x USB 3.2 Gen 1 Type-C, 3 x USB 3.2 Gen 1, 2 x USB 2, 1 x optical S/PDIF, 5 x audio

Operating system
Microsoft Windows 10 Home 64-bit

Warranty
Two years parts and labour, followed by one year labour only. One year collect and return, then return to base

Fierce PC's system is protected by a three year labour warranty with two years of parts coverage and a year of collect and return service – a solid deal.

Performance

At 1080p, the RTX 2060 Super played our test games with minimums between 65fps and 88fps with DLSS enabled in Battlefield V, and at 2,560 x 1,440, it ran with minimums that ranged between 52fps and 62fps. That's enough speed to play any single-player title smoothly and handle any esports game on 144Hz displays. It's faster than the cheaper PC Specialist system too.

CPU performance is middling though. This rig is faster than the PC Specialist in the Handbrake video encoding test, but it's slower in image editing and multi-tasking. Its overall score of 210,932 is only a little quicker. It's not a surprise – the Lumina's 4.5GHz all-core overclocked speed doesn't go beyond the CPU's conventional single-core turbo pace. Still, this CPU is better than any equivalent Intel chip in multi-threaded workloads, and it has the ability to handle mainstream photo editing, video work and content creation. The PCI-E 4 FireCuda SSD is good too, with respective read and write speeds of 4,761MB/sec and 2,529MB/sec.

The Fierce PC is reasonable in thermal tests as well, thanks to its custom water-cooling gear. The CPU and GPU delta Ts of 63˚C and 52˚C are fine, and it's quiet – there's a low rumble, but it's subtler than most PCs, and is barely louder during tough workloads.

ILLUMINATED
+ Solid performance
+ Great water-cooled design
+ Quiet operation

EXTINGUISHED
− Expensive for the spec
− CPU overclock has little impact
− Mediocre motherboard

BENCHMARK RESULTS

SHADOW OF THE TOMB RAIDER
1,920 x 1,080, Highest Detail, TAA

Fierce PC Lumina Lava Ultimate — 88fps / 116fps

1,920 x 1,080, Highest Detail, TAA

Fierce PC Lumina Lava Ultimate — 62fps / 78fps

TOTAL WAR: WARHAMMER II
1,920 x 1,080 Ultra Detail, DX11, FXAA

Fierce PC Lumina Lava Ultimate — 70fps / 93fps

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

Fierce PC Lumina Lava Ultimate — 57fps / 67fps

BATTLEFIELD V
1,920 x 1,080, Ultra settings, DX12, High DXR, TAA

Fierce PC Lumina Lava Ultimate — 58fps / 70fps

2,560 x 1,440, Ultra settings, DX12, High DXR, TAA

Fierce PC Lumina Lava Ultimate — 42fps / 49fps

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

Fierce PC Lumina Lava Ultimate — 52fps / 60fps

Minimum | Average

59,869 GIMP IMAGE EDITING

516,101 HANDBRAKE H.264 VIDEO ENCODING

243,817 HEAVY MULTI-TASKING
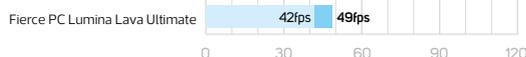
210,932 SYSTEM SCORE

Conclusion

The Fierce PC Lumina Lava Ultimate balances high-end design with mainstream components. The orange-themed design and swappable faceplates look great, the overclocked GPU has enough power for gaming and esports, and the CPU is versatile. It's expensive for the spec, though, and that premium could net you more powerful components if you eschew the aesthetics. You may soon be able to find Nvidia GeForce RTX 3070 systems for only a little more money.

This PC isn't about performance value though – it's about getting a great-looking water-cooled PC for an affordable price, and it does that. If you want a PC with high-end looks without the absurd price of top-tier components, the Fierce PC ticks the box.

MIKE JENNINGS

VERDICT
Expensive for the core spec, but the fantastic looks are joined by decent gaming speeds at a price that isn't overly prohibitive.

PERFORMANCE **20**/25

DESIGN **23**/25

HARDWARE **21**/25

VALUE **21**/25

OVERALL SCORE **85**%

SCAN 3XS VENGEANCE XTi iCUE / **£2,400** inc VAT

SUPPLIER scan.co.uk

Scan's 3XS Vengeance XTi iCUE is the first PC to arrive on our test bench with an Asus GeForce RTX 3080 card. Nvidia's new GPU microarchitecture promises big efficiency and performance improvements, thanks to a new 8nm manufacturing process and huge upgrades to the sheer amount of hardware that can be crammed into the new GPU.

Indeed, the RTX 3080 has 8,704 stream processors, 68 RT cores and 10GB of GDDR6X RAM, with 760GB/sec of memory bandwidth. It's not only a massive upgrade over the RTX 2080 and Super cards, but also the RTX 2080 Ti, as you can see in our full review on p16. The statistics are impressive considering this PC's £2,400 price – systems with the RTX 2080 Ti cost hundreds of pounds more just a month ago.

The rest of the specification is solid. The 12-core AMD Ryzen 9 3900X runs at its stock base and boost speeds of 3.8GHz and 4.6GHz, and there's 16GB of 3200MHz DDR4 memory. Storage comes from a 1TB Corsair MP600 NVMe SSD that exploits the AMD CPU to serve up PCI-E 4 support alongside a 2TB Seagate Barracuda hard drive. The PC is also powered by a superb Corsair RM650x PSU, which is a modular unit with 80 Plus Gold certification.

Meanwhile, the Asus ROG Strix B550-E Gaming motherboard has spare 1x and 16x PCI-E slots, two vacant memory slots, 2.5Gbps Ethernet and dual-band Wi-Fi 6. At the rear, it has two full-sized USB 3.2 Gen 2 ports and a Type-C connector, as well as a USB 2 Type-C connector for audio hardware.

On-board audio comes from a solid SupremeFX S1220A chipset, and the board has a POST display as well. On the downside, there's no super-fast USB 3.2 Gen 2x2, and four of the full-sized USB ports at the rear use USB 2 rather than USB 3. The second M.2 slot also only supports PCI-E 3, not PCI-E 4.

It's all housed in a smart-looking new Corsair iCUE 4000X chassis, with tempered glass front and side panels. The front of the case has a robust motherboard tray and a neat ridge of metal to hide cable-routing holes, and the rear has two 2.5in mounts and room for a sole 3.5in hard disk. As usual, Scan has done a great job on the build: the cabling is impeccable, the Corsair cooler's radiator is slotted neatly into the front, and most parts are easy to access.

Scan protects this PC with its standard three year parts and labour warranty, with a year of on site cover. It's a good deal and that on site service is a welcome bonus.

Performance

The RTX 3080 is comfortably faster than all of Nvidia's RTX 2080-series GPUs. It excels at 2,560 x 1,440, with even our highly demanding Metro Exodus Ultra settings test never dropping below 42fps, and our other ray-traced game benchmarks staying above 59fps. It struggled in Metro Exodus at 4K without DLSS, but enabling DLSS pushed the frame rate into the realms of playability. You'll only need to drop the settings a notch to make this game smoothly playable with ray-traced eye candy at 4K.

SPEC

CPU
3.8GHz AMD Ryzen 9 3900X

Motherboard
Asus ROG Strix B550-E Gaming

Memory
16GB Corsair Vengeance RGB Pro 3200MHz DDR4

Graphics
Asus GeForce RTX 3080 10GB

Storage
1TB Corsair MP600 M.2 SSD, 2TB Seagate Barracuda hard drive

Networking
2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi, Bluetooth 5.1

Case
Corsair iCUE 4000X RGB

Cooling
CPU: Corsair Hydro H150i RGB Pro XT with 3 x 120mm fans; GPU: 3 x 90mm fans; roof: 2 x 120mm fans; rear: 1 x 120mm fan

PSU
Corsair RM650x 650W

Ports
Front: 1 x USB 3.1 Gen 1, 1 x USB 3.1 Gen 1 Type-C, 1 x audio; rear: 2 x USB 3.2 Gen 2, 1 x USB 3.2 Gen 2 Type-C, 4 x USB 2, 1 x USB 2 Type-C, 5 x audio

Operating system
Microsoft Windows 10 Home 64-bit

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

There's not much you can't do with this GPU – it will get beyond an average 60fps in most games at 4K, and it has awesome raw shader power too, averaging 204fps in our 4K Doom Eternal benchmark.

With the exception of Shadow of the Tomb Raider, this PC's frame rates aren't as good as the results in our RTX 3080 review on p16, but those results were recorded using an Intel CPU with all cores overclocked to 4.8GHz, rather than a stock speed AMD CPU. Importantly, though, the Scan's gaming results are still superb.

The Ryzen 9 3900X CPU is superb in productivity tests though. Its result of 818,014 in our heavily multi-threaded Handbrake video encoding easily beats the Intel Core i9-10900K, which is 90,000 points slower. Scan's PC was marginally slower than the latest Intel chips in our single-threaded image editing test, but this won't make much of a difference in everyday use. The AMD chip is a better bet than Intel for content-creation, and hardly a slouch in games either.

Meanwhile, the PCI-E 4 SSD delivered fantastic read and write speeds of 4950MB/sec and 4263MB/sec respectively, which is faster than any SSD you'll find on an Intel machine. The Scan is a great thermal performer too – the GPU's peak delta T of 45˚C is fantastic, and the CPU's maximum of 52˚C is similarly impressive. The noise levels are tremendous: no matter the task, the Scan was whisper-quiet.

BENCHMARK RESULTS

DOOM ETERNAL

2,560 x 1,440, Vulkan, Ultra Nightmare settings

Scan 3XS Vengeance XTi iCUE: 234fps / 344fps

3,840 x 2,160, Vulkan, Ultra Nightmare settings

Scan 3XS Vengeance XTi iCUE: 128fps / 204fps
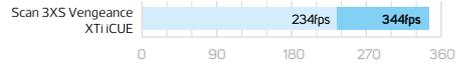
METRO EXODUS

2,560 x 1,440, Ultra, HairWorks off, Advanced PhysX off, Ultra RT
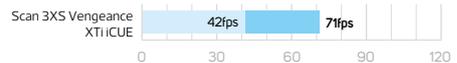
Scan 3XS Vengeance XTi iCUE: 42fps / 71fps

3,840 x 2,160, Ultra, HairWorks off, Advanced PhysX off, Ultra RT

Scan 3XS Vengeance XTi iCUE: 28fps / 39fps

3,840 x 2,160, Ultra, HairWorks off, Advanced PhysX off, Ultra RT, DLSS

Scan 3XS Vengeance XTi iCUE: 38fps / 58fps

SHADOW OF THE TOMB RAIDER

2,560 x 1,440, Highest settings, High ray-traced shadows, TAA

Scan 3XS Vengeance XTi iCUE: 59fps / 82fps

3,840 x 2,160, Highest settings, High ray-traced shadows, TAA

Scan 3XS Vengeance XTi iCUE: 39fps / 47fps
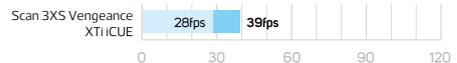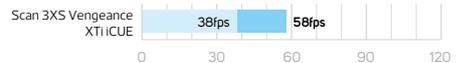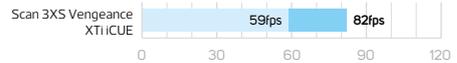
3,840 x 2,160, Highest settings, High ray-traced shadows, DLSS

Scan 3XS Vengeance XTi iCUE: 52fps / 66fps

99th percentile | Average

58,395 — GIMP IMAGE EDITING

818,014 — HANDBRAKE H.264 VIDEO ENCODING

290,336 — HEAVY MULTI-TASKING

300,625 — SYSTEM SCORE

AVENGERS

+ Incredible gaming ability
+ Fast, versatile AMD CPU
+ Smart, solid and neat case
+ Cool, quiet operation

ULTRON

− Intel faster in some games
− Some PCI-E 4 storage limits
− Limited connection options

Conclusion

Nvidia's new GPU is fantastic, and Scan has paired it with a CPU that has loads of multi-threaded ability. The rest of the specification is good, the system is quiet, and the chassis is smart and easily navigable. There aren't many major issues. Some Intel-based rigs will be a little faster in games but slower in heavily multi-threaded applications, and the motherboard could have better connections. These small issues don't put us off though – if you want next-gen gaming power and multi-threaded CPU ability then this is a winner.

MIKE JENNINGS

VERDICT

Fantastic Ampere-powered gaming, top-notch components and a great build.

PERFORMANCE
24/25

DESIGN
23/25

HARDWARE
24/25

VALUE
22/25

OVERALL SCORE
93%

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ISSUE 207 / DECEMBER 2020

NVIDI NAILS IT

RTX 3080

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Custom kit

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

RAZER ACARI / **£59.99** inc VAT

SUPPLIER razer.com

The Razer Acari is an understated mousepad, with unremarkable 420 x 320mm dimensions. At first glance, it brings surprisingly little to the table, considering that its price would usually net you a pad with an array of programmable RGB lighting, or enough surface area to keep frost off a car. However, it's when it's in use that the Acari really shines, or rather, sparkles.

The surface has a very light, even texture, which allows a mouse to glide across it, while still offering enough resistance to prevent it from slipping. The surface gets its sparkle from the oleophobic coating, which resists dust and oil while improving the accuracy and responsiveness of your mouse sensor. The net result of all this technology is an extremely good mouse pad surface, and it's comfy to use as well. That said, it does cost £60. If you have the money then the Acari is as good as mouse pads get, but you can get a still-decent pad for a fraction of this price.

Overpriced 🟡🟡🟡🟡⚪ **Reassuringly expensive**

PICK-ME MOBILE PHONE COOLER / **£16.73** inc VAT

SUPPLIER amazon.co.uk

Cooling a smartphone while it's being used isn't an easy task – you can't just sit it on a stack of fans like a laptop. With that in mind, a level of respect is due to the Pick-Me Mobile Phone Cooler, simply for taking on this difficult design challenge. Unfortunately, problems appear once you start to look at how well it works.

The Pick-Me is powered by a rechargeable battery that you charge with a micro-USB cable, which is a neat idea because you don't want it draining your precious phone power. The device itself consists of a variable-speed LED fan that attaches to the back of the phone via suction cups.

However, the suction cups aren't very strong, the fan is neither big nor rapid and ultimately, you're just pushing a little bit of air against the outer casing of the phone for as long as the device stays attached, which isn't that long. The device has a lumpy gamer aesthetic to it too, which unfortunately doesn't lend itself to ergonomics, so you can't really comfortably hold it in place while in use.

Fandom 🟡⚪⚪⚪⚪ **Fans**

EASYSMX GAME PAD / **£17.99** inc VAT

SUPPLIER amazon.co.uk

The EasySMX Game Pad is about as straight down the line as a budget wireless PC gamepad gets. Powered by a couple of AA batteries, the EasySMX has no wired options or charging, but does its business via a responsive USB wireless connector. The buttons are exactly where you'd expect them for an Xbox-pattern pad, and the shoulder buttons and triggers operate with the same feel and with the same short pull and shape.

Visually, the EasySMX is understated but not completely joyless, plus it has a good shape and a solid heft to it. It doesn't reinvent the wheel or bring much to the fine art of gamepad design, but instead aims for the marks set by more established designers for an affordable price, and it hits that target comfortably. For a no-frills and no-wires Xbox-style gamepad, the EasySMX is hard to beat in its price range.

Cheesy 🟡🟡🟡⚪⚪ **Easy**

FUNTIME MINI ARCADE MACHINE / **£21.50** inc VAT

SUPPLIER amazon.co.uk

There's usually a degree of unity between the form of a retro gaming device takes and the games it carries. However, the Funtime Mini Arcade bucks this trend by looking like a classic standing arcade cabinet, while carrying an inventory of 200 games that seem most reminiscent of very early PC and home computer games, at least in terms of the graphics and colour palette.

The selection features a wide variety of games. There's a crude clone of Zaxxon, a wobbly version of Spy Hunter, a game that feels like a 1942-style shooter but with a couple of surprisingly interesting twists, and then of course, the dozens of barely functional oddities. The overall experience of wading into this sea of strangely coloured and vaguely familiar games is marred significantly by the controls. While the classic arcade cabinet has an iconic design, if you shrink it down and pick it up, it's not a great control device. Another flaw is the Music button that just turns off all the sound. It all adds up to a curious but ultimately disappointing gizmo.

More ●●○○○ **Merrier**

GODLIKEMATE SOUND BOARD / **£22.99** inc VAT

SUPPLIER amazon.co.uk

The Godlikemate Sound Board is a small budget USB sound device, which does its expected job, as well as some additional jobs not very well, which confuses matters. The device uses a USB connection for power and also to set itself up as a USB sound card on a PC, with 3.5mm in and out jack sockets. You can also connect the Sound Board to a smartphone via USB or Bluetooth; combined with its small size and durability, this makes it useful away from home.

Once it's wired up, you can get the sound board to modify and manage the sounds you're recording, adding echo, and adjusting pitch, volume, bass or treble. You can even add some pre-recorded sound effects, but they aren't great. Allowing user-recorded sounds to be added to the buttons instead, or using the buttons for more effects on the input, would arguably be more useful. The efforts of the Godlikemate Sound Board to go the extra mile fall a little flat, but that first mile is well done.

What are you like mate? ●●●○○ **God-like mate**

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

LABS TEST

Heatrippers

Antony Leather pits eight TRX4 liquid coolers against AMD's 3rd-gen Threadripper

How we test

AMD's colossal Threadripper CPUs can work with lesser coolers but to get the most from them you need something a little more powerful. We've gathered eight of the latest Threadripper-compatible all-in-one (AIO) liquid coolers to see which is best placed to keep your many-cored PC cool and quiet.

For consistent thermal testing, we've used a Threadripper 3960X that has been overclocked to 4.2GHz using a vcore of 1.265V. This is slightly higher than the CPU can manage at stock speed, so it should provide a decent workout for any cooler. We also use 32GB of 3466MHz Corsair Vengeance RGB memory along with a Samsung 960 Pro SSD and Corsair RM850i PSU. Our test system is housed in a Fractal Design Meshify C case and runs Windows 10.

We put the Threadripper processor under full load using Prime95 but disabled AVX instructions. After ten minutes we take a temperature reading using AMD's Ryzen Master software. We then subtract the ambient air temperature from the recorded CPU temperature to give a delta T result to allow us to test in a lab that's not temperature controlled. A weighted calculation is used to score the cooling.

The feature score takes into account aspects such as software control, lighting, expansion possibilities and whether you get PWM fans. The design score considers installation, noise and the aesthetics while the value score takes all the results into account as well as the price.

Contents

ALPHACOOL EISBAER EXTREME 280 / **£197** inc VAT

As one of our favourite coolers right now, and given its cooling prowess, the Alphacool Eisbaer Extreme 280 goes up against our mighty Threadripper 3960X and its 24 cores with a confident look on its face. This massive AIO liquid cooler sports a pair of 140mm fans and massive 280mm radiator enclosed in a shroud that houses its own refillable illuminated reservoir.

The ability to top up this cooler is crucial, as the Eisbaer Extreme 280 is expandable, with quick-release fittings part way down the tubes allowing you to plumb in extra waterblocks and piping. The fittings separate easily with no spillage, making for an AIO cooler that's both far more versatile than most and easier to work with than many custom water-cooling loops.

At £197, it's also extremely expensive, even compared with the large radiator-sporting, RGB-equipped and software-controlled models from Corsair and NZXT that we're testing. The benefit, though, is that its fans top out at an ear-pleasing 1,300rpm, so despite offering some of the best cooling we've seen on other CPU sockets, it's also one of the quietest coolers we've tested. This is also

thanks to the powerful Laing D5-style pump, which also features speed control, so you can fine-tune it to your liking without losing much cooling performance.

The trick, though, is housing the enormous radiator in your case, as it's over 15cm wide and nearly 40cm long and its depth of 64mm will also mean it's around a centimetre thicker than your typical 30mm-thick radiator and single row of fans.

Out of the box, the Eisbaer Extreme 280 isn't compatible with AMD's Socket TR4 or TR4X and you'll need to buy the separate mounting kit, but this only costs a few pounds. Installation is simple on Socket TR4X with just screws and springs securing through a mounting plate to the CPU socket threads. However, there's a good 8mm or so of uncooled space either side on the Threadripper heatspreader, as the waterblock doesn't span the entire area.

This seemed to have an impact in our cooling test too, as it only managed a CPU delta T of 56°C compared to the 51°C achieved by the far cheaper Cooler Master MasterLiquid ML360 RGB TR4 with its elongated contact plate. However, the Eisbaer Extreme 280 still managed this result with considerably less noise than the MasterLiquid ML360 RGB TR4, which was unpleasantly loud at full speed.

It was also quieter than both NZXT coolers, but again, they were also a little more potent

in cooling our Threadripper 3960X and are noticeably cheaper too. However, the Eisbaer Extreme 280 was much better than the Fractal Design Celsius+ S28 Prisma and bettered both Corsair coolers too.

Conclusion

It might lack the potency it offers on other sockets, due to its relatively small waterblock not covering the whole Threadripper heatspreader, but the Alphacool Eisbaer Extreme 280 managed its respectable result with far less noise, which will appeal to those pushing their CPU to its limits on a regular basis.

It's also expandable, making it easy to add other components to the loop with minimal fuss and has a powerful enough pump to deal with numerous extra components. You'll need to pay attention to its size, but if you need your Threadripper PC to be cool and quiet, then it's definitely worth stumping up the extra cash.

MOUNT EVEREST
+ Expandable
+ Quiet 140mm fans
+ Powerful pump

MOLE HILL
− Huge radiator shroud
− Not the very best cooling
− High price

SPEC

Compatibility Intel: LGA2011, LGA2011-v3, LGA2066, LGA1200, LGA115x, LGA1366; AMD: Socket AM4, AM3/+, AM2/+ FM2/+, FM1, TR4, TRX4

Radiator size with fans (mm)
156 x 386 x 64 (W x D x H)

Fans 2 x 140mm

Stated noise Up to 31dBA

VERDICT
Quiet and powerful, but also expensive.

COOLING	FEATURES	
34/40	18/20	**OVERALL SCORE**
DESIGN	VALUE	**84%**
19/20	13/20	

FITTING
Easy

ANTEC NEPTUNE 240 / **£80** inc VAT

SUPPLIER cclonline.com

We spotted that the Antec Neptune 240 is compatible with AMD's Threadripper sockets when we reviewed it first a couple of issues ago, so felt it would be fun to see how it coped with our current favourite CPU in AMD's high-end desktop line-up. It comes equipped with a 5-port PWM fan and lighting hub.

All five fan headers on the hub are standard 4-pin connectors, not proprietary ones like you find on some controllers and you can connect the hub to a single fan header on your motherboard to control all five fans at the same time.

The RGB lighting uses 3-pin digital addressable RGB ports, so you can control the lights on the pump and both 120mm fans. We love the fact that you can hook up to all four major motherboard manufacturer's 3-pin RGB ports too, with an adaptor included for some of the more finicky connectors. This means you can use their software to control the illumination. The included hub also has buttons to manually control the lighting colour and modes.

As usual, thermal paste is pre-applied onto the contact plate, which is milled from 0.8mm-thick copper.

It doesn't quite cover the entire heatspreader on a Threadripper CPU but does a better job here than many other coolers, with just 6-7mm either side left uncooled. The lack of extra thermal paste in the box does mean

that you'll need to buy more should you need to replace your CPU.

The Neptune 240's pump actually resides in the edge of the radiator, and this makes things much easier from a cable management point of view, keeping your CPU socket area free from clutter. However, to accommodate this, the radiator is a little longer than usual at 287mm. This only adds a centimetre or so to the length of a typical 240mm radiator but you'll want to double-check the space in your case to be on the safe side.

The pair of 120mm fans can spin up to 1,600rpm, which is far lower than many other coolers on test this month, but this did mean that like the Alphacool Eisbaer Extreme 280, it wasn't too unpleasant to sit next to when running at full speed. For those considering adding more fans, you'll need to purchase additional screws, as Antec only includes enough to mount the included fans in the box.

The mounting mechanism is typical of Asetek-licensed coolers and is easy to deal with, especially on Socket TRX4 where you just need to secure a quartet of socket pins and thumbscrews. A CPU delta T of 61°C was reasonable, especially given the cooler's limited fan speed, but the Cooler Master MasterLiquid ML360 RGB TR4 was 10°C cooler. However, it matched the larger Fractal Design Celsius+ S28 Prisma and bettered the Corsair H100i Pro XT too.

SPEC

Compatibility Intel: LGA115x, LGA1200, LGA2066, LGA2011; AMD: Socket AM4, AM3/+, AM2/+, FM2/+, FM1, TR4, TRX4

Radiator size with fans (mm)
121 x 287 x 52 (W x D x H)

Fans 2 x 120mm

Stated noise 36dBA

BAZOOKA

+ Fan and lighting hub included

+ Reasonable cooling for the cash

+ Easy to install

SPUD GUN

− Much better cooling available for more cash

− No extra thermal paste or additional fan screws

− No software control

Conclusion

While it's less effective with Threadripper CPUs than it was on other sockets, the Antec Neptune 240 is affordable, quiet and kept our overclocked Threadripper 3960X in check too, which is great considering its low noise and price. However, the NZXT Kraken X63 was much better in the cooling department and only costs around £50 more.

VERDICT

Decent cooling and features for the cash, although there are better TRX4 coolers.

COOLING	FEATURES	
30/40	18/20	**OVERALL SCORE**
DESIGN	VALUE	**82%**
15/20	19/20	

FITTING
Easy

COOLER MASTER MASTERLIQUID ML360 RGB TR4 / **£130** inc VAT

We've seen extended contact plates do well in cooling AMD's hefty Threadripper CPUs in the past and we were glad to see Cooler Master offering a reasonably priced RGB-equipped cooler with one too. The MasterLiquid ML360 RGB TR4 has a contact plate that completely covers the heatspreader, although not all of it actually sits under the pump to be actively cooled.

Still, it's better than leaving portions of the heatspreader completely to its own devices, so it will be interesting to see how it fares against more expensive coolers that have smaller plates.

At £130, it's reasonably priced for a 360mm AIO liquid cooler too, and while there's no software control, its pump and fans feature RGB lighting with 4-pin compatibility for motherboards and a controller included for manual tweaking too.

Cooler Master includes a splitter cable for this to cut cable clutter and also adds a fan splitter cable too so you can control all three fans from a single motherboard header. The trio of 120mm Air Balance fans peak at 2,000rpm making them fairly potent, but they only have average static pressure of 2.34mm H2O.

The radiator is about as small as you can get for a 360mm model, at just 394mm long and 27mm deep, so it should fit in any case that claims support for this size of radiator.

If you want to add another row of fans, you'll need to buy the screws yourself, as only enough are included to mount the included fans. Installation is simple thanks to it only requiring sprung screws and a mounting plate to secure the pump section to the CPU socket.

The RGB lighting was bright and vivid on the fans, but the pump section looked a little bland compared with that on the NZXT and Corsair coolers, and there's no software control for the fans or lighting either. Still, most motherboards offer decent fan control these days, so it's not a dealbreaker.

Thankfully, while you might pay over the odds for an otherwise basic cooler, the extra R&D Cooler Master has put in has paid off, as the MasterLiquid ML360 RGB TR4 managed the lowest CPU delta T on test of 51°C. This is at least 2°C cooler than the next best cooler, and its closest competitors are more expensive.

It was 4°C cooler than the Alphacool Eisbaer Extreme and 3°C cooler than NZXT Kraken X63, although its fans did produce quite a racket at full speed. However, you could tune these back and still have it outperform or match other coolers.

Conclusion

The Cooler Master MasterLiquid ML360 RGB TR4's design is rather dated, but if you care more about cooling than RGB lighting and noise, then it's the best option we've tested, to deal with AMD's 3rd-gen Threadripper CPUs, only bowing to NZXT's 360mm Kraken X73 due to it having more features. It handled our overclocked Threadripper 3960X with ease, and is also very compact and easy to install.

It also goes to show that properly covering the heatspreader on Threadripper CPUs can help achieve the best thermals. There are better equipped and more attractive options and several quieter ones too, but you'd need to invest in custom liquid cooling to get much better temperatures.

SPEC

Compatibility AMD: Socket TR4, TRX4

Radiator size with fans (mm)
119 x 394 x 27 (W x D x H)

Fans 3 x 120mm

Stated noise 6-30dBA

THREADRIPPER
+ Great cooling
+ Compact radiator
+ Easy to install

STRIPPED THREAD
– Fans are loud at full speed
– Aesthetics are dated
– No software control

VERDICT
Great cooling and compact size, but a little lacking on features.

COOLING	FEATURES	OVERALL SCORE
37/40	16/20	**85%**

DESIGN	VALUE
15/20	17/20

FITTING
Easy

CORSAIR iCUE H100i RGB PRO XT / **£115** inc VAT

SUPPLIER scan.co.uk

The Corsair iCUE H100i RGB PRO XT is a slightly updated version of the company's excellent H100i RGB Platinum coolers, which we loved thanks to its quiet low-load performance mixed with blistering cooling at full speed (in addition to a few extra decibels). It offered unparalleled cooling for a 240mm cooler in our tests, so we were keen to try a slightly jazzed-up version in the form of the iCUE H100i RGB Pro XT.

This model is reasonably priced for an all-singing, RGB-equipped, AIO liquid cooler. However, it does lack RGB fans, as do most coolers this month. Instead, it's the pump section that brings the RGB party, with 16 individually addressable LEDs around the edge and in the centre of the pump top.

These lights can be synchronised with other Corsair components using the company's iCUE software, matching its memory or lighting strips as well as linking up with your motherboard's lighting.

By default, the cooler will respond to its own coolant temperature when ramping up

fans, so as not to continually fluctuate them according to CPU temperature. However, while there are several fan modes to choose from, you can also create your own and even switch to the CPU temperature being the trigger for fan speed. The iCUE H100i RGB PRO XT also features a new zero rpm mode for the fans.

The iCUE H100i RGB PRO XT comes with mounting plates for AMD's Threadripper CPU socket as well as the plethora of other parts for other sockets, so if you switch or transplant the cooler in future, it has you covered. The iCUE H100i RGB PRO XT uses similar 2,400rpm fans to the H100i RGB Platinum, which have a monstrous 4.2mm H2O static pressure.

Installation is blissfully easy, thanks to Corsair's oversized thumbscrews and the fact you have no motherboard backplate to deal with, and the right pins for Threadripper sockets are colour-coded too. As usual, there's no extra thermal paste, so you'll need to buy more if you ever need to reapply it.

Despite its prowess on other sockets, the iCUE H100i RGB PRO XT failed to get a firm grip on temperatures when dealing with our Threadripper 3960X CPU, with the best CPU delta T in extreme fan and pump mode set in iCUE being 63°C, and even higher at the quiet fan speed setting.

This could be due to the small contact plate, which leaves large areas of the heatspreader

unchecked, but despite several thermal paste reapplications, and checking the fans were at full speed, this was the best it could do.

Conclusion

We were surprised that the sibling of one of our favourite 240mm air coolers fared so poorly, but the Corsair iCUE H100i RGB PRO XT definitely isn't a great choice for dealing with Threadripper CPUs. Even the much cheaper Antec Neptune 240 managed to better it, so it seems its design is somehow suited to other sockets. The iCUE H115i RGB Pro XT performed much better, so we suspect numerous factors were at play here, but it's ultimately one to avoid for your Threadripper PC.

DSLR
+ Vivid RGB lighting
+ Software fan and light control

DISPOSABLE
− Poor cooling for the price
− Loud at full speed
− Cheaper coolers are better

SPEC

Compatibility Intel: LGA2011, LGA2011-v3, LGA115x, LGA1200, LGA1366; AMD: Socket AM4, AM3/+, AM2/+, FM2/+, FM1, TR4, TRX4

Radiator size with fans (mm)
120 x 277 x 27 (W x D x H)

Fans 2 x 120mm

Stated noise Up to 37dBA

VERDICT
Great cooling on other sockets, but poor value for a Threadripper PC.

COOLING	FEATURES	OVERALL SCORE
28/40	19/20	**76%**
DESIGN	VALUE	
14/20	15/20	

FITTING
Easy

CORSAIR H115I RGB PRO XT / **£132** inc VAT

Like its baby sibling, the H115i RGB Pro XT has previously wowed us with its cooling and software control. However, with it sharing the same contact plate as the H100i Pro XT, it similarly struggles when it comes to keeping Threadripper chips cool. That said, it offers a little more headroom than its smaller sibling.

This is a USB-controlled unit, like most of Corsair's coolers, so you'll need a spare USB 2 header to use its iCUE software to control the pump, fans and lighting. Two ML140 magnetic levitation bearing fans are fed by the pump section, but they're not RGB-enabled so there's a few less cables to deal with.

The 140mm fans are limited to 2,000rpm, which is 400rpm less than the H100i variant's 120mm fans. This helps to keep things a little quieter while the larger size of the fans ensures there's minimal impact on cooling. The cooler's quiet mode has a more aggressive impact on peak fan and pump speeds than NZXT's CAM software, limiting the speed of the cooler's pump, for example, to around 1,900rpm in quiet mode, rising to 2,600rpm at full speed. As with all of Corsair's coolers, the fans and pump are set to respond to coolant temperature, so there's a smooth ramp-up of speeds.

Even at full speed, the pump remained fairly quiet, with only the most sensitive ears likely to need to tune it down. The fans did ramp up more noticeably but emitted a not unpleasant airflow blast, rather than anything more screechy or whining.

Only the top of the pump has RGB lighting and the 16 digitally addressable LEDs can be controlled individually. The lighting effects are extensive in the iCUE software and you can create your own, with full control of all 16 LEDs available. Other Corsair components can also be incorporated into your dazzling display as well.

The cooler has the same components as the iCUE H100i RGB PRO XT, with a two-piece mounting plate and thumbscrews, which are easily dealt with on Threadripper sockets. Plus, if you want to add more fans, Corsair includes an extra set of screws in the box too.

The peak temperature of a delta T of 57°C was much better than its 240mm sibling, but still not enough to better most other coolers, with NZXT, Alphacool and Cooler Master's offerings all posting better results while often remaining quieter too. The temperature rose to 61°C in the quiet speed mode, thanks to slower fan and pump speeds, but here it was matched by the Antec Neptune 240 with similar noise levels and a much lower price.

Conclusion

The Corsair H115i RGB Pro XT performed much better than the H100i Pro XT in our tests, but it was still not a match for most other coolers on test in terms of cooling. Both NZXT coolers were better, offering better cooling for similar noise levels and including software fan control. The Cooler Master MasterLiquid ML360 RGB TR4 was significantly better performing for the same cash too. We do like Corsair's software and aesthetics, but it just misses out to some stiff competition when it comes to dealing with Threadripper CPUs.

SPEC

Compatibility Intel: LGA115x, LGS1200, LGA2066, LGA2011; AMD: Socket AM4, AM3/+, AM2/+, FM2/+, FM1, TR4, TRX4

Radiator size with fans (mm)
137 x 322 x 52 (W x D x H)

Fans 2 x 140mm

Stated noise 36dBA

OVERCLOCKED
+ Great software
+ Detailed fan and pump control
+ Excellent cooling

OVERCOOKED
− Quiet profile limits fan and pump speeds
− Average cooling
− 140mm fan size may limit compatibility

VERDICT

Great on other sockets but it doesn't quite pack the same punch with Threadripper.

COOLING	FEATURES	OVERALL SCORE
31/40	19/20	**82%**
DESIGN	VALUE	
16/20	16/20	

FITTING
Easy

FRACTAL DESIGN CELSIUS+ S28 PRISMA / **£150** inc VAT

We've reviewed a number of 280mm AIO liquid coolers in the past 12 months, but despite an increasingly crowded market, the Fractal Design Celsius+ S28 Prisma still managed to pick up an approved award thanks to decent cooling, an innovative cable management system, full RGB lighting and reasonable noise levels.

However, we've seen other coolers that did well on alternative CPU sockets not hold up when it comes to dealing with AMD's Threadripper CPUs, so it's anyone's guess as to how the Celsius+ S28 Prisma will do in this group test.

You get a useful hub located on the radiator that provides power for your fans, so you won't need to run cables from them to your motherboard, with only the pump requiring a 4-pin header and RGB header for the fan and lighting control. This is thanks to the tubes themselves housing these cables and running them up to the fans out of sight: a far neater solution than that used by NZXT's cooler's this month.

At £150, it is rather expensive, though, and trumps two out of the three other 280mm coolers in this regard. There's also no software fan or lighting control, although modern motherboards offer similar control these days. There is an automatic control mode, which cuts noise but also reduces cooling. It's at least an option if you prefer a quieter system. This is enabled by twisting the pump housing, switching between automatic and PWM mode. The hub includes two additional 4-pin fan headers to power a second row of fans, although screws for these are not provided.

Both the pump and fans will adjust their speed according to the fan header, with the pump ranging from 600-2800rpm while the fans peak at 1,700rpm. Once the coolant temperature hits 55°C, the cooler will force both to maximum speed. The automatic control mode uses coolant temperature to control speeds from the start, but we did see a drop off in performance, most likely as the pump wasn't quite dishing out a high enough flow rate.

The RGB lighting extends to the pump and fans and is vivid enough, if not quite on par with some of Corsair's coolers, but it certainly has the most flair in this group test. Being a standard Asetek cooler, it uses the adaptor included with Threadripper CPUs to mount to these sockets, which is incredibly simple to use, as all parts are pre-mounted. The downside is that the contact plate is both small and circular, so it doesn't get close to covering the entire heatspreader.

A CPU delta T of 61°C isn't particularly inspiring and sits joint second from last, being matched by the cheaper and smaller Antec Neptune 240. This could be due to the smaller contact plate compared with some other coolers, including the Antec, but also due to its lower fan speeds. By comparison, the similar NZXT Kraken X63 managed 54°C with its more powerful fans.

Conclusion

Sadly, the Fractal Design Celsius+ S28 Prisma comes up short when dealing with Threadripper CPUs and the NZXT Kraken X63 is a much better buy, retailing for a similar amount, and offering much better cooling and software fan and light control. The Fractal is a little quieter but not enough to make up for its other shortcomings.

VERDICT

An attractive, tidy cooler, but it offers lacklustre cooling for the cash on Socket TRX4.

SPEC

Compatibility Intel: LGA115x, LGA1200, LGA2066, LGA2011; AMD: Socket AM4, AM3/+, AM2/+, FM2/+, FM1, TR4, TRX4

Radiator size with fans (mm)
143 x 324 x 55 (W x D x H)

Fans 2 x 140mm

Stated noise 36dBA

3D PRINTER
+ Fan and lighting hub included
+ Easy to install
+ Reasonably quiet at full speed

3D GLASSES
− Better cooling available for the same price
− No additional fan screws
− No software control

COOLING	FEATURES	OVERALL SCORE
30/40	15/20	**74%**
DESIGN	VALUE	
16/20	13/20	

FITTING
Easy

NZXT KRAKEN X63 / £135 inc VAT

T here's not much that's new over its excellent predecessor with the Kraken X63, apart from a refreshed design offering a slightly bigger LED ring and more vivid lighting. The fans are the same Aer P 140mm models as used with the Kraken X62 and the coolers look very similar too. Thankfully, the price has stayed the same, with the Kraken X63 leaving you with change from £140.

Sadly, this doesn't include RGB fans like you get with the slightly more expensive Fractal Design Celsius+ S28 Prisma, but there are a few additional features. The LED holographic pump top looks stunning and will jazz up any motherboard too. You also get software control courtesy of NZXT's CAM program. We've had issues with this in the past, but with the Kraken X63, it was a problem-free experience.

Rather than limit cooling like Corsair's iCUE software in quiet mode, the software does tend to allow the pump and fans to ramp up quickly once the CPU temperature reaches a rather tame 60°C, so it's not as aggressive at limiting noise compared with Corsair's coolers. You

can create custom profiles, too, though, and switch between coolant and CPU temperatures for the speed control, so there's plenty of tweaking available.

When you buy a Threadripper CPU, an adaptor for Asetek cooler pumps is included in the box, which allows them to be secured to either Socket TR4 or TRX4. It's a single-piece design and you simply clip it to the pump and tighten the four included screws.

Thermal paste is pre-applied, which is handy, but you'll need to buy more if you need to reapply it, as no extra is included in the box. Installation, then, couldn't be easier and the radiator is certainly far more compact than the Alphacool Eisbaer Extreme 280 too.

Given the poor performance of the Celsius+ S28 Prisma and average results posted by the Corsair H115i RGB Pro XT, we didn't hold out much hope for the Kraken X63, but its powerful fans and internal design managed a CPU delta T of just 54°C with our overclocked Threadripper 3960X. This even beat the mighty Alphacool Eisbaer Extreme, and was 9°C better than the Corsair H100i Pro XT too, although the fans did dish out quite a din at full speed.

Switching to the quiet profile saw an identical result, but the fans took a little longer to spin up. Only the Cooler Master MasterLiquid ML360 RGB TR4 managed a better result, knocking another couple of degrees off this temperature.

Conclusion

With an aging pump design and no Threadripper-specific features, we didn't expect much from the NZXT Kraken X63, but its cooling impressed us, given other coolers fared far worse. It's clear that a full-cover contact plate will certainly improve cooling further, as the Threadripper-specific Cooler Master MasterLiquid ML360 RGB TR4 performed better still, but the Kraken X63 is proof that you don't always need a full-cover design to get excellent performance.

It's not the quietest cooler and the Alphacool Eisbaer Extreme is absolutely worth the extra cash if low noise is your priority, but if you want a cheaper 280mm AIO liquid cooler for your Threadripper PC, this is a great choice.

ZEN 2
+ Great cooling
+ Good software control
+ Attractive pump lights

BULLDOZDER
− No full-cover contact plate
− Not the quietest

SPEC

Compatibility Intel: LGA2011, LGA2011-v3, LGA115x, LGA1200, LGA1366; AMD Socket AM3/+, AM2/+, FM2/+, FM1, TR4, TRX4

Radiator size with fans (mm)
315 x 143 x 55 (W x D x H)

Fans 2 x 140mm

Stated noise Up to 38dB(A)

VERDICT
Great cooling for Threadripper CPUs, and you get plenty more besides.

COOLING	FEATURES	OVERALL SCORE
35/40	19/20	**86%**
DESIGN	VALUE	
16/20	16/20	

FITTING
Easy

NZXT KRAKEN X73 / **£160** inc VAT

We've looked at a pair of 360mm models in this month's Threadripper cooler group test, with the NZXT Kraken X73 going up against the Cooler Master MasterLiquid ML360 RGB TR4. The latter is cheaper and has RGB fans as well as a pump, but it lacks the NZXT cooler's software fan and pump control and general swagger.

Like its sibling, you'll need to fish out the socket adaptor that's included with your Threadripper CPU in order to secure the cooler to your motherboard, but this does make it one of the easiest coolers on test to install.

Using a 360mm radiator, it's likely to be compatible with plenty of cases where 140mm radiators are too wide, plus the radiator is also a standard half-height affair so doesn't stretch to gargantuan dimensions or use a shroud like the Alphacool Eisbaer Extreme. As you may want to install it into the front of the case, the Kraken X73 is equipped with length 40cm hoses to allow its pump to reach your motherboard, although it's usually best to have it exhausting out the roof.

The cooler isn't limited to Threadripper sockets either so if you switch to something else in the near future, you won't need to buy any extra parts as it includes mounting kits for all current sockets.

It uses three Aer P 120mm fans and a splitter cable runs from the pump housing

powering them. Add in the SATA power and USB connector and there are quite a few cables that will need to be tidied away. The included fans reach up to 2,000rpm, so are fairly potent but still generally quiet.

The pump was restrained in terms of noise levels too, especially at low loads, so won't interrupt your YouTube binging. NZXT's CAM software was straightforward and easy to use and provides control over the pump's RGB lighting as well as the fan and pump speeds.

You can select from several profiles, but all result in the fans and pump eventually hitting top speed quite quickly. However, you can create a custom fan profile to take more control as well as switch between CPU and coolant temperatures for the fan input.

With the Kraken X63 hitting a great CPU delta T of just 54°C, we were hoping for better from its bigger brother. It didn't smash that record, but did shave a degree off that temperature with a delta T of 53°C. This is second only to the other 360mm radiator cooler on test – the Cooler Master MasterLiquid ML360 RGB TR4, which shaved a further two degrees off that result. The

Kraken X73, though, outperformed every other cooler, bettering Corsair's efforts by at least 4°C and even the Alphacool Eisbaer Extreme too. However, the latter was considerably quieter at full speed.

Conclusion
The NZXT Kraken X73 offers great cooling, simple installation, handy software control and snazzy RGB lighting. It's undoubtedly a great cooler, but it also adds £25 to the price of NZXT's very capable X63, while also being pricier than Cooler Master's MasterLiquid ML360 RGB TR4, which offers better cooling for less money. Meanwhile, the Alphacool Eisbaer Extreme is pricier, but much quieter, all of which puts the Kraken X73 in a limbo. However, if you want its lighting and software control, it remains a great choice. **CPC**

SPEC

Compatibility Intel: LGA2011, LGA2011-v3, LGA2066, LGA1366, LGA115x, LGA1200; AMD: Socket AM4, AM3/+, AM2/+, FM2/+, FM1, TR4, TRX4

Radiator size with fans (mm)
120 x 394 x 52 (W x D x H)

Fans 3 x 120mm

Stated noise 21-36dBA

KRAKEN

+ Powerful cooling

+ Good software

+ Easy installation

MINNOW

− Cheaper models offer similar cooling

− Noisy at full speed

− No RGB fans

VERDICT

A powerful, stylish cooler with software fan control.

COOLING	FEATURES	
36/40	19/20	**OVERALL SCORE**
DESIGN	VALUE	**84%**
16/20	13/20	

FITTING
Easy

LABS TEST

Smooth landing

With Microsoft's new Flight Sim impressing all who survey it, there's never been a better time to buy a flight stick. **Edward Chester** tests the latest models

How we test

We've tested six flight controllers of various types, with prices ranging from under £30 to £400, with plenty in between, and all of them will get the basic job done. When it comes to choosing which is right for you, though, there's a few factors to consider.

The first is whether you just care about terrestrial flight or space flight too. For conventional aeroplanes, you just need two axes of movement: pitch and roll. To control these axes, the stick tilts forward and back and left and right. Then, you can control the rudder (yaw) either with separate pedals or via keyboard input.

If, however, you're working in space, you want to not only control pitch and roll but yaw as well. In which case, you'll want a flight stick that twists to provide the most intuitive all-in-one system for controlling all three axes. Such three-axis sticks also offer a convenient way to incorporate rudder control into one stick for aeroplane flight.

For any single-stick setup, you ideally want it to also incorporate analogue throttle control, with at least one hat switch or D-pad, plus a handful of programmable buttons and triggers. A hat switch is like a D-pad, but it tends to have a domed top for easier control with the side of the thumb. They're used for many controls, including providing a means of quickly switching your direction of view.

Beyond a single-stick setup, you can also add a second stick for controlling the forward/back, up/down and left/right thrust of your craft in space sims. In addition, you can buy separate throttle controls that provide a more sophisticated analogue throttle control (often with independent left and right throttles) and a host of extra buttons, dials and hat switches that your left hand can control.

We tested all the sticks in a variety of games, including the latest Microsoft Flight Simulator (see p68), Star Citizen and the air combat sections of Star Wars Battlefront II. The latter requires very rapid control of movements and throttle, plus precise control in the central portion of the stick for finessing your dogfighting manoeuvres. Flight Simulator is a much more placid experience, but its in-depth controls can make use of the many extra buttons (and split throttles) on higher-end sticks. Meanwhile Star Citizen's space exploration is best experienced with a dual-stick setup. All the sticks tested worked fine with all three games.

Contents

CH PRODUCTS FLIGHTSTICK PRO / £100 inc VAT

The CH Products Flightstick Pro is a bare bones joystick that offers just four buttons, one hat switch and two-axis control. It's also been available almost completely unchanged for 20 years, and yet it still costs £100. As you may have guessed, though, the reason for the high price is its far higher level of build quality and precision than your typical joystick.

Not that this build quality is obvious at first sight. The Flightstick Pro is a utilitarian-looking device, with a dull black plastic used for all but the thumb buttons, and even they're white and grey. As you can probably guess, RGB lighting hasn't made the feature checklist either.

However, the moment you get your hands on this joystick, you notice just how well it's put together. It's surprisingly large and heavy, and there's a smooth yet weighty quality to the movement of the joystick. The buttons have a precise response too and you immediately get the sense that the whole setup is built to last.

It also helps that the Flightstick Pro's design is almost completely symmetrical, making it ideal for left and right-handed use. The only non-symmetrical features are the pitch trim and throttle dials, which sit on either side of the stick. This makes it less convenient to dynamically adjust throttle with your right hand if you're left-handed, but you can certainly cope by simply crossing your right arm under your left.

As well as the feeling of quality, the FlightStick Pro's design also makes it feel very comfortable in your hand. The joystick grip is large enough to not require too tight a grip, while all the buttons and the hat switch fall easily under thumb, as does the trigger under your index finger. Obviously, people with particularly small or large hands may struggle, but that's true of nearly all one-size-fits-all controllers. Even then, the action is light enough that you can easily control smaller movements with just your fingertips holding the base of the stick – ideal for small adjustments when cruising.

The joystick's movement is superb. Rather than having a two-axis ball joint, it has two single-axis barrel joints, one inside the other. This approach has enabled CH Products to make the action of each axis much smoother and more precise than any other stick on test, bar the much more expensive Thrustmaster Warthog. You can effortlessly move the joystick very precisely, even in the centre of its movement range, while still having plenty of maximum movement.

The inherent problem here, though, is the lack of a third axis or rudder control. That's not a major problem for most flight sim situations, as you can fairly easily get by with using keyboard input for rudder control. However, if you do want a more precise, analogue input, you'll need to accompany this joystick with a set of rudder pedals. What's more, for space sims, twist joysticks offer an even more intuitive way of controlling that third axis.

CH Products also offers the Combatstick and Fighterstick, which up the button count from four on the Flightstick Pro to 18 on the Combatstick and 24 on the Fighterstick, although both these controllers still only offer pitch and roll control.

Conclusion

The CH Products Flightstick Pro doesn't offer the masses of features and third-axis control of some flight sticks. However, for the core two-axis, pitch and roll movement and analogue throttle control that's key in most flight sims, this joystick delivers the goods, and does so in a way that far surpasses some of its fancier-looking rivals.

PROFESSIONAL
+ Excellent precision
+ Top-notch build quality
+ Easy manual trim controls
+ Ambidextrous

AMATEUR
− Two-axis only
− Very basic button selection
− Expensive for the features

SPEC

Axes 2

Throttle control Yes

HOTAS No

Buttons 4

Rudder control No

VERDICT
A fantastic quality flight stick, even if it's light on features.

PERFORMANCE	FEATURES
40/40	25/40

VALUE
17/20

OVERALL SCORE 82%

LOGITECH EXTREME 3D PRO JOYSTICK / **£35** inc VAT

SUPPLIER currys.co.uk

I t's astonishing just how low the price of capable joysticks can drop. This Logitech Extreme 3D Pro costs just £35 inc VAT, yet it includes three-axis stick control, a throttle control and 12 programmable buttons, along with an 8-way hat switch. The flight stick market sits in stark contrast to racing wheels, where you generally have to spend well over £150 to get even a passable experience.

But back to the Extreme 3D Pro, this joystick doesn't just impress with the sheer number of features for the money, but with its build quality too. While it's all made from plastic, it all feels solid enough to survive plenty of years of gaming abuse, as well as tumbles onto the floor. The base also has a plentiful 200 x 200mm footprint, which provides a surprisingly secure footing on any large and stable flat surface.

Meanwhile, the stick itself feels well planted, with only a modest amount of wobble in its centre before each axis' resistance is engaged. The buttons aren't the absolute crispest and most satisfying ones to press on test, but they're still good for the money – there were no occasions where we weren't sure if a button had been triggered or not.

We also found the grip of the stick to be very comfortably contoured, with all the controls falling into the right place and the resting platform for the side of your hand helping to take the strain off your arm. It's a bit of a shame Logitech didn't just extend that platform round

to the other side, though, as this would make the whole stick's design a bit more ambidextrous – you can otherwise just about get away with using the stick with your left hand.

Also, the stick movement is a little stiffer than the likes of the CH Products Flightstick Pro, making it slightly more tiring to hold in position for long periods – especially if you're also twisting the stick at the same time – although it's still manageable.

The twisting stick action allows it to control rudder movement on aircraft, although it's actually not as intuitive as using a separate rudder control for terrestrial flight. Instead, it comes into its own for space flight, where you're truly controlling all three axes of twist at once. Unlike Logitech's X56 HOTAS (see p54), you don't get on-board dials for allowing control of all thrust vectors as well, so you'll need to invest in a second joystick if you want analogue control of those inputs.

It's the movement and sensitivity of this joystick that's most surprising for the price though. While you don't get anywhere near the accuracy and smoothness of the CH Products Flightstick Pro or Thrustmaster Warthog, it's still satisfyingly responsive in its centre, and has a much smoother transition from its centre to extreme angles than Logitech's X56 HOTAS. The throttle control also works well and smoothly. For just £35 inc VAT, it's astonishingly accomplished.

The only real gripe we found was the very basic software. Logitech does provide an app to program all the buttons, but support isn't integrated into the company's main gaming software app, and the separate app clearly

hasn't been updated in years. For such a major peripherals manufacturer, we'd expect more up-to-date support.

Conclusion
Don't let this joystick's low price put you off. While its stick movement can't compete with the best models out there, it's surprisingly capable and puts several more expensive models to shame. With true 3D control, plenty of buttons and throttle control, it covers all the essentials for getting started in most terrestrial and space flight sims.

SPEC

Axes 3	
Throttle control Yes	
HOTAS No	
Buttons 12	
Rudder control No	

EXTREME
+ Three-axis control
+ Incredibly cheap
+ Loads of buttons
+ Throttle control

AVERAGE
− Quite stiff
− Basic software

VERDICT

A low price, capable performance and a decent feature set makes the Extreme 3D Pro a standout bargain.

PERFORMANCE	FEATURES
30/40	35/40

VALUE 20/20

OVERALL SCORE 85%

LOGITECH G X56 HOTAS / **£220** inc VAT

If features per pound were the only scoring criteria, the Logitech (previously Saitek) X56 HOTAS would easily romp home with the win. This two-piece, Hands On Throttle And Stick (HOTAS) system, with separate joystick and throttle sections, is absolutely packed to the gills.

The joystick offers three-axis movement and is festooned with buttons and hat switches. Meanwhile the throttle control has separate left and right throttle controls, so you can control the engines of multi-engined craft independently (or both controls can be locked together). There are also loads more buttons and hat switches on the throttle control, along with arguably the single feature that really elevates this whole setup in terms of core features, which is two further dials for left/right and up/down throttle control.

Combined with the main throttle sticks, these dials allow for full control of all thrust vectors in space flight sims. The system isn't as slick as using a second joystick, as the main throttle controls are quite stiff and not ideal for quick or small adjustments. Also, both the dials are controlled by the thumb, so sophisticated multi-vector movements are tricky. But still, at least the option's there.

As with the other flight sticks on test that pack in loads of features, all those buttons and controls have been optimised for right-hand only use, and unlike the Logitech Extreme 3D Pro, you really can't use this 666 setup the other way around, in a left-handed configuration. There are extra buttons on the side of the stick that would get in the way of your hand, and the throttle control's extra buttons are nearly all accessed via the thumb.

When it comes to build quality, you're also very much paying for all those features rather than premium build quality. There are a few metal pieces, such as the bars that protect the switches on the throttle control, but otherwise it's all plastic, although it does all feel solid enough.

Thankfully, though, Logitech has recently given the X56 a bit of a makeover from its garish stylings of before. The physical design is the same, but the bright blue colour scheme has gone, and instead you get a muted all black and grey affair, other than the RGB lighting used to backlight some dials and other controls.

All the various controls are of middling quality. They're responsive and solid enough, but they don't have the same level of satisfying tactility as truly high-end flight control gear. The bigger problem, though, is the joystick action. The joystick uses a spring and cup tensioning system that, a bit like a buckling spring keyswitch keyboard, offers an initial resistance then falls away as the spring buckles.

This means the stick feels stiff and unresponsive in its crucial central zone – where accuracy is so important for activities such as dogfighting – then suddenly the whole stick lurches too far outwards as the spring collapses. Logitech provides several different springs of different tensions for you to try, but they all suffered the same core problem.

Some users may not mind this style of movement, but we found the X56 to be the worst stick on test for ease of smooth flight controls, even if the tracking of the stick is more accurate than cheaper options.

Conclusion

A festival of buttons and extra dials makes this a hugely versatile and capable HOTAS flight stick combo. However, the core movement of the flight stick lacks the smoothness and subtlety of movement of even far cheaper options.

VERDICT

A mass of features is let down by a flight stick that feels stiff and unresponsive in its crucial central zone.

PERFORMANCE	FEATURES	OVERALL SCORE
20/40	35/40	**70%**
	VALUE 15/20	
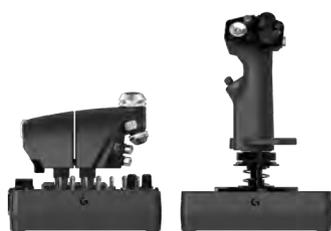
SPEC

Axes	3
Throttle control	Yes (dual)
HOTAS	Yes
Buttons	35
Rudder control	No

HOTAS

+ Three-axis control
+ Masses of features
+ HOTAS control

HANDS OFF

− Poor main joystick feel
− Pointless multi-spring tensioning system

SPEEDLINK PHANTOM HAWK / **£30** inc VAT

Speedlink is well known for churning out incredibly keenly priced peripherals, and the Phantom Hawk is no exception. Readily available for under £30, it packs in as many features as the Logitech Extreme 3D Pro and, like that stick, it proves that even very cheap flight sticks are still worthy investments if you only occasionally dabble in flying games.

The overall feature list and design of the Phantom Hawk is very similar to the Extreme 3D Pro, with a square base that gently slopes down towards the edges, and upon which you'll find a simple throttle slider and half a dozen programmable buttons. On the stick, you get a single 8-way hat switch as well as a D-pad – a feature that the Logitech lacks. There's also a thumb trigger and forefinger trigger, along with a button that sits under the little finger.

It's a decent array of features but the slightly more symmetrical design of the Logitech feels more intuitive in use. In the case of the Phantom Hawk, the throttle sits on the left side, rather than the front, so it's not as easy for either hand to reach it. Also, the shape of the handle isn't as amenable to being used in a different hand as the Logitech.

In addition, there's a silver plastic protective piece that wraps over the front of the stick, as though it were a handle guard for a sword. It serves no purpose here, unless you plan to upend the stick and use it as the hilt for your next cosplay weapon.

The base of the Phantom Hawk is a little narrower than that of the Logitech, and it's equipped with four small suction cups on the underside. These cups hinder more than help the stick though. For those surfaces to which they do stick, they're not overly reliable and the stick still has some wobble to it. Meanwhile, for the majority of surfaces to which they don't stick, they end up narrowing the effective width of the base, making the stick much less stable. Thankfully, you can remove the cups, and although the Logitech is still more stable, removing the cups does greatly improve the stability of the Speedlink.

When it comes to the action of the stick, it offers control of all three axes, again thanks to the stick rotating. It works reasonably well too, offering a fairly smooth and accurate input that's at least suitable for arcade-style flight games. There is a fairly significant dead zone in the centre, though, which makes it difficult to make fine adjustments. In this regard, it's noticeably worse than the Logitech Extreme 3D Pro, so that stick is definitely worth the extra few pounds.

Conclusion

If your budget really can't stretch even as far as £35 for the Logitech Extreme 3D Pro, the Speedlink Phantom Hawk just about does the job as an even cheaper alternative. However, this price difference is minimal, and the step up in quality with the Logitech is significant enough that we'd recommend most people spend the extra cash. The dead zone on the Speedlink Phantom Hawk's stick, and its less ambidextrous layout and shape, means the Logitech is not only better quality but better suited to a wider range of gamers too.

VERDICT

Super-basic but still capable and cheap, this is a reasonable option but it's well worth paying the extra few quid for the Logitech Extreme 3D Pro instead.

HAWKEYE	**HAWK THE SLAYER**
+ Decent value	− A little unsteady
+ 3-axis control	− Slight dead zone in centre of stick
+ Plenty of buttons	− Stiff throttle control

SPEC

Axes 3	
Throttle control Single	
HOTAS No	
Buttons 12	
Rudder control No	

PERFORMANCE 20/40

FEATURES 30/40

VALUE 15/20

OVERALL SCORE **65**%

THRUSTMASTER HOTAS WARTHOG / **£400** inc VAT

SUPPLIER thrustmaster.com

The Thrustmaster HOTAS Warthog has been a standout product in the flight stick market for almost ten years now. Modelled after the control system of the A10 aircraft from which this flight system gets its name, the Warthog is a serious piece of engineering.

Built almost entirely from metal, is weight is colossal. The stick alone weighs over 3kg, and with its wide, relatively thin metal base, you definitely don't want it to fall off your desk and land on your foot. That metal base does make for an immensely stable platform, though, and there are holes in it, making it easy to screw down the whole setup to your simulation rig.

Nearly every switch is on par with the real deal too, with metal levers and the sort of reassuring switch action that only properly made equipment can create. Every aspect of this HOTAS system is satisfyingly hefty and high-quality. All of which is, of course, as you'd hope, given the high price of this system. Even though lockdown has inflated prices and

limited availability of most flight sticks, you could still expect to pay over £300 for this setup or around £200-£250 for the stick alone, even before these trying times.

The flight stick itself has no controls on its base but does have plenty up top. There are three 8-way hat switches and a 4-way hat switch, along with two thumb buttons, two little finger buttons and a hefty metal trigger. The stick can also be removed and swapped out for an F-16C Viper grip or an F/A-18C Hornet grip. Each of these grips costs around £170, while the base on its own costs £120.

Meanwhile, the throttle control is as packed with features as you'd expect. There are twin throttle sticks, two trim wheels, an 8-way hat switch and masses of toggle switches, all of which again have the same satisfying high quality you'd expect from professional equipment. It's a bit of a shame the throttle controls themselves are made of plastic, as they feel noticeably less robust than the rest of the system.

The feel of the joystick is fantastic though. Its movement is smooth and it's surprisingly easy to move, despite the clear weight of the handle itself. It's easy to just operate the stick with your fingertips from its base. Compared with the likes of the Logitech X56, it's a difference of night and day.

However, one feature you miss here is third axis control. There are no rudder buttons as such, and no twist control in the stick: this setup is really only for terrestrial flight sims. You could still use a second stick to control an extra axis and thrust vectors, but you'd then still need rudder pedals and one further control surface.

There's also a steep learning curve in getting all the gear set up properly and, ultimately, it's overkill for the vast majority of users. We'd strongly recommend trying a more basic stick first before taking the plunge.

Conclusion

Every aspect of this HOTAS setup screams high quality, with nearly every switch and surface built to replicate the real deal. It's a hugely satisfying, tactile piece of equipment. It's also hugely capable, but only when it comes to terrestrial flight sims. The lack of third axis control makes it less suited to space flight sim control, and even for flight sims, you'll still need to invest in some rudder pedals for the full effect.

VERDICT

A fantastic, high-quality flight stick but its high price and lack of third-axis control inherently limits its appeal.

PERFORMANCE	FEATURES	OVERALL SCORE
40/40	30/40	**83%**
	VALUE	
	13/20	

TANK BUSTER

+ Fantastic build quality
+ Accurate flight control
+ Loads of features

TANK DUSTER

− Expensive
− Very heavy

SPEC

Axes 2

Throttle control Yes (dual)

HOTAS Yes

Buttons 36

Rudder control No

THRUSTMASTER T.1600M FCS HOTAS / **£140** inc VAT

SUPPLIER thrustmaster.com

The Thrustmaster T.1600M is a feature-packed HOTAS flight control system with a separate 3-axis joystick and throttle control. It doesn't look dissimilar to the Logitech Extreme 3D Pro with the addition of a throttle control, except this whole system is considerably more expensive than that controller, with the joystick alone costing nearly double the price of the Logitech.

What does that extra outlay get you, other than the throttle control? Well, for a start, the joystick is truly ambidextrous. All the buttons are arranged in mirror image and the additional single throttle slider (so you still get throttle control, even without the separate throttle control) is right in the middle. You can even swap out the contoured panels on the stick to use it in a left-handed configuration.

This ability to use the T.1600M in both left and right-handed configurations makes it a clear top choice for making a twin-stick space sim setup, sometime called a Hands On Stick And Stick (HOSAS) setup. Forget the throttle control, just buy two of these sticks and you're in space flight sim heaven.

Each stick houses an array of buttons at the top, consisting of a front trigger, one hat switch and three more buttons that can be activated by your thumb. That's not a huge selection but enough to get by.

The base of the joystick is also home to that throttle slider and a symmetrical array of 12 buttons, with six on each side. We found these buttons to be a little awkwardly placed and difficult to tell apart by feel alone, so they aren't ideal in some situations. That's less of a concern in a HOTAS or HOSAS setup, but it's not ideal for a single joystick setup.

Meanwhile, the separate throttle control uses an unusual linear sliding action where the whole unit glides forward and back on rails, rather than rotating about a point. That's not necessarily uncommon when compared with real-world plane throttles, but the pivoting type works better on flight sticks.

It also houses a rudder control at the front that you operate with your fingertips, along with three more hat switches for your thumb. On balance, it's a very well thought out addition to the main joystick, and the combination successfully covers all flight and space sim situations.

Getting back to the main joystick, it offers a largely similar feel to the Logitech Extreme 3D Pro, with just a touch more smoothness and precision. It's a relatively subtle difference, though, and along with the generally plasticky build, you feel like you should be getting more for your money.

SPEC

Axes 3

Throttle control Yes (single)

HOTAS Yes

Buttons 30

Rudder control Yes

SATURN 5
+ Three-axis control
+ Incredibly cheap
+ Loads of buttons
+ Throttle control

BOTTLE ROCKET
– Quite stiff
– Basic software

Conclusion

Offering a solid balance of features, versatility and price, the Thrustmaster T.1600M is a great option, whether you just need a joystick or want a more sophisticated HOTAS or HOSAS setup. Both the stick and throttle control offer loads of features and the stick being ambidextrous is a real boon. It's just a shame the overall build quality isn't a little better. For twice the cost of the Logitech Extreme 3D Pro, the T.1600M doesn't feel like a huge build quality upgrade. **CPC**

VERDICT

A very capable and versatile flight control ecosystem for a decent price, even if it looks and feels a little cheap and plasticky.

PERFORMANCE 31/40

FEATURES 40/40

VALUE 15/20

OVERALL SCORE **86**%

How we test

MOTHERBOARDS

TEST PROCESSORS
> **Intel LGA1200** Intel Core i9-10900K
> **Intel LGA2066** Intel Core i9-7900X
> **AMD AM4** AMD Ryzen 9 3900X
> **AMD TRX4** AMD Threadripper 3970X

Our test gear comprises a GeForce RTX 2070 Super Founders Edition and a 2TB Samsung 970 Pro SSD (or a PCI-E 4 1TB Corsair MP600 SSD on X570 and TRX40 boards). 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. All CPUs are cooled by a Corsair Hydro-X water-cooling loop, with two XR5 240mm radiators, an XD3 RGB reservoir and an XC7 RGB waterblock.

We test with our RealBench suite and Far Cry New Dawn on Windows 10 Home 64-bit. We also test the board's M.2 ports, and record the noise level and dynamic range of integrated audio using RightMark Audio Analyzer. Where possible, CPUs are overclocked and benchmarked again.

PROCESSORS

TEST MOTHERBOARDS
> **Intel LGA1200** MSI MEG Z490 Ace
> **Intel LGA2066** MSI MEG X299 Creation
> **AMD AM4** Gigabyte X570 Aorus Master
> **AMD AM4 (APU)** MSI X470 Gaming Pro Carbon
> **AMD TRX4** Asus ROG Zenith II Extreme
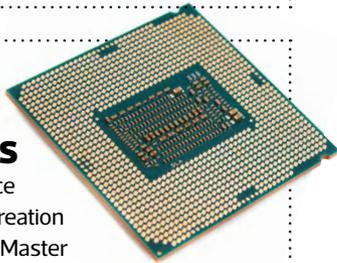
Our CPU test setup comprises a GeForce RTX 2070 Super Founders Edition (or an APU's integrated GPU), a 2TB Samsung 970 Pro SSD, and Corsair Vengeance RGB 3466MHz DDR4 memory – a 16GB dual-channel kit for mainstream systems, and a 32GB quad-channel kit for HEDT systems. A Corsair Hydro-X water-cooling loop, with two XR5 240mm radiators, an XD3 RGB reservoir and an XC7 RGB waterblock is also used.

We use Windows 10 Home 64-bit, and test with our RealBench suite, as well as Cinebench for 3D rendering and Adobe Premiere Pro for video export times. Far Cry New Dawn and Metro Exodus test gaming performance. Finally, we record the total power draw of the test PC. We run all tests at stock speed and at the highest stable overclocked frequency.

MONITORS

We test image quality with an X-Rite 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. For gaming, we test a monitor's responsiveness subjectively and then also use Blur Buster's excellent ghosting UFO test to check the sharpness of the display in high-speed motion.

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 4.8GHz with 1.2V vcore, Asus ROG Strix Z370-E Gaming 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, MSI X470 Gaming Pro Carbon AC motherboard.

AMD TRX4
AMD Threadripper 3960X overclocked to 4.2GHz with 1.265V vcore, 32GB of 3466MHz Corsair Vengeance RGB memory, Samsung 960 Pro SSD, Corsair RM850i PSU, ASRock TRX40 Taichi 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 ray tracing.

Every graphics card is tested in the same PC, so 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 can't produce playable frame rates at this setting.

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
Metro Exodus Tested at Ultra settings with Ultra ray tracing, but with Advanced PhysX and HairWorks disabled. We run the game's built-in benchmark, and report the 99th percentile and average frame rates.

Battlefield V Tested in DirectX 12 at Ultra settings on every card. If a GPU also supports real-time ray tracing, we then test it with DXR enabled on High settings with TAA, and also with DLSS if it's supported. We run through a one-minute custom benchmark in the 'Under No Flag' War Story, recording the 99th percentile and average frame rates with FrameView.

Shadow of the Tomb Raider Tested at the Highest settings preset with High ray-traced shadows enabled. We test with TAA, and also with DLSS if it's supported. We run the built-in benchmark and record the 99th percentile and average frame rates with OCAT.

Doom Eternal Tested at Ultra Nightmare settings, with resolution scaling disabled. We run a custom benchmark in the opening level of the campaign, and record the 99th percentile and average frame rates with FrameView.

POWER CONSUMPTION
We run Metro Exodus at Ultra settings with Ultra ray tracing at 2,560 x 1,440. We measure the power consumption of our whole graphics test rig at the mains during the test, and record the peak power draw. 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 5 3400G	scan.co.uk	#194 p20	£132
CPU COOLER	AMD Wraith air cooler included with CPU	N/A	#194 p20	£0
GRAPHICS CARD	AMD Radeon RX Vega 11 integrated into CPU	N/A	#194 p20	£0
MEMORY	16GB (2 x 8 GB) Corsair Vengeance LPX Pro 3200MHz (CMK16GX4M2 Z3200C16)	scan.co.uk	#204 p74	£65
MOTHERBOARD	Asus TUF B450M-Plus Gaming (micro-ATX)	awd-it.co.uk	#204 p74	£79
STORAGE	500GB WD Blue SN550 (M.2 NVMe)	scan.co.uk	#204 p24	£62
Total £338				

Budget gaming system

Quad-core CPU, 1080p gaming

Needs a micro-ATX or ATX case. We recommend a 450W 80 Plus power supply. See Issue 204, p74 for an example build guide.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 3 3300X	ebuyer.com	#203 p28	£120
CPU COOLER	ARCTIC Freezer 7 X	scan.co.uk	#202 p20	£18
GRAPHICS CARD	PowerColor Radeon RX 5600 XT	ebuyer.com	#204 p74	£255
MEMORY	16GB (2 x8GB) Corsair Vengeance LPX Pro 3200MHz (CMK16GX4M2Z 3200C16)	scan.co.uk	#204 p74	£65
MOTHERBOARD	Asus TUF B450M-Plus Gaming (micro-ATX)	awd-it.co.uk	#204 p74	£79
STORAGE	500GB WD Blue SN550 (M.2 NVMe)	scan.co.uk	#204 p24	£62
Total £599				

UPGRADES

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
SWAP GRAPHICS CARD	Nvidia GeForce RTX 2060 (1080p gaming with ray tracing and some 2,560 x 1,440 gaming)	scan.co.uk	#199 p50	£288
SWAP STORAGE	1TB WD Blue SN550 (M.2 NVMe)	scan.co.uk	#204 p24	£144

Entry-level RTX gaming system

6-core CPU, 2,560 x 1,440 gaming, real-time ray tracing at 1080p

Needs a micro-ATX or ATX case. We recommend a 550W 80 Plus Bronze power supply. See Issue 201, p76 for an example build guide.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 5 3600	scan.co.uk	#195 p16	£197
CPU COOLER	Antec Neptune 240	scan.co.uk	#204 p16	£80
GRAPHICS CARD	Zotac GeForce RTX 2060 Super Mini	ebuyer.com	#199 p53	£365
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3466MHz (CMW16GX4 M2C3466C16)	scan.co.uk	#201 p76	£124
MOTHERBOARD	MSI MAG B550M Mortar (micro-ATX)	ebuyer.com	#204 p42	£140
STORAGE	500GB WD Blue SN550 (M.2 NVMe)	scan.co.uk	#204 p24	£62

Total £968

UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 2070 Super*	scan.co.uk	#193 p16	£434
ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	#166 p54	£95
SWAP STORAGE	1TB WD Blue SN550 (M.2 NVMe)	scan.co.uk	#204 p24	£114

We recommend waiting until the launch of the GeForce RTX 3070 before making a GPU purchase in this price league.

Mid-range gaming system

8-core CPU, 2,560 x 1,440 gaming with real-time ray tracing, and some 4K gaming

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	scan.co.uk	#200 p51	£299
CPU COOLER	Antec Neptune 240	scan.co.uk	#204 p16	£80
GRAPHICS CARD	Nvidia GeForce RTX 2070 Super*	scan.co.uk	#193 p16	£434
MEMORY	16GB (2 x 8GB) ADATA XPG Spectrix D60G 3600MHz (AX4U3600 38G17-DT60)	amazon.co.uk	#199 p57	£129
MOTHERBOARD	Asus ROG Strix X570-E Gaming (ATX)	overclockers.co.uk	#193 p44	£290
STORAGE	1TB Corsair MP600	scan.co.uk	#193 p26	£176

Total £1,408

UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	#166 p54	£95
SWAP CPU COOLER	Corsair H100i RGB Platinum (240mm AIO liquid cooler)	scan.co.uk	#185 p82	£110

We recommend waiting until the launch of the GeForce RTX 3070 before making a GPU purchase in this price league.

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 3900XT	overclockers.co.uk	#205 p18	£480
CPU COOLER	Corsair H100i RGB Platinum (240mm AIO liquid cooler)	scan.co.uk	#175 p20	£110
GRAPHICS CARD	Nvidia GeForce RTX 3080 Founders Edition	nvidia.com	#207 p16	£649
MEMORY	16GB (2 x 8GB) ADATA XPG Spectrix D60G 3600MHz (AX4U3600 38G17-DT60)	amazon.co.uk	#199 p57	£129
MOTHERBOARD	MSI Prestige X570 Creation (E-ATX)	overclockers.co.uk	#193 p48	£440
STORAGE	1TB Corsair MP600	scan.co.uk	#193 p26	£176
	Total £1,984			
UPGRADES				
ADD SECONDARY STORAGE	4TB Western Digital Blue	overclockers.co.uk	#166 p54	£95
SWAP CPU	AMD Ryzen 9 3950X (16 cores)	scan.co.uk	#197 p24	£690

Heavy multi-threading workstation

Serious multi-threaded power, 1080p gaming

Needs an E-ATX case with room for a 240mm all-in-one liquid cooler. We recommend a 750W 80 Plus Gold power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Threadripper 3960X	scan.co.uk	#197 p18	£1,240
CPU COOLER	NZXT Kraken X63 (280mm AIO liquid cooler)	overclockers.co.uk	#207 p47	£135
GRAPHICS CARD	Nvidia GeForce GTX 1660 Super	ebuyer.com	#199 p46	£190
MEMORY	32GB (4 x 8GB) Corsair Dominator Platinum RGB 3600MHz	scan.co.uk	#197 p20	£279
MOTHERBOARD	ASRock TRX40 Taichi (E-ATX)	overclockers.co.uk	#198 p44	£470
STORAGE	1TB Corsair MP600	scan.co.uk	#193 p26	£176
	Total £2,490			
UPGRADES				
SWAP GRAPHICS CARD	Nvidia GeForce RTX 3080 Founders Edition (4K gaming with real-time ray tracing)	nvidia.co.uk	#207 p16	£649
SWAP CPU	AMD Threadripper 3970X (32 cores - massive multi-threaded power)	scan.co.uk	#197 p19	£1,810
ADD SECONDARY STORAGE	4TB Western Digital Blue	cclonline.com	#166 p50	£95

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 Z490 (LGA1200)	Asus ROG Strix Z490-I Gaming	scan.co.uk	#206 p40	£286
AMD B550 (AM4 budget)	Asus ROG Strix B550-I Gaming	overclockers.co.uk	#206 p44	£210
AMD X570 (AM4 mid-range)	Asus ROG Strix X570-I Gaming	overclockers.co.uk	#198 p20	£290

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ALL-PURPOSE	Cooler Master MasterBox NR200P	overclockers.co.uk	#206 p18	£90
MID-RANGE	Phanteks Enthoo Evolv Shift Air	overclockers.co.uk	#195 p49	£95
PREMIUM	NZXT H1	scan.co.uk	#201 p24	£299

CPU coolers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
LOW-PROFILE	Noctua NH-D9L	amazon.co.uk	#143 p17	£54

Micro-ATX

Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
AMD X399 (TR4)	ASRock X399M Taichi	scan.co.uk	#179 p28	£320
AMD B550 (AM4)	MSI MAG B550M Mortar	ebuyer.com	#204 p42	£140

Cases

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

ATX cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Phanteks Eclipse P300 Glass	overclockers.co.uk	#176 p28	£55
BUDGET QUIET	be quiet! Pure Base 500	scan.co.uk	#196 p24	£70
SUB-£100	be quiet! Pure Base 500DX	overclockers.co.uk	#202 p39	£99
COMPACT	Fractal Design Define 7 Compact	scan.co.uk	#203 p32	£100
MID-RANGE	Phanteks Eclipse P600S	overclockers.co.uk	#202 p44	£128
SUB-£150	Fractal Design Define 7	overclockers.co.uk	#204 p18	£149
PREMIUM	Phanteks Enthoo Evolv X	overclockers.co.uk	#187 p24	£200

Networking

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ROUTER (WI-FI 6)	TP-Link Archer AX6000	overclockers.co.uk	#196 p57	£280
MESH ROUTER (WI-FI 6)	Asus AiMesh AX6100	amazon.co.uk	#196 p54	£336
WI-FI ADAPTOR	TP-Link Archer TX3000E	overclockers.co.uk	#196 p58	£50
SINGLE-BAY NAS BOX	Synology DS118	box.co.uk	#174 p34	£155
DUAL-BAY NAS BOX	Synology DS220j	box.co.uk	#200 p22	£152
DUAL-BAY MEDIA NAS BOX	Synology DS218play	box.co.uk	#174 p34	£217

Monitors

F – FREESYNC, G – G-SYNC, W – ULTRAWIDE

Up to 24in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN, 144Hz, TN, 1,920 x 1,080, F, G	AOC G2590FX	scan.co.uk	#190 p53	£178
24IN, 144Hz, VA, 1,920 x 1,080, F	AOC C24G1	cclonline.com	#191 p28	£183
24IN, 165Hz, TN, 2,560 x 1,440, G	AOC AGON AG241QG	amazon.co.uk	#169 p55	£500

Up to 28in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN, 144Hz, IPS, 1,920 x 1,080, F, G	AOC 27G2U	scan.co.uk	#201 p53	£230
27IN, 165Hz, VA, 2,560 x 1,440, F	MSI Optix MAG272CQR	box.co.uk	#201 p28	£399
27IN, 240Hz, IPS, 1,920 X 1,080, F, G	Acer Nitro XV273	alza.co.uk	#204 p25	£383
27IN, 144Hz, IPS, 2,560 x 1,440, F, G	Asus TUF Gaming VG27AQ	overclockers.co.uk	#201 p54	£450
27IN, 165Hz, IPS, 2,560 x 1,440, F, G	Gigabyte Aorus FI27Q	overclockers.co.uk	#201 p55	£450
27IN, 240Hz, TN, 2,560 x 1,440, F, G	AOC AG273QZ	overclockers.co.uk	#202 p27	£280

Over 28in

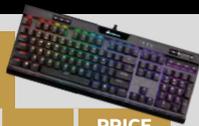| CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
31.5IN, 60Hz, VA, 4K, F	iiyama ProLite XB3288UHSU	scan.co.uk	#205 p43	£350
34IN, 144Hz, IPS, 3,440 x 1,440, W, F	iiyama G-Master GB3461WQSU	cclonline.com	#206 p53	£396
34IN, 144Hz, IPS, 3,440 x 1,440, W, F, G	LG UltraGear 34GN850	overclockers.co.uk	#206 p55	£970
35IN, 200Hz, VA, 3,440 x 1,440, W, G, HDR	Asus ROG Swift PG35VQ	scan.co.uk	#198 p58	£2,499
43IN, 120Hz, VA, 4K, F, G	Asus ROG Strix XG438Q	amazon.co.uk	#205 p39	£1,005

Non-gaming

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN, 60Hz, IPS, 4K	AOC U2790PQU	amazon.co.uk	#194 p30	£348

Peripherals and audio

Gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
MEMBRANE	Corsair K55 RGB	amazon.co.uk	#201 p45	£50
BUDGET MECHANICAL TENKEYLESS	HyperX Alloy FPS Pro	amazon.co.uk	#201 p46	£63
MECHANICAL	Corsair K68 RGB	overclockers.co.uk	#181 p53	£100
MECHANICAL MMO	Corsair K95 RGB Platinum	overclockers.co.uk	#164 p26	£150
PREMIUM MECHANICAL	Corsair K70 Mk.2 Low Profile	scan.co.uk	#193 p56	£150
PREMIUM MECHANICAL TENKEYLESS	Asus ROG Strix Scope TKL Deluxe	scan.co.uk	#202 p24	£140
LUXURY MECHANICAL	Razer Hunstman Elite	box.co.uk	#193 p59	£185

Gaming mice

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET GAMING	Corsair M55 RGB Pro	amazon.co.uk	#200 p24	£30
FIRST-PERSON SHOOTER	SteelSeries Rival 600	box.co.uk	#184 p59	£65
MMO	Razer Naga Trinity	scan.co.uk	#186 p52	£80
WIRELESS	Corsair Dark Core RGB Pro	amazon.co.uk	#202 p25	£90
AMBIDEXTROUS	Razer Lancehead Tournament Edition	amazon.co.uk	#177 p53	£75
ULTRA LIGHTWEIGHT	Glorious PC Gaming Race Model O	overclockers.co.uk	#195 p58	£53

Peripherals and audio cont ...

Game controllers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
RACING WHEEL	Logitech G29 Driving Force	argos.co.uk	#202 p50	£230
PREMIUM RACING WHEEL	Fanatec CSL Elite PS4 Starter Kit	fanatec.com	#202 p49	~£453
GAMEPAD	Microsoft Xbox One Wireless Controller	argos.co.uk	#191 p56	£50
BUDGET FLIGHT STICK	Logitech Extreme 3D Pro Joystick	currys.co.uk	#207 p52	£35
FLIGHT STICK	Thrustmaster T.1600M FCS HOTAS	thrustmaster.com	#207 p56	£140

Gaming headsets

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
STEREO	Sennheiser GSP 300	amazon.co.uk	#194 p56	£88
SURROUND	Asus ROG Centurion	cclonline.com	#163 p49	£171
WIRELESS	Corsair Virtuoso RGB Wireless	ebuyer.com	#204 p50	£160

Speakers

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

Non-gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
WIRELESS MULTI-DEVICE	Logitech K780	ebuyer.com	#203 p58	£62
TENKEYLESS MECHANICAL	Majestouch Convertible 2 Tenkeyless	keyboardco.com	#203 p55	£140

PCs and laptops

Pre-built PC systems

CATEGORY	NAME	CPU	GPU	SUPPLIER	ISSUE	PRICE (inc VAT)
ENTRY-LEVEL RTX GAMING	PC Specialist Magma R2	AMD Ryzen 5 3600XT stock speed	Nvidia GeForce RTX 2060 Super	pcspecialist.co.uk	#205 p30	£1,324
8-CORE GAMING	Wired2Fire Predator	AMD Ryzen 7 3700X stock speed	Nvidia GeForce RTX 2060 Super	wired2fire.co.uk	#196 p40	£1,411
GEFORCE RTX 3080 GAMING	Scan 3XS Vengeance XTi iCUE	AMD Ryzen 9 3900X stock speed	Nvidia GeForce RTX 3080	scan.co.uk	#207 p34	£2,400
PREMIUM MINI-ITX	Corsair One i160	Intel Core i9-9900K stock speed	Nvidia GeForce RTX 2080 Ti	corsair.com	#190 p32	£3,250
WATER-COOLED 16-CORE GAMING	CyberPower Hyper Liquid Ultra 9 RTX	AMD Ryzen 9 3950X stock speed	Nvidia GeForce RTX 3080	cyberpowersystem.co.uk	#203 p38	£3,196
DREAM PC	Scan 3XS Barracuda	Intel Core i9-10980XE OC to 4.3GHz	Nvidia GeForce RTX 3090	scan.co.uk	#145 p58	£13,694

Laptops

CATEGORY	NAME	CPU	GPU	SCREEN	SUPPLIER	ISSUE	PRICE (inc VAT)
THIN AND LIGHT GAMING	Asus ROG Zephyrus G14 GA401IV	AMD Ryzen 9 4900HS stock speed	Nvidia GeForce RTX 2060 Max-Q	14in 2,450 x 1,440 IPS 60Hz	overclockers.co.uk	#202 p28	£1,800
GAMING	Chillblast Phantom 17	Intel Core i7-9750H stock speed	Nvidia GeForce RTX 2070	17.3in 1,920 x 1,080 IPS 144Hz	chillblast.com	#197 p53	£1,790

Games

RICK LANE / INVERSE LOOK

A GOLDEN AGE

Now is the best time ever to be a PC gamer, argues Rick Lane

It's amazing what can change in a decade. Ten years ago, PC gaming was laden with a sense of foreboding. Console gaming was riding high, and manufacturers were pushing platform exclusivity hard. This situation left the PC without many of the biggest mainstream releases, including the likes of Halo, Fable and Metal Gear Solid among many others.

Meanwhile, many of the PC's most successful gaming genres – first-person shooters, real-time strategy games and MMOs – seemed to be slowly dying out, as the developers who normally made those games instead focused on catering to a broader, multi-platform audience.

Microsoft in particular appeared determined to paint itself as the villain here. Not only did it largely neglect the PC in favour of the Xbox (an ecosystem over which the company has full control), but what little attention it gave to PC gaming seemed hostile and draconian. Microsoft lumbered many of the best PC games, including BioShock, Gears of War and Grand Theft Auto IV, with the miserable Games for Windows Live Service. It was a vain attempt to protect a portion of the PC market against the growing ubiquity of Steam.

Today, the situation couldn't be more different. Rather than avoiding the PC, most publishers and manufacturers can't seem to get enough games onto it. Microsoft has performed a complete about-face on its PC gaming policy. Not only is the company releasing many of its games onto Steam (including the new Flight Simulator and the upcoming Halo Infinite), but the Xbox Game Pass service also provides access to

> ## Microsoft has performed a complete about-face on its PC gaming policy

a huge array of games for an astonishingly low price. Microsoft has even announced that all console exclusives for the Xbox will be available on Game Pass at launch, potentially saving players hundreds of pounds.

But it isn't only Microsoft whose attitude has warmed to the PC. One of the PC's most surprising advocates over the past ten years has been Sega. Not only is Sega now one of the PC's key strategy publishers, owning both The Creative Assembly and Relic Entertainment (creators of Total War and Dawn of War), but it's also ported a whole bunch of Japanese console games that would never had made it to PC otherwise, including the likes of Vanquish, Bayonetta and the hugely popular Yakuza and Persona series.

Even Sony, whose incredible line of exclusives has helped the PS4 to dominate this console cycle, has begun slowly drip-feeding its games onto the PC. July saw the launch of Death Stranding on PC, while Horizon: Zero Dawn released onto PC in August. This is partly due to the success of PlayStation Now, Sony's game-streaming subscription service for PlayStation, which also has a PC app.

Meanwhile, the PC is also riding high with its own exclusive game distribution services, with Steam's nigh-constant sales, the Epic Store's weekly free games and Gog's dutiful curation of the PC's classic library. The PC has become a gaming cornucopia, offering play in abundance often for little or even no money at all. We've come a long way since the dark days of Games for Windows Live, and the PC now offers the broadest access to games of any system in existence. **CPC**

Rick Lane is Custom PC's games editor ✦ @Rick_Lane

A Total War Saga: Troy / **£29.99** inc VAT

DEVELOPER Creative Assembly Sofia / **PUBLISHER** Sega

The Iliad might be Western Literature's original war story, but Homer's poem is as much a character drama as an epic military tale. It's not so much about Achaea vs Troy, but Agamemnon vs Priam, for example. Thankfully, A Total War Saga: Troy understands the importance of character in the Trojan War, featuring an excellent, personality-driven campaign.

You can choose one of several heroes on either side of the Trojan war, with your goal ultimately being either the capture or defence of Troy. Each hero has their own unique play style that dramatically alters the slant of the campaign. Achilles, for example, is a master warrior, but he's unable to temper his emotions, and his violent mood swings can dramatically affect the strength of both his army and his economy. As a result, you end up with highly distinctive campaigns that effectively capture each character's perspective of the Trojan War.

This is one of several ways Creative Assembly Sofia has tweaked Total War's formula to better suit its pseudo-historical setting. The game's economy is also based on bartering resources. Each non-city settlement produces one of five resource types. Acquiring a regular influx of all five can be difficult, but you can trade your surplus resources with other factions to balance it out, resulting in clear, straightforward and engaging economy management.

As for battles, Troy lets you recruit 'mythical' units into your army, including spear-throwing harpies, giants from Euboea and even the Minotaur. However, while these units are superpowered, they're not supernatural. Troy lends a human perspective to Greek myth, so giants are simply extremely large soldiers, while the Minotaur is an even bigger soldier wearing a cow skull as a helmet. It's an intriguing interpretation that fits well with the game's attempt to ground Homeric legend in reality.

Despite minimal military technology, Troy's battles are also enjoyable and have surprising tactical depth. There's a wide variety of infantry units and some of the best battle maps the series has ever seen. That said, Troy does suffer from a few vulnerabilities in the foot department. The new trading system results in constant pestering for resources by the AI, to the point where it becomes exhausting. Also, while Troy's battles are excellent, the lack of siege equipment makes sieges slow and nasty meat grinders.

Finally, although the individual characters are great, there's little meaningful interaction between them. Compared with Three Kingdoms, Troy's diplomacy and relationship systems are sorely undercooked, which means the whole conflicts ends up feeling rather cold and dispassionate.

A Total War Saga: Troy doesn't quite capture the emotion that drives the Homeric poems detailing the Trojan War, but it's still a smartly constructed and interesting take on the Total War formula that's well worth investigating if you're an aficionado of the series.

RICK LANE

TROJAN HORSE

+ Great battles

+ Character-driven factions

+ Interesting mythical units

ACHILLES HEEL

− Bothersome campaign AI

− Boring sieges

− No character relationship systems

/ VERDICT

A Total War Saga: Troy presents a cold but enjoyable spin on the Trojan War.

OVERALL SCORE

80%

Microsoft Flight Simulator / **£59.99** inc VAT

DEVELOPER Asobo Studio / **PUBLISHER** Xbox Game Studios

FLIGHT SIMULATOR

+ Incredible, to-scale recreation of Earth
+ Surprisingly accessible
+ Great flying

FRIGHT STIMULATOR

− Smaller environmental details often wrong
− Not much set content

I t's hard to create simulation games with mass appeal, because simulators by their nature expect the player to already be interested in the experience being simulated. Whether it's a hyper-realistic racer, a railway sim or a war game, simulation games are geared towards people who want the full, unfiltered experience of a specific part of life, and don't need any persuasion as to why that might be entertaining.

Microsoft Flight Simulator is different. This latest iteration of one of the pillars of PC gaming truly is an experience designed for everyone. Not only that, but its mass appeal doesn't come at the cost of the enthusiast audience. Its simulation of flight is as true and dedicated as that of any other game in the series.

The difference between this Flight Simulator and previous versions is that it isn't simply a game about flying. It's specifically a game about flying anywhere you want. Flight Simulator lets you pick any location on the planet – any airport, any city, any place you can imagine, and fly to it, from it, around it and over it. It puts the world outside your cockpit, and lets you spin it to any point that pleases you.

As a feat of technology, Flight Simulator is astounding. The exact nature of how it all works is complicated, but the basic process is that Flight Simulator combines data from Microsoft's Bing Maps satellite mapping, with a series of algorithms designed to simulate weather, light conditions, terrain elevation and building generation. The result is that Flight Simulator can take the imagery from Bing maps, give it the appropriate vertical relief, populate it with trees, buildings, vehicles and so on, and then stream the resulting image to your PC.

In this way, Flight Simulator lets you fly across an astonishingly accurate representation of the entire globe, and that's not all. While the game fills in most small details with algorithmic broad strokes, 341 of the world's cities have been recreated with photorealistic precision. The game also draws from real air traffic data to populate its skies with AI planes. You can even sync the game's weather up to real satellite data, flying through accurately simulated cloud banks, storms and even hurricanes.

The result is a tantalising virtual sandbox. Want to conduct an airborne tour of the city of London? You can do that. Want to fly over some of the world's great monuments? The Pyramids of Giza, the Golden Gate Bridge, the Hagia Sofia? You can do that. Want to tick off every Formula 1 racetrack, the world's highest mountains and the great river deltas? You can do all of those and countless more. Aside from having to fly the plane, there's no barrier to entry either. Once the game launches, you can click on any spot on the globe, hit 'Fly' and you'll spawn instantly in mid-air over your chosen location.

Whether or not you're a plane enthusiast, Flight Simulator's ability to satisfy your inner explorer is phenomenal. If you want to get the most out of it, however, at some point you're going to have to learn how to handle the game's steel birds. To that end, Flight Simulator offers an eight-mission Flight School that teaches you the basics of flight in a classic Cessna 152.

Lessons range from maintaining heading and altitude, to take-offs, landings and holding patterns, right up to your first complete flight. Flight Sim also lets you adjust the realism of the simulation to your current ability, enabling you to add or take away specific flight and navigation aids as you like.

Once you've got a handle on the basics, you can start thinking about flying. Again, Flight Simulator is flexible here, letting you perform full flight checks and start-ups on the airport tarmac, before taxiing to your position in the queue. You can start on the runway, or even in mid-air.

Then there are the planes themselves – 20 different vehicles, each with a unique flight model and cockpit instrumentation. Smaller planes, such as the Cessna 152 and Daher TBM 930, are easier to handle for a new pilot, but are also more fickle in bad weather, prone to being buffeted around by the elements. Compare that with the Boeing 747 and Airbus A380, which are extremely stable in flight, assuming you can get them up off the tarmac.

As both a demonstration of technology and a representation of flight, Flight Simulator is peerless. In terms of play, your enjoyment will depend on your inventiveness. Beyond the flight school, the only real structure is a handful of challenges designed to test your general flying skills and navigational abilities.

After that, it's up to you to create your own fun. You're not going to be starting your own private courier service, or doing side-quests as a stunt pilot. If you like your games to come with well-established progression ladders then you may find Flight Simulator's freewheeling approach rather unsatisfying.

Similarly, Flight Simulator isn't always a thrilling experience. Like actual flight, it can be monotonous at times. If you're spending nine hours crossing the Atlantic, don't expect the game to be pelting you with turbulence and bird-strikes every five minutes. The game does all it can to let you skip the boring bits if you want though – you can fast-forward longer flights, for example.

Also, while the game's recreation of the globe is a phenomenal achievement, not every location is equally well served. The algorithm regularly gets smaller details wrong, especially when it comes to figuring out specific building types. You'll see bridges descending underwater, and British castles and heritage sites represented as apartment blocks.

In addition, although the game controls work wonderfully on an Xbox pad, playing with a keyboard and mouse requires constant nudging of the plane's speed and altitude to keep it steady. As for using flight sticks and rudder-pedals, the quality of the experience will vary depending on the type you buy. Importantly, not all flight sticks are compatible with the game, so do your research before you spend any money (see our flight stick Labs test on p50).

In the end, though, it's impossible not to be bowled over by Flight Simulator's astonishing technical achievement. Having a photo-realistic recreation of the entire world at your fingertips is a truly wonderful relaxation device, with the ability to hop in a Beechcraft Bonanza and fly over the Alps, or twist and turn your way through the Grand Canyon in an Aviat Pitts Special. At a time when travelling is especially difficult and perilous, Flight Sim's virtual globe couldn't be any more welcome.

RICK LANE

/ **VERDICT**

Bolstered by technology that's nothing short of miraculous, Flight Simulator is back and better than ever.

OVERALL SCORE

90%

FACTORIO / £21 inc VAT

DEVELOPER Wube Software / **PUBLISHER** Wube Software

FACTORY
+ Ingenious concept
+ Engrossing, self-perpetuated puzzles
+ Look, it's just great, alright?

SCHMACTORY
− Visual perspective can obscure problems
− Combat a mixed bag

/ VERDICT

A stunningly designed build-your-own-puzzler, Factorio is a managerial masterpiece.

OVERALL SCORE

91%

Factorio is one of the best management sims in years. You play an explorer whose spaceship crashes onto a remote planet rich in resources. To escape, you need to construct a new rocket-ship and, to stand a chance of success, you need to automate the process, building assembly lines to carry resources to special machines that craft objects for you.

Factorio's focus on production and automation is what makes it special. Rather than crafting individual objects, you instead create self-perpetuating processes. A basic assembly line involves three key items – assembling machines that create objects, conveyor belts that transport resources to assembly machines, and inserters that connect conveyor belts to assemblers.

At the outset, establishing production chains is simple enough. To make iron plate, for example, you need a mining drill to mine resources, a furnace to smelt the iron ore into plate and a fuel source such as coal (which also needs to be mined from the ground). Iron plate, however, is used to make many other objects, so you need a way to transport large quantities of it around your factory.
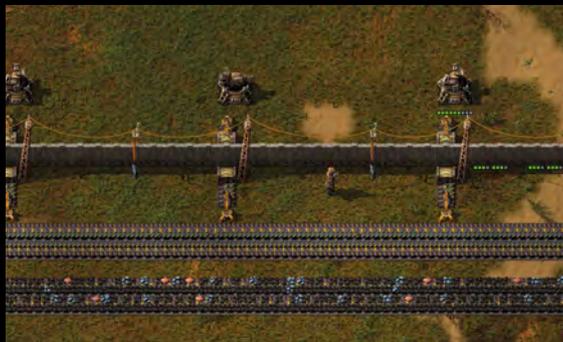
Many important items also require steel, which is made by smelting five iron plates in a separate furnace, so you need individual production lines for both iron plate and steel. You need to ensure there's enough of the former to make the latter, but that there's also enough iron plate to make the other objects you need. That's an extremely basic example of what Factorio involves.

Each new object you create is more complex than the last, requiring larger amounts of a wider variety of resources. The midgame involves building pumpjacks to pump oil from the ground, alongside oil refineries and chemical plants to transform it into new products, while the late game sees you building nuclear plants powered by uranium for even more complicated production.

Each new assembly line is a logic puzzle that you create for yourself to solve and, as your factory grows, these puzzles become ever trickier and more elaborate. It's a combination that's scarily absorbing. There are always new objects and materials to create, improve or fix. At the end of all that, you get the payoff of seeing a new production line kick into motion. Watching every component click and whir as plastic or sulphur rolls onto your conveyors for the first time is spellbinding.

There are a few minor problems. The top-down perspective can sometimes obscure problems in your factory (such as missing conveyor belts jamming up production). Meanwhile, the insectoid enemies who attack your base when it generates too much pollution can be a nuisance, although the game's engagement with the environmental problems created by mass production should be applauded. These are minor niggles though. Overall, Factorio is inspired, a management extravaganza that will have you playing into the small hours for days on end.

RICK LANE

IRON HARVEST / £ 44.99 inc VAT

DEVELOPER King Art Games / **PUBLISHER** Deep Silver

A spiritual successor to Relic's Company of Heroes, Iron Harvest asks 'what if World War I had mechs in it?' The answer, apparently, is that the Russian Revolution never happens, Poland is annexed by Russia as part of its truce with Germany, and Nikola Tesla becomes one of the most sought-after military minds on the planet.

That's the setup for the lavish strategy campaign, where you can play as three different factions duking it out as the fragile Armistice between the war's eastern powers (alternatively named Rusviet, Saxony and Polania) teeters on the brink of collapse. A typical mission sees two factions battling over control points scattered across an isometric map. These control points generate resources you can use to construct new buildings and units, with the ultimate goal of destroying the enemy base.

Core play is similar to Company of Heroes, with players deploying a mixture of infantry, armour and artillery as they attempt to dominate the battlefield. Whereas Company of Heroes had tanks, Iron Harvest has giant, diesel-powered mechs. They're wonderfully designed, deliberately ramshackle creations, ranging from small anti-infantry units, such as the Polanian Smialy (basically a giant

metal rifleman), to hulking mech-destroyers such as the Rusvian Gulay-Gorod.

Iron Harvest's presentation is generally excellent. When combat is in full swing, it's a truly mighty spectacle. Large mechs are armed with thunderous artillery cannons that can reshape the entire battlefield, obliterating streets into craters and destroying entire buildings. One campaign mission sees you guiding a 'Battle Train' armed with an enormous artillery gun through a mountain pass. More broadly, the campaign tells an interesting, character-driven story, complete with fully voiced and animated cutscenes. The only disappointment is the script; while earnestly written, it's also corny and cliched.

There's a wide range of tactical options. Many infantry units act as direct counters to other unit types. Flamethrower units, for example, will annihilate all other infantry, but are next to useless against mechs. Anti-mech gunners, meanwhile, can pulverise enemy mechs with their hand-cannons, but lack the accuracy to do sustained damage to infantry. All units also have special abilities that can change the course of a fight if deployed correctly.

Unfortunately, the arrival of larger mechs onto the battlefield brings problems. Their obscene power reduces fights to gigantic slugging matches, nullifying much of the game's tactical depth. Large mechs are also slower than a treacle waterslide, taking several minutes to get to whatever battle is currently raging. Combined with the lack of tactical variety in commanding large mechs, this means the endgame fights become ponderous battles of attrition.

Iron Harvest can't quite match the pacing and refinement of Relic's strategy masterpiece, but it remains a spectacular and frequently thrilling strategy experience in its own right.

RICK LANE

IRON HARVEST

+ Awesome mechs
+ Spectacular combat
+ Lavish campaign

IRON DEFICIENCY

− Clumsy writing
− Bigger mechs lack tactical variety
− Slow endgame

/ VERDICT

Iron Harvest isn't the sprightliest strategy game around, but it's one of the most spectacular.

OVERALL SCORE

82%

REALITY CHECK

Rick Lane readies his bow to shoot out the latest happenings in the VR world

IN DEATH: UNCHAINED / £22.99 inc VAT

DEVELOPER Superbright / **PUBLISHER** Superbright

Originally released in 2018, In Death was a granite-hard fantasy rogue-like game that saw players battling enemies with a bow and arrows in a randomly generated, dark Gothic world. In Death: Unchained is an Oculus Quest-exclusive version of that game, which simultaneously improves and diminishes the core In Death experience.

As demonstrated by Apex Construct and Valve's The Lab, archery lends itself naturally as a VR mechanic, and In Death: Unchained does a great job of replicating what makes virtual archery so enjoyable. You must learn how to draw your bow and aim accurately, as arrows can pass between a zombie's legs or thunk into the shields of templar Knights. The combat engine also has a real sense of weight into it. You can feel the force of arrows as they fly from your bow and strike the target.

Aside from the nuanced bow shooting, what mainly distinguishes In Death: Unchained from other VR shooters is that it's extremely challenging. The game minimises story and narrative elements to focus squarely on its brutal and challenging combat. While wielding a bow gives you the advantage of range, it puts you at a disadvantage in close combat, and there are often far more enemies than you can feasibly keep at bay.

The game does provide you with a shield to block incoming attacks, and occasionally lets you refill your health bar, but for the most part, it's seriously challenging. At times it leans too hard on the player too soon, making the game's later areas difficult to access.

In Death: Unchained is specifically an Oculus Quest-exclusive version of the game, and the port results in some changes that both positively and negatively affect play. On the positive side, you're no longer attached to your computer by a cable trailing around your ankles. This game involves *a lot* of dodging.

On the downside, the game suffers from a slight visual downgrade, primarily in terms of draw distance, making it harder to identify and shoot targets at long range. Nonetheless, it remains an impressive VR spectacle – the towering Gothic architecture looks fantastic in stereoscopic 3D.

In Death: Unchained's main issue is that, in a rare instance, the Oculus Quest's inside-out tracking system is a hindrance rather than a help. A bow is normally drawn back to your shoulder, but the Quest's built-in cameras sometimes struggle to track your hand to this position, meaning you can't always fire the bow at a natural angle. You can still play the game well enough, but the sense of immersion is rather diminished.

It's unfortunate that the Quest can't consistently replicate a standard bow-shooting action, because the liberation it offers in terms of movement does make for a slightly easier and more enjoyable experience than the original game. Despite this limitation, though, in the end, like the weapon on which it's based, In Death: Unchained remains simple and effective.

UNCHAINED

+ Great bow combat
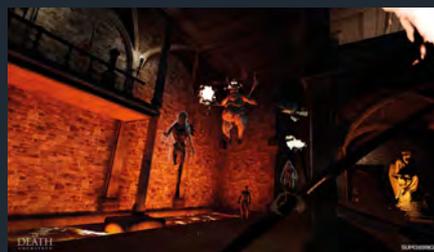+ Impressive environments
+ Quest brings extra freedom

UNHINGED

− Too hard
− Quest makes bow control harder
− Slight visual downgrade compared with Rift version

VERDICT

In Death: Unchained makes for an entertaining, if imposingly difficult, fantasy bow shooter.

OVERALL SCORE

70%

GNOMES & GOBLINS

Gnomes & Goblins is an unusual VR project conceived by Jon Favreau, director of films such as Iron Man and the showrunner of Disney's The Mandalorian series. It's a fantasy adventure in which players explore an enchanted woodland, home to the titular magical creatures, and it's due for release by the time you read this.

Sitting halfway between a game and an interactive narrative experience, Gnomes & Goblins blends exploration with a spot of Stardew Valley-style farming. The cute little gnomes have distinctive personalities, and you can help them turn their forest glade into a little fruit farm, digging irrigation ditches and seeding the land so that strawberries and other fruit can grow. You can also go boating down rivers with your new forest pals and participate in games such as axe throwing.

In development for over four years, visually Gnomes & Goblins looks superb, brimming with detail and sporting a Fable-like fairy tale vibe. A short preview version of the game released in 2016 offered a taste of what Gnomes & Goblins hopes to offer. It's undoubtedly pretty and relaxing, but it appears to be more of a light sequence of minigames strung together by story than a more systemic experience.

This isn't necessarily a problem – it worked well enough for Star Wars: Vader Immortal. Nonetheless, VR games have evolved considerably in the past few years, so we've yet to see whether the game's light puzzling and management will be enough to satisfy a more seasoned VR audience. **CPC**

OPINION
VIRTUAL HOBBIES

Most of the discussion around VR either focuses on the hardware itself or its scope for entertainment, but VR also has considerable practical potential. Its acute simulation of manual dexterity means that, in theory, it can be used as a training tool for any skill that involves complex use of your hands. There are some professional-grade examples already, such as VR training software for surgeons, but it could go further, with software that caters for hobbyists and enthusiasts.

A surprisingly popular game on Steam is PC Building Simulator (pictured), which lets you build virtual PCs out of virtual components – it sold 100,000 copies in its first month when it launched in 2018. It's a fun game in its own right, but it's also useful as a tool for learning how to build a PC without the risk of accidentally frying expensive components.

That said, anyone who has a built a PC before will know that the hands-on experience is quite different from the theory. Having a VR version would let users get hands-on with each component, learning how to screw in the motherboard, install your CPU, slot in each component and wire it all up properly.

This approach could be applied to virtually any form of manual skill or hobby, including car mechanics, woodworking and even painting models. VR could help you learn these skills, or practise specific projects, without the risk of ruining the end result. Imagine being able to test paints and styles for Warhammer models before committing them to plastic, or do a run-through of a Lego build before moving onto the real thing.

INSIDE AMPERE

NVIDIA'S GEFORCE RTX 3080 HAS STOMPED ALL OVER ITS PREDECESSORS, BUT WHAT MAKES IT TICK? **MARK SIMPSON** TAKES A DEEP DIVE INTO NVIDIA'S AMPERE ARCHITECTURE

Two years ago, Nvidia's mighty Turing architecture brought acceleration for ray tracing to games, introducing the gaming world to the wonderfully realistic lighting, reflections and shadows of the movies. However, because ray tracing is such a different kind of computational problem to solve compared with traditional rasterised graphics, it has a totally different data flow and a comparative lack of ability to lean on the processing parallelism inherent to modern GPUs.

Turing — and indeed any GPU design that wants to solve the same problem, including Ampere — had to be constructed in a particular way, which caused compromises in the design for regular workloads that don't need ray tracing. Thanks to the comparatively large process node used to make Turing GPUs, they also consumed more power and took up more space than many people expected.

What's more, Nvidia passed a large chunk of the cost of its investment in hardware accelerated ray tracing to you, the graphics enthusiast. So not only were Turing GPUs comparatively big, hot and power-hungry, but they were also expensive, and shockingly so for some of the high-end models.

Headline performance from the microarchitecture for non-ray-traced workloads was still incredibly strong, however, and in the absence of strong competition, Nvidia has had the top of the graphics product stack to itself for the past couple of years – it's even managed to carry on and develop the Ampere microarchitecture before AMD or Intel had a chance to fire back against Turing.

Initial Ampere GPUs

After what feels like ages of teasing, Nvidia CEO Jensen Huang took to his spatula-filled kitchen to show us the first three Ampere-based GeForce RTX 3000-series products built using two different GPUs. We expect at least one more lower-end Ampere-based chip, likely called GA106, to help fill out the family and give us the GeForce RTX 3060 and below, but right now, Nvidia has only introduced the GA102 and GA104 chips as the powerhouses for the company's initial consumer range.

A100, the chip Nvidia announced in May for its new datacentre products, doesn't have as close a relationship to GA102 as you might think. While Nvidia uses one of TSMC's 7nm process variants for the 54.2 billion-transistor, 826mm^2 A100 chips, it's using a higher-performance 8nm variant offered by Samsung Electronics for GA102 and GA104, called 8N. Comparatively, Turing GPUs were built with TSMC's 12nm FFN process.

GA102 has 52 per cent more transistors than the top-end Turing TU102, while also being 17 per cent smaller
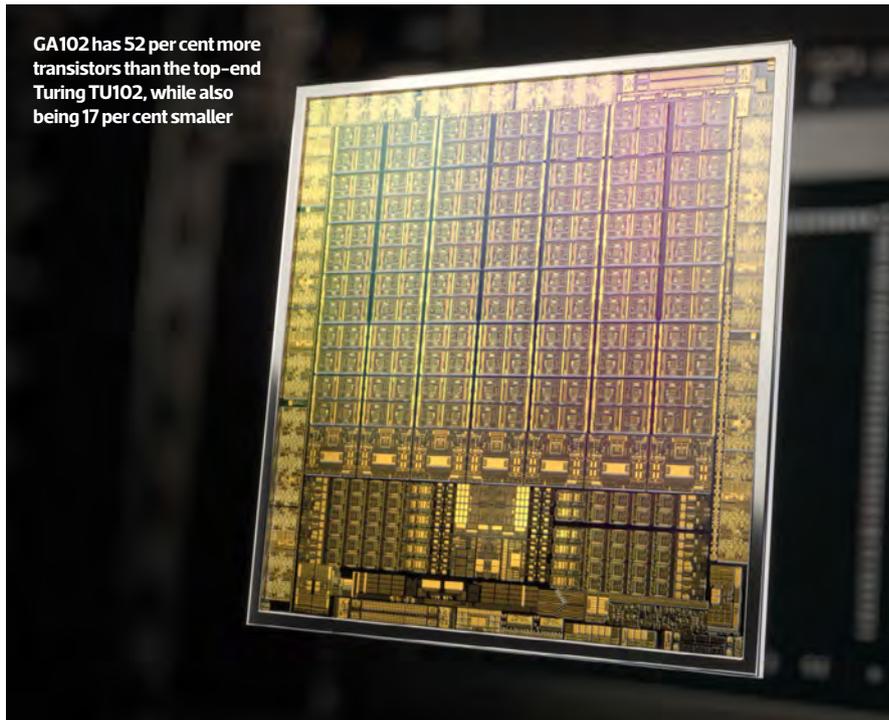
GA102 ends up being a 28.3-billion-transistor chip that occupies 628mm^2, and the switch to the 8nm process boosts the GA102's transistor count by 52 per cent over the range-topping TU102 in the Turing family, all while being nearly 17 per cent smaller. A full GA102 contains seven Ampere-class Graphics Processing Clusters (GPCs), which are the top-level building block Nvidia defines in its GPUs.

Each GPC contains a dozen 128-core Streaming Multiprocessors (SMs) for a faintly ridiculous total of 10,725 Ampere-class CUDA cores. The core feeds into a partitioned 6MB L2 cache — the same size as TU102 — that sits in front of the 384-bit GDDR6X memory bus.

While you can argue with the definition of a core, this is the first time a single GPU from any vendor has had over 10,000 parallel arithmetic datapaths. We have to offer kudos to Nvidia's engineers and the modern process technology that makes that possible.

GA102 is the heart of two announced GeForce RTX products: GeForce RTX 3080 and GeForce RTX 3090. The former has six of the chip's seven total GPCs enabled, which cuts down the figures as you'd expect: 8,704 total CUDA cores with 10GB of 19 Gbps GDDR6X memory connected to a 320-bit memory bus. This setup gives you 760GB/sec of memory bandwidth, despite disabling 64 bits of the available memory controller capacity. This vast memory capacity is so far ahead of Turing's previous range-topping £1,000+ GeForce 2080 Ti that you'd be well and truly forgiven for expecting an equally eye-watering price, but it costs just £649 inc VAT.

That's where the GeForce GTX 3090 steps in. All seven GPCs are active here, with Nvidia only turning off a couple of SMs on the whole chip — likely for yield reasons rather than to wait for a full 84-SM product somewhere in the future. This connects to 24GB of GDDR6X memory and delivers a configuration with almost 1TB/sec of memory bandwidth and 10,496 enabled CUDA cores. Add in the 1.7GHz boost clock and it effectively doubles the peak performance of last year's Titan RTX with its

All seven GPCs are enabled in the GeForce RTX 3090, giving you over 10,000 CUDA cores

fully enabled TU102 GPU. That's amazing when you consider that the Titan RTX cost £2,499, but the GeForce RTX 3090 costs just £1,399.

That awkwardly high pricing hasn't gone away with Ampere at the top end, but what it buys you in this generation, on paper at least, is bananas compared with high-end Turing GPUs. We'll dig into the potential reality of that on-paper promise after a tour of GA104.

GA104

GA104 is the nominal mid-point of the Ampere gaming family if you accept that a GA106 is undoubtedly on the way at some point in the future. Measuring a hair over $392mm^2$, and with 17.4 billion transistors on the same Samsung 8N process as GA102, it's a six-GPC part with eight SMs per GPC and an appropriately sized 4MB L2 cache. There's also a maximum of 8GB of GDDR6 memory (not the turbocharged X

variant) connected to a 256-bit memory bus. Nvidia has only announced one product that uses GA104 so far — the GeForce RTX 3070 — although we expect more later.

The GeForce RTX 3070 takes a very slightly cut-down GA104 with just one TPC switched off. We'll dive into TPCs later, but it's basically a pair of SMs that share a texture unit, so 256 CUDA cores disappear from the headline spec of a full GA104 in the GeForce RTX 3070. Boost clocks for the shader core in this generation sit between 1.7 and 1.725GHz, depending on the particular card, which also holds true for the 3080 and 3090 cards based on GA102, although we're sure some board partners will take it higher for their special editions.

Ampere GTX?

Turing also introduced some cut-down GPUs that shared the vast majority of their bigger

siblings' feature set, but removed two key hardware features — ray-tracing acceleration and the Tensor cores that accelerate machine learning. They're used in cheaper GTX-branded cards, such as the GeForce GTX 1650 and 1660 ranges. These omissions enabled Nvidia to cut costs and assemble products that didn't have the raw horsepower to justify carrying those features into silicon.

We don't expect that to happen this time around with Ampere though. Even if Nvidia does create smaller chips in the 200-300mm² range, we expect them to take advantage of the much denser Samsung 8nm process technology — assuming Nvidia sticks to that, of course — to deliver the new SM feature set, including ray tracing and new Tensor cores, across the full Ampere family.

Deep dive!

Now that we've looked at the first two Ampere chips and the trio of products based on them, it's time to dive into the meat of the architecture and figure out what's new, how it compares with Turing, and what it means for anyone who wants to grab an Ampere and put it to work. There are some crucial differences in the microarchitectural view of Ampere that will unlock some fresh understanding about where we could see improvements in real-world gaming performance, so let's dive in.

The Ampere GPC

It's the GPC that contains the vast majority of the parts needed for the chip to function, and forms the top-level building block in the Nvidia taxonomy, so let's start there and head downwards. Each GPC contains an implementation-dependent number of Texture Processing Clusters (TPCs). A TPC is a pair of SMs that share access to a texture unit and associated memory hierarchy. It makes a lot of sense for SMs to share a texture unit in practice, given the size of the Nvidia SM in all of its modern GPU generations, and the ratio of shading-to-texturing work that has to happen in modern gaming workloads.

The Ampere texture unit hasn't gained any new features or per-clock performance improvements relative to the unit in Turing, but it's still incredibly powerful as a shared structure on which the pair of SMs can lean to perform texture sampling. You're looking at eight samples per clock rate for each TPC here.

As we mentioned earlier in our discussion of the RTX 3090, that GPU has a single TPC

EACH GPC CONTAINS 12 STREAMING MULTIPROCESSORSORS FOR A FAINTLY RIDICULOUS TOTAL OF 10,725 CUDA CORES ACROSS THE WHOLE CHIPX

The GeForce RTX 3070 is based on a slightly cut-down GA104 with one TPC switched off

In this diagram of the GeForce RTX 3080, you can see six GPCs, each containing 12 SMs

disabled, leaving 41 out of 42 of them still smashing through your game's total texturing workload. If you multiply 41 times eight samples per clock at the 1.695GHz boost clock, you get an honestly ridiculous total of 556 billion fully filtered samples per second.

As an example, if you're running a game at 4K at 60fps, you're looking at processing 500 million pixels per second. At its full texturing rate, a GeForce RTX 3090 could texture every pixel in a game running at that resolution and frame rate over 1,100 times.'

The Ampere SM

The Ampere SM is where most of the core microarchitectural changes can be found. Nvidia's Turing SM was the most complex, most efficient and highest-throughput shader core in the company's history. That's quite the accolade and Nvidia would have to dig deep to improve it

generationally, but it's safe to say Nvidia did the requisite digging.

In our Turing analysis (see Issue 196, p84), we speculated that Nvidia would probably love to create a tailored SM for each part of the market that it wants to address – say, one for the products aimed at cloud compute, remote rendering and machine learning markets, and one that's more aimed at consumer graphics workloads as its focus. However, we said Nvidia couldn't really do that because of the costs involved in creating such a specialised per-market SM. We're going to have to eat our words now, though, since it's exactly what Nvidia has done with Ampere: consumer Ampere designs have a fundamentally different SM structure to the one found in the datacentre-focused A100.

Much like Turing and other Nvidia designs before it, the Ampere SM can be broken down

into a quartet of smaller structures that can operate independently, each with their own control logic. Whereas the Turing SM is made up of four identical 16-wide arithmetic logic unit (ALU) structures, Ampere deviates from that simplicity in order to considerably beef up the width and processing power of its SM machinery.

Each SM in Ampere has four of the following: a 16-wide ALU structure called a datapath, which can perform either floating point or integer instructions in a given clock; another 16-wide datapath that can only run floating point instructions in parallel with the first 16-wide datapath; a 3rd-generation Tensor core; a special function datapath; a scheduler and dispatch unit that controls what runs on those resources; a supporting memory system with instruction cache and load/store hardware to let the SM talk to the outside world.

MUCH LIKE TURING, THE AMPERE SM CAN BE BROKEN DOWN INTO A QUARTET OF SMALLER STRUCTURES THAT CAN OPERATE INDEPENDENTLY

The scheduler and dispatch hardware lets each quarter of the SM run independently from the others at the instruction level, as they have their own scheduling and dispatch logic, which is responsible for figuring out what instruction is next and preparing for the SM to run it. To let all of that processing logic run freely, Ampere also has a beefed-up memory system deep inside the SM.

SM memory hierarchy

Turing already took a pretty big step with the performance of the SM's memory system, so it might cause some initial surprise to see Nvidia make large changes in the same way with Ampere, not least because memory-related parts of a GPU tend to consume significant power and surface area.

Each quarter of the Ampere SM datapath logic shares a 128KB L1 shared memory system, up from 96KB in Turing. For a long time, Nvidia has been able to perform a neat trick with this L1 system inside the SM to benefit the mix of workloads running on it – L1 partitioning. Because it operates as both a cache and a general-purpose shared memory for threads running on the SM, it's designed to be statically partitioned depending on what's running.

When running graphics code, Nvidia splits the Ampere L1 three ways: 64KB for caching texture data and register overspill (up from 32KB in Turing); 48KB for general shared memory (down from 64KB in Turing); and 16KB reserved for supporting other bits of the graphics pipeline. We think it's also likely to be used to support acceleration of ray tracing.

Nvidia has also doubled the bandwidth into and out of L1, which can now deliver data to the SM at a rate of 128 bytes per cycle. Total L1 bandwidth therefore doubles, which is pretty wild when you think about it, since it means you end up with double the number of wires out of that memory to connect it to the rest of the SM.

In compute mode, the 128KB can be split up in numerous ways, and this time it's all under programmer control: 0, 8, 16, 32, 64 and 100KB can all be statically allocated as shared memory across all of the SM's datapath resources so they can efficiently communicate, with whatever's left acting as a general L1 cache. Some L1 has to always be available, which is why 100KB is the maximum a programmer can specify for the compute mode split.

In terms of registers for the SM programs to use, Nvidia hasn't increased the size of the 16,384-entry register file (RF) in the Ampere

SM compared with the one in Turing, which is a little surprising given the addition of that new 16-wide, 32-bit floating point datapath in each SM quartet.

When running shader or compute programs, each program needs a number of registers to hold the source and destination data for each instruction. For example, imagine that a equals $b \times c + d$. Here, a, b, c and d are all registers needed by the *multiply-add* instruction that's being run – one for the result and the other three to feed in the operands, and they're all allocated from the shared RF.

However, if you add processing resources to the SM, as Nvidia has done in Ampere, without a commensurate increase in the number of registers provided by the RF, then there's comparatively fewer available registers for the processing resources to share. We believe that could have an outsize effect on the real-world performance of Ampere in shader-heavy situations.

The takeaway on the SM memory hierarchy is that Nvidia made a big stride on the shared L1 system, but didn't beef up the RF to help the new extra floating point datapath it added. Let's look at that now.

Ampere CUDA cores

The Turing CUDA cores that made up the bulk of the SM processing resources made a big leap in that generation, gaining the ability to run floating point and integer instructions in parallel for the first time on a big high-performance GPU.

Each Turing SM quarter also contains a special function unit, which is responsible for running more esoteric operations that tend to take longer than a single cycle to execute. These operations also show up in shader programs way more infrequently than the more common *add*, *multiply* and *multiply-add* instructions usually run by the primary datapaths. That's still there in Ampere at the same rate.

As mentioned in the look at the top-level SM structure, what's new is the addition of a completely separate floating point-only datapath (and 32-bit floating point only to boot, which is also important) to sit alongside the *float+integer* datapath that was already there from Turing's CUDA core. This is cheap to implement, as it only supports 32-bit, and it doubles the 32-bit floating point performance of the design in terms of the top-level headline numbers. That's great, since graphics leans on that heavily. However, in order for the hardware
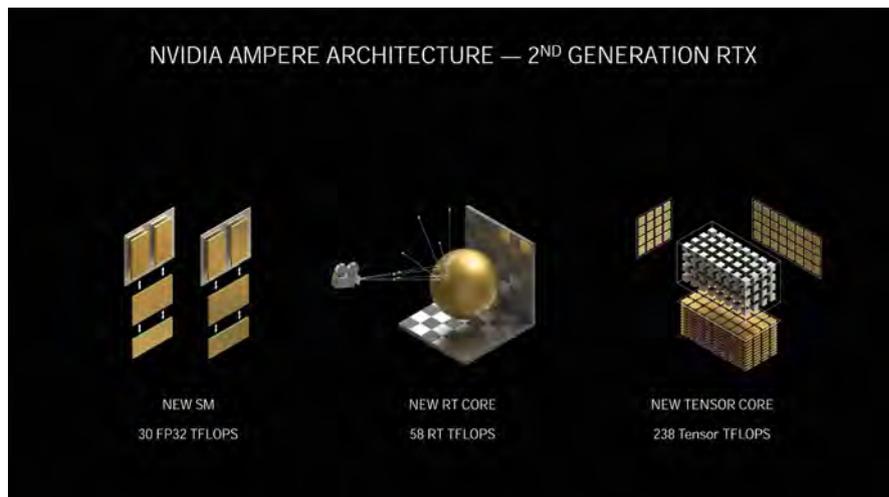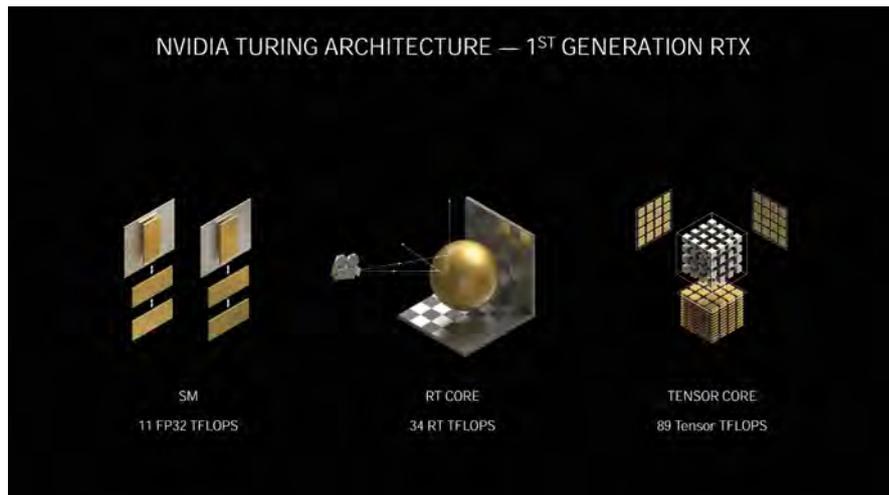
Ampere massively improves the performance of Nvidia's Tensor and RT cores compared with Turing

to efficiently use that extra performance, a number of important factors need to align.

The first is the availability of those RF resources we mentioned earlier. To run the new floating point datapath takes registers, and Nvidia didn't beef up the size of the RF when adding the new processing power to the design. The second is the ability of Nvidia's Ampere shader compiler to analyse the shaders and compute programs that application developers provide to the compiler to be turned into machine instructions that the Ampere SM can run, and find independent floating-point instructions that can be run in parallel.

Graphics shaders tend to have an amount of independent instruction-level parallelism (ILP) baked in when it comes to modern shader-heavy effects that games contain, so that's broadly fine because it gives the compiler a chance to find that independent work in the general case. It's not as if it's never possible and

that extra independent floating point work can never be found. That's step one.

Then the compiler has to identify that ILP and turn it into something the primary and secondary datapaths can run in parallel, sharing the underlying RF. That's the hard part, and what could hold Ampere back in shader-heavy situations until the Ampere compiler matures and Nvidia's engineers have had a chance to file off the rougher edges over time. To sum up: it's not trivial to make use of that doubling of 32-bit floating point horsepower, but when that's possible, the shader performance will go through the roof.

In terms of total structure of the SM then, each one has the following: 4 x 16-wide primary ALU datapaths that can do 32-bit and 16-bit float plus integer processing; 4 x brand-new 16-wide secondary ALU datapaths that can only do 32-bit float; 4 x 3rd-gen Tensor cores, 4 x SFU (each is likely just 4-wide, but that's

fine because it's not used too much); and 4 x 2nd-gen RT cores. That means each SM has a total of 128 of what Nvidia calls CUDA cores, four Tensor cores, four RT cores and that shared memory hierarchy we discussed earlier.

Ampere Tensor core

Nvidia first introduced Tensor cores in its datacentre only Volta architecture, but it's only been a single architectural generation, Turing, that's brought them along to the GeForce party. They're significantly more capable in Ampere, though, and Nvidia has made it clear that Tensor cores should now be considered part of the general-purpose processing horsepower of the design, not just a special part off to one side that's maybe only used in games that support DLSS upscaling.

Turing added a fairly flexible set of integer data type operations to the Tensor core design that Volta introduced, and Ampere beefs it up with support for a couple of new machine learning-specific data types. One is called BFLOAT16, which has fairly wide adoption in the industry — Intel supports it, as does Google in its TPU, and machine learning accelerator IPs available from licensing companies also have support.

There's also one that Nvidia has invented, called TensorFloat-32 (TF32). Don't let the name fool you – it's not a full 32-bit-wide data type. Instead, Nvidia is borrowing aspects of full 32-bit precision that's available in *part* of the type – the 8-bit part that controls the range of numbers that can be worked on, and the 10-bit precision part from FP16 computation that the Tensor core already supports. So TF32 is only really 19 bits wide (1 sign bit, 8 bits of range, 10 bits of precision).

We think the Tensor core probably will see more application in games outside of DLSS over time, given that it's quite flexible now and supports a range of data types that you also find in graphics code. It requires some compiler and RF gymnastics that are even more complicated than those required to add the separate 32-bit only secondary floating point datapath we already discussed, but we expect it to happen more over the lifetime of Ampere products, possibly in special cases for particular games at the start.

Even if it stays limited to use in DLSS, that's fine since at least it's being used in more games over time, meaning Nvidia's investment in putting it into consumer hardware will increasingly pay off.
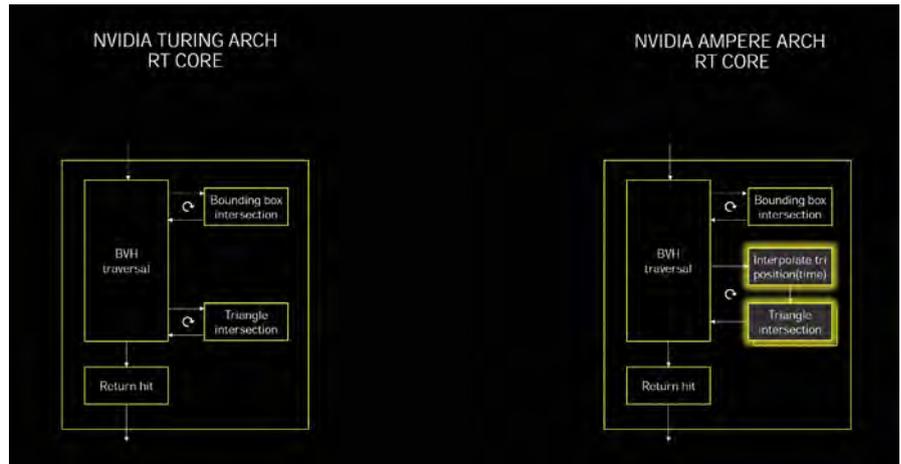
The Ampere RT core has a new sub-unit that can effectively hallucinate new triangles to test against, in order to more easily apply motion blur
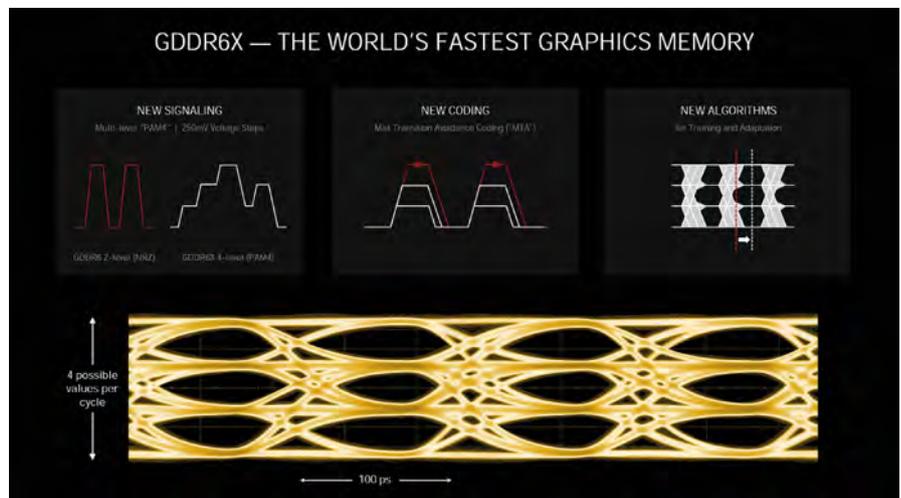
GDDR6X memory doubles the per-pin bandwidth of GDDR6 at the same clock

Ampere RT core

On the full spectrum from no ray tracing acceleration at all to a complete hardware implementation of all you might want to do in a ray tracer, Turing's implementation sat early on the spectrum, accelerating two of the key parts of real-time ray tracing workloads. These two parts are testing of rays against what's in the scene hierarchy, and streaming in and traversal of that hierarchy as the rays are being tested against it. Ampere advances Turing's efforts in two key ways.

To set the scene, here's a quick primer on why you need a scene hierarchy in the first place. Because ray tracing is effectively a search for which triangle a ray will hit, and because you want to do that in parallel to take advantage of the parallel nature of the GPU, you want to make that search is as efficient as possible. You want to be able to exit the search as early as possible
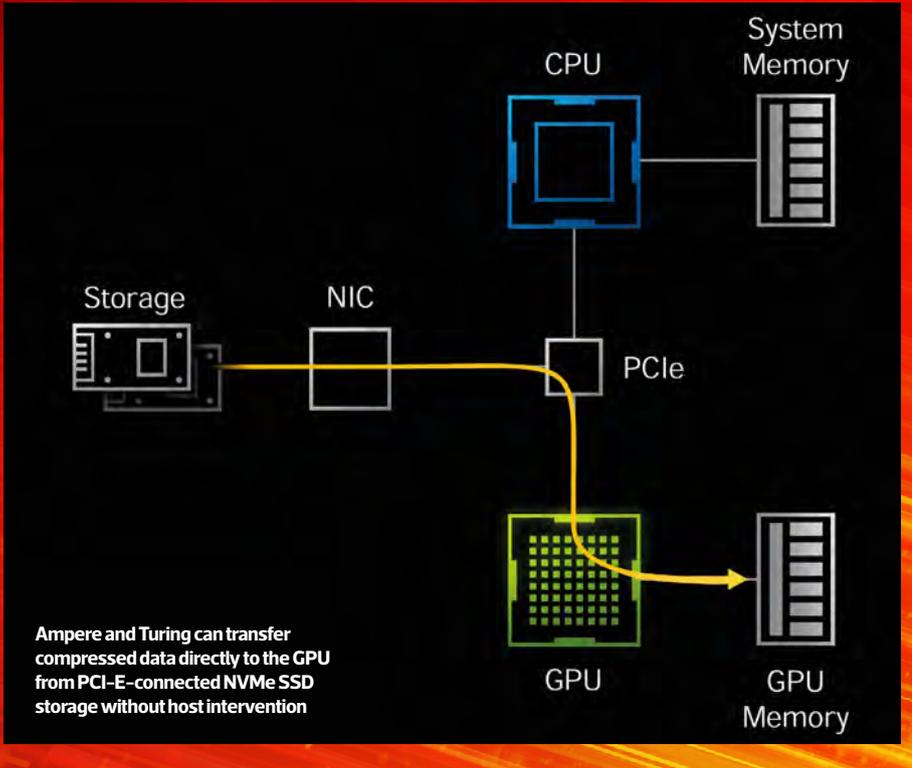
if the ray isn't going to do what the programmer wants – to hit something of interest.

As a result, you divide up the scene into a hierarchy of boxes that first contain rough groups of everything inside them, and first test your rays against that top level of boxes in the scene see if they hit them. If they do, they know to continue down the hierarchy of boxes, testing each one in turn, until some triangle data at the bottom is hit or not. If at any point the ray-box test doesn't pass, you know to stop that ray.

Back to Nvidia's implementation of the RT core, Nvidia has doubled the amount of parallel ray-box and ray-triangle intersections each Ampere RT core can perform, letting them perform the scene hierarchy search twice as fast as in Turing.

Nvidia has also allowed the Ampere RT core to work in parallel with the other events occurring in the SM. In the SM analysis, we

NVIDIA HAS DOUBLED THE AMOUNT OF PARALLEL RAY-BOX AND RAY-TRIANGLE INTERSECTIONS EACH RT CORE CAN PERFORM

Ampere and Turing can transfer compressed data directly to the GPU from PCI-E-connected NVMe SSD storage without host intervention

figured that Nvidia reserves part of the shared memory for some specific graphics pipeline work. We think the new ability to more often run the RT core for ray tracing in parallel with other tasks on the SM is in part helped by that 16KB reservation of the SM's shared memory.

That ability to not block the rest of the SM while the RT core is operating, plus the doubled throughput for testing, should significantly enhance ray-tracing performance in the parts of a frame that need it on Ampere products, compared with an equivalent Turing part. Competing hardware from other vendors who still haven't shipped DXR or Vulkan ray-tracing compliant products will now have an even harder time catching up.

The RT core also gains a new ability, with a new sub-unit that can effectively hallucinate new triangles to test against, in order to more easily apply motion blur to the scene. By very slightly changing the position of an existing triangle in the scene by advancing where the triangle will be located in the future, before the rest of the RT core tests it, you get free and very high-quality motion blur. It's unlikely to be added to games because of the temporal aspect — the game needs to a priori to know the future, effectively time travelling! — but it's worth mentioning here for completeness.

GDDR6X memory

It's worth spending a little bit of time on GDDR6X in the context of Ampere, since while it's not present on all the products that implement Ampere GPUs, it's the technology that gives the bigger configurations a total memory bandwidth very close to the symbolic 1TB/sec mark. It gets there by abusing high-speed data signalling as much as possible, in order to squeeze as many bits per second down the individual wires that connect a GDDR6X DRAM chip to the chip that needs it.

It's a big generational leap, doubling the per-pin bandwidth of GDDR6 at the same clock. That can help in ray tracing, since traversal is a bandwidth-heavy task that now runs in parallel with other graphics workloads. It's also comparatively very power-hungry.

However, doubling the per-pin data rate of the memory requires a commensurate increase in power, both at the DRAM side in the GDDR6X device itself, and also on the GPU side in the connecting physical interfaces that talk to the DRAM devices. GDDR6X significantly helps bandwidth, but it significantly increases power consumption to get there.

RTX IO and DirectStorage

Lastly, there's another feature in Ampere that also exists in Turing, but which Nvidia chose to disclose now that API support is going to arrive in DirectX: the ability to transfer compressed data directly to the GPU from PCI-E-connected NVMe SSD storage without host intervention, which Nvidia calls RTX IO. Being able to directly transfer data from an SSD isn't a new invention – AMD has a similar feature in its GPU design – but being able to transfer compressed data without needing the CPU to decompress it is new – Microsoft calls it DirectStorage.

It enables the GPU to effectively amplify the bandwidth of whatever PCI-E standard connects to the GPU and NVMe storage system, by transferring compressed blocks at the PCI-E line rate and then decompressing them after they hit the GPU. While it will be a long time before every PC on the market has this kind of capability, Ampere and Turing GPUs are ready to take advantage of it if the rest of your system is capable.

State of play

Nvidia's statement of intent with Ampere is clear. The company has taken full advantage of Samsung's 8N tech to create new GPUs that significantly beef up top-line shader performance with the new 32-bit floating point datapath, while doubling headline ray-tracing performance with the testing hardware and the RT core operating in parallel to the rest of the SM. It can also feed the really big configurations with GDDR6X memory, with the potential to read compressed data directly from storage while the CPU is busy with other stuff.

There are some performance hurdles for the new hardware to overcome, especially in the new SM, which might lead to some less than perfect scaling in the real world, but there's no denying the headline performance is incredibly impressive and that Nvidia has paid attention to keeping the really big Ampere configurations adequately fed with memory bandwidth, so the new hardware can breathe freely. It's a really strong launch from Team Green. **CPC**

KEEPING UP APPEARANCES

MONITOR REFRESH RATES CONTINUE TO CLIMB, BUT HOW FAST IS FAST ENOUGH? EDWARD CHESTER INVESTIGATES THE WORLD OF SUPER-FAST MONITORS

T o some of us it doesn't feel like all that long since 144Hz screens were the bee's knees, but with 240Hz monitors now commonplace and a new raft of 360Hz screens set to arrive in the coming months, it begs the question of just how fast we need to go before gaming monitors are truly fast enough. We won't truly find that out until we've tested those 360Hz screens, but we wanted to test at least as far as we can with current technology.

What's more, there are several other factors at play when it comes to how responsive a monitor feels, such as response time, the LCD panel type and whether a display uses any form of backlight strobing blur reduction. We put all these factors to some subjective gaming tests to get an indication of what makes the biggest difference to our gaming performance, and to find out what the ultimate gaming monitor might look like.

The test setup

There are several different ways in which you can try to test the responsiveness of gaming monitors, such as recording actual game results or creating custom tests using light meters and custom software. However, both those solutions have their problems, with the former generally introducing a few too many variables (although it could work with a large enough data set), and the latter potentially getting too far away from testing true human interaction with the display. It would also be difficult for you to replicate these results and see for yourself.

As such, we settled on a middle ground. The test is a straight replication of game-like aiming input, but the software is laser-focused on replicable test results, with none of the other variables of real games. In other words, we used an aim trainer app. It's called KovaaK 2.0, and you can download it from Steam for £7.19. Plenty of other aim trainer apps are also available.

It has a host of scenarios that test different aiming skills, such as rapidly flicking to randomly appearing static targets, constantly tracking a moving target or clicking on rapidly moving, randomly appearing targets. We used one of the latter style of tests, called 1wall5targets_pasu and found under the Core Clicking playlist of tests. It requires a lot of concentration, but our initial tests showed it was among the most profoundly affected by changes in refresh rate.

In the test, small red spheres randomly appear and float around rapidly until you manage to hit one, at which point another appears to take its place. The test tracks the total number of hits, the shots taken and the resultant accuracy. We recorded a minimum of five run-throughs of the test for each of the test scenarios, averaging the results, and taking note of the accuracy and the total number of shots. We found that five runs was enough to get consistent results in most tests, but occasionally a few more were required to eliminate outliers.

We also ran a few other tests in KovaaK, such as the tracking test that measures your ability to keep your cursor locked onto a single moving target, essentially simulating the lightning gun in Quake. As we mentioned

We used the 1wall5targets_pasu test in KovaaK 2 for all our tests

83

KovaaK 2.0 has a host of other tests for measuring your skill at different types of aiming

previously, we found the targets test to be the most effective, so we've based our measurements on that, but we also observed notable differences in several other tests, so the findings here aren't only applicable to this one extreme test scenario.

Refresh rates

Kicking off with the most obvious differentiator of gaming screens, we used a 240Hz TN monitor – the Acer XB252Q – for all our refresh rate tests, reducing its maximum refresh rate with each test, from 240Hz

KovaaK 2.0 has a built-in max FPS scale that allowed us to test all the way down to 30Hz

through 144Hz, 100Hz and 60Hz. We also recorded a test at 30Hz to see just how bad the situation could get, and reflect scenarios where it's not the screen that's the limiting factor but perhaps your game's frame rate. To test at 30Hz we used the in-app maximum frequency limit, as you can't select lower than 60Hz for the monitor's own refresh rate.

Why the big jump from 144Hz up to 240Hz? Well, one factor to consider with refresh rates is that you're inherently getting diminishing returns. A move from 30Hz to 60Hz is only a 30Hz difference, but it's also a doubling of the refresh rate and a halving of the display time of each frame from 33.3ms to 16.7ms. However, even the nearly 100Hz leap from 144Hz to 240Hz is only a 66 per cent increase and a move from 6.9ms to 4.2ms frame display time. As such, testing at, say, 120Hz or 180Hz would be too granular to provide a particularly meaningful result.

The results are surprising, being both compelling

and relatively linear. When it comes to accuracy, we fully expected to see a minimal improvement from 144Hz to 240Hz and much more of a general trend towards that idea of diminishing returns, with a big leap from 30Hz to 60Hz and less of an improvement as the refresh rate increased further.

We do start to see that trend with the step up from 144Hz to 240Hz being a little less than that from 100Hz to 144Hz but it's still a significant jump. Likewise, the step up from 30Hz to 60Hz was surprisingly small, especially given just how much worse it felt and looked in action.

Regardless, this test does suggest there's potential for significant performance gains with those upcoming 360Hz screens. Of course, the increase in refresh rate between 240Hz and 360Hz is only 50 per cent, down from the 66 per cent for the uptick from 144Hz to 240Hz, so we could yet find the in-game performance improvement to be minimal, but these results at least give us some hope.
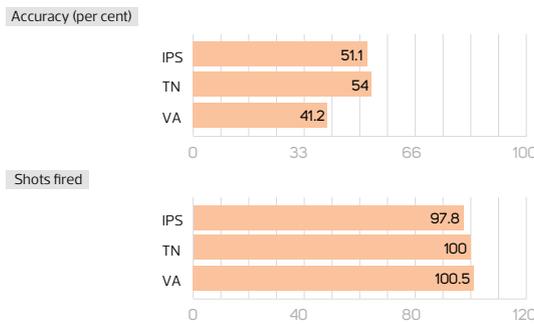
Meanwhile, what's clear is that, yes, faster refresh rates up to a certain point really do potentially make a big difference. Moving from only hitting 31.8 per cent of your shots (or, to be more realistic, 37.4 per cent) to 60.5 per cent is huge and would absolutely make the difference in 1v1 shootouts.

REFRESH RATES

Accuracy (per cent)

30Hz	31.8
60Hz	37.4
100Hz	44.6
144Hz	54
240Hz	60.5

0   33   66   100

Shots fired

30Hz	85.3
60Hz	86.7
100Hz	93.3
144Hz	100
240Hz	107

0   40   80   120
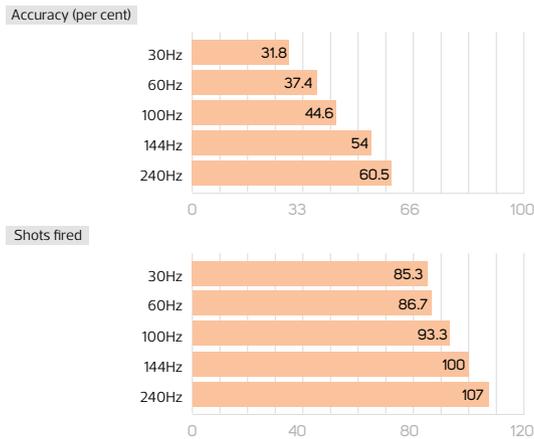
Accuracy and total shots fired both increased as the refresh rate went up

LCD PANEL TYPES

Accuracy (per cent)

IPS	51.1
TN	54
VA	41.2

0   33   66   100

Shots fired

IPS	97.8
TN	100
VA	100.5

0   40   80   120

TN monitors clearly show their advantage in this test, although the results are closer overall than you might expect

Looking at the total number of shots, there's also a trend of increasing shots with a higher refresh rate. With lower refresh rates, we could track the spheres and accurately hit them, but once we lost concentration on one, it was harder to quickly pick out our next target. At high refresh rates, it was easier to quickly flick from one target to the next.

Multiply the accuracy by the shots fired over the course of each one-minute test and you're looking at a total damage output of 27 units at 30Hz vs 65 units at 240Hz. In other words, on average, you have the potential to deal over double the damage with the faster frame rate over the same period of time. Even the step up from 144Hz to 240Hz gave us nearly a 20 per cent damage uptick.

Response times and panel types

Next up in our suite of tests was to establish the size of the difference made by the response times of various LCD panel types.

In general, there are three main LCD panel types: IPS, TN and VA, with each having a few key pros and cons. IPS has the best viewing angles and tends to be best for colour accuracy, so it's the choice for professional image and video editing displays. However, it has middling response time performance, averaging around 5ms grey-to-grey for a modern fast-refresh panel.

TN has the fastest response time (generally averaging under 3ms grey-to-grey), making it traditionally the choice for gaming monitors. However, TN panels generally have the worst image quality, with poor viewing angles being their big downside. Finally, VA has significantly better contrast, with both IPS and TN panels generally maxing out at a 1,000:1 contrast ratio, while VA panels can hit as high as 5,000:1 (although more typically 2,000:1-3,000:1).

However, VA panels generally have the worst average response time of around 8ms for a modern gaming panel.

Bringing this back to our game tests, we used our same XB252Q to represent TN panel technology and then also grabbed an Asus VG27AQ to represent IPS and an AOC CU34G2X to stand up for VA. Each panel was set to 144Hz refresh rate at a resolution of 1,920 x 1,080 and its optimal overdrive setting was used. This isn't the purest comparison, as these screens aren't all the same size and native resolution, but it's representative enough to get an idea of responsiveness.

The results weren't quite as compelling as those for the refresh rate comparisons, but there were still some trends. Firstly, the TN screen came out on top for accuracy, but not by as much of a margin as we expected.

The IPS screen put up a good fight, only being beaten to the top spot by 2.9 per cent. This was doubly surprising as – a bit like with the 30Hz TN test – the IPS panel felt noticeably more sluggish than the TN panel while we were using it, but the results suggested it didn't ultimately make a huge difference to our performance.
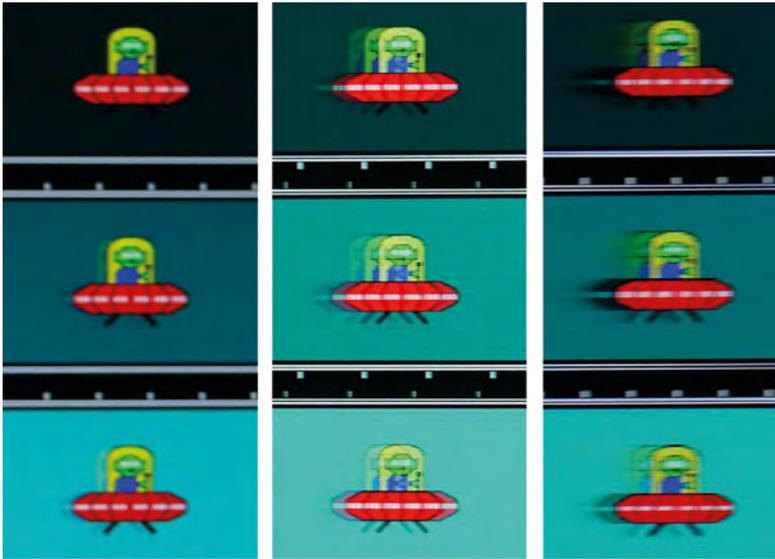
Meanwhile, the VA panel significantly trailed both other panel types. Ghosting and a general lack of clarity in the fastest moving parts of the image were obvious and this smudginess clearly affected our test results, with it scoring significantly worse than even a TN screen running at 100Hz.

Backlight strobing

Our final key test was to see just how much of an impact was made by backlight-strobing blur-reduction techniques. These techniques flash the backlight of an LCD on and off in sync with each frame, which in theory helps to trick the eye into seeing a sharper image when tracking moving objects. Black frame insertion, as it's more generally called, is a technique that dates back to the earliest days of cinema and is often still used today for

THE TN SCREEN CAME OUT ON TOP FOR ACCURACY

The darker background and contrastingly brighter red spheres seemed to help counteract the slower response of the VA panel

BACKLIGHT STROBING

Accuracy (per cent)

IPS blur reduction off	51.1
IPS blur reduction on	57
TN blur reduction off	54
TN blur reduction on	58.6

0   33   66   100

Shots fired

IPS blur reduction off	97.8
IPS blur reduction on	100
TN blur reduction off	100
TN blur reduction on	106.7

0   40   80   120

Our tests clearly show the benefit of backlight strobing, regardless of LCD panel type

The Blur Busters ghosting test exposes the slower response times of IPS (middle) and VA panels (right) compared with TN displays (left)

24fps film – it's a similar principle to the one used in a zoetrope.

For this test we used the XB252Q and VG27AQ (we didn't have a VA display with backlight strobing available), setting them to 144Hz and running through our tests again, this time recording results with backlight strobing on and off.

Here we saw significant gains for both panels when blur reduction was enabled. The TN panel netted a 4.6 per cent improvement in accuracy, while the IPS display gained 5.9 per cent. The slightly larger gain for the IPS panel tallies with one of the advantages of blinking off the backlight, which is that it masks the smearing that can result from a slower response time, and the IPS panel has the longer response time.

Subjectively, both blur reduction modes felt like they made a marked improvement to overall clarity when in motion. This appeared to help particularly with longer movement shots, where the screen would otherwise blur a lot, and moments where we were chasing and trying to catch up with the sphere – it seemed easier to predict the movement.

But what about the games?

We've established that TN displays with backlight strobing and a refresh rate of 240Hz or higher would make for the ultimate gaming monitor performance, but does this really translate to a broad swathe of games? Most games don't need anywhere near this level of responsiveness. Any game that's inherently slow-paced, or that focuses more on cinematic visuals than lightning-fast responses, will be far better served by ticking along at 60Hz-100Hz and upping the resolution to 4K instead.

Even for faster games, such as first-person shooters, beat 'em ups, racing titles and even competitive real-time strategy games, split-second response times and pin-point accuracy isn't the be-all and end-all. For these sorts of games, a 100-144Hz refresh rate is generally enough to get a smooth experience, and you can get much larger, higher-resolution screens in this refresh rate range.

It's only when we get to the most extreme competitive first-person shooters where 240Hz and 360Hz monitors make a case for themselves. Famously, most competitive Counter-Strike players have played at no higher than 1080p for years, and often at much lower resolutions, in order to get the absolute fastest possible frame update time. Even when playing over the Internet, the one or two milliseconds it can take for a screen to update could make all the difference.

Moreover, as we've seen in our tests, a faster refresh rate can help significantly with the ability to accurately track a target and converge your aim point on that target within that brief window of time.

Tick tock

As well as many games not really benefiting hugely from super-fast refresh rates, even some very competitive titles have

Counter-Strike: Global Offensive is one of the games that benefits most from ultra-fast refresh rates

Some competitive FPS games, such as Apex Legends, initially had maximum frame rate limitations

MOST GAMES DON'T NEED THIS LEVEL OF RESPONSIVENESSS

other limitations. For a start, the tick rate of servers for most online shooters is often just 20-30Hz (Apex Legends and Fortnite, for example) and at most will stretch to 128Hz (Counter-Strike: Global Offensive and Valorant, for example).

Tick rate is the frequency at which the server updates each player's game with information from itself and all the other players online. As it can be relatively slow, there's clearly only so much advantage in your display updating ten times faster.

The other factor is that some games have a built-in maximum refresh rate. Most modern competitive shooters are essentially unlimited, but Apex Legends, PlayerUnknown's BattleGrounds (PUBG) and Fortnite all used to have 144Hz caps. Apex Legends' predecessor, Titanfall still has this limitation.

Even with these other limitations, though, there can still be an advantage to having an even faster refresh rate on your monitor. For instance, if a server update arrives at your machine in the middle of a frame, your system has to wait for that frame to finish (variable refresh rate adaptive sync technologies not

withstanding). By shortening the delay in update (lag) of every possible aspect of your system after the server update, and after the game's maximum refresh rate, you still potentially get that fractionally quicker update and snappier feel.

The future

So, finally, once and for all, it's safe to put to bed the debate about fast refresh rate gaming monitors, right? Well, one factor we haven't addressed so far is that our tests weren't remotely double blind (where neither the tester nor the person administrating the test knows what settings are used), or even blind (where the tester doesn't know what settings are used). I was the sole tester and knew precisely which setting I was using each time.

Our tests are intended to give an indication of the benefits of high refresh rates from a subjective point of view, but you'd need a full double-blind study with a large data set to draw a stronger conclusion.

However, we noticed such clear differences between refresh rates in our tests that we feel comfortable saying that faster refresh rates do likely make a difference and seemingly

we haven't reached the limit yet. However, we're clearly approaching that limit. While we've no doubt manufacturers will be pushing to go beyond 360Hz, it certainly seems likely that advances much beyond that figure will drop into single percentage point differences in accuracy.

Even if that's the case, though, you can still add backlight strobing for an extra push, and of course, opting for a TN panel is still the best choice if getting the fastest response is your top priority.

The latter point makes it all the more intriguing that those upcoming 360Hz displays actually use IPS technology, which would suggest they slightly disadvantage themselves. We'll have to see when we get them in for review. **CPC**

Asus' new ROG Swift PG259QN touts a super-fast 360Hz refresh rate

PROJECT SPUTNIK

INSPIRED BY SPACE EXPLORATION AND BUILT WITH LASERS, THIS SCRATCH-BUILT PC IS FIT FOR ORBIT. LOBACHEV ANDREY VLADIMIROVICH (S.PIC), GUIDES US THROUGH ITS CREATION

SYSTEM SPECS

Weight 10.3kg

Dimensions (mm) 320 x 370 x 520 (W x D x H)

Sponsors ASRock, TeamGroup

Case Scratch-built from 2mm aluminium sheet

PSU Cooler Master MWE 750 Full Modular

Motherboard ASRock Fatal1ty X470 Gaming-ITX/AC

Graphics card ASRock Phantom Gaming X Radeon RX590 8GB OC

RAM TeamGroup Delta RGB 3000MHz 2 x 8GB

Storage 2 x TeamGroup Delta RGB 250GB SATA SSD

CPU cooler Cooler Master MasterLiquid Lite 240

As a child, all the boys wanted to become astronauts, and I was no exception. I've always been fascinated by science fiction novels about space exploration, space travel, robots, spacecraft and distant galaxies. It was inevitable that this influence would find its way into my mods at some point.

I first got into modding when I was invited to participate in the Cooler Master Case Mod World Series (CMWS) 2016 competition.

Since then, I've prepared my projects every year specifically for this competition, and in 2017, I even managed to take first place with my VEGA project. The Sputnik project was no exception and was made specifically for the CMWS 2020 competition.

Preparing for takeoff

The first sketches of this Sputnik-inspired PC began to appear a couple of years ago. At that time, I had no experience working with aluminium and decided to start with a simpler project to avoid expensive mistakes. This led to the creation of my SimpleCase project, which helped immensely in learning to how to deal with laser cutting, bending and joining thick sheet metal.

A previous project of my named VEGA won the CMWS 2017 competition
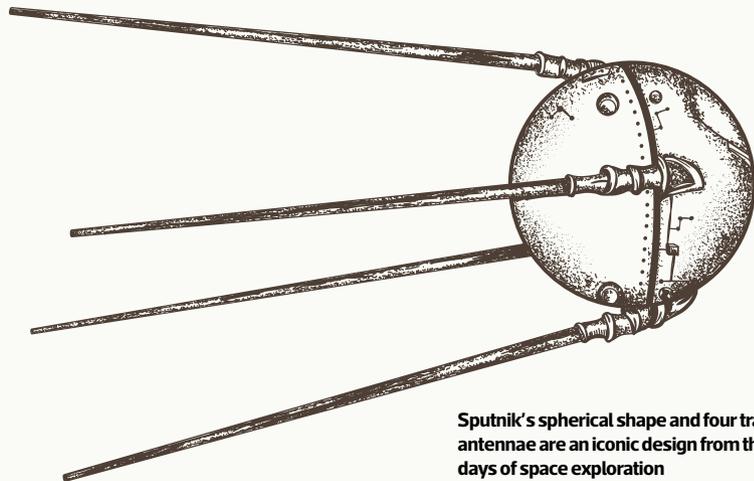
Sputnik's spherical shape and four trailing antennae are an iconic design from the early days of space exploration

The case can sit on any of its sides, its front or on its long legs/antennae

As the year 2020 approached, the old pencil sketches of the Sputnik project were retrieved, and the project started afresh. Looking at these sketches now, I see how little the finished project has in common with those first drawings. The layout and frame were redesigned several times, and the perforations that are a crucial part of the overall design have changed a huge number of times.

Both SimpleCase and Sputnik lean heavily on the use of laser cutting. As well as making it easy to cut out large sheets of aluminium and incorporate details like holes for fixings, it also makes it easy to create intricate shapes such as

After many months of careful designing, the drawings were ready and I was going to give them to my local laser-cutting facility, but something unexpected happened: a car accident. A car veered off the oncoming lane and into me and my vehicle. The car was a write-off, but fortunately no one was injured. All available money was used to buy a new car, and the project was again frozen for several months. Time passed, during which the drawings were once again revised and refined, but finally the time came to get them cut. I was very thankful to the laser-cutting company for letting me film and photograph the process.

90-degree angles were anathema to this case design

ALTHOUGH THE FINAL CASE WAS RELATIVELY SIMPLE TO COMPLETE ONCE ASSEMBLED, IT TOOK A HUGE AMOUNT OF TIME TO DEVELOP THE DESIGNS

the perforations that cover this case. The case is constructed from 2mm-thick aluminium. This provides a good balance of lightness and rigidity. Although the final case was relatively simple to complete once assembled, it took a huge amount of time to develop the designs.

To design the laser cutting path, I used a 2D vector editor, with each piece designed separately – there was no 3D CAD here.

'I Am Speed!'
The Sputnik project was conceived as a high-speed spacecraft. Even static, standing on a table, it had to look dynamic. To create this effect, the front triangular section is sloped forwards, like a sprinter coming up from the blocks. Sputnik had its trailing aerial plumage already, which helps with the speedy look, but I wanted to make things more angular, to fit in with the

All the panels were precision cut using an industrial laser cutter

There's very limited space inside Sputnik, so cooling was tricky
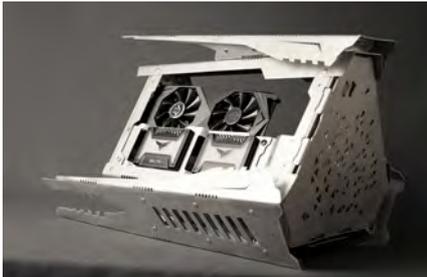
The tops of TeamGroup's SATA SSDs have RGB lighting, so they needed to be on show

triangular theme that was required to provide some flat surfaces for the components to fit on.

There are no simple rectangular shapes or 90-degree angles in the design of this case – every angle had to feel more interesting. Even the USB connectors on the front panel are installed asymmetrically, and the ventilation holes are triangles of all sorts of different types and sizes.

I also wanted the project to be installed not only in one horizontal position, but vertically too. The case can sit on any of its three sides, the top / front panel or on its antennae legs. The length of the legs ensures the cables coming from the motherboard's IO panel and the power supply aren't squashed when in this configuration.

I designed the front panel to be removable, which comes with a few benefits. For a start, it hides the rivets that were used to join the panels of the case. Secondly, it made installing the LED backlighting easier and thirdly, it means I can design a replacement panel. I originally wanted to create a convex panel that would have been a closer match to the spherical shape of the real Sputnik but the bending machine available to me didn't support this. By making the panel removable, though, I can always return to the project if new equipment becomes available.

After laser-cutting, all the parts had to be sanded down and tidied up, then several had to be bent into shape too, which I did myself using a manual metal brake. This was a key area of learning from SimpleCase. That case taught

me the limits of the length of metal I could bend and how to increase those limits by adding perforations to the bend lines. The panels were then fitted together using rivets. Although these are a permanent fixing, it's easy enough to drill them out again if I decide to change something.

Cooling is crucial

An important factor in the design of this case was keeping it small. After all, Sputnik itself was very small, and creating the triangular, rotationally symmetrical and long-legged design I was hoping for would have made the case huge with anything other than mini-ITX hardware inside.

As is ever the case, though, mini-ITX cases can be challenging when it comes to cooling, due to the limited internal air space. And this applied double, as there's no room for any extra case fans in this project. As such, I had to think carefully about where and how to position components.

The ATX power supply, which was left over from a previous project, was installed across the case, taking cold air from the bottom and pushing out hot air through perforations on the side of the case. The mains power input is then redirected from the back of the PSU to the back of the case.

The motherboard sits behind the PSU, with the graphics card mounted at an angle above

it, using a PCI-E extension cable. This left very limited space for a CPU cooler, which meant a water-cooling system was going to be required. However, I couldn't use a fancy hard-line loop, and even conventional flexible tubing would have been a risk, as the panel with the radiator has to be removed to gain access to the inside of the case. Instead, an all-in-one liquid cooler was used.

There was enough space inside for a 240mm cooler with two fans that would pull air from the outside of the case, and blow it through the

BEING ABLE TO VERTICALLY MOUNT THE CASE ALSO HELPS WITH COOLING, AS THE HOT AIR CAN EASILY FLOW UP AND OUT THE PERFORATIONS

radiator and onto the graphics card's backplate, giving it a little additional cooling (the graphics card has two fans of its own that pull cool air through the holes in another side panel and vent it into the case). The extra airflow also helps to cool the RAM and VRM area of the motherboard. The large cooler will also allow me to install a more powerful processor in the future. Being able to vertically mount the case also helps with cooling, as the hot air can easily flow up and out the perforations in the top / front of the case.

A little help from some friends

When I was sure that the project was viable, I turned to some sponsors for help. ASRock Taiwan and TeamGroup responded to my request. The folks from ASRock provided the ASRock Fatal1ty X470 Gaming-ITX/AC

The assembled main case evokes the shiny metal exterior of the real Sputnik

Project Sputnik by S.PiC

A black and white powder-coat paint job was the finishing touch to this build

motherboard and the ASRock Phantom Gaming X Radeon RX590 8GB OC graphics card for the project. TeamGroup also provided a 2x8GB kit of its Delta RGB 3000MHz RAM as well as two 250GB Delta RGB SATA SSDs. As this was a simple, balanced gaming PC build, it was decided to buy an AMD Ryzen 5 2600 processor, as it's sufficient for most games and affordable. It's an easy upgrade if a more powerful processor is later needed as well.

After receiving the components, I started fitting and refined some details of the project. For example, a new mounting plate for the SSDs was designed that helped show off their

Cat supervision is a necessity in designing scratch-build PC cases

RGB lighting and hide their cabling. Side covers were also made with special air intake wings, which are not only decorative details, but also give rigidity to the side covers.

Time for a paint job

The rough assembly was successful and I had a brutal aluminium spaceship in front of me. People compared it to a projectile, which to me meant I'd succeeded in conveying the sense of speed and movement I was aiming for. However, I didn't plan to stop there. I decided to paint the case in contrasting colours. The plan was to have a dark colour for the main body, so it sinks into the background a little more, and then have a bright white for the wings and front panel, visually turning them into a kind of frame.

Once the decision was made, the case was disassembled and shipped off to get powder-coated. I had to wait a long time for the parts to return due to restrictions imposed in connection with COVID-19. However, eventually they did arrive and I was very pleased with the result.

Final assembly was a bit tricky, due to the compact placement of components, leaving

very little room to manoeuvre. It was the cable management that took up most of the time, although this was made a little easier by having all the perforations to use for fixing cable ties.

It takes quite a long time to make and build a project, but if you shoot a video at the same time, it takes much longer. Fortunately, I'm not the only one who likes my hobby. I had lots of support from my curious cat, who regularly manages to find her way into all my videos.

The head of the cat control department is known to all the subscribers of my YouTube channel (**youtube.com/c/spic_mod**). It's she who should be thanked for the logo on my projects.

My sons are also interested in my projects. They are still young and their favourite games at the moment are Rayman Legends and Lego Ninjago. For such games, this PC will be more than powerful enough. Hopefully, one day, they'll follow in my modding footsteps too.

The Sputnik project won bit-tech.net's Mod of the Month May 2020 and is set to participate in the Cooler Master Case Mod World Series 2020. **CPC**

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

ANALYSIS
The hidden costs of 3D printing

Much like two-dimensional printing, 3D printing started as the sole preserve of the well-heeled industrialist. In the years since the technology launched in anything close to a consumer-friendly format, prices have been plummeting. It's now possible to pick up a 3D printer for under £200 inc VAT that's capable of making surprisingly high-quality prints.

But that's not the whole story. Much like the owner of a 2D laser printer will need to budget for paper, toner and potentially fuser units and drums, the extras you need to enjoy success with your 3D printer can cost as much as the printer itself or more. This

guide will help you to get an idea of the costs involved. It's based on stereolithographic (SLA) printing; the costs involved in fused filament fabrication (FFF) printing are usually lower. All the prices listed below include VAT.

The hardware
To start, you'll need a printer. There's a range of LCD-based SLA printers on the market, but one highlight is the Creality LD-002R. Priced at just £152 from **creality3dofficial.com** and shipped from a UK warehouse, the LD-002R has impressive specifications for the price.

When it arrives, though, it's not ready to print. Just as a 2D printer needs ink or toner, an SLA 3D printer needs resin. There's a wide variety of resins available, some of which boast special properties, such as transparency or the ability to glow in the dark.

The best option for a newcomer, however, is a water-washable resin, such as the Elegoo Water-Washable Clay Grey, which costs £25 for 500g from **amazon.co.uk** (the same supplier for the rest of the parts listed below). If you opt for non-water-washable resin instead, you'll need some isopropyl alcohol

Water-washable resins need little more than tap water and a tub, but beware of residue build-up

SLA printers such as the Creality LD-002R are cheap, but beware of the hidden costs

to clean the part post-printing, which will set you back another £10 for 500ml.

If you're on a budget, you can do a post-print wash in a device as simple as a Sistema Klip-It tub for £5, but if you want the best results, you should upgrade to an ultrasonic cleaner, which start from £17. If you don't want to waste your resin, you'll also need

If you want good results, you can't rely on the sun for curing – try the Elegoo Mercury instead

a way to filter it and pour it from the printer's vat back into the bottle – a Ruesious funnel and filter set works well for £6.

SLA-printed parts typically have support structures, which need clipping away post-wash, so you'll need to add on a product such as the Boenfu side-cutter for (£8 for two). You'll also need another £8 for wet-and-dry paper to finish the surface and hide the marks made by the support structures.

Unlike FFF prints, SLA prints also need to cure further once they're out of the printer. While leaving the prints out in the sun is an option, you'll get better results with a UV exposure unit such as the £55 Elegoo Mercury. If you have the budget, an Anycubic Wash and Cure Box takes care of both the cleaning and curing stages, but at £180, it costs more than the printer itself.

The consumables

There are ongoing costs to consider as well. The use of water-washable resin means you at least won't need to keep buying isopropyl alcohol for cleaning. However, you'll find the cleaning tub becomes encrusted over time, so expect to need a few spares along the way.

You'll need more resin, of course, and how much depends on what you're printing: the larger the printer, the more resin it takes. You'll also need protection: the Creality printer comes with two pairs of disposable gloves and two three-layer face masks – both critical items of personal protective equipment (PPE) you'll need to use whenever you're handling the resin. You can get a 50-pack of Jointown face masks for £20, and £12 will get you a box of 100 TouchGuard latex gloves.

An SLA printer can deliver great results, but don't expect a large print area or flexible prints

The printer is only half the story – you'll need accessories and consumables to really get started

There's more to the printer than the resin too – the resin vat is separated from the printer's LCD panel by a sheet of plastic known as FEP release film. Over time, this plastic sheet becomes dull, and is easy to scratch if you have a failed print that sticks to the vat. Even the most careful users will need to replace the FEP on a semi-regular basis – a five-pack of Elggo sheets suitable for the Creality cost £24.

Totting it up

Once you add it all up, assuming you're using the water-washable resin without isopropyl alcohol, that '£152' 3D printer has now set you back nearly £315 inc VAT. There will also be ongoing costs as you buy more resin, work through the five-pack of FEP sheets and replace the single-use PPE items. While it's hard to argue with the quality of the prints from SLA printers, these costs are certainly worth bearing in mind when considering a purchase – and should form part of your initial budget, to avoid any nasty post-delivery surprises.

REVIEW
RISC OS Direct

There aren't many desktop operating systems that can trace their code base all the way back to 1987. Apple's macOS as it stands today launched afresh in 2001, the 'New Technology' that underpins Windows 10 didn't hit the market until 1993, and Linus Torvalds announced Linux as 'just a hobby' in the newsgroup comp.os.minix in 1991. RISC OS, though, is a different beast.

Originally developed as 'Arthur' in 1987 by Acorn Computers as the operating system for its newly launched Archimedes personal computers – the first from the company to run its in-house ARM architecture processors as a primary rather than secondary CPU – RISC OS could have died when Acorn left the PC market, but that's not what happened.

The operating system's longevity was assisted by its popularity for multimedia set-top boxes, aided by the acquisition of the operating system by Pace Micro. Even after set-top boxes had moved on, though, development continued – first by RISCOS Ltd (ROL) and later by Castle Technologies. The latter would release portions of its work under an open-source licence via an organisation dubbed RISC OS Open Ltd (ROOL), rather confusingly unrelated to ROL.

That confusion carries on through version naming: ROL and ROOL's RISC OS projects ran concurrently for a time, with ROL releasing the last version of what it called RISC OS 6 in 2009. ROOL's RISC OS 5, however, continues to be developed to this day, meaning RISC OS 5.26 is considerably newer than RISC OS 6.2.

It's into this confusion that the Raspberry Pi launched. Based on a newer version of the core ARM – now known as Arm – technology that underpinned the Archimedes, the low-cost Raspberry Pi single-board computer proved an ideal platform for RISC OS users at a fraction of the cost of rival boards. As new models launched with increasing performance, interest in RISC OS development grew, and it's into this burgeoning, although still admittedly niche, sector that RISC OS Direct has launched.

At its heart, RISC OS Direct is simply RISC OS Developments' version of ROOL's RISC OS 5 family. However, it's built with a view to getting not just the die-hard Acorn fans over to its side, but also those entirely new to the world of
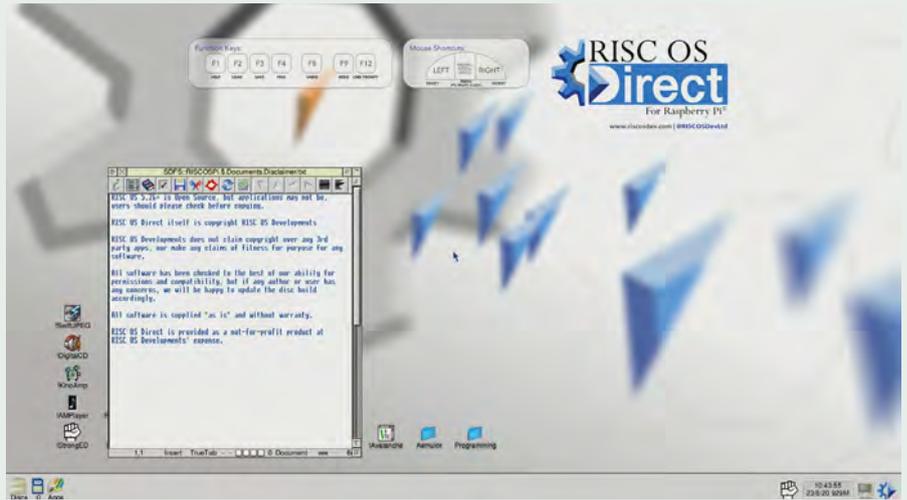
A sight to put joy in any Acorn fan's heart, RISC OS Direct is more than just a nostalgia grab
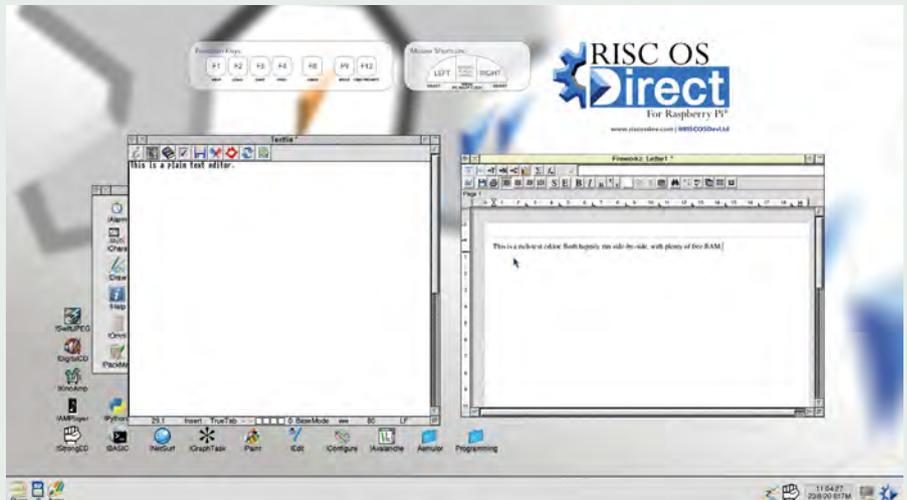
RISC OS is perfectly happy multitasking, and even 1GB of RAM is plenty
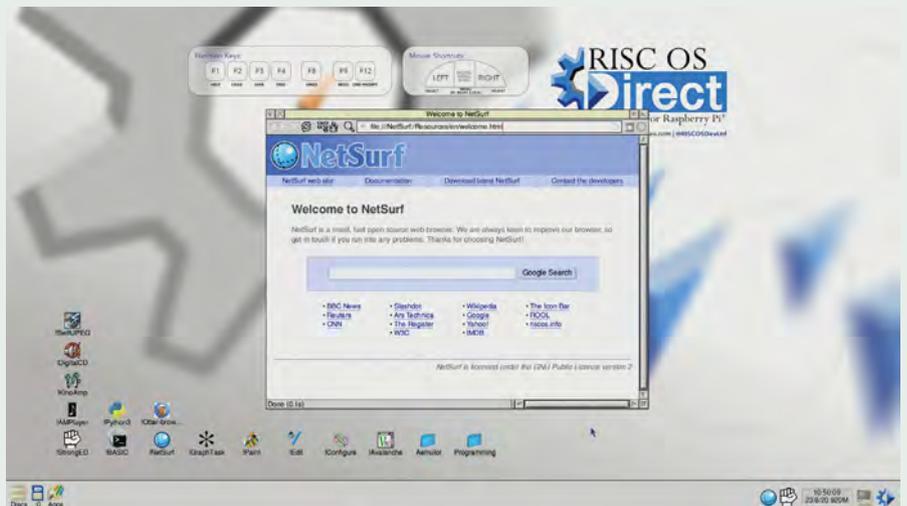
Two separate browsers are installed, although NetSurf struggles with modern websites
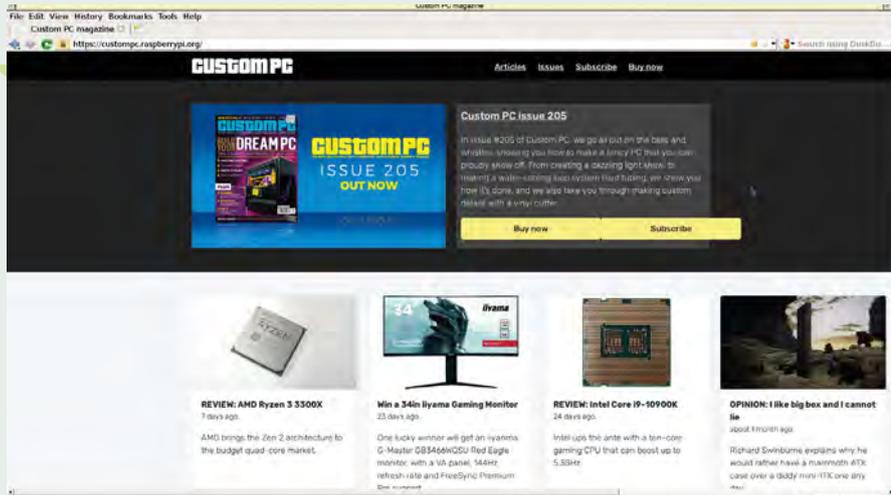
Otter Browser is better than NetSurf, but still fails to render the Custom PC homepage properly

You can't be a modern OS without a storefront, and for RISC OS that storefront is PlingStore

ZX Spectrum Next smashes second crowdfund goal

TBBlue's ZX Spectrum Next computer (reviewed in Issue 202) has blown past a crowdfunding goal for a second production run, raising over £1.4 million at the time of writing.

An FPGA-powered modern successor to the Sinclair ZX Spectrum, the ZX Spectrum Next raised over £700,000 on its first crowdfunder. While launching two years late, it proved popular enough for a second production run, which will now take place with a view to shipping by August 2021. Prices have, however, gone up. The top-end ZX Spectrum Next Accelerated cost £230 in the original run, but now costs £325 (inc VAT). See **specnext.com** for more information.

RISC OS. It comes with a selection of software pre-installed, and a wallpaper that doubles as a quick-reference guide.

For anyone who cut their teeth on an Archimedes or RISC PC, RISC OS will be immediately familiar – its appearance and mode of operation has barely changed in the decades since its launch. For anyone coming from Linux, macOS or Windows, there will be a period of acclimatisation, particularly when it comes to RISC OS' shifting of context menus from the right mouse button to the middle.

As it uses the same windows, icons, menus and pointer (WIMP) paradigm as any other modern desktop OS, though, it shouldn't take anyone long to get to grips with RISC OS, and there's plenty to see in RISC OS Direct.

This distribution makes no bones about its focus on pulling in programmers to revitalise the RISC OS software ecosystem. The desktop has a directory called 'Programming', which contains a variety of languages and tools, alongside handy reference material – including a full electronic copy of Martyn Fox's First Steps in Programming RISC OS Computers.

There are also two web browsers – NetSurf and Otter Browser, which make a brave though ultimately less than successful attempt at rendering modern websites. There's a text editor and word processor, as well as image editing and video playback tools. There's even the latest version of PipeDream, a productivity suite that will be immediately familiar to anyone who was involved with educational computing in the UK in the 1980s.

There's also the PlingStore, RISC OS' electronic storefront. Double click on the icon and, if you're connected to a network, you'll be

delivered a list of programs that can be installed in just a couple of clicks. Many of them are free, but a handful of them require a user account and payment via credit or debit card to install.

RISC OS Direct, like plain old RISC OS, hasn't forgotten its roots. It comes pre-installed with Aemulator, an emulator that bridges the gap between classic Archimedes and modern RISC OS systems. Aemulator takes classic 26-bit programs and translates the instructions into 32-bit mode on the fly, meaning it's possible to take any Archimedes programs you have lying around and, if you can still read the disks, load them into RISC OS on a Raspberry Pi.

There's one big caveat though. RISC OS Direct is, at present, only compatible with the Raspberry Pi 3 and below. Work is in progress to port RISC OS to the faster Raspberry Pi 4, but at the time of writing had not been completed.

RISC OS Direct is available to download from **riscosdev.com/direct** for free.

REVIEW
Computing Across America

Staying connected to the Internet is easy now, but 'going online' used to be a process, and one that wasn't easy to do outside the confines of the office or a few forward-looking homes.

It was in this significantly more disconnected world that Steven Roberts had an idea: sell his belongings, build a custom bike dubbed the Winnebiko, and travel across the USA with little more than his wits and a TRS-80 Model 100 portable computer.

To put that into perspective, the Model 100 launched in 1983 and came with just 8KB of memory as standard, expandable to 32KB. Built around a 2.4MHz Intel 80C85 processor, the all-in-one unit ran on four AA batteries and had an unlit single-colour TN LCD panel offering eight lines of text at 40 characters per line, or a rather cramped 240 x 64 bitmap display.

Roberts was betting that he could continue his technology journalist and commentator career from just this device and an acoustic coupler – a variant of dial-up modem; rather than plugging directly into a telephone line, this hugged a telephone handset allowing it to work from payphones as well as private lines – plus a subscription to pre-World Wide Web online service CompuServe.

For much of the first half of the book, the plan doesn't go so well: money is always tight, and Roberts' regular communications back to a physical office acting as a fixed point of call frequently include references to threatening letters and past-due bills. The project was saved, however, by a deal to write this book.

Sadly for technophiles, there's rather more 'America' than 'computing' in its pages. The book is written directly from Roberts' recollections, based on notes taken during the Winnebiko trips cross-country, and concentrates more on the human aspect than the underlying technology that made it possible.

Less 'human', in fact, and more 'women'. Much of the book is given over to Roberts' sexual encounters – real, hoped for and imagined. While some seemingly salacious setups, such as being invited to bunk up in a women's college dorm, don't pay off, others
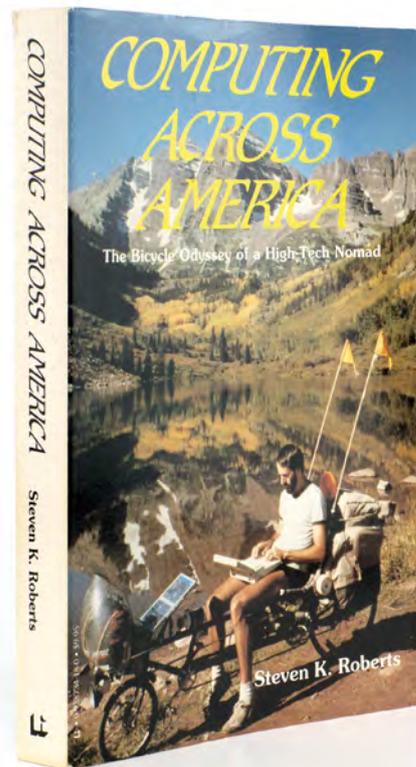
You'd be forgiven for thinking Roberts spent less time 'computing' and more time 'canoodling' across America

undeniably do. However, it's hard to feel happy for the author when faced with a series of paragraphs detailing Roberts' live-chat cybersexual escapades with a flirtatious CompuServe member, while also sharing meatspace with real-life women who would have been dismayed to discover what had really captured Roberts' interest on the Model 100's screen.

The book takes a few paragraphs out to describe in brief the operation of the Winnebiko and Roberts' work with the Model 100; a little more time is spent gushing over the benefits of upgrading mid-trip to a Hewlett-Packard Portable – partly because HP provided it as promotional consideration.

The end of the book isn't the end of Roberts' journey. He's still playing the role of 'high-tech nomad' today, having traded the Winnebiko for a boat converted into a floating lab – now for sale, as he moves onto yet another adventure. Computing Across America, ISBN 0-938734-18-0, is out of print, but second-hand copies are sometimes available, or the book can be borrowed electronically for free from the Internet Archive (**archive.org**). CPC
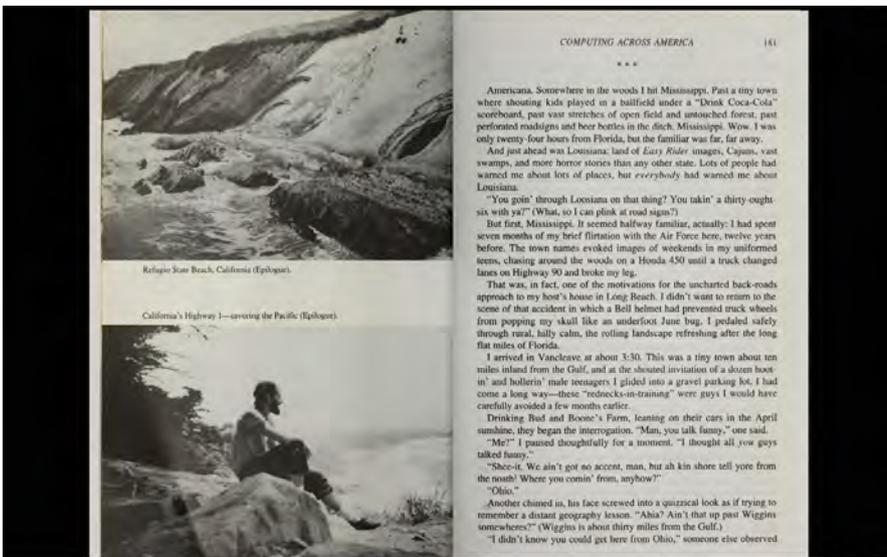
The book is long out of print, but can be borrowed for free from the Internet Archive

Gareth Halfacree is a keen computer hobbyist, journalist, and author. His work can be found at **freelance.halfacree.co.uk** @ghalfacree

WIN

A 32IN CURVED IIYAMA GAMING MONITOR

We've got a cracking 32in gaming monitor up for grabs this month, thanks to iiyama. One lucky **Custom PC** reader will get an iiyama G-Master GB3266QSU Red Eagle monitor sent to their home, with a curved VA panel and a 144Hz refresh rate.

- **31.5in VA panel**

- **1500R curve**

- **3,000:1 contrast ratio**

- **144Hz refresh rate**

- **FreeSync Premium**

- **1ms response time (MPRT)**

- **2,560 x 1,440 resolution**

- **2 x HDMI and 2 x DisplayPort inputs**

- **Stereo 5W speakers**

- **USB 3 hub**

WORTH
£350

Immerse yourself in the game with the GB3266QSU Red Eagle. This 32in monitor's VA panel has a 1500R curve, a 1ms response time (MPRT), a 144Hz refresh rate and a 2,560 x 1,440 resolution, giving you an immersive viewing experience and superb image quality.

The height-adjustable stand ensures you can easily change the screen position, while the easily customisable screen offer predefined and custom gaming modes. Meanwhile, the Black Tuner function gives you control over dark scenes to make sure details are always clearly visible.

SUBMIT YOUR ENTRY AT **CUSTOMPC.CO.UK/WIN**

ANTONY LEATHER'S

Customised PC

Case mods, tools, techniques, water-cooling gear
and everything to do with PC modding

Always check CPU waterblock compatibility

When it comes to water-cooling your hardware, there are plenty of reasons to do your research first to make sure your new cooling system will not only handle the heat dished out by your components, but will also be compatible with your

CPU waterblocks are generally universal when it comes to supporting specific AMD or Intel motherboards

hardware. Radiators usually fit into appropriate fan mounts, for example – a location with two 120mm fan mounts next to each other can usually offer a home to a 240mm radiator.

You have to check clearance with other components, of course, but it's true as a general rule of thumb, even in small form factor cases.

Waterblocks are a slightly different matter. Graphics card PCBs tend to vary a lot and, unless you opt for a model made by the GPU manufacturer, such as Nvidia's Founders Edition series, or a reference PCB with a blower-style fan, you'll likely be at the mercy of waterblock manufacturers when you want to find a waterblock for your particular model.

Thankfully, with plenty of waterblock manufacturers around these days, including newcomers such as Corsair, it's quite rare that you'll be left out in the cold. It's still a good idea, though, to consider buying your graphics card with water cooling in mind, perhaps

stumping up a little extra for a Founders Edition card, or waiting for the likes of EK Water Blocks to announce its plans for compatibility with partner cards.

However, I was caught out recently when it comes to CPU waterblocks. Generally, I've never had an issue with compatibility. After all, there are limits put on motherboard manufacturers to maintain a keep-out zone around the CPU socket. You might have issues with some large CPU coolers and memory slots or large heatsinks, but generally waterblocks should fit, as they don't interfere with these parts, and they sit very low.

I was testing Asus' ROG Strix B550-I Gaming mini-ITX motherboard last month and for some reason I was getting consistently high CPU temperatures. In fact, high is a bit of an understatement. I thought I'd forgotten to apply thermal paste, that the block itself was clogged.

I switched to a completely different waterblock and the problem was fixed
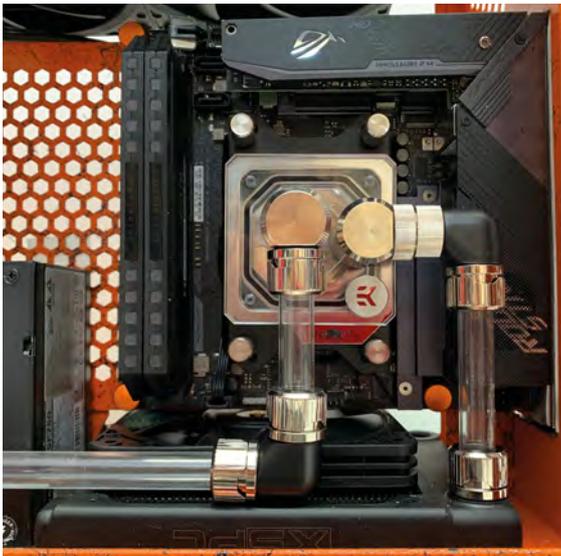
instantly. However, after inspecting and dismantling the previous block, I couldn't find any reason for it to be performing so poorly. I reseated it and, with fresh thermal paste applied, I secured it to the motherboard for a second attempt. However, I noticed that the block appeared to be sat at an angle and looked as though it wasn't sitting flush on the CPU heatspreader. My suspicions were correct – when I removed the block to take a look, most of the thermal paste was untouched on the CPU.

As it turns out, a power circuitry heatsink on the motherboard was fouling the very large Corsair Hydro X waterblock housing, and preventing
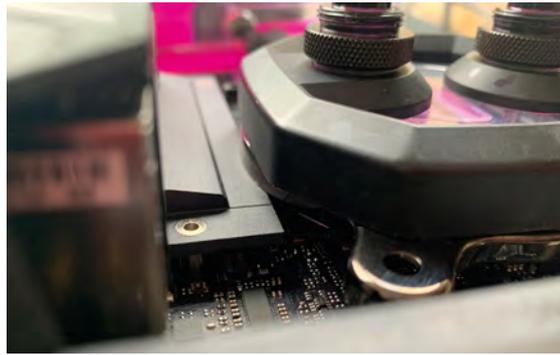
The Corsair waterblock fouled the VRM heatsink on this motherboard

it from sitting on the CPU properly. I was about to reach for the phone to shout expletives at Asus and Corsair, but decided to check Corsair's product page first and noticed that there was a

motherboard compatibility list. The Asus board, and plenty of others too, were not on it. I was honestly a bit taken aback, given that I've been water-cooling PCs for nearly two decades. I've never had this issue with another waterblock – they're generally considered universal, perhaps with different mounting fittings for different sockets.

Anyway, the moral of this story is to always remember to check CPU waterblock compatibility with your motherboard before purchasing your block. It's highly unlikely there will be issues, but I thought I'd bring this to your attention to save you the aggravation I went through last month.

Motherboards finally compete on features

A couple of years ago, reviewing motherboards became a bit tedious. The boards were getting more and more similar, both aesthetically and in terms of features, with little to distinguish them. Most had switched to a black colour scheme, sporting RGB lighting to add some flair, and prices have gone up quite a bit over the past few years too.

It's now rare to see features such as power buttons, reset buttons, clear-CMOS buttons and LED POST code displays on sub-£200 boards, while most boards have Realtek ALC1220 audio, and the same number of SATA and M.2 ports. Unless there was notably better overclocking performance or
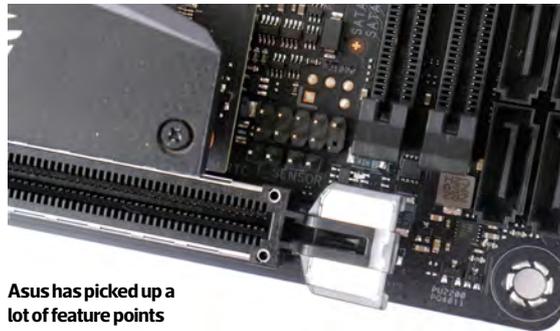
Asus has picked up a lot of feature points in our reviews thanks to items such as thermal probe headers being included

USB Type-C headers are another sought-after feature

software, scores and recommendations were often close calls.

However, I've noticed a change with many motherboards, where there's now a renewed focus from manufacturers to compete in a number of areas that are of concern to enthusiasts. Power delivery is one, and the quality and cooling on offer is much better overall than it was a few years ago too, which means motherboards are now much better able to handle higher power draws and increasing core counts. Poor-performing boards have been the subject of enthusiast scorn too.

Ports are another area where enthusiasts and reviewers swing from one board to another. USB Type-C headers for compatible cases are

becoming increasingly important, and in some of my video reviews on my CrazyTechLab YouTube channel, some comments have criticised manufacturers for excluding them.

We praised Asus in last month's mini-ITX group test, thanks to its great cooling and inclusion of thermal probe headers on both its B550 and Z490 chipset boards – features that every other manufacturer's board lacked.

I was disappointed with Gigabyte here too, as it included these features on many of its larger boards, tapping into its excellent EFI and software-based fan control interfaces. Had it included them with its mini-ITX boards, the company would have fared considerably better, especially when water cooling is becoming increasingly popular, as are high-end mini-ITX systems.

Now more than ever, enthusiasts are paying close attention to features, and I'm glad to see manufacturers listening, at least to some degree. Prices are certainly quite high, as are expectations, but with so many USB standards floating around, I don't envy motherboard manufacturers at the moment either. **CPC**

Antony Leather is Custom PC's modding editor 🐦 @antonyleather
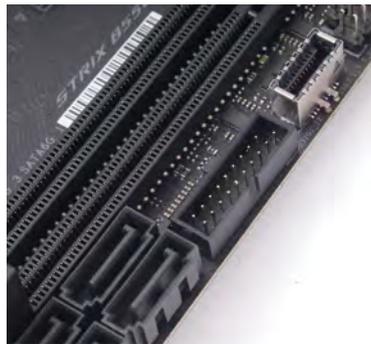
How to
Add ports to reservoirs

Inlet and outlet ports not in quite the right places for your tubing run? **Antony Leather** shows you how to add a new port to your reservoir

TOTAL PROJECT TIME / 2 HOURS

Modern water-cooling reservoirs are often quite flexible when it comes to ports, enabling you to point the inlets and outlets in the right directions for your loop. They can even offer multiple ports for both inlet and outlet functions, with the rest of the ports sealed using blanking plugs. However, not every reservoir will work with every angle of tubing you want, and sometimes the reservoir you really want doesn't have all the ports in the right places.

Thankfully, it's actually quite easy to add a G1/4in threaded hole to your reservoir, using basic tools and some elbow grease. In this guide, we'll show you how to do it in a way that makes it look as if your new port was always there.

TOOLS YOU'LL NEED

Spray lubricant
Most hardware stores

Tapping tool and 1/4in BSP x 19 TPI second cut tap
ebay.co.uk

Drill with 3mm and 12mm bits
amazon.co.uk

Masking tape
Most hardware stores

1 / INSPECT THE RESERVOIR
To see if you can add ports to your reservoir, first check if it's made from a suitable material in the area where you want to add your port. Avoid cutting through multiple materials, and ensure the thickness of the wall is at least 5mm in order to avoid it cracking when the fitting is inserted.

2 / IDENTIFY PORT LOCATION
If you're adding a port, it's likely you'll be needing it to be in a specific location to suit the rest of your loop. Check that this location has enough clearance away from other ports and mounting holes in the acrylic.


3 / CHECK FOR INLET AND OUTLET
You'll need to have an idea about the flow direction of your loop and reservoir before you add the port. If you're adding a port to the main tank, the port will need to act as an inlet to fill the tank and not an outlet.
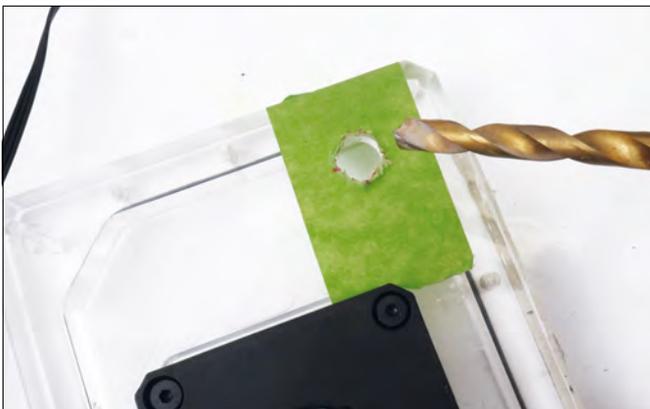
4 / MARK UP HOLE

Start by adding masking tape to the area, so you can draw onto it easily and prevent slips with your drill from scratching the reservoir. Mark a centre point here to drill your hole.
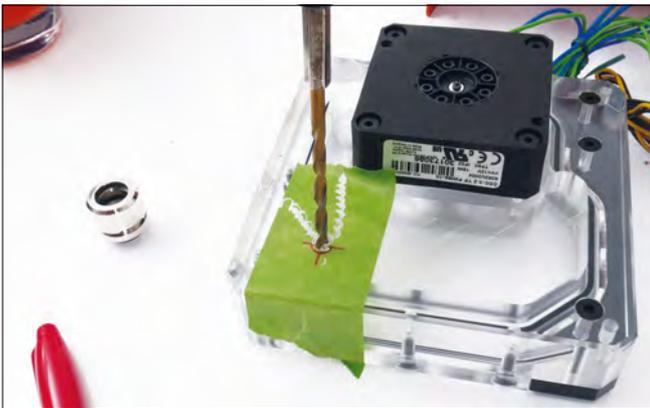
5 / DRILL PILOT HOLE

Use a 3mm drill bit to create a pilot hole for the larger drill bit to use as a guide. This will also make cutting the larger hole a little easier.

6 / ENLARGE THE HOLE

Use a 12mm drill bit to drill the final hole. This will ensure there's enough material into which the tap can bite to create the threads, but not so much as to prevent the tap bit from fitting into the hole.

7 / USE THE TAP

With the larger hole created, insert a G1/4in tap bit into the tool and then place it squarely into your drilled hole. Start by pressing firmly and allowing the tap to cut into the hole. When you feel significant resistance, back the tap out of the hole, clean off the debris and go in again.

8 / LUBRICATE THE HOLE

Add a little 3-In-One, WD40 or a similar lubricant to the hole, to reduce friction in the latter stages. Remove the tap and spray a little liquid into the hole, adding more as required. Keep cutting into the material by turning the tap tool and then backing off. Eventually you'll create the G1/4in thread.

9 / INSTALL YOUR FITTING

The fitting should now screw into the thread, but may initially require a bit of force. If you struggle to get it to bite, use the tap tool again to work the thread a little more. Once your fitting is in place, check that its O-ring sits flush with the reservoir. Needless to say, leak testing is essential once you've filled your loop.

▶

How to
Add extra fan mounts

Antony Leather takes you through the art of creating fan blowholes in your case

👆 TOTAL PROJECT TIME / 2 HOURS

With graphics card coolers sporting ever weirder airflow systems, and elaborate water-cooling loops becoming more popular, some cases just aren't flexible enough to point airflow in the right direction for everyone's chosen setup. Budget cases in particular can often benefit from a few extra fans, and they often lack fan mounts in otherwise common locations, which would enable them to boost cooling or allow for water-cooling gear to be installed.

In this guide we'll show you how to create your own fan mounts, by cutting your own fan blowhole, and equip your new fan mount with a dust filter too. You'll then be able to beef up your PC's cooling in a variety of locations.

TOOLS YOU'LL NEED

Masking tape
Most hardware stores

Dremel and reinforced cutting disc
Most hardware stores

Holesaw
wickes.co.uk

Black marker pen
Most hardware stores

Rounded metal file
Most hardware stores

Grille or dust filter
ebay.co.uk

Drill and drill bits
Most hardware stores

1 / SELECT LOCATIONS

There are plenty of locations where you can add fan mounts to your case, but they're most easily created on flat metal panels, such as rooves or bases. Mounting extra fans in these areas can also benefit graphics card and CPU cooling.

2 / CHECK CLEARANCE

Before cutting your blowhole, check for clearance on the inside your PC, to make sure your fan won't clash. Check for motherboard heatsinks in the area, as well as reinforcement beams inside your case, which you'll want to avoid cutting if possible.

3 / 120MM VS 140MM FANS

If you have the space, you don't need to stick to 120mm fans and can consider 140mm fans instead, which usually offer lower noise levels and higher airflow than their 120mm counterparts. They're the same thickness as 120mm fans, but are wider and longer, so check you have enough room.

4 / TYPES OF GRILLES

If your fan is exhausting air from your case then you don't need to worry about filters. However, it's always a good idea to protect yourself and others from fan blades using a grille. These are cheap, and you can opt for snazzy designs or even 3D-print your own ones.
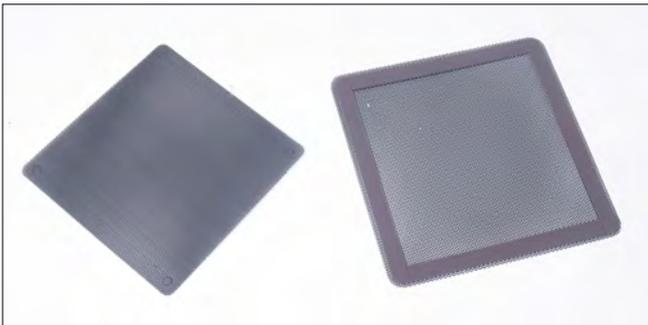
5 / DUST FILTERS

If your fan will be acting as an intake, then you need to use a dust filter. There are a few options here, and the easiest is using an off-the-shelf filter that fixes between the fan and mount, or you can use a magnetic filter that attaches to the outside. You can also create your own filter using a material such as nylon tights or thin cloth.

6 / MARK UP FOR CUTTING

Use masking tape to draw your blowhole position. This tape will also protect the case if your saw blade slips. Mark the spot for a pilot drill in the centre of your fan mount. We'll be using a 114mm hole saw to create our fan blowhole, with a pilot drill mandrel.


7 / DRILL PILOT HOLE

Allow the pilot drill to create its guide hole. Do this gently, as it's easy for it to slip at first, which will result in your hole being off-centre. Once it's passed through the panel, lift the holesaw away and check that the pilot hole is lined up for the holesaw to make its cut in the right place.

8 / USE HOLESAW

The holesaw will cut a single large chunk out of your case, but it can be tough to cut through steel cases, so take your time. Apply medium pressure with the saw but, when you're nearing the end, back off the pressure and allow the weight of the drill to do the work.
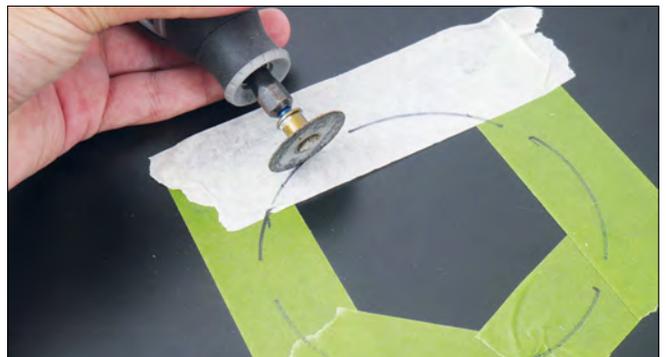
9 / USE A DREMEL

If you don't have a drill, you can mark out a circle for your fan blowhole and gradually work a Dremel with a reinforced cutting disc around the hole to cut it out. This will take much longer than a holesaw, and will need more finishing work, but will save on the cost of extra tools. Make sure you use mask and eye protection.

10 / FILE EDGES

Use a rounded metal file (**Ed:** with less rust on it!) to get rid of sharp edges around the hole, and continue filing until the edges are smooth. Alternatively, you can also use a Dremel and sanding attachment.


11 / COLOUR THE EDGES

If you have a black case, you can use a permanent marker pen to colour the bare metal. This will make your cutting work look far less obvious than with the bare silver metal on show from its meeting with the saw.

12 / MARK UP DRILL HOLES

With your hole cut, line up your fan and use it as a template to drill your fan-mounting holes. The screws just need to pass through the panel, so use a drill bit that's slightly larger than the screws included with your fan.
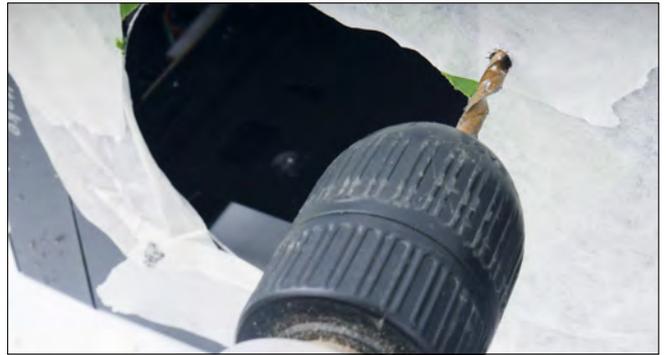

13 / DRILL SCREW HOLES

Go ahead and drill the mounting holes into your case, checking the alignment of each one first to ensure that they all line up. If one hole ends up being slightly amiss, you can use a small metal file to open it in the desired direction and the screw head will usually cover the oversized hole.

14 / INSTALL FILTER

Now go ahead and install your filter or fan grille, ensuring it's the right way around. Grilles usually sit on the outside of the case, while some filters are best placed between the fan and your case's panel.
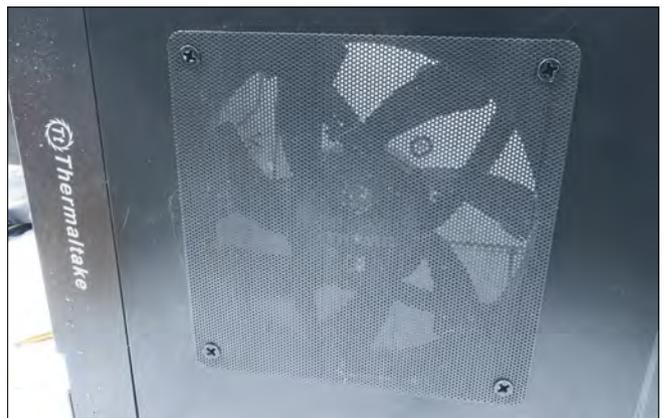
15 / INSTALL FAN

If you're installing the fan in the base of the case, flip it upside down to make the installation process easier. Hold the fan in place from underneath, then insert the mounting screws. Don't tighten one fully, but instead move around and tighten each screw a few rotations in turn. **CPC**

Folding@home

Join our folding team and help medical research

ACTIVE USER MILESTONES

USERNAME	POINTS MILESTONE
Shirty	5,000,000,000
Dave_Goodchild	1,000,000,000
Allan_Smith	700,000,000
tarka_dahl	600,000,000
sonic_vortex	500,000,000
Christopher_N._Lewis	200,000,000
rjcman	200,000,000
Simlec	200,000,000
NoizDaemon666	100,000,000
chubarker	80,000,000
dis80786	70,000,000
mort6dav3	60,000,000
TechnoStuck	60,000,000
Chaplain-Brawl	50,000,000
40138	50,000,000
phys1csb0y	50,000,000
meandmymouth	50,000,000
awstcomputers	40,000,000
jvbrugger	30,000,000
MEH_Desktop	30,000,000
gKitchen	30,000,000
YCDCN22	30,000,000
Liaw_Jun_Xian	20,000,000
Mr_Blue_Jam	20,000,000
anadir2	20,000,000
Geoff.Ashden	10,000,000
Maleor	9,000,000
marcostheblack	9,000,000
TokerRizla	9,000,000
Will_Walton	9,000,000
Howard	7,000,000
Chebob	7,000,000
SirNigel16	5,000,000
TheRepublicofKirkup	4,000,000

USERNAME	POINTS MILESTONE
BrawnyFanta	4,000,000
Jim	4,000,000
markdiss	3,000,000
JasperofBelper	3,000,000
Unreal2will	3,000,000
leeoliver24	3,000,000
Parmesan	2,000,000
Lightning	2,000,000
G4zm4n	1,000,000
Sidog21	1,000,000
Sonic67	1,000,000
Trotski	900,000
suggestable	900,000
manfromthezoo	800,000
yonedafolding	600,000
MDT	600,000
Thunder	500,000
Cole	500,000
Rabaks	300,000
FlamingBadger	300,000
RedGamerDanger	300,000
Wenna	300,000
Kempes17	300,000
revMaxx	200,000

WHAT IS FOLDING?

Folding@home uses the spare CPU and GPU cycles for medical research, with a current focus on COVID-19. You can get the client from **foldingathome.org/start-folding** and our team's ID is 35947. Once you pass a significant milestone, you'll get your name in the mag – we'll print all the milestones we can fit on the page. You can discuss folding with us and other readers online at the bit-tech forums (**custompc.co.uk/FoldingForum**).

TOP 20 PRODUCERS

RANK	USERNAME	DAILY POINTS AVERAGE	OVERALL SCORE
1	Dave_Goodchild	13,482,871	1,146,723,248
2	DocJonz	10,831,032	12,452,174,540
3	Shirty	7,411,210	5,123,598,623
4	tarka_dahl	6,234,056	691,705,979
5	Desertbaker	5,793,027	2,551,700,273
6	Lordsoth	4,502,513	4,417,170,545
7	Slavcho	3,601,434	2,970,052,455
8	PC_Rich	3,138,463	6,213,970,284
9	BurnedFastfood	2,090,296	171,525,908
10	pcchameleon	1,774,147	152,846,028
11	rjcman	1,456,650	219,550,364
12	Allan_Smith	1,417,867	724,771,251
13	Little_Willie	954,801	276,091,571
14	sonic_vortex	942,634	524,475,655
15	Dickie	909,507	1,107,782,488
16	Simlec	904,803	200,525,300
17	gKitchen	871,267	37,787,804
18	KevinWright	794,464	1,209,910,842
19	kornvdd	705,410	176,254,324
20	Chaplain-Brawl	630,404	56,913,074

TOP 15 OVERALL

RANK	USERNAME	POINTS	WORK UNITS
1	DocJonz	12,452,174,540	324,804
2	PC_Rich	6,213,970,284	162,841
3	Shirty	5,123,598,623	38,984
4	Nelio	4,417,170,545	523,610
5	Lordsoth	4,282,301,179	174,063
6	HHComputers	3,544,050,839	85,007
7	Slavcho	2,970,052,455	67,781
8	piers_newbold	2,703,256,197	107,638
9	Desertbaker	2,551,700,273	59,978
10	Scorpuk	2,544,545,152	57,727
11	clanseven	2,223,720,446	33,156
12	Unicorn	1,753,462,654	57,079
13	daxchaos	1,637,104,710	41,302
14	Laguna2012	1,527,029,380	51,930
15	apeman556	1,473,567,286	52,001

Retro tech

INSTALLING DOS ON VINTAGE HARDWARE

Following our recent vintage PC building guide, **K.G. Orphanides** shows you how to get a retro PC up and running with FreeDOS

Because MS-DOS 6.22 is increasingly hard to obtain legitimately – your options are old floppies on eBay or an annual Microsoft Visual Studio subscription that costs over a grand – you're better off with a modern open source DOS. We're using FreeDOS, an actively developed MS-DOS-compatible operating system that's sufficiently close to the original that neither you nor your software are likely to notice the difference. You can grab a copy from **freedos.org**

> ## It comes with quality-of-life features, such as PS/2 and USB mouse drivers

It comes with quality-of-life features, such as PS/2 and USB mouse drivers, Tab command completion, file decompression tools and support for FAT32 file systems – it can handle soft reboot and shutdown commands too. Connect your FreeDOS PC to the Internet, and there's an even a package manager, FDNPKG, to help you install and update your system utilities.

PARTITION YOUR DISK AND INSTALL DOS

FreeDOS's current stable release is version 1.2, but we recommend using the near-final live CD release candidate of FreeDOS 1.3. From the FreeDOS website, follow the release candidate link to **custompc.co.uk/FreeDOS** and download FD13-LiveCD.zip. Burn it to a CD-ROM, make sure the BIOS on your DOS PC is set to boot from CD before hard disk, insert the disc and boot the machine. If your DOS system doesn't have a CD-ROM drive, there's also an FD13-Floppy image.

At the FreeDOS menu, select Install to harddisk – this works fine on a CompactFlash card, as used in our hardware guide too. If your drive is blank, you'll be asked if you want to partition it. Select Y to automatically partition drive C – the maximum available partition size will be used.

Reboot when prompted and select Install to harddisk again. Erase and format drive C when prompted. Select your keyboard layout and then choose 'Full installation including applications and games'. Confirm your choice, wait for installation to complete, eject the CD and reboot. If you need more control of your disk partitioning, instead select Use FreeDOS 1.3 in Live Environment Mode and type FDISK at the command prompt.

Unlike MS-DOS, FreeDOS supports FAT32, which means you can have hard disk partitions bigger than 2,047MB. If your disk is 2TB or larger, you'll be asked if you want to enable FAT32 support. Click Yes here, unless you specifically want to create multiple smaller partitions that are backwards compatible with older versions of MS-DOS.

USING DOS

DOS is a command line operating system, and if you've ever used Windows' cmd, it will feel familiar. It's case-insensitive: commands, paths and file names don't have to be typed in UPPER CASE but are often styled that way. To run an

```
Free FDISK is capable of using large disk support to allow you to
create partitions that are greater than 2,048 MB by using FAT32
partitions.  If you enable large disk support, any partitions or
logical drives greater than 512 MB will be created using FAT32.

IMPORTANT:  If you enable large disk support, some operating systems
will be unable to access the partitions and logical drives that are
over 512 MB in size.


Do you want to use large disk (FAT32) support (Y/N).[Y]?
```

Unlike standalone versions of MS-DOS, FreeDOS supports the FAT-32 file system

The FreeDOS 1.3 RC3 live disk makes testing, formatting and installation a convenient menu-driven affair

executable file – which will typically have a .COM, .EXE or .BAT extension – just type its name without the extension. File and directory names are limited to eight characters and extensions to three, with longer names curtailed with a tilde (~). When you're finished with DOS, you just turn off the computer. Some older programs don't even have the option of quitting back to the command line.

EDITING DOS CONFIG FILES

As it loads, DOS looks for specific user instructions in files traditionally known as AUTOEXEC.BAT and CONFIG.SYS, in the root of your boot drive, whether that's a floppy or your C:\ partition. As we're using FreeDOS, these are actually called FDCONFIG.SYS and FDAUTO.BAT. FreeDOS includes a selection of useful drivers, such as ones for mice and CD-ROM drives, and these are already called in its boot files.

The easiest way to create or modify these files, assuming you're using a CompactFlash or SD card for your hard disk,

is to simply mount your drive on your usual PC with a card reader and copy in the lines you need using a GUI editor, such as Notepad in Windows. If you prefer to write or edit config files under DOS, just use FreeDOS' EDIT command for a very capable MS-DOS editor with mouse support. If you want to comment on a line, put the word 'rem' in front of it. This is handy for troubleshooting and working out exactly what lines you need in your boot files.

DRIVERS

Although FreeDOS has some integrated drivers, you'll still need the manufacturers' drivers for your sound card, possibly your graphics card, and any non-standard interfaces or unusual input devices, such as specialist joysticks and Zip drives.

Your first stop for driver sourcing should be Vogons Drivers (**vogonsdrivers.com**), a spin-off of the popular and infinitely helpful Vogons retro gaming message board. The drivers generally come with full instructions and examples of the lines you'll need to insert in boot-time config files. Another useful collection of hardware drivers, this time with a focus on storage devices, can be found at Hiren & Pankaj's Homepage (**hiren. info/downloads/dos-files**).

FreeDOS' default FDAUTO.BAT file includes the most common SET BLASTER address line for Sound Blaster compatible cards. This will be enough in many cases, but you may still have to add the path to the actual driver yourself, as well as assigning your own MIDI settings. For example:

```
SET BLASTER=A220 I5 D1 H5 P330
SET MIDI=SYNTH:1 MAP:E
SET SOUND=C:\DRIVERS\SB16
```


The OS comes with FreeDoom, but real Doom works well too

```
1 - Load FreeDOS with JEMMEX, no EMS (most UMBs), max RAM free
2 - Load FreeDOS with JEMM386 (Expanded Memory)
3 - Load FreeDOS low with some drivers (Safe Mode)
4 - Load FreeDOS without drivers (Emergency Mode)

 Select from Menu [1234], or press [ENTER] (Selection=1)

 Singlestepping (F8) is: OFF
```

Pre-defined startup menus provide commonly required memory configurations, but you can add your own too

Under DOS, you'll generally have an easier time of configuration if you stick with ISA cards, although we got the PCI Sound Blaster Live! 5.1 from 2000 working with some tweaking of its driver's CTSYN.INI file. If you run into IRQ or DMA conflicts, check your motherboard's bios settings – if in doubt, disable on-board components such as unused parallel and serial ports, and – especially if you're using PCI components – disable Plug and Play and enable Legacy Mode.

Graphics drivers were far less important in the DOS era than now: if your card supports the VGA display mode, you can select VGA from your game's installation options and it will work. In some cases, such as with the 3dfx Voodoo range of 3D graphics cards, DOS games that supported them would come bundled with the relevant driver – GLide in the case of Voodoo. However, you may need to copy your own more recent copy of the driver file into the game's directory – we copied the glide2x and glide3x DLL and OVL files from our Voodoo 3 3500 TV's Windows driver disk and it worked fine.

TRANSFERRING DATA

If you're using a CompactFlash or SD card-based DOS drive and have a reader connected to your PC, you can just mount your entire DOS drive under your normal Windows, Linux or macOS operating system and copy any files you want to it. This convenient approach makes it easy to get retro games you've bought on **gog.com** or Steam onto your DOS drive – we tried this with the Steam versions of Quake and Ultimate Doom, and both games worked fine on our retro machine.

Alternatively, you can burn a load of DOS software to a data CD and transfer it the old-fashioned way. However, if you're using standard IDE hard disks, or you don't want to routinely open your DOS PC to load up its hard disk, you might want to add USB mass storage support to FreeDOS.

If your motherboard has the common UHCI-compliant host controller, then you're in luck, as FreeDOS includes Bret Johnson's USBDOS drivers (**bretjohnson.us**). We recommend just invoking them as needed to keep memory consumption down, rather than loading them in FDAUTO.BAT.

If your vintage system only has an OHCI controller, or if you're using a newer motherboard with an EHCI USB chipset, then you'll need Panasonic's multi-chipset USBASPI driver (**custompc.co.uk/USBASPI**) and use the Motto Hairu USB Mass Storage driver (**custompc.co.uk/Hairu**) to mount your disks. To add an OHCI controller in FDCONFIG.SYS, add the following lines, modifying the driver paths as appropriate:

```
DEVICE=C:\DRIVERS\USBASPI1.SYS /V /O
DEVICE=C:\DRIVERS\di1000dd.sys
```

USB drives must be plugged in at boot time to be accessible.

CPU THROTTLING

If you're using a 500MHz PC from 2000 to run games from 1991, your processor will make older clock cycle fixed software run impossibly fast. FreeDOS includes the SLOWDOWN tool to counter this problem.

For Origin's Martian Dreams, for example, with an executable called MARTIAN.EXE, we just typed SLOWDOWN MARTIAN in its directory. You can then reduce speeds by pressing Ctrl and Alt together until you get the speed with which you're happy.

MEMORY MANAGEMENT

The classic DOS games came from a time when only 640KB of conventional (or base) memory could be directly used in MS-DOS 'real mode'. Even then, that was a tiny amount of

KNOW YOUR FREEDOS COMMANDS

DIR
List everything in the current directory. FreeDOS by default applies the /P command extension to pause when the screen is filled. Press space to see more.

DIR /W
Show filenames and extensions only, in a columnated list.

X:
Change to specified drive letter, swapping 'X' for the letter of the drive you want to access.

CD PATH
Change Directory to the specified directory name or path, replacing PATH with the name of the directory you want to access.

CD..
Move back to previous directory

**CD **
Move to top level directory

MD NAME
Make a Directory called NAME

COPY X:\PATH\ X:\NEW\PATH
Copies files and directories from one place to another

MOVE X:\PATH\ X:\NEW\PATH
Moves files and directories to a new location

EDIT
The friendliest DOS text editor

RESET
You don't have to type reset to reboot your PC, but FreeDOS gives you the option

SHUTDOWN
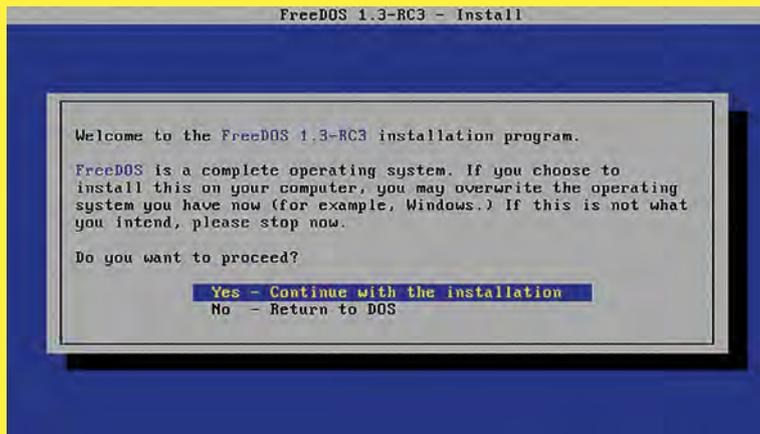Another optional FreeDOS command for the comfort of modern computer users

FDISK
DOS partitioning tool

FORMAT X
Formats the specified drive (replace X with the appropriate drive letter). This will erase its contents and ready it for use with DOS

FreeDOS 1.3-RC3 - Install

Welcome to the FreeDOS 1.3-RC3 installation program.

FreeDOS is a complete operating system. If you choose to install this on your computer, you may overwrite the operating system you have now (for example, Windows.) If this is not what you intend, please stop now.

Do you want to proceed?

    Yes - Continue with the installation
    No - Return to DOS

You can usually install straight from the CD without any fuss, but you can run FDISK from the live OS if you need more control over drive partitioning

RAM with which to play, so methods of increasing available memory were rapidly introduced. These included a 64KB high memory area, expanded memory of up to 32MB (EMS) and extended memory of up to 4GB (XMS).

In FreeDOS, these memory areas are controlled by HIMEMX, JEMMEX, and JEMM386, which are invoked in FDCONFIG.SYS.

From the late 1980s onwards, most games included installers

To free up extra memory, DOS users traditionally have to juggle extended memory management tools, load drivers into the high memory area, and winnow out unnecessary drivers until there's enough memory available to load your desired application.

If you're using an IDE CompactFlash reader for your retro machine, you can plug it into a card reader on a Windows PC to easily copy and edit files for your OS

As an alternative to using the old-school boot floppies that most gamers had at the time, we're going to use FreeDOS' integrated startup menu system.

FreeDOS has already done a lot of the work for us here, creating high memory and JEMM386 expanded memory startup options.

If you need the maximum amount of conventional memory available, select option 1, Load FreeDOS with JEMMEX, no EMS (most UMBs) and max RAM free, which nets us 643KB of available conventional memory.

If you're running one of the many 1990s games that require EMM386 expanded memory (their manuals will tell you if they do), you want option 2.

MAKE YOUR OWN BOOT MENU
In FDCONFIG.SYS, a MENUDEFAULT section defines four numbered startup menus. We can add an extra option 5 like this:

```
MENU 5 - SB LIVE (JEMM386, HIMEM, NO USB)
```

In the same file, you can add specific lines to a chosen menu number by putting the number(s) and a question mark at the start of the line. For example, putting '125?' before a line means it will be included in boot options 1, 2 and 5 – we've added '5?' to lines that call HIMEMX, JEMM386 and FDAUTO. BAT to include those features in our new menu option.

In FDAUTO.BAT, a quick way to load drivers that only apply to your new menu option is to insert an 'if not' block just before :FINAL at the bottom. For example, the following lines enable a PCI Sound Blaster Live! if we select menu option 5, but skips straight past it if we select any other menu option:

```
IF NOT "%CONFIG%"=="5" GOTO FINAL
:SBLIVE
SET MIDI=SYNTH:1 MAP:E MODE:0
SET BLASTER=A220 I5 D1 H5 P330 T6
SET CTSYN=C:\DRIVERS\SBLIVE\DOSDRV
C:\DRIVERS\SBLIVE\DOSDRV\SBEINIT.COM
```

INSTALL A GAME
Software installation is usually blissfully simple under DOS. From the late 1980s onwards, most games included installers, so you just need to insert your install CD or floppy, go to its drive letter (for example, type 'a:' at the C prompt to go to your floppy drive) and run the installer, usually called INSTALL or SETUP.

You'll probably be asked to select your graphics mode, sound card and choose an install location – this should be drive C. The installer will copy over its files and tell you what you need to run to play the game. You may need to do some disk swapping during this process, and games with CD audio will also require the disc to be in the drive while you're playing the game. Some games don't have installers, but if you copy all their files into a directory on your hard disk, you can usually run them from that location. **CPC**

Readers' drives

The Silent Storm

Sam Liggat dived headfirst into the deep end with his first hardline water-cooling system. This monster Threadripper PC features loads of freehand tuning bends across two loops, attached to two colossal 560mm radiators. Now that's some serious cooling power!

/MEET THY MAKER

Name Sam Liggat

Age 33

Occupation Owner/head tech of Kingdom of Airsoft Ltd

Location Dundee, Scotland

Main uses for PC CAD, video editing, gaming, email

Likes Taking things apart, Airsoft, strongman training

Dislikes When my tools are borrowed and not returned to their place

CPC: What inspired you to build this PC, and why did you choose to build it in the Thermaltake Tower 900 chassis?

Sam: It all started when I ran out of fast storage on my old rig. We have a painfully slow internet connection at my workshop, so I found myself having to delete old programs and games whenever I had to install something new. I picked up an Asus PCI-E NVMe expansion card, but my old motherboard didn't support lane bifurcation, so only one drive was accessible.

I'd been feeling the itch to build a new PC for a while anyway, so this was the perfect excuse. The Threadripper was the ideal choice, due to the colossal number of PCI-E lanes, allowing me to run multiple NVME drives alongside a fast graphics card, EVGA sound card and Vive wireless card.

In all honesty, the CPU isn't used to its full capacity most of the time. I do some video transcoding for YouTube and a fair bit of CAD modelling for 3D printing, but most of the time only four or five cores are in use. The real benefit comes from all those PCI-E lanes.

Once I'd settled on Threadripper, I knew that noise was going to be the biggest concern. I like quiet PCs, but I'm not willing to sacrifice performance for low-noise operation – there had to be a way to achieve both. This led directly to the motherboard choice, as the additional power handling allows it to run much cooler than other options, and the choice to use enormous 560mm radiators with

the Thermaltake Tower 900 case – it was the only case that could handle multiple 560mm rads as standard.

CPC: Those tight bends and turns in the tubing look like a lot of work – why did you choose to go with this method rather than using angled fittings and straight tubing?

Sam: I took my inspiration there from the existing builds I'd seen in Tower 900 cases. I really liked some of the designs, but I thought a more complex, fluid-pipe setup would contrast well with the strong, simple geometric shape of the case. I work with miniature gearboxes for airsoft guns every day, which can be very fiddly and frustrating, so I felt I was up for the challenge.

CPC: How did you go about measuring, cutting and bending the tubing?

Sam: This was my first hardline water-cooling loop. To avoid unnecessary frustration and
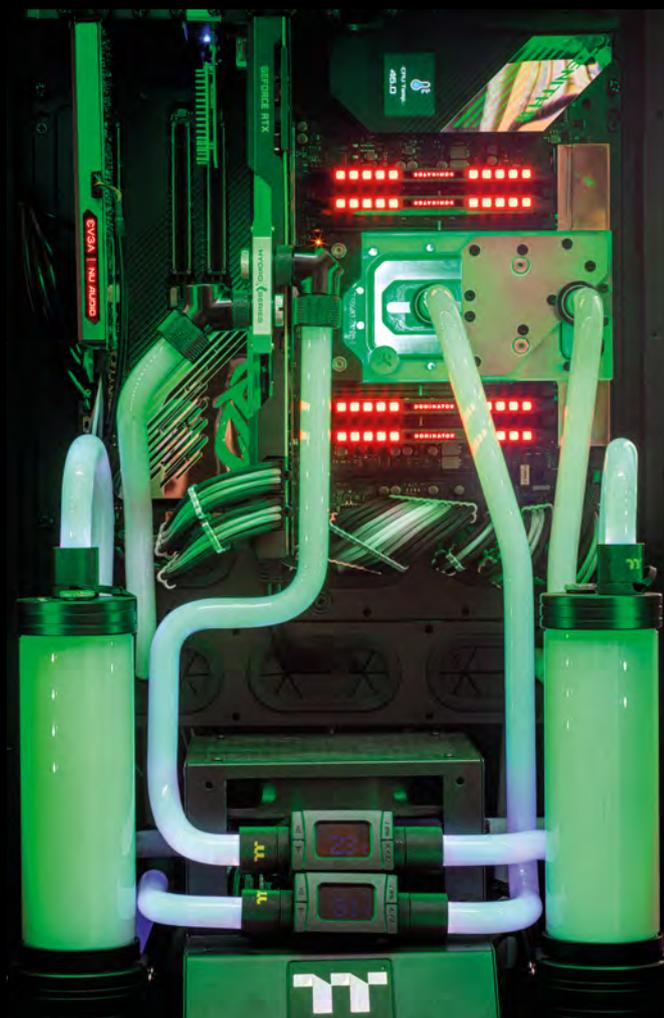
minimise compatibility issues, I tried to stick with one brand as much as possible. I went with Thermaltake PETG 16mm tubing, and used the Thermaltake tube-cutting tool kit for most of the tube work. I measured imagined! I chose the 560mm radiators, so I could use ultra-quiet fans but still adequately cool the beastly processor.

I then went for two loops, as I didn't want the CPU to be dumping

I thought a more complex, fluid-pipe setup would contrast well with the strong, simple geometric shape of the case

using paracord and a tape measure, and I also mocked up each run after each bend.

CPC: That's an enormous amount of cooling power. Why did you use two loops with 560mm radiators?
Sam: Ha ha, yeah, it turned out to be a lot more complex than I initially

excess heat into the GPU cooler, or the other way around.

The Bio-Loop PWM fans (all 13 of them) are barely audible when running at 11 per cent speed, but the system is still able to keep the CPU at 55°C or cooler under light load, and under 70°C under full load, while the graphics card has yet to breach 46°C

under full load. There's plenty of room for overclocking too. The CPU is currently running at stock speed for the most part, but the graphics card has an additional 11 per cent overclock above the Asus Strix factory overclock.

Separating the two loops also allows for easier expansion, so I can upgrade the graphics card when something new comes calling. The left loop is connected to the CPU/ motherboard monoblock and then back to the right-side radiator. The right loop cools the graphics card and is connected to the left-side radiator. Both loops cross at the front and then again at the back.

I also knew I wanted to have the two coolant temperature monitors at the front, to occupy that dead space and hide all the cables inside

SYSTEM SPECS

CPU AMD Threadripper 3960X

Case Thermaltake Tower 900

Graphics card Asus ROG Strix GeForce RTX 2080Ti OC

Storage 1TB Corsair PCI-E 4 SSD for OS; 2 x 1TB Samsung 970 Pro NVMe SSDs

Memory 64GB Corsair Dominator Platinum RGB 3400MHz (tweaked for tighter timings)

Motherboard Asus Zenith II Extreme Alpha TRX40

PSU Corsair AX1600i Titanium

Cooling Dual custom water-cooling loop comprising: 2 x Thermaltake PR22-D5 Silent pump/reservoir combos, 2 x Thermaltake in-line temp monitors, 3 x Thermaltake Pacific Pro 90-degree fittings, 1 x Thermaltake Pro 45-degree fitting, 20 x Thermaltake Pacific Pro compression fittings, EK-Quantum Momentum monoblock for Asus Zenith II Extreme Alpha motherboard, Corsair Hydro waterblock for Asus RTX 2080 Ti Strix with Thermal Grizzly thermal pads, 5m of Thermaltake PETG hardline tubing, 2 x EK-Coolstream 560mm radiators, 2 x EK 3-way fittings (modified to work with the Thermaltake Pro fittings), 2 x Thermaltake Pro ceramic drain ports, 4 litres of Thermaltake Pastel White coolant, 1 x Thermaltake RGB fitting kit, 13 x Black Silence Noiseblocker eLoop aRGB PWM 140mm fans

the central column, so the loop designs were loosely planned around them.

CPC: How useful are the temperature monitors?

Sam: They're definitely not essential – they were more of an aesthetic choice, with the bonus of letting you easily monitor the coolant temps. They monitor the coolant as it leaves the reservoir and, at that point, even under full load when stress testing, the coolant temperature rarely exceeds 35°C.

CPC: Where did you get those PSU cables, and how did you plan the cable routing?

Sam: The Asus motherboard came with a 20 per cent off coupon for CableMod US, so that's where I bought the cables. The PSU comes with long cables, but they weren't long enough for this case, so I knew I was always going to need longer ones. Cable routing is a guilty pleasure of mine, so it was pretty straightforward and there's heaps of space to keep them neat and in line. There are a few hidden cable ties between some of the bundles to keep them in position.

CPC: How did you plan the lighting?

Sam: Lighting was a bit of an afterthought in terms of planning. Initially I planned to keep it very simple, with just some white lights here and there, but my six-year-old daughter convinced me otherwise. I picked up some Asus aRGB strips and

Thermaltake RGB fittings for the tubing, but I wasn't sure where they would go until I started. The aRGB strips sit nicely in the front inside edges of the case, and aren't visible from most angles. The RGB fittings went wherever I could neatly hide their power cables.

**CPC: Did you perform any custom case modifications?**

Sam: There weren't many modifications required. I made a cutout in the motherboard tray, so I could run the rear-mounted NVME drive with a heatsink.

I cut it out with a Foredom rotary tool and finished it off with a hand file and some silicon carbide lapping paper, using with a light silicon oil to prevent the grit from clogging.

CPC: Did you come across any difficulties?

Sam: The biggest pain was mounting the fans and radiators on the mounts. The fans come with their own zero-vibration mounting kit, but their screws weren't thick enough to bite into the radiator threads. Meanwhile, the screws that came with the rads weren't long enough to go through both sides of the fans but were too long to go through just one side. I ended up having to cut down and finish 32 screws by hand just to mount the fans and rads.

The other main difficulty was getting those coolant monitors level and spaced apart correctly. They're only supported by the tubing – a
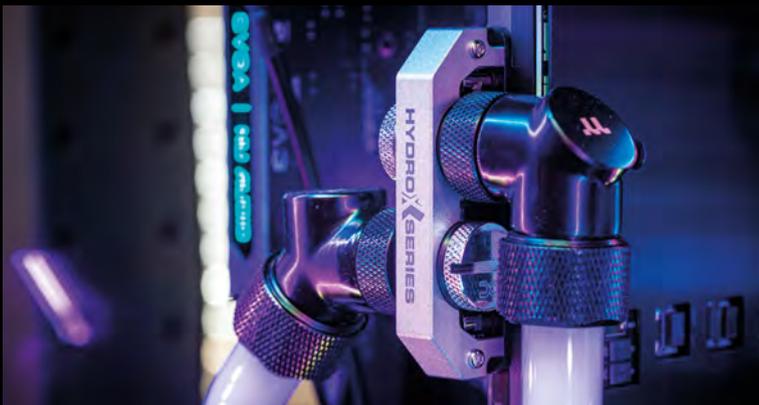
Even under full load when stress testing, the coolant temperature rarely exceeds 35°C

freehand spiral that was the most complex part of the build. In order to get them sitting (almost) perfectly, I had to mount all the water-cooling gear in place with the support rod fully inside the tube, and heat the tube in situ while holding it still as it cooled. I had to do the same with the tube going to the GPU – the right tube has four bends and the left one has five.

CPC: Are you happy with the end result, or do you wish you'd done some of it differently in retrospect?

Sam: I'm around 98 per cent happy with this build. It's the dream machine I've fantasised about for years, but there are a couple of little imperfections. One or two of the bends aren't quite perfect, but I can correct them when I next drain the system. I'll build in a couple of air-bleed ports as well – there are two air bubbles that I simply can't flush out due to the complexity of the loops. The weight of the system (almost 50kg) precludes tilting it to work them out, but a couple of valves at the top will sort that problem. **CPC**

JAMES GORBOLD / HARDWARE ACCELERATED

A PHENOMENAL GPU LAUNCH

With stunning performance, but also an inability for supply to meet demand, James Gorbold looks behind the scenes of the RTX 3080 launch

The Nvidia GeForce RTX 3080, the first of a new breed of graphics cards based on the Ampere architecture, launched this month to overwhelmingly positive reviews. I'm sure by now you've already read the extensive coverage in this issue, so I'm not going to cover all that again.

The main point to understand is that, because the RTX 3080 delivers such a huge increase in performance over previous-gen graphics cards, it redefines expectations. It delivers up to 50 per cent greater speed than the RTX 2080 Super; in real-world terms, this means the ability to play games at 4K with ray tracing enabled.

This really puts the innovative but sluggish RTX 20-series GPUs firmly in their place, as they provided a mere 15 per cent gen-on-gen speed increase versus the 10-series. Looking at it another way, the RTX 3080 delivers superior performance to the RTX 2080 Ti at around half the price.

Scan expected the RTX 3080 to be a massive launch, and had been working closely with Nvidia for weeks to secure as much stock as possible. However, from the moment websites around the world went live at 2pm on 17 September, it was clear that gamers couldn't get enough of the RTX 3080.

Within minutes we had received thousands of orders, in excess of the stock available on launch day, and far higher than any other product launch in the 30-year history of Scan. To put this into context, we received 2,000 per cent more orders for the RTX 3080 than the RTX 2080 Ti, the best-selling GPU from the previous RTX generation at launch.

Retailers worldwide, including Nvidia's own webstore where it sells Founders Edition cards, all experienced this same overwhelming demand, so much so that some websites were unable to cope and had availability issues. As a result, responsible retailers have reverted to a 'notify me' system rather than taking pre-orders that potentially could take months to fulfil. Nvidia has even gone as far as publishing an apology on its website.

In the meantime, if you weren't one of the lucky gamers who managed to get hold of an RTX 3080 at launch, here's some behind-the-scenes information on the supply situation. Graphics cards are made from four key parts, the GPU and accompanying DRAM, the PCB, the cooler and finally, passive components such as capacitors and resistors.

Starting with the GPU and DRAM, Nvidia is ramping up supply but, as with any new complex chips, yields at launch are relatively low, so it will take weeks, if not months, for yields to significantly improve. The supply of PCBs is on a similar timescale, as these typically have a lead time of around four to six weeks.

> It will take weeks, if not months, for yields to significantly improve

What you might not be expecting to learn is that coolers could also be a real bottleneck. They require a lot of raw materials and there are frequently capacity issues at thermal factories, so it could take as long as eight to ten weeks for graphics card manufacturers to load up on parts.

The last piece of the puzzle, passive components, is more straightforward. Despite there being upwards of 1,500 such components on a typical graphics card, many will already be used from previous designs and will be easy to source.

Finally, it's worth remembering that the launch of the RTX 3080 comes off the back of a manufacturing crisis in Asia caused by COVID-19. As such, there are still challenges in the global supply chain for all products. **CPC**

James Gorbold has been building, tweaking and overclocking PCs ever since the 1980s. He now helps Scan Computers to develop new systems.