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NVIDIA GEFORCE RTX 4080

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- ▶ AI FRAME GENERATION – DLSS 3 TESTED AND EXPLAINED
- ▶ INSIDE THE ADA LOVELACE ARCHITECTURE
- ▶ FULL REVIEW OF NVIDIA'S LATEST GPU



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Welcome

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/ FROM THE EDITOR

Wealthy competition

Jensen's green team has once again stormed our benchmark suite with its latest GPU (see p14). Nvidia's new transistor-packed Ada architecture can still stomp on all the last-gen cards even when it only has 9,728 CUDA cores in a small 379mm² die at its disposal.

The GeForce RTX 4080 is undoubtedly a triumph of chip design, and you can read all about how the new Ada architecture works in our full deep dive on p70. While this is all brilliant if you have a fat wallet, though, it's hard to get round the depressing fact that cards based on this new GPU cost at least £1,269 inc VAT. That's almost twice the price of the GeForce RTX 3080 when it launched at £649 just two years ago. It remains to be seen if this pricing strategy will pay off long-term for Nvidia, but if it can sell its stock at this price then there's no reason why the company would reduce the prices.

If we all decided to not buy GPUs at these prices then they would have to come down, but let's face it, that's not going to happen. The scalping problem during the pandemic and crypto-mining boom showed that a lot of people are prepared to pay extremely high prices for GPUs in the right circumstances. That leaves us with one answer to this problem – competition.

AMD has lifted the lid on its forthcoming RDNA 3 GPUs (see p12), and the company is aiming hard at Nvidia's pricing, with top-end cards that come in at under a grand. That's still extremely expensive compared with recently, of course, but it's a welcome move in the current climate.

AMD successfully made the CPU market competitive again with its Ryzen CPUs, and it's now taking a hit from Intel in the current chip battle (see p98), which is likely to result in AMD's new CPUs coming down in price. Either way, competition means CPUs are still affordable, unlike Nvidia's latest GPUs.

AMD says it has improved ray-tracing performance, but we doubt it will beat Nvidia's latest GPUs here. In other areas, though, it looks set to be competitive, and cost much less money. If AMD can get the right balance of performance and price, prices will have to come down. We can hope, can't we? **GPC**



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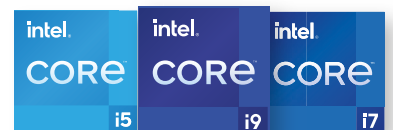


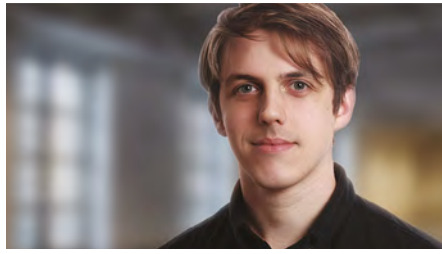
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RICHARD SWINBURNE / VIEW FROM TAIWAN

AMD'S PRICE PUZZLE

Richard Swinburne likes the pricing of AMD's upcoming new GPUs, but the total platform cost of AM5 is still far too expensive

I'm not going to be everyone's favourite columnist when I sing the praises of a graphics card that will cost a thousand quid, but AMD's new Radeon RX 7900 XTX and 7900 XT launch gave me cause to be hopeful. A \$999 US (around £1,043 inc VAT) graphics card is undoubtedly really expensive, but dare I suggest it's also quite good value?

Follow my logic here – the way the Radeon RX 7900 XTX and XT are stacked indicates that the Radeon RX 7800 and 7700 series coming next year should provide a decent generational boost for fair prices. This stands in contrast to what happened with the pricing of Nvidia's latest GPUs, as well as the GeForce RTX 4080 12GB, which was derided as such a terrible idea by everyone that Nvidia 'unlaunched' it. The rumour is that Nvidia is going to relaunch it as the RTX 4070 Ti, which honestly seems like putting lipstick on a pig considering the anaemic spec.

I wonder how long we will have to wait for lower tiers of Ada Lovelace graphics cards, such as the RTX 4070 and 4060, to arrive. It seems Nvidia is pretty happy to let its three-year-old RTX 3000 series, and even its old RTX 2060 cards, fill the mid and mainstream market for the foreseeable future. Yawn.

Of course, if you're all about the big AAA headline games and want nothing less than the most delicious graphics to pop your eyeballs, then yes, you're saving your pennies, renting your toothbrush and selling a spare kidney to get the newest Nvidia RTX 4090 or 4080. It's clear AMD has focused on rasterisation performance rather than ray tracing, and it won't compete in the halo/flagship space.

It's clear that AMD has focused on rasterisation performance rather than ray tracing

That's what generates headlines, because ray tracing is still the hot new thing, but there's also a lot of games that are dependent on raster performance and don't use ray tracing at all. For example, Last gen's Call of Duty Modern Warfare had an element of ray tracing, but the just launched Modern Warfare 2 doesn't. I feel that's a significant consideration.

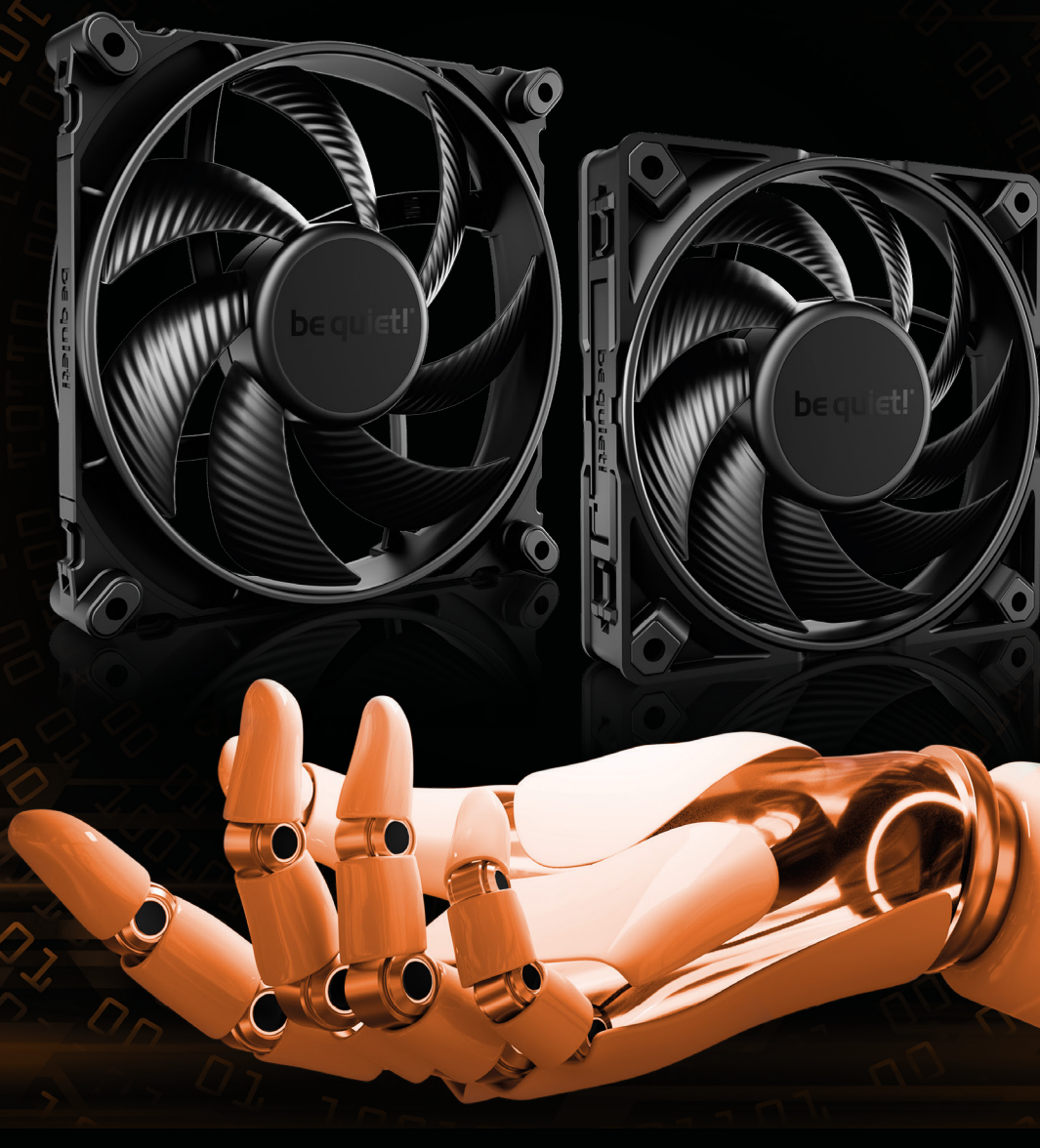
The story on the CPU front, though, is less positive for AMD. It's latest Ryzen 7000-series CPUs are reportedly selling so badly that its Ryzen 7 5800X3D alone is significantly outselling all its Ryzen 7000-series CPUs combined in some markets. For example, [mindfactory.de](https://www.mindfactory.de) recently shared its monthly sales stats, which showed the 5800X3D topping 4,000 sales, while the new Ryzen 7000-series CPUs were in the low hundreds.

AMD's China team has already dropped Ryzen 7000-series CPU prices by 20 per cent – a huge discount for its brand-new technology. In the USA, Microcenter is giving away a free 32GB DDR5 kit with every Ryzen 7000-series CPU and motherboard just to get sales. AMD is still making a good profit from the 5800X3D, of course, but it's not exactly a ringing endorsement of your latest technology if everyone flees to the old gear.

AMD needs to get its A620 chipset out pronto. I truly can't believe I'm pining for the base entry-level chipset, but here we are. I'll admit that last month I made the wrong call, assuming the most affordable B650 motherboards would be £150, when they finally launched at £200.

That's just silly money for what you get. AMD must work hard to bring A620 motherboards down to £125, or even £100, otherwise AM5 is going to be a dead platform for a long while. **GPC**

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](https://twitter.com/ricswi)



LEAP IN INNOVATION

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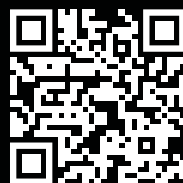
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TRACY KING / SCEPTICAL ANALYSIS

EXTREMIST GAMING

Tracy King turns her sceptical eye to claims that extremists are using video games as tools to recruit young people

While mainstream social media burns around us, alternative platforms are growing in popularity, although not as much as some have predicted. While Mastodon has, at the time of writing, added a million new users, I doubt most will stick around and brands certainly aren't going to set up home there.

There is currently no paid advertising option, and without centralised reach, most advertisers won't bother having a brand account. This, of course, is one of the points of Mastodon – separate servers and communities for separate interests. Quality over quantity. Reach is achieved on merit. That's almost the opposite of Twitter.

However, it's precisely that type of niche community potential, with its in-jokes and tribalism, that attracts those of us who have always lived on the social margins. Nerds, geeks, early adopters, tech enthusiasts, makers, modders, coders – we've all found our communities online where (if you're like me and grew up pre-internet) it used to be very hard to find like-minded friends.

One of the biggest fears of the impending changes to social media is the potential for a rise in political extremist content (of either the far right, the far left or various religions, depending on who you ask). While researching whether that's a legitimate fear or a moral and technological panic, I came across a far more interesting topic: the claim that terrorist groups are using video games to recruit young people, exploiting that same niche community mentality that attracts anyone feeling marginalised.

This is the most recent instalment in an ongoing saga about video games corrupting innocent minds and causing violence, which hit the mainstream after the Columbine murderers were found to be Doom players. I'm also a Doom player, as are millions of other people. So, no.

Before that, the bogeyman was Dungeons & Dragons, and before that, it was heavy metal, rock and roll, and so on. But is this time different? Kind of. Rather than insisting video games are subliminally influencing teens to become violent, this time the claim is that extremists are deliberately encouraging violence and recruiting kids to their ideologies via video games.

Various, this comes via the chat function of existing games – niche communities about specific games on places such as Reddit, Discord and Steam; videos using imagery from games; and even making games that look innocent but are in fact extremist recruitment tools. These claims are so serious, the United Nations hosted a roundtable discussion

last year (it's online), during which I noticed the conflation of 'extremist content' with 'slurs'. Kids using socially proscribed insults aren't extremists.

At various points, extremist groups have used video game culture as propaganda, such as Call of Duty appearing in IS recruitment ads, and gaming platforms have always had extreme political content, some of which gets banned. However, of the handful of research papers I read that attempt to study this type of ideological recruitment strategy, none satisfied me that it's actually working, and some relied on the disproven assertion that there's a link between games and violence.

One of them even suggests that Western governments advertise at esports events with anti-extremism messaging. I don't think that would work, because what's being described is one-to-one parasocial relationships based on shared interests. Those interests could be anything. The video game component is no more the key to recruitment than films, sex or anything else that interests young people. If researchers are serious about tackling this issue, they'd do well to understand that games aren't special, they're just popular. **GPC**

Kids using socially proscribed insults aren't extremists

Gamer and science enthusiast Tracy King dissects the evidence and statistics behind popular media stories surrounding tech and gaming [@tkingdot](#)

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Letters

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NVIDIA INVESTIGATING MELTING CABLES

Following a number of online complaints about melting 12VHPWR cables when plugged into GeForce RTX 4090 graphics cards, Nvidia has stated that 'we continue to investigate the reports, however we don't have further details to share yet'.

Several photos of melted 16-pin plugs and sockets have appeared online since the RTX 4090 launch, prompting various theories for the reasons. Tech YouTube channel Gamers Nexus managed to reproduce the effect in its lab (custompc.co.uk/CableMelt), where the cable was producing smoke. The site also analysed the cables, and put the problem down to a number of factors, including manufacturing debris inside the cable connectors, as well as improper installation.

It's a rare occurrence (less than 1 per cent), but Nvidia has stated that the company and its partners are 'committed to supporting our customers and ensuring an expedited RMA process for them'. If you do buy a graphics card that requires a 16-pin 12VHPWR cable, make sure it's well and truly plugged into the graphics card socket and clicked into place before switching on your PC.

NEXT-GEN RADEONS SET TO UNDERCUT NVIDIA

AMD has outlined two cards based on its new RDNA 3 architecture. The Radeon RX 7900 XTX and 7900 XT are planned to launch at \$999 US (~£1,068 inc VAT) and \$899 (~£961 inc VAT), massively undercutting the prices of Nvidia's latest RTX 4000-series GPUs.

RDNA 3 sees AMD shifting to a chiplet-style design, where the main GPU is called the Graphics Compute Die (GCD) – a 300mm² chip fabricated on TSMC's 5nm process. This is surrounded by six 37mm² Memory Cache Dies (MCDs), which are produced on TSMC's 6nm fabrication process, and there's a 5.3TB/sec interconnect between the chiplets.

With RDNA 3, each Compute Unit (CU) contains 128 stream processors, a single 2nd-generation RT processor for ray tracing and two AI accelerators. The latter is a feature that's been lacking on AMD GPUs until now, compared with the Tensor cores on Nvidia GPUs.

Ray-tracing performance has also been improved, with AMD now stating that the new chips have 'new ray box sorting and traversal'. AMD claims the new GPUs improve ray tracing performance by up to 50 per cent per CU compared with RDNA2 chips.

A Radeon RX 7900 XTX GPU will have 96 CUs, giving you 12,288 stream processors, 192 AI accelerators and 96 RT cores, along with 96MB of 2nd-generation Infinity Cache. These cards will also be equipped with up to 24GB of GDDR6 memory attached to a 384-bit wide memory interface, giving you much more memory bandwidth than the 256-bit wide interface on the Radeon RX 6900 XT.

Meanwhile, the Radeon RX 7900 XT has 84 CUs enabled, giving you 10,752 stream processors, along with 80MB of Infinity Cache and up to 20GB of memory attached to a 320-bits wide memory interface.

AMD has also taken a new approach to clock speeds, decoupling the front end frequency from the shader clock. It's the latter that's quoted as the game clock (2300MHz on the 7900 XTX), but the front end runs at 2500MHz.

AMD is making strong claims about performance, including that the Radeon RX 7900 XTX hits 109fps in Assassin's Creed Valhalla at 4K with maximum settings. While we have a different test rig from AMD, if these figures are in the same ballpark on our setup, they're in the same league as the GeForce RTX 4090 in our tests, which averaged 108fps. It's also much faster than the Radeon RX 6950 XT, which averaged 75fps in this game.

AMD also claims the Radeon RX 7900 XTX can hit 135fps in Doom Eternal with ray tracing at 4K. The new GPUs are scheduled to launch on 13 December and will use standard 8-pin PCI-E power connectors, rather than requiring a 16-pin 12VHPWR cable. Look out for a full review in our next issue.



Wireframe

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Reviews

NVIDIA GEFORCE RTX 4080 / ~£1,329 inc VAT

SUPPLIER overclockers.co.uk

We're writing this review the day after the GTX 4080 launched, by which time we'd usually expect every UK retailer to be out of stock, while a bunch of seriously overpriced cards were appearing on eBay. Not this time, though. Nvidia has sold out of Founders Editions, but both Scan and Overclockers still have RTX 4080 stock, with prices starting from £1,329 inc VAT for a Zotac card at the latter.

We don't yet know whether this is a result of plentiful supply, or overambitious pricing from Nvidia in the middle of a UK cost of living crisis, but it certainly makes a change. Even so, that price is still £60 higher than the £1,269 Founders Edition price, and even that price was still a long way from the £649 launch price of this card's predecessor, the GeForce RTX 3080, just two years ago.

It's a new approach to pricing from Nvidia, where both the top-end flagship card and its nearest sibling cost well over a grand at launch. It remains to be seen whether it will pay off, but the RTX 4080 has its work cut out if Nvidia is going to justify that whopping price. Despite being closer to the flagship product's price than previous 80-series Nvidia GPUs, the RTX 4080 has a substantially lesser spec on paper.

A smaller chip

Rather than being based on the same AD102 GPU as the RTX 4090, but with a few parts disabled, the RTX 4080 is instead based on a whole new GPU called the AD103. It uses the same Ada Lovelace architecture (see our full deep dive on p70) as AD102, but it's much smaller. AD103 has a 379mm² die area, but this still packs in 45.9 billion transistors, thanks to TSMC's 4N manufacturing process.

As a point of comparison, the top-end Ampere GA102 GPU had a much larger area of 628.4mm², but only packed in 28.3 billion transistors. AD103 is still a complex chip, then, even if it doesn't have anywhere near the 76.3 billion transistors found in the AD102 chip.

A fully enabled AD103 chip has six Graphics Processing Clusters (GPCs) with 12 Streaming Multiprocessors (SMs) each, and another GPC that contains a further eight SMs. If all the parts are enabled, you get a total of 10,240 CUDA cores, but the RTX 4080 disables four of the chip's SMs, giving you 9,728.

That's a lot of shading power, and it means there's a bit of headroom for a fully enabled 'RTX 4080 Ti' card or similar at a later date. However, on paper, it pales in comparison with the 16,384 CUDA cores found in the RTX 4090. Likewise, the RTX 4080 has 76 3rd-gen RT cores for ray tracing, but the RTX 4090 has much more at 128.

You also get 8GB less memory, and the RTX 4080's 16GB of GDDR6X memory is only attached to a 256-bits wide memory interface, compared to the 384-bits wide interface on the 4090. In this case, though, the memory is quicker than that of the RTX 4090, running at 1400MHz (22.4GHz effective). This gives you a still-potent total memory bandwidth of 716.8GB/sec, although that's still much narrower than the RTX 4090's memory bandwidth, which breaks the 1TB/sec barrier.

SPEC

Graphics processor

Nvidia GeForce RTX 4080,
2205MHz base clock,
2505MHz boost clock

Pipeline

9,728 CUDA cores, 112 ROPS

RT cores

76 (3rd-gen)

Tensor cores

304 (4th-gen)

Memory

16GB GDDR6X, 1400MHz
(22.4GHz effective)

Memory interface

256-bit

Card interface

16x PCI-E 4

Bandwidth

716.8GB/sec

Power connectors

1x 16-pin / 3x 8-pin



The RTX 4080 can potentially compensate for that comparative lack of memory bandwidth with its whopping cache allocation though. It's equipped with 65,536KB of L2 cache, compared to just 6,144KB on the GeForce RTX 3090 Ti.

It's also clocked much higher than its Ampere-based predecessors, with a base clock of 2205MHz and a boost clock of 2505MHz. However, thanks to the huge cooler supplied with the Founders Edition (which is identical to the cooler on the RTX 4090 FE), our RTX 4080 was regularly boosting to a peak of 2805MHz during game testing. Comparatively, the RTX 4090 was only boosting to around 2735MHz.

On paper, then, the RTX 4080 looks set to be a much lesser chip than the RTX 4090, but how does that bear out in actual game benchmarks?

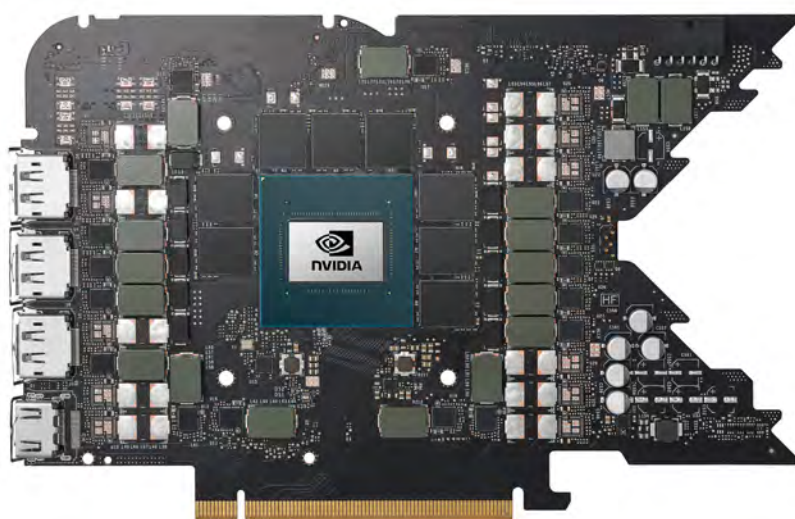
Performance

Despite its comparative lack of processing power, the RTX 4080 isn't far off the performance of the 4090 in a lot of tests, partly because there's only so far that some games can scale at certain resolutions. The results are generally pretty close at 1,920 x 1,080 as a result, and in some cases, the RTX 4080 is faster here. There isn't much between the two GPUs at 2,560 x 1,440 either (where the RTX 4080 storms every single test), but they start to get further apart at 4K.

That's not to say the RTX 4080 can't cope with 4K – it's still perfectly capable at this resolution. Its average of 92fps in Assassin's Creed Valhalla with a 65fps 99th percentile frame rate is superb, and it also hits our frame rate target in Metro Exodus with ray tracing on High at 4K, without DLSS enabled. However, while the latter is a great result, it's still a fair way off the 96fps from the RTX 4090.

Where you start to see the two GPUs really diverge is in a game such as Doom Eternal, which scales exceptionally well with more GPU power. Here, the RTX 4080 averaged 318fps at 4K, compared to 414fps for the RTX 4090, but they're still both amazing results. It can cope fine with ray tracing in this game at 4K too, and without needing to use DLSS. It averaged a superb 209fps here, which again is well behind the RTX 4090's 276fps, but still well in front of the 171fps of the RTX 3090 Ti and the 103fps of the Radeon RX 6950 XT.

The interesting test for this card is Cyberpunk 2077 – a highly demanding game that was beyond Ampere GPUs at 4K with ray tracing enabled, even with DLSS. The RTX 4090 could do it, but can the RTX 4080 also cope?



The answer is yes, but not quite as convincingly, at least not until the game officially supports DLSS 3. With no ray tracing, and the game running at Ultra settings, the RTX 4080 averaged 57fps, which is fine, but the RTX 4090's 69fps average is a markedly smoother experience.

Neither card could cope with this game running at native 4K with ray tracing, but if you enable Medium ray tracing and set DLSS to Balanced, the RTX 4080 again hits 57fps. The RTX 4090's 69fps is higher again, but the RTX 4080 is well in front of the 46fps of the RTX 3090 Ti.

Push the settings up to the Ultra ray tracing preset, with DLSS on Quality, and the RTX 4080 averages 50fps with a 44fps 99th percentile result. You can get away with playing the game at these settings, but the RTX 4090's 54fps 99th percentile and 64fps average is noticeably smoother in action. The RTX 4080's 16GB of memory is genuinely useful here too, as the graphics memory usage peaked at 13,296MB during this test.

Next we come to DLSS 3, which still isn't officially supported in Cyberpunk 2077 yet, but Nvidia has given us access to a preview build to test it with the new GPUs. DLSS 3 cleverly uses AI to generate extra frames to improve the frame rate (see our deep dive on p70 for more information) and, aside from a few occasional artefacts, it works surprisingly well.

The RTX 4080 wasn't far off the RTX 4090's performance with DLSS 3 enabled, with a huge 104fps average at 4K and an 88fps 99th percentile. That's a cracking result, and the game looks brilliant at these settings.

Thanks to its smaller, less complicated chip than the RTX 4090, the RTX 4080's power efficiency isn't terrible either. Our system drew 480W from the mains with the RTX 4080 installed, and this was consistent at all resolutions. Conversely, our system drew 535W with the RTX 4090 running at 2,560 x 1,440, but it then peaked at 619W at 4K. It's still at the upper end of our power draw graphs, but it's in the same sort of league as the Radeon RX 6800 XT and GeForce RTX 3080.

REASSURINGLY EXPENSIVE

- + Fantastic ray-tracing performance
- + DLSS 3 support
- + Decent power efficiency

RIP OFF

- Extremely expensive
- Seriously, the price is ridiculous



As with the RTX 4090, the 4080 also uses the new 16-pin power connector, with a 3 x 8-pin PCI-E adaptor included in the box. There have been several reports of these plugs melting in some circumstances online (see p12), and while it's rare, it pays to make absolutely sure that the 16-pin connector is well and truly clipped into the power socket.

Meanwhile, the GPU temperature peaked at 63.8°C during benchmarking, with a 77°C hotspot reading. Comparatively, the RTX 4090 hit 67.5°C with a 77.6°C hotspot. The massive cooler is clearly doing its job well, and it never became irritatingly noisy during testing either.

Conclusion

While the RTX 4080 is clearly an incredible piece of silicon engineering, it's hard to get excited about a card that only a select few people will be able to afford in these times. That said, if you can afford to splash out, but can't quite run to the cost of the RTX 4090, then the RTX 4080 is a superb card.

It only starts to (slightly) struggle when you pile on all the settings in very demanding games at 4K, but even then you can hit a perfectly acceptable compromise between graphics settings and frame rates. Its support for DLSS 3 will also be an enormous boon when more games officially support it.

However, we suggest holding fire for at least a month. AMD's next-gen GPUs are due to launch in December, and the red team is planning to significantly undercut Nvidia when it comes to pricing. Let's hope that some healthy competition can smack the GPU business back down to earth.

BEN HARDWIDGE

VERDICT

Surprisingly quick performance from Nvidia's smaller Ada GPU. It's second only to the mighty RTX 4090, but it's also hugely overpriced.

PERFORMANCE
44/50

FEATURES
20/20

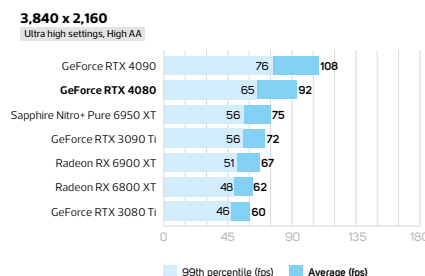
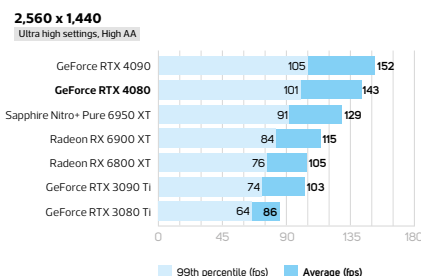
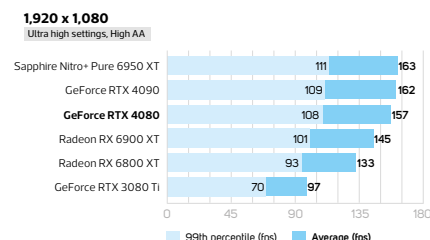
VALUE
5/30

OVERALL SCORE

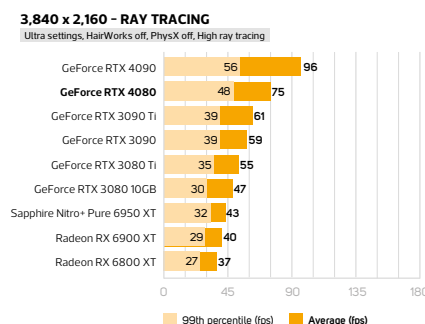
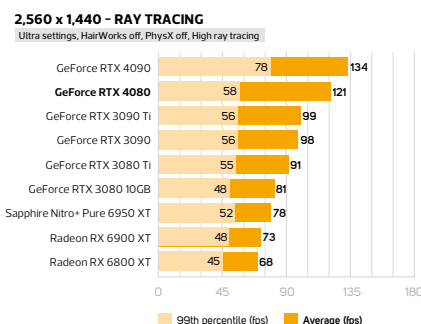
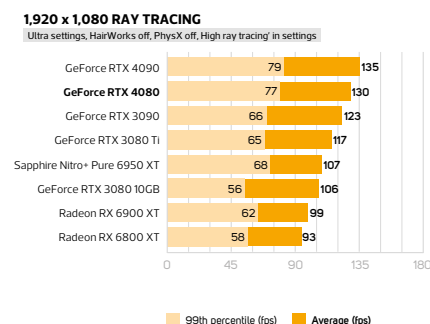
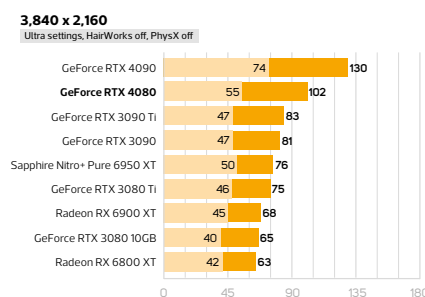
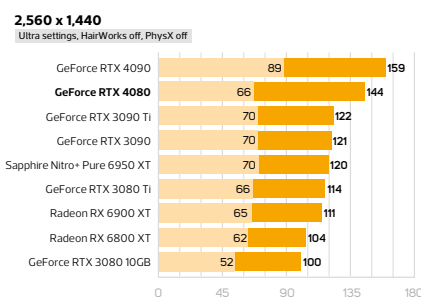
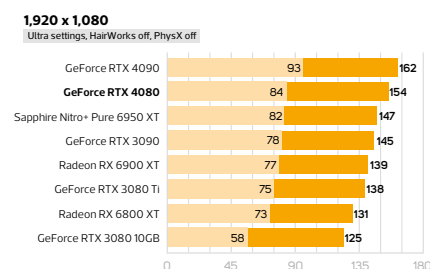
69%

GEFORCE RTX 4080 RESULTS GRAPHS

ASSASSIN'S CREED: VALHALLA



METRO EXODUS

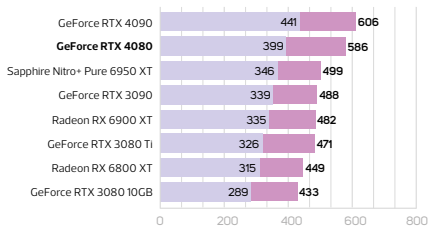


GEFORCE RTX 4080 RESULTS GRAPHS

DOOM ETERNAL

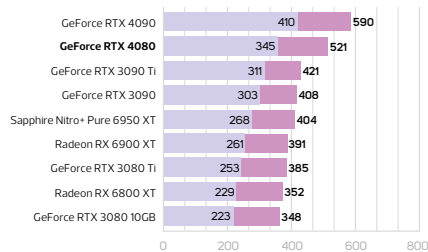
1,920 x 1,080

Ultra Nightmare settings



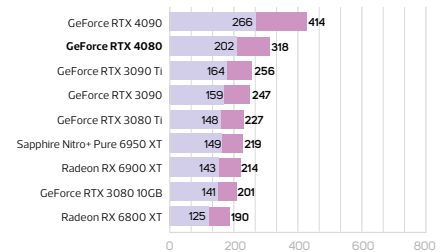
2,560 x 1,440

Ultra Nightmare settings



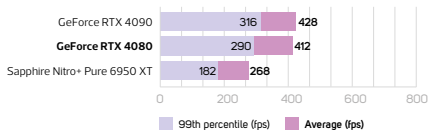
3,840 x 2,160

Ultra Nightmare settings



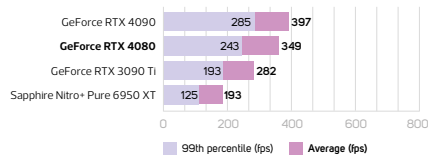
1,920 x 1,080 - RAY TRACING

Ultra Nightmare settings, ray tracing enabled



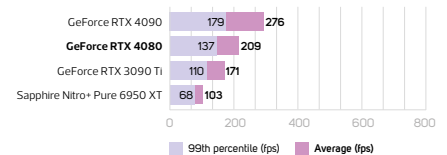
2,560 x 1,440 - RAY TRACING

Ultra Nightmare settings, ray tracing enabled



3,840 x 2,160 - RAY TRACING

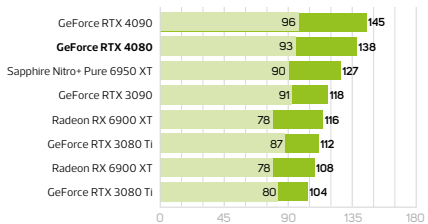
Ultra Nightmare settings, ray tracing enabled



CYBERPUNK 2077

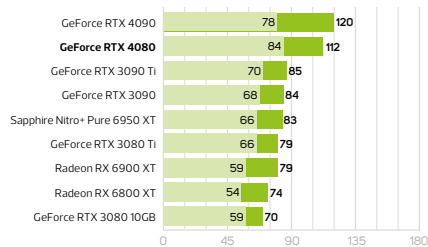
1,920 x 1,080

Ultra preset, no ray tracing



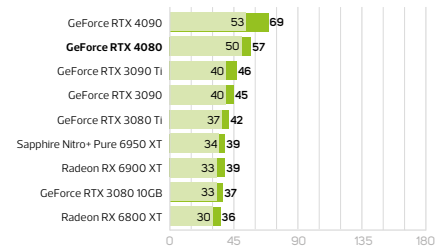
2,560 x 1,440

Ultra preset, no ray tracing



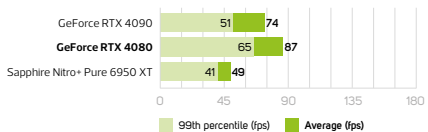
3,840 x 2,160

Ultra preset, no ray tracing



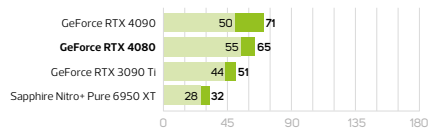
1,920 x 1,080 - RAY TRACING

Medium ray tracing preset, DLSS disabled



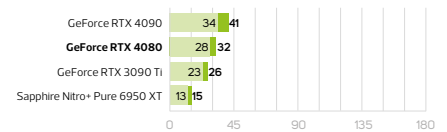
2,560 x 1,440 - MEDIUM RAY TRACING

Medium ray tracing preset, DLSS disabled



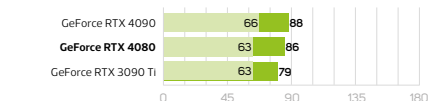
3,840 x 2,160 - MEDIUM RAY TRACING

Medium ray tracing preset, DLSS disabled



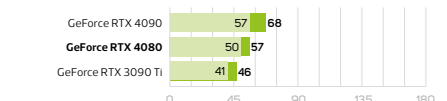
2,560 x 1,440 - MEDIUM RAY TRACING + DLSS

Medium ray tracing preset, DLSS Balanced



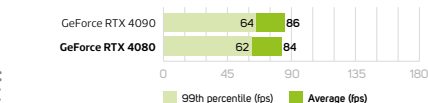
3,840 x 2,160 - MEDIUM RAY TRACING + DLSS

Medium ray tracing preset, DLSS Balanced



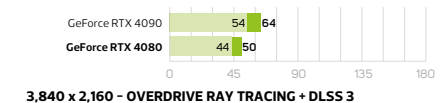
2,560 x 1,440 - ULTRA RAY TRACING + DLSS

Ultra ray tracing preset, DLSS Quality



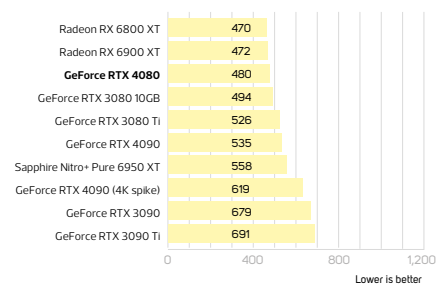
3,840 x 2,160 - ULTRA RAY TRACING + DLSS

Ultra ray tracing preset, DLSS Quality



PEAK TOTAL SYSTEM POWER CONSUMPTION (WATTS)

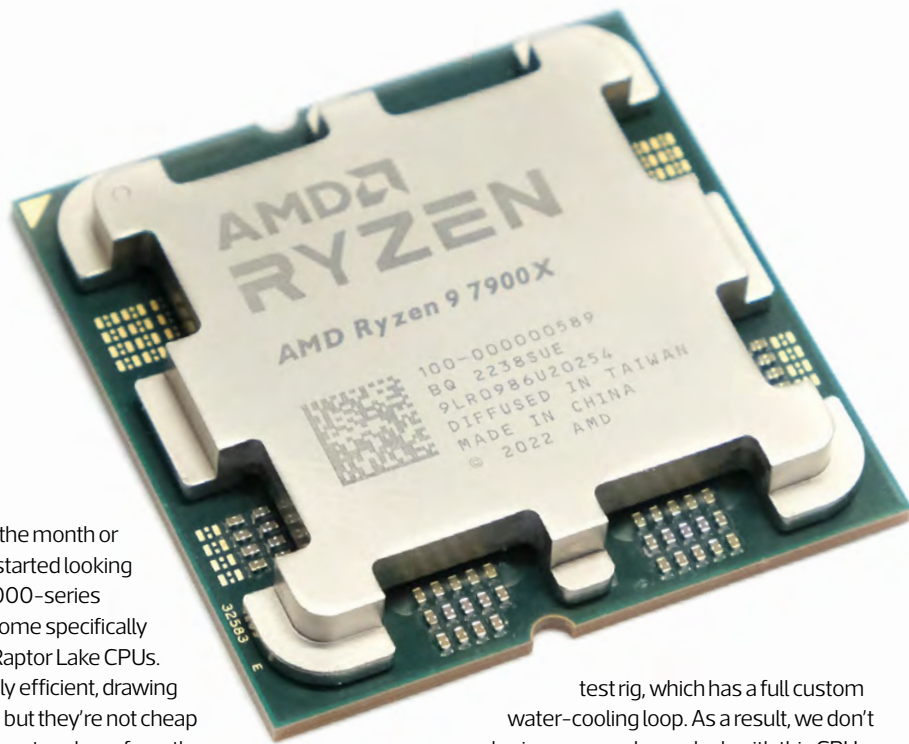
Metro Exodus, 2,560 x 1,440, Ultra settings



SOCKET AM5 PROCESSOR

AMD RYZEN 9 7900X / £549 incVAT

SUPPLIER ebuyer.com



A lot has changed in the month or two since we first started looking at AMD's Ryzen 7000-series CPUs, and that change has come specifically from Intel with its 13th-gen Raptor Lake CPUs. AMD's new chips are certainly efficient, drawing less power than Intel's rivals, but they're not cheap either. The Ryzen 9 7900X is a step down from the flagship Ryzen 9 7950X, retailing for £549, which places it £100 below the new Intel Core i9-13900K – it also costs £50 more than the Core i9-12900K and £80 more than the Core i7-13700K.

Needless to say, it needs to be better than both of those CPUs in order to justify its premium, and it also needs to match or batter the Ryzen 9 5950X. The latter currently costs the same price, following some hefty Ryzen 5000-series price cuts recently. AMD hasn't upgraded the core counts on any of its Ryzen 7000-series CPUs, though, so the Ryzen 9 7900X still has the same 12 cores and 24 threads as its predecessor. What has changed are its clock speeds.

The Ryzen 9 5900X could hit a peak boost frequency of 4.8GHz, but this rockets up to a massive 5.6GHz with the Ryzen 9 7900X. Even the latter's all-core boost was significantly higher than the Ryzen 9 5900X's peak boost, sitting at up to 5.3GHz across all 12 cores. Both CPUs have 64MB L3 cache, but the more important L2 cache has been doubled to 12MB in the new model.

That comes at a cost in terms of thermals though – the TDP has risen from 105W to 170W between the new CPUs, thanks to the increased power on tap in Socket AM5 compared with AM4. In fact, the Ryzen 9 7900X was pretty toasty under heavily multi-threaded workloads, usually hitting 90°C quite quickly in our

test rig, which has a full custom water-cooling loop. As a result, we don't recommend using a manual overclock with this CPU.

Under the hood you'll find two 8-core Core Complex Dies (CCDs) with four CPU cores disabled, and in some instances, single-CCD Ryzen 7000-series CPUs are faster than dual-CCD chips, thanks to lower latency when dealing with inter-die communication. For instance, we saw slightly higher gaming performance in some tests with the single-die 8-core Ryzen 7700X than with the Ryzen 9 7950X, despite the latter having higher clocks speeds.

Performance

Sadly, we weren't able to add a Core i7-13700K to the graphs yet as Intel hasn't sent us a sample, but we'll hopefully get to test one in our next issue. Otherwise, AMD's Ryzen 7000-series CPUs have been consistently ahead in our

SPEC

Base frequency
4.7GHz

Max boost frequency
5.6GHz

Core
Zen 4

Manufacturing process
5nm

Number of cores
12 x physical (24 threads)

IGP
AMD Radeon Graphics

Simultaneous Multithreading (SMT)
Yes

Cache
64MB L3, 12MB L2

Memory controller
Dual-channel DDR5, up to 5200MHz

Packaging
AMD Socket AM5

Thermal design power (TDP)
105W

Features
Precision Boost 2, Precision Boost Overdrive 2, FMA3, F16C, SHA, BMI / BMI1 + BMI2, AVX-512, AVX2, AVX, AES, SSE4a, SSE4, SSSE3, SSE3, SSE2, SSE



12 DAYS OF CHRISTMAS

- + Excellent multi-threaded performance
- + Superb image editing performance
- + Power-frugal compared with competition

MISTLETOE & WINE

- No faster in games than cheaper models
- Ryzen 9 5950X is much cheaper for upgraders
- Struggles to stand out from the crowd

GIMP image editing test, which stresses single-threaded performance, and the Ryzen 9 7900X was no exception. It came third overall in our graphs (see p20), and managed to pip the Core i9-13900K to the post in this test, as well as being noticeably quicker than the Ryzen 9 5950X and Core i9-12900K.

It was potent in our heavily multi-threaded Handbrake video encoding test too, managing a fantastic score of 1,239,069, which was enough to better the Core i9-12900K and Ryzen 9 5950X, which both barely cracked one million points – only the Ryzen 9 7950X and Core i9-13900K offer significantly more performance here. It gained the second highest multi-tasking score in our graphs and had the third fastest overall RealBench system score too. This sat at 450,644 compared to 387,778 for the Core i9-12900K and 374,124 for the Ryzen 9 5950X.

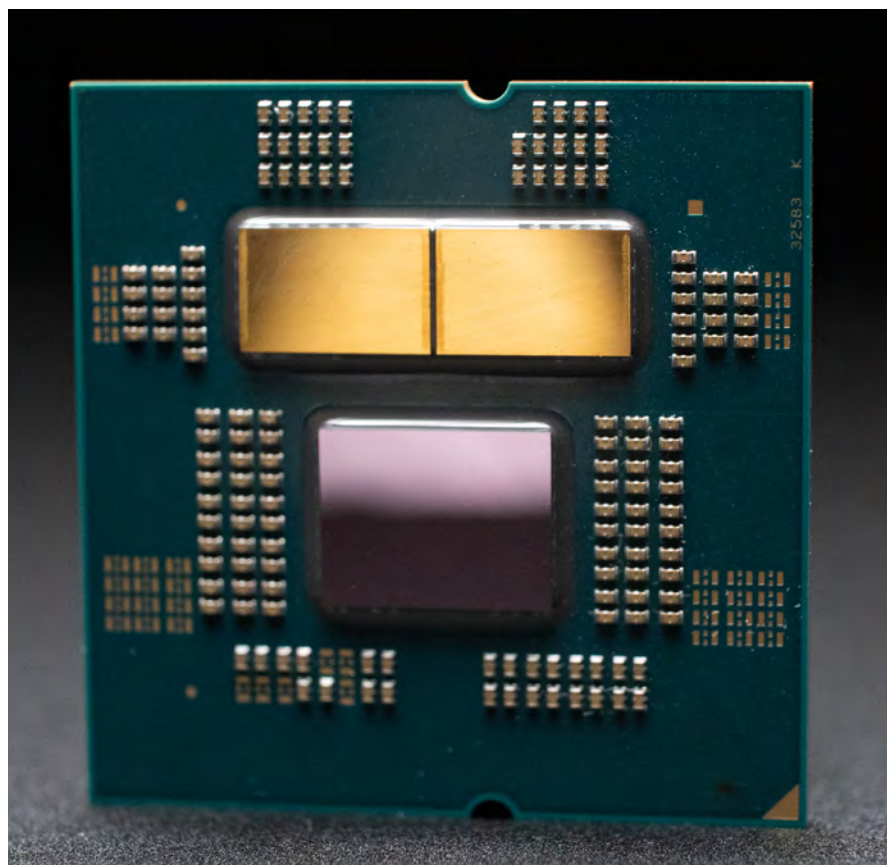
Its comparative lack of cores was telling in Cinebench, though, and even the Core i9-12900K was snapping at its heels, with a score of 27,579 compared to 28,843 for the new AMD CPU. With a 10,000-point gap between the Ryzen 9 7900X and the 7950X, and a 12,000-point difference between the 7900X and the Core i9-13900K, it's clear that Intel's extra E-Cores provide an edge if you do lots of multi-threaded work.

The single-threaded Cinebench score lagged behind Intel's Raptor Lake CPUs too, with the Core i9-13900K bettering it by nearly 200 points and the Core i5-13600K only sitting a few points behind. In our Prime95 multi-threaded stress test, total system power consumption sat at 325W, which was over 100W more than with the Ryzen 9 5950X, but it did manage to undercut the Core i5-13600K here.

Games weren't as impressive as other areas for the Ryzen 9 7900X either, with the Core i9-13600K and Ryzen 7 5800X3D managing to better it in Far Cry 6 by a few frames per second. While margins were slim in Watch Dogs: Legion, the Ryzen 7 7700X provided to be a little quicker than the 7900X as well, as did the Core i5-13600K.

Conclusion

The competition in the CPU market at the moment is fierce and there aren't many bad options, meaning the Ryzen 9 7900X certainly has its place and ushers in new levels of performance for under £600, despite AMD not having upped core counts this time around. As an all-rounder, the 7900X makes some sense, given that it's miles faster than the similarly priced Ryzen 9 5950X in every single test and usually has the measure of the Core i9-12900K too, including in games.



Sticking with games for a moment, it's clear that you don't get more performance by opting for more expensive, higher-boosting Ryzen 7000 CPUs. In fact, due to its dual-CCD construction, the Ryzen 9 7900X was a touch slower in one game than cheaper Ryzen 7000-series models. This means you need to weigh up your needs and avoid willy waving. Comparatively, Intel still enjoys scaling in games right up to the Core i9-13900K.

Performance elsewhere revolves around multi-threaded and lightly threaded performance, but we were a tad disappointed with the 7900X's Cinebench score, given it was barely any quicker than the Core i9-12900K, although it did beat the similarly priced Ryzen 9 5950X. On the plus side, in the GIMP image editing test, it was much faster than these CPUs.

Overall then, it's a positive, if mixed bag for the Ryzen 9 7900X. Its biggest issues are the cheaper platform cost for the similarly priced Ryzen 9 5950X and Intel's 13th-gen CPUs, as well as offering zero benefit over cheaper models in games. For a mixed gaming and content creation system, though, it's a very powerful if overpriced CPU.

ANTONY LEATHER

VERDICT

A good all-rounder but it's no faster than cheaper CPUs in games and the price is high.

PERFORMANCE
43/50

FEATURES
14/15

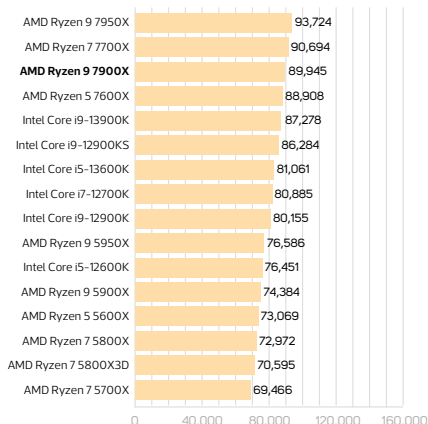
VALUE
25/35

OVERALL SCORE

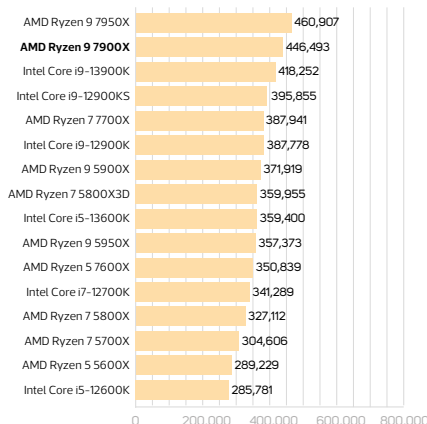
82%

AMD RYZEN 9 7900X RESULTS

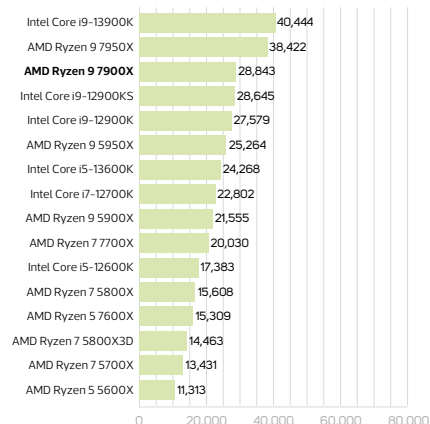
GIMP IMAGE EDITING



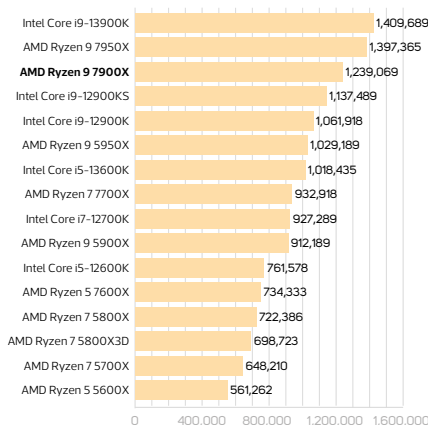
HEAVY MULTI-TASKING



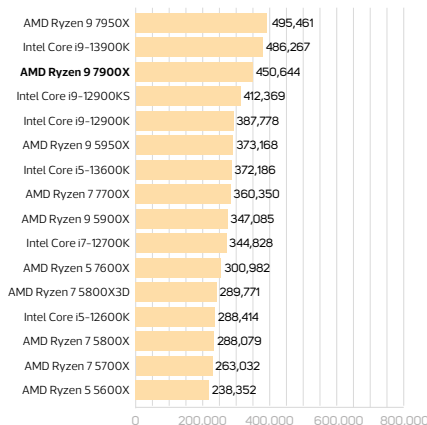
CINEBENCH R23 MULTI-THREADED



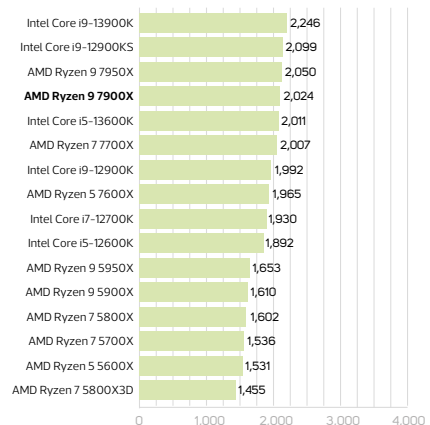
HANDBRAKE H.264 VIDEO ENCODING



SYSTEM SCORE

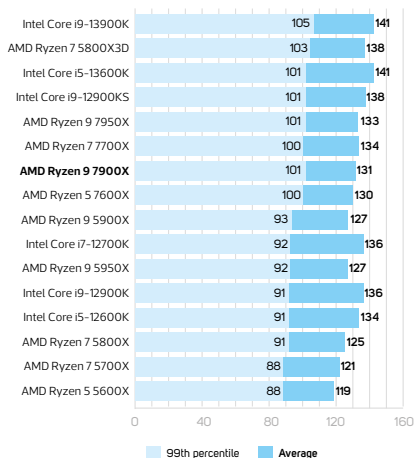


CINEBENCH R23 SINGLE-THREADED



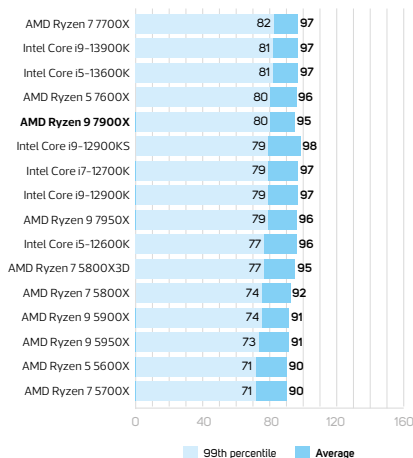
FAR CRY 6 (FPS)

1,920 x 1080, Ultra settings



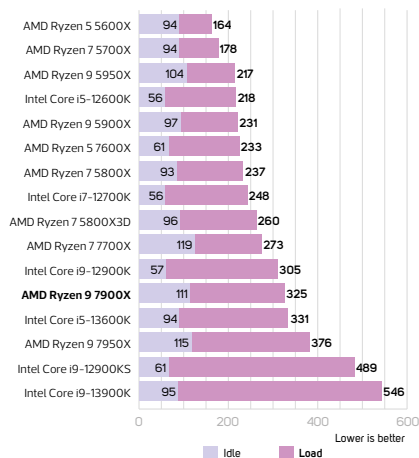
WATCH DOGS: LEGION (FPS)

1,920 x 1080, Ultra settings



TOTAL SYSTEM POWER CONSUMPTION (WATTS)

Windows desktop / Prime95 smallFFT



27IN GAMING MONITOR

AOC 27G2SPU / £230 inc VAT

SUPPLIER ebuyer.com

BUDGET BRILLIANCE

- + Fantastic default image quality
- + Solid gaming performance
- + Decent feature set for the price

BORINGLY BASIC

- Not as cheap as predecessor
- Slightly sluggish response time
- Only 1080p resolution

SPEC

Screen size
27in

Resolution
1,920 x 1,080

Panel technology
IPS

Maximum refresh rate
165Hz

Stated response time
4ms GTG

Max brightness
250cd/m² SDR and HDR

Backlight zones
1

Stated contrast ratio
1,000:1

Adaptive sync
FreeSync and G-Sync compatible

Display inputs
1x DisplayPort 1.4, 2x HDMI 2, VGA

Audio
2x 2W speakers, headphone out

Stand adjustment
Height, pivot, rotation, tilt

Extras
100 x 100mm VESA mount, 4-port USB 3 hub, MBR blur reduction mode

The AOC 27G2U has been the best budget 27in gaming monitor on our Elite list for a while, but the pricier 27G2SPU is set to be its replacement, costing a bit more money but offering plenty of upgrades.

It doesn't look particularly fancy, but it has slim, low-profile edges and a generally compact design that means it doesn't dominate your desk, although the flashes of metallic red on the stand and bottom bezel look a bit cheesy. Its V-shaped base projects further forward and is wider than necessary too. On the plus side, the stand offers height, pivot, rotation and tilt movements, so you can easily set up the display how you want it.

Connection options are good as well. While you don't get USB Type-C video input, you do still get an extra input – a D-SUB VGA port! Along with that marvel of modern technology, you also get a DisplayPort input and two HDMI ports, plus a 4-port USB 3 hub, headphone jack and pair of basic 2W speakers.

The menu control system could be better though. It uses a row of four buttons on the underside of the panel's edge, where they sit alongside an identical-feeling power button. Not only is it easy to hit the power button accidentally, but the buttons are small and difficult to press, plus the menu system isn't intuitive.

Thankfully, while menu navigation is cumbersome, the options are excellent. You get a proper brightness-adjustable sRGB mode for reining in the panel's otherwise extended colour gamut (124 per cent sRGB), there are extensive, clearly labelled colour-tweaking controls and you get all the gaming options you could expect at this price.

As this is only a 1080p panel, image quality is rather let down by overall sharpness, with a pixel density of just 81 pixels per inch (ppi). That compares to 93ppi for the 2,560 x 1,440 32in screens in this month's Labs test and 110ppi for typical 27in 2,560 x 1,440 screens. That's not great for detailed image editing or watching the latest 4K video, but it's great for gaming, especially if your graphics card has limited processing power.



Moreover, in every other regard, this screen's image quality is exceptional. Its out-of-the-box colour temperature (6,474K) and gamma (2.21) are all but perfect, while contrast is very high for an IPS panel at 1276:1. We also measured a maximum brightness of 354cd/m² – miles above its rated 250cd/m².

Being an IPS panel, viewing angles are excellent too. All told, there's no need to touch any settings but the brightness control on this display, unless you're using the sRGB mode, which also delivers spot-on image quality.

On paper, this 165Hz screen's gaming performance is less immediately compelling, as its initial response time varies between 13.2ms with no overdrive and 8.9ms at maximum overdrive. There are IPS screens available that are twice as rapid. However, in practice, this display still feels plenty snappy enough for accurate aim tracking. Moreover, its blur reduction mode tightens it up even further, bringing greater clarity to fast motion.

Conclusion

Although its response time is far from the lowest for an IPS gaming panel, the AOC 27G2SPU still delivers reliable gaming performance. Add in its excellent image quality, good connection options and pivoting stand, and you have a compelling panel for its price.

EDWARD CHESTER

VERDICT

Not quite as cheap as its predecessor, but still a great value gaming monitor.

IMAGE QUALITY
26/30

GAMING
22/30

FEATURES
16/20

VALUE
16/20

OVERALL SCORE

80%

MICRO-ATX CASE

JONSBOD30 / £95 inc VAT

SUPPLIER overclockers.co.uk

It's been a while since we've looked at a micro-ATX case, and the Jonsbo D30 is quite different from your usual off-the-shelf chassis. For starters, it doesn't have any fans as standard, while cases such as Kolink's Citadel Mesh RGB come fully equipped with fans.

The latter also used a traditional front-to-back airflow system and typical plastic and steel construction. The Jonsbo D30, on the other hand, has the majority of its fan mounts in the roof and base. It also lacks any fan mounts in the front section

and sports largely aluminium construction with a smattering of glass and steel. This means it weighs just 5kg, and it's reasonably compact too, measuring just 24cm wide and 33cm tall, although its length of 40cm gives it a hefty footprint.

A lot of that volume is a result of the case offering plenty of room for large components, with 168mm of CPU cooler clearance, and it also supports ATX PSUs. Due to the way the D30's PSU mount is positioned, with the PSU mounted down vertically at the front with the use of an angled kettle lead, if you use a 170mm or shorter PSU, there's up to 355mm of graphics card clearance too – this figure reduces to 305mm if you use a longer PSU.

Immediately we can see the benefits of using an SFX PSU in this chassis design. Doing so would have shaved inches off the case's depth and width, and even mounting it on its side would have made it no longer, but could have reduced the width a little. Still, with monstrous graphics cards all the rage at the

moment, a little extra space is welcome and there's plenty of space even for a massive RTX 4090 card in here, which will benefit from the large vented area below it too.

While there are no fans as standard, there are plenty of options here, with two 120/140mm mounts in the roof and the same in the base, along with a single 120mm fan mount in the rear. Jonsbo says the radiator limit in the roof and base is 240mm, but if you use slim 280mm radiators from Alphacool, and slim 140mm fans, you can fit larger radiators in both locations and still have enough clearance for a dual-slot graphics card.

Despite its elegant exterior and use of premium materials, the D30 does lack a bit of finesse when it comes to building a PC into it. You have to remove four screws in order to release the lid and remove the side panel, and it would have been easy for Jonsbo to add a pop-off or magnetic hinged panel here. The base and roof panels, which are home to the fan mounts, would make for perfect removable trays to make installing fans and radiators easier as well, but these are riveted in place instead.

Also, while the rear vent holes might look pleasant, large circular holes are very inefficient compared with hexagonal



SPEC

Dimensions (mm)

240 x 401 x 325 (W x D x H)

Material

Aluminium, steel, glass

Available colours

Silver, black, white

Weight

4.96kg

Front panel

Power, 1x USB 3 Type-C, 1x USB 3, stereo

Drive bays

1x 3.5in/2.5in, 3x 2x 2.5in,

Form factor(s)

Micro-ATX, mini-ITX

Cooling

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

CPU cooler clearance

168mm

Maximum graphics card length

355mm

JON BON JOVI

- + Good cooling
- + Great air and water-cooling support
- + Elegant design

JON BONJELA

- Basic accessories and features
- No USB 3.2 Gen2 Type-C support
- Limited cable stowage

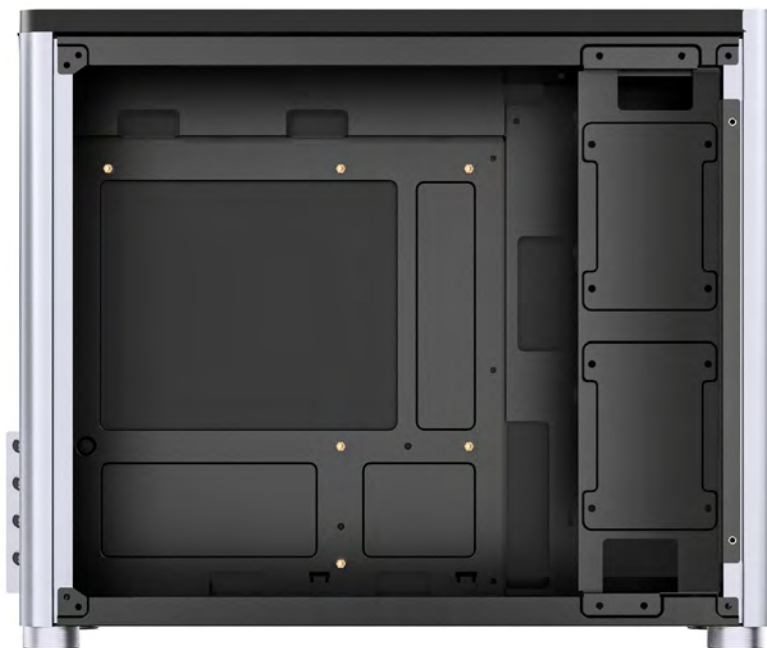
holes, and we suspect the vents here are circular because they're cheaper to create. Jonsbo has also cut costs with the front Type-C port, which is limited to USB 3 speeds and doesn't use a proper Type-C header. Thankfully, the rest of the case is fantastic, with excellent build quality, dust filters and an eye-catching design, with minimal fuss on the front panel.

Storage options are basic, with a single 3.5in hard disk mount that's shared with a 2.5in mount, plus three further 2.5in mounts. There are four expansion slots, so using triple-slot graphics cards won't be an issue either. Our last complaint, though, is limited cable stowage. There's zero clearance behind the far side panel, unless you're only routing extremely thin cables, and there are only small compartments at the front of the case to make up for it. You'll definitely want to keep your wiring simple.

Performance

With no fans included as standard, we added some of our own with one for testing – we installed one in the base below the graphics card, and another in the rear of the case to aid our CPU cooler. This resulted in a CPU delta T of 47°C, which was a touch warmer than the result from the Kolink Citadel Mesh RGB with its multiple fans and vented front panel. The GPU delta T was better, though, undercutting the Citadel Mesh RGB by 2°C thanks to the option to point fans straight at the GPU cooler.

We'd be inclined to add another fan to the base of the case before moving on to the roof, but it's clear the case would be quite at home with AIO liquid coolers, while also leaving you



the option to install a custom water-cooling loop with a short graphics card and small reservoir. The closed front section helps to keep noise leakage to a minimum too, although some noise does escape through the roof.

Conclusion

As a blank canvas, the Jonsbo D30 has a lot to offer both air and water-cooled systems, with plenty of space for fans, large coolers, beefy graphics cards and well-placed radiator mounts. It's particularly suited to housing large graphics cards and can easily swallow monsters such as Nvidia's new GeForce RTX 4090 Founders Edition. The case looks fantastic too, and despite a lack of finesse in the build process, working with the D30 is relatively easy.

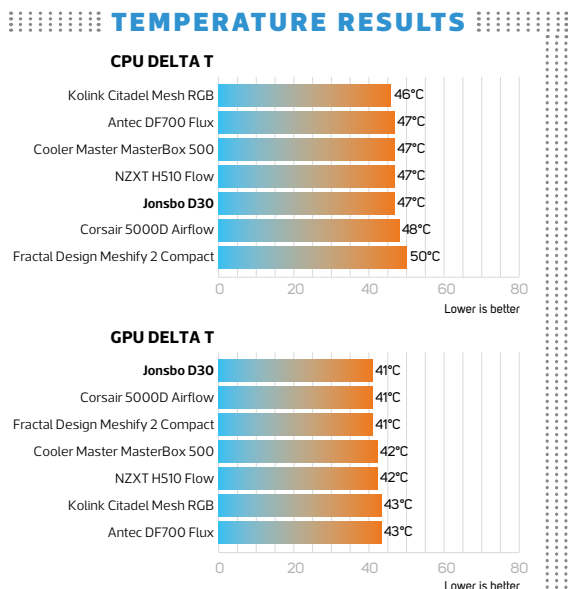
For £95, the D30's shortcomings can mostly be forgiven, especially with the materials used, but a couple of issues left a sour taste in our mouths, even at this price. The lack of a full fat USB Type-C port on the front panel was disappointing, and it would be so easy for Jonsbo to make the side panels tool-free, and add removable top and bottom fan mounts too. These are standard features on many similarly priced cases now, which leaves the Jonsbo D30 feeling like it's all style and little substance.

However, it's not overly expensive, it has great hardware and cooling support and it's otherwise a solid home for a high-end air or liquid-cooled micro-ATX PC. Just make sure you kit it out with some fans and be prepared to spend a little extra time tidying those cables.

ANTONY LEATHER

VERDICT

Great air and water-cooling potential in an attractive chassis, but it's a bit basic.



COOLING
26/30

FEATURES
13/20

DESIGN
25/30

VALUE
17/20

OVERALL SCORE

81%

X670E MOTHERBOARD

ASUS ROG STRIX X670E-E GAMING WIFI / £526 inc VAT

SUPPLIER [box.co.uk](https://www.box.co.uk)

The Asus ROG Strix range has traditionally occupied a middle ground between the company's Prime and TUF ranges, and its top-end ROG offerings. The boards often lack certain premium features, but still give you some frills and decent bang for your buck. In recent years, though, Strix boards have

been getting increasingly lavish and attractive, and the ROG Strix X670E-E Gaming WiFi is now a full-on high-end product with a price to match.

Thankfully, the good looks you'd expect for this price are here in abundance, with a large RGB-enabled hologram sitting on the huge I/O shroud heatsink, and a PCB covered in cooling hardware. Two enormous heatpipe-linked heatsinks cool the 18+2-teamed power stages, and all four of the M.2 ports are cooled on top and below. The M.2 heatsinks are substantial as well, with a large heatpipe-equipped heatsink catering for the top slot that supports PCI-E 5 SSDs.

Meanwhile, a large 9in-long heatsink caters for the pair of lower M.2 ports, which also support PCI-E 5 SSDs, and Asus has seen fit to include an upgrade heatsink for this too, which is the same length but nearly an inch thick. We're guessing this isn't fitted as standard, as it might interfere with the 16x PCI-E slots above and below it, plus the standard one is fine for a pair of even the

toastiest of current SSDs, but it might be handy for when super-fast PCI-E 5 SSDs start appearing.

The rear I/O panel is well populated too – we doubt anyone will be left wanting for USB Type-A ports with a massive count of ten available, all of which support USB 3.2 Gen 2. There are also three Type-C ports, one of which supports USB 3.2 Gen 2x2, as does with the Type-C header on the PCB. It's one of the most potent USB setups we've seen on a motherboard, although there's a notable exception of USB 4 or Thunderbolt, which is disappointing at this price.

On the rear panel, you'll also find aerial mounts for the 802.11ax 2x2 Wi-Fi 6E adaptor, HDMI and DisplayPort outputs, a clear-CMOS button and a USB BIOS FlashBack feature, along with the full selection of audio ports, including an optical.

The PCB also offers a bit more pizzazz than usual, including Asus' superb PCI-E slot Q-release feature, which frees your graphics card at the push of a button. You also get the screw-free M.2 Q-Latch system, which we've loved since it was introduced, removing the need to use tiny screws to secure your SSD.

Water-cooling enthusiasts will like the thermal sensor input too, as it enables you to set your radiator fans to react



SPEC

Chipset

AMD X670E

CPU socket

AMD Socket AM5

Memory support

4 slots: max 64GB DDR5 (up to 6400MHz)

Expansion slots

Two 16x PCI-E 5, one 16x PCI-E 4

Sound

8-channel Realtek ALC4080

Networking

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

Cooling

Eight 4-pin fan headers, VRM heatsinks, M.2 heatsinks

Ports

4 x SATA 6Gbps, 3 x M.2 PCI-E 5, 1 x M.2 PCI-E 4, 10 x USB 3.2 Gen 2 Type-A, 1 x USB 3.2 Gen 2x2 Type-C, 2 x USB 3.2 Gen 2 Type-C, 1 x USB 3.2 Gen 2x2 Type-C header, 3 x surround audio out

Dimensions (mm)

305 x 244

M.2

- + Excellent feature set
- + Superb audio performance
- + Brilliant M.2 and VRM cooling

M25

- Very expensive
- Lacks USB 4 and Thunderbolt
- Could do with a Reset button

to coolant temperature rather than CPU temperature, which is much better for noise control, albeit with the need for a thermal probe. You also get eight 4-pin fan headers, along with a Start button and LED POST code display.

However, for initial testing or extreme overclocking, we'd like a reset button too. The LED post code display is very useful, though, as X670E motherboards can take a long time to boot. Without it, you'll be left wondering if there's a problem, when in fact the board is fine.

While Asus' software worked well in terms of overclocking, fan and RGB control, these features seem to be split across its newer Armoury Crate and AI Suite programs. We recommend sticking to Armoury Crate, which provides fan and lighting control – it even picked up our Kingston RGB test memory straight away and integrated it with the motherboard lighting.

The fan control section is excellent too, offering the ability to select from different temperature sources for fan speed, including the thermal probe header or GPU.

The EFI is also superb, with an excellent layout, clarity, a decent range of options and an equally good fan control suite should you not wish to use the software.

Performance

The Strix's VRM temperature benefited from the massive heatsinks sitting on top of the power circuitry, topping out at 55°C with our Ryzen 9 7950X under load for ten minutes, with the CPU itself breaching the 90°C mark in under 20



seconds, although that's normal. The M.2 temperature of 57°C in the top slot when using our Kingston Fury Renegade PCI-E 4 SSD was excellent as well, so we upped the ante with the extremely toasty WD Black SN850, which peaked at 65°C. This is one of the lowest temperatures we've seen with this SSD, and it's 15°C lower than it was in the cramped Asus ROG Strix X670E-I Gaming WiFi.

The audio performance from the SupremeFX Realtek-based ALC 4080 codec was superb too, with a -119dBA noise level, 119dBA dynamic range and 0.003 per cent THD.

In terms of power draw, our test PC drew 354W from the wall under load, which was 20W lower than the average we've seen on other Socket AM5 boards, but the ROG Strix X670E-E Gaming WiFi was also quite quick to rein in clock speeds if the CPU got toasty. Despite this, it still managed a RealBench system score of 488,606, which was nearly identical to the scores of the Asus ROG Strix X670E-I Gaming WiFi and Asus TUF Gaming X670E-Plus WiFi.

Conclusion

Despite being a great motherboard, the fact of the matter is that £500 is a huge amount to pay for a motherboard, especially in these times, and also when you consider that Asus has perfectly good models such as the TUF X670E Plus WiFi that cost nearly £200 less and cope with a Ryzen 9 7950X perfectly well. That said, Socket AM5 has a long lifespan ahead of it, so if you plan on getting an all-singing, all-dancing motherboard now and keeping it for a few years, then we can sympathise with those who won't shy away from splashing out on something special.

The ROG Strix X670E-E Gaming WiFi has almost every feature you'd want at this price, except maybe USB 4 and Thunderbolt 4, plus it's nearly £100 cheaper than the admittedly excellent ASRock X670E Taichi, has an excellent EFI and its software isn't bad either.

The biggest issue, though, is that it feels like piggy in the middle. There are far cheaper boards available that offer a decent home even for a Ryzen 9 7950X, and spending a little more gets you even more high-end features. Still, if spending £600 is out of the question, but £500 sounds more palatable, this is a great motherboard if you can afford it.

ANTONY LEATHER

VERDICT

A stunning, well-featured motherboard, but its price is extremely high.



PERFORMANCE
32/35

FEATURES
32/35

VALUE
18/30

OVERALL SCORE

82%

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The image displays three issues of Custom PC magazine. The first cover on the left features an AMD processor and the text 'THE BEST-SELLING MAG FOR PC HARDWARE, OVER'. The middle cover has a red background with the text 'THE BEST-SELLING MAG FOR PC HARDWARE, OVER'. The third cover on the right features an NVIDIA GeForce RTX 4080 graphics card and the text 'THE BEST-SELLING MAG FOR PC HARDWARE, OVER'. A white mug with a yellow star logo and the text 'CUSTOM PC BEVERAGE APPROVED' is shown next to the magazines. A yellow circle with a red plus sign is also present.

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M.2 PCI-E 4 NVME SSD

SAMSUNG 990 PRO /

2TB £284 inc VAT (reviewed); **1TB £154** inc VAT

SUPPLIER cclonline.com

SOLID STATE

- + Huge sequential speeds
- + Good 4K random speeds
- + Decent warranty and endurance rating

RIGHT STATE

- Very expensive
- Slower than competition in some tests
- No 4TB model available yet

With an enviable reputation in the SSD market, Samsung is another manufacturer to have snuck out one more PCI-E 4 SSD under the radar, just when we thought everyone was moving to PCI-E 5. Like the WD Black SN850X we've also reviewed this issue (see opposite), Samsung is vying for both PC and console markets with the 990 Pro, which is available with or without an RGB-enabled heatsink.

It's the heatsink-less 2TB version we're reviewing here, and while the WD Black SN850X has seen a substantial price cut and costs around £200 for this capacity, the 990 Pro still hovers around the £280 mark. That's a sizeable difference, and even the 1TB model's £154 price tag dwarfs the sub-£120 price tag of the similar WD model. Value isn't the 990 Pro's strong point, then, but maybe speed can tempt people to part with their cash instead.

The SSD uses an in-house Samsung controller, codenamed Pascal, along with 2GB of LPDDR4 memory as a cache for its V-NAND TLC memory. Like the WD Black SN850X, it also sports a software feature called TurboWrite 2, which acts as a buffer to boost performance.

This buffer sits at 10GB on the 2TB model we tested but can be enlarged to up to 226GB using Samsung's software. Speaking of capacities, while WD already has a 4TB version of its Black SN850X available, Samsung has said a 4TB model of the 990 Pro won't arrive until 2023, meaning 2TB is the current limit for this drive.

Specifications are similar to the WD SSD, though, with both drives offering an endurance rating of 1,200TBW, a five year warranty, a stated read speed of 7,300MB/sec and a claimed write speed of 6,600MB/sec.

The WD Black SN850X failed to top 7,000MB/sec, no matter which M.2 port we used on our test motherboard. However, if we hooked up the 990 Pro to the CPU-linked port on our X570 motherboard, we managed to coax 7,198MB/sec out of it on the CrystalDiskMark sequential read speed test, and 6,754MB/sec in the write test. These are blistering sequential speeds and noticeably quicker than those of the WD SSD.

The Samsung was also slightly quicker in the random 4K 32-queue-depth 16-thread test in CrystalDiskMark, peaking at a read speed



of 3,105MB/sec vs 2,840MB/sec for the WD drive, and also recording a slightly higher write speed. It also managed 520MB/sec in the PCMark 10 full storage benchmark average speed test, compared to 463MB/sec for the WD drive.

However, elsewhere, it was the WD Black SN850X that sat out in front, despite its much lower price. The WD drive beat the Samsung 990 Pro in both read and write speeds in the random 4K single-queue-depth single-thread tests and was much faster in the 3DMark game load time performance.

In Battlefield V, it managed a 1,154MB/sec load time vs 1,035MB/sec for the Samsung drive, while in Call of Duty: Black Ops it hit 965MB/sec vs 739MB/sec for the Samsung drive, and the WD drive's access times were far lower too. The 990m Pro also needs a heatsink to operate at full speed, quickly hitting 75°C in our stress test without one.

Conclusion

We've dished out plenty of awards to Samsung SSDs in recent years, but feel the company has dropped the ball with this one. It's incredibly fast in theory, with the highest sequential speeds we've ever seen, but this doesn't translate into chart-topping performance across the board, and it's certainly not fast enough all round to justify its hefty price premium compared with the competition. It's a seriously fast SSD, especially for those shifting lots of data around regularly, but the WD Black SN850X isn't much slower and costs significantly less money.

ANTONY LEATHER

VERDICT

Very fast in sequential tests, but it's too expensive to be competitive.

SPEC

Full capacity
2TBFormatted capacity
1.81GBHeatsink
NoNAND
TLCController
Samsung in-houseEndurance
1,200TBWWarranty
Five yearsPERFORMANCE
47/50FEATURES
15/20VALUE
17/30

OVERALL SCORE

79%

M.2 PCI-E 4 NVME SSD

WD BLACK SN850X / 4TB £400 inc VAT;

2TB £212 inc VAT (with heatsink, reviewed); 1TB £112 inc VAT

SUPPLIER westerndigital.com

BEANS ON TOAST

- + Excellent speeds
- + Competitively priced
- + 4TB model available

BURNED TOAST

- Sequential speeds aren't chart-topping
- Cheaper SSDs won't feel much slower
- Toasty peak temperatures with stock heatsink

If you thought PCI-E 4 SSDs had already had their last hurrah you'd be mistaken, as several manufacturers have released new high-speed flagship models despite PCI-E 5 SSDs looming on the horizon, including both WD and Samsung (opposite). Of course, you'd need a new PC with a compatible motherboard in order to use a PCI-E 5 SSD anyway, so the WD Black SN850X is certainly a contender if you want to give your current system a speed boost.

Despite only being on the shelves for a short while, the WD Black SN850X has already received a price cut, retailing for just £200 in a heatsink-less 2TB version, with our sample including an RGB lighting-equipped heatsink for an extra £12. The lighting is controlled using WD's Dashboard software, but only includes a small section of lighting next to the printed logo on the heatsink.

While still hideously expensive, the 4TB model has also seen a huge £250 price cut and now retails for £400, with many other models demanding far more than just double the 2TB price. Meanwhile, the 1TB version, which is likely to be a favourite among system builders and upgraders alike, currently goes for just £112 inc VAT.

With the ability to dish out read speeds of up to 7,300MB/sec, you'll need that heatsink on the SN850X too, or at the very least, you'll need to use a heatsink that comes with your motherboard. Even with this chunky slab of illuminated metal attached to it, the SN850X still topped out at 69°C in our tests.

Unless you're dead-set on having an RGB-enabled SSD, we'd suggest opting for the heatsink-less version, saving

some cash and using a larger motherboard heatsink, but bear in mind that this temperature was recorded as a worst-case scenario in our extended stress test.

The SN850X is equipped with WD's own 20-82-20035-B1 controller and triple-level cell (TLC) NAND flash memory. It also comes with a solid five year warranty, and the endurance ratings are excellent, with a rating of 1,200 terabytes written (TBW) for our 2TB sample, although this is fairly standard now, with the Samsung 990 Pro (opposite) offering the same endurance rating.

In terms of performance, the SN850X's 4K single-thread, single-queue-depth random read and write speeds of 83MB/sec and 221MB/sec



respectively in CrystalDiskMark were excellent, offering small advantages over the 990 Pro. The latter managed higher sequential speeds, with the SN850X only hitting 6,300MB/sec read and write compared to 7,198MB/sec and 6,754MB/sec for the Samsung SSD.

The SN850X also has another trick up its sleeve, though, with a Game Mode in its software that can prioritise the loading of game files in order to cut load times.

In the new 3DMark game load time and access time tests, the SN850X was noticeably quicker than the Samsung SSD here.

For example, the WD drive has a load speed of 965MB/sec in Call of duty: Black Ops 4, compared to 739MB/sec for the Samsung drive, and the SN850X's latency of 70µs was tighter than the Samsung's 87µs. In Battlefield V, it peaked at 1,154MB/sec compared to 1,025MB/sec for the Samsung 990 Pro; again, the Black SN850X managed a lower latency of 62µs versus 71µs.

Conclusion

It might not have the absolute fastest sequential speeds available, but the technology under the hood of the Black SN850X, as well as its quick game load times, help it to edge out Samsung's 990 Pro in game-focused tests. We suggest saving a few quid and using your motherboard's M.2 heatsinks instead of paying for the WD one, but even with the heatsink, the current pricing for the SN850X range is superb for the performance on offer.

ANTONY LEATHER

VERDICT

Very fast but, more importantly, much cheaper than the competition.

PERFORMANCE
47/50

FEATURES
16/20

VALUE
27/30

OVERALL SCORE

90%

SPEC

Full capacity
2TB

Formatted capacity
1.81GB

Heatsink
Yes

NAND
TLC

Controller
WD 20-82-20035-B1

Endurance
1,200TBW

Warranty
Five years

DDR5 MEMORY KIT

CORSAIR VENGEANCE RGB DDR5

£256 inc VAT 32GB (2 x 16GB) 6000MHz

SUPPLIER scan.co.uk

BLACKPOOL ILLUMINATIONS

- + Looks fantastic
- + Relatively low profile
- + Reasonable price

BUZZING LIGHT BULB

- No 16GB option
- Not much overclocking headroom
- RGB lighting not quite as bright as other kits

SPEC

AMD EXPO support

Yes

Frequency

6000MHz

Timings

30-36-36-76

Voltage

1.4V

Height (from base)

45mm

RGB lighting

Yes

This is the first Vengeance-branded DDR5

memory kit we've seen from Corsair in the Custom PC labs, and it's good to see this popular brand return and with an aesthetic

tweak too. The past couple of years have been a bumpy ride for a lot of memory manufacturers, as they've contended with pandemic-related supply issues and Intel's decision to mix DDR4 support with new DDR5 memory on its 12th-gen and 13th-gen Core platforms.

However, with AMD sticking to a DDR5-only policy for its latest Ryzen 7000-series chips, we're hoping DDR5 will soon become mainstream, with hopefully lower prices that are more in line with those of DDR4 kits in the future. Corsair is already onto introducing its latest Vengeance RGB DDR5 memory, sitting in between the bland grey modules of its standard Vengeance kits and the super-fancy modules on its Dominator modules. It's fast too, with our test kit rated to run at 6000MHz.

At a price of £226 inc VAT for a dual-channel 32GB kit, it's one of the cheapest 6000MHz kits around, using popular SK Hynix memory dies and retailing for a similar price to the Kingston Fury Beast RGB we reviewed a couple of issues ago. This kit, though, as well as sitting in Ryzen 7000-series CPUs' frequency sweet spot, also sports AMD EXPO compatibility. This means it's fine-tuned for maximum performance and compatibility with Socket AM5 motherboards and Ryzen 7000-series CPUs.

If you've missed the lowdown on EXPO, it's essentially AMD's answer to Intel's XMP, allowing it to set its own parameters instead of those geared towards Intel systems. That said, motherboard manufacturers announced a few months ago that LGA1700 motherboards will support EXPO memory profiles, as well as the usual XMP tech, so there's nothing preventing you from using this kit with a Z790 motherboard, for example.

This specific kit has particularly tight timings too, at 30-36-36-76 compared to 40-40-40-80 for the Kingston Fury Beast RGB, and the modules are also considerably shorter than DDR4 Vengeance RGB Pro DIMMs too, measuring just 45mm tall. Corsair is clearly hoping these kits will find their

way into more systems this way and the company would be right in that thinking.

You still get RGB lighting too, with ten individually controlled RGB LEDs sitting underneath a diffusing light bar. We'd argue that the colours are more vivid than in the original Vengeance RGB Pro modules, but they're maybe not as bright. Still, you get Corsair's iCUE software to control them, which is the best RGB control software in the business, and it lets you select from solid colours as well as numerous lighting effects.

We didn't spot any noticeable performance gains over the cheaper G.Skill Trident Z5 RGB kit; despite only offering XMP profile support, this managed marginally higher scores in our RealBench tests, albeit some within the margin of error, but the Corsair kit's performance was still bang on for a 6000MHz kit. Also, heading to the EFI revealed two EXPO profiles, with a 6200MHz option in addition to the standard 6000MHz profile. However, while the 6200MHz overclocked option proved perfectly stable, we couldn't overclock the kit past 6200MHz without errors creeping into our stress test.

Conclusion

We were worried for Corsair there for a minute, as its first DDR5 memory kits, as with many other manufacturers, have been slow and very expensive. The likes of Kingston might have beaten it off the start line with faster, more affordable kits, but this kit has a more reasonable price. In this case, EXPO only buys you an extra 200MHz, but Corsair's iCUE software and wide compatibility, plus its slightly more vibrant lighting than the G.Skill kit, just about nets it an award.

ANTONY LEATHER

VERDICT

A decent RGB DDR5 memory kit with EXPO support, though it's a tad pricey.



PERFORMANCE
26/30

DESIGN
22/25

VALUE
37/45

OVERALL SCORE

85%

DDR5 MEMORY

G.SKILL TRIDENT Z5 RGB

£236 inc VAT 32GB (2 x 16GB) 6000MHz

SUPPLIER memoryc.co.uk

PITCHFORK

- + Low-profile heatsinks
- + Lighting can be controlled by your motherboard
- + Competitive price

SPORK

- No 16GB option
- Not much overclocking headroom
- RGB lighting could be brighter

It seems that DDR5 memory is finally gaining some traction as the prices of dual-channel kits edge

towards the £200 mark, although this still means there's a £65 gap between the likes of the G.Skill Trident Z5 RGB kit and its DDR4 equivalents. Still, if you want a premium Z690 or Z790 motherboard, or indeed any system based on AMD's new Socket AM5 platform, then you'll need to jump onto the DDR5 bandwagon.

Retailing for a little more than Corsair's Vengeance RGB DDR5 kit (see opposite), the Trident Z5 RGB has an even shorter profile, measuring just 42.5mm high and shaving another 2.5mm off the height of the Corsair kit, despite the Trident Z5 modules still sporting large heatsinks and RGB lighting. Like the Corsair kit, these G.Skill Trident Z5 RGB modules also sport SK Hynix memory dies under their heatspreaders, but they also have looser memory timings at 36-36-36-96 compared to 30-36-36-77; however, that's likely tied into the fact this isn't an AMD EXPO-rated memory kit.

Instead, it's just Intel XMP-certified, but it will still run fine in AMD Socket AM5 systems – it just won't be as fast in some scenarios, although the differences will be small (see Issue 231, p21). Like the Corsair kit, there's no 16GB option, so you're forced to opt for a hefty 32GB kit at the very least, but that's what we'd be buying for a high-end system these days anyway. A Windows 11 system soon uses more than 16GB once you have several Photoshop images and Chrome browser tabs open, and while the days of paging to a mechanical hard disk are largely gone now, you should be looking at 32GB for a top-end system now.

Back to the Trident Z5 RGB modules, their lighting is accurate, but it isn't as bright as the lighting on Corsair's Vengeance RGB modules. Despite their short height, though, the modules' diffusing light bar was easily visible from the side as well as the top, thanks to cut-outs in the heatsinks on either side. If you prefer your RGB memory to be understated rather than garishly in your face, then you'll approve of these modules' lighting.

To control the lighting, G.Skill has its own software, which is fairly basic compared with Corsair's iCUE software, but it does the job, whether you pick from lighting effects or millions of solid colours. There are eight individually

controlled LEDs

in each module, which

can be set to specific colours

or brightness levels, or there are seven effects, such as rainbow, strobe or cycling.

However, the modules also support ASRock, Asus, Gigabyte and MSI's RGB software, so at least you can synchronise them with other devices, such as fans or lighting strips connected to headers on those motherboards, as well as any RGB lighting on the boards themselves.

Performance was also fine, with this kit even being a little faster than the EXPO-rated Corsair Vengeance RGB kit (see opposite) in some of our RealBench tests, although only by tiny margins. There's not much overclocking headroom, but there are limited benefits for this on both AMD and Intel systems anyway.

Conclusion

The G.Skill Trident Z5 RGB might not be exactly cheap compared with DDR4 memory, but you won't find 32GB of 6000MHz DDR5 memory for much less money, especially with RGB lighting. If lighting is important, then Corsair's bigger ecosystem would tempt us away from this kit, but it's great to be able to use your motherboard's lighting software to add these modules into your motherboard's control system. With its reasonable price, low-profile heatsinks and understated RGB lighting, these modules are a solid choice for a new DDR5 memory kit.

ANTONY LEATHER

VERDICT

A decent price, low-profile heatsinks and full motherboard lighting support – a solid DDR5 memory choice.



SPEC

AMD EXPO support

No

Frequency

6000MHz

Timings

36-36-36-96

Voltage

1.35V

Height (from base)

42.5mm

RGB lighting

Yes

PERFORMANCE
26/30

DESIGN
21/25

VALUE
40/45

OVERALL SCORE

87%

WIRELESS GAMING MOUSE

COOLER MASTER MM712 / £80 inc VAT

SUPPLIER amazon.co.uk

MMMM

- + Excellent gaming performance
- + Smart design
- + Wired, wireless and Bluetooth connections

HMMMM

- Not suited to larger hands
- Only really suited to fingertip grip
- Dongle cover easy to lose

Cooler Master's recent gaming mice have largely impressed us, with the MM711 picking up an Approved award in our recent Labs test. The company's latest MM712 is a variation on that very mouse, adding wireless connections and numerous other changes. The biggest and most visually obvious change is that the MM712 no longer sports external weight-saving perforations. Instead, the company has sealed the mouse back up and kept its weight-saving endeavours to internal tweaks.

Overall, it's a move that makes a lot of sense; while exterior holes offer an easy way to reduce weight, they expose the innards to grot and grime from the outside world. What's more, the MM712 is 2g lighter than the MM711, so it's clear the exterior holes aren't needed to create a very light mouse.

Thanks to that external change, the MM712 cuts a clean, minimalist figure, especially in the black finish of our review sample – a white version is also available. The RGB-illuminated Cooler Master hexagonal logo on the rear provides just a little bit of flair without breaking the otherwise clean look of the mouse.

The symmetrical shape also helps to create that clean look, although like the Corsair Katar Elite Wireless (opposite), it lacks side buttons on the right edge to make it a truly ambidextrous design.

The MM712 is small, with a length that's around 10mm shorter than the likes of the NZXT Lift or Logitech G Pro X Superlight. Despite this stubbiness, the back of this mouse flares out to be as wide as larger mice, giving it sides that angle inwards towards the front. We found this made it less of a universally appealing shape and best suited to a fingertip grip, using just your little finger on the side.

In addition to having a 2.4GHz wireless connection, the MM712 houses a USB Type-C port on its front that can charge and connect the mouse to your PC. Plus, it supports Bluetooth, which comes with the bonus of more than doubling the battery life of using the 2.4GHz wireless dongle, although it doesn't have the bandwidth for very fast-paced gaming. A hole on the underside of the mouse can store the wireless dongle. However, it's covered by a rather flimsy plastic flap that we can see easily snapping or getting lost.

Also on the underside of the mouse is a DPI button, a slider switch for changing between Bluetooth and wireless modes, plus there's a pairing button. Up top, you get just four buttons and a scroll wheel/middle button, all of which feel precise and entirely well suited to the high demands of intense gaming sessions.

The MM712 uses an unspecified PixArt optical sensor with a maximum GPI of 19,000, maximum acceleration of 50g and maximum movement speed of 400 IPS. It's a top-notch sensor that performed flawlessly in our tests.

Meanwhile, the lighting, polling rate, DPI, lift off distance, button assignment, wireless sleep mode, button response time and more can be controlled via Cooler Master's MasterPlus software, which is quite a comprehensive list of settings. However, the software insists on filling your entire screen (at 2,560 x 1,440) even when in windowed mode, which is annoying.

Conclusion

The versatility of wired, wireless and Bluetooth modes makes this a great all-rounder mouse, while its gaming performance is flawless. Only its shape may be of concern to some, as its short, flared-rear design doesn't have universal appeal, being best suited to smaller hands and fingertip grip.

EDWARD CHESTER

VERDICT

A very capable mouse for a good price, but its shape won't suit everyone.

SPEC

Weight

58g

Dimensions (mm)

62 x 117 x 38 (W x D x H)

Sensor

PixArt optical, 19,000 DPI, 50G acceleration, 400 IPS

Buttons

5 (left, right, middle, forward, back)

Stated battery life

80 hours wireless, 180 hours Bluetooth

Cable

1.9m, lightweight braided USB Type-A to-USB Type-C

Wireless connections

Bluetooth and 2.4GHz wireless, USB-C to USB-A adaptor, USB-A wireless dongle

Extras

DPI button on underside



DESIGN
14/20

FEATURES
18/20

PERFORMANCE
26/30

VALUE
22/30

OVERALL SCORE

80%

WIRELESS GAMING MOUSE

CORSAIR KATAR ELITE WIRELESS / £45 inc VAT

SUPPLIER amazon.co.uk



Corsair has been slowly embracing the modern trend for lightweight gaming mouse, and the Katar Elite Wireless is the latest model to get the slimming treatment. The previous Katar Pro Wireless, which used an AA battery rather than a built-in rechargeable unit, weighed 96g whereas the Elite Wireless version flips that number right round, coming in at just 69g.

While that's considerably lighter than its predecessor and generally quite light for a wireless mouse, it's certainly not the lightest. Moreover, considering the compact size of the Katar, it still feels fairly dense compared with some competitors.

The shape is a bit peculiar too. From its relatively wide top middle section, its symmetrical form narrows considerably towards the back and base. Corsair bills the shape as being for claw and fingertip grip, and sure enough, the lack of rear bulk isn't suited to palm grip. However, we found the backside parcity not overly suited to claw grip either.

Moreover, the narrowing towards the base results in the mouse having steeply angled sides that cause your fingers to slip down the sides and under the mouse. As a result, we didn't find it the most comfortable or versatile shape for fingertip grip either. As ever, mouse shape is

very subjective, but this mouse isn't designed for universal appeal.

Housed in the top area of the mouse are five main buttons, including a DPI button set behind the scroll wheel. The scroll wheel is lightweight and rubberised, but doesn't have very defined detents, so it doesn't feel as accurate as some alternatives.

Up front is a USB Type-C port that can be used to charge and connect the mouse to your PC, while a slider on

the underside lets you switch to Bluetooth or 2.4GHz wireless modes. The included dongle for the latter uses a standard USB Type-A connection, as does the other end of the main USB cable.

There's no Type-C to Type-A adaptor included for plugging the dongle into the end of the main cable, as on the Cooler Master MM712. The cable itself is also a plain rubberised one, rather than the lightweight braided style favoured by many gaming mice. It's sufficiently flexible to provide only modest cable pushback though.

Also on the underside is a stowage hole for the dongle; like the Cooler Master MM712, this has a little clip-on plastic cover that we can see getting broken or lost quite easily.

Alongside this is the sensor, which boasts some mind-boggling specs, with a maximum DPI of 26,000, maximum acceleration of 50g and maximum movement speed of 650 IPS. Suffice to say, the sensor won't be any encumbrance to your gaming performance.

We were less impressed by the primary left and right buttons. Corsair talks up its 'zero gap' technology, to ensure the buttons feel as responsive as possible, but while we didn't feel any gaps, the button click feels a little soft and undefined.

Conclusion

The Corsair Katar Elite Wireless is a capable and versatile gaming mouse that will suit those with small-to-medium hands who prefer a fingertip or claw grip. However, while it's solid enough, its buttons feel a tad mushy and its shape is far from universally appealing. It's good, then, that it's an impressively affordable mouse, offering a lot of features for its £45 inc VAT asking price, especially for a wireless model.

EDWARD CHESTER

VERDICT

A versatile and capable gaming mouse for a great price, although its shape is a bit odd and its buttons feel a tad mushy.

DEADLY WEAPON

- + Excellent sensor performance
- + Great value
- + Wired, wireless and Bluetooth connections

DULL BLADE

- Slightly odd shape
- Only really suited to fingertip grip
- Mushy-feeling main buttons

SPEC

Weight
69g

Dimensions (mm)
62 x 117 x 38 (W x D x H)

Sensor
PixArt optical, 26,000 DPI,
50G acceleration, 400 IPS

Buttons
6 (left, right, middle,
forward, back, DPI)

Stated battery life
60 hours wireless, 110
hours Bluetooth

Cable
1.9m, tangle free rubber USB
Type-A-to-USB Type-C cable

Wireless connections
Bluetooth and 2.4GHz wireless,
USB Type-A wireless dongle

DESIGN
12/20

FEATURES
17/20

PERFORMANCE
22/30

VALUE
28/30

OVERALL SCORE

79%



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INTEL Z790 GAMING PC

SCAN 3XS FLUID
TORRENT CS / £6,899 inc VATSUPPLIER custompc.co.uk/ScanCS

Scan's 3XS Fluid Torrent CS is like a monument to excess, the ultimate system you could build right now. The Nvidia GeForce RTX 4090 GPU and the Intel Core i9-13900K CPU are both overclocked, the memory is tweaked, and a high-end custom water-cooling loop chills the hardware. Scan has even deployed automotive-grade paint, custom backplates and an etched side window to add finesse.

There's no doubting the RTX 4090's gaming credentials. This new GPU deploys 16,384 CUDA cores, 128 RT cores and 24GB of memory, along with Nvidia's new Ada Lovelace architecture, and this rig's card has undergone two tiers of tweaking. The Asus TUF OC card beneath the EK waterblock boosts the core's standard boost clock from 2520MHz to 2565MHz, and Scan has further overclocked the core to 2960MHz, as well as overclocking the memory from 1310MHz to 1440MHz.

You'll find similar tweaking in the LGA1700 socket, where the Core i9-13900K has had its maximum P-Core boost clock of 5.8GHz revised to 6GHz.

And yes, that's a 2-core boost clock not an all-core overclock, thanks to some clever work in the Asus ROG Strix Z790-E Gaming WiFi motherboard's EFI by Scan.

There's more overclocking in the memory department. The Torrent's 64GB of great-looking Corsair Dominator Platinum DDR5 memory runs at 6000MHz, rather than its stock speed of 5600MHz, and the latency timings are tightened from 40-40-40-77 to 30-39-39-51. The rest of the

specification is suitably forceful, with a 2TB Samsung 980 Pro PCI-E 4 M.2 SSD and an 80 Plus Gold-certified Corsair RM1000x PSU.

The motherboard is a bit of a beast too. The Asus ROG Strix Z790-E Gaming WiFi looks the part, with huge heatsinks and RGB LEDs, and it has virtually every high-end feature. Its primary 16x PCI-E slot and M.2 socket support PCI-E 5, and most of its other PCI-E slots and its four remaining M.2 connectors rattle along with PCI-E 4.

Connection options comes from 2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi 6E and Bluetooth 5.3, and the board has an 18+1 power phase design, a POST display and smart quick-release latches on the PCI-E and M.2 sockets.

The board also sports loads of fan headers, a Thunderbolt 4 header and a USB 3.2 Gen 2x2 socket that supports 30W fast-charging. You're spoiled for choice at the rear as well – there are two Type-C connectors, including one that runs using USB 3.2 Gen 2x2, and ten more full-sized USB ports at varying speeds.

Of course, the main centrepiece of this PC is the superb custom water-cooling system. Front and floor-mounted



SPEC

CPU

Intel Core i9-13900K
overclocked to 6GHz boost

Motherboard

Asus ROG Strix Z790-E Gaming WiFi

Memory

64GB Corsair Dominator Platinum
5600MHz DDR4 overclocked to 6000MHz

Graphics

Asus GeForce RTX 4090 24GB

Storage

2TB Samsung 980 Pro M.2 SSD

Networking

2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi

Case

Fractal Design Torrent

Cooling

CPU: EK CoolStream SE 360mm radiator with 3 x 120mm fans, EK Quantum Velocity2 waterblock, EK Quantum Kinetic TBE 300 D5 PWM pump/reservoir; GPU: EK CoolStream SE 360mm radiator with 3 x 120mm fans, EK Quantum Vector2 waterblock; rear: 1 x 140mm fan

Ports

Front: 1x USB 3.2 Gen 2 Type-C, 2x USB 3, 2x audio; rear: 1x USB 3.2 Gen 2x2 Type-C, 1x USB 3.2 Gen 2 Type-C, 6x USB 3.2 Gen 2, 4x USB 3, 5x audio, 1x optical S/PDIF

Operating system

Windows 11 Home 64-bit

Warranty

Three years parts and labour, one year on site then return to base





AQUAMAN

- + Record-breaking performance
- + Incredible custom design
- + Loads of memory
- + Surprisingly quiet

BLACK MANTA

- Eye-watering price
- Cramped internals

360mm radiators chill the CPU and GPU, with the former topped by an EK Quantum Velocity2 waterblock and the latter equipped with a Quantum Vector2 unit. A mix of matt and chrome hardline tubing crosses the chassis, and behind that, there's an EK 300mm reservoir and pump unit.

The loops look brilliant, and the rest of the build looks great. This system includes Scan's CS pack, which means you get extra customisation options. Our review sample is painted with the same Nardo Gray colour you'll find on Audi cars, and matt black paint has been added to the front and back case vents. Scan has also performed a custom etch on the glass side panel, which has this esteemed publication's logo on our sample, but you can have your own design etched too.

Scan's CS service also includes extra performance tweaks and optimisations, as well as in-depth contact with the design team. It's all covered by Scan's great warranty, which gives three years of both parts and labour coverage, and your first year also includes a collect and return service.

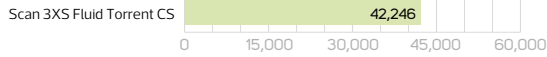
It's all housed in a Fractal Design Torrent, which is a great case, with sleek looks and exceptional build quality. Its top PSU mount keeps the unit out of sight without a shroud, and the chassis serves up a USB Type-C port and two full-sized USB connectors at the front. The six 120mm fans and 140mm exhaust fan all have white RGB LEDs, and that lighting carries over to the rest of the internals. It's all customisable, although there's no denying the monochrome look is clean and stylish.

Around the rear, you'll find impeccable cabling, with a custom Scan backplate hiding more cables, and there's full braiding throughout.

The only practical downside to having all this gear is that the Torrent is cramped inside, making it difficult to access the various internal slots and connectors. Still, those are

BENCHMARK RESULTS

CINEBENCH R23 MULTI-THREADED



92,267

GIMP IMAGE EDITING

DOOM ETERNAL

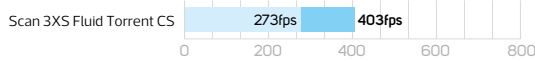
2,560 x 1,440, Vulkan, Ultra Nightmare settings



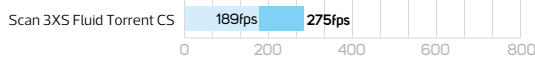
1,512,490

HANDBRAKE H.264 VIDEO ENCODING

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

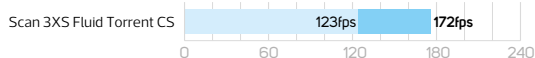


3,840 x 2,160, Vulkan, Ultra Nightmare settings, ray tracing



ASSASSIN'S CREED VALHALLA

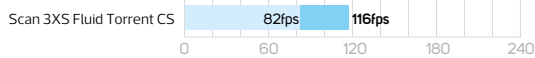
2,560 x 1,440, Ultra High settings, High AA



457,137

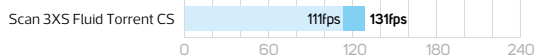
HEAVY MULTI-TASKING

3,840 x 2,160, Ultra High settings, High AA



CYBERPUNK 2077

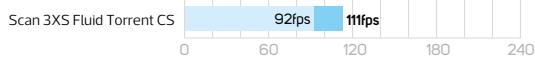
2,560 x 1,440, Ultra preset, no ray tracing



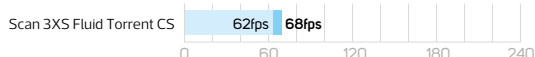
535,403

SYSTEM SCORE

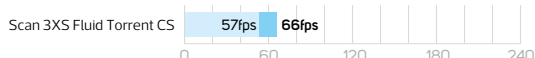
2,560 x 1,440, Ultra ray tracing preset, DLSS Quality



3,840 x 2,160, Ultra preset, no ray tracing

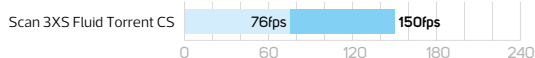


3,840 x 2,160, Ultra ray tracing preset, DLSS Quality

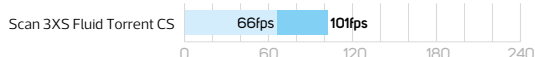


METRO EXODUS

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



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



99th percentile Average

minor quibbles when this PC is equipped with top-end components and won't need upgrading for a long time.

The other big factor, of course, is the price. This CS rig costs £6,899, and even if you ditch the CS extras, it still comes in at £6,299. You're not only spending a lot of money on the top-end components here, but also for the custom water-cooling loop, particularly as the latter extends to the GPU. If you have this sort of money to spend on a PC, though, value is a much lesser concern than getting the best components in an awesome-looking and cool-running setup, and the Scan really delivers here.

PERFORMANCE

Not all the CS pack upgrades are visual, and Scan's tweaks and overlocks paid dividends in benchmarks. The overclocked RTX 4090 is a beast – its 4K average of 116fps in Assassin's Creed Valhalla is 8fps beyond the GPU's result in our standalone review, for example. In Cyberpunk 2077 with Medium ray tracing and Balanced DLSS at 4K, the RTX 4090 averaged 70fps, and it can even play this game with Ultra ray tracing and Quality DLSS enabled.

Of course, when DLSS3 is more widely available, you'll also be able to get huge frame rates in games such as Cyberpunk 2077, thanks to its AI frame-generation tech (see p70). The Scan also averaged 403fps in Doom Eternal at 4K, and this only dropped to 275fps with ray tracing enabled – an amazing result that shows the potential for playing undemanding games at very high frame rates, even with ray tracing.

There's no shortage of processing power either. The overclocked Core i9-13900K rattled through our Handbrake test with a score of 1,512,490, which is more than 100,000 points beyond the CPU in our recent review – it's the best video encoding result we've ever seen.

The Scan's result of 42,246 in the Cinebench R23 multi-core test was also a record-breaker, and its overall RealBench system score of 535,403 tops our charts and outpaces every rival. The SSD helps too: its read and write speeds of 6,817MB/sec and 5,089MB/sec are excellent.

Scan's CPU isn't flawless – the tweaked Core i9-13900K still couldn't overhaul AMD's Ryzen 9 7950X in our image editing test, which stresses single-threaded performance, for example. But the differences are paper-thin, and this processor remains a content creation powerhouse.

Impressively, the Torrent delivered this record-breaking performance without much accompanying fan noise. During gaming tests, the system was quieter than many high-end rigs, and while the fan speeds did occasionally ramp up, the noise was never intrusive. The GPU's delta T of 34°C was superb for such an immensely powerful graphics card.



In a single-core work benchmark the Torrent hardly made any noise and its CPU cores attained their tweaked speed of 6GHz. The Scan's poorest thermal performance came in a multi-threaded work benchmark, but the modulating fan noise was no worse than that on other high-end PCs and not bad enough to prove distracting. The processor's multi-core top speed of 5.7GHz was fine, and its delta T of 64°C is also acceptable.

CONCLUSION

Scan has a hard-won reputation for building incredible high-end PCs, and the Fluid Torrent CS doesn't disappoint. The overclocked GeForce RTX 4090 and Core i9-13900K deliver sensational pace in games and applications, and elsewhere, you get loads of memory, fast storage and a feature-packed motherboard. This PC isn't just about the hardware either. Scan's CS pack delivers improved great performance and looks, and the Torrent shows off superb water-cooling and customisation.

The price is vast, though, and you could get performance levels that approach the Scan's pace from other PCs that cost hundreds of pounds less – albeit without the tweaks and customisations. However, if you're flush with cash and want a personalised, powerful PC for every task imaginable – and for showing off – then there's no denying the quality on offer here.

MIKE JENNINGS

VERDICT

Incredible performance, superb design and fantastic attention to detail, but only if you can afford the sky-high price.

PERFORMANCE

24/25

DESIGN

25/25

HARDWARE

24/25

VALUE

17/25

OVERALL SCORE

90%

Custom kit

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

BEURER TL41 DAYLIGHT THERAPY LAMP / £74 inc VAT

SUPPLIER [argos.co.uk](https://www.argos.co.uk)

The relationship between computers and ostensibly superfluous extra lights is well established, but what if there was an extra light that wasn't actually superfluous? That's the goal of the Beurer TL41, a daylight therapy lamp. That means it attempts to simulate sunlight, in order to counteract the effects of shorter days and longer nights on human psychology, by tricking the body into thinking the sun is shining. What this means in a practical sense is that the Beurer TL41 is an extraordinarily bright lamp.

The Beurer, for all its gentle aesthetics and friendly intentions, hits you like the curtains being flung open on a bright morning. Under ideal operating



conditions, it's supposed to sit within half a metre or so of you, bathing you with light.

In terms of controls, the Beurer TL41 has an 'on' button at the front, that's notably not a switch – the design is too sleek and smart to be defiled by something as overtly functional as that – instead, you have to poke at an indistinct spot on the front of the case until it turns on or off, which feels too clever by half, although it does look spiffy. Results will vary from person to person – for serious bouts of Seasonal Affective Disorder you'll want to see a doctor, but for folks intrigued by the idea of perking themselves up through winter by blasting themselves with an electronic fake sun, the Beurer TL41 is a solid (though very bright) option.

Five lights ●●●●● Four lights ○

HYPERX PULSEFIRE MOUSE MAT / £14.99 inc VAT

SUPPLIER [amazon.co.uk](https://www.amazon.co.uk)

The HyperX Pulsefire is one of those gaming accoutrements that manages to pair a bombastic science fiction-type name with a no-nonsense product. In this instance, the Pulsefire is a plain black mousepad with a fabric surface layer over a rubbery honeycomb grip pattern. The edges are neatly stitched, and the surface is smooth and uncluttered. The lack of flourishes shouldn't be mistaken for a lack of quality, however – the Pulsefire provides a precise, comfortable and very stable surface. The Pulsefires are available in a range of sizes, from the usual 30 x 36cm mat for £14.99 inc VAT, to a sprawling 90 x 42cm model for £34.99 inc VAT.



Epic frippery ●●●●● Job done

KENSINGTON SD5700T DOCKING STATION / £329.99 inc VAT

SUPPLIER [amazon.co.uk](https://www.amazon.co.uk)

This inscrutable metal box does pretty much everything. At the front is a UHS II SD 4 card reader, a USB charging port, a 3.5mm headphone socket and a Thunderbolt 4 port, which you connect to whichever device you want hubbed-up. At the back is the power pack socket, LAN port, three more Thunderbolt 4 ports and three USB 3.2 Gen 2 ports. This makes for a fast USB hub, and its Thunderbolt 4 ports can provide dual 4K or single 8K video output at 60Hz. The power pack also means you can recharge laptops via the connection.

The expansion possibilities are transformative for laptops, while opening up a lot of options for desktops where USB Type-C and Thunderbolt ports are a premium. A sleek generational upgrade on the classic USB hub.



Plugged up ●●●●● Connected

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

CUSTOM PC

MINCE PIE MEGATEST

We apply our demanding testing principles to the latest festive pastry treats to find this year's top mince pie



GREGGS LITTLE GIFTS OF JOY / £1.75 for six

The Greggs mince pie doesn't look like it's trying very hard. It's a shallow, flat, plain pie, and while this is a distinctive look in itself, there's nothing about it that looks promising. Until you eat it. In this case, the proof is in the pie and the pie is good. A strong flavour to the filling, but pleasant with it. The pastry is great, but isn't supplied in an overwhelming amount. There's also a subtle but sweet aftertaste – it's all here. All substance, not so much style, but we're not reviewing pies as table decorations. As an added bonus, they're also vegan-friendly.



ALDI SPECIALLY SELECTED / £1.75 for six

A sizeable pie with a star and snowflake pattern, plus a fruity, pudding-like filling. There's a good texture to it all as well, and a little sprinkle of sugar on top helps, although there is some blandness to the pastry. It doesn't stray so far as to be bad, but it's also not wowing anybody with its masterful baked goodness. In a year where the average pie is a pretty good pie, the Aldi Specially Selected Mince Pie makes its way comfortably into the pack, although it begs the question of what happened to the pies that didn't get selected.



M&S CLASSIC ALL BUTTER / £2 for six

A star-shaped vent surrounded by holly and sprinkled with sugar is a curious decoration, inviting the kind of juvenile humour that we're not going to indulge today. Oh no. No butt-hole jokes today. Even if some pie designs clearly present themselves for it. The M&S Classic All Butter is a fairly decent offering. There's buttery pastry, as advertised, although in our pack, it's a little dry and darker than the picture on the packaging, almost but not quite to the point of burned. There's an agreeable filling too, although it's nothing fancy. Even with its flaws, this is a reasonable feed.



ASDA EXTRA SPECIAL LUXURY / £2.25 for six

A big and well-constructed pie. The ASDA Extra Special Luxury does everything by the numbers from the first bite. The pastry has a good taste to it – it's on the dry side, but that's only noticeable because everything else feels like it's exactly how it should be. There's a citrusy edge to the filling, but it's not too severe – it's well balanced with the rest of the chunky fruit. A great all-round contender.



Taste testers: Antony Leather, Ben Hardwidge, Mike Jennings and Phil Hartup **Reviews:** Phil Hartup



TESCO FINEST CRUMBLE TOPPED / £2.25 for six

These rather small pies share a similar design with the Waitrose Heston oddities, but Tesco seems to have pitched its design at a more conventionally Christmassy approach. As much as the top is crumbly and sugary, and the base is thick and biscuity, it's still recognisably a mince pie once you're munching on it, with a light boozy flavour to the filling and a sticky consistency. The flavours don't quite mesh as well as they might, tending towards cancelling each other out, but it is still an interesting take on a mince pie, even if it doesn't quite nail it.



WAITROSE ALL BUTTER / £2.25 for six

Underneath this neat little star-and-snowflake combo decoration, plus a sprinkling of sugar, sits an extremely good pie. The pastry is yielding, but not mushy, and tastes satisfyingly buttery, while the filling is chunky, and sweet with clear undertones of citrus that linger, and are welcome to do so. The Waitrose All Butter hits all the right notes, right across the board.



TESCO / £1.09 for six

Tesco's standard pie is a sad-looking effort with a rather slapdash construction. Unfortunately, the presentation is indicative of what's to come, with bland, crumbly pastry that feels like it takes too much effort to chew. There's an opportunity for the right filling to save the day, but that doesn't happen. It has a strong flavour – you can't miss it – but it isn't the right flavour. It's worth paying slightly more for better pies.



SIMMONS LUXURY MINCE PIE / £3.95 for six

It seems so simple. A big, tall, solidly constructed pie with great pastry and a delicious filling. It's visually so on point that it looks almost like a cartoon of a mince pie, from an encyclopaedia or a flashcard teaching about Christmas snacks. The Simmons Luxury Mince Pie is bafflingly good, to the extent that you wonder what this Hertfordshire bakery's secret is, or what everybody else is up to in the ten months of the year that they too could have been perfecting their pies.

The drawbacks are the price and relative scarcity – Simmons is a bakery chain that's local to Hertfordshire and the surrounding area, but you can't get them anywhere else. That's brilliant if you're Antony, who brought these pies into the office, but it's rubbish if you live anywhere else (which includes the rest of the tasting panel). If you have a local Simmons, though, you'll want to grab these pies.



ASDA EXTRA SPECIAL LUXURY SPICED RUM / £2.25 for six

This hearty-looking pie is decorated with an attractive lid of overlapping stars and icing sugar, and it's assembled solidly out of fine tasty pastry. With this pie, however, it's what's inside that counts, and what's inside tastes of rum. This is so rummy. Rum for days. Rum for nights. Rum for the hills. You've never tasted so much spiced rum, short of actually taking a hefty swig from the bottle. This is formidable stuff.

Where it gets into trouble with the judges is that, even those who like spiced rum don't want almost the entirety of a minced pie barring the outer edge of the crust to taste like it. Everything is overwhelmed. It's not unpleasant, and it's not rum in a bad way, but it's still very, very rum.





M&S COLLECTION / £3 for six

M&S has opted for a Christmas shuriken as its Collection pie decoration this year, an oft underappreciated festive favourite. The innovations continue throughout the pie, such as the surprising choice to make the pastry so very, very dry. That can't have been accidental. The flavour is good in spite of this, although the general consistency isn't helped by the dryness of the pastry. It still manages to be quite good overall, just a little wayward.



MR KIPLING DEEP FILLED / £1.85 for six

The Mr Kipling pie leads with a slightly bland pastry, and unfortunately that's kind of the overwhelming theme here – there's just so much of it. You're working your way through this bland pastry, helped a little on the first bite with a sprinkle of sugar but if you're baking a pie this reliant on sugar for the pastry flavour then you've messed up somewhere. The filling is present, but its flavour isn't strong enough to fight its way out of its weighted pastry blanket.



MORRISONS THE BEST / £2.25 for six

This pie has a slightly uneven assembly with a double star-shaped lid that doesn't quite hold it all together. It's fairly insubstantial and the pastry isn't particularly interesting, although the filling then punches into your taste buds with some nice boozy notes and a pleasant lingering aftertaste, dragging the whole pie up to the good side of average. Calling these pies 'The Best' might not be entirely accurate, but they turned out okay.



WAITROSE HESTON SPICED WITH A LEMON TWIST / £3.50 for four

The weird and wide Waitrose Heston returns to see if the world is ready for a big circular lemony beast for its Yule snacking pleasure, and it turns out that the answer is no. The Heston rolls in with a biscuity base, a crumbly lemony top layer and a spicy citrusy filling. It's all very well executed, but where is it trying to go?

The crumble mince pie is a rare specimen, not completely unique this year, but leaning so heavily on the lemons doesn't feel quite as Christmassy as the judges would prefer. You only get four in a box, but they are big units. More of a case of the wrong pie in the wrong holiday, but it's not without its charms. That said, previous tasting panels have loved this pie, and it's really down to a matter of taste rather than poor execution. If you want a mince pie, then go elsewhere, but if a crumbly round biscuit with a lemony taste sounds like your thing, then you'll like these.



SAINSBURY'S TASTE THE DIFFERENCE BRANDY INFUSED / £2.25 for six

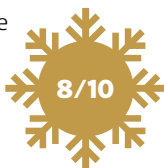
These large, brandy-infused lumps manage to deliver both a decent buttery pastry, sprinkled with a light dusting of sugar, and an enjoyable filling that marries fruit flavours with the titular brandy infusion. The filling has a good amount of chunkiness to it – there can be a tendency for some pies to have the filling blended down almost to a paste, but this one brings the lumps. It doesn't quite come together as well as some pies on test this year, but it's very pleasant nonetheless.





WAITROSE BROWN BUTTER WITH COGNAC / £2.25 for six

This large, understated pie has a light dusting of sugar. The pastry is fragile, though tasty, but the main event is the filling. It has such a rich flavour of cognac that you could eat one of these while assembling murder suspects in a drawing room. If you have an aversion to cognac, this pie is a bad idea, but if you like it, the taste is very well delivered here. It's perhaps a little overpowering, but it's good.



MORRISONS / £1.25 for six

This small, snowflake-bedecked pie has a sprinkle of sugar and a slightly wonky construction, evoking a look of either 'home-made' or 'slapdash industrial process' depending on how well disposed you feel. In this instance, nobody was feeling particularly well disposed. The flavours hit strangely, with an artificial over-egged vibe, as though a stronger flavour might cover for an imperfect one. The overall result is a less than pleasant taste and aftertaste. Less is more, and sometimes none is best.



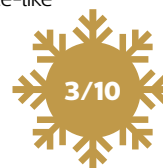
ALDI HOLLY LANE DEEP FILLED / £1.39 for six

A snowflake-patterned pie with a very light dusting of sugar suggests a confidence in this pie's flavour. Sadly, though, the pastry is tasteless and takes a long time to chew. There's some filling in there, and it's not all bad – you can get hints of something better while munching the pastry into submission, but that's hardly a ringing endorsement. This was a properly rough one.



M&S JOYOUS LATTICE / £2 for six

The first bite is with the eye, and in this regard the M&S Joyous Lattice Mince Pies are exceptional – they look great, the latticework is neat and tidily cut, and the presentation is immaculate. It all takes a turn for the worse when you eat them, though, which is about as fundamental a disappointment as you can fit in a pie. Despite the lattice-like nature of the lid, there just feels like there's so much pastry here, and so little filling relative to it. The pastry is bland and has a grainy consistency that turns to a muddy one while you chew. What hints of the filling you can get aren't enough to mitigate the mess.



CO-OP IRRESISTIBLE ALL BUTTER / £2.25 for six

The presentation here isn't bad – there's an effort made with the double star and sprinkle of icing sugar, which makes the general off-kilter appearance look a shade more palatable. The texture is a little wide of the mark though – the pie is squishy and a little bland, although the flavours, when they come together, are where they ought to be. The pastry is a little sad, and the filling could do with a little more chunkiness. Overall, though, while this pie is might not be irresistible, it definitely isn't bad. **CPC**



How we test

MOTHERBOARDS

TEST PROCESSORS

- **AMD AM5** AMD Ryzen 9 7950X
- **Intel LGA1700** Intel Core i9-13900K

We use a GeForce RTX 3070, plus a WD Black SN850 SSD (LGA1700) or Kingston Renegade SSD (AM5) to test the speed of M.2 ports and heatsink performance. For memory, we use 16GB of Corsair 3466MHz Vengeance RGB Pro DDR4 RAM, 32GB of Kingston 6000MHz Fury Beast DDR5 RAM (LGA1700) or 32GB of G.Skill Trident Z Neo EXPO RAM (AM5).

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 6 on Windows 11. We test each board's M.2 ports with CrystalDiskMark, and record the noise level and dynamic range of integrated audio using RightMark Audio Analyzer.



MONITORS

We test image quality with an X-Rite iDisplay Pro colorimeter and DisplayCal software to check 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 response time with an Open Source Response Time Tester, and use Blur Busters' ghosting UFO test to check the sharpness of a display in high-speed motion.



PROCESSORS

TEST MOTHERBOARDS

- **AMD AM5** ASRock X670E Taichi
- **Intel LGA1700** Asus ROG Maximus Z790 Hero

We use a GeForce RTX 3070, plus a Samsung 970 Evo SSD (LGA1700) or Kingston Renegade SSD (AM5). We use 32GB of Kingston Fury Beast 6000MHz DDR5 RAM (LGA1700) or 32GB of G.Skill Trident Z Neo EXPO RAM (AM5). The CPU is cooled by a Corsair Hydro-X water-cooling loop, with two XR5 240mm radiators, an XD3 RGB reservoir and an XC7 RGB waterblock.

We use the latest version of Windows 11 with security updates, plus the latest BIOS versions and drivers. We record results at stock and overclocked speeds, and tests include our RealBench suite, Cinebench, Far Cry 6 and Watch Dogs: Legion.

For games, we record the 99th percentile and average frame rates either using the game's built-in benchmark or Nvidia FrameView. Finally, we note the idle and load power draw of the whole system, using Prime95's smallfft test with AVX disabled.



CPU COOLERS

We use CoreTemp to measure the CPU temperature, before subtracting the ambient air temperature from this figure to give us a delta T result, which enables us to test in a lab that isn't temperature controlled. We use Prime95's smallest FFT test with AVX instructions disabled to load the CPU and take the temperature reading after ten minutes.

For the Intel LGA1200 system, we take an average reading across all eight cores, and for the LGA1700 system, we take an average reading across both the P-Cores and E-Cores. AMD's CPUs only report a single temperature reading, rather than per-core readings, so we list what's reported in Core Temp.

TEST KIT

Fractal Design Meshify C case, 16GB of Corsair Vengeance RGB Pro memory, 256GB Samsung 960 Evo SSD, Corsair CM550 PSU.

INTEL LGA1700

Intel Core i9-12900K at stock speed, Asus ROG Maximus Z690 Apex motherboard.

INTEL LGA1200

Intel Core i9-11900K at stock speed with Adaptive Boost enabled, MSI MEG Z590 Ace motherboard.

AMD AM4

Ryzen 7 5800X overclocked to 4.6GHz with 1.25V vcore, or Ryzen 5 5600X overclocked to 4.6GHz with 1.25V vcore on low-profile coolers, MSI MEG X570 Unify 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 at 1,920 x 1,080, 2,560 x 1,440 and 3,840 x 2,160, using an AOC U28G2XU monitor.



TEST KIT

AMD Ryzen 9 5900X, 16GB (2 x 8GB) of Corsair Vengeance RGB Pro SL 3600MHz DDR4 memory, Asus ROG Strix B550-E Gaming motherboard, Thermaltake Floe Riing 240 CPU cooler, Corsair RM850 PSU, Cooler Master MasterCase H500M case, AOC U28G2XU monitor, Windows 11 Professional 64-bit.

GAME TESTS

Cyberpunk 2077 Tested at the Ultra quality preset and Medium ray tracing preset if the GPU supports it. We run a custom benchmark involving a 60-minute repeatable drive around Night City, and record the 99th percentile and average frame rates from Nvidia FrameView.

Assassin's Creed Valhalla Tested at Ultra High settings with resolution scaling set to 100 per cent. We run the game's built-in benchmark, and record the 99th percentile and average frame rates with Nvidia FrameView.

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 Nvidia FrameView. This test requires a minimum of 8GB of graphics card memory to run, so it can't be run on 6GB cards.

Metro Exodus Tested at Ultra settings with no ray tracing and both Advanced PhysX and HairWorks disabled. We then test it again with High ray tracing if the GPU supports it. We run the game's built-in benchmark, and report the 99th percentile and average frame rates.

POWER CONSUMPTION

We run Metro Exodus at Ultra settings with High ray tracing at 2,560 x 1,440, and measure the power consumption of our whole graphics test rig at the mains, recording the peak power draw.



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.

Advertisement feature

PC BUILDING SIMULATOR 2 / £19.99 inc VAT

DEVELOPER Spiral House Ltd / PUBLISHER Epic Games Publishing

Costing just £20, PC Building Simulator 2 gives you an affordable, fun way to play with all the hardware you've seen in these pages or further afield. It's also a useful way to learn how to build a PC and what goes where, as well as to see how your PC will look.

The new game improves over the original in a number of ways too. For starters, there's definitely an added sense of visual prowess and realism to the components. The features don't just include more PC components either, as you can enter the EFIs of completed PCs, overclock them, stress-test them and

Use a thermal imaging camera to see whether your PC is overheating

even alter memory timings. Want to practise entering the EFI for some overclocking using the Del key? Well, you can do just that here without fear of messing up anything.

A new career

The build process is accurate down to small details, such as removing side panel screws and expansion slot covers. If you head to Career mode, the game will actually take you through these motions and the process of building a whole PC, along with a role-playing game where you run a PC shop.

You receive emails from customers asking for their PCs to be rid of viruses, upgraded or even spray-painted, all the while you're

aiming to keep an ailing PC repair shop afloat and earn money, learning useful PC building and troubleshooting tips in the process. It's an interesting dynamic that helps to lessen the learning curve of not only building a PC, but also how to use the simulator.

Some parts are deliberately repetitive, such as removing individual screws or case components, or connecting individual cables. There's method to this, though, as it means you see where those cables go, and even use the game as a guide, as you can clearly make out different port and cable types.

Thousands of component choices

Switching to the Free Build mode gives you the ability to pick from thousands of component combinations, and the scale of the database of rendered items is staggering. There are graphics cards of all shapes and sizes, CPUs, motherboards and cases of all popular form factors, along with storage

You can bend the rigid tubing an infinite number of times until you get it just right





You can enter the EFI to try overclocking your system without fear of messing up anything

devices, PSUs and even waterblocks, custom cables and fans.

There's everything you need to pick your dream bunch of hardware and then see how it looks when it's all assembled. What's more, as the products are based on actual parts, you're able to see how your chosen graphics card will look in a certain case, whether it fits, and even choose between vertical and horizontal mounts with compatible cases.

Plan your loop

You can delve into even greater depths too, such as creating your own water-cooled PC with rigid tubing. You can bend the tubing an infinite number of times until you get it just right, with the benefit of seeing what looks best when your virtual PC is powered on. As rigid tubing is expensive, this is a very useful feature for planning a water-cooled build.

With this latest edition, there's an added sense of visual prowess and realism to the components



You get custom benches from which to work as well. If you want to mod your PC with vinyl stickers and spray paints, you'll want the modding table, with water cooling and standard work bench options too. If only we all had this much space at home.

Use your virtual rig

One feature we found extremely useful was the ability to test and use the PC you've built. You can enter its virtual OS, install programs such as Cinebench and 3DMark. You can even run fan-control software including fan curves with which you can tinker, then use a thermal imaging camera to see how it performs.

The idea is that if you build a PC and don't add enough fans, or install them incorrectly, the camera will show your PC getting hot. The data is simulated rather than obtained from a nightmarish task of testing thousands of component combinations. However, the



Play at running a computer shop to get used to the PC building process

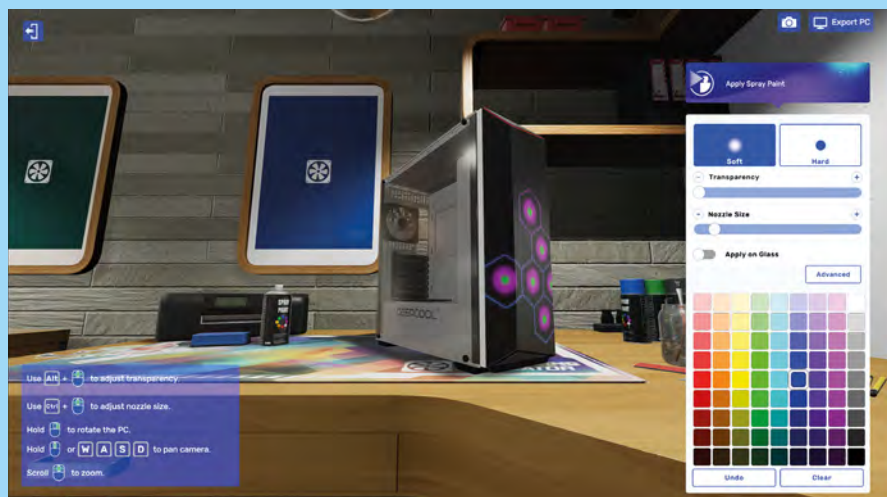
data from benchmarks is based on real-world data for those components. The PC will even blue screen too, which doesn't sound like a fun gaming feature, but again, it's designed to emphasise components overheating and teach you about the quirks that seasoned PC enthusiasts know how to avoid.

Adding a couple more case fans or using a bigger CPU cooler, for example, can show real-time improvements, so it's not just checking compatibility between components, it's making sure the physics are working too.

Whether you're a seasoned pro, or if you've never touched a piece of PC hardware, there's something for everyone here – planning your water-cooling loop, working out how to get into your motherboard's EFI and taking those first steps in setting up your own PC.

The free 1.1 Update for PC Building Simulator 2 also launches on 7 December, bringing support for the GeForce RTX 4090, AMD Ryzen 7000-series CPUs, Intel ARC and Raptor Lake, plus much, much more. The game is more detailed, dynamic and useful than the original, and it's available from the Epic Games Store (store.epicgames.com) for £19.99 inc VAT.

Head to the modding table if you want to mod your PC with vinyl stickers and spray paints



LABS TEST

32in gaming monitors

If you're after some big-screen gaming fun, but don't have the GPU grunt to play games at 4K, 2,560 x 1,440 32in displays are the way to go. Edward Chester puts six to the test

How we test

Not all of us need ultrasharp monitors with a high pixel density. Sometimes it's just fun or indeed necessary to have a massive screen with a more modest resolution. As such, while 32in 4K screens might be the ultimate option for many users, a 32in panel with a 2,560 x 1,440 resolution is an ideal choice for many of us. It certainly helps that they're generally cheaper than 4K equivalents, and you also need much less GPU power if you want to run games at your screen's native resolution.

We've grabbed six of the latest models, which range in price from just over £300 inc VAT to nearly £700 inc VAT. For that sort of cash, you get the latest features, such as USB Type-C video input for easy connection of laptops and other mobile devices, high colour gamut panels that can deliver the colour range (if not the contrast) of HDR and one panel even has a remote control.

To test the monitors, we first looked at the design, build quality and other physical features, including aspects such as ergonomics and connection options. We then assess image quality using a combination of subjective tests for viewing angles and gaming performance, as well as objective testing for image quality using an X-Rite iDisplay Pro colorimeter, checking for colour balance, gamma and native contrast.

Next, we enable HDR to see what difference this makes to the overall viewing experience. We subjectively observe the difference, as well as testing for maximum brightness and contrast using the DisplayHDR Test app.

Finally, we run our response time tests, using the OSRTT tester and software. This measures the speed of the change of colour of the panel, giving a real-world measure of how fast the panel responds.

Contents

- Cooler Master GM32-FQ / p49
- Corsair Xeneon 32QHD165 / p50
- Dell G3223D / p51
- iiyama G-Master GB3271QSU / p52
- MSI Optix MPG321QRF-QD / p53
- Philips Momentum 5000 32M1N5500VS / p54
- Results graphs / p55

COOLER MASTER GM32-FQ / £365 inc VAT

SUPPLIER box.co.uk

Despite being billed as a display that balances work and play, the GM32-FQ still boasts a 165Hz refresh rate, adaptive sync support and a backlight strobing blur reduction mode, so there's plenty to keep fast-twitch gamers interested.

It's also incredibly thin. With a full view of the back, you can plainly see the thick lower middle section that holds all the connections and other paraphernalia, but from any front angle, this display cuts a sleek figure. Not surprisingly, this slimness results in the worst backlight uniformity on test, with notable drops in brightness in the top corners, but it's still not so bad as to be a major concern for users of this type of panel – it's not a professional image editing display.

It also has a slim stand and a dainty base, although it's a little wobbly. However, the stand amazingly still manages to offer height, rotation and tilt adjustment, which is

impressive for its size. Connections are similar to the other panels on test, with the addition of a USB Type-C video input for connecting laptops or other mobile devices that support DisplayPort Alt mode over USB.

The two USB 3 ports can also be shared with devices connected to the Type-C port and the display will provide up to 15W of power to connected devices. Enabling a full single-cable system for your laptop, the display even has speakers, but they're so weedy that your laptop's speakers might be better anyway.

A column of buttons down the right rear of the panel controls the menus, although sometimes options feel like they're not in the place you expect and the buttons are less intuitive than a mini joystick. All the options you need are included though.

Meanwhile, the display itself uses an IPS panel so viewing angles and image stability are excellent. Contrast is also notably a little higher than some IPS panels, giving the image slightly more depth than lower-contrast models.

This is also a high colour gamut display that stretches to 95 per cent of the DCI-P3 colour space, or 130 per cent of the sRGB space. That's not quite as massive a colour range as the likes of the Corsair 32QHD165, but it's still enough to technically meet most HDR colour requirements. There's also an sRGB mode with adjustable brightness, if you need or like to limit the colour range.

The Cooler Master's maximum brightness of 370cd/m² isn't all that high but adequate for any non-HDR use. Out-of-the-box colour accuracy is also impressive, with very good colour balance and decent gamma.

As for gaming, adaptive sync means tearing and stuttering are eliminated with modern AMD and Nvidia graphics cards. Turn this off and you can also enable a backlight-strobing



SLIMLINE

- + Excellent image quality
- + Impressively slim
- + USB Type-C video input

DRAW THE LINE

- Wobbly stand
- Sluggish response time
- Disappointing panel uniformity

blur reduction mode that tightens up the in-motion sharpness of the panel even further.

However, the response times are a little sluggish. At its lowest overdrive setting, the average of nearly 12ms is very slow for a 165Hz IPS panel. Even at maximum overdrive, the panel only manages 8.3ms, which is nearly double that of some other panels on test. The gaming experience is still decent, but other IPS panels are notably snappier.

Conclusion

With its low price, decent all-round image quality and USB Type-C connection, the GM32-FQ is a solid option. Its response time is a little sluggish, though, so those seeking a panel that errs more towards gaming responsiveness will be better off elsewhere.

VERDICT

Its response time is a little sluggish, but it's otherwise a great-value all-rounder.

IMAGE QUALITY

26/30

FEATURES
16/20

GAMING

18/30

VALUE
18/20

OVERALL SCORE

78%

SPEC

Screen size 32in

Resolution 2,560 x 1,440

Panel technology IPS

Maximum refresh rate 165Hz

Stated response time 1ms MPRT

Max brightness 400cd/m² SDR and HDR

Backlight zones 1

Stated contrast ratio 1,200:1

Adaptive sync FreeSync Premium, G-Sync compatible

Display inputs 1x DisplayPort 1.4, 2x HDMI 2, 1x USB Type-C

Audio 2 x 2W speakers, headphone out

Stand adjustment Height, rotation, tilt

HDR certification DisplayHDR 400

Extras 100 x 100mm VESA mount, HDMI, DisplayPort and USB Type-C cables, 2-port USB 3 Type-A hub

CORSAIR XENEON 32QH165 / £550 inc VAT

SUPPLIER scan.co.uk

One factor that's immediately obvious with this display is the chunkiness of its base. Several of the displays on test are quite hefty – most notably, the very weighty iiyama – so they have quite sizeable stands too. However, the Corsair's base dwarves them all. It measures a massive 47cm wide and 33cm deep, compared to around 30 x 25cm for the other displays on test. The stem of the stand is also a wide piece of extruded aluminium.

The overall effect, particularly of the aluminium stem, is of a more premium finish than most of the other displays. However, it's not enough of a difference to really sell the design and the base is genuinely impractical. It doesn't offer extras, such as the pivot function of the iiyama, although it has height, rotation and tilt functions.

The Corsair goes some way to justifying its premium price thanks to the inclusion

of a USB Type-C video input. Its USB hub can also be used to pass keyboard and mouse functions back through to your laptop. There's a headphone jack as well, but no speakers. The USB Type-C socket will provide 15W of power as well, which is enough to charge phones and tablets but not large, powerful laptops.

Other connection options consist of a single DisplayPort input and two HDMI ports, while the rear is home to just the two USB ports, with no extras on the sides for easy access. The menu control sits on the rear right of the panel. It's a single mini joystick that offers precise, snappy control. There are no obvious omissions in the menus, and it's easy to get the display set up as desired.

The screen uses an IPS panel and has the glossiest finish of the panels on test – it's still semi-matt but the finish isn't as coarse as some others, which gives an immediate depth to darker scenes. Thanks to its quantum dot colour filters, resulting in a massive 116 per cent DCI-P3 (165 per cent sRGB) colour space coverage, this panel's colours are truly dazzling. An sRGB mode is on hand to dial this back, though, if needed.

Out-of-the-box image quality is iffy, with pretty poor colour balance. Switching to the custom colour mode makes this even worse, requiring a hefty shift from 100 x 100 x 100 RGB to 100 x 91 x 91 to get an accurate colour balance. With that tweak made, though, this panel offers excellent image quality. Gamma, delta E colour accuracy and contrast are all decent, as is maximum brightness.



HDR benefits from the massive colour range, but with no way to boost the panel's contrast, HDR content lacks the actual dynamic range that's so important for it to make a big impact.

As for gaming performance, this panel isn't the fastest but is certainly up there with the faster models on test and it feels snappy. Adaptive sync is supported on both AMD and Nvidia GPUs and it works as well as expected. You'll have to turn it off to access the panel's backlight strobing blur reduction mode though. This mode works well to increase sharpness with fast motion, but reduces the brightness to just 122cd/m².

Conclusion

The Corsair Xeneon 32QHD165 does a decent job across the board, with a smart design, good image quality, USB Type-C support and decent gaming performance. Its stand is a bit chunky, though, and its price is high considering its main extra feature is just a slightly wider colour gamut than other non-quantum dot panels.

VERDICT

A solid performer, but too pricey and chunky.

SPEC

Screen size 32in

Resolution 2,560 x 1,440

Panel technology IPS

Maximum refresh rate 165Hz

Stated response time 1ms MPRT

Max brightness 400cd/m² SDR, 440cd/m² HDR

Backlight zones 1

Stated contrast ratio 1,000:1

Adaptive sync FreeSync Premium, G-Sync compatible

Display inputs 1x DisplayPort 1.4, 2x HDMI 2, 1x USB Type-C

Audio Headphone out

Stand adjustment Height, rotation, tilt

HDR certification DisplayHDR 400

Extras 100 x 100mm VESA mount, HDMI, DisplayPort and USB Type-C cables, 2-port USB 3 Type-A hub

HEAVY WEIGHT

- + Excellent image quality
- + Good gaming performance
- + USB Type-C video input

WEIGHING YOU DOWN

- Chunky stand
- High price

IMAGE QUALITY

24/30

FEATURES
16/20

GAMING

22/30

VALUE
13/20

OVERALL SCORE

75%

DELL G3223D

/ £350 inc VAT

SUPPLIER dell.com

This Dell monitor is notably smart, with its simple silver stand design, plain black frame and subtly integrated RGB lighting on the back of the screen, which can of course also be turned off. There's a premium feel to the plastics too – this doesn't feel like a cheap, utilitarian model. The included stand offers height, rotation and tilt adjustment, but not pivot, and it can be removed to reveal a standard 100 x 100mm VESA mount for use with monitor arms.

DELICIOUS

- + Excellent image quality
- + Useful USB Type-C video input
- + Solid gaming performance

DELLUSIONAL

- Slightly low contrast ratio
- No backlight strobing blur reduction

SPEC

Screen size 32in

Resolution 2,560 x 1,440

Panel technology IPS

Maximum refresh rate 165Hz

Stated response time 1ms GTG

Max brightness 400cd/m² SDR and HDR

Backlight zones 1

Stated contrast ratio 1,100:1

Adaptive sync FreeSync Premium Pro, G-Sync compatible

Display inputs 1x DisplayPort 1.4, 2x HDMI 2, USB Type-C DisplayPort 1.4 Alt mode

Audio Headphone out

Stand adjustment Height, rotation, tilt

HDR certification DisplayHDR 400

Extras 100 x 100mm VESA mount, USB Type-C upstream port with one USB 3 charging port and one USB 3.2 gen 1 downstream port, rear RGB lighting, DisplayPort and USB Type-C cables

For connection options, you get the standard single DisplayPort 1.4 and two HDMI 2 ports, which are joined by a USB Type-C input. This can be used to output video and audio to a connected laptop, phone or tablet, and supply power. However, it can only provide 15W of power, which is insufficient to provide any charging ability to our Dell XPS 15 test laptop, for instance. All those connections are positioned on the rear centre of the panel, facing down.

You also get two USB ports and a headphone jack positioned to the far left on the underside of the frame. If you choose to connect your keyboard and mouse via these ports, though, the cables are very visibly dangling from the side of the screen.

Any device connected to the USB ports and headphone jack will also be connected to any connected USB Type-C devices, so you can use your keyboard and mouse on your laptop via a single cable. It's a shame the monitor has no speakers, though, as this would make for a truly all-in-one desktop setup.

Meanwhile, the menus are controlled by a mini joystick and there are four extra quick menu buttons, which seem rather unnecessary when you already have the joystick. Otherwise, the menus are mostly easy to navigate with no obvious feature omissions.

The G3223D has the same core panel specs as most of the other displays on test, with its IPS panel maxing out at 165Hz. The panel's surface has a (very) matt finish that, when combined with the panel's inherently modest contrast of 830:1, makes for an image that while far from washed out isn't quite as punchy as some of the other panels on test.

Otherwise, image quality is very good, with a decently accurate colour balance, near-perfect gamma and on-par delta E colour accuracy



right out of the box. The colour range of this display is extended to 95 DCI-P3, providing HDR-like colour vibrancy, though reproduction of HDR content isn't up to much with such a modest contrast ratio. An sRGB mode is also on hand to reduce the colour gamut to 100 per cent sRGB. This locks out some colour settings but allows you to adjust brightness and provides accurate image quality.

When it comes to gaming, this display doesn't take top marks but puts in a good showing. It has FreeSync and G-Sync support, and its response time is nippy, accounting for overshoot with the perceived response time score. The only downside is the lack of a backlight strobing blur reduction mode.

Conclusion

A stylish design, useful feature set, great image quality and solid gaming performance make the Dell an excellent, low-cost 32in gaming screen. It's not the absolute fastest, and its contrast is a little low, but these considerations are balanced by its affordability.

VERDICT

Slightly low on contrast and lacking a blur reduction mode, but this is otherwise a great screen for the price.

IMAGE QUALITY

26/30

FEATURES
16/20

GAMING

24/30

VALUE
18/20

OVERALL SCORE

84%

Iiyama G-MASTER GB3271QSU / £320 inc VAT

SUPPLIER scan.co.uk

Among the cheapest panels on test this month, the iiyama G-Master GB3271QSU wants for nothing in terms of core specs, and even includes a remote control, but it's also lacking in a few key areas.

For starters, while it looks smart enough, it still looks a bit boxy and lacks a certain finesse. The Philips is just as squared off but has a smarter appearance. However, this display does include a feature not found on any of the other panels on test, which is a stand that can pivot the display into a portrait mode. Not only can this be genuinely useful in and of itself, but it also makes accessing the ports at the back much easier.

The stand also offers height, rotation and tilt adjustment, and a VESA mount is included too. The stand also has a very heavy base (making up 11.3kg of the screen's total weight), which keeps the iiyama in place, but can cause the stand to swing around

when you're carrying or setting up the monitor, so watch it doesn't swing and clobber you.

The iiyama is one of only two panels on test not to offer USB Type-C video input, but you do get an extra DisplayPort input instead. There's also a 4-port USB 3 hub, with two ports on the back and two on the side, which are tucked out the way so cables don't visibly sprout from the side of the panel. Speakers are included too, along with a headphone jack, although they sound weedy. For any purpose other than very low volume listening, they're too shrill to be usable.

As for that remote control, its receiver sits just below the iiyama logo on the bottom bezel and it can be used to quickly select input, control volume and brightness, power off the display and switch between image profiles. It's a handy addition that makes up for the slightly clunky multi-button menu control system on the rear of the panel.

The panel itself is a bit of a mixed bag. If you're seeking a high-gamut, HDR-like colour experience, this display isn't for you. It reaches just 105 per cent of the sRGB colour space, so HDR simply isn't an option. Not that colours look washed out – indeed, this panel delivers the best contrast of all the IPS monitors in this test, reaching a ratio of 1,152:1. There's just not that extra zing to bright colours.

More importantly, though, this display just looks a bit fuzzy. We couldn't put our finger on the exact culprit, other than suspecting the very matt screen finish was to blame, but the result is a hint of graininess to the image.

We also found that, despite table-topping response time results, this panel felt sluggish in action. All the other IPS panels on test felt sharper and more responsive in games. It's by no means terrible but its raw numbers



MASTERFUL

- + Remote control for menus
- + Class-leading response time
- + High contrast for IPS

MASTER'S FULL

- Fuzzy-looking image
- Gaming feels sluggish
- No high colour gamut mode

don't tell the whole story. Adaptive sync is included to eliminate tearing and stutter, and if you turn this off you can turn on a backlight strobing blur reduction mode. This helped, but it didn't revolutionise this display's gaming performance.

Conclusion

A great price, a handy remote and a pivot function are all notable plus points with this display, plus its contrast is excellent. However, its display lacks a little sharpness compared to the other IPS panels on test, and it doesn't feel as fast in action as its response time results suggest.

VERDICT

A good-value display but it's not without its quirks.

IMAGE QUALITY

20/30

FEATURES
18/20

GAMING

20/30

VALUE
16/20

OVERALL SCORE

74%

SPEC

Screen size 32in

Resolution 2,560 x 1,440

Panel technology IPS

Maximum refresh rate 165Hz

Stated response time 1ms MPRT

Max brightness 400cd/m² SDR, 440cd/m² HDR

Backlight zones 1

Stated contrast ratio 1,200:1

Adaptive sync FreeSync Premium, G-Sync compatible

Display inputs 2 x DisplayPort 1.2, 2 x HDMI 2

Audio 2 x 2W speakers, headphone out

Stand adjustment Height, rotation, tilt

Extras 100 x 100mm VESA mount, remote control, 4-port USB 3 hub

MSI MAG OPTIX MPG321QRF-QD

/ **£700** inc VAT

SUPPLIER [amazon.co.uk](https://www.amazon.co.uk)

The MSI MPG321QRF-QD is surprisingly expensive, and while it has a 175Hz refresh rate and USB Type-C video input, it's not immediately obvious why it's nearly twice the price of its competitors. Its all-black livery is neat enough, but there are no obviously premium touches, other than a fairly subtle slash of RGB lighting on the panel's rear.

The panel is surprisingly thick, with sides measuring 1in deep, and a middle section that rises to around 3in deep. Some of this thickness is down to the inclusion of two USB 3 ports on the left edge, joined by microphone and headphone jack sockets, but there are no speakers, let alone ones that justify the bulk. Meanwhile, the stand is simple but sturdy, and offers height, rotation and tilt adjustment but no pivot option.

A subtle but welcome addition is that the power button on the bottom right edge is also the power indicator. The button is also large,

so it's easy to pick out. The menus, meanwhile, are controlled by a single mini joystick on the back right of the panel. It's a responsive control with well-defined clicks for each direction and central press.

The menus themselves offer a reasonably comprehensive selection, and we like the inclusion of resolution, refresh rate, HDR, adaptive sync and input status at the top of menus. One crucial missing feature, though, is any sort of sRGB mode for restricting the panel's otherwise very high colour range.

For video connections, you get a single DisplayPort input and two HDMI ports, along with USB Type-C input. Like the other panels with the latter, this connection will charge low-power devices such as phones but not beefier laptops. Alongside the USB Type-C input on the rear is the USB hub input and two further USB 3 inputs that will share devices with the Type-C port, basically giving you a KVM setup.

The MSI's IPS panel boasts a standard 165Hz refresh rate that's overclockable to 175Hz. Thanks to its use of quantum dot colour filters, it boasts a massive 120 per cent DCI-P3 (170 per cent of the sRGB space) colour space coverage and DisplayHDR 600 rating. This makes for a ludicrously dazzling display with ultra-vibrant colours that, as highlighted earlier, you can't turn down with an sRGB mode.

HDR is otherwise middling, as there's no multi-zone backlight to boost the real-world contrast ratio of 953:1. Out-of-the-box image



quality is good in terms of colour balance, but switching to the User colour mode to fine-tune the display results in a huge loss of contrast.

As for gaming performance, this is where this panel excels. Although the Dell and iiyama pip it to the post for perceived response time (before you account for overshoot correction), its initial response time tops the charts, making for a snappy-feeling panel. Its MPRT Sync backlight strobing blur reduction mode works well too, maintaining sharpness in fast motion. MPRT Sync also works with adaptive-sync, so you don't have to play with screen tearing to get motion blur reduction.

Conclusion

The MPG321QRF-QD is a very solid gaming monitor in many ways, thanks to impressive gaming performance, a dazzling colour range and the inclusion of a useful USB Type-C input. However, all that doesn't add up to it justifying being so much more expensive than most other panels on test. The Corsair also boasts a quantum dot panel and is £150 cheaper right now.

VERDICT

A decent performer in some areas but its price is bafflingly high.

SPEC

Screen size 32in

Resolution 2,560 x 1,440

Panel technology IPS

Maximum refresh rate 175Hz

Stated response time 1ms GTG

Max brightness 400cd/m² SDR, 600cd/m² HDR

Backlight zones 1

Stated contrast ratio 1,000:1

Adaptive sync FreeSync Premium Pro, G-Sync compatible

Display inputs 1x DisplayPort 1.4, 2x HDMI 2, USB Type-C DisplayPort 1.4 Alt Mode

Audio Headphone out

Stand adjustment Height, rotation, tilt

HDR certification DisplayHDR 600

Extras 100 x 100mm VESA mount, HDMI, DisplayPort and audio cables, 3-port USB 3 hub

MAGNIFICENT

- + Great gaming performance
- + Dazzling colour range
- + Useful USB Type-C KVM function

MANGLED

- No sRGB mode
- Bizarrely high price
- Chunky design

IMAGE QUALITY

22/30

FEATURES
18/20

GAMING

28/30

VALUE
8/20

OVERALL SCORE

76%

PHILIPS MOMENTUM 5000 32M1N5500VS

/ **£330** inc VAT

SUPPLIER amazon.co.uk

Thanks to its VA panel, the Philips Momentum 32M1N5500's high native contrast ratio makes it ideal for those seeking an HDR-like image. The Philips is arguably the most elegant display on test as well. The stand has a fetching silver finish, a slim stem and a minimalist claw-fingered base, while the back is finished in sharp angles that give it a premium business vibe.

Sadly, the stand itself lacks any screen movement options other than tilt. As such, if you want to adjust the height of the screen or rotate and pivot it, you'll have to invest in a monitor arm and take advantage of the VESA mount on the panel's rear.

Connection options are typical, with one DisplayPort input and two HDMI outputs, plus none of the USB Type-C frills of some other displays on test. You do get a 4-port USB 3 hub, though, with all four ports situated on the back of the panel.

SPEC

Screen size 32in

Resolution 2,560 x 1,440

Panel technology VA

Maximum refresh rate 165Hz

Stated response time 1ms MPRT, 4ms GTG

Max brightness 550cd/m² SDR and HDR

Backlight zones 1

Stated contrast ratio 3,000:1

Adaptive sync FreeSync Premium Pro, G-Sync compatible

Display inputs 1x DisplayPort 1.4, 2 x HDMI 2

Audio Headphone out

Stand adjustment Tilt

HDR certification DisplayHDR 400

Extras 100 x 100mm VESA mount, HDMI, DisplayPort and audio cables, 4-port USB 3 hub

Speakers are included too, and while they're clear enough at low volumes, they lack any heft and are very shrill at high volumes. A headphone jack is on hand for getting a better class of audio piped to your ears.

A single mini D-pad on the right rear of the panel controls the menus, and while it feels robust, it lacks the positive click of some such controls. Moreover, it functions differently, with it not pressing in to provide an ok/select button. Instead, you move the control to the right to bring up the menu and to then select options within the menu. It's a little clunky.

The options here are extensive, so you should be able to get the display setup just to your liking. There's also an sRGB mode for restricting the otherwise wide colour gamut, but it sets the brightness to maximum, which renders it rather useless.

Maximum brightness is impressive, at a rated and measured 550cd/m². This inherently allows for a far more immersive HDR experience than the other panels on test, along with the measured native contrast ratio of 4,298:1. The lack of backlight zones to further boost the contrast limits HDR reproduction a little, but it's still far more compelling than the other displays on test.

Also compelling is this display's overall image quality. Out-of-the-box colour balance isn't quite perfect but good enough for most use, while gamma is spot on and delta E colour accuracy is good too. Switch to the User colour mode and you just need to shift the blue down from 100 to 98 to get a perfect colour balance. We also noticed no blockiness in very dark grey areas in videos, which we've often found to be a problem with VA screens.

Less impressive is the gaming performance. While it supports FreeSync and G-Sync and trots along at 165Hz, its response time is very sluggish. This results in very



MOMENTOUS

- + Excellent image quality
- + Surprisingly decent gaming experience
- + Smart design

MOMENTARY

- Stand lacks adjustment
- Very slow response time
- Clunky menu system

obvious ghostly smears trailing behind moving objects. Oddly, though, the screen still feels reasonably nippy in use, and switching on its MPRT backlight strobing blur reduction mode tightens up its responsiveness even more. There's still a lot of visible smearing but aim tracking and responsiveness still holds up.

Conclusion

The Philips Momentum 32M1N5500 can't claim to be the fastest gaming monitor around, but it defies its sluggish response time figures to still provide a nippy gaming experience. Add the dazzling brightness, high contrast and excellent image quality and you have a display that's fantastic for work, video and gaming. **GPE**

VERDICT

Not ideal for high-speed gaming, but this capable gaming display has excellent image quality.

IMAGE QUALITY

28/30

FEATURES
15/20

GAMING

21/30

VALUE
16/20

OVERALL SCORE

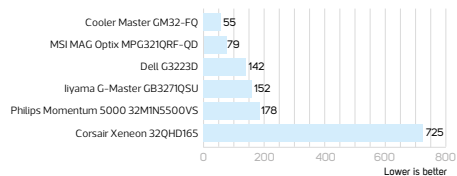
80%

32IN GAMING MONITOR LABS RESULTS

DEFAULT

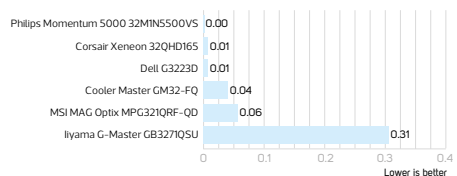
COLOUR TEMPERATURE (KELVIN)

Deviation from ideal result (6,500K)



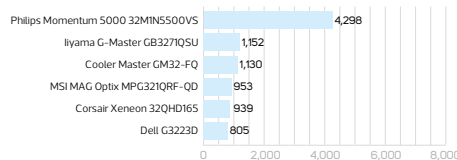
AVERAGE GAMMA

Deviation from ideal result (2.2)



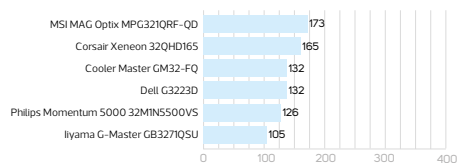
CONTRAST RATIO

Ratio of white-to-black luminance



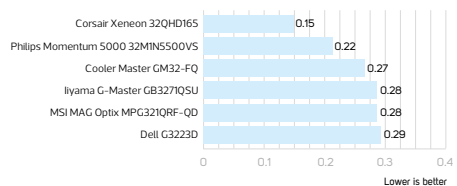
sRGB COLOUR SPACE

Percentage of sRGB colour space covered



COLOUR ACCURACY

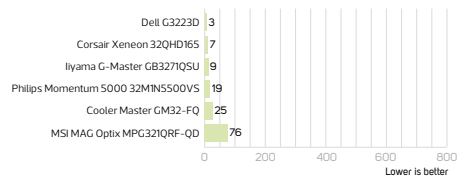
Average delta E 2000



CALIBRATED

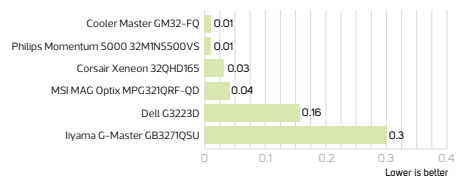
COLOUR TEMPERATURE (KELVIN)

Deviation from ideal result (6,500K)



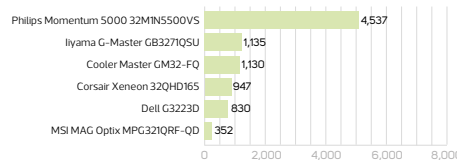
AVERAGE GAMMA

Deviation from ideal result (2.2)



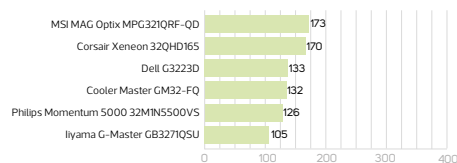
CONTRAST RATIO

Ratio of white-to-black luminance



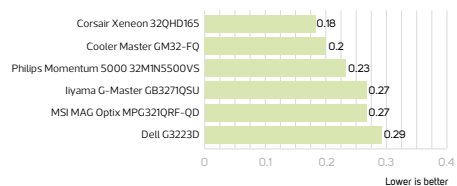
sRGB COLOUR SPACE

Percentage of sRGB colour space covered



COLOUR ACCURACY

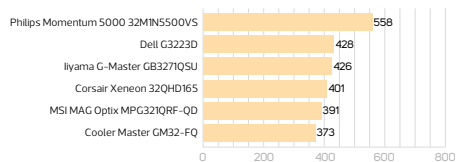
Average delta E 2000



GENERAL

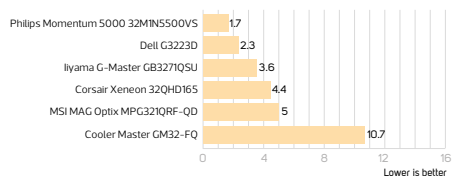
MAXIMUM BRIGHTNESS

Brightness in cd/m² (nits)



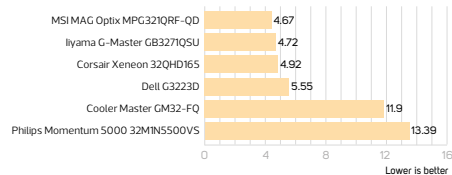
PANEL UNIFORMITY

Deviation from ideal 150cd/m² (nits)



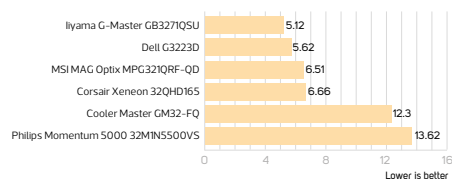
AVERAGE INITIAL RESPONSE TIME

Time in milliseconds



AVERAGE PERCEIVED RESPONSE TIME

Time in milliseconds



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YOUR GIFT GUIDE FOR 2023

THE BEST NEW PRODUCTS YOU CAN BUY
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G-MASTER GB3467WQSU-B1

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CYBERPOWER PC

A custom gaming PC from Cyberpower UK is a perfect treat this Christmas season. With hundreds of parts to choose from – including NVIDIA's GeForce RTX 4080 GPUs – its cutting-edge configurator tool lets you build your dream spec from scratch and finish it with a custom engraved side panel.

Order your gaming PC by 12 December, or pick up a pre-built one by 21 December, for guaranteed Christmas delivery, free UK delivery, and an extended return warranty for all holiday shoppers.

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£229

AOC C27G2ZU/BK

Unleash your potential with this 240MHz, 27-inch display. Its 240Hz refresh rate, 0.5ms response time, and low input lag enable the AOC C27G2ZU to provide a perfectly smooth performance. With its curved design, height adjustment, and swivel ability, the monitor can be adjusted to individual needs. It comes with FreeSync Premium and G-Sync compatibility.

The C27G2ZU/BK is on a Black Friday promotion at £189, which may continue depending on stock, so pick one up early if you find it on sale.

custompc.co.uk/AOCC27

AOC Q27G2E/BK

The AOC Q27G2E/BK offers a 27-inch VA panel with QHD resolution, ShadowControl and super contrast ratio of 3000:1. Enjoy the most responsive gameplay and fastest battles with its stutter-free Adaptive Sync, 155Hz refresh rate, 1ms MPRT, and low input lag to decrease motion blur and input-output delay. Gaming has never been so fun and intense.

custompc.co.uk/AOCQ27



£219

MINI PUPPER

Mini Pupper is an AI-powered, smart, quadruped robot designed for education. Mini Pupper makes robotics easier for schools, home-school families, enthusiasts, and more.

Utilising ROS (Robot Operating System) and with support for OpenCV and OpenCV's official OAK-D-Lite 3D camera module, this open-source robot is powerful and super-expandable.

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FROM
£335

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.

8-core system with integrated graphics

8-core CPU, basic gaming

Needs a micro-ATX or ATX case. We recommend a 450W 80 Plus Bronze power supply. See Issue 218, p76 for an example build guide.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 5700G	awd-it.co.uk	#218 p20	£198
CPU COOLER	AMD Wraith air cooler included with CPU	N/A	#218 p20	£0
GRAPHICS CARD	AMD Radeon RX Vega 8 integrated into CPU	N/A	#218 p20	£0
MEMORY	16GB (2 x 8 GB) Corsair Vengeance LPX Pro 3200MHz (CMK16GX4M2B3200C16)	scan.co.uk	#218 p78	£58
MOTHERBOARD	Asus TUF B450M-PLUS II (micro-ATX) with BIOS flash	awd-it.co.uk	#218 p78	£105
STORAGE	500GB WD Blue SN570 (M.2 NVMe)	scan.co.uk	#222 p20	£44
Total £405				

1,920 x 1,080 gaming PC

6-core CPU, 1080p gaming and ray tracing

Needs an ATX case. We recommend a 500W 80 Plus power supply. See Issue 224, p76 for an example build guide.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i5-12400F	scan.co.uk	#227 p51	£190
CPU COOLER	ARCTIC Freezer i13X	scan.co.uk	#224 p76	£23
GRAPHICS CARD	Nvidia GeForce RTX 3060 Ti	overclockers.co.uk	#228 p90	£429
MEMORY	16GB (2 x 8 GB) Corsair Vengeance LPX DDR4 3200MHz (CMK16GX4 M2B3200C16)	scan.co.uk	#224 p76	£58
MOTHERBOARD	Gigabyte B660 Gaming X DDR4 (ATX)	scan.co.uk	#224 p50	£150
STORAGE	1TB WD Blue SN570 (M.2 NVMe)	scan.co.uk	#222 p20	£71
Total £921				
UPGRADES				
SWAP GRAPHICS CARD	Nvidia GeForce RTX 3070 Ti	nvidia.com	#228 p90	£549
SWAP STORAGE	1TB WD Black SN850X	westerndigital.com	#230 p29	£112

2,560 x 1,440 gaming system

14-core CPU, 2,560 x 1,440 gaming and ray tracing

Needs an ATX case. We recommend a 550-600W 80 Plus Bronze power supply.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i5-13600K	scan.co.uk	#232 p16	£340
CPU COOLER	ARCTIC Liquid Freezer II 240 RGB (240mm AIO liquid cooler)	scan.co.uk	#226 p49	£90
LGA1700 ADAPTOR	ARCTIC Liquid Freezer II Upgrade Kit	scan.co.uk	#226 p49	£5
GRAPHICS CARD	Nvidia GeForce RTX 3070 Ti	nvidia.com	#228 p90	£549
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz DDR4 (CMW16GX4 M2D3600C18)	scan.co.uk	#230 p47	£75
MOTHERBOARD	Gigabyte Z690 Gaming X DDR4*	scan.co.uk	#222 p46	£208
STORAGE	1TB WD Black SN850X	westerndigital.com	#230 p29	£112

Total £1,379

UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	ebuyer.com	#166 p54	£85
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*This motherboard will need its BIOS updated in order to recognise the new CPU. This new BIOS can be downloaded online from custompc.co.uk/GigabyteBIOS and flashed using Gigabyte Q-Flash, as detailed in the motherboard manual.

Mid-range gaming system



14-core CPU, smooth 2,560 x 1,440 gaming and ray tracing, some 4K gaming

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

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i5-13600K	scan.co.uk	#232 p16	£340
CPU COOLER	ARCTIC Liquid Freezer II 240 RGB (240mm AIO liquid cooler)	scan.co.uk	#226 p49	£90
LGA1700 ADAPTOR	ARCTIC Liquid Freezer II Upgrade Kit	scan.co.uk	#226 p49	£5
GRAPHICS CARD	Nvidia GeForce RTX 4080	nvidia.com	#233 p14	£1,269
MEMORY	32GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz DDR4 (CMW32GX4M 2D3600C18)	scan.co.uk	#230 p47	£126
MOTHERBOARD	Asus ROG Strix Z790-A Gaming WiFi D4	scan.co.uk	#232 p34	£400
STORAGE	1TB WD Black SN850X	westerndigital.com	#230 p29	£112

Total £2,342

Core component bundles cont...

4K gaming system

8-core CPU, 4K gaming and ray tracing

Needs an ATX case with room for a 360mm all-in-one liquid cooler.

We recommend a 1000W 80

Plus Gold power supply.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 7700X	overclockers.co.uk	#231 p16	£420
CPU COOLER	Corsair iCUE H150i Elite LCD (360mm AIO liquid cooler)	scan.co.uk	#226 p78	£230
GRAPHICS CARD	Nvidia GeForce RTX 4090	scan.co.uk	#232 p28	£1,800
MEMORY	32GB (2 x 8GB) Corsair Vengeance RGB DDR5 6000MHz (CMH32GX5M 2B6000Z30K)	scan.co.uk	#233 p30	£256
MOTHERBOARD	Asus TUF Gaming X670E-Plus WiFi	cclonline.com	#232 p36	£348
STORAGE	1TB WD Black SN850X	westerndigital.com	#230 p29	£112
Total £3,166				

Content creation system

16-core CPU, 1,920 x 1,080 gaming

Needs an E-ATX case with room for a 360mm all-in-one liquid cooler. We recommend a 750W 80 Plus Gold power supply.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 9 7950X	overclockers.co.uk	#231 p14	£749
CPU COOLER	Corsair iCUE H150i Elite LCD (360mm AIO liquid cooler)	scan.co.uk	#226 p78	£230
GRAPHICS CARD	Nvidia GeForce RTX 3060 Ti	overclockers.co.uk	#220 p53	£429
MEMORY	32GB (2 x 8GB) Corsair Vengeance RGB DDR5 6000MHz (CMH32GX5M2 B6000Z30K)	scan.co.uk	#233 p30	£256
MOTHERBOARD	ASRock X670E Steel Legend	scan.co.uk	#232 p24	£380
STORAGE	2TB WD Black SN850X	westerndigital.com	#225 p27	£212
Total £2,256				
UPGRADES				
SWAP GRAPHICS CARD	Nvidia GeForce RTX 4090	scan.co.uk	#232 p28	£1,800

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.

Mini-ITX



Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Intel Z690 (LGA1700)	Gigabyte Z690I Aorus Ultra Plus	amazon.co.uk	#228 p46	£352
Intel B660 (LGA1700)	Gigabyte B660I Aorus Pro DDR4	awd-it.co.uk	#228 p47	£230
AMD X670 (AM5)	Asus ROG Strix X670E-I Gaming WiFi	scan.co.uk	#232 p38	£460
AMD B550 (AM4)	Asus ROG Strix B550-I Gaming	cclonline.com	#228 p39	£193

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ALL-PURPOSE	Cooler Master MasterBox NR200P	scan.co.uk	#206 p18	£100
TOWER	Ssupd Meshlicious	overclockers.co.uk	#225 p51	£100
HIGH AIRFLOW	Fractal Design Torrent Nano	scan.co.uk	#225 p45	£114
PREMIUM	Streacom DA2 V2	quietpc.com	#214 p51	£199

Other components

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
LOW-PROFILE CPU COOLER	Noctua NH-L12S	scan.co.uk	#219 p54	£59
SFX POWER SUPPLY	Phanteks Revolt SFX 750W	overclockers.co.uk	#228 p74	£120

ATX cases



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
SUB-£100 RGB	Antec DF700 Flux	scan.co.uk	#214 p26	£90
SUB-£100 AIRFLOW	Corsair 4000D Airflow	awd-it.co.uk	#222 p56	£99
COMPACT	Fractal Design Meshify 2 Compact	scan.co.uk	#215 p20	£118
HIGH AIRFLOW	Fractal Design Meshify 2	scan.co.uk	#212 p45	£150
PREMIUM HIGH AIRFLOW	Fractal Design Torrent RGB TG	scan.co.uk	#225 p20	£218
LUXURY	Corsair iCUE 5000T RGB	scan.co.uk	#224 p22	£385

Micro-ATX



Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
AMD B450 (AM4)	Asus TUF B450M-PLUS II	awd-it.co.uk	#218 p76	£95
AMD B550 (AM4)	MSI MAG B550M Mortar	ebuyer.com	#204 p42	£130

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Kolink Citadel Mesh RGB	overclockers.co.uk	#218 p26	£63

Networking



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET ROUTER	Belkin RT3200-UK	amazon.co.uk	#216 p52	£75
ROUTER	Asus RT-AX68U	scan.co.uk	#216 p51	£177
MESH ROUTER	Asus ZenWiFi AX Hybrid XP4	amazon.co.uk	#226 p59	£242
WI-FI ADAPTOR	TP-Link Archer TX3000E	overclockers.co.uk	#196 p58	£50
DUAL-BAY NAS BOX	Synology DS220j	box.co.uk	#200 p22	£164
DUAL-BAY MEDIA NAS BOX	Synology DS218play	box.co.uk	#174 p34	£209
2.5 GIGABIT DUAL-BAY NAS BOX	QNAP TS-231P3	amazon.co.uk	#212 p25	£229

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

Monitors



Up to 25in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN, 144Hz, IPS, 1,920 X 1,080, F, G	AOC 24G2U	cclonline.com	#214 p28	£170
25IN, 240Hz, IPS, 1,920 X 1,080, F, G	Acer Predator XB253Q	box.co.uk	#209 p57	£285
25IN, 360Hz, IPS, 1,920 X 1,080, F, G	Asus ROG Swift PG259QN	box.co.uk	#212 p20	£638

Up to 28in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN, 165Hz, IPS, 1,920 X 1,080, F, G	AOC 27G2SPU	ebuyer.com	#233 p21	£230
27IN, 165Hz, IPS, 2,560 X 1,440, F, G	LG UltraGear 27GP850	currys.co.uk	#229 p48	£379
27IN, 165Hz, VA, 2,560 X 1,440, F, G	AOC CQ27G3SU	overclockers.co.uk	#223 p45	£290
27IN, 240Hz, TN, 2,560 X 1,440, F, G	AOC AG273QZ	overclockers.co.uk	#202 p27	£590
27IN, 240Hz, IPS, 2,560 X 1,440, F, G	Alienware AW2721D	dell.com	#212 p21	£622
28IN, 144Hz, IPS, 3,840 X 2,160, F, G	AOC U28G2XU	overclockers.co.uk	#221 p29	£569

Over 28in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
31.5IN, 60Hz, VA, 3,840 X 2,160, F	iiyama ProLite XB3288UHSU	scan.co.uk	#205 p43	£370
32IN, 165Hz, VA, 2,560 X 1,440, F, G	Philips Momentum 5000 32MIN5500VS	amazon.co.uk	#233 p54	£330
32IN, 165Hz, IPS, 2,560 X 1,440, F, G	Dell G3223D	dell.com	#233 p51	£350
34IN, 144Hz, IPS, 3,440 X 1,440, W, F	iiyama G-Master GB3461WQSU	overclockers.co.uk	#206 p53	£370
38IN, 144Hz, IPS, 3,840 X 1,600, W, F, G, HDR	LG UltraGear 38GN950	currys.co.uk	#208 p30	£899
32IN, 240Hz, VA, 3,840 X 2,160, F, G, HDR	Samsung Odyssey Neo G8	scan.co.uk	#229 p17	£1,299
55IN, 165Hz, VA, 3,840 X 2,160, F, G, HDR	Samsung Odyssey Ark	samsung.com	#231 p34	£2,599

Non-gaming

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN, 75Hz, IPS, 2,560 X 1,440, F	LG 27QN880	amazon.co.uk	#210 p26	£375

Peripherals and audio

Gaming keyboards



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET TKL	SteelSeries Apex 3 TKL	currys.co.uk	#221 p59	£40
MECHANICAL 65 PER CENT	Ducky One 3 SF	overclockers.co.uk	#230 p26	£120
MECHANICAL TKL	NZXT Function MiniTKL	cclonline.com	#226 p32	£104
PREMIUM TKL MECHANICAL	Corsair K70 RGB TKL	scan.co.uk	#214 p31	£150
PREMIUM MECHANICAL	Corsair K70 RGB Pro	overclockers.co.uk	#225 p30	£170
PREMIUM WIRELESS MECHANICAL	Razer BlackWidow V3 Pro	overclockers.co.uk	#208 p60	£230

Gaming mice



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET GAMING	NZXT Lift	scan.co.uk	#232 p55	£40
FIRST-PERSON SHOOTER	Glorious Model O	overclockers.co.uk	#232 p54	£38
AMBIDEXTROUS	Razer Viper 8K	currys.co.uk	#215 p59	£80
MULTI-BUTTON	Roccat Kone XP	roccat.com	#225 p60	£80
WIRELESS	Razer Viper Ultimate	currys.co.uk	#217 p54	£85
PREMIUM WIRELESS	Razer DeathAdder V2 Pro	scan.co.uk	#210 p28	£120
ULTRA LIGHTWEIGHT	Cooler Master MM711	box.co.uk	#232 p52	£30
PREMIUM LIGHTWEIGHT WIRELESS	Logitech G Pro X Superlight	amazon.co.uk	#217 p52	£115

Peripherals and audio cont ...



Game controllers



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
RACING WHEEL	Logitech G29 Driving Force	currys.co.uk	#202 p50	£249
BUDGET GAMEPAD	PowerA Spectra Infinity Xbox Series X	argos.co.uk	#228 p55	£35
MID-RANGE GAMEPAD	Sony DualSense	scan.co.uk	#228 p58	£60
PREMIUM GAMEPAD	Scuf Instinct Pro	scufgaming.com	#228 p57	£200
BUDGET FLIGHT STICK	Logitech Extreme 3D Pro Joystick	currys.co.uk	#207 p52	£55
FLIGHT STICK	Thrustmaster T.16000M FCS HOTAS	scan.co.uk	#207 p56	£130

Gaming headsets

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET STEREO	Roccat Elo X Stereo	amazon.co.uk	#210 p56	£24
STEREO	EPOS GSP 300	amazon.co.uk	#210 p54	£38
WIRELESS	Corsair Virtuoso RGB Wireless	ebuyer.com	#204 p50	£146
PREMIUM WIRELESS	EPOS H3Pro Hybrid	currys.co.uk	#231 p47	£200

Speakers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
STEREO	Edifier R1280DB	overclockers.co.uk	#224 p59	£110

Non-gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
WIRELESS 84-KEY ELECTRO-CAPACITIVE	Niz Mini 84 Pro	keyboardco.com	#220 p29	£132
BUCKLING SPRING MECHANICAL	Unicomp New Model M	keyboardco.com	#219 p26	£129

PCs and laptops



Pre-built PC systems

CATEGORY	NAME	CPU	GPU	SUPPLIER	ISSUE	PRICE (inc VAT)
LUXURY GAMING PC	Scan 3XS Fluid Torrent CS	Intel Core i9-13900K	Nvidia GeForce RTX 4090	custompc.co.uk/ScanCS	#233 p36	£6,899

Laptops



CATEGORY	NAME	CPU	GPU	SCREEN	SUPPLIER	ISSUE	PRICE (inc VAT)
MID-RANGE GAMING	Asus ROG Strix Scar 15 G533ZW	Intel Core i9-12900H	Nvidia GeForce RTX 3070 Ti Laptop	15.6in 2,560 x 1,440 IPS 240Hz	custompc.co.uk/AsusScar15	#227 p40	£2,000
HIGH-SPEED GAMING	Alienware x17 R2	Intel Core i7-12700H	Nvidia GeForce RTX 3080 Ti Laptop	17.3in 1,920 x 1,080 IPS 360Hz G-Sync	custompc.co.uk/AlienwareX17	#227 p38	£3,449

Games



RICK LANE / INVERSE LOOK

NEW PROJEKTS

CD Projekt recently announced a slew of new products, but after the Cyberpunk 2077 fiasco, Rick Lane asks if it's risking its reputation again

CD Projekt (CDP) has just been on a dizzying announcement spree. In the past couple of months, the company has revealed an upcoming expansion to Cyberpunk 2077 named Phantom Liberty, alongside plans for a sequel to Cyberpunk codenamed Project Orion. It's also announced a whole new game codenamed project Hadar, and five (yes, five) new Witcher games, including a new trilogy the company claims will be released over six years.

It's a very different stance from the muted, conciliatory CD Projekt of a couple of months back, and there's much to unpack within these announcements. In the immediate future, there's that Cyberpunk expansion, which is extremely welcome news despite the game's poor launch.

Night City was easily the best part of CDP's sci-fi RPG, and this game world felt criminally underused by the campaign and missions the company created for it. Filling Night City with new adventures is a great way to both repair CDP's reputation, and build the game into a project that better reflects the original pitch.

Unfortunately, that's not what CDP has planned. Phantom Liberty will be the only expansion Cyberpunk receives, as the company directs it focus onto the planned sequel. Now, it's understandable that CDP might want to move on from Cyberpunk 2077, given how the game damaged the reputation of the company, and indeed all these announcements are indicative of broader restructuring.

CD Projekt's co-founder Marcin Iwinski recently announced he was stepping down as joint CEO, while the company is

switching to Unreal Engine 5 to build its new Witcher series (there's no word on whether Orion or Hadar will continue using CDP's REDengine tech). No doubt the company will also be in a heavy recruitment phase with all these new projects in the pipeline, which is probably the reason why they've been announced so early.

Nonetheless, there is a distinct whiff of history repeating itself here. One of the main reasons Cyberpunk crashed so hard was because it had eight years during which to gain altitude. The game was announced back in 2012, with no plans to launch until after The Witcher 3's release.

This created a huge void that filled over time with hype and speculation, leading to intensified frustration when the game was repeatedly delayed. If there's one lesson CDP should have learned from Cyberpunk, it's 'don't announce your game too early'.

Instead, CDP has announced eight new projects, seven of which are only in the primordial stages of development, many, if not all, of which are being built on unfamiliar tech. At best, it's an enormous gamble. At worst, it represents a failure to learn from past mistakes and a colossal misreading of the level of enthusiasm people currently have for CD Projekt's work.

Of course, I'd love to play a new Witcher game, but with the mess of Cyberpunk still smouldering, I'd rather hear about these new games six months from launch, all but ready to go, than years out with nothing to show but a logo and a promise from a company currently suffering from a severe deficit of trust. **CPC**

I'd rather hear about these new games six months from launch

Rick Lane is Custom PC's games editor [@Rick_Lane](#)



A PLAGUE TALE: REQUIEM / £43.99 inc VAT

DEVELOPER Asobo Studio / PUBLISHER Focus Entertainment

Released in 2019, *A Plague Tale: Innocence* was a medieval take on *The Last of Us*. It was an impressive (if occasionally silly) linear action-adventure, combining a stunningly realised medieval world with an affecting story of sibling survival.

Taking place six months after teenage noble's daughter Amicia and her sickly little brother Hugo evaded the clutches of the Inquisition in the last game, *Requiem* transports the duo to the south of France, where they enjoy approximately 15 minutes of peace before a bloody encounter with some frenzied beekeepers (yes, beekeepers) causes Hugo's illness to flare up again.

Plus, because Hugo's illness is directly connected to the hordes of plague rats ravaging medieval France, Amicia rushes Hugo to the nearest city, hoping to get him treated before the rat plague can catch up with them.

Requiem is a darker tale than *Innocence*, which itself wasn't all sunshine and rainbows. The first game centred around a group of children fighting both the rats and the Inquisition, lending its frequently morose narrative a streak of camaraderie and derring-do. *Requiem's* companions are generally less sympathetic, though, and Amicia and Hugo are also more compromised characters than before.

Amicia struggles to balance protecting Hugo with her increasingly violent approach to problem solving, while Hugo, a six-year-old boy through whom the plague has ravaged entire cities, increasingly believes he doesn't deserve to be saved.

One area where *Requiem* clearly improves upon its predecessor is in environment design. The game's 16 chapters are more expansive and detailed than before, and while the game remains a largely linear affair, it does a fantastic job of conveying the size of the world around you.

An early level sees you weave through an entire medieval city, while subsequent chapters explore different spokes stretching out from the urban hub. Latter chapters transport the pair to an idyllic Mediterranean island explored in brief bursts of open-world gaming. Yet while these environments impress as individual spaces, the game is less proficient at connecting them via the plot, lacking the sense of urgency provided by the Inquisition.

Moment to moment, *Requiem* keeps the experience interesting by mixing stealth, combat and puzzles where you manipulate light and darkness to create pathways through swarms of rats. The most notable change is that the game is better at shifting between stealth and combat. Most tools are useful in both scenarios, while Amicia can wield a knife and crossbow for quick enemy dispatches. In general, though, combat is best avoided, as Amicia never feels like a natural warrior even in her angriest moments.

Nonetheless, *Requiem* is worth experiencing for its incredible sights and entertaining blend of action, spectacle and morbid horror. The ending in particular is as bold as it is bleak, and will stick with you long after the credits have rolled.

RICK LANE

PET RAT

- + Great individual levels
- + Enjoyable blend of systems
- + Incredible spectacle

PLAGUE RAT

- Less rewarding story
- Combat still awkward

/ VERDICT

A Plague Tale: Requiem is a bigger and bolder sequel, but also a messier one.

OVERALL SCORE

78%

Return to Monkey Island / £19.49 inc VAT

DEVELOPER Terrible Toybox / PUBLISHER Devolver Digital



It's happened. After 30 years, Monkey Island creator Ron Gilbert has, well, returned to Monkey Island, creating a new game intended as a proper conclusion to the gaming world's most beloved series of point-and-click adventures. Co-directed by fellow Monkey Island designer Dave Grossman, and licensed straight from the recently reformed LucasFilm Games, it's as official a sequel as you'll get short of building the whole game in the SCUMM engine.

But there's a question hanging over Return to Monkey Island. Can an old-fashioned point-and-click adventure keep up with the best of them in the year 2022? Does insult sword fighting cut it when games can reliably replicate actual sword fighting? Does pointing and clicking still satisfy in an age of VR headsets? Does the series' goofy, knockabout humour still land three decades on?

The short answer is 'yes'. The long answer is 'yes, because in many ways, Return to Monkey Island isn't an old-fashioned adventure game'. It's now easy to forget that what made The Secret of Monkey Island so successful were its innovations, and how it made point-and-click adventuring more accessible and entertaining than what had gone before.

It was an adventure game where it was almost impossible to die, that massively refined its verb-based interface and the logic through which puzzles were solved. It did for adventure

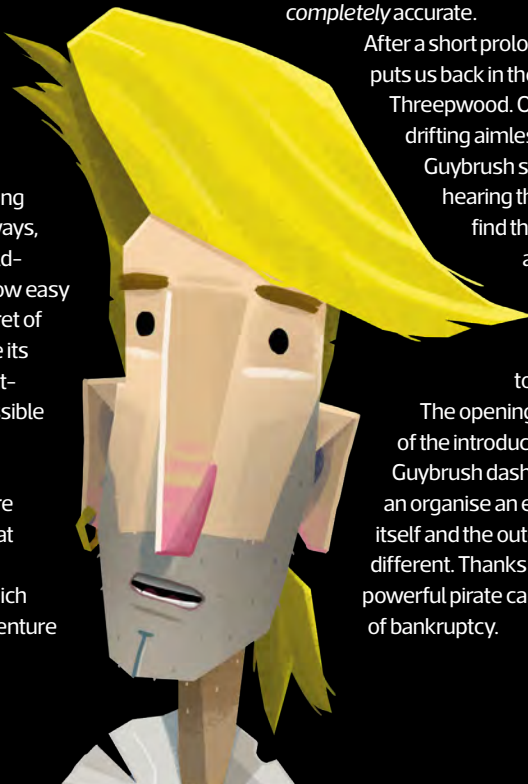
games what Half-Life did for shooters, codifying their abstractions into a package that made more sense.

Return to Monkey Island does the same, but with three additional decades of learning under its brass-buckled belt. This isn't merely a nostalgic throwback to a bygone era, it's a subtle, elegant reinvention of adventure gaming for the modern age.

Return to Monkey Island is a direct sequel to Monkey Island 2, but one that doesn't completely toss the stories from the later games overboard, particularly Curse of Monkey Island. The way it gets around this apparent contradiction is typical of the series, by wryly explaining that the stories we've previously heard weren't *completely* accurate.

After a short prologue that sets all this up, Return puts us back in the royal-blue jacket of Guybrush Threepwood. Older, more dishevelled, and drifting aimlessly through the middle of his life, Guybrush snaps out of his melancholy upon hearing that his nemesis LeChuck plans to find the secret of Monkey Island once and for all. Naturally, Guybrush decides to beat LeChuck to the punch, despite lacking a ship, a crew and money to buy either.

The opening chapter is a playful reimagining of the introduction to Secret. Once again, Guybrush dashes around Mêlée island trying to organise an expedition, but both the island itself and the outcome of his efforts are very different. Thanks to a dodgy financial deal with a powerful pirate captain, Mêlée island is on the verge of bankruptcy.



Most of the shops are closed, and those that aren't, such as the International House of Mojo, are rapidly going out of business. Stan's Used Ships outlet lies empty and dilapidated, while Stan himself lingers in a prison cell, although he's confident of being acquitted for the crime he deftly circles around telling you about.

Confidence is what primarily resonates from this renewed vision of Monkey Island, the way it deftly blends the old with the new, nodding fondly at times past as it watches them drift off into the moonlight. That confidence is most immediately evident in the art style, a radical departure from the sprites of the first two games and the Saturday morning animation of Curse of Monkey Island.

Highly angular and geometric, the game can look disorientating in still images, but it looks glorious in motion, with subtle animations and dynamic lights bringing the highly detailed backgrounds to life. Conversations have a filmic quality to them too, with dialogue sequences punctuated by closeups of characters' faces and objects being handed over.

The busyness of the art belies the cleanness of the game when it comes to interaction. The verb-object interface has wisely been consigned to the past, replaced with a quick, efficient contextual affair where objects can be pulled from your inventory, and either clicked on the screen for an interaction, or on another object in your inventory to combine them.

However, this system still retains the personality of the verb-object interface, by having alternate, specific interactions for every object you can click on. Right clicking on an object in Guybrush's inventory might make him 'appreciate' a knife, 'criticise' a painting, or 'inspect' a toothbrush. Some are even more specific – the inventory interaction for a dodgy drink Guybrush picks up simply reads 'Gross!'



Return to Monkey Island couples this slicker interaction system with puzzles that are as flexible as they are fluid. The game offers two modes, a Casual mode with fewer, easier puzzles, and a Hard mode that's truer to the original Monkey Island games. But even on Hard mode, the puzzles are generally built so that solutions flow logically, while there's an extensive hint system that you can easily access if you get stuck.

Many puzzles call back to earlier games in ingenious ways. An early puzzle requires Guybrush to once again 'obtain' a monocle from Wally at the map shop. When Guybrush gets there, Wally makes a big deal about the impact Guybrush's monocle-theft had on his life, setting up a brilliantly unexpected punchline.

And yes, Return to Monkey Island is funny, often laugh-out-loud so. From one-off jokes, such as a fantastic gag that introduces the 'skip-dialogue' button, to more extended bits, such as the curator of the museum of pirate lore refusing to recognise the real Guybrush Threepwood in his museum stuffed with Guybrush memorabilia.

Beneath the humour, though, is a genuine warmth for the game's world and the characters who reside in it. It would have been easy, for example, to throw friction between Guybrush and Elaine for dramatic effect. Instead, there's a tenderness to their relationship that always makes their encounters a comforting respite from the broader adventure.

The flaws are mostly isolated issues typical of adventure games – the odd line that doesn't land; the odd puzzle that's a bit too obscure. And while it does cater to newcomers, in the form of an interactive scrapbook that runs through the highlights of Guybrush's previous adventures, you'll need to be moderately familiar with previous games to get the most out of it.

None of this changes the fact that Return to Monkey Island is a wonderful conclusion to the series, though, and a fantastic example of how to create a modern-feeling adventure game without compromising on the essentials.

RIK LANE

MONKEY ISLAND

- + A true Monkey Island adventure
- + Smartly modernised
- + Fantastic story to conclude the series

MONKEY BUSINESS

- Some minor issues
- Won't mean much to series newcomers

/ VERDICT

Three decades may have passed, but Guybrush Threepwood has lost none of his goofy charm.

OVERALL SCORE

92%



GROUNDED / £34.99 inc VAT

DEVELOPER Obsidian Entertainment / PUBLISHER Xbox Game Studios



LADYBIRD

- + Novel take on the survival genre
- + Wonderfully realised world
- + Remarkable insects
- + Satisfying exploration and crafting

LAWN MITE

- Can be a harsh teacher

/ VERDICT

Grounded is a prime example of how the best things can come in small packages.

OVERALL SCORE

90%

Grounded sees you exploring a suburban backyard, having been reduced to ant-size in a science-experiment gone awry. Grounded's most striking feature is how it transforms the humble garden into a sprawling and dangerous wilderness. Individual grass stalks loom over you like trees, while the underlying soil is churned and rugged like a battlefield.

Garden detritus such as discarded trowels, broken toys and empty soda cans become vast, imposing landmarks, while the surrounded houses and trees are so inconceivably huge that your shrunken eyes can't properly focus on them. All the while, you're surrounded by a rainforest-like hum of animal activity, from ants chirruping as they scuttle through the undergrowth, to bees droning overhead like World War II bombers.

Mechanically, Grounded is a typical survival affair, mixing exploration with an elaborate crafting system and base building, but these conventional systems are given fun twists by the game's diminutive theme. For example, you obtain clean water by knocking dewdrops off grass stalks and then chasing them around the ground, forge armour by smashing up acorn shells with a pebble-hammer, and

craft arrows by plucking thorns from the stalks of towering thistles. It refreshes the ruleset of survival gaming with its own delightfully silly internal logic.

However, Grounded's greatest success is its depiction of the garden's many insects. Not only do they look and sound incredible (the pigeon-like warble of a passing ladybird is a stroke of genius), but they also have fully simulated behaviours and routines that make the world feel alive.

Red ants, for example, are friendly by default, but they'll regularly try to steal food from your camp, and will fiercely defend their anthill home. Gnats are naturally drawn to water and light, while pesky lawn mites harass any creature that comes near them. Then, of course, there are the spiders – terrifying apex predators that can trap you in sticky webs and kill you in a couple of bites.

Indeed, while thematically light-hearted, Grounded is surprisingly challenging by default. Taking on a stinkbug or a wolf spider head-on is rarely a good idea even if you're well equipped. You need to outsmart these formidable foes, using height to your advantage by climbing up plants, or luring them into battle with other, equally tough bugs. Defeating enemies with brains rather than brawn makes for satisfying play, although the learning process can be painful at times, as death means you drop all your equipment and must slog across the garden to retrieve it.

There's a range of difficulty options that lessen the challenge (as well as an option to disable those terrifying spiders outright), and whether you're up for a challenge or not, Grounded is an essential survival experience, a delightfully novel adventure that squeezes every drop of fun from its core concept.

RICK LANE



PRODEUS / £19.99 inc VAT

DEVELOPER Bounding Box Software / PUBLISHER Humble Games



Of all the retro shooters released since 2018's DUSK, Prodeus comes closest to capturing the feel of Doom and Quake. Placing you in the role of a space marine on an asteroid under assault by two warring interdimensional factions, Prodeus grabs your attention in two ways.

First, there's its hybrid presentation, which combines the '2.5d' graphics of Doom (3D levels and 2D sprites) with modern lighting and visual effects. The result is a distinctive and highly dynamic visual style, where explosions and reflections interplay with the angular geometry and pixelated foes. That dynamism is further enhanced by the stupendously violent combat. Enemy sprites are highly deformable, while your gunshots coat environments in almost absurd amounts of crimson.

Prodeus' flashier side is supported by strong mechanical foundations. Its weapons are dependable FPS regulars with little twists. Your trusty shotgun, for example, has a charged alt-fire mode that sets enemies aflame, while the lightning gun transforms into a powerful railgun when aiming down the sights. Enemy encounters are designed to encourage full use of this arsenal, with different weapons being variously effective depending on which enemies your facing, their numbers and their strength.

The enemies themselves, however, are one of Prodeus' weaker elements. While perfectly acceptable cannon fodder, most of them are unsubtle knockoffs from Doom's demonic roster, including variants of Imps, Cadodemons, Pinkies and Lost Souls. Prodeus' second enemy faction



features a few more original designs, but its ranks are mostly filled by recoloured versions of those Doomlike foes – it's one of the few areas where Prodeus displays the limitations of its budget.

The game makes up for its creatively lacking adversaries with its level design, though, which seamlessly blends traditional abstract mazes with more modern, architecturally coherent spaces. Each level is based around a specific concept. Marksman, for example, sees players evading potshots from a nearby sniper tower, while Hazard involves raising the water level inside a vast canyon to access new pathways. It's rarely content to be a straightforward corridor shooter, and it's always exciting to see what idea it will throw at you next.

Prodeus also resurrects a long-neglected feature of first-person shooters – secret hunting. Each level is stuffed with hidden rooms and pathways that reward you with a resource known as 'ore'. This resource can be used to buy special weapons and character upgrades, which increase your manoeuvrability and ammo capacity. Annoyingly, though, many of these secrets require the double-jump ability to access, which can't be unlocked until around a third of the way through the game.

Prodeus doesn't attempt to revolutionise the FPS, but neither is it derivative. Its blend of old and new graphical techniques makes it visually unusual, while its level design constantly seeks to improve upon itself. Simultaneously backward-looking and forward thinking, Prodeus is a thoroughly entertaining chimera.

RICK LANE

SHOTGUN

- + Distinctive visual style
- + Imaginative level design
- + Great weapons
- + Secrets galore

SPUD GUN

- Forgettable enemies
- Some arbitrary progression hindrance

/ VERDICT

Prodeus is a joyous celebration of traditional FPS design with an enjoyably modern wrapping.

OVERALL SCORE

86%





INSIDE NVIDIA'S NEW GPU

NVIDIA'S ADA LOVELACE MICROARCHITECTURE IS FINALLY HERE, BRINGING A HOST OF NEW FEATURES AND ASTONISHING LEVELS OF PERFORMANCE. **EDWARD CHESTER** UNPICKS THE INNER WORKINGS OF NVIDIA'S LATEST PIECE OF GAMING SILICON WIZARDRY

While rumours of the sheer horsepower of Nvidia's RTX 4000-series GPUs have swirled around the tech gossip grapevine for a long time, there was always good reason to be sceptical of just how much power would be delivered by these new GPUs. However, as the launch of the GeForce RTX 4090 (Issue 232) and GeForce RTX 4080 (p14) have shown, the rumours were pretty much spot on: these cards are monstrously powerful and monstrously power-hungry too.

Much of that increase in processing capability comes from the AD102 and AD103 GPUs that sit at the heart of this first raft of 4000-series cards simply having more of every building block.

By switching from the larger Samsung 8N manufacturing process used in its RTX 3000-series GPUs to a brand-new

TSMC 4N process, Nvidia has been able to squeeze more of all the building blocks that make up a GPU into the die without it becoming unwieldy.

The numbers involved in this change are more than a little mind-boggling. The AD102 GPU packs in a ludicrous total of 76 billion transistors and 18,432 CUDA cores. That's more than double the 28 billion transistors and nearly double the 10,752 CUDA cores of the RTX 3090 Ti's GA102 GPU. The AD102 isn't subtle.

The new process also brings improvements in performance thanks to the ability to run at increased clock speeds. Where the RTX 3090 ran at a base clock of 1395MHz with a boost clock of 1695MHz, and the RTX 3090 Ti increased these figures to a 1670MHz base clock and 1890MHz boost clock, the RTX 4090 runs at a 2235MHz base

clock and 2,520MHz boost clock. The RTX 4080, with its 9,728 CUDA cores ticks along slightly slower at a 2205MHz base clock and 2,505MHz boost clock, but those are still big leaps over the 1440MHz base clock and 1710MHz boost clock of the RTX 3080.

At launch, we only have these two cards to represent the Ada line-up, so we can't be sure how lower tier cards will fare when it comes to the significant jumps in the number of CUDA cores and the GPU clock speeds. However, it's a fair assumption that there will be large gains.

Originally there were three cards in the launch line-up – the RTX 4090, RTX 4080 16GB and RTX 4080 12GB. However, because of a strong negative reaction to the significantly lower overall specs of the RTX 4080 12GB compared to the RTX 4080 16GB, it has been 'unlaunched' – the 12GB

CARD COMPARISON

	GEFORCE RTX 2080 Ti	GEFORCE RTX 3090	GEFORCE RTX 3090 Ti	GEFORCE RTX 4080	GEFORCE RTX 4090
CUDA CORES	4,352	10,496	10,752	9,728	16,384
GPCs	6	7	7	7	11
TPCs	34	41	42	38	64
SMs	68	82	84	76	128
GPU BASE CLOCK	1350MHz	1395MHz	1670MHz	2205MHz	2235MHz
GPU BOOST CLOCK	1635MHz	1695MHz	1860MHz	2505MHz	2520MHz
TENSOR CORES	544 (2nd-gen)	328 (3rd-gen)	336 (3rd-gen)	304 (4th-gen)	512 (4th-gen)
RT CORES	68 (1st-gen)	82 (2nd-gen)	84 (2nd-gen)	76 (3rd-gen)	128 (3rd-gen)
TEXTURE UNITS	272	328	336	304	512
ROPS	88	112	112	112	176
MEMORY SIZE AND TYPE	11GB GDDR6	24GB GDDR6X	24GB GDDR6X	16GB GDDR6X	24GB GDDR6X
EFFECTIVE MEMORY SPEED	14GHz	21GHz	21GHz	22.4GHz	21GHz
L1 CACHE / SHARED MEMORY	6,528KB	10,752KB	10,752KB	9,728KB	16,384KB
L2 CACHE	5,632KB	6,144KB	6,144KB	65,536KB	73,728KB
TOTAL BOARD POWER	260W	350W	450W	320W	450W
TRANSISTOR COUNT	18.6 billion	28.3 billion	28.3 billion	45.9 billion	76.3 billion
DIE SIZE	754mm ²	628.4mm ²	628.4mm ²	379mm ²	608.5mm ²
MANUFACTURING PROCESS	TSMC 12nm FFN (FinFET Nvidia)	Samsung 8N Nvidia custom process	Samsung 8N Nvidia custom process	TSMC 4N Nvidia custom process	TSMC 4N Nvidia custom process

version didn't just have 4GB less RAM, but also far fewer CUDA cores and a 192-bits wide memory interface compared with the 256-bits wide interface on the 16GB version.

It's strongly expected that the 12GB GeForce RTX 4080 card will relaunch soon enough as an RTX 4070-series GPU of some sort with a lower price – here's hoping anyway.

As well as these 'more of everything in a smaller space' changes, the Ada architecture also brings several other under-the-bonnet tweaks compared with the Ampere architecture that preceded it.

The most prominent of these is improved ray-tracing performance, thanks to the

development of a new RT core, and improved matrix operation performance thanks to a new Tensor core.

New software features are also being launched along with the new hardware. DLSS 3, the latest version of the company's upscaling technology, introduces optical flow acceleration, which inserts entirely new extra frames in between traditionally rendered frames, resulting in big frame rate increases for minimal processing outlay.

Meanwhile, shader execution reordering enables developers to more efficiently order the execution of ray-tracing calculations, providing up to a 2x performance in ray-tracing shader throughput.

A CHANGE OF MANUFACTURING

Although the microarchitecture of a chip can be considered separate from the manufacturing process used to produce it, in practice architectures are generally optimised to work with a specific manufacturing process. As such, the move from using Samsung's 8N manufacturing process for its Ampere GPUs to TSMC's 4N process for its Ada GPUs is an integral part of the difference between Nvidia's two most recent architectures, and it's the natural place to start when talking about such an enormously complicated GPU.

TSMC's 4N process is a refined version of its 5N process – both are still classed as



The AD102 is manufactured using TSMC's latest 4N (5nm) process, more than doubling the density of its previous chips

5nm component-size processes, but the 4N process has a slightly higher density. While 5N has a density of around 138 million transistors per mm² (MTr/mm²), 5N has a density of 146MTr/mm². The 4N process also brings an up to 11 per cent increase in potential clock speed over 5N. Those density figures compare to a mere 45MTr/mm² for the Samsung 8N (8nm) process used to make Nvidia's Ampere GPUs.

As a result of this huge increase in transistor density, the die size of the AD102 is 'only' 608.5mm² compared to the 628.4mm² of the GA102, which itself already saw a significant drop in size compared with the TU102 GPU (used in the top-tier RTX

The AD102 GPU is remarkably similar in core structure to the previous-generation GA102 GPU, just with more of the main building blocks

2000-series GPUs and manufactured using a 12nm process). That chip had a whopping area of 754mm² despite packing in only 18.6 billion transistors.

For context, AMD's current flagship graphics card, the Radeon RX 6950 XT, uses a GPU called the Navi 21 (based on the company's RDNA2 architecture), which measures 520mm² and incorporates 27 billion transistors. Compared to the 28 billion transistors in the 628.4mm² die of the GA102, this translates to a slightly higher transistor density, which comes courtesy of AMD's use of TSMC's 7nm process, which has a density of 51.5MTr/mm² compared to the 45MTr/mm² of Samsung's 8N process.

Meanwhile, AMD's just-announced RDNA 3 GPUs (powering its new Radeon RX 7000-series graphics cards) will be the first to use a chiplet design where multiple smaller dies are combined to provide the card's total processing power. The main GPU functions remain on a single die, rather than being split up into multiple chips, and instead, it's the large caches and memory interface elements that have been offset onto other dies.

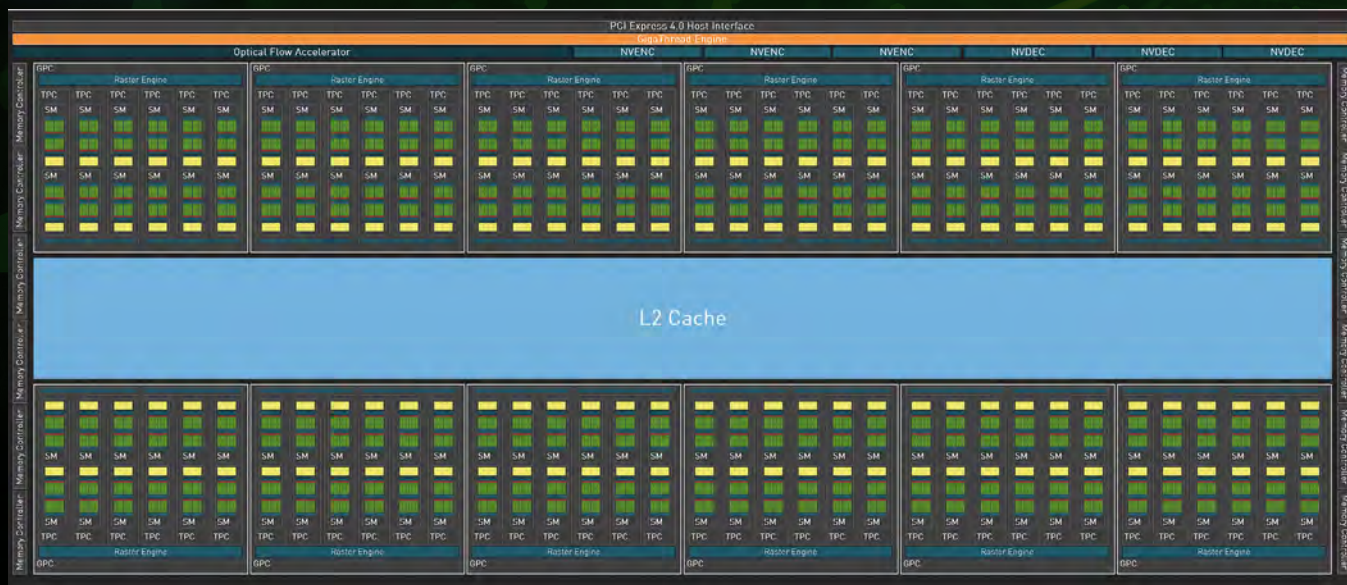
The upshot is that the main Graphics Compute Die (GCD) of the upcoming flagship Radeon RX 7900 XTX measures just 300mm², but it will be joined by six 37mm² Memory Cache Dies (MCDs). Although the size difference between the GCD and Nvidia's AD102 is huge, suggesting there's a lot of sense to this chiplet approach, AMD's design does also use fewer transistors in

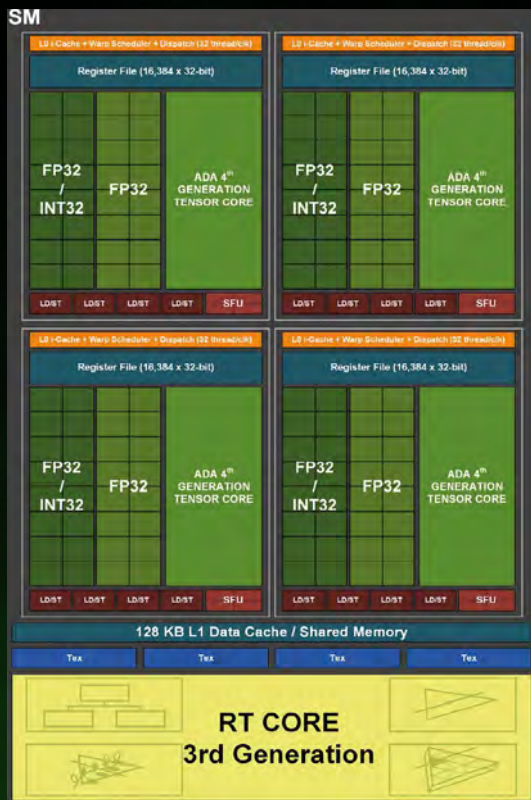
total. The total transistor count of one GCD and six MCDs is 58 billion, compared to the 76 billion of AD102.

AMD's GCD will be produced on TSMC's 5N process, rather than its latest 4N process, while the MCDs will use TSMC's even older, cheaper and slightly larger 6nm process. In theory, this production method should result in cheaper overall production costs, due to the higher yields associated with smaller dies, but will come at the expense of slightly lower clock speeds and power efficiency as both processes are larger than the ones used to make Nvidia's latest GPUs.

Back to Ada Lovelace's new process and, as already highlighted, it brings with it big leaps in clock speed over the older Samsung process and improvements to power efficiency. Those base and boost clock improvements from the RTX 3090 to the RTX 4090 highlighted earlier amount to 60

The GPC of AD102 is structurally identical to that of the Ampere architecture





The addition of 3rd-gen RT cores and 4th-gen Tensor cores gives extra processing power to each SM of the Ada architecture

per cent and 49 per cent upticks respectively. Those are big leaps by any measure.

Meanwhile, power efficiency has taken a huge step forward, with Nvidia claiming the RTX 4090 will deliver double the performance of the RTX 3090 when running at the same power level. This is a claim we saw borne out in our testing, with the RTX 4090 using significantly less power than the RTX 3090 and RTX 3090 Ti when not maxing out the card's performance.

Of course, not content to just hit that same power level as before, Nvidia has pushed the RTX 4090 beyond the same power envelope as the RTX 3090, so that it boasts a 450W total board power compared to the RTX 3090's 350W. Again, this was shown in our testing when we really pushed the card hard at 4K with ray tracing – the RTX 4090's total system power draw leapt from 535W when running at 2,560 x 1,440 resolution to 619W when running at 4K.

In order to accommodate these power requirements, and to neaten up the cabling, Nvidia has used the new 12VHPWR 16-pin power from the ATX 3 spec to accommodate

the power delivery. However, there have already been reports of these connectors melting under the load of the card if they're not installed and handled carefully – some versions of these connectors have soldered joints that can crack if the cable is bent.

In comparison, AMD's upcoming RX 7900 XTX RDNA3

the underlying architecture. Many of the core building blocks are very similar to the company's previous Ampere architecture but there are several tweaks throughout.

If we look at the block diagram of the AD102 GPU that powers the RTX 4090 and RTX 4080, we can see that it's very similar to the GA102 GPU that preceded it, just with more of everything. Around a central core of L2 cache are arranged 12 graphics processing

THE NEW AD102 GPU IS VERY SIMILAR TO THE GA102 GPU THAT PRECEDED IT, JUST WITH MORE OF EVERYTHING

GPU has a still very high total board power of 355W, but the cards are set to use two conventional 8-pin PCI-E power supply plugs, rather than a proprietary new connector.

The power draw situation isn't so dramatic as you start moving down the stack of Ada graphics cards, with the RTX 4080 16GB

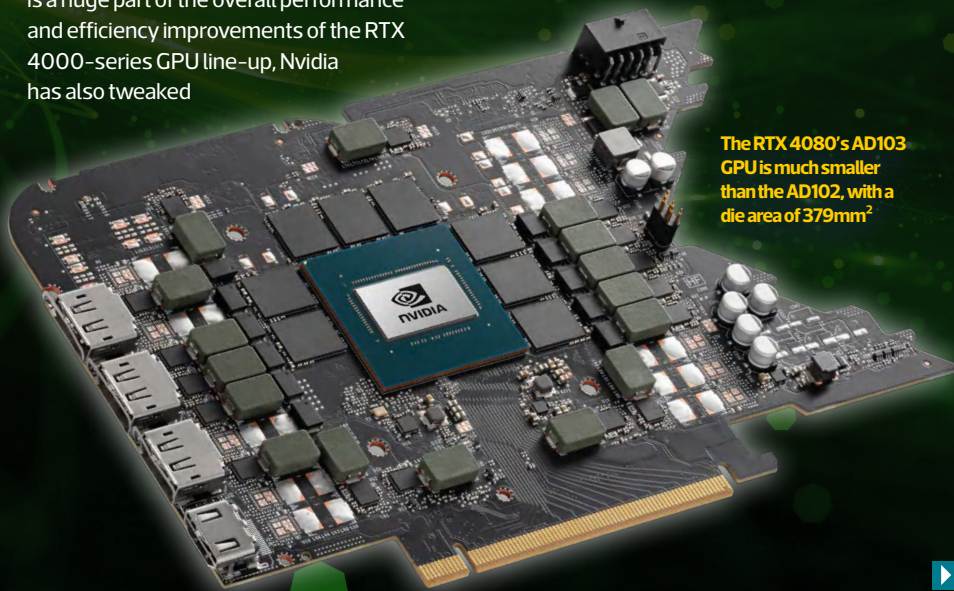
already dropping to a 320W total board power and the now-cancelled RTX 4080 12GB had just a 285W total board power. However, the former still uses the new connector, so you'll need to use the bundled adapter to connect to an older power supply.

THE BUILDING BLOCKS

While the change in manufacturing process is a huge part of the overall performance and efficiency improvements of the RTX 4000-series GPU line-up, Nvidia has also tweaked

clusters (GPCs), each of which contain six texture processing clusters (TPCs) and an accompanying raster engine. In turn, each of these TPCs houses one Polymorph engine (for tessellation and other geometry shading functions) and two streaming multiprocessor (SM) blocks. The latter are arrangements of 128 CUDA cores separated into four further sub-blocks, four texture units and four Tensor cores, joined by one RT core per SM.

CUDA cores are the heart of Nvidia's GPUs. They come in two different types, with some able to process just 32-bit floating point (FP32) operations and some able to process either one FP32 operation or an integer (INT) operation per clock cycle. Combined into two blocks of 16 of each type, these blocks of 32 CUDA cores are delivered tasks in waves, with each block of cores performing



The RTX 4080's AD103 GPU is much smaller than the AD102, with a die area of 379mm²



Based on the smaller AD103 GPU, the RTX 4080 only has 9,728 CUDA cores

the same function on multiple sets of data at once. This enables the efficient parallel processing that's the central tenet of good GPU design.

Each block of 32 CUDA cores is also joined by one Tensor core for performing specialised matrix multiply and accumulate operations – more on this later – along with four load/store units for memory loading and storing operations, and a block of four special function units for performing operations such as sin, cosine, reciprocal and square root. There's also a 16KB register file, L0 instruction cache and the warp scheduler, which distributes the waves of operations to the CUDA cores.

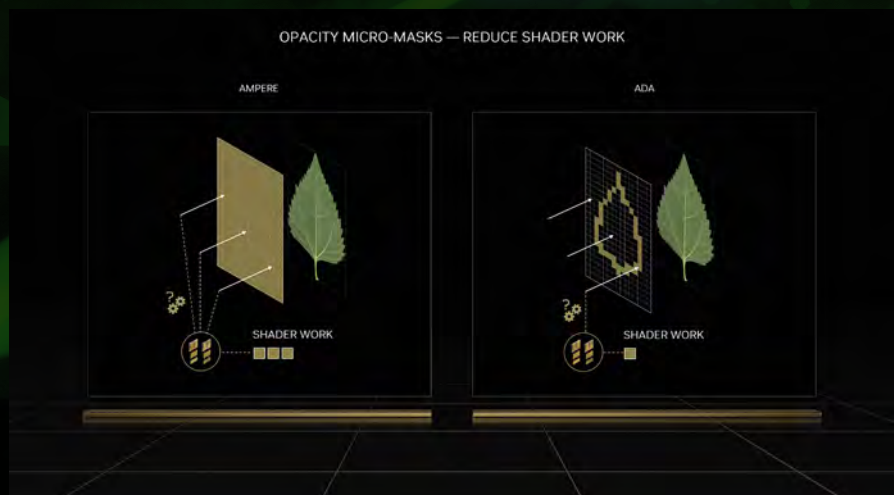
If you zoom back out to look at the whole die block diagram you can see that atop – from a block diagram perspective, not necessarily a physical arrangement perspective – this arrangement of SMs, TPCs and GPCs is the PCI-E 4 interface, the new Optical Flow Accelerator, the NVENC video encoder blocks and the GigaThread Engine. The latter manages the overall schedule of work for the whole GPU.

Compare this arrangement with the block diagram of the Ampere architecture's GA102 GPU, and we can see that the older architecture had this same arrangement of building blocks.

A total of 128 CUDA cores, four Tensor cores and one RT core are combined to form one SM, then two SMs, then add one RT core and a Polymorph engine to form each TPC. Twelve TPCs then go on to form each GPC when combined with a raster engine block.

The most obvious difference between these two chips, then, is that the new AD102 chip houses 12 GPCs but the GA102 contains only seven. As a result, while the AD102 contains 18,432 CUDA cores, 144 RT cores, 576 Tensor cores and 576 texture units, GA102 packs only 10,752 CUDA cores, 84 RT cores, 336 Tensor cores and 336 texture units.

The new Opacity Micromap engine accelerates the handling of alpha-tested geometry





Other obvious differences between the two block diagrams include the size of the L2 Cache. This change in block size is indeed reflective of the massive hike in L2 Cache that Nvidia has packed into the AD102. Whereas GA102 houses 6,144KB of L2 Cache, AD102 has 98,304KB – 16x more.

Nvidia claims this larger cache has benefits across the board but that it's particularly beneficial for complex operations such as ray tracing. Otherwise, that's it for key differences that Nvidia has made public, other than the addition of new RT and Tensor cores.

This month also sees the introduction of Nvidia's new GeForce RTX 4080 GPU (see p14), which uses the smaller AD103 GPU. Based on the same architecture as

the AD102, it has a much smaller 379mm² die, but its count of 45.9 billion transistors is still way in front of the 28.3 billion in the top-end Ampere GA102 chip. At full strength, an AD103 GPU has seven GPCs, 40 TPCs and 80 SMs, giving you 10,240 CUDA cores. However, the RTX 4080 only has 38 of the TPCs enabled, giving you 9,728 CUDA cores.

THE NEW RAY-TRACING CORE

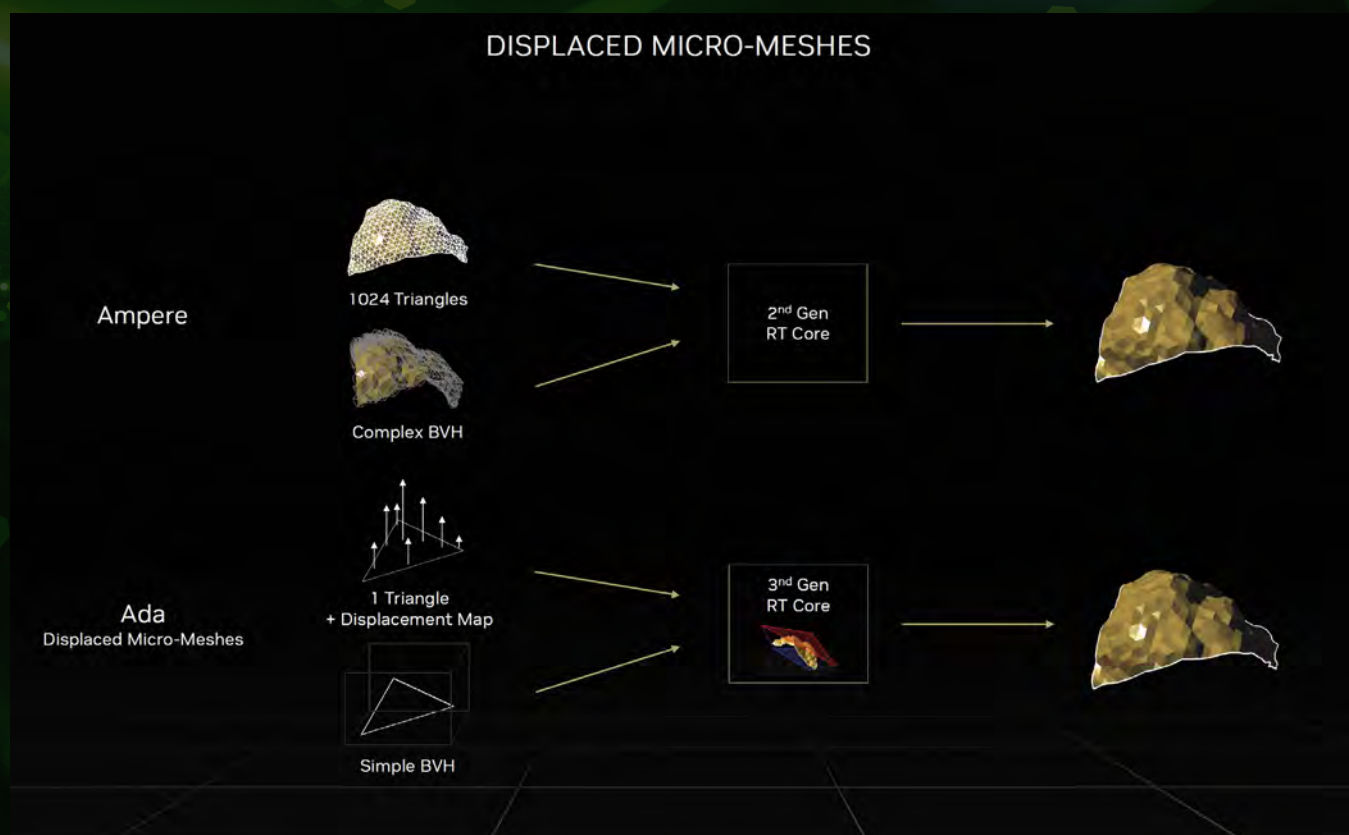
The biggest single block change to the Ada architecture, at least from the point of view of benefits to a user, is the addition of a new 3rd-generation RT core. Like previous iterations of its RT cores, the new versions have a Box Intersection Engine for calculating bounding box ray intersections, and a

Triangle Intersection Engine for calculating triangle ray intersections. However, this 3rd-generation core also introduces two new blocks – an Opacity Micromap Engine and a Displaced Micro-Mesh Engine.

To recap, bounding box intersections are the first step in calculating how rays interact with a scene. In order to keep processing to a minimum, bounding boxes (or volumes) are created around objects (or parts of objects) within a scene, and a bounding volume hierarchy (BVH) table is generated, which defines the order of bounding volumes in the scene. As a result, there might be one bounding volume for a whole building, which then contains multiple bounding volumes defining rooms and a further volume defining an object within that room.

When calculating the paths of a ray, the algorithm first checks whether any rays intersect the outermost/largest volume. If the ray misses the volume, no more work needs to be done for all the objects or volumes within that volume. However, if the ray does intersect with the first bounding

Geometry shading can complicate ray-tracing workloads, but the new displacement micro mesh engine of Ada lightens the load



SHADER EXECUTION REORDERING



Ray-tracing workloads are inherently disordered, making them difficult to parallelise. Shader execution reordering helps to organise things a little better

volume then the ray moves further into the BVH, checking the next intersections with these smaller bounding volumes. Once the full BVH has been traversed, the next stage of the process is calculating the intersection of the ray with the triangles that make up the objects in each intersected volume.

With Ada, the bounding box engine hasn't seen a boost in performance but the triangle intersection engine has been improved, with the new Ada engine boasting a doubling in throughput compared to Ampere.

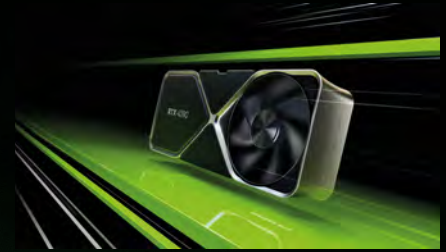
As for those two new blocks, the first of these deals with a specific problem to do with using transparent textures for creating detail on flat surfaces in on-screen objects. Rather than forming complex objects, such as chain-link fences or the hundreds of leaves on a tree out of complex geometry, game engines use flat images (textures) with transparent sections (the gaps in the fence or between leaves) and paste these onto simple flat objects.

That works fine for normal rasterisation tasks, but when you introduce ray tracing, and you have to calculate how a ray interacts with all the fine transparent details of that texture, you end up throwing off the efficiency of the highly optimised triangle intersection accelerator.

The Opacity Micromap Engine, then, takes these textures and forms an opacity micromap from them, which defines the texture as a grid of tiny triangles, each with

an opacity state of opaque, transparent or unknown (the latter is for triangles that are neither fully transparent or opaque). If the triangle is transparent, the ray intersection can be ignored. If it's opaque, a hit is recorded and returned. Finally, if it's unknown, control is returned to the SM for further shader work to be undertaken.

The key to this micromap is that it allows the triangle intersection engine to treat most of the transparent texture in the same manner it treats other solid-object triangles, so it can rattle through the calculations quickly. Without this ability, further shader operations are required that interrupt this efficient process. Nvidia says it has observed up to 'a doubling of scene



traversal performance in applications with alpha-tested geometry', but points out that the performance advantage is very scene dependent.

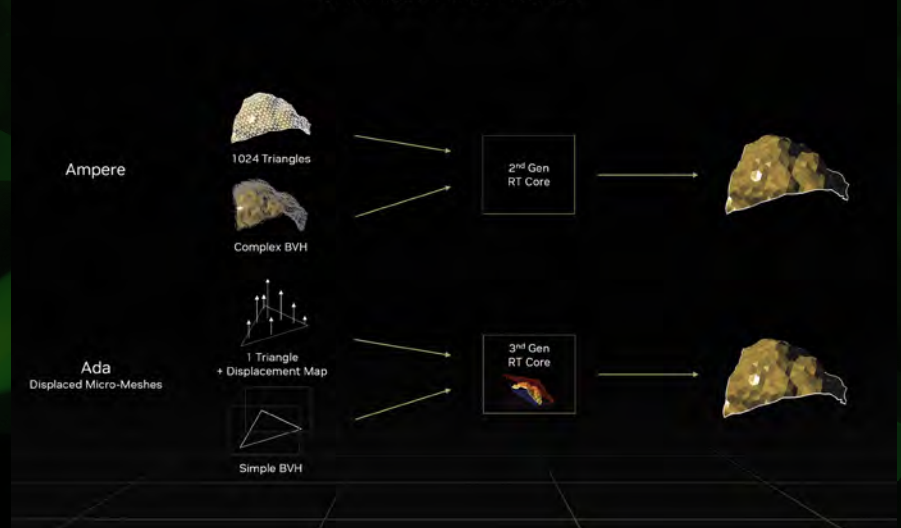
As for the Micro-Mesh engine, this deals with the complication that arises from using tessellation. This is where a simple version of a 3D object is used for some parts of the graphics pipeline, and then extra triangles are added to the object later to add more detail, using techniques such as displacement mapping.

These extra triangles greatly increase the complication of the bounding volume hierarchy (BVH), so the micro-mesh engine recognises where tessellation has occurred and uses the simpler form of the model to calculate a baseline of how rays interact with it. It then moves on to using the full complex model for the next stages of rendering the scene.

The upshot of the Micro-Mesh engine is significantly faster generation of the BVH and a significant reduction in the complexity

The micro-mesh engine recognises where tessellation has occurred and uses a simpler form of the model to calculate a baseline of how rays interact with it

DISPLACED MICRO-MESHES





and size of the BVH. In three examples Nvidia has provided, the BVH generation was on average 10x faster and 11x smaller than without the Micro-Mesh engine.

The upshot of these ray-tracing improvements is that Nvidia extends its already considerable lead over AMD when it comes to ray-tracing performance. AMD's

advantage over performing the same functions using the general-purpose compute units (CUDA cores) of the GPU.

AMD, in contrast, doesn't have such dedicated cores in its current GPUs, although its forthcoming RDNA3 architecture does feature a new AI accelerator core, two of which will be found in each compute unit.

THE BOUNDING BOX ENGINE HASN'T SEEN A BOOST IN PERFORMANCE, BUT THE TRIANGLE INTERSECTION ENGINE HAS BEEN IMPROVED

upcoming RDNA3 architecture boasts a 1.5-1.7x improvement in ray-tracing performance over RDNA2, but that probably isn't even enough to close the gap between RDNA3 and Nvidia's older Ampere architecture.

THE NEW TENSOR CORE

Another area where Nvidia holds a distinct advantage over AMD's current graphics architecture is in having hardware for matrix multiply and accumulate operations, which are commonly used in AI and high-performance computing applications.

The Tensor cores in the company's existing architectures are dedicated to these functions and hold a huge performance

advantage over performing the same functions using the general-purpose compute units (CUDA cores) of the GPU. AMD, in contrast, doesn't have such dedicated cores in its current GPUs, although its forthcoming RDNA3 architecture does feature a new AI accelerator core, two of which will be found in each compute unit.

Back to Nvidia, the new Tensor cores in the Ada architecture deliver more than double the FP16, BF16, TF32, INT8, and INT4 performance (measured in the distinctly non-standard unit of Tensor TeraFLOPS) of the previous Ampere architecture. The company's Hopper FP8 Transformer Engine for accelerating the training of AI has also been added, delivering over 1.3 PetaFLOPS of tensor processing in the RTX 4090.

The significance of this for most home users will be modest, as despite Nvidia's efforts to suggest tools such as DLSS require Tensor cores for on-the-fly AI calculations, very few gaming workloads take advantage of Tensor cores.

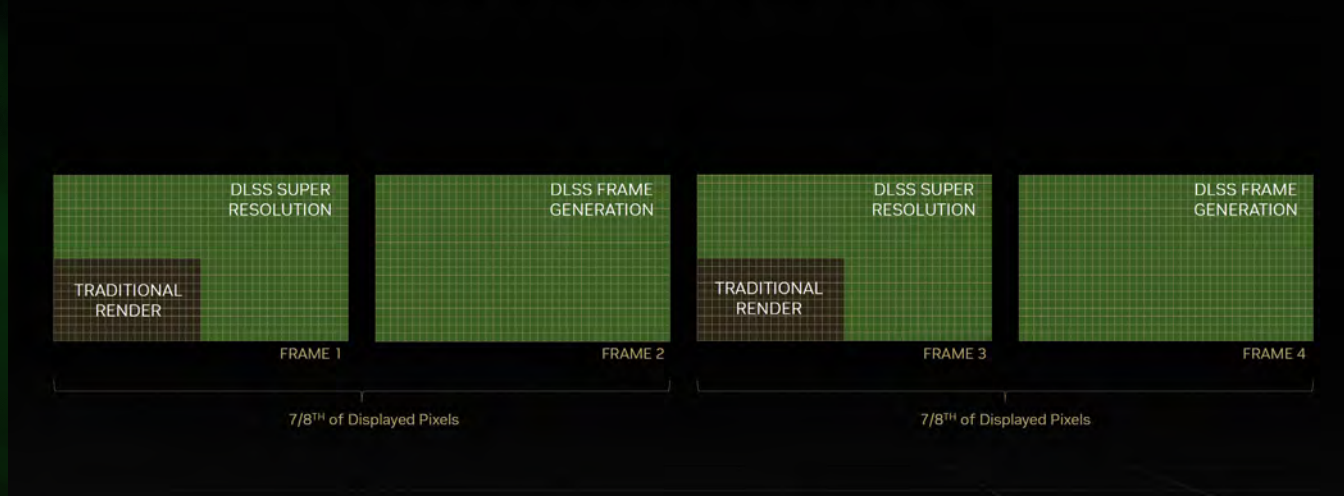
Cyberpunk 2077's new Overdrive mode gets a performance boost from Shader Execution Reordering

SHADER EXECUTION REORDERING

Two of the biggest new features to arrive with the Ada Lovelace architecture are software features that Nvidia has provided for developers. The first of these is Shader Execution Reordering (SER), which looks to solve the problem of GPUs being best suited to running a single function across multiple pieces of data, which causes problems when you introduce ray-tracing workloads, which inherently result in unordered, jumbled up workloads.

The reason for this disorder is that ray tracing works by calculating the paths of rays of light interacting with the surfaces of objects in a scene, and while the first stream of rays and their surface collisions can be calculated in parallel batches – because they all have the same starting point and direction, so they tend to meet the same surface in order – for subsequent bounces of each ray, they could all be going off in completely different directions, depending on the surface with which they interact.

SER, then, allows a developer to step in and, instead of having the second ray bounce calculations performed in the same order as the first bounces – and as a result, potentially be invoking all manner of

DLSS 3 RECONSTRUCTS 7/8TH OF DISPLAYED PIXELS

Combine DLSS 3 with DLSS 2, now called DLSS Super Resolution, and the GPU only needs to render 7/8ths of the pixels displayed on the screen

different shader operations, depending on the secondary surface with which the ray is interacting – they can reorder the second bounce calculations to be performed in clusters, based on the second surface the rays are hitting.

This then means the GPU can more efficiently invoke the shader operations for that surface on several of the rays at once, before moving onto a different shader operation for the next surface and its set of ray interactions.

According to Nvidia's figures, SER can provide up to a 2x performance improvement for ray-tracing shaders with high levels of ray divergence. As a real-world example, it says Cyberpunk 2077 can benefit to the tune of up to 44 per cent faster performance when running with the game's ray tracing set to its forthcoming Overdrive mode.

DLSS 3 AND OPTICAL FLOW ACCELERATION

The final major piece of the Ada puzzle is the introduction of deep learning super sampling 3 (DLSS 3), which ... is not a good name for this new technology.

You see, DLSS 3 is not a super sampling technique (deep learning or otherwise) for upscaling lower-resolution game

There are significant performance gains to be had by enabling DLSS 3

output to look better on higher-resolution screens. Instead, it uses similar AI-derived image generation techniques to DLSS 2 but to create entirely new frames. It's so unrelated to DLSS 1 and 2 that you can even enable DLSS 3 without lowering

frame to generate a guess at a new version of that frame. So, rather than increasing your game's frame rate by reducing the initial workload of the graphics card, and upscaling the output, DLSS 3 instead keeps your graphics card working at full pelt to generate

IT'S SO UNRELATED TO DLSS 1 AND 2 THAT YOU CAN EVEN ENABLE DLSS 3 WITHOUT LOWERING THE OUTPUT RESOLUTION OF YOUR GAME

the output resolution of your game – no upscaling will be happening at all, just extra frame generation.

The technology uses motion vectors from the game (a measure of how objects and the view were moving when the current frame was generated), and the previous output

the best initial image quality, but then provides a smoother-looking experience by upping the frame rate with 'fake' frames.

It's an interesting twist on the idea of AI frame generation and the performance uplift is striking. In our own testing with the GeForce RTX 4090, we saw Cyberpunk



DLSS COMBINES MOTION VECTORS & OPTICAL FLOW FOR ACCURATE MOTION ESTIMATION



DLSS 3 uses motion vectors from the game engine, as well as optical flow data from analysing existing frames, to predict how the next frame of an image will look

So, if your game's running at 30fps, each generated frame is shown for a very noticeable 33ms, whereas at 120fps, you're only seeing a 'bad' frame for 8ms.

As a result, you still get the benefit of a smoother frame rate to help you better judge your aim, or the braking point for a corner, for instance, without constantly being thrown by incorrect image artefacts.

DLSS 3 can also reduce the load on your CPU when you're playing games with high frame rates – as the CPU's essentially not doing anything for half the frames. As such, there's potential for some gamers to find a better overall performance balance by turning on DLSS 3, if their CPU is proving a bottleneck. Games such as Microsoft Flight Simulator are cited as examples where a fast, smooth frame rate are required along with a lot of CPU work.

While DLSS 3 is mostly a software system, like previous DLSS implementations, it takes advantage of Nvidia's dedicated Optical Flow Accelerator engine, which is essentially a refined version of the optical flow accelerators used to encode and decode video. Despite these being present on previous RTX cards, though, for now DLSS 3 is being restricted to only working on RTX 4000-series cards. Here's hoping Nvidia adds support for older cards too in the future. **CPC**

2077 leap from a 68fps average at the Medium ray-tracing preset with DLSS 2 on its Balanced setting, to 118fps with DLSS 3 and a preview build of the game's new Overdrive ray-tracing mode. That compares to only 46fps on the RTX 3090 Ti using the Medium ray-tracing preset and DLSS 2 in Balanced mode.

The downside to DLSS 3 is that, just as with previous versions of DLSS, the performance uplift comes with some image quality compromises. Fast motion can throw off the frame generation predictions, creating blurred details and halo effects around moving objects. Drastic changes in image,

such as your view moving from out behind a wall, can result in completely garbled, made-up images that are half wall and half the view beyond.

A key positive with this technology, though, is that while these effects are more prevalent in fast-moving game types, such as first-person shooters or racing games, they become inherently less noticeable as the frame rate climbs.

That's because, unlike DLSS 2 where every frame is affected by the upscaling, with DLSS 3 you can potentially still see normal, unaffected frames (assuming you run DLSS 3 at native resolution) interspersed with what can sometimes be iffy-looking fake frames, so as the frame rate increases, the time that each 'bad' frame is shown decreases.

DLSS 3 allows for the creation of entirely new frames to fit between fully rendered conventional frame, for an increased overall frame rate

FRAME GENERATION POTENTIAL Animation Smoothness | Overcome CPU Bottlenecks | Amazing RT Effects





LIGHTS ALIVE:

A PC ENTHUSIASTS' GUIDE TO RGB LIGHTING

ANTONY LEATHER PROVIDES SOME ILLUMINATION ON THE OFTEN CONFUSING WORLD OF RGB LIGHTING

As you probably already know, an RGB lighting strip is made up of LEDs that can display red, blue and green colours, mixing up a bit of primary school science to create other colours. That means these LEDs can display an almost unlimited number of colours, while older LEDs could only display a single fixed colour.

This flexibility isn't just for creating pretty rainbow effects though. It's useful for transferring your RGB lighting components from an old PC to a new one with a different colour scheme, and also enables you to match that new colour scheme exactly instead of using a generic red or green. Of course, if you've seen PCs on Instagram or TikTok, you'll notice the other benefits of RGB lighting too, such as effects you'll be seeing for days when you close your eyes.

It's not limited to standard lighting strips either, as motherboards, graphics cards, cases and all manner of third-party accessories offer ways to illuminate your PC. The sheer number of connectors, standards and control systems can make RGB a highly confusing field, though, especially if you want to coordinate lighting across components made by several manufacturers. Over the next few pages, we'll be discussing the various connectors, ecosystems and accessories in order to give you the knowledge you need to build an RGB PC that cooperates with your needs.

WHY IS IT CONFUSING?

There are several issues with RGB lighting that can make it confusing in terms of connecting various components together,

and synchronising colours or lighting effects. The first comes from the different standard connector types. There are two key types of RGB connectors catering for the two standards, and both are now common on most motherboards.

The original 12V connector has four pins, while the newer and more capable 5V connector has three pins. A 12V 4-pin RGB accessory can only display a single colour at any one time. For example, a 12V 4-pin LED strip can tap into the entire RGB colour spectrum, but will need to show that colour across all its LEDs at the same time. This means it's unable to offer fancy rainbow lighting effects or allow you to control individual LEDs.

The 5V 3-pin connectors, also known as digital or ARGB, indicate devices that allow



On the left is a 5V 3-pin RGB connector. The fourth hole is blocked, which means it's impossible to connect it to a 12V 4-pin header

you to control individual LEDs. This could be on an LED strip or memory module, perhaps with a moving strobe or rainbow effect, or

DON'T KILL YOUR RGB DEVICE – READ THIS FIRST!

Always read the instructions. We say this because, in some situations, it's possible to hook up an RGB device to the wrong port and put 12V through a 5V device, which will usually fry it. This is rare, but we've seen plenty of devices that either require specific adaptors or, more worryingly, have a full 4-pin connector with four working pin holes, when actually it's a 3-pin device and connecting it to a 4-pin RGB header will result in disaster. Usually 3-pin connectors will have the unused port blocked off, so it's impossible to connect it to the wrong header.



connectors also have 3-pins, they look like the older 12V connectors, except with one pin removed in the centre.

Gigabyte, though, has had the three pins sat next to each other, so you can't plug normal ARGB devices into Gigabyte motherboards without an adaptor. Thankfully, these are often included, and modern Gigabyte motherboards either include both types of ARGB headers or only the more

manufacturers using their own connectors. The likes of Corsair, NZXT, Phanteks and Thermaltake often have their own ecosystems and proprietary connectors, which only work with their own hardware and lighting controllers. This can help to keep your setup simple – for example, with Corsair's iCUE software, plugging in Corsair components means the software has been tested with all of them.

However, it also means that simple devices such as LED strips with standard 4-pin 12V or 3-pin 5V connectors can't be used with these controllers out of the box, and they're not compatible with other ecosystems either. Want to use that Phanteks Halos RGB fan frame with a Corsair lighting controller? Well, sadly you're out of luck.

There are ways around this in some instances, though, such as using adaptors

A proprietary connector on Thermaltake's Toughfan 12 RGB kit. This sends fan speed and lighting information over a single connector

FOR STARTERS, THERE ARE TWO TYPES OF ARGB CONNECTORS AND THEY'RE NOT COMPATIBLE WITH EACH OTHER PHYSICALLY

having a purple colour blend into blue or green across the rest of the LEDs. These ARGB devices are usually the ones to buy, as you get the best of both worlds. You have the ability to set all LEDs to a specific colour, but also to apply all manner of lighting effects and control individual LEDs if you want.

That sounds simple enough – just two connectors with one offering more control – but it's not quite that simple. For starters, there are two types of ARGB connectors and they're not compatible with each other physically. Gigabyte has often used a 3-pin ARGB connector, but while standard ARGB

common type. Adaptors converting one to the other are also available, while many third-party lighting accessories include them too.

The situation is made worse, however, thanks to RGB lighting accessory



Most motherboards are equipped with both 12V 4-pin and 5V 3-pin headers to control both types of lighting





Adaptors are available to convert proprietary connectors to standard 3-pin ones

to convert these proprietary connectors to standard 3-pin or 4-pin RGB connectors. After all, the underlying technology is the same (as long as you're using the right voltage), and if you chop off the connectors and hardwire two 3-pin devices together, for example, they'll work fine, as long as you get the cables the right way around. These adaptors can often be found on eBay or Amazon and don't cost much.

RGB ECOSYSTEMS

Modern RGB devices are complicated, with some components, such as memory modules, communicating over the system



LED lighting strips offer a simple and effective way to illuminate your PC

adaptors to work or, where they're not available, you'll have no option except to run devices in isolation without the ability to synchronise lighting effects.

Thermaltake's components are often prime examples. Its new Toughfan 12 RGB fan kit, for example, has proprietary connectors for its fans, which combine PWM signals and lighting control, and there are no

especially 12V 4-pin and 5V 3-pin ones, are the same, it's a simple matter of sticking a proprietary connector on one end and a standard connector on the other end, and you have an adaptor.

These will allow you to connect standard devices to otherwise closed ecosystems, and the adaptors are available for the likes of Corsair, NZXT and Phanteks devices too. They're available for a few pounds and some manufacturers, such as Phanteks, actually offer adaptors themselves.

THERE'S NOTHING WRONG WITH A CLOSED RGB ECOSYSTEM, BUT BE AWARE OF ITS LIMITATIONS WHEN IT COMES TO ADDING OTHER HARDWARE

management bus rather than using cables. Corsair's iCUE software works flawlessly with its memory modules, as well as its other unique devices, such as keyboards, mice and headsets, and to some extent that's because it's part of a closed ecosystem.

That said, it has begun to open up to other component makers. Some of its lighting controllers offer standard 3-pin headers, even though Corsair's own RGB lighting strips still use its proprietary 3-pin ones. This at least allows you to connect third-party fans or LED strips to its components and control them using its software, and to synchronise lighting effects across components too. Corsair also allows for control over certain motherboard RGB headers and on-board lighting, such as those from Asus, although it's a little haphazard.

The downside, of course, is that some components either require additional

adaptors available for them to hook them up to standard connectors, nor to connect other devices to the included controller. Its software allows for some other devices to be connected, from the likes of MSI or Razer, but that's about it.

In short, you need to research your potential purchases very carefully. There's nothing wrong with a closed RGB ecosystem, but be aware of its limitations when it comes to adding other hardware if you want to avoid disappointment.

BEAT THE MANUFACTURERS

Ecosystems are all very well, but their primary purpose is to force you to use a manufacturer's own hardware, often at inflated prices compared with standard RGB lighting strips or other accessories. However, there are ways around these limits. As the voltages and pinouts for RGB devices,

GETTING STARTED

You need two components for RGB lighting – a controller and the actual lighting components. The controller can be your motherboard, with most models offering RGB lighting control through 12V 4-pin or 5V 3-pin connectors, along with the manufacturer's own software. If you buy an RGB LED strip that's either 3-pin or 4-pin, it



The Phanteks Digital-RGB Starter Kit gives you all the essentials



Lian Li's Uni fans can be daisy-chained together

should work with your motherboard with no other hardware required.

The next step up is to buy a separate controller, and a model such as Phanteks' Digital-RGB Starter Kit is ideal, as it includes all the gear you need, as well as adaptor cables to control the included LED strips from a standard 5V 3-pin header instead of the included controller, which is fairly basic. However, the kit has the potential to control an entire PC's worth of lighting.

TYPES OF ACCESSORIES AND COMPONENTS

You might think RGB lighting is all about LED strips, and to some extent that's true. Strips offer the easiest and most effective way

Corsair's iCUE LC100 kit



to illuminate your PC, but PC lighting has moved on quickly, with even more elaborate products now available. RGB lighting on fans doesn't just stick to the centre hub, for example, but can include the rear of the fan or, in the case of Thermaltake's Toughfan 12 RGB, the frame itself.

If you prefer the look of diffuse light strips to glaring LEDs, then Phanteks' Neon Combo set includes lengths of digital RGB strips, with opaque covers that provide solid-looking lengths of colour you can bend around your case or components.

Meanwhile, Corsair's iCUE LC100 mimics popular traits on social media for patterned shapes of RGB lighting, except here they're miniaturised into triangles that can fit onto flat surfaces or around edges.

Graphics cards have sported RGB lighting for a while, and the latest models have even made it their party piece, such as the flamboyant GameRock models from Palit.

Unbelievably, there are even ways to illuminate your power cables too, designed to sit between the end of your PSU's cables and your components, courtesy of Lian Li's Strimer kits.

DAISY CHAINING IS YOUR FRIEND

Another issue with RGB lighting is the number of cables it can necessitate. This can result in hideous amounts of spaghetti in your case, which can be a nightmare to route and tidy away. However, manufacturers are aware of this issue, and many components can be daisy-chained together in order to reduce cable clutter.

Taking this one step further, Lian Li's Uni Fan kits do away with cables nearly altogether, with its fans sporting clip-together

designs that allow contact pads to press together, sending fan speed and RGB signals between them. You could connect several fans in series, but use a single RGB cable to control all of them. This also makes installing the fans much easier than usual, as you have a single object to secure, rather than several.

WHERE TO PUT YOUR LIGHTS

Securing RGB lighting components is usually straightforward, as the components often have adhesive pads, Velcro or securing mechanisms to fix them in place – some are also magnetic, which is ideal if you have a steel case. The location of your RGB components is critical if you're to achieve the desired effect, whether it's to colour-match the lighting to your case and components, or simply to illuminate it.

Fans generally don't do that well at illuminating large spaces, so it's pointless installing RGB fans behind a closed front panel if there's no mesh in the front through which they can shine. Having an RGB fan in the rear fan mount, though, is often the first location people opt for, as it's clearly visible through a windowed side panel.

Typical LED strips can be placed anywhere, but to avoid them glaring at you constantly, it's best to place them in the roof of the case, or in the front, so they illuminate your case without being directly visible. Placing them at the rear of the case can look great, though, as they'll shine forwards to face you. Ultimately, RGB lighting is about expression, so don't be afraid to test-fit your lighting in different locations to see what looks best to you. **GPB**

The roof of your case is a great location for your LED strips, where they can illuminate your case without blinding you on a daily basis





GARETH HALFACREE'S

Hobby tech

The latest tips, tricks and news in the world of computer hobbyism, from Raspberry Pi, Arduino, and Android to retro computing

REVIEW

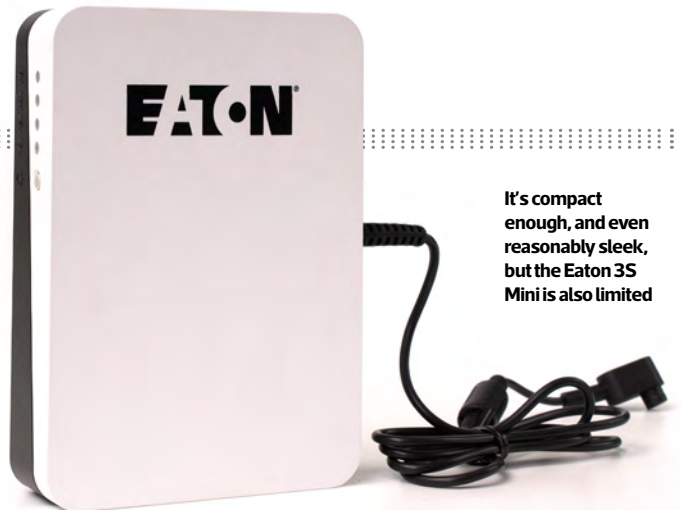
Eaton 3S Mini UPS

Uninterruptible Power Supplies, or UPS units, are useful gadgets – power goes in one end, hits a battery and comes out of the other – and in the event the power stops going in, the battery takes over. They're a staple of the data centre industry, and not an uncommon feature in home offices either.

Most, though, are bulky. Many are designed to live in 19in racks, and the models targeted at small or home office use sometimes mimic multi-gang trailing sockets but are noticeably bulkier.

It's no surprise – inside each of them is a hefty sealed lead-acid battery and enough circuitry to turn incoming mains-voltage alternating current (AC) into 12V direct current (DC) to charge the battery, then turn the battery's 12V DC output back into at least an approximation of mains-voltage AC again.

The Eaton 3S Mini is different. First of all, it's small, as the name implies. Measuring just 95.5 x 136 x 30mm, it's roughly the same size as a chunky external hard drive. It also makes no attempt to output alternating



It's compact enough, and even reasonably sleek, but the Eaton 3S Mini is also limited



One of the smallest UPS units around, can Eaton's 3S Mini deliver?

current, at mains voltage or otherwise. Instead, it puts out direct current, vastly simplifying the circuitry inside.

The Eaton 3S Mini is effectively two products in one. It's designed to entirely replace the existing power supply for a range of equipment, from network switches and routers to IP telephones and cameras – almost, but not quite, any device you could expect to run from a DC power brick.

It's also a UPS, of course, thanks to a pair of 3.7V 2.2Ah lithium-ion batteries housed



The incoming mains cable is replaceable, unlike the DC output cable

within it. Under normal usage, these batteries charge themselves from the mains and then sit there doing nothing; when the power's cut, they kick in and keep the connected device ticking over until power can be restored.

Until the batteries run out, of course.

Eaton claims a 120-minute runtime, based on an average device, although this can be pushed to a claimed five hours for low-power gadgets or as little as 40 minutes for one stretching the limits of the Eaton's 36W power delivery capabilities.

To benchmark the company's claims, the Eaton 3S Mini on test was connected to a VDSL router configured as a wireless access point – advertising its network but sitting largely idle. On a full charge, the UPS managed to keep it running for around 75 minutes after the power was cut – not quite as high as the company's claims, but enough to keep going during minor power cuts.

There are a few caveats to the device's use, though, starting with its compatibility. Eaton rates the 3S Mini at 36W, and allows it to output four voltages through a selection switch at the side: 9V, 12V, 15V and 19V. Most voltages can deliver up to the full 36W, but for 9V devices, the UPS is rated at 3A for a maximum output of 27W.

That may not be enough, as many higher-end routers and wireless access points are now being shipped with 12V PSUs delivering over 3A, making the Eaton 3S Mini underpowered. That doesn't just mean cutting short the time it can protect the device from power loss, but also potentially browning-out the router itself, crashing it at times of high load.

Another issue is the UPS has only a single output, which is moulded into place and not user-replaceable if you'd prefer one that's shorter or longer, or if you end up damaging the stock wire. The end of the cable is



LEDs are the only notification system on offer

designed to accept one of the four barrel-jack power connectors bundled, but while the four cover most common power jack sizes, they're not universal and can only be installed in centre-pin positive alignment.

There's also a noticeable lack of monitoring capability. A network, USB or serial connector like a grown-up UPS is perhaps too much to ask, but there's no audible alert on power loss either. Four LEDs at the side, which normally show the selected voltage, switch to provide a 100–75–50–25 per cent readout of the remaining battery, but that's as far as it goes.

The biggest missed opportunity, aside from a power-only USB port for driving a single-board computer or IP camera, is the lack of wall-mount capabilities. Clad in relatively discrete two-tone plastic, the Eaton 3S Mini is ideal for putting next to an Optical Network Terminal (ONT) in a fibre-to-the-premises installation, but there's no way to fix it to the wall. It's light enough, at least, so 3M Command Strips can do the job.

Available at a price of £46.15 inc. VAT from amazon.co.uk, the Eaton 3S Mini is a lot cheaper than a 'real' UPS. However, unless you're powering relatively lightweight devices for only short periods, it lacks the grunt you need for true peace of mind.



NEWS IN BRIEF

Hardkernel relaunches ODR0ID-H family

Hardkernel has announced the reboot of its ODR0ID-H range of x86 single-board computers, launching the ODR0ID-H3 and ODR0ID-H3+ with Intel Celeron N5105 and Pentium Silver N6005 processors respectively. 'It is more powerful, offers higher performance and comes in two brand new models,' Hardkernel's Lisa Park claims of the new range, adding that there's 'a configurable Unlimited Performance mode allowing the CPU to run in sustained turbo boost mode'.

The compact machines are provided without memory, supporting up to 64GB across two DDR4 SODIMM slots, with pricing starting at \$129 US (around £114 ex VAT) on hardkernel.com/shop now.



The device is good to power a range of devices, but not high-end routers

REVIEW

Keyboardio Model 100

It can take a little while to get accustomed to using split keyboards, which promise an ergonomic typing experience by keeping your wrists at a more natural angle than standard keyboards. A relatively sedate design, as on the Keychron Q8 Alice (reviewed in Issue 231), can be learned pretty quickly; a more aggressive design, such as

Keyboardio's Atreus (Issue 211), is a bigger challenge. And then there's the Model 100.

Keyboardio's latest open-source keyboard design is the successor to the original Model 01 – the keyboard from which the company derives its butterfly logo. Not only is the layout split, but the keyboard itself is split too – more on this later.

The Model 100 is designed to turn heads. The enclosure is finished in wood – the buyer's choice of walnut or maple – rather than plastic or aluminium, and the keycaps are custom-designed specifically for the keyboard. The layout also curves in three dimensions, with a swooping cluster positioned under the thumb providing access to modifiers, Space, Super and Backspace. Then there's Fun.

Like the Atreus, which was designed for portability, the Fun button is designed to switch between layers – it makes up for the reduced number of physical keys by allowing the user to define multiple functions for each key, switching up and down layers



The two halves can connect with any straight-through RJ45 network cable

as required. Here, though, the Fun button is positioned out of reach of fingers and thumbs, so you can push it down with the body of your hand instead, keeping your digits positioned on the traditional keys.

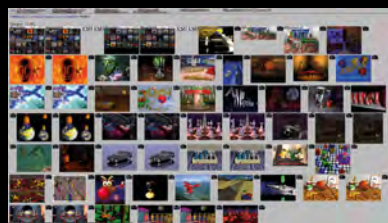
Underneath the custom keycaps are RGB LEDs for backlighting, which shines clearly through the carefully constructed markings. Lift a keycap and you reveal hot-swappable mechanical switches, which can be replaced at will without soldering – our sample came equipped with clicky Kailh Box White switches.

NEWS IN BRIEF

Textfiles.com serves 133 million vintage files

Digital archivist Jason Scott has announced a new feature on **Textfiles.com** called DiscMaster. It's a search system for vintage computer files uploaded to The Internet Archive, and provides access to over 133 million files at the time of writing. Scott describes it as an 'experimental website to browse and search vintage computer files from **archive.org**,' adding that 'thousands of new files are added daily'.

Pulling individual files from CD-ROM and floppy disk images, the site offers images, text files, audio files, video files, executables and nearly nine million files categorised simply as 'unknown'. The site can be accessed online now at **discmaster.textfiles.com**



This wooden-cased split beast isn't your average keyboard



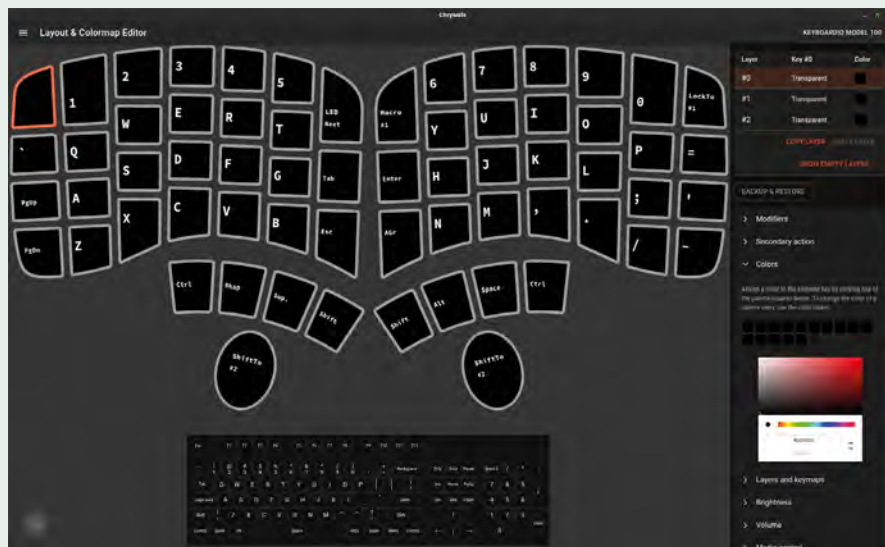
The carry case is of a high quality, but there's no room for the spider stands

What makes the Keyboardio special, though, is its split design. The keyboard is built as two halves, a left and a right, connected via an RJ45-terminated cable – two lengths are supplied, with any network cable serving in a pinch. If you wanted to have the two halves at opposite sides of a room, you could just thread a long enough cable between them and it's a possibility, although having them no further apart than your outstretched arms is a better idea.

Flipping over the two halves reveals two mounting options. The first is a slide rail, designed for use with bundled clips – using these, you can clip the two halves together to make a single fixed keyboard. The second is a tripod-style screw point, which accepts the bundled 'spider' feet.

Made of plastic with a foam base, the angled feet are designed to spin before being screwed into place. Depending on the angle to which you spin them, they tilt the keyboards one way or another – allowing for a smooth adjustment, you can 'tent' them from a low outside to a peaked middle, or lean them towards the user, away from the user, or even in a 'valley' shape, which can't be recommended as a comfortable way to type.

If this near-infinite level of adjustment, combined with the ability to position the halves at any distance, isn't enough, there's an even more radical idea. During the keyboard's crowdfunding campaign, Keyboardio showed a beta user attaching the



Chrysalis offers plenty of customisation, making good use of those Fun buttons

two halves to camera slings hanging from a belt, turning the Model 100 into a wearable device for typing on-the-go.

Speaking of being on the move, the company has – as with the Atrous – bundled a high-quality travel case, along with a few extras: the sliding clips, two lengths of RJ45 cable, a USB Type-C cable, a key puller, spare switches and a screwdriver – the latter is to encourage investigation of its open-source innards. Its only negative is that there's no room inside for the spider feet, which need to be carried separately.

Customisation is handled via the open-source Chrysalis, available for Linux, macOS and Windows. It's smooth and easy to use, although a firmware bug with launch models needs to be patched when the software prompts you, in order to avoid settings corruption.

The Model 100 isn't for everyone, or even for most people. It's not ideal for portability, as once ensconced in the travel case it's pretty bulky. There's no wireless support, and the layout will slow you down considerably unless you're willing to put in effort to learn it.

But for those looking for a premium keyboard, who find off-the-shelf designs limited and rival split keyboards lacking in adjustability, there's nothing like the Model 100 available – except the long-discontinued Model 01.

The only final hurdle, then, is the price. At \$349 US (around £310 ex VAT) from



A few bonuses are provided, including a cheap but usable screwdriver

shop.keyboard.io, the Keyboardio Model 100 sits at the upper end of the keyboard market, beaten only by radical ergonomic designs aimed at the enterprise market. The quality certainly befits the price, but it will be hard to stomach for anyone who isn't sure they'll take to the novel layout. **GPC**



ANTONY LEATHER'S

Customised PC

Case mods, tools, techniques, water-cooling gear
and everything to do with PC modding

Noctua's NA-TPG1 AM5 thermal paste guard

AMD's Ryzen 7000-series CPUs offer a huge step up in performance compared with Ryzen 5000-series chips, and you're even able to use Socket AM4 coolers on the new Socket AM5 chips, as long as they don't use a custom backplate – thankfully, that exclusion only affects a handful of coolers and waterblocks. A large part of the reason this cooler compatibility was made possible is the design of AMD's new CPUs themselves.

The heatspreader on Ryzen 7000-series CPUs has a unique look, with lots of notches around the edges. If you're wondering why AMD went with this design, it's largely down to keeping the CPU socket to a similar size as AM4. Adding the notches enabled AMD to place extra chips onto the CPU substrate, instead of making the CPU package bigger, and you can clearly see the notches are filled with these extra chips.

These chips in the notches are one reason I wouldn't want to use electrically conductive thermal paste on a Socket AM5 CPU, but a more annoying issue is that they're also great traps for any type of thermal paste.

This issue was raised the instant we saw the new heatspreader design, and sadly I can confirm that thermal paste does indeed readily find its way into those notches. It happens as you install your CPU cooler, with the pressure squeezing any excess out the sides, with any rotation of the CPU cooler during installation, or when you remove



Place a Noctua NA-TPG1 guard on top of your Socket AM5 CPU while it's in the socket, before you apply any paste

it, making matters worse. It can also happen when you clean paste off the CPU afterwards.

If you just install your cooler and CPU once, you may not need to worry, especially if you nail the minimum amount of thermal paste required too. However, if you swap out your cooler or motherboard for an upgrade, or otherwise do this regularly, then it compounds the problem. It's been a real issue for me testing Socket AM5 motherboards, as I reapply thermal



Noctua's NA-TPG1 thermal paste guards aim to prevent thermal paste from spilling into the notches around the heatspreader

paste each time and if I don't completely clean the CPU and cooler, the thermal paste builds up.

Other CPUs are easy to clean, as their heatspreaders have square edges, but cleaning Ryzen 7000-series CPUs is much more time-consuming. There are also gaps around the edges of the heatspreader on AM5 CPUs, which can allow thermal paste to get under it. I was thinking of ways to prevent thermal paste from going in places you don't want it on these CPUs, but before I could put my ideas to the test, Noctua came up with a solution called the NA-TPG1 or thermal paste guard.

The press kit I received includes three guards, but retail kits will include cleaning wipes too. The guards are thin plastic sheets that sit over the CPU and hug the edges of the heatspreader, sitting on top of it once you've installed it

into the socket and closed the latch. As it sits nearly level with the heatspreader, it prevents thermal paste from slipping down over the sides of it and into those notches.

I applied the usual cross pattern of thermal paste and installed a cooler, then removed it a few minutes later to allow the paste to spread. The guard actually came away with the cooler when I removed it, stuck to it with thermal paste, but the CPU didn't have any thermal paste in those notches, despite the cooler being rotated a little during installation.

Suspecting that the clean-up process would result in thermal paste getting into the notches, I applied a fresh guard on top of the CPU and then cleaned it and this worked well. Critically, doing the same but without guards saw thermal paste enter the notches, and even more



Remove the cooler and you'll find no thermal paste has crept into the notches around the heatspreader

ended up in these areas when I was wiping off the paste afterwards.

The guards work, but you'll need to make sure your kit includes a couple of guards, so you can apply another one if needed. The kit is reasonably cheap at around £7 inc VAT, and should be available in the UK by the time you read this.

My favourite new CPU? Intel's Core i5-13600K

Raptor Lake has landed, and while LGA1700 doesn't exactly have a long lifespan ahead of it, the power in single-threaded and multi-threaded applications on offer with Intel's 13th-gen CPUs is excellent, so you won't be needing an upgrade for quite a while anyway.

A Core i5 chip should offer decent bang for your buck. It's where you'll end up pointing your wallet if you're stepping up from a low-end CPU and want more grunt in all departments, but without spending a fortune. K-series Core i5 chips have historically been overclockable too, although Intel and AMD's recent CPUs haven't seen much potential here and that's been a bit sad.

Thankfully, the Core i5-13600K is overclockable too. Voltages were regularly above 1.4V at stock speed, so this seemed a good place to start. Its usual boost frequencies peak at 5.1GHz

for all-core and single-core boosts, but I hit 5.7GHz across all of our sample's P-Cores quite easily. That's a massive 600MHz higher than the single or all-core boost stock frequencies, and there were tangible performance boosts in games and content creation.

Unlike the Core i9-13900K, it wasn't a particularly tricky CPU to cool, although once overclocked, you're looking at temperatures in the high 80-90°C range with decent cooling. I just love the fact that overclocking is actually possible and worthwhile again with this CPU. It's a factor that's been missing for a while, at least to this degree, and I've not seen worthwhile overclocking available for a couple of generations with Intel and AMD processors.

This CPU also offers good value compared with the competition and thanks to its E-Cores, it's no slouch when it comes to heavily multi-threaded work too. The Core i5-11600K and Core

i5-12600K were pretty good examples of what a Core i5 chip should offer, but the Core i5-13600K is the best one since Intel made one with more than four cores. As an added bonus, it works in older (and cheaper) motherboards than AMD's Ryzen 7000-series CPUs too, and with DDR4 memory. **CPC**

Powerful, affordable and overclockable – the Core i5-13600K is a great new chip from Intel



How to 3D-print PC accessories

Antony Leather shows you how to design and 3D-print objects for your PC

TOTAL PROJECT TIME / 2 HOURS

Your average PC case is more flexible today than it has ever been, with all sorts of customisation options and accessories. However, sometimes components just aren't flexible enough for your needs, or you might want to customise them in other ways, particularly if you want to fit custom water-cooling gear. You might even want to create entirely new objects, or redesign the ones included with your components, such as mounting mechanisms or fan grilles.

With a 3D printer, you can easily design and create objects with none of the mess or fuss of dealing with metals. In this guide, we'll show you how to design your object and modify it once it's printed. For our examples, we'll show you to create a custom water-cooling reservoir mount to save drilling holes in your case, and also show you how to download and print your own case feet.

TOOLS YOU'LL NEED



3D printer (or 3D printing service
such as [surfacecan.co.uk](https://www.surfacecan.co.uk))
[amazon.co.uk](https://www.amazon.co.uk)



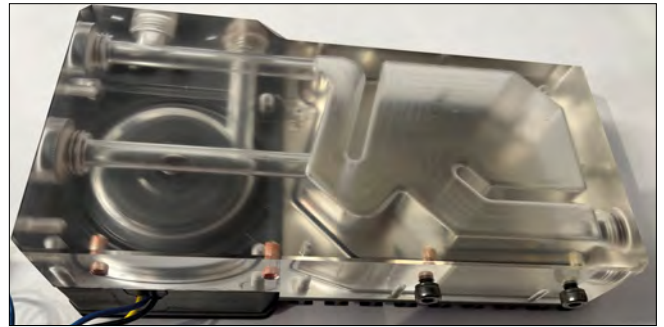
Ruler
Most hardware stores



Gorilla mounting tape
Most hardware stores



Drill and drill bit
Most hardware stores



1 / WORK OUT WHAT YOU WANT TO PRINT

You can design practically any object you like and 3D-print it. There are thousands of PC-related objects you can download for free that have been created by other people too. Don't be afraid to create a new design, though, as it's simple to do. We'll be creating a custom reservoir mount to allow us to secure it anywhere in our case.

3D PRINT FILE

120 RADIATOR BRACKET



DOWNLOAD

SIDE FAN BRACKET



DOWNLOAD

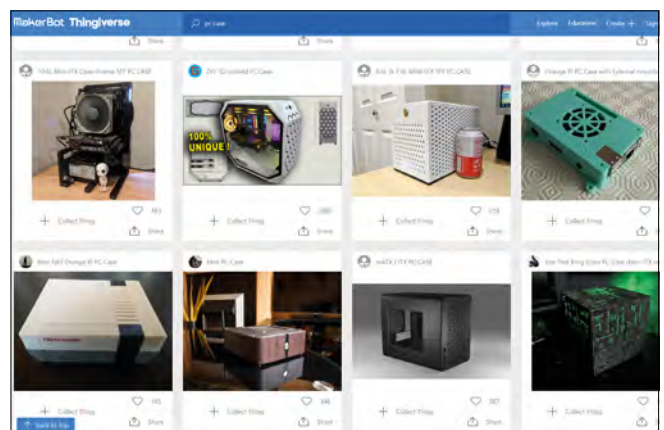
FEET



DOWNLOAD

2 / CHECK MANUFACTURERS' WEBSITES

A lot of case manufacturers offer a variety of 3D-printable objects for some case models, so it's worth checking your case manufacturer's website to see if it offers components you can download for free. These options often include alternative case feet and fan mounts.



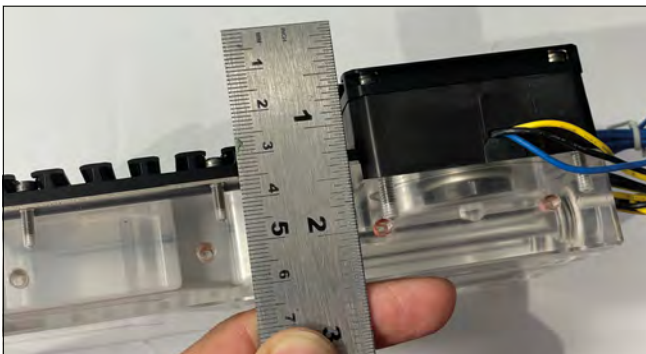
3 / CHECK ONLINE DATABASES

Websites such as [thingiverse.com](https://www.thingiverse.com) are online databases of pre-rendered objects you can download, usually for free. These are user-created objects, so you'll probably find objects here that are more varied or universal than those available on manufacturers' websites.



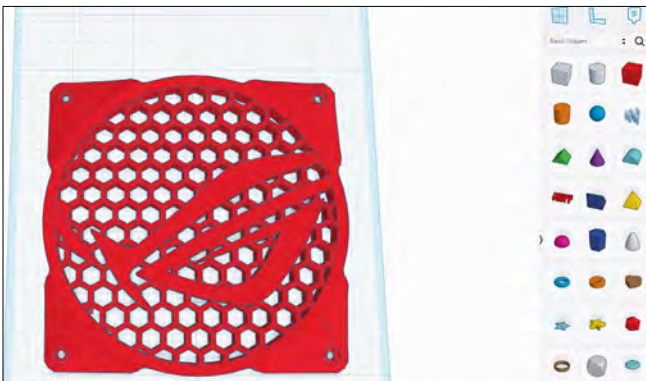
4 / WORK OUT MOUNTING POINTS

If you want to create a custom hardware mount, perhaps for a reservoir or motherboard, you first need to work out how to fix it to the object. Most components have existing mounting points you can use to attach custom 3D-printed objects.



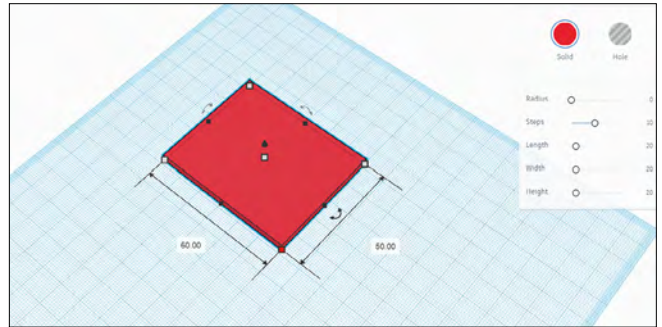
5 / WORK OUT MEASUREMENTS

In order to work out the size of your object, you'll need to make some accurate measurements of the area to which you want to fit it. For example, with our reservoir, we want the mount to sit on the side and to reach far enough backwards to clear the pump.



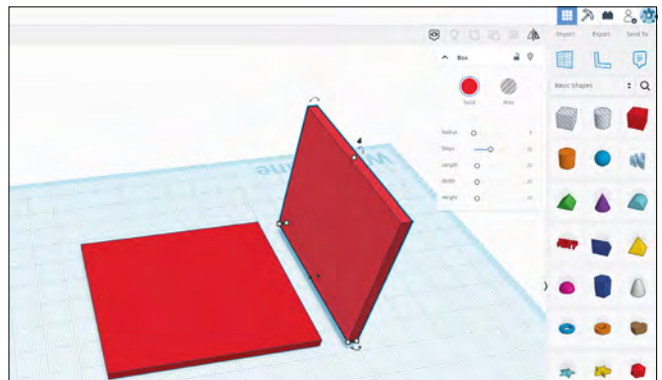
6 / USE TINKERCAD

Tinkercad (tinkercard.com) is a fantastic and easy-to-use online program that can create 3D objects. You can also download what's known as an STL file, and upload this file to your 3D printer software or a 3D printing service. There are excellent beginner guides on YouTube too.



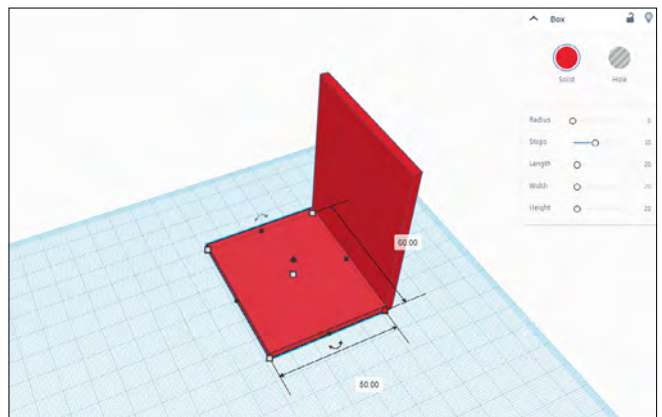
7 / CREATE FLAT SQUARE

Start by creating a flat square object with the correct width and length. In our case, this needed to be 50mm long and 60mm wide in order to align with our Phanteks reservoir's mounting holes, and clear the pump mounted on the rear. You want all the sections to be 3mm thick in order to be strong enough.



8 / ADD ANGLED SECTION

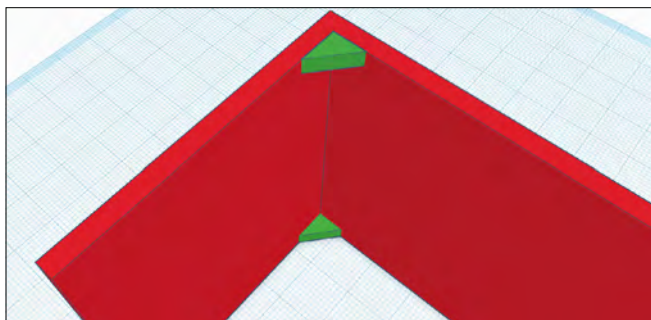
We're making a right-angled section to mount our pump to our case, so we need to add an end piece to our first part. You can do this by adding another square section, but this time raise it upwards.



9 / GROUP OBJECT

Select the whole object by holding down the left mouse button and moving the selection tool over both sections. Now click the 'group object' button at the top to merge the two objects into one. You can now move the two sections as one, so saving the STL file will create a single object to print.





10 / ADD SUPPORTS

If your object is going to be load-bearing then you need to add supports. Small triangles inserted into the corners will provide added strength to prevent it from bending.

PRINTING CASE FEET



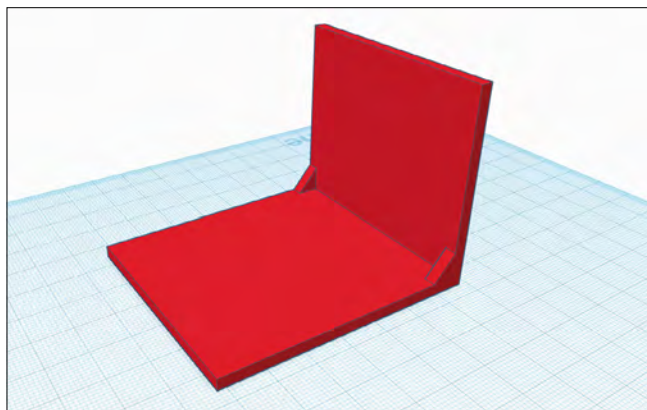
1 / REMOVE EXISTING FEET

Different objects will secure in various ways, and case feet usually require screws, especially if the files are created by your case manufacturer. The Ssupd Meshlicious has several feet design files available to download from its web page. In this case, you need to remove the stock rubber pads, revealing the mounting holes, then replace the pads afterwards.



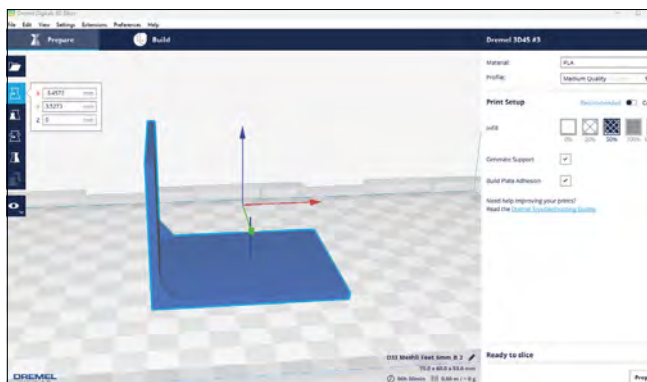
2 / INSTALL CASE FEET

Use the 6-32 screws included with the case to secure the feet from the outside. Using larger than usual case feet can improve airflow, as well as help to give your case a unique look.



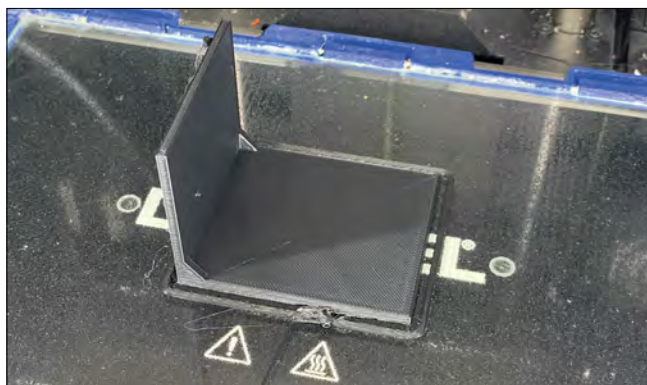
11 / PLACE OBJECT FLAT

Finally, group the object again to combine the supports and then place it with the largest flat side pointing face down. The printer will set the filament down from the bottom up, so you need to avoid overhangs as well.



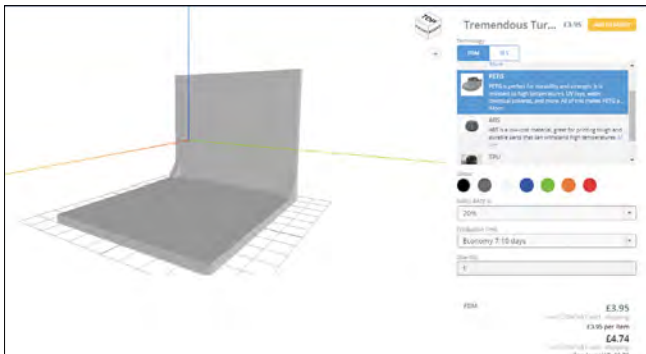
12 / USE HIGH-DENSITY, HIGH-QUALITY SETTINGS

For any 3D-printed object that needs strength, you need to aim for at least 20 per cent infill, ideally 50 per cent. You want the object to be aesthetically pleasing too, so a quality of 0.2mm or better is recommended for avoiding obvious 3D print lines.



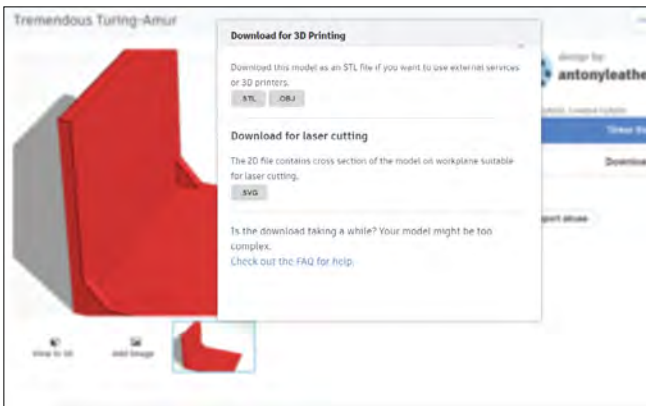
13 / PRINT YOUR OBJECTS

We recommend using PETG or PLA filament. Send the file to your printer and, once it's completed, check for imperfections. If the object is on full view then ideally you want your object to be blemish-free. However, you can sand 3D-printed objects, drill them and even paint them.



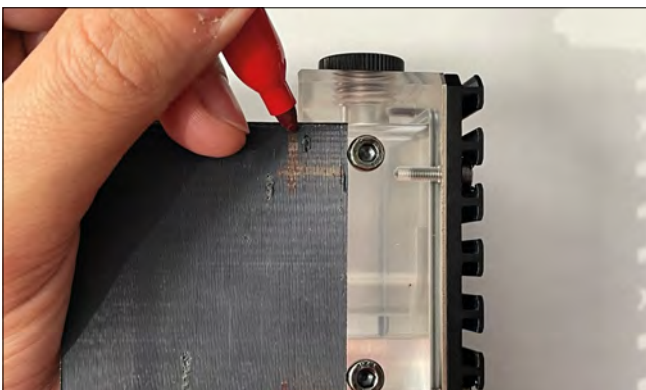
14 / USE A THIRD-PARTY PRINTING SERVICE

You don't need your own 3D printer to create your objects cheaply. Using third-party services such as [surfacescan.co.uk](https://www.surfacescan.co.uk) enable you to create them for a few quid. The reservoir mount we made here cost less than a fiver to print and post using PLA or PETG filaments.



15 / GET YOUR STL FILE

To use a 3D-printing service, grab your STL file from Tinkercad, then upload it to your preferred printing service website. The likes of [surfacescan.co.uk](https://www.surfacescan.co.uk) will give you an instant quote for your part.



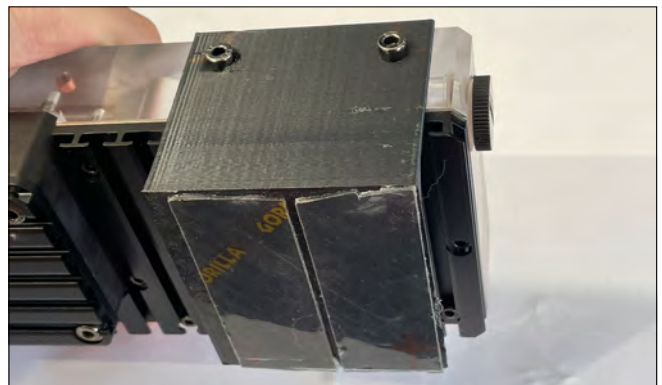
16 / MARK UP DRILL HOLES

You can either add additional measurements to your object, in order to leave areas open for screws, or if you're not confident with such precise measurements, you can drill them afterwards. Mark up the hole locations using the mounting holes on your object as a guide, or measure the distance between the hole centres.



17 / DRILL HOLES

Check the screw thread size and use a drill bit 0.5mm larger for the holes, so the thread passes easily through the holes. Use a low pressure and low speed to drill the holes, in order to avoid cracking or separating the print lines.



18 / ADD MOUNTING TAPE

We want to place our reservoir mount in a custom location without drilling holes, but still be able to remove it easily by detaching the screws. We've used Gorilla mounting tape, which is strong enough to hold any reservoir. Apply this to the mount then attach your object.



19 / INSTALL OBJECT

Now place your object in the location you need, ensuring it's level and in the right spot – in our case, the reservoir needs to be in the right place for our tubing routes. Press it firmly into place in order to ensure the mounting tape sticks to the case. **GPC**

Readers' drives

The Venom Desk

Working in aluminium window and door manufacturing, Daniel Hunter had the skills and tools needed to make this stunning aluminium desk rig, which contains two high-end AMD-based systems for multiplayer gaming



/MEET THY MAKER

Name Daniel Hunter

Age 31

Occupation Aluminium window and door manufacturing

Location Cannock, Staffordshire

Main uses for PC Gaming and creating 3D print files

Likes Dungeons & Dragons, gaming, movies, rock music, most foods (I'm a big foodie), Jack Black (he's one of my favourite people in the world), anime, manga, motorbikes and building PCs

Dislikes Beans, celery (the only foods I don't like!), mess, sports, really busy shops and the cold

GPC: Let's start at the beginning. What inspired you to build this desk-based PC system?

Daniel: I'd always dreamed of building such a system, but never really had the money to do it. I'd seen systems that were built into desks and just thought they were amazing – the work that goes into them and their unique, custom nature – and I wanted to create the most distinctive PC possible.

GPC: How did you plan out this build?

Daniel: I drew four designs of the desk, all by hand – on the final drawing, I got the exact size of every component and drew it to a 1:7 scale, so I could cut the aluminium to size, and see how small I could make the desk.

GPC: It looks like there are at least two systems in there? What are the specs and what do you use them for?

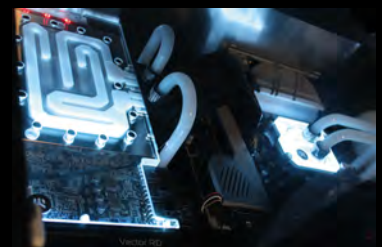
Daniel: There are two systems in the desk, which was a big feat to achieve with the size and routing of all the parts. I mainly wanted two systems because multiplayer on computers isn't really ideal compared with consoles, but I wasn't moving to consoles for multiplayer. Instead, I decided to get two PCs, so me, my wife and my friends could play multiplayer PC games in the same room.

GPC: What materials did you use to make the desk, and how did you cut them to shape, finish them and assemble the final piece?

Daniel: The desk is completely made out of aluminium. I own an aluminium windows and doors company (with my brother and friend), so I'm used to working with aluminium and have all the machinery to cut and weld it, plus

CNC equipment. At the start, it was a case of drawing up my first design and working out where I wanted the parts – I'm a sucker for symmetry, so I tried to make it all match up as best as possible.

After drawing it up I did a second revision, showing where I would feed all the cables and water-cooling pipes. I then changed where some parts were located, because originally the GPU in the second system was air-cooled – I was going to use a Radeon RX 5600 XT from my old system. However, I decided that if I was going to do this then I should do it properly and make it futureproof. I wanted to be able to play all my games





SYSTEM 1 SPECS

CPU AMD Ryzen 9 5950X

GPU PowerColor Red Devil
AMD Radeon RX 6900 XTU
overclocked to 2640MHz

Storage 2 x 2TB Seagate
FireCuda 530 2TB, 2TB
Samsung 870

Memory 32GB TeamGroup
8Pack RIPPED Edition

Motherboard Asus ROG
Crosshair VIII Dark Hero

PSU Corsair HX1000

Cooling Custom water-cooling
loop using EKWB components

SYSTEM 2 SPECS

CPU AMD Ryzen 9 5900X

GPU PowerColor Red Devil AMD
Radeon RX 6900 XT

Storage 2TB Samsung 970 Evo
Plus, 2TB Samsung 870

Memory 16GB TeamGroup
8Pack RIPPED Edition

Motherboard ASRock X570
Pro 4

PSU Corsair HX1000

Cooling Custom water-cooling
loop using EKWB components

at maximum resolution on my Samsung Odyssey monitors, and with good frame rates.

My last drawing was to scale after I got the measurements for all the parts. I wanted to figure how small as I could make the desk while still having an adequate gap between each of the components, and with the gaps being of equal size in most places. After doing the final draft, I ordered all the aluminium and computer parts that were required.

When I got the box section of aluminium, I then cut all the frame pieces on the saw that we use to cut windows and doors at work. I cut all the pieces millimetre-perfect for the framework, and I left the plates until it had been welded – when aluminium is welded, it can move a little here or there, as it's classed as a soft metal.

Once my brother had welded all the parts I had cut together, it was ready for grinding down the welds, and filling and sanding all the

joints before the frame was sent off to be painted with car-grade paint.

Once it was painted, I took it back to my house and started marking out all the components and drilling the mounting points for them – every part is screwed down or mounted on some form of bracket, nothing is loose in the desk. Every component also

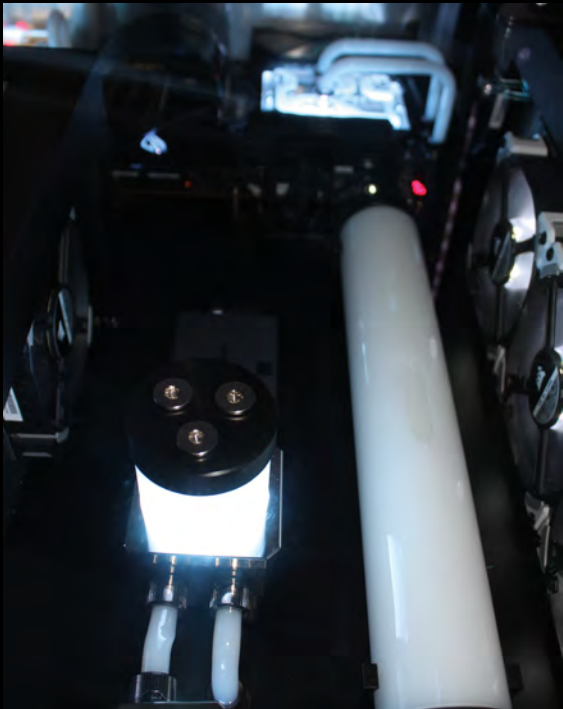
I'm used to working with aluminium, and have all the machinery to cut and weld it

has holes underneath it for cable routing. Once every component was in position I then had to start planning all the hard tubing for the water-cooling loop, marking out all the holes for the bulkhead fixings and then drilling all of them.

I then went back to work with the metal sheet to make the side plates – I cut these all to size with a skill saw and the pull-out saw we

use to make conservatory roofs. Once all the plates were cut out, I then spent the rest of the day making programs on our FOM CNC machine to cut out all the slots for the radiator grilles, hardware mounting points, fan mounting points and the slots for all the AIO and GPU connection points. It was a very tedious a frustrating day getting all the calculations and points correct and all to the right size, but it was easy enough once I had done a couple of the plates.

I then took all the plates home, de-burred them and countersunk all of the mounting holes. I then fixed them onto the framework by drilling into the frame and tapping the holes so the plates screw on and off easily enough. The plan



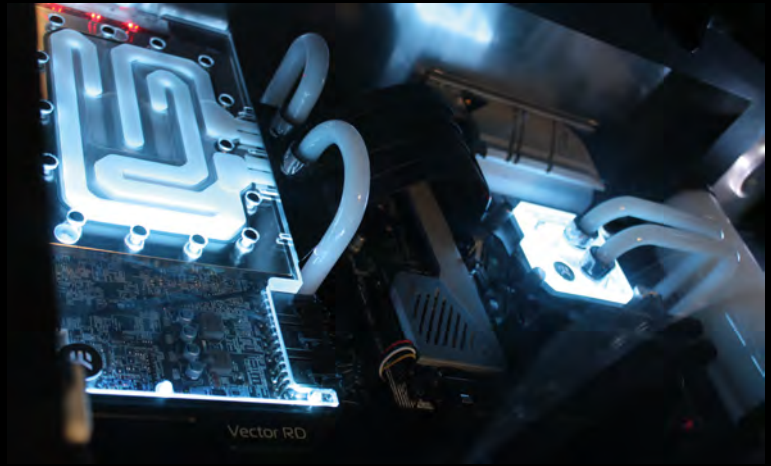
was that, once I'd tested the plates in place, I was going to take them back off and send them away to be painted with a colour theme based on Marvel's Venom – the plates were going to be painted black with some stencil airbrushing on them.

However, once they were in position with all the parts inside it just looked jaw-dropping – the bare aluminium looked like it was made to be on that desk. I then changed my mind about the Venom theme and decided to stick with how it is now.

After the plates were all in place, and the parts were fitted, I measured the glass I needed and got it on order. By the end of that week I had done all the hard tubing and soft tubing for the water-cooling loops, put the cables all in position ready for the finishing touches.

GPG: That's a lot of reservoirs! How many water-cooling loops are in the desk, and what do they cool?

Daniel: There are three water-cooling loops in the desk. One has a 480mm radiator, 400mm reservoir



and a 160mm res/pump combo unit, which cools the CPU and GPU of the second (smaller) PC. Then there are two loops for the main PC – one with a 360mm radiator, 400mm reservoir and a 160mm res/pump combo, which cools the CPU. The other loop has a 360mm radiator, two 250mm reservoirs and a 160mm res/pump combo, and it cools the GPU in the main PC.

The main system has been overclocked, and I wanted to squeeze as much out of it as possible, so I put as much cooling power as I could fit into the desk. The second system is staying at stock speed and has adequate cooling for AMD's base-level auto overclocking feature.

Filling three water-cooling loops all at the same time was a learning curve, as my previous water-cooling experience had

just involved a res/pump unit, a radiator and running two soft tubes to a component. After an air-leak test on all three of the loops (before filling), I was confident they were all okay.

GPG: What sort of glass is that on the top?

Daniel: I purchase a lot of glass for the company, so I gave the required sizes to one of our suppliers and requested 6mm toughened glass with polished edges for the top.

GPG: Where are all the cables routed?

Daniel: Underneath the desk there is a 40mm cavity between the bottom aluminium plates, where I routed all of the water-





cooling tubing (the soft tubing is underneath the main area), and the cables to all the components. This was very important to me, because other desk PCs I'd seen had cables and tubing visible all throughout the desk, but I really am a 'less is more' person and I wanted just the components to be visible.

CPC: How is all the RGB lighting controlled and synchronised?

Daniel: The RGB lighting is all controlled through the motherboards – I just got RGB splitters that I connected to each component and then to the correct motherboard. ASRock and Asus have their own software, and I just set all the lights to white, so they went with the theme.

CPC: Did you come across any difficulties?

Daniel: There are some factors that you never really consider until you reach that part of the build, and for me that was the fact that soft tubing doesn't want to bend at a

90-degree angle within a 25-20mm gap, so I had to buy 90-degree tubing fittings to go underneath the desk.

CPC: How long did it take you to complete this build, from start to finish?

Daniel: The build has taken a year from start to finish. I drew it all up, ordered all the parts, cut all the aluminium and then came the long hiatus of waiting for my brother (he's a brilliant aluminium welder but also very busy) to weld the desk together.

After that, it took me four weeks to do the painting, drilling and cutting the side plates, getting the glass and so on. It was probably a complete working time of five or six weeks, but I had to wait for my brother to weld the custom design of the desk. I could only work on the desk after work and on weekends, as I had work throughout the days, but I was working on it every evening.

CPC: Are you completely happy with the end result, or do you wish you'd done some of it differently in retrospect?

Daniel: The only part that I really would have changed is getting the welding done sooner, so my parts were still classed as (AMD hardware only) the best of the best. Knowing all the new hardware is now coming out is disheartening, but otherwise the components in it are amazing and it looks great – the pictures don't do it justice compared with seeing the real thing. **CPC**



WIN CORSAIR HYDRO X WATER-COOLING GEAR



To enter your rig for possible inclusion in Readers' Drives, your build needs to be fully working and, ideally, based in the UK. Simply send us a couple of photos on Twitter (@CustomPCMag) or Facebook (CPCMagazine), or email low-res ones to ben.hardwidge@raspberrypi.com. Fame isn't the only prize; you'll also get your hands on some fabulous prizes, courtesy of Corsair.

Corsair Hydro X Series XD3 RGB Pump/Reservoir C

The Corsair Hydro X Series XD3 RGB Pump/Reservoir Combo features a high-performance DDC PWM pump, integrated RGB lighting and in-loop temperature sensor to drive even the most compact custom cooling systems. It has a high-performance Xylem DDC PWM pump controlled via PWM to deliver the perfect flow balance for your loop. There are also 16 individually addressable RGB LEDs, which light up the pump head to produce stunning, customisable lighting effects to match your build.



WORTH
£151

Corsair Hydro X Series XC7 RGB CPU Water Block

The Corsair Hydro X Series XC7 RGB CPU Water Block combines premium construction, vivid RGB lighting and extreme cooling performance to become the centrepiece of your water-cooling loop. It has a nickel-plated copper cold plate and more than 60 high-efficiency micro-cooling fins, which efficiently draw heat away from your CPU, lowering operating temperatures and allowing for maximum overlocks. You can choose a version for Intel or AMD CPU sockets.



WORTH
£70

Corsair Hydro X Series XR5 240mm Radiator

The Corsair Hydro X Series XR5 240mm Water Cooling Radiator delivers extreme custom cooling performance, with a 30mm radiator thickness and premium copper core. Its dual 120mm fan mounts on each side are ready for your most ambitious custom cooling build, and its 25 micron-thick cooling fins offer a high thermal transfer rate.



WORTH
£55



JAMES GORBOLD / HARDWARE ACCELERATED

RYZEN AND FALLING

James Gorbold takes a look at the buying patterns for AMD and Intel's latest CPUs

There's all still to play for in the GPU market, but the dust has settled on the first big launches of the year – AMD's Ryzen 7000-series CPUs and Intel's 13th-gen Core CPUs – and it's looking decidedly one-sided.

Here's where the situation stands right now for these mighty new CPUs. The key metric for the success of any launch is sales, or pre-orders if stock is limited, and I'm pleased to report that AMD managed its stock situation much better for this launch than for the Ryzen 5000 series, with plenty of CPUs to go around.

Nevertheless, sales have been lacklustre to say the least. As of mid-November this year, Ryzen 7000-series chip sales lag way behind those of 13th-gen Core chips, with the flagship Ryzen 9 7950X selling around half as well as Intel's Core i9-13900K. The 7900X is a bit more popular than the 7950X, but it's still a long way from being a hot seller. It gets worse still for AMD as you travel down the stack, with Intel's equivalently positioned SKUs – Core i7 vs Ryzen 7, Core i5 vs Ryzen 5 and so on – outselling AMD's by a ratio of up to four to one.

This is bad news for AMD so close to launch, as the CPUs are very competitive indeed, with great performance in both games and content creation applications. However, its overall market share is already beginning to slip behind that of Intel. There's a lot of slow-moving stock in the channel, so there's increasing pressure to lower prices to stimulate sales. All that's really keeping AMD's market share from dropping off a cliff is continuing demand for Ryzen 5000-series CPUs, although this has begun to drop off massively in the past couple of weeks.

In contrast, Intel didn't manage its launch stock well and should have waited a few more weeks to release to market.

It's clear that AMD made the wrong call about only supporting DDR5

However, there are plenty of 13th-gen Core CPUs available now, and all three principal K-series models are selling well. Unlike AMD, Intel has also succeeded in transitioning customers from its earlier 12th-gen platform to the new 13th-gen silicon.

So what has gone so badly wrong for AMD's Ryzen 7000 series? After all, the initial reviews were very positive and there's still a lot to like about the new CPUs, in particular their power efficiency, which is much better than that of the equivalent Intel chips. The real issue lies not in the CPU themselves, but in two other aspects of the platform, the memory and the motherboards.

It's clear that AMD made the wrong call about only supporting DDR5, as it still commands a massive price premium over DDR4. The gap is slowly closing, but as of mid-November, DDR5 is still around 64 per cent more expensive. What's worse, there's precious little performance difference between DDR4 and DDR5, so you're paying a whole lot more for no benefit.

The second big problem is motherboard pricing, with X670 and B650 motherboards being way more expensive than necessary and the cheapest boards tipping the scales at over £400 and £200 respectively. The problem is further exacerbated by Intel 13th-gen CPUs being supported by a much wider range of motherboards.

Combine the motherboard prices with the non-beneficial premium of DDR5 and you're looking at a big premium to upgrade to AMD's new platform. AMD can (and already is) helping with this to some extent by encouraging lower CPU prices, but the CPU is just one part. A lot needs to change, and quickly, if AMD wants the Ryzen 7000 series to really compete. **CPC**

James Gorbold has been building, tweaking and overclocking PCs ever since the 1980s. He now helps Scan Computers to develop new systems.



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