HOW TO WATER-COOL A GEFORCE RTX 4090

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RADEON REVENGE

AMD UNDERCUTS NVIDIA BY OVER £300, BUT ARE ITS NEW GPUs FAST ENOUGH?

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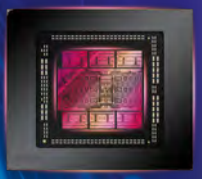

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Welcome

Custom PC Issue 234

/ FROM THE EDITOR

Timing is everything

We're finishing up this issue just before Christmas, and we've only just got the last of the recent slew of massive hardware launches out the way. Intel and AMD have both launched new CPUs and motherboard chipsets, Nvidia has brought out a new GPU architecture and now AMD has done the same with its latest RDNA 3 chips.

It's been an exhausting few months, and at the end of it, I have to ask why so many hardware launches had to come out right at the end of the year. As James Gorbold outlines on p98, there are barely any RDNA 3 cards for retailers anyway.

But there's also a deeper problem here, which is that you need to be really sure your new CPU or GPU is absolutely up to scratch if you're planning to bring it out at the same time as your immediate competitor. In previous times, Nvidia would bring out a new GPU, then around six months later, ATi would bring out a competitor that would beat it and so on.

That's all stopped now. AMD hasn't had a new GPU that's well and truly beaten the best that Nvidia has to offer for years, and part of that is down to timing. As we show in our reviews on p14, the Radeon RX 7900 XTX is on par with the GeForce RTX 3090 Ti in ray tracing, and beats it in terms of general shader performance. If it had come out at this price six months ago, AMD would have had a clear winner on its hands, ahead of Nvidia on both performance and price.

Instead, it's come out just after the launch of Nvidia's excellent (though massively overpriced) GeForce RTX 4000-series GPUs, meaning it can only compete by undercutting the price. It's arguably done it, but only because the RTX 4080 is so ridiculously overpriced, and even then, it's not a clear run, especially when you add ray tracing to the mix.

On the plus side, this is the closest AMD has got to high-end competitive GPU performance for many years. Add that to several years of success in the CPU business, and there's hope that AMD might have the headroom to invest more in its GPU business, and get properly ahead of the competition six months before it can hit back. That's what AMD needs to do if it wants to really compete in the GPU space again. CPC

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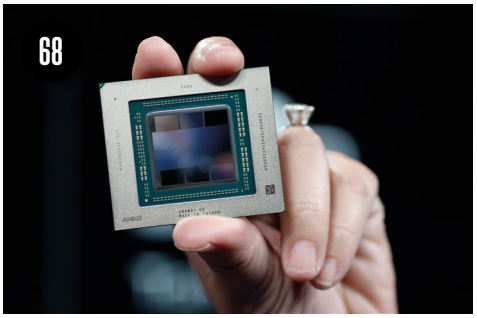

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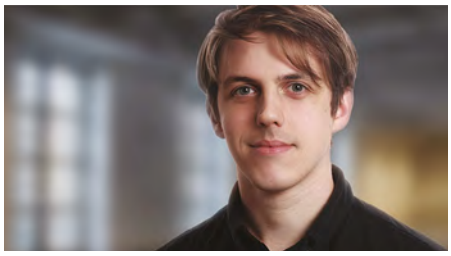

RICHARD SWINBURNE / VIEW FROM TAIWAN

BEYOND DDR5

The tech inside GDDR6W could give us the next-gen memory for our future CPUs, says Richard Swinburne

It's rare we get a new type of memory, and Samsung recently surprised us with its new GDDR6W tech. The 'W' means it's 'wide' and can send twice the data per cycle of standard GDDR6 memory, doubling the bandwidth per chip. Achieving a data bus that is both wide and fast (22Gbps) are two performance factors that are typically mutually exclusive, so this is a significant breakthrough.

GDDR6W uses chip-stacking within each package (fan-out wafer-level packaging), in order to put one layer of memory ICs on top of another and connect them with tiny copper pillars. This also doubles the capacity within each chip. It means a high-end GPU with 16GB of memory and a 256-bit interface could need only four GDDR6W chips, rather than the eight normally required, simplifying the PCB design. It's ideal for gaming laptops, but useful on desktop cards too.

What I see, though, is that this technology is a stepping stone towards future CPU designs. Increasing DDR5 speeds is becoming too costly, and the DIMMs themselves are reaching the limit of the physical, plug-in design.

DDR5 speeds have soared since launched, with premium (expensive) motherboards and CPUs that won the silicon lottery even hitting effective frequencies of 8000MHz. These new bandwidth highs are great because CPU core counts have continued to grow unabated, and all of them need to talk to memory.

However, memory performance isn't just governed by speed, but also latency. DDR5 has the former in spades, but it's still not achieving lower latencies than a decent quality kit of much cheaper DDR4 memory – this matters not only in gaming benchmarks, but also in everyday use. Reducing DDR5 system cost is difficult because doing so required higher-quality PCBs and more advanced chips. Also, each DIMM needs its own power regulation, while DDR5 motherboards from both AMD and Intel also remain expensive. DR5 is still in its early days right now, but inevitably, we can expect the demands on memory bandwidth to keep increasing.

So what needs to change about future memory design to make it more affordable to everyone? Well, I foresee Samsung's 'W' technology being used in lieu of plug-in DIMMs, where several DDR 'W' chips are attached directly to the CPU substrate. You would buy a CPU and choose 32GB or 64GB of memory as one item, just like you would spec a smartphone.

The memory would just come in the form of more chiplets added to the normal CPU packaging, a process that would have a lower cost compared with the expensive silicon interposer required for HBM memory. Bringing the memory as close as possible to the CPU silicon would enable Intel and AMD to achieve much faster speeds and potentially lower latency, without needing costly motherboard and DIMM designs.

> AMD and Intel wouldn't need a JEDEC stamp

You can imagine, for example, a mainstream 6/8-core CPU coming with dual-channel memory, while a 12/16-core CPU features tri-channel and a 24/32-core chip has quad-channel memory. This keeps a similar memory bandwidth per core throughout the whole stack, all without needing a new motherboard.

There are obviously downsides. Choosing memory is a core part of the PC building experience and being able to reuse it in different builds is a big benefit. That said, the old 'two spare DIMM slots to upgrade later' setup is already dead. DDR5's design has effectively killed four-DIMM builds because the achievable speed and reliability drops significantly if you're using four high-speed modules.

AMD and Intel wouldn't need a JEDEC stamp for this system either, just a collaboration with memory makers – you could well be looking at different PC layouts in the future. CPC

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

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TRACY KING / SCEPTICAL ANALYSIS

TRIPLE NOMINATED

Tracy King asks why video game awards aren't taken as seriously as the big movie award ceremonies

Sometimes, if it's relevant or I'm feeling mischievously pretentious, I'll drop a casual, 'oh yes I met so-and-so at the BAFTAs' into a conversation about the aforementioned so-and-so. The other person usually hesitates, trying to decide if I'm a nob for mentioning it (yes) or if they're actually impressed (sometimes), which is just enough time for me to make a cheeky face and say, 'the video game BAFTAs.'

There's always either a palpable relief or slight disappointment that turns into a knowing laugh. The sad truth is, the video game BAFTAs aren't taken as seriously as the film and TV BAFTAs, even by the game-playing public. They don't attract international A-list celebrities, they aren't televised and the clothes winners wear aren't scrutinised in magazines or social media. Games just aren't as glamorous, sexy or luvvie as TV and film.

Likewise, the new inclusion of a video game soundtrack category in the 2022 Grammys, or to give its full and heavily caveated title, Best Score Soundtrack for Video Games and Other Interactive Media, didn't really raise any headlines, except ones to complain that the shortlist perhaps didn't recognise the full depth and breadth of game music.

It's a reasonable criticism, although the category is new, so maybe it'll take a few decades to settle in. However, there is a risk that the game category has been included because gaming is a rich and popular industry, not because the Grammy committee understands or cares about video game music.

The awards are Hollywood to their core (they were founded in the 1950s to rectify the exclusion of some recording professionals from the Hollywood Boulevard 'walk of fame'). Gaming isn't particularly Hollywood.

Although I don't disagree with traditional sound and visual awards including new media, and welcome the inclusion of such categories, it's not the same as awards by the gaming industry that understand the media in the same way the film directors who founded the BAFTAs understood theirs.

The current closest event to that is The Game Awards, founded in 2014 by Kotaku contributor Jeff Keighley, which replaced the short-lived Spike awards. Attempts by others to create industry awards had failed, so Keighley wisely courted exclusive content (such as a Nintendo gameplay reveal in 2014), the backing of the big industry players and player feedback. Voting is 90 per cent by expert committee, and 10 per cent by the public, which is perhaps a little fairer than some of the more heavily gate-kept film awards.

> There's a culture of not taking game awards seriously

And yet, the average gamer either hasn't heard of or doesn't care about The Game Awards. They're not a selling point like 'BAFTA winner' or 'Three-time Grammy nominated'. Maybe in part that's because of the personal nature of gaming – my hundred hours in a JRPG vs someone else's 12 hours in a cute but short indie puzzle platformer are hard to compare fairly, but both might be eligible for game of the year.

Similarly, game genres are incredibly slippery, and technology that changes the end-user experience such as VR is still evolving – the closest film got to that is 3D. But still, there's a culture of not taking game awards seriously, and that's a shame.

Maybe awards are nonsense and I shouldn't care about whether anyone takes them seriously. However, I do think it's important that innovation, art, storytelling and player experience are rewarded and respected. Can you honestly tell me you don't have an answer if I ask 'what's your 2022 game of the year?' The Games Awards gave that to Elden Ring. For what it's worth, mine is PowerWash Simulator. There's still hope for the BAFTAs. CPC

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

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Letters

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CORSAIR FLEXI-MONITOR UP FOR PRE-ORDER

Corsair's first bendable monitor is now available for pre-order, with a UK price of £2,099 inc VAT at **corsair.com**. The 45in panel has the ability to be bent from being fully flat to having an 800R curve, meaning you can have the best of both worlds depending on your needs at the time.

The Xeneon Flex 45 has a resolution of 3,440 x 1,440 with a 21:9 aspect ratio, and Corsair says its OLED display enables it to offer a peak brightness of 1,000 nits and a 1,500,000:1 contrast ratio. There's also a 240Hz refresh rate, as well as support for both Nvidia G-Sync and AMD FreeSync Premium. The company says units are expected to begin shipping in late December 2022.

GEFORCE RTX 4080 PRICE DROPS

If you thought that the £1,269 launch price of Nvidia's GeForce RTX 4080 was too steep then it looks like you were right. We've heard several reports of disappointing sales of Nvidia's second-rung Ada GPU since the launch, and the company has already responded by dropping the price of the Founders Edition to £1,199 inc VAT. Not only that, but prices of cards from board partners have also started to drop, with a Palit GameRock RTX 4080 card currently available at **scan.co.uk** for £1,189 inc VAT.

AMD RELEASES FSR 2.2

AMD has released another revision to its FidelityFX Super Resolution tech, which it says will upgrade the 'upscaling image quality of FSR 2.1 with further quality enhancements to alleviate ghosting on fast-moving objects'. The tech is already supported in Need for Speed Unbound, and AMD says that F122 will also get an update in January 2023 to support it.

Synthetic 3D benchmark 3DMark will also be getting an update to support FSR 2.2, with the inclusion of a 'built-in frame inspector tool'.

FRACTAL GOES NORTH

Fractal Design has introduced a new case design that goes beyond the usual aluminium and plastic construction, adding walnut or oak panelling, along with brass or steel details, plus a faux leather tab at the back that lets you easily pop off the top panel. Fractal claims the North 'integrates stylishly into your living space', while offering 'an intuitive interior layout.'

In addition to its unique looks, the North offers room for a 360mm radiator in the front, and a 240mm unit in the top, while also allowing up to 350mm of clearance for a graphics card, which drops to 300mm if you have a 360mm radiator in the front. Other features include a meshed top panel, and there's also a mesh version of the case that offers a meshed side panel for extra ventilation too. The North is available to pre-order from **scan.co.uk** now for £135 inc VAT.

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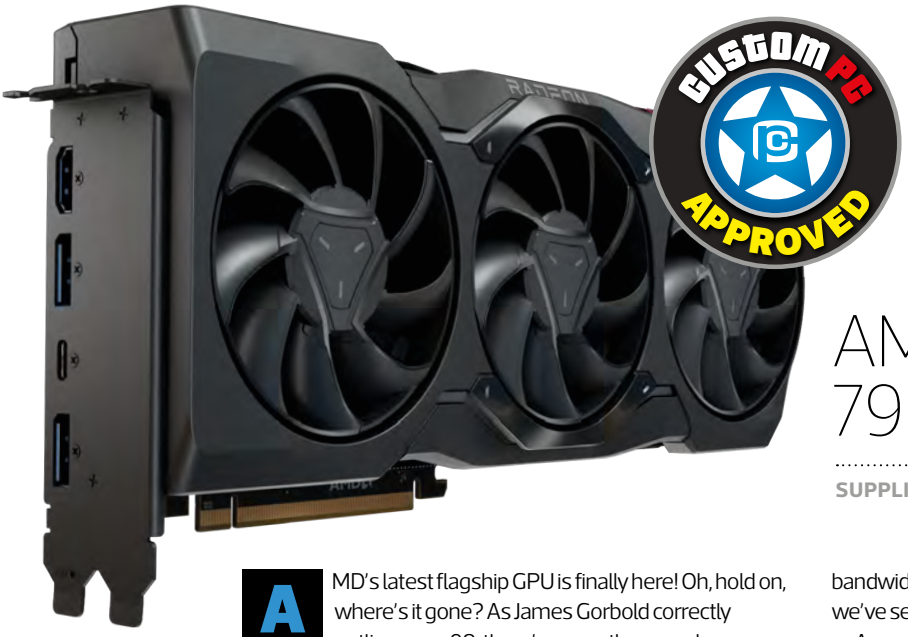

AMD RADEON RX 7900 XTX / £999 inc VAT

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SPEC

Graphics processor
AMD Radeon RX 7900 XTX, 2269MHz game clock, 2499MHz boost clock

Pipeline
6,144 dual-issue stream processors, 192 ROPS

RT cores
96

Memory
24GB GDDR6, 2500MHz (20GHz effective)

L3 cache
96MB

Memory interface
384-bit

Card interface
16x PCI-E 4

Bandwidth
960GB/sec

Power connectors
2 x 8-pin

Card length
287mm

Expansion slots
2.5

AMD's latest flagship GPU is finally here! Oh, hold on, where's it gone? As James Gorbold correctly outlines on p98, there's currently severely insufficient stock of the Radeon RX 7900 XTX. That's a shame, because AMD's new top-end GPU is actually pretty good. It's still overpriced at £999 inc VAT, but it looks like a veritable bargain next to Nvidia's GeForce RTX 4090 and 4080. We've taken a full deep dive into the new RDNA 3 architecture in our feature on p68, but we'll go through the essentials here too.

RDNA 3 sees AMD makes its first move to a modular, chiplet-based approach to GPU package design. Instead of having the whole lot in one monolithic die under the heatspreader, AMD has separated the L3 cache and memory controller from the main processing units, dividing them into chiplets.

Both the Radeon RX 7900 XTX and the 7900 XT (see p16) are based on the Navi 31 GPU; in the case of the 7900 XTX, this gives you 96 AMD Compute Units, each containing a 2nd-generation AMD RT core, which gives you 6,144 dual-issue stream processors.

You also get 96MB of L3 cache in the Memory Cache Dies (MCD) surrounding the main GPU, called the Graphics Compute Die (GCD). This arrangement gives the Radeon RX 7900 XTX a wide 384-bit memory interface that, when combined with the 24GB of 2500MHz (20GHz effective) GDDR6 memory, gives you a total memory bandwidth of 960GB/sec – not far off the 1TB/sec+ figures we've seen from Nvidia's top-end GPUs.

As a point of comparison, the top-end RDNA 2 GPU, the Radeon RX 6950 XT, had 5,120 stream processors and a 256-bit memory interface that, when combined with its 16GB of 2250MHz (18GHz effective) GDDR6 memory, gave it a total memory bandwidth of 576GB/sec. However, the Radeon RX 6950 XT did have 32MB more L3 cache.

Clock speeds have also increased over RDNA 2. The Radeon RX 6950 XT had a quoted game clock of 2100MHz and a boost clock of 2310MHz, but the Radeon RX 7900 XTX raises those figures to 2269MHz and 2499MHz respectively. These quoted figures are also quite conservative – we saw the Radeon RX 7900 XTX hit a peak boost clock of 3106MHz in our game tests, and it was consistently running at over 3GHz.

The AMD-made card we tested for this review also has a much more elegant design than Nvidia's latest Founders Edition cards. It sticks with the tried and tested 8-pin PCI-E power connectors, avoiding potential for melting power sockets, while also providing wide compatibility with existing PSUs. It also only takes up two (and a bit) expansion slots.

Irritating fan noise wasn't an issue during testing, and our sample hit a peak GPU temperature of 62°C with a peak hotspot reading of 89°C. The latter is toasty, and the backplate became hot to touch, but we didn't observe any throttling.

Performance

With a revised GPU architecture, more and faster memory, and a greater number of stream processors, the Radeon RX 7900 XTX should be significantly quicker than its predecessor,

and this is fully borne out in our test results. Not only that, but the 7900 XTX is also quicker than Nvidia's pricier GeForce RTX 4080 in some tests. In fact, it even beats the RTX 4090 in some games at 1,920 x 1,080.

However, you don't spend a grand on a GPU to run games at 1080p, so we're going to focus on performance at 4K and 2,560 x 1,440. Even here, there's one game where the Radeon RX 7900 XTX outperforms the GeForce RTX 4090, which is Assassin's Creed Valhalla. The two GPUs perform similarly in this game at 4K, and the Radeon RX 7900 XTX's 79fps 99th percentile result and 106fps average are superb.

Metro Exodus is also a strong title for the Radeon RX 7900 XTX. The RTX 4090 is in front, but that's to be expected from a card that costs upwards of £1,699. With no ray tracing enabled, the 7900 XTX remains ahead of the RTX 4080 here though – the averages are similar, but the Radeon has a substantially higher 99th percentile figure.

However, the two cards swap places once you add ray tracing. AMD has clearly done a lot of work on improving its ray tracing performance, but Nvidia's latest GPUs have the upper hand.

That said, the Radeon's average of 61fps in this game at 4K with ray tracing is still a cracking result, and its 99th percentile figure of 44fps is well ahead of the 39fps from the GeForce RTX 3090 Ti, Nvidia's former flagship, which still costs £1,149 inc VAT from Nvidia's online shop.

The situation in Cyberpunk 2077 was similar, with the Radeon RX 7900 XTX outperforming the GeForce RTX 4080 at the standard Ultra preset (and averaging over 60fps to boot). However, the Radeon dropped behind once ray tracing was enabled. To be fair, not even the RTX 4090 can play this game at 4K smoothly with ray tracing unless you enable DLSS, but the Radeon RX 7900 XTX again performed similarly to the RTX 3090 Ti.

Not even enabling FSR 2.1 can make this game smoothly playable at 4K with Medium ray tracing on the Radeon RX 7900 XTX, with a 48fps average and 41fps 99th percentile result. Comparatively, the RTX 4090 averages 68fps at the same preset with DLSS enabled, and the RTX 4080 hits 57fps.

The Nvidia cards also have the added bonus of AI frame generation via DLSS 3, which massively improves frame rates with ray tracing, even if it doesn't always look perfect. AMD has clearly worked hard on its silicon with this generation of GPUs, but there's none of the groundbreaking software innovation we saw with DLSS 3 on show here.

When it comes to high frame rates, in Doom Eternal, the Radeon RX 7900 XTX was behind both the new Nvidia GPUs, buts its frame rates were still superb, averaging a massive 308fps at 4K, and still maintaining a 167fps average with ray tracing enabled.

Finally, we come to power draw, where the Radeon RX 7900 XTX couldn't be described as frugal, but is much more efficient than the last-gen GeForce RTX 3090 Ti, and our system also didn't spike into the 600W range when running at 4K, which we saw with the GeForce RTX 4090. Our system drew a peak of 546W with the Radeon RX 7900 XTX installed.

Conclusion

With a price of £999 inc VAT, AMD has cut out an attractive market slot for the Radeon RX 7900 XTX. Its raw shader power is right up there with much pricier Nvidia GPUs, and its ray tracing power is on par with the GeForce RTX 3090 Ti. AMD still can't catch Nvidia's latest GPU tech when it comes to ray tracing, and it's a shame there are no big software innovations such as DLSS 3, but the Radeon RX 7900 XTX has power where it counts. Let's hope more stock appears in the new year, and that the sub-£1,000 price sticks.

BEN HARDWIDGE

SHADER

- \+ Much cheaper than RTX 4080
- \+ Improved ray tracing performance
- \+ Strong shader performance
- \+ Standard power connectors

SHADY

- – Severely limited stock
- – No AI frame generation tech
- – Still expensive
- – Nvidia still faster at ray tracing

VERDICT

Great shader power for the money, and while Nvidia's Ada GPUs are faster at ray tracing, the new Radeon is on par with the RTX 3090 Ti. It's just a shame there's no stock.

PERFORMANCE **44/50**

FEATURES **16/20**

VALUE **20/30**

OVERALL SCORE **80%**

AMD RADEON RX 7900 XT / £899 inc VAT

SUPPLIER overclockers.co.uk

Unlike its bigger sibling, the Radeon RX 7900 XT was still in stock at its MSRP of £899 inc VAT at the time of going to press, and while that's good to see in these times, there's also a reason for it. Like the GeForce RTX 4080, the Radeon RX 7900 XT is priced too close to its respective flagship GPU for the spec on offer.

There's only £100 separating the two cards, and the variety of SKUs on offer from board partners means that in many cases, you can pick up a stock-speed Radeon RX 7900 XTX for the same price as an overclocked Radeon RX 7900 XT, and the former is absolutely the better card to buy.

That said, it's still refreshing to see two top-end GPUs launch below £1,000 inc VAT in these high-priced times and the Radeon RX 7900 XT is still a potent card. It's based on AMD's new RDNA 3 architecture (see our feature on p68 for the full deep dive), which divides the GPU package into a Graphics Compute Die (GCD), containing all the main processors, and several Memory Cache Dies (MCDs), which contain the L3 cache and memory controller system.

The Radeon RX 7900 XT only has five enabled MCDs, compared to six on the Radeon RX 7900 XTX, which drops the L3 cache down to 80MB from 96MB, and also reduces the width of the memory interface from 384 bits to 320.

It also means the card can only address 20GB of memory, rather than 24GB, but that's still plenty and it runs at the same 2500MHz (20GHz effective) speed as the memory on the flagship GPU. The result is an overall memory bandwidth of 800GB/sec, which is well behind the 960GB/sec of the Radeon RX 7900 XTX, but still above the 716.8GB/sec of the GeForce RTX 4080.

Some of the Compute Units (CUs) on the GCD have also been disabled, giving the Radeon RX 7900 XT 84 CUs compared to 96 on its bigger sibling. Each CU contains a 2nd-generation AMD ray tracing core and 64 dual-issue stream processors, meaning you get 5,376 of the latter in total on the Radeon RX 7900 XT.

Clock speeds have also been dropped a bit on the 7900 XT, with AMD quoting a typical game clock of 2025MHz and a 2394MHz boost clock. However, as with the Radeon RX 7900 XTX, we found these figures were highly conservative, with the Radeon RX 7900 XT peaking at 2913MHz during benchmarking.

The lower clocks and lesser spec put less of a strain on the cooler than on the Radeon RX 7900 XTX though. The peak GPU temperature we recorded during testing was 62°C with a top hotspot reading of 78°C, which are similar results to the temperature readings from the GeForce RTX 4080 Founders Edition with its colossal cooler.

SPEC

Graphics processor
AMD Radeon RX 7900 XT, 2025MHz game clock, 2394MHz boost clock

Pipeline
5,376 dual-issue stream processors, 192 ROPS

RT cores
84

Memory
20GB GDDR6, 2500MHz (20GHz effective)

L3 cache
80MB

Memory interface
320-bit

Card interface
16x PCI-E 4

Bandwidth
800GB/sec

Power connectors
2 x 8-pin

Card length
276mm

Expansion slots
2.5

Performance

Despite its lesser spec, the Radeon RX 7900 XT gets off to a great start in our benchmarks (over the page), beating the GeForce RTX 4090 in Assassin's Creed Valhalla at 1,920 x 1,080. It also holds its own against the GeForce RTX 4080

IN STOCK

+ Under £900
+ Much faster than Radeon RX 6950 XT
+ Standard power connectors

SOLD OUT

- Overpriced for spec
- Nvidia Ada GPUs are faster at ray tracing
- Starts to struggle at 4K

in this game at 2,560 x 1,440. It's only when you up the resolution to 4K that the XT starts to falter, but it's still not far off the GeForce RTX 4080 here, and it's well ahead of the Radeon RX 6950 XT and GeForce RTX 3090 Ti.

This game is renowned for preferring AMD's GPUs, though, so how does it hold up in other games? Moving to Metro Exodus without ray tracing, the Radeon RX 7900 XT is slower than the RTX 4080 at 2,560 x 1,440, but not by a huge margin and it's well ahead of all the last-gen GPUs. Again, performance drops off at 4K, with its average frame rate dropping by 15fps compared with the XTX, although it's still perfectly playable on the XT.

Add ray tracing to the mix, though, and the Radeon RX 7900 XT isn't as convincing. Its average falls behind the last-gen RTX 3090 at 2,560 x 1,440, while still maintaining a solid frame rate, but it drops down to 51fps at 4K, putting it behind the RTX 3080 Ti and 10fps behind the Radeon RX 7900 XTX.

Likewise, in Cyberpunk 2077 without ray tracing, the Radeon RX 7900 XT held up pretty well, with a cracking average of 106fps at 2,560 x 1,440 and a still playable average of 54fps at 4K. Enable the Medium ray tracing preset, though, and it starts to struggle. It can still maintain a decent frame rate at 2,560 x 1,440 if you enable FSR 2.1, but it can't cope at 4K.

Meanwhile, moving to Doom Eternal showed up the gulf in processing power between the 7900 XT and the XTX, with the former regularly being about 40fps behind its bigger sibling once you get above 1,920 x 1,080.

It still coped well with this game at high frame rates, though, even at 4K with ray tracing enabled. It was significantly slower than the RTX 4080 in this test, but it's still playable. Plus, let's not forget that the RTX 4080 costs a good £300 more than the Radeon RX 7900 XT.

Finally, we come to power consumption, where our system's peak draw of 503W with the Radeon RX 7900 XT installed was a good 23W higher than with the RTX 4080 in place. The RTX 4080 has the edge on performance per watt, but the 7900 XT still draws less power than the RTX 3080 Ti.

Conclusion

If the Radeon RX 7900 XT cost £799, this would be a clean run for AMD, but at £899, it muddies the waters to the point where you might as well get the much better performance of the XTX model for £100 more. It can't compete with Nvidia's latest GPUs either, but that's hardly surprising when they cost so much more money. It's not far off the pace of the RTX 4080, though, and it's much quicker than AMD's previous flagship, the Radeon RX 6950 XT.

If you're playing games at 2,560 x 1,440, then the Radeon RX 7900 XT is a solid card, even with ray tracing enabled and particularly if you can enable FSR 2.1. However, it starts to struggle at 4K, especially once you add ray tracing to the mix, and the Radeon RX 7900 XTX copes better here. That's a problem when there's only a £100 price difference between the two cards. Arguably, the 7900 XT would be more appropriately named the 7800 XT and have a lower price.

That said, it's great to see AMD pricing both its two new GPUs under the £1,000 mark in these times, and the Radeon RX 7900 XT is at least in stock. The Radeon RX 7900 XTX gives you better bang per buck, but the 7900 XT is still a decent choice if you're looking to play games at 2,560 x 1,440.

BEN HARDWIDGE

VERDICT

Solid gaming performance, but the price is wrong. This would be a winner if it were called the Radeon RX 7800 XT and cost £799, but at £899, it's too closely priced to the significantly more powerful Radeon RX 7900 XTX.

PERFORMANCE
42/50

FEATURES
16/20

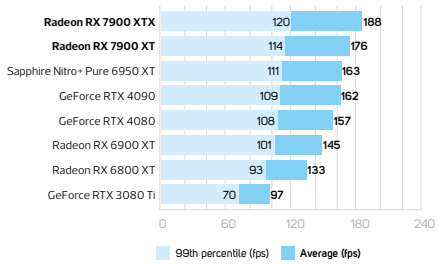
VALUE
18/30

OVERALL SCORE
76%

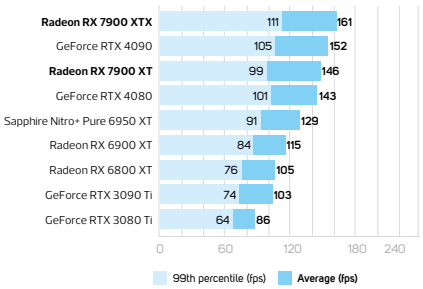
AMD RADEON RX 7900 XT AND XTX RESULTS

ASSASSIN'S CREED VALHALLA

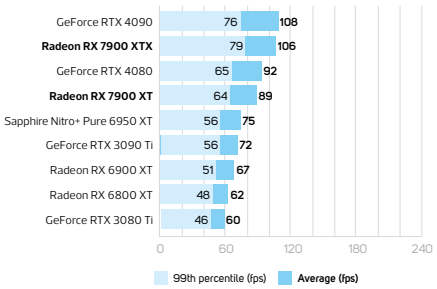
1,920 x 1,080
Ultra high settings, High AA



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

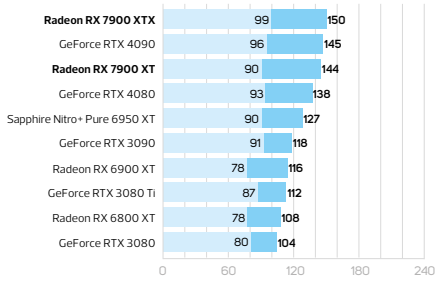


3,840 x 2,160
Ultra high settings, High AA

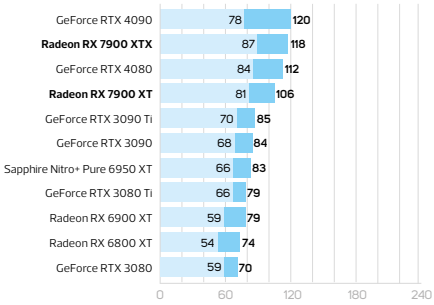


CYBERPUNK 2077

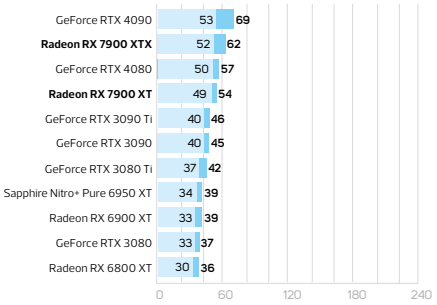
1,920 x 1,080
Ultra preset, no ray tracing



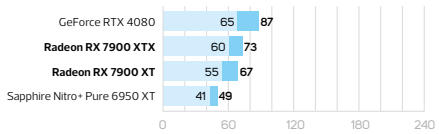
2,560 x 1,440
Ultra preset, no ray tracing



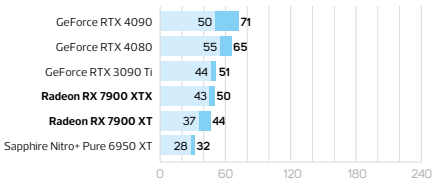
3,840 x 2,160
Ultra preset, no ray tracing



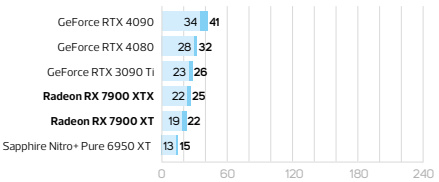
1,920 x 1,080 - RAY TRACING
Medium ray tracing preset, DLSS disabled



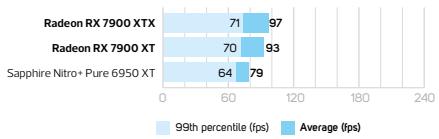
2,560 x 1,440 - MEDIUM RAY TRACING
Medium ray tracing preset, DLSS disabled



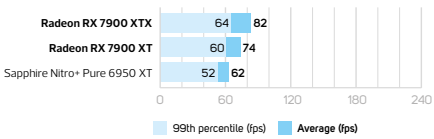
3,840 x 2,160 - MEDIUM RAY TRACING
Medium ray tracing preset, DLSS disabled



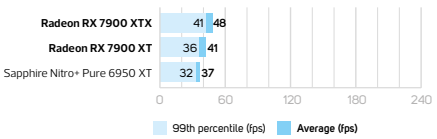
1,920 x 1,080 - MEDIUM RAY TRACING + FSR 2.1
Medium ray tracing preset, FSR Balanced



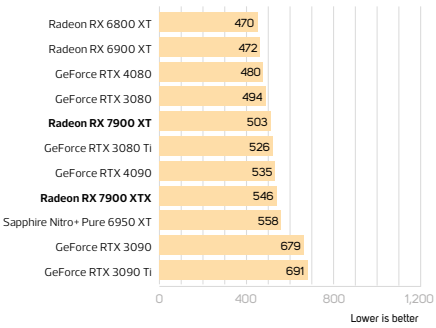
2,560 x 1,440 - MEDIUM RAY TRACING + FSR 2.1
Medium ray tracing preset, FSR Balanced



3,840 x 2,160 - MEDIUM RAY TRACING + FSR 2.1
Medium ray tracing preset, FSR Balanced



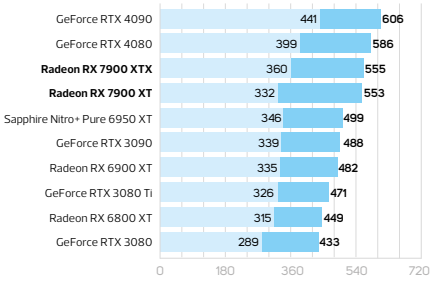
PEAK TOTAL SYSTEM POWER CONSUMPTION (WATTS)
Metro Exodus, 2,560 x 1,440, Ultra settings



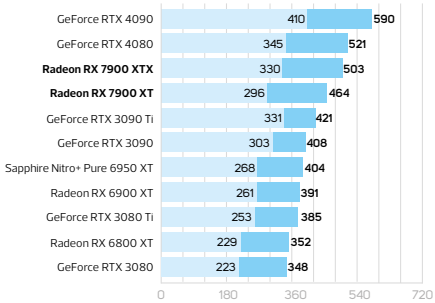
AMD RADEON RX 7900 XT AND XTX RESULTS

DOOM ETERNAL

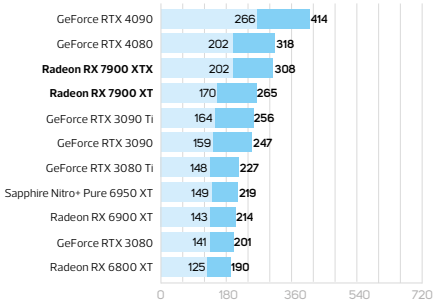
1,920 x 1,080
Ultra Nightmare settings



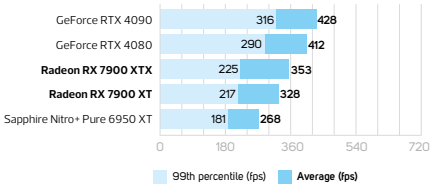
2,560 x 1,440
Ultra Nightmare settings



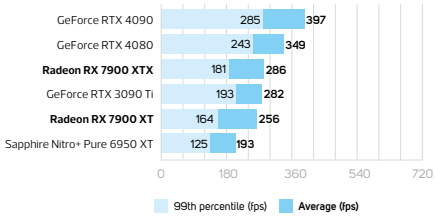
3,840 x 2,160
Ultra Nightmare settings



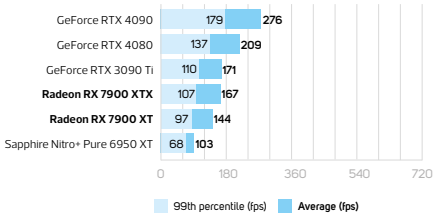
1,920 x 1,080 - RAY TRACING
Ultra Nightmare settings, ray tracing enabled



2,560 x 1,440 - RAY TRACING
Ultra Nightmare settings, ray tracing enabled

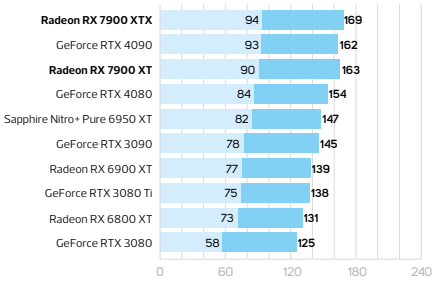


3,840 x 2,160 - RAY TRACING
Ultra Nightmare settings, ray tracing enabled

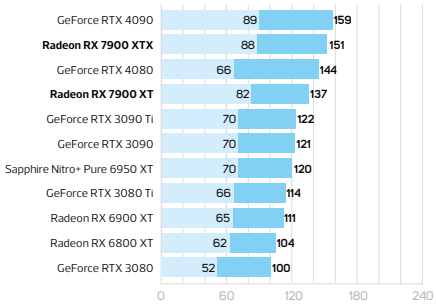


METRO EXODUS

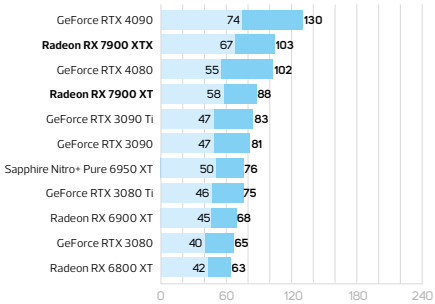
1,920 x 1,080
Ultra settings, HairWorks off, PhysX off



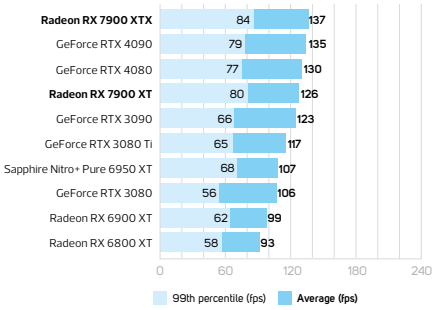
2,560 x 1,440
Ultra settings, HairWorks off, PhysX off



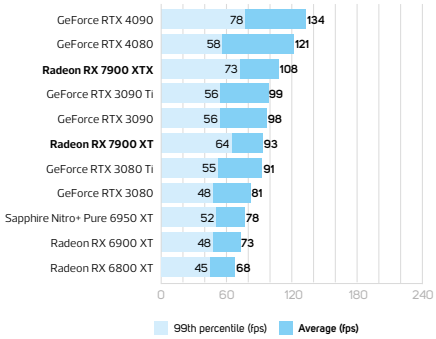
3,840 x 2,160
Ultra settings, HairWorks off, PhysX off



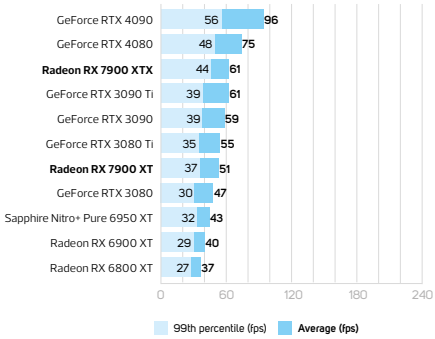
1,920 x 1,080 - RAY TRACING
Ultra settings, HairWorks off, PhysX off, High ray tracing



2,560 x 1,440 - RAY TRACING
Ultra settings, HairWorks off, PhysX off, High ray tracing



3,840 x 2,160 - RAY TRACING
Ultra settings, HairWorks off, PhysX off, High ray tracing



LGA1700 CPU

INTEL CORE i7-13700K / £449 inc VAT

SUPPLIER scan.co.uk

We've had a bombardment of new silicon launches over the past couple of months, even if you forget about GPUs and concentrate on CPUs. AMD and Intel have both fired broadsides of very different CPUs, with the latter focusing on high core counts, its new Raptor Lake architecture and some very high frequencies to win the fight. The Core i7-13700K is the last Raptor Lake CPU to land in our lab from the launch line-up, and given that the Core i5-13600K was awesome, we're excited to see how it fares in our benchmarks, as well as with overclocking.

Compare this new chip with its 12th-gen Alder Lake predecessor, and practically every part of this CPU has been tweaked, from frequencies to maximum turbo power and core count. The number of Raptor Cove Performance cores (P-Cores) has stayed the same at eight, and these cores also support Hyper-Threading, meaning they can execute 16 concurrent threads. However, the number of Gracemont Efficient cores (E-Cores) has increased from eight to 16, with the CPU giving you a total of 16 cores and 24 threads, compared to 12 cores and 20 threads with the Core i7-12700K.

Comparably, its big sibling, the Core i9-13900K, has double the number of E-Cores at 16, so it will offer significantly more multi-threaded performance. However, the Core i5-13600K sits just behind the 113700K, lacking two of its P-Cores, but sporting the same number of E-Cores, so it may get pretty close in terms of performance to the 113700K, while demanding less cash. Your wallet could be particularly happy here too, as the Core i7-13700K costs a whopping £110 more than the Core i5-13600K, with us having spotted the latter going for just £330 inc VAT when we wrote this review.

The boost frequencies of the Core i7-13700K sit a fair bit below those of the Core i9-13900K, with a maximum of 5.4GHz for its P-Cores, and we regularly saw it hitting between 5.3GHz and 5.4GHz in Windows too. This is 300MHz higher than the Core i5-13600K's boost clock, but 400MHz short of the Core i9-13900K. In multi-threaded workloads, we saw its P-Cores hit an all-core boost of 5.2GHz as well. This was 100MHz higher than the Core i5-13600K's all-core boosts, so the Core i7-113700K is a fairly potent CPU out of the box.

As well as competition from its own siblings, there's also intense competition from AMD here in the form of the Ryzen 9 7900X. AMD has slashed prices of its Ryzen 7000-series CPUs in recent weeks, in order to tempt people over to its pricey DDR5-only Socket AM5 platform, but this has only brought its price in line with that of the Core i7-13700K – the Ryzen 9 7900X still goes for around £450 inc VAT in the UK. It lags behind the Intel CPU in terms of core count, with just 12, but those are all full-on Zen 4 cores and it can handle the same number of threads.

SPEC

Base frequency
P-Core 3.4GHz, E-Core 2.5GHz

Max boost frequency
P-Core 5.4GHz, E-Core 4.2GHz

Core
Raptor Lake

Manufacturing process
10nm (Intel 7)

Number of cores
8 P-Cores, 8 E-Cores, (24 threads)

Hyper-Threading
Yes

Cache
30MB L3, 24MB L2

Memory controller
Dual-channel DDR4 and DDR5

Packaging
LGA1700

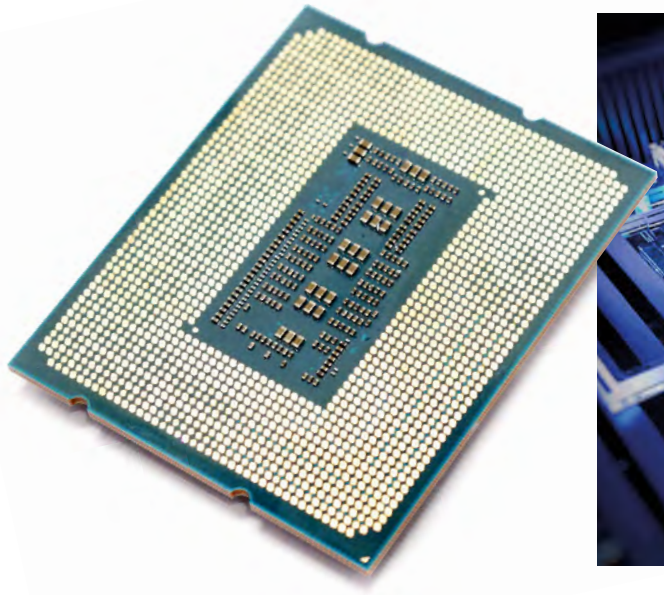
Thermal design power (TDP)
253W

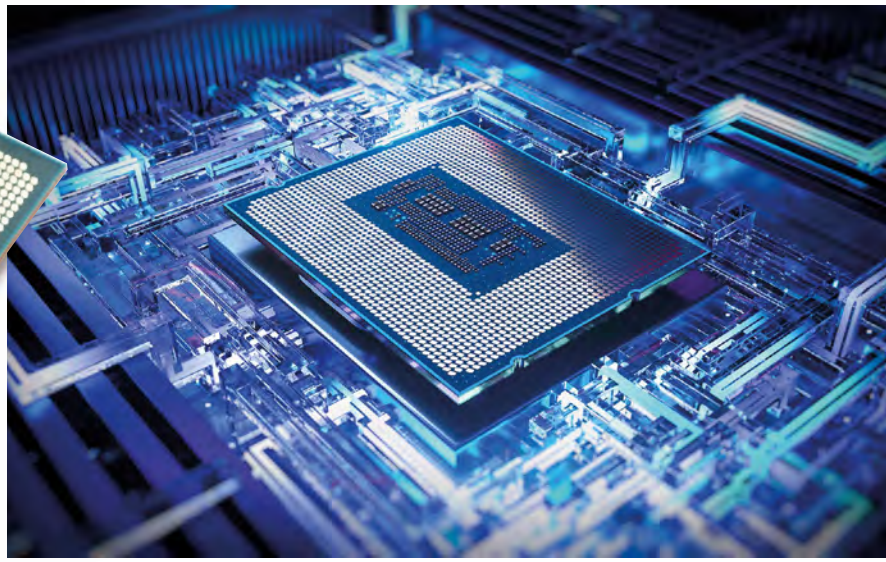
Features
Turbo Boost Max Technology 3, Turbo Boost 2, FMA3, F16C, SHA, BMI / BMI1 + BMI2, AVX2, AVX, AES, SSE4a, SSE4, SSSE3, SSE3, SSE2, SSE, MMX

Performance

Overclocking the Core i7-13700K was sadly not as fruitful as it was with the Core i5-13600K, as we could only get our sample to run at 5.5GHz across all its P-Cores, while the latter could hit a couple of hundred megahertz higher. This was enough to provide a 100MHz boost to the maximum boost frequency, though, and 300MHz to the all-core boost frequency – achieving it required us to input a vcore of 1.35V and for us to open the taps on the power and current limits in our motherboard's EFI.

At stock speed, the Ryzen 9 7900X produced a score of 89,945 in our RealBench image editing test, which stresses single-threaded performance. This was well ahead of the Core i7-13700K, which scored just 82,711, but AMD's Ryzen 7000-series CPUs have a consistent edge in this test. The Core i5-13600K hit 81,061 here, so it's very close to the 13700K despite the 300MHz boost clock deficit.





In our heavily multi-threaded video encoding test, the Core i7-13700K managed to score 1,197,961 compared to 1,239,069 for the Ryzen 9 7900X, with a sizeable lead over the Core i5-13600K's 1,018,435. Meanwhile, AMD had a huge lead in our multi-tasking test, but was only slightly better overall when it came to the overall system score, with both CPUs offering a decent lead over the Core i5-13600K.

Moving to Cinebench R23's multi-threaded test saw the Core i7-13700K outpace the Ryzen 9 7900X by over 1,000 points and its score of 30,137 was way ahead of the Core i5-13600K's 24,268, showing that the Core i7-13700K is the superior chip for heavily multi-threaded content creation workloads.

Intel also had a lead in the single-threaded test, with a score of 2,099 compared to 2,024 for the Ryzen 9 7900X and 2,011 for the Core i5-13600K. Intel also had a lead in Far Cry 6, with a 10fps average frame rate advantage over the Ryzen 9 7900X, but only 1fps over the Core i5-13600K, while Watch Dogs: Legion saw all three CPUs producing similar frame rates.

Overclocking added a reasonable amount to the RealBench system score, but not enough to beat the Ryzen 9 7900X, although it came close in the image editing and video encoding tests. The overclock added another thousand points or so in Cinebench too, extending the Intel chip's lead, but games saw little improvement.

Finally, power consumption was drastically in AMD's favour with a 325W peak system draw for the Ryzen 9 7900X eclipsed by 389W for the Core i7-13700K and 415W when it was overclocked.

Conclusion

Thanks to DDR4-compatibility and support for 12th-gen motherboards, the Core i7-13700K will cost less to own than the Ryzen 9 7900X once you factor in the entire system cost. The AMD chip is a little faster in some tests, but the two chips are pretty much evenly matched most of the time. Socket AM5 may have a longer lifespan than LGA1700 in the future, but we'd still opt for the Core i7-13700K over the Ryzen 9 7900X given the current overall system cost.

However, the fact remains that the Core i5-13600K is significantly cheaper and, thanks to a core count that's not much lower, it's really not far behind. It was even a little faster than the Core i7-13700K in some tests.

If you need the added multi-threaded grunt of the Core i7-13700K then it's just about worth the extra cash, but only when all of its cores are fully used for long periods. It's also significantly cheaper than the Core i9-13900K, but while it's a fantastic CPU, we'd definitely advise most people to save some money and go for the Core i5-13600K instead.

ANTONY LEATHER

VERDICT

A good match for AMD's Ryzen 9 7900X, and with a lower overall system cost, but the cheaper Core i5-13600K is a better fit for most people's needs.

SLOT-IN UPGRADE

+ Great multi-threaded performance
+ Lower overall system cost than Ryzen 9 7900X
+ Much cheaper than Core i9-13900K

NEW SYSTEM REQUIRED

- Core i5-13600K just as fast in many tests
- Power-hungry
- Limited overclocking headroom

PERFORMANCE **43/50**

FEATURES **14/15**

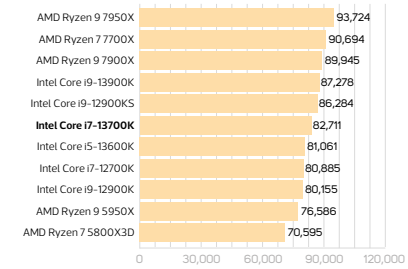
VALUE **27/35**

OVERALL SCORE **84%**

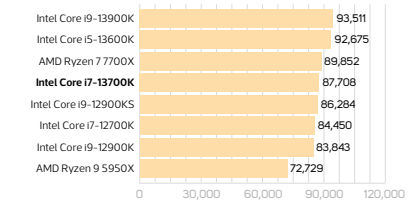
INTEL CORE i7-13700K RESULTS

GIMP IMAGE EDITING

Stock speed

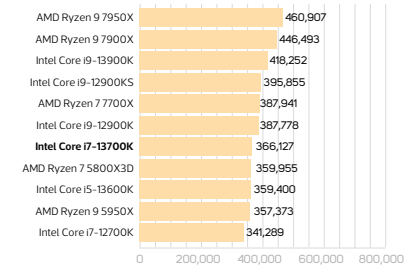


Overclocked

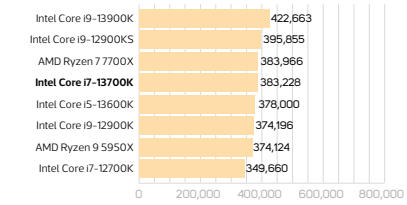


HEAVY MULTI-TASKING

Stock speed

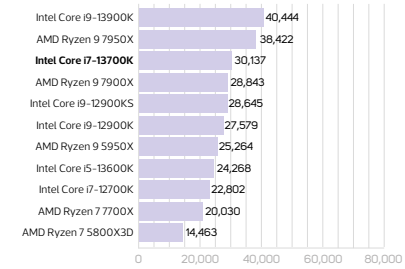


Overclocked

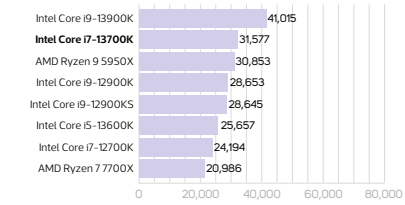


CINEBENCH R23 MULTI-THREADED

Stock speed

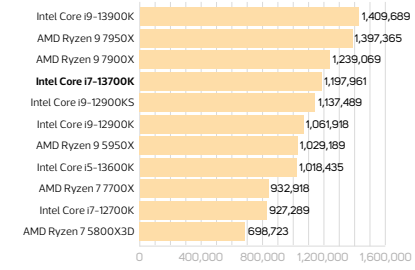


Overclocked

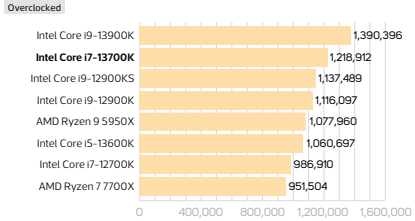


HANDBRAKE H.264 VIDEO ENCODING

Stock speed

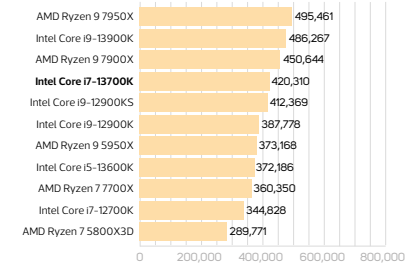


Overclocked

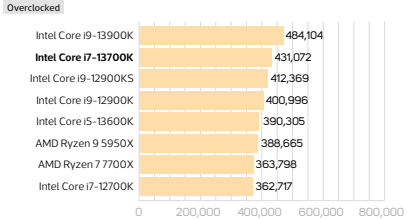


SYSTEM SCORE

Stock speed

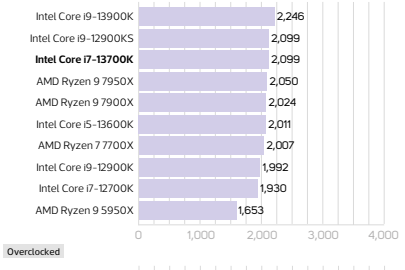


Overclocked

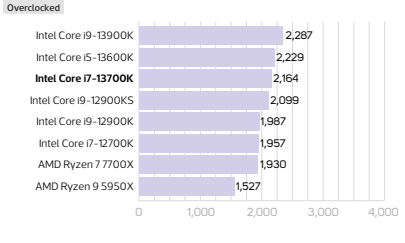


CINEBENCH R23 SINGLE-THREADED

Stock speed

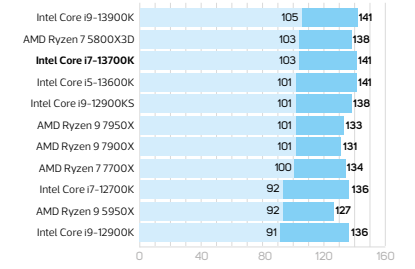


Overclocked

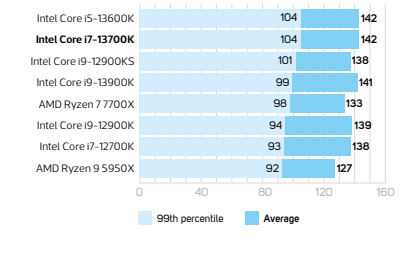


FAR CRY 6 (FPS)

Stock speed, 1,920 x 1,080, Ultra settings

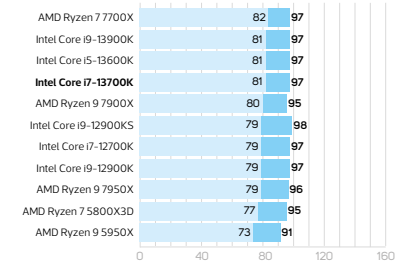


Overclocked, 1,920 x 1,080, Ultra settings

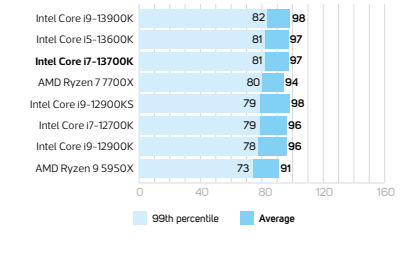


WATCH DOGS: LEGION (FPS)

Stock speed, 1,920 x 1,080, Ultra settings

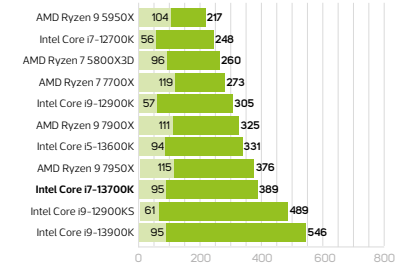


Overclocked, 1,920 x 1080, Ultra settings

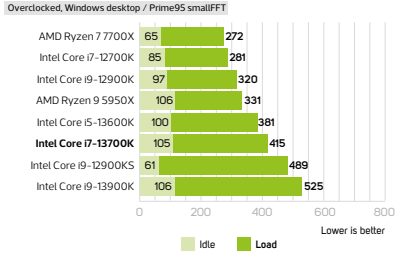


TOTAL SYSTEM POWER CONSUMPTION (WATTS)

Stock speed, Windows desktop / Prime95 smallFFT



Overclocked, Windows desktop / Prime95 smallFFT



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SPEC

Chipset
AMD B650

CPU socket
AMD Socket AM5

Memory support
4 slots: max 64GB DDR5 (up to 6600MHz)

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

Sound
8-channel Realtek ALC4080

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

Cooling
Seven 4-pin fan headers, VRM heatsinks, M.2 heatsinks

Ports
6 x SATA 6Gbps, 1 x M.2 PCI-E 5, 3 x M.2 PCI-E 4, 7 x USB 3.2 Gen 2 Type-A, 2 x USB 3 Type-A, 2 x USB 2 Type-A, 1 x USB 3.2 Gen 2x2 Type-C, 1 x USB 3.2 Gen 2 Type-C header, 1 x LAN, 3 x surround audio out

Dimensions (mm)
305 x 244

As the first motherboard based on AMD's new B650 chipset to land in our lab, the MSI MPG B650 Carbon WiFi has plenty of expectations riding on it. One of those is doing what the B450 and B550 chipsets did for Socket AM4, which is making owning a Ryzen system more affordable. Sadly, though, at a price of £337 inc VAT, it's actually more expensive than some X670E motherboards we've reviewed, and only around £30 cheaper than the excellent ASRock X670E Steel Legend.

Part of the reason is that the differences between the two chipsets are minimal, with few low-end X670E boards offering close to the flagship chipset's maximum number of USB and SATA ports. For example, the ASRock X670E Steel Legend actually has fewer SATA ports than the MPG B650 Carbon WiFi, fewer Type-A USB 3.2 Gen 2 ports on the I/O panel and even one less fan header.

Due to the B650 chipset's limitations compared with X670, though, the MSI board does lag behind when it comes to USB Type-C credentials, only offering a 20Gbps Type-C Gen 2x2 port on the rear panel, with its Type-C header limited to 10Gbps. Comparatively, the ASRock board benefits from Gen 2x2 support on both the rear port and front panel header. Still, the MSI MPG B650 still wins here overall, given it costs less money and has more ports.

We'd argue the MPG B650 Carbon WiFi is better-looking than the ASRock board too, with some chunky heatsinks cooling the quartet of M.2 SSD connectors and the 16 power phases that feed the CPU cores. Speaking of M.2 ports, MSI has one of the best features we've seen in a while, which is a tool-free M.2 installation process. The top heatsink has a push-pin operated clip on one side that allows you to remove it without needing a screwdriver, and a small latch then secures the SSD, which is cooled on both sides.

The end result is that there's no need to deal with fiddly little screws and screwdrivers, and you can install your SSD in seconds. Our only gripes with this system are that the heatsink is quite hard to clip back into place once an SSD is installed, and that the mechanism is only present on that top M.2 slot.

This is a feature we'd like to see on appearing on all motherboards in the future, much like we usually see built-in rear I/O panels these days. That top M.2 slot also supports

CARBON FIBRE

- + Excellent feature set
- + Great M.2 cooling
- + Tool-free M.2 heatsink

CARBON SCORING

- – CPU rarely topped 5GHz all-core boost
- – Some M.2 ports share PCI-E lanes with GPU
- – Software could do with some polish

PCI-E 5 for (hopefully forthcoming) super-fast SSDs, while the rest are limited to PCI-E 4. The second and third M.2 slots share bandwidth with your graphics card if you use both of them too, with your GPU being knocked back to eight PCI-E lanes (instead of 16) if you use SSDs in both those slots.

MSI has also squeezed both a clear-CMOS button and a USB BIOS flashback button on the rear I/O panel, along with HDMI and DisplayPort outputs, a 2.5 Gigabit Ethernet port and antennas for the 802.11ax Wi-Fi. You also get Realtek ALC4080 audio with an optical output. Sadly, though, despite the board punching above its weight in some areas, there are no handy on-board overclocking or testing tools, such as a POST code display, or on-board power and reset buttons.

The software is also a little clunky, and MSI requires you to first download its MSI Centre software, and then also download an obscure add-on called User Scenario, in order to access its software fan control system. Both this and the fan section in the EFI are easy to use, though, and also allow you to switch temperature inputs beyond just your CPU, although the options sadly don't include external thermal sensors or your graphics card.

Performance

The fancy M.2 heatsink on the MPG B650 Carbon WiFi's top M.2 slot kept our PCI-E 4 SSD running at a chilly 54°C and returned some awesome speeds to at 7,406MB/sec and 6,865MB/sec for read and write respectively.

Performance from the Realtek ALC4080 audio was respectable too, offering a dynamic range of 107dBA, noise level of -108dBA and total harmonic distortion (THD) of 0.003 per cent – much better results than we've seen from Realtek's cheaper ALC897 codec.

When dealing with our 16-core Ryzen 9 7950X, the MPG B650 Carbon WiFi's VRMs hit a peak of 58°C, but the board struggled to maintain a high boost clock with this toasty CPU, particularly under sustained multi-threaded loads, despite the CPU being water-cooled. We've seen this CPU regularly hit all-core boost frequencies over 5GHz on other boards, and while the MSI did manage this, it struggled to maintain it – after a few seconds the CPU sat between 4.6GHz and 4.8GHz.

Conclusion

While the MSI MPG B650 Carbon WiFi sadly doesn't have a significantly lower price than boards based on the top-end X670 chipset, it does have some great features that place it above some of the X670 boards at the cheaper end of this scale. The good news is that, while it's not particularly cheap, the MSI MPG B650 Carbon WiFi sadly still offers a much cheaper way to own a Socket AM5 motherboard that hasn't had its features slashed compared with an X670E model.

As a result, while it's not anywhere near as wallet-friendly as its B450 or B550-based predecessors, the MPG B650 Carbon WiFi is essentially a mid-range premium Socket AM5 motherboard for a bit less cash than boards based on the flagship chipsets.

We don't recommend pairing it with the top-end Ryzen 9 7950X, but it's a great choice if you're looking to build a mid-range Socket AM5 system, as long as you're happy with a USB 3.2 Gen 2 header rather than Gen 2x2 Type-C, and you're not planning to use more than two M.2 SSDs.

ANTONY LEATHER

VERDICT

More premium than its chipset suggests, and cheaper than similar X670E boards. It's still expensive, but it's a decent board.

PERFORMANCE **32/35**

FEATURES **30/35**

VALUE **22/30**

OVERALL SCORE **84%**

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DDR5 MEMORY

THERMALTAKE TOUGHRAM XG RGB D5 / £213 inc VAT (32GB, 6000MHz, dual-channel)

SUPPLIER scan.co.uk

We have yet to see many 32GB DDR5 memory kits rated to 6000MHz or faster speeds dip under the £200 mark, but that reality is edging closer and this month, it's Thermaltake's turn to push the needle a little closer to the line with its latest Toughram modules. Retailing for £213 inc VAT and sitting at 6000MHz, the Toughram XG RGB D5 is one of the cheapest kits of this speed or higher we've seen that includes RGB lighting.

It's a far better effort than the Toughram RC DDR5 we reviewed a few months ago. Not only does it retail for £150 less, but it also offers a frequency that's 1200MHz higher. The modules look stunning too, with grey and black heatsinks, which feature a mirrored section in between them, along with multiple RGB lighting zones. They're not exactly low-profile, though, standing at 48mm tall, so you'd do well to check memory clearance if you have a large CPU cooler that overhangs the DIMM slots, or a chunky radiator in the top of your case.

In terms of spec, it has fairly tight timings of 36-38-38-76 and a voltage of 1.3V, courtesy of Hynix M-die memory chips that are the current standard of affordable, high-frequency DDR5 memory kits.

They don't usually allow for much overclocking headroom, especially if you keep the voltage at stock settings. That said, our kit hit a wall of 6400MHz, which is decent enough compared with other kits, and enough to offer a good amount of bandwidth for an AMD Socket AM5 systems too. That said, there's no AMD EXPO support here, although we've seen mixed benefits from this tech in our testing, depending on the kit we're using.

We pitted the Toughram XG RGB D5 against a G.Skill 6000MHz Trident Z5 Neo AMD EXPO kit with 30-38-38-96 timings. In our image editing RealBench test, the former scored 87,068, with a Handbrake video encoding score of 1,398,180 and total system score of 492,139. These results were very close to the 87,451 image editing score, 1,400,140 video encoding score and 492,501 system score of the G.Skill kit. You'll be losing little to no performance opting for the Toughram XG RGB D5 over a similar EXPO kit if you want to use it in a Socket AM5 system.

When it comes to the light show, there are 16 RGB LEDs under the heatspreaders, split into eight lighting zones. If you use Thermaltake's TT RGB Plus software, each of these zones can be set to a specific colour, or take part in the usual lighting effects you typically see on RGB hardware, such as rainbow or scanning effects.

The lighting is set under diffusing bars and is both punchy and colour accurate, with less obvious gaps between the LEDs than we saw on Kingston's similarly priced Fury Beast memory. What's more, the lighting on these modules is also supported in Asus, Gigabyte and MSI's own RGB software, so you can synchronise the lighting with that of your motherboard.

TOUGH RAM

+ Lighting can be controlled by your motherboard
+ Competitive price
+ Solid performance

TOUGH MUTTON

- Limited overclocking headroom
- Modules are quite tall
- No official EXPO support

SPEC

AMD EXPO support
No

Frequency
6000MHz

Timings
36-38-38-76

Voltage
1.3V

Height (from base)
48mm

Lighting
Yes

Conclusion

It's great to see another option for affordable DDR5 memory available, and the Thermaltake Toughram XG RGB D5 is well priced, looks great, offers decent timings and frequency, and works with most motherboard manufacturers' lighting software too. They're not short modules, but if you want RGB lighting, Thermaltake finally has the goods.

There's no need to worry about AMD EXPO support either, as our tests showed it kept up with a G.Skill 6000MHz Trident Z5 Neo AMD EXPO kit with similar specs, so we can recommend this kit for owners of both Intel LGA1700 and AMD Socket AM5 systems.

ANTONY LEATHER

VERDICT

Well-priced DDR5 memory with great RGB lighting, although the modules are a tad tall.

PERFORMANCE 26/30

FEATURES 22/25

VALUE 40/45

OVERALL SCORE 88%

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+ Fantastic gaming performance
+ Decent overall image quality
+ Useful feature set

BLISTERED HEELS

– No USB Type-C input
– Lacklustre HDR
– No blur reduction mode
– Expensive

With its 270Hz refresh rate and massive 32in panel, the Acer Predator XB323U is potentially ideal for those seeking blistering gaming performance without compromising on screen size. Once extricated from its enormous box, the XB323U strikes a stylish figure with its very slim bezels and large but slim V-shaped foot.

The stand, which is in large part made from solid metal with a metallic grey paint finish, offers height, rotation and tilt adjustment, but the panel can't be pivoted into portrait orientation. For features, the Acer includes a typical input selection of one DisplayPort connector and two HDMI ports, plus there's a 4-port USB 3 hub with two ports on the rear and two on the left edge. A headphone jack and some rather tinny speakers are also present. There's no USB Type-C input for connecting laptops and tablets though.

Meanwhile, a mini D-pad and four buttons sit on the right rear of the panel. The top button is for power while the other three interact with the on-screen menus, as does the mini D-pad. It's a speedy and largely intuitive control system.

Thanks to its 2,560 x 1,440 resolution on a large 32in panel, the XB323U has a relatively low pixel density of 92ppi, so it doesn't produce a very sharp image when you're sat up close. However, this isn't an issue for competitive gaming and it's a level of sharpness on par with 24in 1080p displays.

Otherwise, this panel produces largely excellent image quality. Its measured contrast ratio of 1,051:1 is typical for an IPS panel, while its default colour temperature of 6,705K is reasonably close to the desired level of 6,500K. With a massive 170 per cent coverage of the sRGB colour space (120 per cent DCI-P3), this monitor also has very vivid colours with good delta E colour accuracy (0.28 average).

The extended colour range works wonders for HDR content and its performance is bolstered by a high 655cd/m² (measured) maximum brightness in HDR mode. However, contrast doesn't rise beyond 1,000:1, so HDR ultimately lacks its titular dynamic range.

The three slight flies in the ointment are noticeable IPS glow in the corners, which can create a slightly grey look when watching dark images. The uniformity of the panel is a bit ropey too, with the left edge dropping an average 7.4 per cent in brightness. Also, while the sRGB mode reins in that wide colour gamut, it has poor colour balance (7,529K) and also locks out colour adjustments.

Thankfully, it gets back on track when it comes to gaming. Its speedy 270Hz refresh rate (which requires overclocking the panel from its default 240Hz) provides a fantastically responsive experience. Its average initial response time of 6.1ms, using its Normal overdrive mode, isn't all that fast (it's nearly double the 3.7ms frame time of a panel running at 270Hz), but cranking the overdrive up to Extreme results in a much nippier 4.1ms response time while only introducing minimal colour overshoot.

It's a shame there's no backlight strobing blur reduction mode for further sharpening up the display's response, though.

SPEC

Screen size
32in

Resolution
2,560 x 1,440

Panel technology
IPS

Maximum refresh rate
270Hz

Stated response time
1ms

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

Backlight zones
1

Stated contrast ratio
1,000:1

Adaptive sync
FreeSync Premium, G-Sync compatible

Display inputs
1 x DisplayPort 1.4, 2 x HDMI 2

Audio
2 x 2W speakers, headphone out

Stand adjustment
Height, rotation, tilt

HDR certification
DisplayHDR 600

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

Conclusion

You pay a premium for the extra-fast refresh rate of this panel, with several rivals offering a 165Hz refresh rate for half the price. However, if you simply must have the fastest possible response for a 32in IPS panel, the XB323U delivers the goods.

EDWARD CHESTER

IMAGE QUALITY 26/30

GAMING 26/30

FEATURES 16/20

VALUE 12/20

OVERALL SCORE 80%

VERDICT

Overkill for most people's needs but ideal for competitive gamers seeking a big panel.

STEREO GAMING SPEAKERS

EDIFIER G2000

/ £70 inc VAT

SUPPLIER scan.co.uk

Affordable, compact desktop PC speakers that still have decent sound quality are hard to find these days, with the market having essentially divided into cheap rubbish or pricey premium options. The Edifier G2000 bucks that trend, offering solid audio quality and a decent feature set for £70 inc VAT.

These speakers are small and dense. They each stand just 128mm tall, 104mm deep and 105mm wide, although their angled stance means they take up a little more desk space overall (roughly 125mm). With the left speaker weighing 622g and the right one weighing 722g, they're markedly heavier than most similarly sized budget speakers.

Their stretched hexagonal shape is fetching enough, as is the simple exposed-driver front and plain black finish, even if it's a bit plasticky-looking. However, the addition of RGB lighting around the rear of the speakers adds little, especially as the lighting can't be synced with any standard RGB-controlling apps. You can cycle through various colour and effect options but the choices are limited. If the plain black look is a bit dull for you, the G2000 is also available in white and pink.

You get a 3.5mm stereo jack input and a USB audio connection, plus there's also Bluetooth and a subwoofer jack, enabling conversion of these stereo speakers into a 2.1 configuration. Edifier offers a whole host of its own subwoofers, or any other standard analogue sub will work.

On the left side of the right speaker are the controls, which consist of a button for power (hold down) and input selection (tap), while below this is a volume control that we found to be rather unresponsive. Below this is a button for cycling through the sound profiles (tap) and the lighting effects (hold down).

As with Edifier's larger G5000 speakers (see Issue 231), powering on, input selection and sound profile selection (music, movie, gaming) are greeted by obnoxious voice prompts or revving engine noises, which significantly detract from the appeal of using these speakers day to day.

The left and right speakers are also tethered by a fixed 1.8m cable, which is sufficiently long for most purposes but is less convenient than a removable cable and harder to replace if it gets damaged. Another small issue is that there's no headphone socket.

The speakers use a 12V power input, with a small power adaptor included in the box, along with a USB cable for connecting to your PC and a 3.5mm jack cable for auxiliary inputs.

Setting up the G2000 is easy, with Windows instantly recognising the speakers as a USB audio output. However, the low height of the speakers means they benefit considerably from being raised up (ideally via small speaker stands) to reduce sound reflection off the surface of your desk.

A single 2.75in driver and rear bass port is housed in each speaker, while the amplifiers provide 8W RMS to each speaker. That doesn't sound like the greatest recipe for sonic power, and sure enough, these speakers can't compete with larger units for bass depth, frequency range and volume. However, the sound is impressive for their size.

Overall volume is more than ample for home office listening and can easily stretch to kitchen party duties, while the addition of a subwoofer would make these adequate for even larger occasions. Top end detail is plentiful, if a little forced at times, and there's mid-range warmth and surprising power to upper bass frequencies. Sub bass frequencies are understandably lacking though.

GAMER PERFORMANCE

+ Surprising amount of power
+ Good price
+ Small footprint

GAMER STYLING

− Irritating 'gamer' additions
− No headphone ouput
− Speakers linked by fixed cable

SPEC

Weight
722g (right speaker), 632g (left speaker)

Dimensions (mm)
105 x 104 x 128 (W x D x H) per speaker

Drivers
1 x 2.75in driver per speaker

Connections
Bluetooth, 3.5mm aux, USB

Frequency range
98Hz-20kHz

Extras
USB and 3.5mm auxiliary cables; RGB lighting

Conclusion

With surprising sonic power from their compact package, and plenty of features on tap, the G2000 is a decent speaker set for its price. The volume control is a bit finicky, though, and the RGB additions and silly voice/noise prompts are downright annoying, so it's not a perfect package.

EDWARD CHESTER

DESIGN 10/20
FEATURES 18/20
SOUND QUALITY 22/30
VALUE 24/30
OVERALL SCORE 74%

VERDICT

Compact, affordable, sonically impressive and packed with plenty of features. It's just a shame about the silly 'gamer' additions.

WIRELESS GAMING MOUSE

ROCCAT KONE AIR / £60 inc VAT

SUPPLIER uk.roccat.com

CON AIR

+ Reasonable price
+ Decent battery life
+ Great sensor performance

CON MAN

– Large width limits appeal
– Heavy for a travel-orientated mouse
– Competitors offer longer battery life

The Roccat Kone Air is, frankly, a peculiar new addition to the company's gaming mouse line-up. It joins the ranks of travel-orientated gaming mice, such as the Razer Orochi and Corsair Katar Pro, that rely on conventional AA batteries rather than rechargeable units to provide hundreds of hours of use between charges. However, unlike most such mice, this one isn't small or light and it can house two AA batteries rather than one.

It's the size and weight of this mouse that really perplexes. With a whopping 82mm width, and a more conventional (but still sizeable) 132mm length and 43mm height, this mouse is a classic palm-grip-only design that fills the entire space under your hand. This bulk is matched by a considerable 96g weight without any batteries, which then rises to 119g with one battery and 147g with two batteries. By today's standard, that's a seriously weighty rodent.

Helping considerably with the usability of such a large and weighty mouse is the fact that the sides have a double-injected rubber coating to aid grip. Unlike soft-touch coatings, this is a thick layer that should last considerably longer before wearing out.

The Kone Air has a hefty maximum battery life figure of 800 hours when using Bluetooth, but that's with two AA batteries and it still falls short of the 950 hours of the Razer Orochi, which uses just one AA battery. With one battery, the Kone Air drops to 400 hours on Bluetooth.

Using its faster 2.4GHz wireless connection with a 1000Hz polling rate, battery life drops to 500 hours with two batteries and 250 hours with one battery. These are still decent figures, which mean you don't have to swap batteries for several months, but the Orochi again outclasses it by achieving 450 hours using one battery. A single battery is included with the Kone Air.

Like many mice powered by AA batteries, the Kone Air doesn't include any sort of wired operation – it's wireless only – so you must be careful you aren't caught short without enough charge. The batteries fit via the rear of the mouse, the top panel of which slides off, and you can also store the 2.4GHz wireless dongle here. On the underside of the mouse is a sliding switch for choosing between Bluetooth and wireless modes, and to switch it off.

As with the Kone XP Air (see Issue 230), the Kone Air also includes a few extra buttons over and above your typical left, right, middle, back and forward buttons. There's a convenient DPI button on the top, and below your thumb there's a button that defaults to Easy-Shift[+].

Rotate your thumb downwards onto this button and it changes the function of any of the other buttons, essentially doubling the number of functions, although good luck trying to twist your thumb to hit the Easy-Shift[+] button, and either of the back and forward buttons. Roccat's Swarm software is required to configure these functions, but they work without the software once they're programmed.

Roccat's latest 19K DPI Owl-Eye optical sensor is present in this mouse and it provides as excellent tracking performance as we'd expect, keeping up with extreme mouse movements without missing a beat.

SPEC

Weight
96g without battery, 119g with one battery, 147g with two batteries

Dimensions (mm)
82 x 132 x 43 (W x D x H)

Sensor
Roccat Owl-Eye 19K – optical, 19,000 DPI, 50G acceleration

Buttons
7 (left, right, middle, forward, back, top DPI, under thumb)

Cable
None

Extras
Bluetooth 5.1 and 2.4GHz wireless connectivity, internal USB dongle storage, one or two AA battery operation

Conclusion

The Roccat Kone Air offers good value and a versatile mouse with excellent gaming performance. However, its size and weight limit its appeal, especially as a travel mouse, plus its battery life is half that of at least one major rival.

EDWARD CHESTER

VERDICT

Excellent performance, features and value but its size and weight limit its travel-orientated appeal.

DESIGN **12/20**

FEATURES **16/20**

PERFORMANCE **22/30**

VALUE **24/30**

OVERALL SCORE **74%**

INTEL Z790 GAMING PC

CYBERPOWER INFINITY X139 PRO / £3,699 inc VAT

SUPPLIER cyberpowersystem.co.uk

Nvidia's new GeForce RTX 4080 is locked and loaded inside both of this month's review PCs, and the CyberPower Infinity X139 Pro is the priciest of the two. In the CyberPower's case, its MSI Ventus 3X OC slightly overclocks the GPU's boost clock from 2505MHz to 2530MHz. The underlying RTX 4080 GPU is also based on Nvidia's new Ada Lovelace architecture, and is equipped with 9,728 CUDA codes and 16GB of GDDR6X memory.

It's an amazing piece of gaming silicon, and CyberPower has elevated the rest of the internals to match. Intel's Raptor Lake range-topping Core i9-13900K has eight Hyper-Threaded P-Cores with a top all-core boost speed of 5.5GHz. You also get 32GB of DDR5 memory clocked to 5600MHz and two PCI-E 4 SSDs. The 1TB Solidigm P44 Pro is the smaller and faster boot drive, while a Solidigm P41 Plus adds 2TB of secondary space.

MSI also supplies the PSU and motherboard, and they're both great choices. The MSI MPG A1000G is a fully modular 1,000W PSU with 80 Plus Gold certification, and the MSI MAG Z790 Tomahawk Wi-Fi consistently impresses. Its main 16x PCI-E slot supports PCI-E 5, it has four heatsink-covered PCI-E 4 M.2 connectors, and connection options include 2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi 6E and Bluetooth 5.3.

Audio is good thanks to Realtek's ALC4080 codec, and the board has two CPU power connectors, a 16+1 power phase design and debug LEDs. The rear I/O panel is packed, and includes a super-fast USB 3.2 Gen 2x2 Type-C connection, a secondary Type-C port, eight full-sized USB sockets, and buttons to clear and flash the BIOS. The only notably missing features are on-board power and reset buttons, plus a POST code display.

Still, it's an impressive specification, and it's clear where this pricier PC excels alongside the cheaper Wired2Fire. That rig's motherboard uses DDR4 memory, it has one fewer M.2 connector, lesser-quality audio and fewer USB connectors. Beyond the board, Wired2Fire's system only has a single SSD and it relies on a Core i5 processor. The two rigs converge in the warranty department though – they both have five year labour deals with two years of the all-important parts coverage.

CyberPower's ambitious hardware slots inside a Corsair 5000D Airflow case. It's a robust, good-looking chassis, and the PSU shroud, cable covers and CyberPower's fastidious cable tidying keep the interior neat.

Meanwhile, the MSI RTX 4080 card takes up three slots, and a sizeable EK 360mm AIO liquid cooler cools the CPU, but the top of the motherboard isn't blocked and the interior is accessible. Around the back, there's room for three 2.5in drives and two 3.5in drives. There's also a fan board with two vacant headers, alongside an accessory tray.

SPEC

CPU
3GHz Intel Core i9-13900K

Motherboard
MSI MAG Z790 Tomahawk Wi-Fi

Memory
32GB Kingston Fury Beast 5600MHz DDR5

Graphics
MSI GeForce RTX 4080 16GB

Storage
1TB Solidigm P44 Pro M.2 SSD, 2TB Solidigm P41 Plus M.2 SSD

Networking
2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi 6E, Bluetooth 5.3

Case
Corsair 5000D Airflow

Cooling
CPU: EK Basic 360mm radiator with 3 x 120mm fans; GPU: 3 x 90mm fans; front: 3 x 120mm fans; rear: 1 x 120mm fan

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

Operating system
Windows 11 Home 64-bit

Warranty
Five years labour with two years parts. First two years collect and return, then return to base

Performance

There's not much the RTX 4080 won't handle when it comes to games. We played Cyberpunk 2077 with Medium ray tracing and Balanced DLSS, and the RTX

LOVELACE

+ Excellent gaming pace
+ Awesome CPU power
+ Great motherboard and two SSDs
+ Consistently quiet, no matter the workload

LOVE ACTUALLY

– Pricier than rivals
– Can't hit peak all-core CPU boost clock

4080 delivered a 99th percentile minimum of 50fps. In Assassin's Creed Valhalla at 4K, the CyberPower didn't drop below 66fps and it averaged 94fps.

The RTX 4080 will handle virtually any ray-traced game at 4K until you start using the most demanding settings, and DLSS 3 has shown it has the potential to dramatically improve frame rates further here with its AI-based frame generation tech – it just needs more support in games.

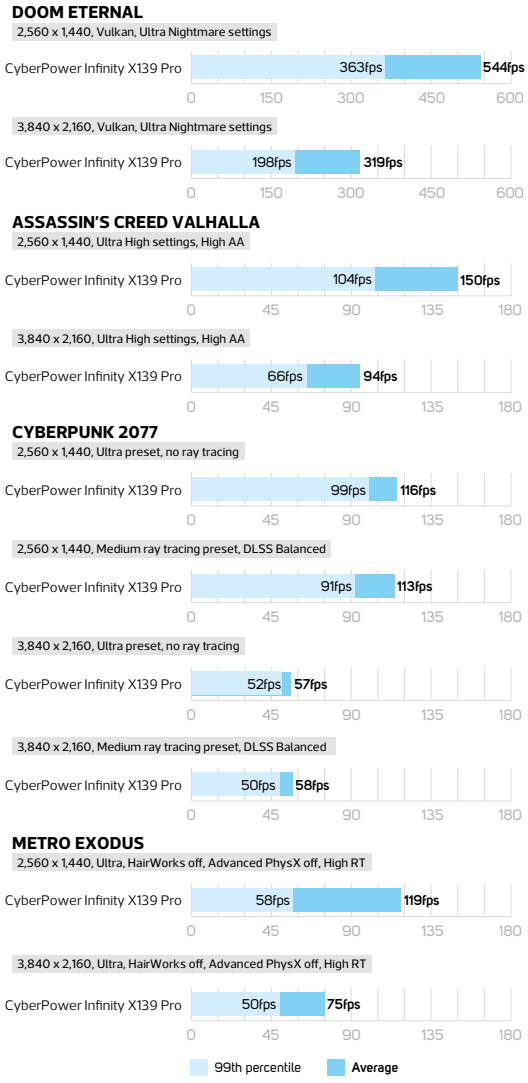
CyberPower's PC didn't overhaul the cheaper Wired2Fire in gaming tests though. The two rigs delivered virtually equal results in Doom Eternal and Assassin's Creed at 4K, and the Wired2Fire was faster in Metro Exodus. Instead, the CyberPower came into its own in application benchmarks.

The Core i9-13900K scored 1,440,000 in our heavily multi-threaded video encoding benchmark – a 43 per cent improvement on the Wired2Fire's Core i5 chip and faster than AMD's contenders. CyberPower's PC beat the Wired2Fire in the multi-tasking test too, and the Core i9-13900K's overall result of 503,415 maintained the CyberPower's lead over Wired2Fire.

There's not much between this high-end chip and the Core i5-13600K in single-threaded workloads, and AMD's Ryzen 9 7950X beats both – but the Core i9-13900K still offers near-unbeatable content-creation pace. It's ably supported by the SSDs – the main drive's read and write speeds of 7,100MB/sec and 6,355MB/sec are superb, and the secondary drive offered solid pace of 4,085MB/sec and 3,382MB/sec.

The CyberPower is also an impressive thermal performer when gaming. It's consistently quiet, and there's barely any difference between the rig's gaming noise level and its idle output. It's less impressive during multi-core CPU tests, where the processor hit a delta T of 77°C and throttled to 5.3GHz, but that doesn't ruin productivity and noise levels remained modest – it's not much below the stated peak all-core boost of 5.4GHz, and this is a notoriously difficult CPU to keep cool.

BENCHMARK RESULTS



75,600
GIMP IMAGE EDITING

1,440,000
HANDBRAKE H.264 VIDEO ENCODING

430,154
HEAVY MULTI-TASKING

503,415
SYSTEM SCORE

Conclusion

CyberPower's system delivers a huge amount of graphics and processing power alongside a great motherboard and chassis. The Core i9 CPU and top-notch motherboard make this PC a superior content-creation and multi-tasking option than its rival, but we still recommend the Wired2Fire for gaming. The latter delivers comparable RTX 4080 gaming speed at a lower price, but if you want a PC that does it all then this CyberPower rig is a top choice.

MIKE JENNINGS

VERDICT

Great performance, a superb motherboard and slick design, although you can get similar gaming pace for less money elsewhere.

PERFORMANCE **24/25**
DESIGN **23/25**
HARDWARE **23/25**
VALUE **19/25**
OVERALL SCORE **89%**

INTEL Z690 GAMING PC

WIRED2FIRE REACTOR EXTREME / £2,399 inc VAT

SUPPLIER wired2fire.co.uk

Nvidia has made waves over the past couple of months with its overpriced GPU launches, but the Wired2Fire Reactor Extreme includes an RTX 4080 for a surprisingly low price of £2,399 for the whole system. The MSI Ventus 3X OC card also improves the core's original boost clock from 2505MHz to 2535MHz, and it's the same triple-slot card as CyberPower included in this month's pricier Infinity system (see p32).

Instead of cutting GPU power, the Wired2Fire delivers a more conventional specification elsewhere, prioritising the build towards gaming. The Core i5-13600K is a mid-range Raptor Lake CPU with six Hyper-Threaded P-Cores and a top turbo pace of 5.1GHz. It's a long way short of the Core i9-13900K inside the £3,699 CyberPower, but our tests have shown that it's still plenty fast enough for gaming.

The Wired2Fire also has 32GB of DDR4 memory rather than DDR5, and a single 1TB mid-range SSD rather than two faster drives. The 750W Seasonic Focus GX750 power supply is a fully modular unit with 80 Plus Gold efficiency, but the CyberPower's PSU has a massive 1,000W output.

It's a similar story from the Asus Prime Z690-P WiFi D4 motherboard, which gets the basics right. It uses DDR4 rather than DDR5, although our tests have shown that DDR4 works fine with Raptor Lake. It's also based on the last-gen Z690 chipset, but again that's fine for most people's needs. Finally, it has three M.2 connectors rather than four – and only two have heatsinks.

You get some decent connection options, though, including 2.5Gbps Ethernet, Wi-Fi 6E and Bluetooth 5.2. One downside is the entry-level Realtek ALC897 codec, which is fine for everyday use, but the CyberPower's MSI board offers superior ALC4080 audio. Meanwhile, the rear has one USB 3.2 Gen 2x2 Type-C connector and five Type-A ports.

There are several areas where the Wired2Fire can't match the CyberPower, but that's no surprise considering the massive price difference – and none of the Reactor's lesser components introduces big problems. Crucially for gaming, the two have the same GPU, and both systems are protected by an excellent five year labour deal with two years of parts coverage.

It's all housed in a Lian Li Lancool 215 enclosure, which has good build quality and some smart design touches, such as the pair of 200mm RGB-lit intake fans and the rear-mounted fan hub with plenty of spare headers. Elsewhere, it's a conventional mid-tower with a PSU shroud, magnetic dust filters and room around the back for a couple of 2.5in drives. The cabling is a little untidy though.

SPEC

CPU
3.5GHz Intel Core i5-13600K

Motherboard
Asus Prime Z690-P WiFi D4

Memory
32GB ADATA XPG Gammix D45 3600MHz DDR4

Graphics
MSI GeForce RTX 4080 16GB

Storage
1TB Intel 760p M.2 SSD

Networking
2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi 6, Bluetooth 5.2

Case
Lian Li Lancool 215

Cooling
CPU: ID-Cooling Frostflow X 240 with 2 x 120mm fans; GPU: 3 x 90mm fans; front: 2 x 200mm fans; rear: 1 x 120mm fan

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

Operating system
Windows 11 Home 64-bit

Warranty
Five years labour with two years parts. First two years collect and return, then return to base

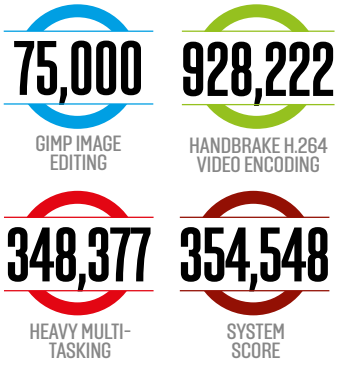
Performance

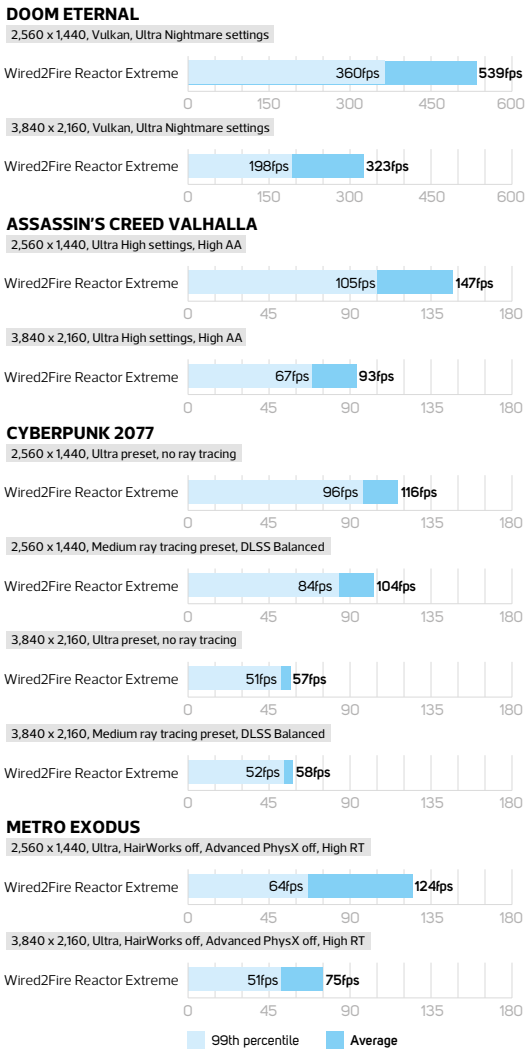
The Wired2Fire might be a lot cheaper than CyberPower, but they share a GPU and the Reactor punches above its weight when it comes to gaming performance. This PC equals or outpaces the CyberPower in most of our gaming benchmarks, and even when it's slower, it's never far behind.

That's impressive, and the RTX 4080 offers stellar speed across most of our tests. Its 51fps 99th percentile in Metro Exodus with high ray tracing is great, and it was even 1fps faster in Cyberpunk 2077 at 4K with medium ray tracing and balanced DLSS enabled. It easily broke the 60fps barrier in Assassin's Creed at 4K, and those Doom Eternal results are fantastic. Indeed, the RTX 4080 will only struggle with the most ambitious games and graphics settings – only the RTX 4090 is better.

Not surprisingly, the Core i5-13600K falls behind the Core i9 inside the CyberPower, but it's not without its charms. Its image editing score of 75,000 remains virtually identical to the score of the pricier processor, and that pace goes some way to explaining how the RTX 4080 keeps up with the more expensive system.

BENCHMARK RESULTS





URANIUM

- \+ RTX 4080 is hugely quick
- \+ Solid single-threaded CPU pace
- \+ Relatively low price

URANUS

- – CPU cooler struggles in multi-core workloads
- – Modest motherboard
- – Irritating fan noise

The comparative lack of cores means the Wired2Fire falls well behind the CyberPower in our heavily multi-threaded Handbrake video encoding test, but it's still far from slow here. One slight disappointment is the SSD's read and write speeds of 3,941MB/sec and 2,963MB/sec, which are fine, but there are plenty of quicker drives out there.

The mid-range processor is topped with an ID-Cooling Frostflow X 240 liquid unit, but it struggles with this CPU under its block. In a multi-core benchmark the P-Cores soon hit a delta T of 77°C and then throttled. The fan noise was also noticeable when the CPU cores were pushed hard, and it's certainly irritating if you want to work in a quiet environment. The Wired2Fire's noise was quieter during gaming and everyday computing and none of the noise was calamitous, but it's a definite minus point.

Conclusion

Wired2Fire has optimised this PC for fast gaming pace without paying through the noise, and it largely succeeds. The RTX 4080 certainly delivers in games, with performance that belies this PC's comparatively low price. The Wired2Fire might not have the huge multi-threaded ability of the CyberPower, but the Core i5-13600K is still plenty fast enough for most people's needs.

Its components and case don't have the finesse or futureproofing you'll find on pricier PCs, and it's also a bit noisy when running at full pelt, but the Reactor delivers RTX 4080 gaming power at a competitive price. It's ideal if you want fast ray-tracing performance in games without paying over the odds.

MIKE JENNINGS

VERDICT

The RTX 4080 supplies superb gaming pace at a great price, though this PC can't compete in every department.

PERFORMANCE **22/25**

DESIGN **20/25**

HARDWARE **21/25**

VALUE **24/25**

OVERALL SCORE **87%**

Custom kit

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

JBL FLIP 6 / £129 inc VAT

SUPPLIER argos.co.uk

The JBL Flip 6 is a Bluetooth speaker approximately the size of a large beer can, which means you can take it almost anywhere. It has a big, simple control interface, tough construction and its IP67 rating indicates protection from dust and short-term immersion in water.

There's a USB Type-C charging port on the back that doesn't require a cover, which is a plus, as they tend to be a point of weakness over time, and playback time on the battery is good for 12 hours. The sound quality is great for a speaker of this small size too, being crisp and clear while delivering solid bass notes.

Meanwhile, using the JBL Portable app allows the use of software called PartyBoost, which enables multiple compatible JBL speakers to work together to provide stereo sound, or simply more sound. The JBL Flip 6 fits the bill for a travelling speaker.

No can do ●●●●○ **Cancan**

AGPTEK CLEANING KIT / £12.99 inc VAT

SUPPLIER amazon.co.uk

If the Swiss Army was all about cleaning electronic devices instead of sporking everything, the AGPTEK cleaning kit might be sequestered in its backpacks. This kit notably lacks the elegance of a multi-tool; it's more accurately described as a dusting brush with a compartment that holds the extra tools, namely a foam prodder for digging dust out of hard-to-reach places, a smaller, firmer brush with a scraper on the back, for digging more tenacious grot out of smaller areas, and a key-cap remover.

These tools in themselves are reasonably well constructed and the main brush is good for lightweight cleaning jobs. You're not going to be able to shift a carpet of dust with the AGPTEK kit, but it's fine for basic maintenance.

Serious mess ●●●○○ **Frivolous tidiness**

KLIM OPTICS OTG CLIP-ON ANTI BLUE LIGHT GLASSES / £22.97 inc VAT

SUPPLIER amazon.co.uk

This handy clip-on pair of yellow lenses sits on top of a pair of your own presumably prescription glasses (although kudos to any committed hipsters wearing them just for fun). The idea is that they filter out the amount of blue light from screens and, in theory, reduce eye strain and let you sleep better. The lenses and clip are mechanically very well made, they attach easily and securely, and they're supplied with a glasses case, a bag and a cleaning cloth.

The shape of the lenses is quite narrow, which is fine for a screen, because your point of focus should be directly in front. They definitely take the edge off a screen's brightness and blue light too, and without reducing the acuity of vision. Everything looks yellow as a result, but they do take the edge off blue light glare.

Mk 1 eyeball ●●●●○ **Kiroshi Optics**

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

Wireframe

Join us as we lift the lid on video games

Visit **wfmag.cc** to learn more

How we test

MOTHERBOARDS

TEST PROCESSORS

- **AMD AM5** AMD Ryzen 9 7950X
- **Intel LGA1700** Intel Core i5-13600K

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.

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 CoreTemp.

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.

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.

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.

LABS TEST

Raptor captors

Antony Leather tests half a dozen of the latest Z790 motherboards to find the best homes for Intel's new chips

How we test

This month we're taking a look at six Intel Z790 LGA1700 motherboards at a range of prices, in order to find which boards offer the best features for your cash, and to gauge how well they handle and overclock Intel's latest 13th-gen CPUs. As it has plenty of overclocking headroom, we'll be using a Core i5-13600K to test the boards, which has 14 cores and 20 threads, making it a suitable choice for gamers and content creators alike.

We'll be looking at VRM temperatures, as well as SSD temperatures using any supplied heatsinks, and we'll also be taking a good look at the layout and feature set of each board. Our chosen boards offer ether DDR5 or DDR4 memory support, and with the former, we're using a 32GB kit of 6000MHz Kingston Fury Beast DDR5 memory, while we're using our trusty 16GB Corsair Vengeance RGB Pro 3466MHz kit for the latter.

We use a 2TB Kingston Fury Renegade PCI-E 4 M.2 SSD to gauge M.2 performance and temperatures from the ports and heatsinks, running a Windows 11 installation with CrystalDiskMark to grab results in its sequential tests, and to run back-to-back benchmarks to record the peak M.2 temperature.

We use the latest BIOS versions for each board, as well as an Nvidia GeForce RTX 3070 Founders Edition graphics card, and we grab results at stock speed and when overclocked. Our test systems use a Barrow Rhopilema test bench and a full custom water-cooling systems, including two 240mm radiators and a Laing DDC pump to eliminate any cooling bottlenecks.

We also use RightMark's Audio Analyzer software to measure the dynamic range, noise level and total harmonic distortion of the on-board audio. Other tests include our RealBench suite for application performance, Far Cry 6, Cinebench R23's single and multi-threaded tests and total system power consumption.

Our final scores at the end of each review are based on a weighted calculation, which accounts for each motherboard's performance, features and value for money, with the overall score being the total sum of those three values.

Contents

- ASRock Z790 PG Lightning D4 / p41
- ASRock Z790 PG Riptide / p42
- Asus ROG Maximus Z790 Hero / p43
- Asus ROG Strix Z790-A Gaming WiFi D4 / p44
- MSI MAG Z790 Tomahawk WiFi DDR4 / p45
- MSI MPG Z790 Carbon WiFi / p46

ASROCK Z790 PG LIGHTNING D4 / £209 inc VAT

SUPPLIER overclockers.co.uk

If there's any proof needed that Intel has a cheaper platform than AMD right now, it's motherboards such as the ASRock Z790 PG Lightning D4, which costs just over £200, accepts DDR4 memory and even manages to include a 16x PCI-E 5 slot in its spec list. The question is, what has ASRock had to cut in order to get a Z790 board out the door at this price?

Well, there's just one M.2 heatsink for a start, and rather skinny heatsinks elsewhere too, but it does offer a 14+1+1 power phase delivery. Sadly, though, it doesn't have a VRM temperature readout in its software, so you're unable to check they're not cooking themselves.

Meanwhile, its count of seven Type-A USB ports on the rear I/O panel are enough for most people's needs, and six of them are USB 3 or faster. You even get a USB 3.2 Gen 2x2 Type-C port here too. Sadly, the Type-C front panel header is limited to USB 3 specifications and there's no Wi-Fi, but all of the M.2 ports support PCI-E 4 and you get four SATA 6Gbps ports as well as 2.5 Gigabit Ethernet.

The pricier ASRock Z790 PG Riptide (see p42) does bag you a few more features, such as an additional four SATA 6Gbps ports, a PCI-E 5 M.2 port, additional M.2 heatsinks and an extra USB port. Both boards also have comparatively weak Realtek ALC897 audio systems, with only three audio ports and no optical output. They also both lack Wi-Fi and have few stand-out features. The Z790 PG Riptide does admittedly look snazzier than the Lightning D4, but you'll need to also factor DDR5 memory into your system pricing.

Meanwhile, ASRock's software is basic and feels dated, but it's ultimately less clunky to use than MSI's software. The fan control section works well, even if it's rather simplistic, as is its counterpart in the EFI. All the usual options are here, but ASRock splits the usual overclocking, frequency and voltage options into different pages, which makes it time-consuming to get an overclock.

At stock speed, this budget board kept Intel's Core i5-13600K at its peak all-core boost of 5.1GHz in our extended stress test with a power draw of 389W, which is similar to other boards. Its video encoding and Cinebench scores of 1,008,921 and 24,159 respectively were right on the money too.

The latter rose to 25,883 once the P-Cores were overclocked to 5.7GHz with a vcore of 1.35V. It was annoying not being able to see a digital readout of VRM temperatures, but our IR probe didn't reveal any hotspots higher than 50°C. The M.2 temperature of 66°C using the top heatsink was fairly high though. You'll want to make sure you have airflow directed over a high-speed SSD in this slot.

LIGHTNING

- \+ Great price
- \+ Happy to overclock a Core i5-13600K
- \+ DDR4 memory support

FRIGHTENING

- – Limited features
- – No Wi-Fi
- – Mediocre audio

SPEC

Chipset Intel Z790

CPU socket Intel LGA1700

Memory support 4 slots: max 128GB DDR4 (up to 5333MHz)

Expansion slots One 16x PCI-E 5, one 16x PCI-E 4, three 1x PCI-E 3

Sound 8-channel Realtek ALC897

Networking 1x Realtek 2.5 Gigabit LAN

Cooling Seven 4-pin fan headers, VRM heatsinks, M.2 heatsink

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

Dimensions (mm) 305 x 244

Conclusion

If you want a Raptor Lake CPU, but don't want to spend much more than £200 on a motherboard, then the ASRock Z790 PG Lighting D4 is a basic but solid option for a Z790 system. However, if you have a little more money at your disposal, and you don't already have some DDR4 memory, we recommend spending a little more money and going for the ASRock Z790 PG Riptide, which looks better and has a few extra features.

VERDICT

A great price for a Z790 board, but it doesn't have many features.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
28/35	23/35	29/30	80%

ASROCK Z790 PG RIPTIDE / £239 inc VAT

SUPPLIER overclockers.co.uk

With two Z790 boards sitting so close in price this month, you'd be right to ask what the differences are between the ASRock Z790 PG Riptide and ASRock Z790 PG Lightning D4. If you're looking to cut down your costs as far as possible then the latter is a solid choice, with the added bonus of support for DDR4 memory. If you're happy to buy new memory and pay a little extra for DDR5, though, the Riptide looks a lot snazzier than the bare bones Z790 PG Lightning D4, plus it has a few extra features.

You get more heatsinks for M.2 SSDs for starters, and ASRock even manages to include a PCI-E 5 M.2 port equipped with an oversized heatsink, although we're still waiting for the first PCI-E 5 SSDs to appear on the horizon. The other four M.2 connectors all support PCI-E 4 and a there's a huge count of eight SATA 6Gbps ports too – if you have a bunch of hard disks to use, this is the board for you.

There's still no VRM temperature readout, but the heatsinks here are larger than those on the ASRock Z790 PG Lightning D4, which is ideal if you're planning to use a Core i9 CPU. There's RGB lighting on the PCH heatsink and, as with all other boards on test this month, you get 3-pin and 4-pin RGB lighting headers too.

Meanwhile, the rear I/O panel offers a useful tally of eight Type-A USB ports, but its Type-C port is restricted to USB 3 specification. Thankfully, if you do need more speed and power, the Type-C header on the motherboard offers USB 3.2 Gen 2x2.

Out of the box, the board returned decent benchmark numbers with a RealBench system score of 371,347, Handbrake video encoding score of 1,028, 571 and Cinebench multi-threaded score of 24,268. Importantly, it overclocked our Core i5-13600K fine, which is more than can be said for the MSI boards in this test.

It also managed to overclock our CPU to 5.7GHz with a vcore of 1.35V, but ASRock seems to apply a big amount of loadline calibration, which can see this figure rise to over 1.4V, so you'll need some decent cooling. After overclocking, the Cinebench score rose to 26,050, offering a decent gain over stock speed.

As with the PG Lightning, there's no VRM temperature readout, but our IR probe found a peak of 45°C in our stress test, and the actual temperature won't be too far from this. Our SSD also only hit 59°C with the large heatsink, which was on par with other boards on test. Finally, audio performance was typical of an older Realtek codec, with a dynamic range of 95dBA and noise level of -93dBA – this is fine for everyday computer use, but it lags behind the quality audio on offer from the Asus and MSI boards.

SPEC

Chipset Intel Z790

CPU socket Intel LGA1700

Memory support 4 slots: max 128GB DDR5 (up to 6800MHz)

Expansion slots One 16x PCI-E 5, one 16x PCI-E 4, one 1x PCI-E 3

Sound 8-channel Realtek ALC897

Networking 1x Realtek 2.5 Gigabit LAN

Cooling Seven 4-pin fan headers, VRM heatsinks, M.2 heatsinks

Ports 8 x SATA 6Gbps, 1 x M.2 PCI-E 5, 4 x M.2 PCI-E 4, 2 x USB 3.2 Gen 2 Type-A, 4 x USB 3, 2 x USB 2, 1 x USB

Dimensions (mm) 305 x 244

Conclusion

It might lack some features, but the ASRock Z790 PG Riptide offers a PCI-E 5 M.2 port, it overclocked our Core i5-13600K fine and is also gives you change from £250. It doesn't have the visual prowess of pricier boards, but it offers far better value. If you're happy to splash out on new memory, this is a great budget buy.

RIPPED

+ Only £239
+ PCI-E 5 M.2 port
+ Good overclocker

TORN

- Mediocre audio
- Needs DDR5 memory
- No Wi-Fi

VERDICT

An LGA1700 motherboard with PCI-E 5 M.2 and graphics support for a great price, although it needs DDR5 memory.

PERFORMANCE 28/35 | FEATURES 25/35 | VALUE 29/30

OVERALL SCORE 82%

ASUS ROG MAXIMUS Z790 HERO / £659 inc VAT

SUPPLIER novatech.co.uk

The Asus ROG Maximus Z790 Hero looks fabulous, and every bit like a board that can cope with the monstrous Intel Core i9-13900K. Its huge RGB lighting array on its massive I/O heatsink shroud is also sure to turn heads. Underneath it sits a 20+1 phase teamed power delivery, and to the south is a trio of PCI-E 4 M.2 ports with heatsinks that cool both sides of your SSDs. We used the large heatsink at the base of the PCB to test M.2 temperatures and it kept our PCI-E 4 M.2 SSD below 50°C.

Thankfully, you also get a PCI-E 5 M.2 port, which is located in a 2-port M.2 expansion card next to another PCI-E 4 M.2 port, which uses of one of the two 16x PCI-E 5 slots, plus you get six SATA 6Gbps ports too. There's a pair of Thunderbolt 4 ports on the rear I/O panel as well, plus a USB 3.2 Gen 2x2 Type-C header on the PCB.

In addition to the latter dishing out speeds of up to 20Gbps, it also features Quick Charge 4+, which can charge devices at 60W as long as you hook up a 6-pin PCI-E power connector into the slot next to it.

There are nine Type-A USB ports too, all of which support USB 3 speeds or faster. You also get 802.11ax Wi-Fi, but sadly, the Ethernet port is still only 2.5 Gigabit, which you can get on either of ASRock's boards this month for a third of the price.

The Realtek ALC4082-equipped ROG SupremeFX audio system offers an ES9218 Quad DAC, plus a USB interface to offer up to 32-bit/384kHz audio – impressive numbers that are irrelevant for human hearing. It performs well though. We recorded a noise level of -113.7dBA and dynamic range of 111.7dBA, with a super-low THD of 0.002 per cent, which are some the best results we've seen from on-board audio.

For enthusiast features, you get water flow sensors, a thermal probe input for syncing your radiator fans with coolant temperature, as well as a 36W 4-pin header for water-cooling pumps. The board is also equipped with the same quick-release PCI-E slot button we've seen on other premium Asus boards, plus there are power and reset buttons, an LED POST code display, USB BIOS FlashBack and a clear-CMOS button too.

Using Asus' excellent EFI and software, we easily overclocked our Core i5-13600K to its usual 5.7GHz with a vcore of 1.35V, but we had to apply maximum loadline calibration to fix the voltage dropping under load. The VRM temperature of 49°C was excellent too, and this result was only a couple of degrees higher when dealing with a Core i9-13900K.

Conclusion

It's outrageously expensive for what used to be Asus' cheapest ROG Maximus board brand, but it's the price you have to pay if you want all the best that Intel's Z790 chipset has to offer, such as Thunderbolt 4, PCI-E 5 graphics and M.2 support, plus a feature-packed PCB and accessory box.

The ROG Strix Z790-A Gaming D4 is much cheaper and only needs DDR4 memory, but if you're in the market for a top-notch Z790 board, the Hero is fantastic.

SPEC

Chipset Intel Z790

CPU socket Intel LGA1700

Memory support 4 slots: max 128GB DDR4 (up to 7800MHz)

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

Sound 8-channel ROG SupremeFX ALC4082

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

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

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

Dimensions (mm) 305 x 244

SUPERHERO

+ Gorgeous looks
+ Amazing feature set
+ Excellent software and EFI

DISPOSABLE HERO

- Expensive
- Cheaper boards offer a lot of the same features

VERDICT

Ridiculously expensive, but the extensive feature set goes a long way towards justifying its price tag.

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

ASUS ROG STRIX Z790-A GAMING WIFI D4 / £388 inc VAT

SUPPLIER ebuyer.com

The Asus ROG Strix Z790-A Gaming WiFi D4 is arguably just as good-looking as the pricier ROG Maximus Z790 Hero, but costs nearly £300 less and shaves a significant amount off the price of the MSI MPG Z790 Carbon WiFi too. Unlike the MSI MAG Z790 Tomahawk WiFi DDR4, some premium features have filtered down to this more affordable board as well.

These include Asus' quick-release PCI-E slot button, double-sided SSD cooling for the top M.2 slot (although no tool-free installation), and USB 3.2 Gen 2x2 support for both the rear Type-C port and the on-board Type-C header. There are USB BIOS Flashback and clear-CMOS buttons on the rear I/O panel and a large RGB-illuminated logo on the I/O shroud, as well as RGB lighting on the I/O panel.

That's not to say that this board has feature parity with the Hero – the latter also steps up to include Thunderbolt 4 on the rear I/O panel, a PCI-E 5 M.2 port and some nifty accessories, including a large M.2 expansion card, none of which are found on the ROG Strix Z790-A Gaming WiFi D4.

SPEC

Chipset Intel Z790

CPU socket Intel LGA1700

Memory support 4 slots: max 128GB DDR4 (up to 5333MHz)

Expansion slots One 16x PCI-E 5, two 16x PCI-E 4, one 1x PCI-E 3

Sound 8-channel ROG SupremeFX ALC4080

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

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

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

Dimensions (mm) 305 x 244

The Strix's 16+1 phase design power delivery system is also less lavish than that of the Hero, but it's still solid, and the Strix's on-board audio is based on Realtek's ALC4080 codec, just like the Hero. You only get four SATA 6Gbps ports on the Strix, compared to six on the Hero and even eight on the ASRock Z790 PG Riptide, but four is usually more than enough for most people's needs these days.

You also get a thermal probe header with this comparatively affordable board, which pairs well with the board's excellent fan control suites in Asus' EFI and software. This is a feature the pricier MSI MPG Z790 Carbon WiFi lacks, and its software is clunky too. The sensor allows you to use a thermal probe to control your fans based on coolant temperature, rather than the CPU temperature, which is useful for water-cooled systems.

The Strix's audio performance was on par with that of the ROG Maximus Z790 Hero, with a noise level of -114dBA, dynamic range of 115.5dBA and THD of 0.0016 per cent, which are the joint best result on test. The M.2 temperature of 50°C with our PCI-E 4 SSD was excellent too.

Meanwhile, the VRM temperature of 48°C with our overclocked Core i5-13600K at a P-Core frequency of 5.7GHz with a 1.35V vcore was cooler than the MSI MPG Z790 Carbon WiFi, and the Strix produced solid benchmark results, and a Cinebench multi-threaded score of 24,656 that rose to 26,332 once overclocked.

QUICK RELEASE

+ Attractive design
+ Good feature set
+ DDR4 support

DELAYED RELEASE

– Still pricey
– No tool-free M.2 heatsinks
– No PCI-E 5 M.2 support

Conclusion

It's a shame there's no PCI-E 5 M.2 port on the Strix, as someone spending £400 on a motherboard is likely to want the latest tech, but with no SSDs in sight yet, this isn't a dealbreaker. Otherwise, we definitely recommend the Asus ROG Strix Z790-A Gaming WiFi D4 over the MSI MPG Z790 Carbon WiFi, and unless you want scope for using PCI-E 5 SSDs in future, or you really want Thunderbolt 4, then it also offers much better value than the ROG Maximus Z790 Hero.

VERDICT

Still pricey, but the Strix strikes a great balance between the cheap and over-the-top options on test this month.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
32/35	31/35	25/30	88%

MSI MAG Z790 TOMAHAWK WIFI DDR4 / £329 inc VAT

SUPPLIER box.co.uk

MSI's Tomahawk range of motherboards have previously really impressed us, with this board's Z690-based predecessor sitting on our Elite list for a good few months. There's a good £70 price difference between the MSI MAG Z790 Tomahawk WiFi DDR4 and the Z690 board, though, and it's up against some stiff competition. ASRock offers much cheaper options in both DDR4 and DDR5 flavours, and the superb Asus ROG Strix Z790-A Gaming WiFi D4 only costs £50 more.

The Tomahawk gets off to a good start by being equipped with a better-quality on board audio system than both the ASRock boards on test this month, thanks to Realtek's ALC4080 codec, and there's an impressive count of seven SATA 6Gbps ports on offer here too, which is more than either Asus motherboard. Comparatively, ASRock's Z790 PG Riptide has eight SATA ports and costs less money, but lacks the Tomahawk's USB 3.2 Gen 2x2 support on both its rear Type-C port and front panel header.

Every M.2 port on the Tomahawk has a heatsink and all of them support PCI-E 4 as well, although none of them is PCI-E 5-capable. The cheaper ASRock Z790 PG Riptide has a single PCI-E 5 M.2 port and a hefty heatsink for that slot, while both the MSI and ASRock boards have a 16x PCI-E 5 slot for graphics.

There are 16 power phases feeding the CPU, which is two more than you get on ASRock's Z790 PG Riptide, but both boards have equally massive heatsinks on them, with the MSI board having the advantage of offering a VRM temperature readout, so you can keep an eye on the thermals.

The Tomahawk also boasts 802.11ax Wi-Fi, as well as USB BIOS flashback and clear-CMOS buttons, but its software is clunky. This is especially the case when it comes to MSI's fan control suite, where the whole effort is less polished than either Asus or ASRock's equivalents, even if the latter was very basic.

During testing with our Core i5-13600K, the Tomahawk also dipped down to 5GHz from 5.1GHz in multi-threaded workloads, resulting in some slower results than the ASRock Z790 PG Riptide in multi-threaded tests. The latter gained a video encoding score of 1,028,571 compared to 942,749 for the MSI, and a Cinebench multi-threaded score of 24,268 compared to 23,989.

The MSI's VRM temperature of 51°C was decent, though, as was the M.2 temperature of 60°C. Audio performance was slightly better than that of the ASRock Z790 PG Riptide as well, with a dynamic range of 100dBA and noise level of -103dBA compared to 95dBA and -93 dBA. MSI's EFI is also excellent and we hit 5.7GHz across the P-Cores with a vcore of 1.35V, boosting the Cinebench multi-threaded score to 25,814.

Conclusion

The MSI MAG Tomahawk WiFi DDR4 offers decent bang for your buck and trumps the Asus ROG Strix Z790-A Gaming WiFi D4 in a few areas too. The latter is a more solid option, though, with better software, fan control, a thermal probe header, quick-release PCI-E slot and a snazzier design, albeit for an extra £50.

HAWK

- \+ Wi-Fi included
- \+ Good VRM and M.2 cooling
- \+ USB 3.2 Gen 2x2 Type-C port and header

TERRY SILVER

- – Cheaper boards offer nearly as much
- – Struggles to maintain all-core CPU boost
- – No PCI-E 5 M.2 port

SPEC

Chipset Intel Z790

CPU socket Intel LGA1700

Memory support 4 slots: max 128GB DDR4 (up to 5333MHz)

Expansion slots One 16x PCI-E 5, one 16x PCI-E 4, one 1x PCI-E 3

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

Dimensions (mm) 305 x 244

VERDICT

A solid base for a Z790 system, but you can get better bang for your buck elsewhere.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
29/35	28/35	24/30	81%

MSI MPG Z790 CARBON WIFI / £530 inc VAT

SUPPLIER ebuyer.com

Just like its Tomahawk-branded sibling, the MSI MPG Z790 Carbon WiFi costs a lot more than its Z690-based predecessor, and supports the same CPUs. However, the new board includes a PCI-E 5-capable M.2 port, its USB 3.2 Type-C header is now Gen 2x2 capable and the I/O panel now features a clear-CMOS button and a Smart button, which can be used to reset the PC, switch all the fans to maximum speed or several other tasks via the EFI.

You also get the tool-free M.2 port and heatsink we saw on MSI's B650 board this month (see p24), and an extra power phase for the CPU, giving you a 19+1+1 power delivery system. The price is still hefty, though, especially when the cheaper Asus ROG Strix Z790-A Gaming WiFi D4 offers similar features except that PCI-E 5 M.2 port.

There's a lot to like here though. The MPG Z790 Carbon WiFi board looks great, with massive heatsinks covering the M.2 ports and VRMs, with the latter linked by a heatpipe too. All of its M.2 ports have heatsinks and SSDs are cooled on both sides, plus there's an LED POST code display and MSI's EFI is much easier to navigate than ASRock's equivalent.

That said, MSI's software is clunky and easily bettered by that of the Asus boards. The latter have better fan control both in software and the EFI, with additional options for temperature sources, including their thermal probe headers, which is useful for custom water-cooling loops.

As you'd expect, you also get 2.5 Gigabit Ethernet, and the extra money over the ASRock boards buys you 802.11ax Wi-Fi along with Realtek ALC4080 audio too. Plus you get a handy total of eight Type-A USB ports.

During testing, we unfortunately saw the same all-core boost drop as we saw on the MSI MAG Z790 Tomahawk WiFi DDR4, with our Core i5-13600K's clock speed falling from 5.1GHz to 5GHz, but it still performed better than the Tomahawk in our heavily multi-threaded video encoding test with a score of 1,029,277 compared to 942,749. The Carbon still couldn't crack 24,000 points in Cinebench's multi-threaded test either, lagging behind other manufacturers' boards, albeit by just a few hundred points. This score rose to 25,963 with a 5.7GHz clock speed applied to our Core i5-13600K's P-Cores.

Meanwhile, the audio system's dynamic range of 106dBA and noise level of -106dBA bettered both ASRock boards, but both Asus boards managed to achieve better results in RightMark's Audio Analyzer software. Finally, our PCI-E 4 SSD stayed below 59°C under load, returning a read speed of 7,059MB/sec and write speed of 6,793MB/sec and the Carbon's VRM temperature never rose above 53°C once overclocked.

SPEC

Chipset Intel Z790

CPU socket Intel LGA1700

Memory support 4 slots: max 128GB DDR5 (up to 7600MHz)

Expansion slots One 16x PCI-E 5, one 16x PCI-E 4, one 1x PCI-E 3

Sound 8-channel Realtek ALC4080

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

Cooling Seven 4-pin fan headers, VRM heatsinks, VRM heatpipe, M.2 heatsinks

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

Dimensions (mm) 305 x 244

SOLAR

+ Tool-free M.2 port and heatsink
+ Good M.2 and VRM cooling
+ Feature-packed I/O panel

COAL

- Expensive
- Lacks pizzazz
- Far cheaper boards offer similar features

Conclusion

While it's a solid motherboard, the MSI MPG Z790 Carbon WiFi doesn't feel like a it's worth £500 – it lacks the necessary pizzazz, generous feature set and wow factor you'd expect at this price. If you really want to splash out, we recommend spending the extra cash for the lavish Asus ROG Maximus Z790 Hero, but unless you're desperate for DDR5 support and a PCI-E 5 M.2 slot, we recommend most people save some money and go for the Asus ROG Strix Z790-A Gaming WiFi D4 instead. CPC

VERDICT

A solid effort, but it lacks the pizzazz needed to carry a half-a-grand price tag.

PERFORMANCE	FEATURES	VALUE	OVERALL SCORE
29/35	30/35	21/30	80%

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LABS TEST

Top typing tools

Edward Chester takes six of the latest premium gaming keyboard models for a tap dance

How we test

Outside of the money-no-object world of fully custom keyboards, you'd have been forgiven for thinking the mechanical keyboard market had reached its zenith several years ago. There has long been a multitude of well-built, stylish keyboards with RGB lighting, lots of switch options and plenty of gaming keys available.

However, more recently, we've seen a surprising number of innovations that have transformed the premium mechanical keyboard landscape. The latest models include features such as hot-swappable switches that can just be pulled straight out and replaced, with no soldering required.

Removable cables are also now common, providing extra versatility, while a couple of the keyboards in this test even have removable numpad sections, enabling you to switch between a compact TKL layout or a full-sized keyboard.

Keycaps that use a tougher PBT plastic rather than ABS are also now more common, and some use a doubleshot manufacturing method, where two layers of plastic are used to form the legends on the keys, rather than just having them screen printed. This method leads to the legends essentially being impervious to wearing away.

In our tests we first consider design, looking at styling, build quality, ease-of-use and the convenience provided by extra features. If you're paying this much money, you should expect a keyboard that doesn't just function well but looks and feels the part too.

We then test each model across a variety of everyday tasks, such as general desktop use, typing and gaming. Most tests are subjective, based on several days of use getting to grips with each model's various pros and cons. However, we do also objectively test the noise output of each keyboard using a decibel meter located 20cm above the keyboard during typing.

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ASUS ROG CLAYMORE II / £200 inc VAT

SUPPLIER overclockers.co.uk

The original Asus Claymore was the first keyboard we'd reviewed with a detachable numpad, allowing you to switch between a conventional full-sized layout and a compact TKL arrangement, so you could free up desk space for your mouse when gaming, or even have the numpad on the left of the keyboard. It was an interesting but expensive idea for the time, and it lacked in a few other areas. Now Asus is back with a revised version that includes a wireless connection and uses Asus' own RX mechanical switches.

As well as several feature changes, the design of the Claymore has changed, mostly for the better. The original Claymore had a premium-feeling thick metal top to its case, but its edges were rather sharp and the way the numpad section slotted onto the sides meant the metal sections regularly made contact, leading to a clunky mechanism that scratched itself.

The Claymore II retains a metal top but it's a simpler flat piece, rather than the bent, angled form of before. As a result, the Claymore II's numpad joining system is much slicker and there's no chance of catching your nails on the sharp edges. That said, the joining system isn't a patch on that of the Mountain Everest, which also boasts the ability to easily connect the numpad at a distance thanks to its use of standard USB Type-C ports.

The actual styling of the Claymore II is arguably a step backwards though. The old design had an industrial appeal whereas the new version has a slightly cheesier look, with its glowing ROG logo and slashes of light in the top left corner. The slightly angular font of the keys likewise has a very 'gamer' look, but other people's tastes may vary from ours.

Back to the improvements, and a major plus point is the addition of a wrist rest, which is well padded and reasonably wide. It spans the full width of the keyboard, which gives you more of a support area, but means you're left with excess length when using the keyboard in TKL mode. Perhaps for this reason, the rest doesn't attach to the keyboard and instead just sits on the desk where it's free to be slid to the side.

As well as having a 2.4GHz wireless connection option, the Claymore II can also be hooked up via USB Type-C, which will charge the keyboard as well as connect it to your PC. By default, the port will take advantage of USB Type-C fast charging, or you can slide a switch on the keyboard's rear to enable the adjacent USB pass-through port, which will disable fast charging. It's a neat system, but battery life is notably low at just 18 hours with the backlight off and eight hours with the lights on.

SPEC

Dimensions (mm) 462 x 155 x 39 (W x D x H)

Weight 1.2kg (without cable)

Format Extended (105 keys + media buttons)

Connectivity USB Type-C and 2.4GHz wireless

Switch type Asus RX Red linear or RX Blue clicky optical

Switch life 100 million keystrokes

Backlighting RGB

Extras Four programmable hot keys, wrist rest, volume wheel, USB pass-through

LONGSWORD

+ Useful modular numpad
+ Wireless and wired connections
+ USB pass-through

BUTTER KNIFE

− Not the best modular system
− Cheesy styling
− Low battery life

Asus has used its own optical key switches in this keyboard, which are available in Red linear or Blue clicky versions. They're rated for 100 million clicks and feel much like equivalent Cherry MX models.

However, the key switch stems aren't compatible with alternative Cherry MX-type keycaps, severely limiting this keyboard's appeal for customisation. At least the keycaps are doubleshot (though ABS, not PBT), so the key legends won't wear away soon.

Conclusion

The Asus ROG Claymore II is an intriguing refinement of Asus' original Claymore design. Its modular numpad is easier to use than the one on its predecessor and its simpler metal top isn't as rough and scratch-inducing.

However, the change from Cherry MX switches to Asus' own switches isn't welcome from a customisation point of view, the board's overall design isn't the sleekest and its modularity isn't a patch on that of the Mountain Everest.

VERDICT

Asus may have been first with its modular keyboard idea but it's currently not the best.

DESIGN	FEATURES	OVERALL SCORE
18/25	20/25	76%
PERFORMANCE	VALUE	
20/25	18/25	

CORSAIR K100 RGB / £230 inc VAT

SUPPLIER scan.co.uk

The K100 RGB is Corsair's flagship wired desktop keyboard. On top of a full-sized keyboard layout and a handful of media controls, it adds a column of six extra gaming keys down its left edge that can be programmed for convenient gaming or other desktop macro functions. There's also an iCUE control wheel that can be programmed to control brightness, skip through tracks, switch applications and more.

The top plate of the body is made from brushed aluminium, which gives the keyboard a premium feel. However, the metal isn't as thick as on the older design and its black finish rather hides it construction. The K100 also features 44-zone RGB lighting around the sides, as well as individual lights under all the keys. The rear and side sections don't provide an obvious glow viewed from above, but they're visible from other angles.

There's no lighting along the front, as that's where you attach the magnetic, padded wrist rest. It's sufficiently deep to actually support your wrist, not just sit under your fingers, and the padding is soft. It would be near-perfect if it were just a bit thicker at its front edge to improve the angle of your wrists.

Meanwhile, a very thick, tethered and braided cable protrudes from the centre rear of the keyboard and terminates in two USB Type-A plugs. This arrangement means you can't easily replace the cable, but the second plug provides a connection for a USB pass-through port next to the cable exit.

In front of the cable is a recessed plastic panel in which are hidden the indicator lights for the Lock keys, mute function, Windows key lock and more. It's a clean way of keeping all such indicator lights clearly visible when needed but hidden otherwise. Then, to the right are the media controls – a volume wheel and mute button above buttons for stop, back, play/pause and forward functions. Finally, to the left are the control wheel and buttons for switching profiles and disabling the Windows key.

In the centre of that control wheel is a button that you tap to cycle through the functions of the wheel, with the wheel then adjusting the function. Options include brightness control, track jogging, track selector, macro recording, application switching, vertical scrolling, horizontal scrolling and zoom.

Move down to the keys, and you'll find doubleshot PBT keycaps, so the plastic is harder-wearing than ABS, and the legends won't wear away like on screen printed keycaps. What's more, unlike some doubleshot keycaps, the legends are crisp and bright.

Normally, Corsair's keyboards are available in a wide range of Cherry MX switch types but the K100 is currently only available with Corsair OPX optical switches (reviewed) or Cherry MX speed switches. Both have a similarly light, linear action with a very shallow actuation point (1mm and 1.2mm respectively).

This is useful for gaming, where rapid repeat key presses are used, but we found the way even the slightest touch elicited a key response was rather unforgiving in everyday use, especially when typing. The switches aren't hot-swappable either and the keyboard is quite loud, registering around 67dB from 20cm away.

Conclusion

The addition of a control wheel and extra gaming keys elevates the versatility of the K100 RGB, making it a hugely capable keyboard for gaming and work. Extra touches, such as the premium keycaps and soft wrist rest, all add to the sense of value too. However, you don't get a removable cable, the switches aren't hot-swappable and the Corsair OPX switches are loud, so it's not a clean sweep for Corsair's top dog.

ICUE

- \+ Extra G gaming keys
- \+ Useful iCUE control wheel
- \+ Smart design
- \+ Premium PBT keycaps

I QUEUE

- – No removable USB cable
- – Loud key switch action
- – Switches aren't hot-swappable

SPEC

Dimensions (mm) 445 x 240 x 38 (W x D x H)

Weight 1.3kg (without cable and wrist rest)

Format Extended (111 keys + media buttons and control wheel)

Connectivity USB (tethered)

Switch type Corsair OPX or Cherry MX Speed

Switch life 100 million keystrokes

Backlighting RGB

Extras iCUE control wheel, media controls, cushioned magnetic wrist rest, USB pass-through

VERDICT

A quality, premium keyboard with lots of extra buttons, but its fixed cable and loud keys won't be for everyone.

DESIGN	FEATURES	OVERALL SCORE
21/25	21/25	82%
PERFORMANCE	VALUE	
21/25	19/25	

MOUNTAIN EVEREST MAX / £220 inc VAT

SUPPLIER scan.co.uk

Mountain is a relatively new name in the PC peripherals market, but you'd never have guessed it by looking at its Everest Max keyboard. Far from a simple first attempt to ease into the market, this keyboard has an ambitious modular design that includes removable numpad and media control sections, and it can even be bought in stages.

The idea is that you can pick up the TKL Everest Core keyboard for just £120 inc VAT, or even the barebones keyboard (not currently available), and then later add the media dock (€40 ~£35 inc VAT), numpad (€60 ~£52 inc VAT) and wrist rest (€10 ~£9 inc VAT), or you can just opt for the whole lot at once with the Everest Max (£220 inc VAT). It's a great system in terms of cost saving and customisation and, what's more, it's practical too.

SPEC

Dimensions (mm) 461 x 265 x 43 (W x D x H)

Weight 852g

Format Modular TKL (87 keys) and full-size (105 keys)

Connectivity USB Type-C

Switch type Cherry MX hot-swappable (Brown, Blue, Grey, Orange, Red)

Switch life 50+ million keystrokes

Backlighting RGB

Extras Keycap removal tool, detachable cushioned wrist rest, detachable numpad and media dock, programmable display buttons

The numpad houses a two-ended sliding USB Type-C plug that allows it to plug into either the right or left sides of the main keyboard. It also uses magnets to keep it securely fixed in place, while still being easy to detach. To be able to just quickly and easily unclip your numpad to free up some desk space for your mouse when gaming is so convenient.

The media dock uses a similar fitment system, and it can be placed either on the top right or top left of the main keyboard. It provides LEDs for Scroll/Num/Caps Lock buttons, as well as buttons for back, forward, play/pause, mute and select. The latter is used in conjunction with the multi-function wheel next to it, which can act as a volume wheel or control the keyboard's backlighting, show your CPU/memory/GPU usage, display a clock and more, all from the circular colour display held within it.

Other multi-function mini displays are housed in four buttons that sit at the top of the numpad section. These can be programmed via Mountain's Base Camp software, with options to run programs, open folders, perform OS commands and more. The buttons themselves have a stiff, shallow action, so they're not overly satisfying to press, but their utility is undeniable.

Meanwhile, the wrist rest magnetically attaches to the front of the main keyboard – it doesn't extend to the numpad – and it offers a pleasing cushioned surface. However, we found it to be too narrow and a little wobbly, so that it tipped backwards under the weight of our wrists, raising the front of the keyboard. It's the only slight slipup in this keyboard's practical design.

The modularity does break up the look of the board, but Mountain has embraced this as a feature by curving the corners of each section to highlight that they can be separated.

The keyboard can be configured with standard hot-swappable Cherry MX switches, although only Brown and Red switches are available for UK layouts. The typing experience is also excellent and not overly noisy, despite lacking any specific sound deadening. The keycaps are basic ABS plastic ones with screen-printed lettering, so they won't last as long as doubleshot PBT caps, but they're easy to replace.

Conclusion

This keyboard has blown us away. The amount of features offered by its extra programmable buttons and multi-function dial, combined with its incredibly convenient modular design, make it a powerful tool. It has all the features you could need, yet it can shrink to a compact TKL board in an instant. It's certainly not cheap, but it still provides astonishingly good value when you consider what you get.

TOP OF THE WORLD

+ Amazing module design
+ So much functionality
+ So much customisation
+ Cracking value

ALTITUDE SICKNESS

– Wrist rest wobbles
– Expensive

VERDICT

Utility, convenience and decent value, the Mountain Everest is among the finest products we've ever reviewed.

DESIGN	FEATURES	OVERALL SCORE
23/25	25/25	95%
PERFORMANCE	VALUE	
25/25	22/25	

RAZER HUNTSMAN V2 / £200 inc VAT

SUPPLIER overclockers.co.uk

We've previously looked at the Razer Huntsman V2 Analog (see Issue 213), but that keyboard is a surprisingly different beast to the rest of the current Huntsman V2 line-up. As well as its inclusion of analogue switches, it has an illuminated wrist rest and lacks the sound deadening material and 8000Hz polling rate of the rest of the line-up.

It's this sound deadening that really sets the Huntsman V2 apart from many other mechanical keyboards, and certainly the others on test. It's amazingly quiet, registering just 46dB from 20cm above the unit. That compares to typical readings of over 55dB for the other models on test. The exact noise level will depend on your choice of switch but with the linear switches we tested, there was essentially no discernible clicking or other higher-pitched noises, nor any resonance of the keyboard's case.

What's so remarkable is that there's no dampening in the switches themselves, but just a thin layer of foam between the main PCB – through which the switches project – and the lower portion of the case. We have some concerns over just how long this thin, squished bit of foam will last but the initial results are undeniable.

SPEC

Dimensions (mm) 445 x 240 x 38 (W x D x H)

Weight 913g (without cable)

Format Full size (105 keys)

Connectivity USB (tethered)

Switch type Razer optical Red linear or Purple clicky

Switch life 100 million keystrokes

Backlighting RGB

Extras Media controls, cushioned magnetic wrist rest, internal sound deadening

The actual construction of the keyboard isn't exactly heavyweight, with an attractive but quite thin layer of brushed aluminium topping the chassis, and a basic thin plastic casing forming the underside. The rest of this design largely impresses with the very sleek, minimalist look that we've come to expect from Razer. As well as the clean all-black look, it's the details that impress, such as the crisp font on the keys, the subtle RGB ring lights around the media controls, the neatly integrated Lock indicator lights and the muted default lighting modes.

Talking of media controls, you get a small cluster above the numpad, consisting of a volume wheel (tap to mute), and back, play/pause and forward media buttons. There are no extra programmable keys though. Another feature that's lacking is a removable USB cable; the fixed, slim, braided cable sprouts from the left rear of the keyboard. It has just a single USB plug on its end, giving away that the board doesn't include a USB pass-through.

One additional feature you do get, though, is a lovely wrist rest. It magnetically attaches to the front and it's deep enough to offer meaningful support. Likewise, its cushioning is thick and very soft, providing a wonderfully cushioned landing spot for your hands. As with the sound-deadening foam, we're a little concerned that the soft wrist rest foam won't hold up over the years – compared with stiffer gel wrist rests that go on forever – but the initial experience is lovely.

SILENT

+ Amazingly quiet
+ Very stylish
+ Quality keycaps
+ Lovely wrist rest

DEADLY

– No removable USB cable
– Basic feature set
– Expensive

The full Huntsman V2 line-up – which includes the Tenkeyless and 60 per cent Mini versions – also includes doubleshot PBT keycaps, so the keycaps will take longer to wear to a shine and their legends won't wear away.

This model uses Razer's own optical key switches, which are available in linear or clicky actions. They're rated to 100 million clicks and are compatible with most Cherry MX cross keycaps. We found the overall typing and gaming experience to be excellent using the linear switches.

Conclusion

For a £200 inc VAT keyboard, the Razer Huntsman V2 feels like it's lacking one or two little extra features to be considered great value. However, it looks fantastic, its typing experience is rock solid, you get premium doubleshot PBT keycaps, its wrist rest is wonderfully comfortable and its sound deadening is a revelation – we've seldom heard a mechanical keyboard so quiet.

VERDICT

Stylish and whisper-quiet, the Razer Huntsman V2 lives up to its name as a silent assassin of the mechanical keyboard world.

DESIGN	FEATURES	OVERALL SCORE
23/25	20/25	83%
PERFORMANCE	**VALUE**	
22/25	17/25	

ROCCAT VULCAN II MAX / £200 inc VAT

SUPPLIER uk.roccat.com

While much of the PC tech industry is taking its foot off the gas when it comes to RGB lighting, Roccat is forging ahead. The Vulcan II Max boasts not just full RGB-lit keys with shortened keycaps that expose more of the RGB-illuminated switch below, but it also has a lighting array on the front edge that lights up its included rubber wrist rest.

Subtlety isn't this keyboard's forte, but if you're into the dazzling look, there's no denying the Vulcan II Max delivers the goods. The wrist rest lighting works impressively well. The wrist rest is just a piece of translucent rubber that slots into holes in the front of the keyboard (from which the lights shine), but the light disperses through it surprisingly evenly, and the 16 individual lights make for smooth colour transitions.

All the lighting is also compatible with Roccat's Swarm software, which provides umpteen effects and ways to coordinate your lighting with the rest of your system. The lighting drops to a dimmer standby mode when the keyboard's not in use.

The wrist rest is also comfortable, thanks to its soft rubber build and large footprint, and comfort is also aided by the whole keyboard's low profile. The slim keycaps and body result in a combined 2-3mm lower key height than typical keyboards, plus the front keycaps don't slightly curve up like on many keyboards, meaning the slim wrist rest doesn't need to raise your wrists as high to reduce wrist strain.

We're less keen on the look of the keycaps – they seem to be floating on top of the switches rather than being integral parts of them. On the plus side, the tops are quite wide, rather like the wide, flat keys on laptops, but with more of a pronounced curve on the top so your fingers can centre on the keys easily. We found these caps very comfortable and accurate for typing.

The key switches are Roccat's own Titan II optical switches, which boast a 100 million click lifespan. Currently, the keyboard is only available in a linear switch variety, and in fact it's only available in a US layout too, but other variants should be arriving soon.

The switches feel great, with a typical smooth Cherry MX Red-style linear action that's pleasant for typing and ideal for rapid-fire inputs for gaming. Noise levels are typically high, though, with a marked bottoming out and key return noise, but there's not the slight echoey noise from the case that you hear from some keyboards.

For features, this keyboard only really offers its lighting and the addition of back, forward and play/pause buttons, along with a volume control. The latter is pleasingly tactile, with a relatively stiff, notched action for precise control.

However, there's no USB pass-through, removable USB cable or any other extra buttons. Instead, the cable is tethered and terminates in two USB-A ports, the extra one of which provides power for the lighting. You also get several secondary functions that can be activated via the Fn key. For instance, Fn+Win disables the Win Key while the F1-F12 buttons activate profiles, record macros, mute the microphone and more.

Conclusion

If you simply must have the most RGB lighting at all times then the Roccat Vulcan II Max is the keyboard to buy. Moreover, its wrist rest is comfortable as well as dazzling, plus its funny-looking short keycaps offer a decent typing experience. However, you pay a premium for all that lighting, with other keyboards offering more physical features at this high-priced end of the market.

SPEC

Dimensions (mm) 463 x 236 x 34 (W x D x H)

Weight 1,040g

Format Full size (105 keys)

Connectivity USB

Switch type Roccat Titan II optical Red or Brown

Switch life 100 million keystrokes

Backlighting RGB

Extras Detachable wrist rest

VULCAN SALUTE

+ Dazzling lighting array
+ Comfortable wrist rest
+ Low-profile design

VULCAN DEATH GRIP

- No USB hub
- Few extra features
- High price

VERDICT

Lit up to the max and a solid enough keyboard, but other models offer more features for the same money.

DESIGN	FEATURES	OVERALL SCORE
24/25	15/25	78%
PERFORMANCE	VALUE	
20/25	19/25	

STEELSERIES APEX PRO TKL (2023) / £190 inc VAT

SUPPLIER amazon.co.uk

Taking a leaf out of Apple's book, SteelSeries has chosen to name its new Apex Pro TKL keyboard the Apex Pro TKL (2023), rather than simply add a '2' to its name or switch to a different moniker entirely. Potential confusion aside, though, this is largely a solid update to what was already a stylish and capable keyboard.

Interestingly, so popular was the company's previous Apex Pro TKL (SteelSeries proclaims it the best-selling TKL keyboard in the world), that it has chosen to launch its updated design in this smaller form factor first, with a full-sized version potentially arriving later.

It's a very stylish keyboard. The old version had a low-profile, bent aluminium top that was very fetching, but the new version looks even better. The design is simpler, with its black anodised aluminium top plate surrounded by a plastic outer ring and a neat shadow gap between them. The top plate is so subtle you'd never guess it was even aluminium, though, which arguably defeats the object.

Greatly helping with the look is the almost complete lack of expanded casing for features such as a company logo. Instead, the SteelSeries logo is shown in the OLED display in the top right corner. The clean font of the keycaps helps the styling too, as does the default back lighting effect, which is gentle and colour-coordinated, rather than a dazzling kaleidoscope.

Alongside the OLED panel is a very small metal volume wheel. Frustratingly, its single-direction knurling and stiff action meant we found our winter-dry fingers often slipped over it rather than gripping and turning it. You can tap it in to provide a mute function, while next to it is a play/pause button. This combo also allows you to adjust backlight brightness, switch profiles, record macros and adjust the switch actuation, with the wheel used to select and adjust each setting, while the OLED screen shows the mode.

The actuation of the switches refers to the ability to set the point at which the keypress is triggered, from 0.2mm all the way up to 3.8mm. Moreover, you can configure two different responses to occur at two different levels, such as a game character walking with a light press then running with a deeper press.

This ability is down to the switches using a magnetic hall effect to actuate, rather than relying on a metal contact or breaking a beam of light. It's an intriguing and genuinely useful way of adding extra abilities to a keyboard, but we didn't find it an indispensable feature during our gaming time.

The switches themselves are only available in a linear action but are rated to 100 million presses. Meanwhile, the keycaps are doubleshot PBT so will stand up to years of use without the legends wearing off.

A wrist rest is also included and it magnetically attaches to the front. However, it doesn't have any padding, which is disappointing for a keyboard at this price. You also don't get a USB pass-through, but the cable is at least removable and attached via a USB Type-C port to the left rear of the unit.

On the underside there's also a rubber flap that hides a stowage space for the keycap removal tool – the switches themselves aren't hot-swappable.

SPEC

Dimensions (mm) 355 x 139 x 40 (W x D x H)

Weight 770g (without cable)

Format TKL (87 keys + media buttons)

Connectivity USB Type-C

Switch type SteelSeries Omnipoint linear hall effect magnetic

Switch life 100 million keystrokes

Backlighting RGB

Extras Four programmable hot keys, wrist rest, volume wheel, USB pass-through

PROFESSIONAL PEAK

+ Stylish design
+ Useful secondary key actuation
+ Doubleshot PBT keycaps

AMATEUR VALLEY

– Expensive
– Wrist rest not padded
– Slippery volume wheel

Conclusion

The SteelSeries Apex Pro TKL is a stylish and well-built keyboard, and its multi-level actuation switches are a genuinely useful, if rather niche addition. Its price of £190 inc VAT from **amazon.co.uk** is steep for a TKL layout with this feature set, though, and you can get a better-balanced feature set for similar money elsewhere. CPC

VERDICT

A premium look and feel with clever switches, but its price is high for a TKL layout.

DESIGN	FEATURES	OVERALL SCORE
22/25	18/25	76%
PERFORMANCE	VALUE	
20/25	16/25	

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Our choice of the best hardware available

Core component bundles

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

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	£190
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 (CMK16GX4M 2B3200C16)	scan.co.uk	**#218** p78	£54
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	£42
		Total £391		

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	£170
CPU COOLER	ARCTIC Freezer i13X	scan.co.uk	**#224** p76	£23
GRAPHICS CARD	Nvidia GeForce RTX 3060 Ti	overclockers.co.uk	**#228** p90	£400
MEMORY	16GB (2 x8 GB) Corsair Vengeance LPX DDR4 3200MHz (CMK16GX4 M2B3200C16)	scan.co.uk	**#224** p76	£54
MOTHERBOARD	Gigabyte B660 Gaming X DDR4 (ATX)	scan.co.uk	**#224** p50	£140
STORAGE	1TB WD Blue SN570 (M.2 NVMe)	scan.co.uk	**#222** p20	£66
		Total £853		

UPGRADES				
SWAP GRAPHICS CARD	Nvidia GeForce RTX 3070 Ti	scan.co.uk	**#228** p90	£630
SWAP STORAGE	1TB WD Black SN850X	scan.co.uk	**#230** p29	£110

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	£329
CPU COOLER	ARCTIC Liquid Freezer II 240 RGB (240mm AIO liquid cooler)	scan.co.uk	**#226** p49	£80
LGA1700 ADAPTOR	ARCTIC Liquid Freezer II Upgrade Kit	scan.co.uk	**#226** p49	£5
GRAPHICS CARD	Nvidia GeForce RTX 3070 Ti	scan.co.uk	**#228** p90	£630
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz DDR4 (CMW16GX4 M2D3600C18)	scan.co.uk	**#230** p47	£64
MOTHERBOARD	Gigabyte Z690 Gaming X DDR4*	scan.co.uk	**#222** p46	£201
STORAGE	1TB WD Black SN850X	scan.co.uk	**#230** p29	£110
	Total £1,419			

UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	ebuyer.com	**#166** p54	£85

***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	£329
CPU COOLER	ARCTIC Liquid Freezer II 240 RGB (240mm AIO liquid cooler)	scan.co.uk	**#226** p49	£80
LGA1700 ADAPTOR	ARCTIC Liquid Freezer II Upgrade Kit	scan.co.uk	**#226** p49	£5
GRAPHICS CARD	Nvidia GeForce RTX 4080	scan.co.uk	**#233** p14	£1,190
MEMORY	32GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz DDR4 (CMW32GX4M 2D3600C18)	scan.co.uk	**#230** p47	£104
MOTHERBOARD	Asus ROG Strix Z790-A Gaming WiFi D4	ebuyer.com	**#234** p44	£388
STORAGE	1TB WD Black SN850X	scan.co.uk	**#230** p29	£110
	Total £2,206			

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	£330
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)	corsair.com	#233 p30	£235
MOTHERBOARD	MSI MPG B650 Carbon WiFi	box.co.uk	#234 p24	£337
STORAGE	1TB WD Black SN850X	scan.co.uk	#230 p29	£110
		Total £3,042		

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	£579
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	£400
MEMORY	32GB (2 x 8GB) Corsair Vengeance RGB DDR5 6000MHz (CCMH32GX5M2 B6000Z30K)	corsair.com	#233 p30	£235
MOTHERBOARD	ASRock X670E Steel Legend	scan.co.uk	#232 p24	£365
STORAGE	2TB WD Black SN850X	scan.co.uk	#225 p27	£230
		Total £2,039		

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	amazon.co.uk	**#228** p39	£228

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	£105
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	£60
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	£93
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	scan.co.uk	**#204** p42	£167

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Kolink Citadel Mesh RGB	overclockers.co.uk	**#218** p26	£65

Networking

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET ROUTER	Belkin RT3200-UK	amazon.co.uk	**#216** p52	£74
ROUTER	Asus RT-AX68U	scan.co.uk	**#216** p51	£177
MESH ROUTER	Asus ZenWiFi AX Hybrid XP4	amazon.co.uk	**#226** p59	£248
WI-FI ADAPTOR	TP-Link Archer TX3000E	overclockers.co.uk	**#196** p58	£50
DUAL-BAY NAS BOX	Synology DS220j	box.co.uk	**#200** p22	£161
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

Monitors

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

Up to 25in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN, 144HZ, IPS, 1,920 X 1,080, F, G	AOC 24G2U	scan.co.uk	#214 p28	£200
25IN, 240HZ, IPS, 1,920 X 1,080, F, G	Acer Predator XB253Q	box.co.uk	#209 p57	£280
25IN, 360HZ, IPS, 1,920 X 1,080, F, G	Asus ROG Swift PG259QN	box.co.uk	#212 p20	£389

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	amazon.co.uk	#212 p21	£599
28IN, 144HZ, IPS, 3,840 X 2,160, F, G	AOC U28G2XU	overclockers.co.uk	#221 p29	£620

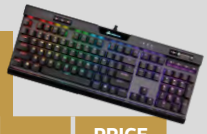
Over 28in

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 32M1N5500VS	amazon.co.uk	#233 p54	£300
32IN, 165HZ, IPS, 2,560 X 1,440, F, G	Dell G3223D	dell.com	#233 p51	£349
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	£1,349
32IN, 240HZ, VA, 3,840 X 2,160, F, G, HDR	Samsung Odyssey Neo G8	scan.co.uk	#229 p17	£1,300
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	£399

Peripherals and audio



Gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET TKL	SteelSeries Apex 3 TKL	currys.co.uk	#221 p59	£45
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	Mountain Everest Max	scan.co.uk	#234 p51	£220
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	£70
MULTI-BUTTON	Roccat Kone XP	roccat.com	#225 p60	£60
WIRELESS	Razer Viper Ultimate	currys.co.uk	#217 p54	£139
PREMIUM WIRELESS	Razer DeathAdder V2 Pro	scan.co.uk	#210 p28	£119
ULTRA LIGHTWEIGHT	Cooler Master MM711	box.co.uk	#232 p52	£30
PREMIUM LIGHTWEIGHT WIRELESS	Logitech G Pro X Superlight	amazon.co.uk	#217 p52	£95

Peripherals and audio cont ...

Game controllers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
RACING WHEEL	Logitech G29 Driving Force	currys.co.uk	**#202** p50	£239
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	£43
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	£29
STEREO	EPOS GSP 300	amazon.co.uk	**#210** p54	£35
WIRELESS	Corsair Virtuoso RGB Wireless	amazon.co.uk	**#204** p50	£137
PREMIUM WIRELESS	EPOS H3Pro Hybrid	currys.co.uk	**#231** p47	£169

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-CAPACATIVE	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)
ENTRY-LEVEL RTX 4080 PC	Wired2Fire Reactor Extreme	Intel Core i5-13600K	Nvidia GeForce RTX 4080	wired2fire.co.uk	**#234** p34	£2,399
PREMIUM GEFORCE RTX 4080 PC	CyberPower Infinity X139 Pro	Intel Core i9-13900K	Nvidia GeForce RTX 4090	cyberpowersystem.co.uk	**#234** p36	£3,699
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	laptopsdirect.co.uk	**#227** p40	£1,980
HIGH-SPEED GAMING	Alienware x17 R2	Intel Core i7-12900HK	Nvidia GeForce RTX 3080 Ti Laptop	17.3in 1,920 x 1,080 IPS 360Hz G-Sync	custompc.co.uk/AlienwareX17	**#227** p38	£3,704

RICK LANE / INVERSE LOOK

BLOCKBUSTED

As large studios struggle to get AAA games out the door, Rick Lane asks how the next wave of revolutionary blockbusters will look

While I enjoyed a wider variety of gaming experiences in 2022 than in any previous year, something was missing. Essentially, the AAA gaming industry didn't turn up. I could count the number of genuine blockbusters that launched on one hand – Elden Ring, Modern Warfare 2, God of War: Ragnarok (which didn't even launch on PC) and maybe A Plague Tale: Requiem if you're feeling generous.

The pandemic undoubtedly had a chilling effect, with numerous major titles sliding into 2023, including Starfield, Redfall and Forspoken. More generally, AAA games are contending with increasingly protracted development times, requiring ever more money and manpower to squeeze a diminishing amount of visual lustre from the next wave of GPUs.

Our expectations of what constitutes a AAA game have also changed. Age of Empires used to be considered a major release, but is last year's Age of Empires 4 in the same league as Elden Ring? This puts greater expectation on an ever-dwindling number of games, which in turn means those developers must ensure the games are perfect.

> Is Age of Empires 4 in the same league as Elden Ring?

The industry also has yet to figure out what the next wave of blockbuster games looks like. If you look back through gaming history, most of the big hitters in each preceding decade revolve around a specific idea. In the 1990s, it was the FPS, in the 2000s, it was the cover-shooter. In the 2010s, it was the open world. These emerging genres provided new, attractive idea-spaces for developers and publishers to progress in terms of technology and design.

Where do blockbuster games go after the open world? The two biggest games of this year – Elden Ring and God of War: Ragnarok – are both firmly rooted in the design philosophies of the previous decade. Perhaps this is because developers' abilities to iterate upon these ideas has dramatically slowed down. But where can you go after the open world? How do you create a genre more ambitious than a freely explorable alternate reality that lasts dozens, if not hundreds, of hours?

There are a couple of potential avenues. Shadow of Mordor's Nemesis system gave us a glimpse of how the future of dynamic narrative could look in games, although its potential to spread throughout the industry was hindered by publisher Warner Bros patenting the system.

The PS5's latest Ratchet & Clank features an intriguing (albeit limited) multiverse concept. The idea of exploring multiple worlds layered over one another has significant potential for both narrative and systemic play. However, even these ideas require an open-world framework to operate – it's simply adding extra stuff onto an existing template.

Perhaps there is nowhere left to go once you start simulating entire worlds, or perhaps the industry is simply too broad for one idea to emerge as the design trend chased by AAA studios. That said, the lack of an obvious new direction could also mean that some clever studio is working on that mystery idea right now, and in two years, I'll be writing feverishly about this radical experience shifting the industry onto an entirely new path. CPC

Rick Lane is Custom PC's games editor @Rick_Lane

Victoria 3 / £41.99 inc VAT

DEVELOPER Paradox Interactive / **PUBLISHER** Paradox Interactive

The latest grand strategy game from Paradox Interactive, Victoria 3 swaps out the dynastic skulduggery of Crusader Kings for a dizzyingly complex Eurogame of industrial production and political progressivism. It lets you pick virtually any nation on the map and broadly do whatever you like with it.

Whether you plan to run an aggressive military dictatorship or a politically emancipated utopia, your country must run at a profit. Victoria 3's economic simulation combines managing a complex network of production chains, and eking profit out of their respective supply and demand. Your country can produce a wide range of goods through many different industries, but all are interconnected.

If you want to manufacture more tools, for example, you'll need additional wood and iron, increasing the demand and price of those goods. You can try to reduce the price of wood by building more logging camps, but logging camps also require tools to operate and so on.

Mastering this intricate economic puzzle is an absorbing challenge, as you adjust tariffs and establish trade routes to influence the price of goods, while implementing new technologies that can suddenly launch your economy to the Moon. Amusingly, having too much money can be as much of a problem as having too little, as economies are based on the gold standard, and stockpiling gold can trigger inflation that reduces your currency's value.

Meanwhile, most of the game's character comes from its political simulation. Through the government panel, you can implement new laws that affects all sorts of factors, from how your country rules its subjects, to the nature of its health service, welfare system and representation of different demographics.

VICTORIA

- \+ Dizzying economic simulation
- \+ Fun political plate-spinning
- \+ Gorgeous, ever-evolving map

GEORGE IV

- – Diplomacy is basic
- – Wars even more so

However, each law must be passed by your government, and that means trying to please a host of different political factions ranging from religious conservatives to left-wing progressives. The ensuing political battles can trigger specific events, or even incite revolution as radicalised factions try to enforce their ideas at gunpoint.

Victoria 3's depiction of the 19th-century world is impressively vivid. The campaign map is rich with detail and highly dynamic, with your country's cities and infrastructure visibly changing as the game progresses. However, there are areas where the game falls short. Diplomacy is mostly about managing alliances and wars, lacking the international subterfuge seen in Crusader Kings. Managing your military is similarly restrictive, with wars taking place on randomly generated fronts over which you have little control.

Consequently, Victoria 3 is more fun when you're focusing on your own country than on a global scale. However, this doesn't make its economic simulation any less engaging, or its political squabbles less fun to watch as they play out. Victoria 3 isn't quite Paradox's best strategy game, but it's nonetheless a lavish and dynamic jaunt through history's most transformative century.

RICK LANE

/ VERDICT

The penny is mightier than the sword in Paradox's most opulent grand strategy.

OVERALL SCORE

80%

Call of Duty: Modern Warfare 2 / **£59.99** inc VAT

DEVELOPER Infinity Ward / **PUBLISHER** Activision

GROUND WAR

+ Weighty, satisfying shooting
+ Decent campaign missions
+ Enjoyable multiplayer

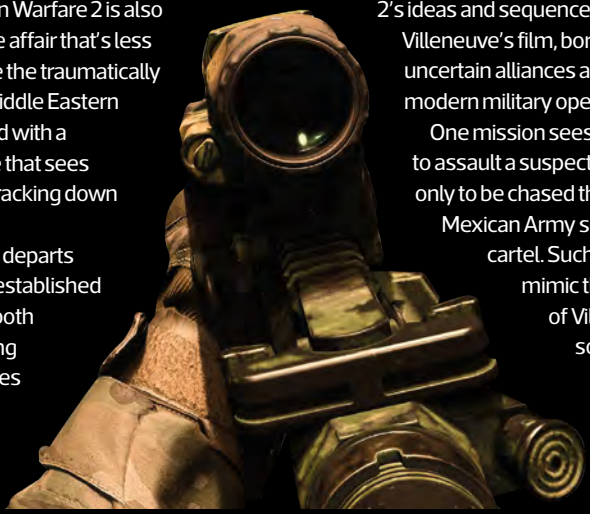
GROUND BORE

– Throwaway story
– Invasion is underwhelming
– No gunfight multiplayer mode

Modern Warfare 2 is the best Call of Duty in years, although given the underwhelming efforts in Call of Duty: Vanguard and Black Ops: Cold War, that isn't saying a whole lot. Nonetheless, series originator Infinity Ward succeeds in recapturing some of the game's former glory, with a single-player campaign that's as creative as it's chaotic, and a multiplayer mode that brings Call of Duty closer than ever to occupying the same territory as EA's Battlefield franchise.

The campaign is notionally a direct follow-up to 2019's Modern Warfare reboot, but in practice has little in common with that game's story. Not only is the plot only tangentially related, but Modern Warfare 2 is also a lighter, more Hollywood-style affair that's less interested in 'realism'. Gone are the traumatically detailed terrorist attacks and Middle Eastern focus of the first game, replaced with a globetrotting action-adventure that sees Captain Price's Task Force 141 tracking down a trio of stolen ballistic missiles.

This doesn't mean the game departs wholly from the new direction established by its predecessor. In terms of both mission structure and underlying feel, Modern Warfare 2 continues to adopt a more grounded representation of how today's soldiers fight. Most missions revolve around small teams performing spec-ops raids on compounds or facilities, frequently mixing both stealth and combat.



In particular, the campaign is inspired by the 2019 level Clean House, which saw players clearing a London townhouse of terrorists in a deadly game of hide-and-seek. Modern Warfare 2 threads this mechanical refrain into multiple levels, with the action organically slowing down and zooming in for tense, dramatic building raids.

More broadly, the campaign draws inspiration from two other sources. The first is Denis Villeneuve's film Sicario, which charts a morally grey US covert operation to combat the Mexican drug trade. Some of Modern Warfare 2's ideas and sequences are clearly inspired by Villeneuve's film, borrowing its themes of uncertain alliances and questionable loyalties in modern military operations.

One mission sees players driving into Mexico to assault a suspected terrorist safehouse, only to be chased through the countryside by Mexican Army soldiers in the pay of a local cartel. Such sequences effectively mimic the operational murkiness of Villeneuve's film, although some elements of these sequences, such as aiming your weapon at civilians to 'de-escalate' them, feel like they're unnecessarily baiting controversy.

Another key influence is the original Modern Warfare. Two of the new game's missions are essentially repackaged versions of levels from the 2007 classic. One sees you protecting your team from enemy attack in an AC-130 gunship, blasting groups of foes with the plane's frightening selection of armaments.

The other riffs on the iconic 'All-Ghillied Up' mission, switching location from the forests surrounding Chernobyl to a stretch of bracing Spanish coastline. Both are well-constructed scenarios – the latter offering some of the most open-ended action in any Call of Duty campaign – but they inevitably exist in the shadow of their pioneering predecessors.

Ironically, Modern Warfare 2 is at its best when trying new ideas. An early mission sees you swimming stealthily through an Amsterdam dockyard, eliminating enemies with silenced weapons in a sequence that feels like a scene from a modern Bond movie. One of the most novel gunfights takes place on a cargo ship in a stormy ocean, with you fighting through lashing rain as loose cargo containers scrape across the deck, threatening to crush you as the ship rolls from side to side.

There's even a mission that introduces crafting to Call of Duty, which initially feels absurd, but improvising weapons out of bottles and mousetraps proves surprisingly entertaining as you skulk through a Mexican town while heavily armed enemies patrol the streets.

In short, the campaign has an entertaining mix of ideas that just about hang together, with a story that's fun if ultimately forgettable. The multiplayer game, by comparison, is more coherent – it's a clear and considered attempt to knock EA's beleaguered Battlefield series out of the running.

At the core of the multiplayer game is Infinity Ward's reworked character and weapon handling, transforming Call of Duty from a frantic popgun rush into a weightier, more purposeful affair. Characters move slower, weapons feel more powerful and dangerous, and aiming down the sight takes noticeable time. These changes mean there's a benefit to playing methodically, moving steadily between cover, listening to enemy shots to pinpoint their location and resting your weapon against cover to steady your aim.

Even in basic team-deathmatch mode, it's satisfying to grapple with Modern Warfare 2's multiplayer game. However, its main assault on Battlefield comes with the return of Ground War. Call of Duty's equivalent to Battlefield's

Conquest mode, Ground War sees up to 32 players vying for dominance over various control points on the map, through a mixture of straightforward gunfights, powerful killstreak abilities and a newly introduced suite of vehicles. Now players can ride into battle in tanks and APCs, or use helicopters to drop off fellow players near control points.

This results in grand, thundering battles where player interactions produce a fantastic spectacle. You'll see artillery from killstreaks whistling through the air before pounding down on your position, before a squad-mate rocks up with a rocket launcher and blasts the offending AC-130 into smithereens.

Ground War gives Call of Duty a strong baseline from which to operate, but its more ambitious large-scale mode is Invasion. This is an unusual blend of team deathmatch and wave-based survival, with each team accompanied by groups of AI soldiers.

The goal for each team is to reach a certain number of points, with one point awarded for killing AI foes, and five points for killing players. It's an interesting idea, but the lack of designated control points makes battles shapeless, while the long, rectangular maps disproportionately favour snipers.

The push towards bigger, bolder game modes also means Modern Warfare 2 loses one of the series' most novel recent multiplayer innovations – Gunfight. This fantastic 2v2 mode saw players battling in lightning-quick duels using randomised weapons, giving 2019's Modern Warfare an exclusive multiplayer feature. Its absence here, combined with the mixed success of Invasion, means Modern Warfare 2's attempt to seize Battlefield's headquarters doesn't wholly succeed.

Nevertheless, there's no question Modern Warfare offers the most compelling package of any recent Call of Duty game. In an age when linear FPS games are increasingly rare, the campaign is a perfectly enjoyable slice of big-budget action. The multiplayer mode, meanwhile, combines a genuinely satisfying shooting experience with impressive player-driven spectacle. Call of Duty's heyday may be in the past, but Modern Warfare 2 is a firm reminder that Infinity Ward can still deliver.

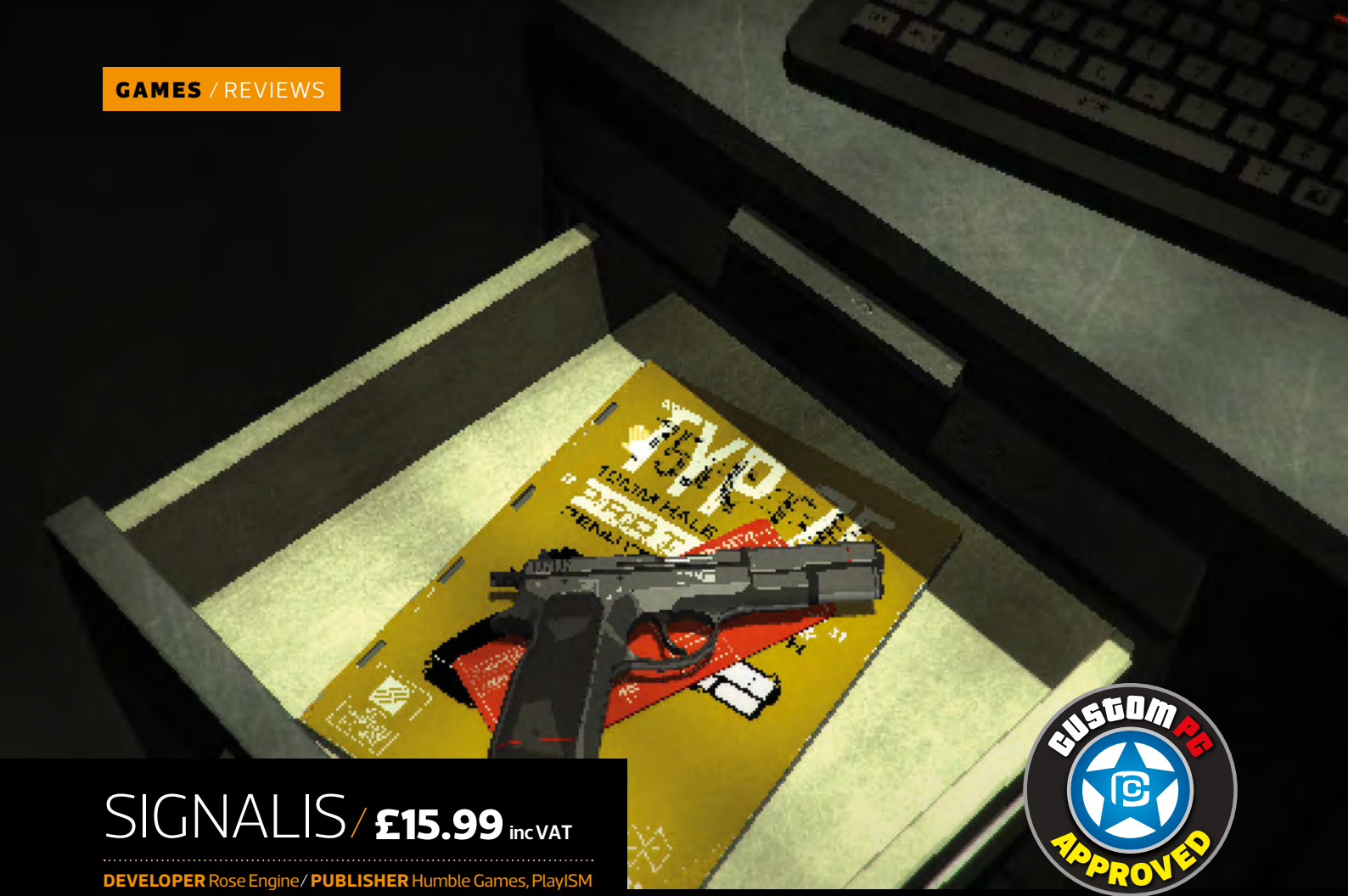
RICK LANE

/ VERDICT

Modern Warfare 2 proves Infinity Ward remains the best of Activision's Call of Duty studios.

OVERALL SCORE

75%



SIGNALIS / £15.99 inc VAT

DEVELOPER Rose Engine / **PUBLISHER** Humble Games, PlayISM

SURVIVAL

+ Excellent visual and audio design
+ Intriguing story
+ Clever tension-building systems

HORROR

– Perfunctory combat
– Inventory is too strict

/ VERDICT

Eerie, unsettling and deeply fascinating, Signalis is a compelling throwback.

OVERALL SCORE

83%

In most survival horror games, entering a safe room provides a moment of respite, but in Signalis it offers only further apprehension, because saving means accessing the terminal with the blood-red screen located somewhere in the room, and accessing this terminal triggers the most awful sound you'll hear in a video game this year.

Somewhere between a rusted metal door squealing open and a shriek of mortal agony, it turns saving from a relief into a reluctant necessity, like fishing your wedding ring out of a public toilet. It's a design flourish that encapsulates Signalis' approach to survival horror. This love letter to PlayStation 1-era classics such as Resident Evil and Silent Hill wants you to never feel safe or feel certain about anything going on in its strange alien facility.

You play Elster, a Replika-class android in search of a fellow android for reasons which, in typical Signalis fashion, aren't entirely clear. You awake from cryostasis in a crashed spaceship, and quickly proceed into a dingy subterranean facility on an alien planet where something has gone terribly wrong.

Aesthetically, Signalis adopts the low-fi 3D graphics of Resident Evil and Silent Hill, but uses them to build its own magnificently strange world. The facility you explore is organised into a Brave New World-style society, where the various androids are organised into different classes that determine both their social roles and their physical and mental capabilities.

The facility itself is inspired by a combination of Japanese anime and German industrialism, blending stylish character design with oppressive concrete architecture and propaganda posters that could be ripped directly from the Berlin wall.

You carefully feel your way around this facility in classic Resident Evil fashion, searching rooms for items that will help you to solve puzzles, and fighting twitching, glitching enemies in tense, if rather functional, combat encounters. You must pick your fights carefully, however, as enemies that aren't burned with a thermite flare can rise from the dead at any time, while other creatures can abruptly appear through loose floor panels.

As an exercise in slow-burning dread, Signalis is masterfully crafted. The game has no real jump-scares, instead relying on its unpredictable systems, subliminal imagery and audio distortion to create a deeply unnerving atmosphere. That said, it does go too far in some areas. Your inventory is incredibly limited, resulting in frequent backtracking through areas to collect items. A little backtracking is necessary to generate some of the game's surprises, but constantly juggling your inventory just to pick up individual items quickly becomes tiresome.

This issue aside, Signalis is a delightfully twisted take on classic survival horror. Like the FPS Dusk, it takes the essential components of its genre and uses them to build a game that's both pleasingly old and terrifyingly new.

RICK LANE

VAMPIRE SURVIVORS / £3.99 inc VAT

DEVELOPER poncle / **PUBLISHER** poncle

Not only does Vampire Survivors cost the price of a London coffee, but it also manages to create some of the most spectacular action you'll see this year out of four measly controls.

Those controls are W, A, S and D. That's it. All you do in Vampire Survivors is move a laughably basic 2D sprite around a map, while waves of equally simple enemies descend on your position. To defend yourself, you have one basic attack that triggers automatically every second or so.

As you guide your character around the map, simultaneously avoiding and eliminating enemies, you'll pick up gems. Collect enough of these jewels, and you can upgrade your character, adding new attacks, such as a wand that spews homing balls of magic, a dagger that fires consistently forwards, or a powerful fireball that shoots in a random direction. The more gems you collect, the more weapons and abilities you can add to your character. All the while, your enemies become tougher and more numerous.

The game continues to escalate, gathering scale and momentum like a snowball rolling down a mountain, until your character is fending off literally thousands of enemies, firing out weapons and beams of energy like a weaponised disco ball that has come loose from the ceiling and is carving its way across the dance floor. Eventually, your character will die, but in doing so, you'll unlock new weapons, new character and new upgrades, so you'll last a little bit longer the next time you enter the fray.

VAMPIRE SURVIVORS

+ Simple, yet spectacular
+ Ingenious progression system
+ Ridiculously cheap

VAMPIRE DERIDERS

– Can reach the point where it plays itself

This combination of wild spectacle and staggered, roguelike progression is what lures you into Vampire Survivors. What keeps you there is the surprising strategic depth lurking beneath its comically simple exterior. Different characters start with different weapons that require you to move around the map in different ways.

Meanwhile, alongside new weapons, you can also improve general stats such as weapon cooldown; after a few upgrades, this turns your basic weapons into endless torrents of death. A fully upgraded character will have enemies literally melting away in front of them, yet there will still come a point when you're simply overwhelmed, and your latest astonishing run comes to an end.

Vampire Survivors is a fascinating exercise in deceptive simplicity. That said, there are times when its simplicity fails to deceive. If you get a particularly good run of early upgrades, the game can essentially play itself for the next 15 minutes. This is fun to watch for a while, but it does eventually become boring.

Most of the time, though, Vampire Survivors delicately balances the opposing sensations of being phenomenally powerful and clinging on for dear life. It's a great game regardless of price. At a measly four quid, it's an absolute steal.

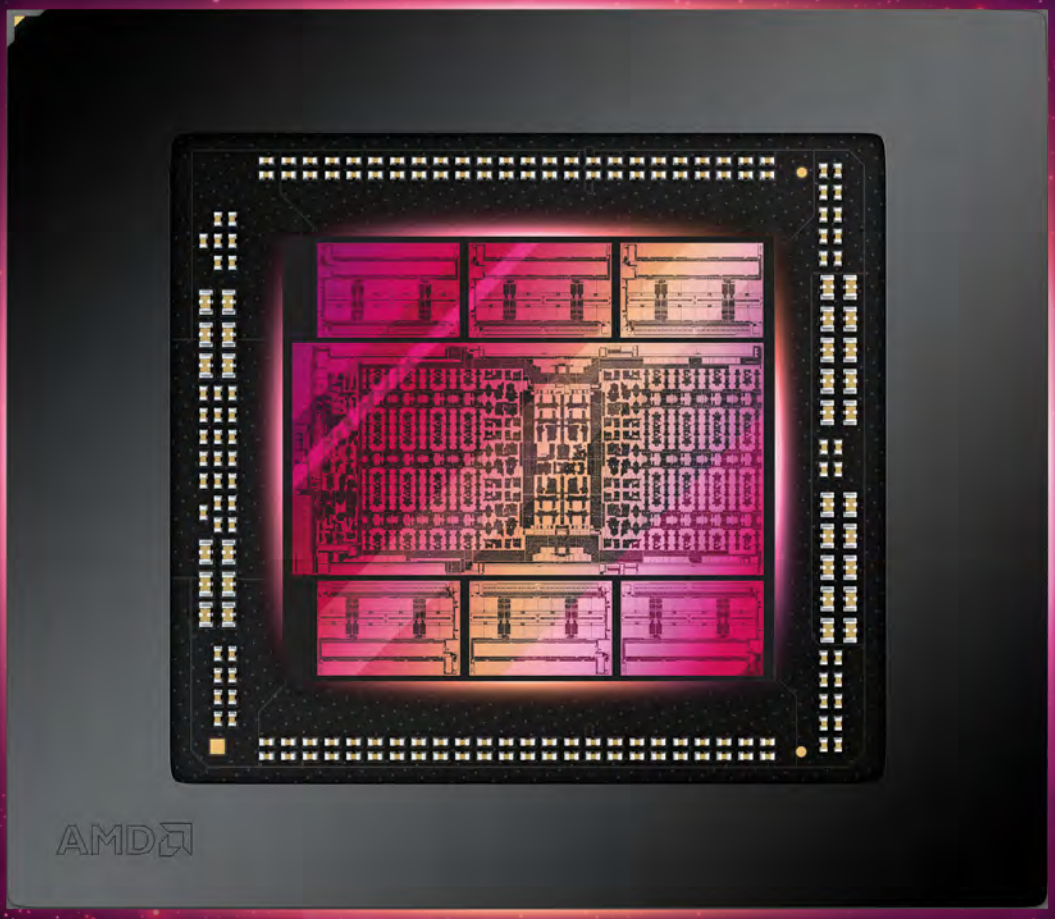
RICK LANE

/ VERDICT

Cheap, accessible and with far more staying power than you'd expect, Vampire Survivors is the bargain of the year.

OVERALL SCORE

88%



RESEQUENCING RDNA

THE THIRD ITERATION OF AMD'S RDNA GRAPHICS ARCHITECTURE IS HERE, WITH AMD APPLYING THE MULTI-DIE CHIPLET APPROACH THAT REVOLUTIONISED ITS RYZEN CPU TO ITS GPUS. EDWARD CHESTER DIVES IN

After several years of struggling in terms of both performance and power efficiency with its GPU designs, the arrival of AMD's 1st-generation RDNA architecture saw the company leap forward in both areas. The second generation of that architecture continued this trend, with a hefty 54 per cent improvement in performance per watt and the introduction of support for ray tracing, making the company's 6000-series graphics cards a compelling mid-range alternative to Nvidia's 3000 series, especially for non-AAA titles that didn't take advantage of ray tracing.

Now AMD's back with its third iteration of RDNA, which rather pleasingly brings with it the exact same claimed 54 per cent increase in performance per watt, while ray tracing performance has improved by a nearly identical claimed figure of 50 per cent. We've seen the result of these improvements in our reviews of the Radeon RX 7900 XTX (p14) and RX 7900 XT (p16), which take big

leaps in both non-ray traced and ray traced performance over the previous-generation Radeon RX 6000-series GPUs.

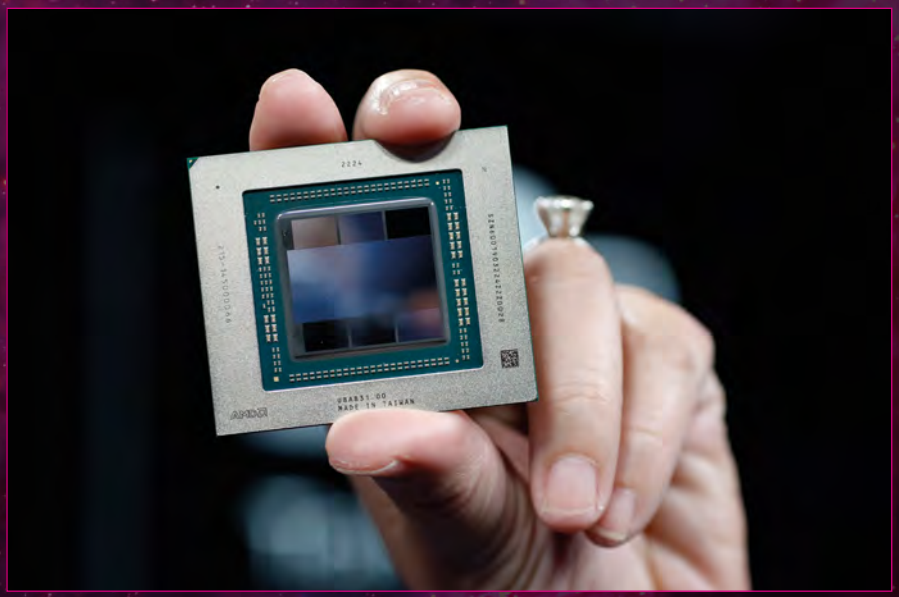
Also new to this iteration of the architecture is the addition of an AI accelerator, which provides dedicated hardware for speeding up the matrix multiply assist operations generally associated with machine learning tasks. These accelerators are the equivalent of Nvidia's Tensor cores, and their introduction means AMD finally has feature parity (if not outright performance parity) for the big duo of features Nvidia first introduced with its GeForce RTX 2000-series GPUs.

For gamers, these AI accelerators won't currently bring much to the table, as AMD doesn't have an AI-accelerated equivalent of Nvidia's DLSS technology, and currently this is the only gaming feature that uses Tensor cores.

Other notable changes include RDNA 3 using TSMC's 5nm and 6nm production processes, rather than the 7nm process of AMD's RDNA 2 chips. This compares with Nvidia's use of TSMC's very latest 4nm process for its GeForce RTX 4000-series GPUs. That 4nm process is a refinement of the company's 5nm process, boasting up to an 11 per cent uptick in performance, 6 per cent higher transistor density and a 22 per cent boost in power efficiency over its 5nm process.

The Radeon RX 7900 XTX (left) and RX 7900 XT (right) share the same Navi 31 GPU but the latter has one MCD and a cluster of compute units disabled

THE FIRST GPU TO IMPLEMENT THE RDNA 3 ARCHITECTURE IS THE NAVI 31, WHICH HOUSES 58 BILLION TRANSISTORS



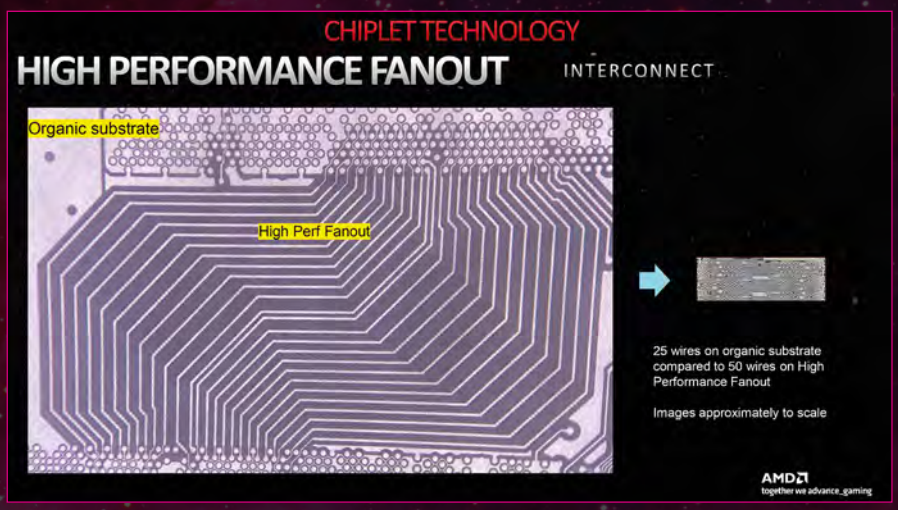
Navi 31 packs in 58 billion transistors and is the first GPU to use a chiplet-based, multi-die design

The first GPU to implement the RDNA 3 architecture is the Navi 31, which houses 58 billion transistors and boasts 61 TFLOPS of performance, according to AMD. These mark significant increases over the 26.3 billion transistors and claimed 12.8 TFLOPS of performance for the previous-generation Navi 21 chip, which was used in the Radeon RX 6950 XT and 6900 XT.

However, the new Nvidia AD102 GPU that sits at the heart of the GeForce RTX 4090 packs a massive total of 76 billion transistors, with Nvidia claiming 83 TFLOPS of processing power; figures that make its relatively reasonable power consumption all the more impressive. Meanwhile, the AD103 GPU of the GeForce RTX 4080 houses just 46 billion transistors.

THE CARDS

To quickly recap, Navi 31 is initially available in the two graphics card configurations we've reviewed this month – the Radeon RX 7900 XTX and 7900 XT. The former is the flagship card and it packs 96 of the architecture's compute units (CUs), providing 6,144 dual-issue stream processors (SPs), 192 AI accelerators and 96 ray tracing (RT) cores. It's coupled with 24GB of GDDR6 VRAM accessed via a 384-bit memory interface, and AMD's quoted game clock speed is 2.3GHz.



A new ultra-compact and dense interconnect system was needed to handle the bandwidth of chiplet GPU design

Meanwhile, the Radeon RX 7900 XT has 12 fewer CUs than the 7900 XTX, resulting in a total of 5,376 dual-issue stream processors (we'll cover what we mean by 'dual' later), 168 AI accelerators and 84 2nd-generation RT cores. It also uses one fewer memory cache die, resulting in a narrower 320-bit interface that communicates with the card's 20GB of GDDR6 VRAM. AMD's quoted game clock speed for this GPU is 2GHz.

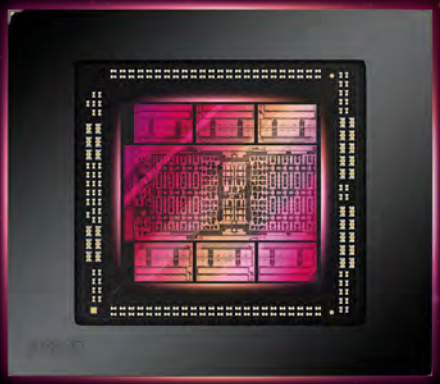
In comparison, the previous-generation Radeon RX 6950 XT has just 80 CUs providing 5,120 stream processors, no AI accelerators and 80 1st-generation RT cores. That GPU was coupled with 16GB of GDDR6 VRAM, accessed through a 256-bit memory interface, and the game clock was 2.1GHz.

As for comparisons with Nvidia's latest cards, differences in architecture mean it's not entirely meaningful to compare the numbers of its CUDA cores (equivalent of stream processors), Tensor cores (equivalent of AI accelerators) and RT cores but it helps to differentiate between Nvidia GPUs. As such, the RTX 4090 packs in 16,384 CUDA cores, 512 Tensor cores and 128 RT cores. The card runs at a 2235MHz base clock with a boost clock speed of 2565MHz.

Meanwhile, the RTX 4080 has considerably less power on paper, with 9,728 CUDA cores, 304 Tensor cores and 76 RT cores. Like the RTX 4090, though, it boasts high peak clock speeds, with a boost clock of 2505MHz and base clock of 2205MHz.

It's also the case that the new Radeon RX 7900-series cards are much more compact than the equivalent GeForce RTX 4000-series cards, and the AMD cards don't require the new infamously melty 16-pin power connector of the Nvidia cards either, instead relying on two 8-pin PCI-E connectors.

The main GPU is the GCD in the middle of the chip, while the cache is found in the smaller chiplets surrounding it



CHIPLET CHALLENGE

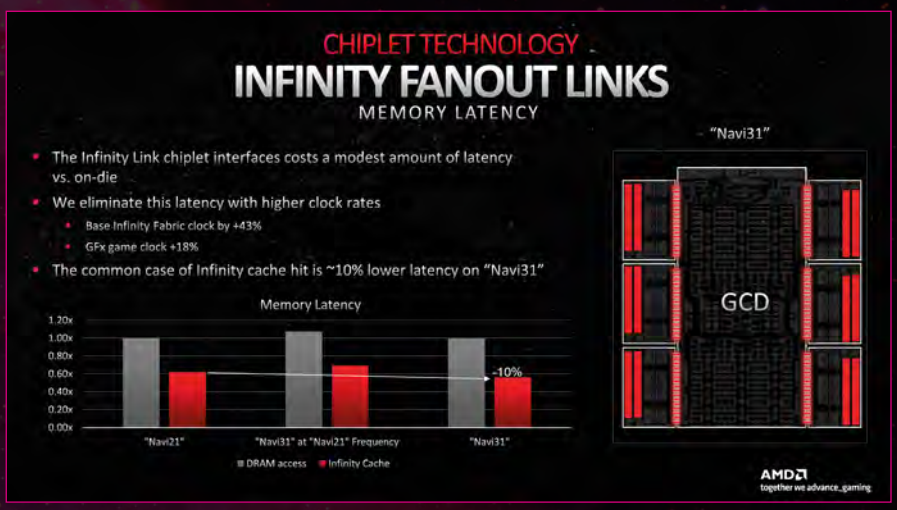
The most prominent feature of the new RDNA 3 architecture is its use of not just new manufacturing processes when compared with RDNA 2, but the use of a chiplet design. Instead of having a single die that encompasses all the main functions of the GPU, as on all previous graphics cards of the past 20 or so years, RDNA 3 uses a single large Graphics Compute Die (GCD) and up to six smaller Memory Cache Dies (MCDs).

The GCD takes care of most of the functions you'd normally associate with a GPU, with all the CUs, RT cores, video encoders and more being housed in that chip. All that has been separated out from the main GPU is the Infinity Cache (a large L3 cache) and the memory interface.

This arrangement runs contrary to a popular rumour in the run up to the RDNA 3 launch, which speculated the upcoming chiplet GPU design would split up the processing portions of the GPU and essentially function in the same way as two graphics cards when using AMD CrossFire or Nvidia SLI. That may well be a future feature of chiplet GPU design, but for now, it's just the caches and memory interface that have been separated from the main GPU die.

THE GCD OF NAVI 31 HAS BEEN KEPT TO JUST 300MM², WHICH COMPARES TO 520MM² FOR THE PREVIOUS-GENERATION NAVI 21 GPU

While only removing the cache and memory interface may not seem like the most significant silicon-saving measure, modern GPUs have large last-level caches and highly sophisticated memory controllers that take up a large portion of a chip. The Infinity Cache of Navi 31 and the L2 cache of the RTX 4090 are both



Off-die interconnects are slower than on-die ones, so Infinity Link only maintains latency parity with Navi 21, despite much higher clock speeds

96MB, which is hefty for an on-die cache. As such, removing these components reduces the size of the rest of the GPU by a significant amount.

Specifically, by moving these functions to its MCDs, the GCD of Navi 31 has been kept to just 300mm^2, which compares to 520mm^2 for the previous-generation Navi 21 GPU. Meanwhile, the AD102 silicon of the GeForce RTX 4090 has a whopping die area of 609mm^2, although the AD103 GPU of the GeForce RTX 4080 has a much more modest 379mm^2 die area.

Each of Navi 31's MCDs measures a tiny 37mm^2 for a combined total of area of 222mm^2 when using a full count of six MCDs. Add that to the 300mm^2 are of the CGD and that's a total die area that's slightly larger than the single die of Navi 21, and much larger than Nvidia's AD103 die, though still markedly smaller than AD102.

Having a combined total die area that's no smaller than a previous GPU design may not seem like it's gaining you much overall. However, not only are both the transistors in the GCDs and MCDs of Navi 31 much more densely packed than in Navi 21 – thanks to smaller manufacturing processes, but there are also several other big advantages to producing a total die area via several smaller dies rather than via one big die.

The first advantage is that even a small reduction in the size of a silicon chip results in the ability to produce significantly more dies per silicon wafer, reducing relative cost and improving yields.

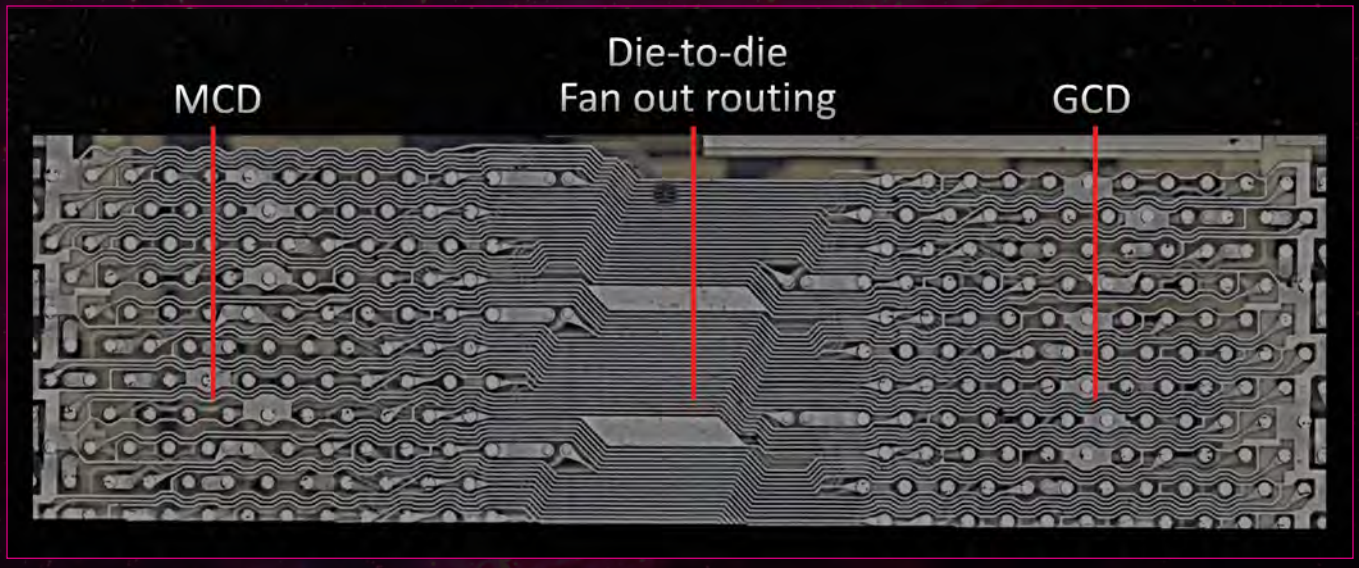
For instance, if we perform some rough calculations using a silicon wafer yield calculator (**isine.com/resources/die-yield-calculator/**), while a typical 300mm-diameter silicon wafer could produce in the region of 89 AD102 GPUs – assuming no defects and a perfect yield – that same wafer could produce 190 Navi 31 GCDs or 1,645 MCDs. That's a heck of a lot more complete Navi 31 chips per wafer than AD102 when averaged out over hundreds of wafers.

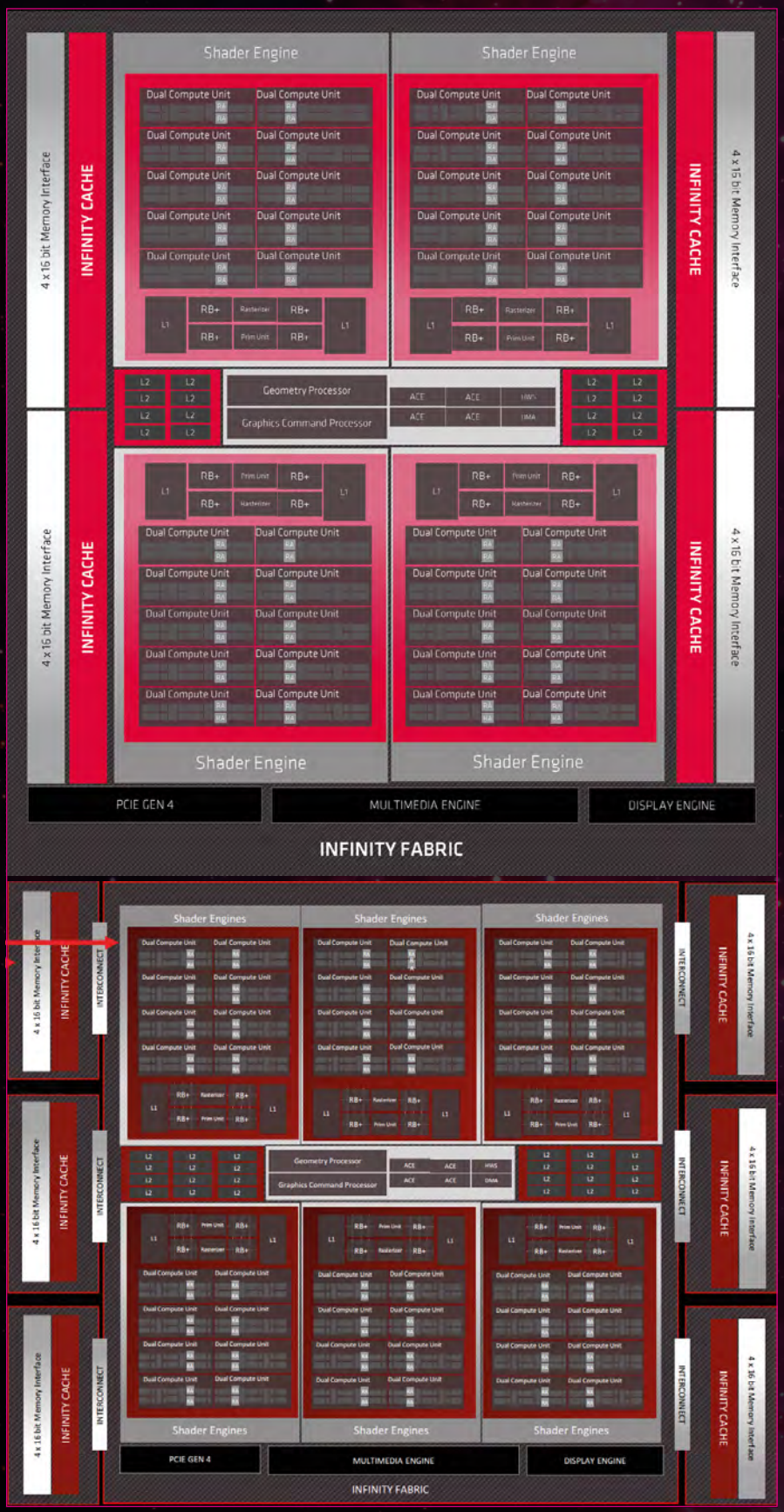
Once you factor defects into the equation the situation becomes even more dramatic. While not all defects will render a die unusable – depending on where the defect lands, that portion of the chip can sometimes be disabled and the rest of the chip used for a lower-tier GPU – getting complete, defect-free dies is the most desirable outcome.

As such, when we include the nominal defect rate of 0.09 defects/cm^2 for TSMC's 6nm process (just as an example – these chips are all produced on slightly different processes, after all), you arrive at a yield of just 46 perfect AD102 GPUs, 138 GCDs and 1556 MCDs per 300mm wafer. Or, to look at it another way, the yield percentage rate – the ratio of good to bad dies – of those same three chips is 58.5 per cent, 76.8 per cent and 96.7 per cent. It's massively more efficient to produce smaller dies.

The other big upside to a chiplet design approach is the ability to use different

The bandwidth of the new high-density interconnect between the MCDs and GCD is 5.3TB/sec





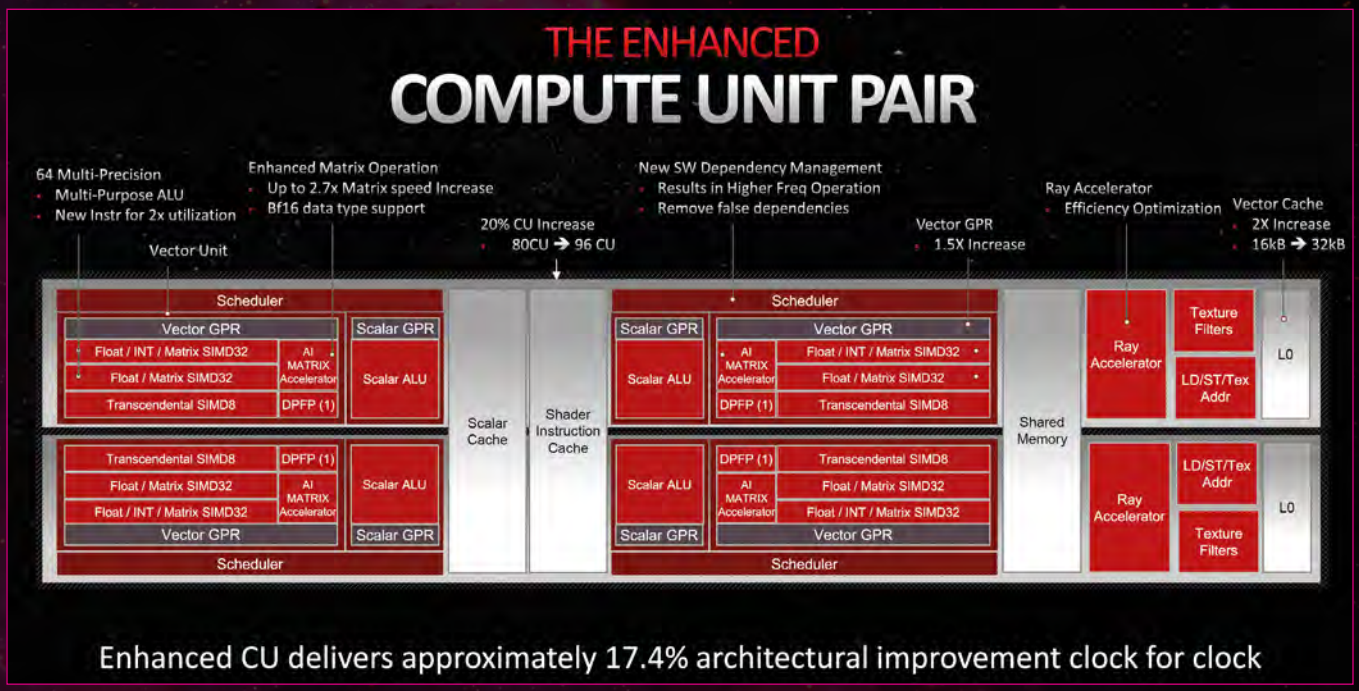
The general layout of RDNA 3 (bottom) is very similar to that of RDNA 2 (top) but extensive changes have been made throughout

manufacturing processes for different portions of the chip, which is precisely what AMD has done. While the GCDs are produced on TSMC's smaller, more up-to-date and more expensive 5nm process, the MCDs are produced on the slightly larger, older and cheaper 6nm process.

Not only does this allow for potential cost savings for producing the MCDs, but it reduces the dependency of AMD on being allocated production time on the latest and most sought-after manufacturing processes. In contrast, not only will Nvidia have had to spend big money to even secure first access to TSMC's very latest 4nm process, but it will be in some ways wasting that cutting-edge process allocation by producing the entirety of its GPUs on that process.

There are some downsides to the chiplet approach though. For a start, while using different manufacturing processes brings potential costs and manufacturing efficiency benefits, it does mean the MCDs don't benefit from the power-saving and higher-performance capabilities of the newer 5nm process, let alone the 4nm process Nvidia is using. However, according to AMD, the components on the MCDs don't scale all that well compared with the GCD components, so there's very little benefit to shrinking them anyway.

The other big hurdle to overcome is assembling the seven different dies into one chip package and getting them to communicate correctly and speedily. Inter-die communication presents an



Enhanced CU delivers approximately 17.4% architectural improvement clock for clock

inherent difficulty, and it's one that's significantly greater when dealing with the thousands of internal connections of a GPU as compared to the hundreds of connections required within a chiplet-based CPU design. To overcome this, AMD has introduced a new interconnect system called Infinity Fanout Links.

Infinity Fanout Links is essentially a high-density PCB trace on an interposer layer that's far smaller than previous chiplet interconnect designs. In one of its slides (pictured on p70) AMD shows the example of the PCB connections used on one of its CPUs compared with the new Infinity Links, and the difference in density is enormous – 10x. The image is also slightly mislabelled (by AMD) – the yellow labels are too far over to the left and should instead be showing that the larger image is the older PCB trace on an organic substrate, while the high-performance Infinity Fanout Links system is to the bottom right.

As well as allowing for a massive increase in connection density, Infinity Fanout Links had to be power-efficient – external links are almost always more power-hungry than on-die connections – and sure enough AMD claims a saving of up to 80 per cent in power consumption when using Infinity Fanout Links over the previous organic package link used for its CPUs. AMD claims the interconnect consumes less than 5 per cent of the GPU's total power.

As for the resultant bandwidth of this new interconnect, it stands at a ridiculous figure of 5.3TB/sec. This bandwidth is shared out among the six MCDs, so it will scale accordingly if any MCDs are disabled.

ONE OR MORE MCDs CAN BE DISABLED TO MAKE A LOWER-TIER GRAPHICS CARD, WITH THE MEMORY BUS WIDTH LOWERING ACCORDINGLY

One downside of Infinity Fanout Links is an increase in latency over using an on-die cache. To get around this latency, AMD has simply cranked up the clock speed of the Infinity Fabric by 43 per cent to achieve the same overall cache latency as on Navi 21. The company has also optimised the cache for better data reuse, ensuring higher cache hit rates, which results in quicker delivery of data to the GCD, while using less power than having to make a request to the graphics card's RAM.

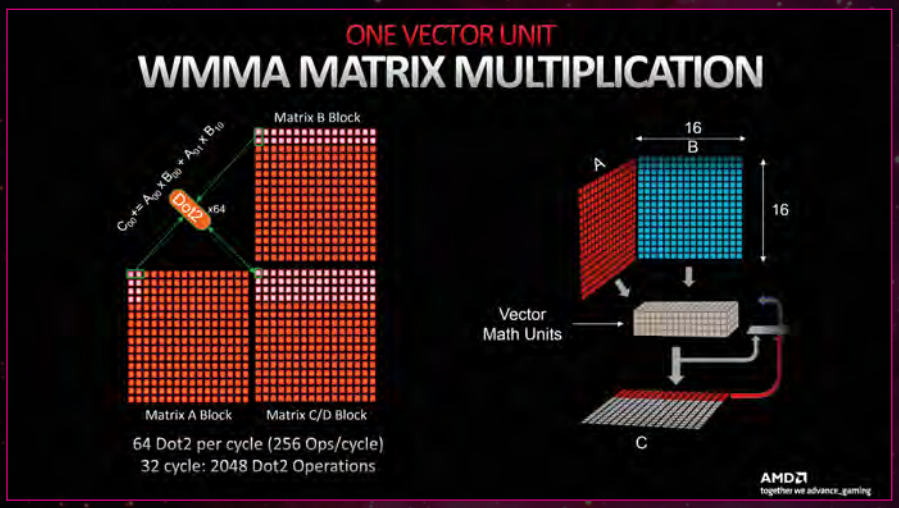
Communications to that memory are made via a dedicate 64-bit path from each MCD, for a combined total of 384 bits for the memory interface, which is coincidentally exactly the same width as the memory interface on Nvidia's GeForce RTX 4090. One or more of the MCDs can be disabled to produce a lower-tier graphics card, with the memory bus width lowering accordingly – the Radeon RX 7900 XT has one MCD disabled and has a 320-bit memory interface.

Although outwardly similar to the compute unit of RDNA 2, the new unit includes a host of changes throughout the design

A NEW CORE

The GCD of Navi 31 is architecturally similar to the previous RDNA 2 GPU design. If we compare the block diagrams of Navi 31 with Navi 21 (opposite), we can see that the overarching layout is much the same. Large clusters of compute units are stacked either side of a central graphics command processor, a geometry processor, various other specialist function blocks and blocks of L2 cache. The graphics command processor controls issuing of instructions to the rest of the GPU.

The compute units are packaged up into six sections of 16 compute units (technically packaged as eight dual-compute units), each of which is called a shader engine by AMD. The GPU will distribute workloads in bulk to each of



A new dedicated matric multiplication unit greatly accelerates typical AI workloads

these shader engines, which they will process in parallel.

Also packed into each Shader Engine are portions of L1 cache, the render backends and rasterisers.

This structure is similar to RDNA 2, except the older design packaged 20 compute units into four shader engines for a total of 80 compute units, whereas Navi 31 has 16 compute units per shader engine and six engines, totalling 96 compute units.

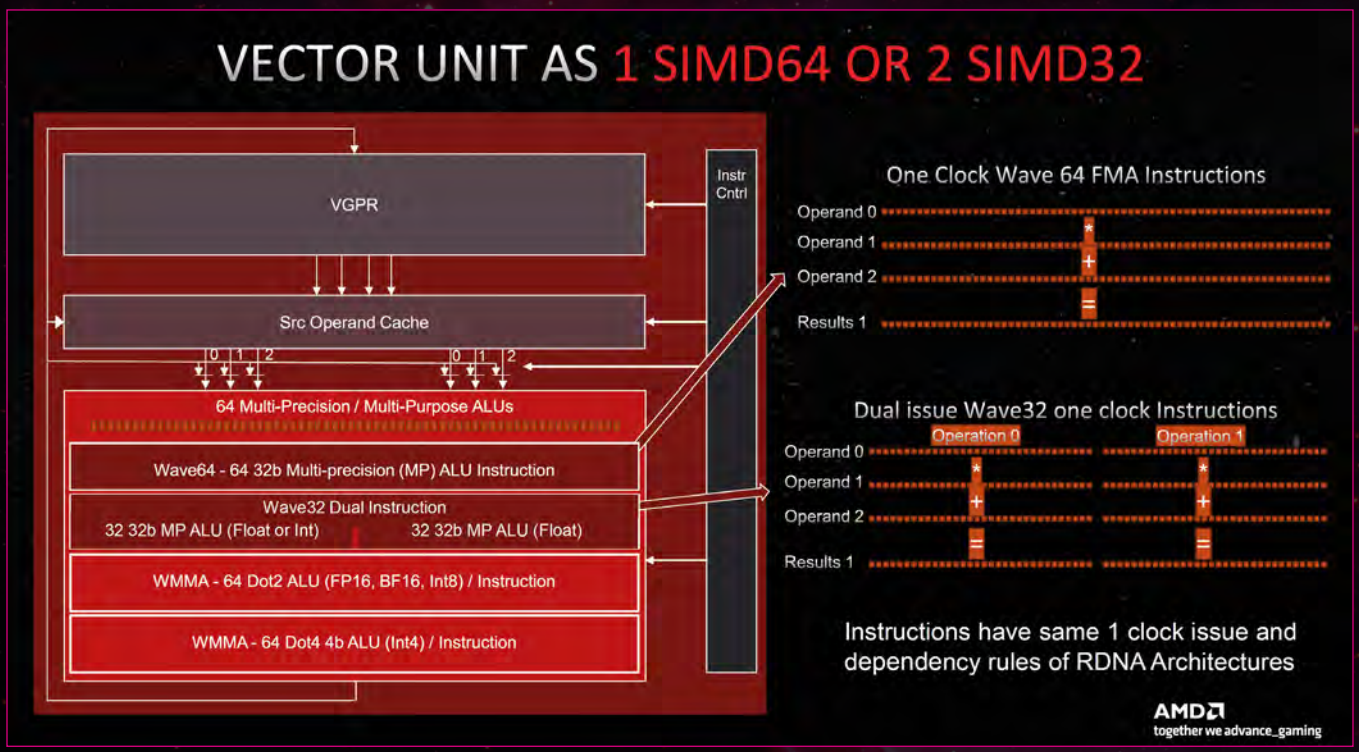
An extra array of floating point stream processors allows for two 32-bit floating point operations per clock cycle, or one 64-bit operation

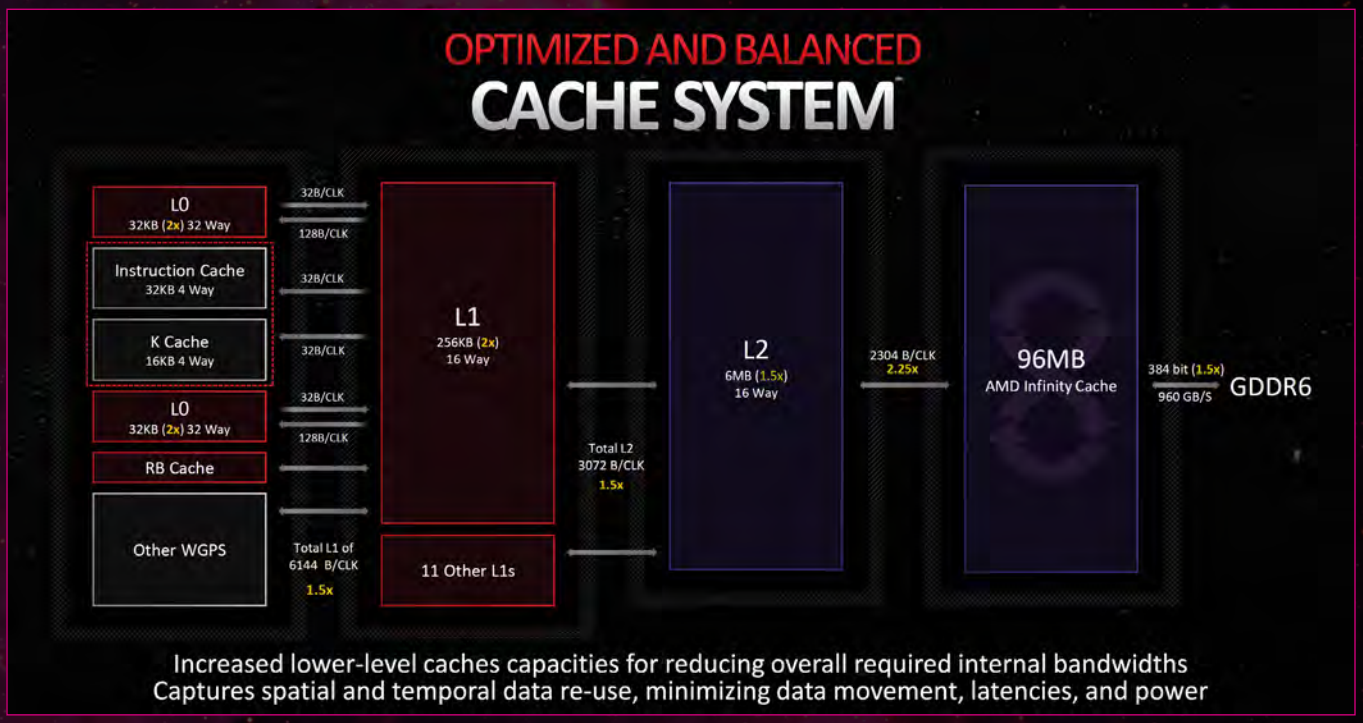
That relatively small 20 per cent increase in the total number of CUs is a bit of a surprise given the large uptick in performance we see between the Radeon RX 6950 XT and the Radeon RX 7900 XTX, especially when we compare this to the increase in the number of CUDA cores from Nvidia's GeForce RTX 3090 Ti to the RTX 4090. The former packed in 10,752 while the latter bumped this to 16,384, for a 52 per cent increase.

The answer to why so much more performance has been gleaned from such a similar number of CUs is, not surprisingly, that the CUs are much more capable than the ones in the older RDNA 2 architecture. What's more, many other enhancements have been made to the rest of the architecture and the whole chip in order to keep those CUs running faster and more efficiently.

Chief among these enhancements is a boost in clock speeds, with AMD claiming that RDNA 3 can in theory boost all the way up to 3GHz. That's far faster than the boost clock speeds used on the company's reference cards, but third-party cards and future, refined GPUs could open up the taps. Power consumption and heat will rise but, depending on the performance uplift, this might be deemed worthwhile for those seeking raw power above all else.

AMD has also decoupled the clock speeds of the front end of the graphics pipeline from the shader engine. While the Radeon RX 7900 XTX is rated to run at a game clock of 2.3GHz, its front end clock speed is actually 2.5GHz. AMD claims pulling back the shader engine speed by just 9 per cent saves 25 per cent on power consumption. As for the Radeon RX 7900 XT, it has a quoted game clock speed of 2GHz but front end clock speed of 2.4GHz.





When it comes to power consumption, AMD claims RDNA 3 can run at half the power of RDNA 2 while providing the same performance, or it can hit 1.3x the frequency while using the same power.

Other overarching improvements include an increase in silicon utilisation of approximately 20 per cent. Silicon that's left unused for whatever reason – perhaps because the feature is deprecated or the architecture is inefficient for typical modern workloads – is wasted space and power, so by trimming the fat AMD can free up space for more useful silicon features, or at the very least just reduce the size of the die further.

A NEW COMPUTE UNIT

The compute unit, or CU, is the beating heart of the RDNA 3 architecture, with each CU housing a stack of stream processors for crunching through the massive amounts of parallel processes that are the grunt work of any GPU. Also included in each CU are two of AMD's new AI accelerators, a 2nd-gen RT accelerator, texture filling and address units and a vector cache. Always arranged in pairs, each CU shares a scalar cache, shader instruction cache and memory block with its neighbour to form a CU pair, or dual CU.

On the surface, not all that much appears to have changed when comparing the CUs of RDNA 2 to RDNA 3. However, there are in fact big changes throughout the design. The single biggest change is the addition to each vector unit (a block of stream processors that work on a single task in parallel) of a second SIMD32 block, which contains 64 stream processors dedicated to floating point and matrix workloads.

THIS ESSENTIALLY DOUBLES THE STREAM PROCESSOR COUNT OF EACH CU, AND IN TURN THE FLOATING POINT PERFORMANCE OF EACH CU

This essentially doubles the stream processor count of each CU, from 64 to 128, and in turn the floating point performance of each CU. However, because this new block doesn't perform integer operations, it isn't strictly a full duplication of the existing stream processor setup.

This has led to a confusing situation whereby AMD has sometimes referred to each CU as still having 64 stream processors and resultingly Navi 31 having 6,144 stream processors, and sometimes referring to it as having 128 stream processors per CU for a total of 12,288.

Larger L0, L1 and L2 caches boost performance throughout the GPU, although the L3/Infinity Cache has actually dropped in size compared with RDNA2

Both figures are technically correct, depending on your parameters, but it's the former figure that tallies more with the 17.4 per cent clock-for-clock performance uptick of the new CU compared with RDNA 2. If it was a full doubling of the stream processor count, we'd expect to see closer to double the clock-for-clock performance.

That said, the higher figure bears a greater resemblance to how Nvidia's Ada Lovelace architecture is laid out, with it housing 128 FP32 CUDA cores per Streaming Multiprocessor (SM), along with 64 dedicated INT32 units.

Other enhancements to RDNA 3's CUs include the addition of those dedicated AI Matrix Accelerators, which include support for BF16 (brain-float 16-bit) and INT4 WMMA Dot4 (Wave Matrix Multiply Accumulate) instructions. This unit works in conjunction with the vector units to perform matrix operations, rather than taking over the task completely, but the net result is a 2.7x increase in matrix workload performance per CU, which should help the uptake of AMD GPUs for professional use.

New hardware-accelerated functions, such as bounding box sorting and ray culling, boost RDNA 3's ray tracing performance

Also included is a 50 per cent increase in the size of the general-purpose vector register for each vector unit, along with a larger shared L0 vector cache. This ensures that each CU simply has more space for data and instructions to be kept as close to the stream processors as possible, saving the GPU requesting data from slower stores elsewhere on the chip.

CACHE SYSTEM CHANGES

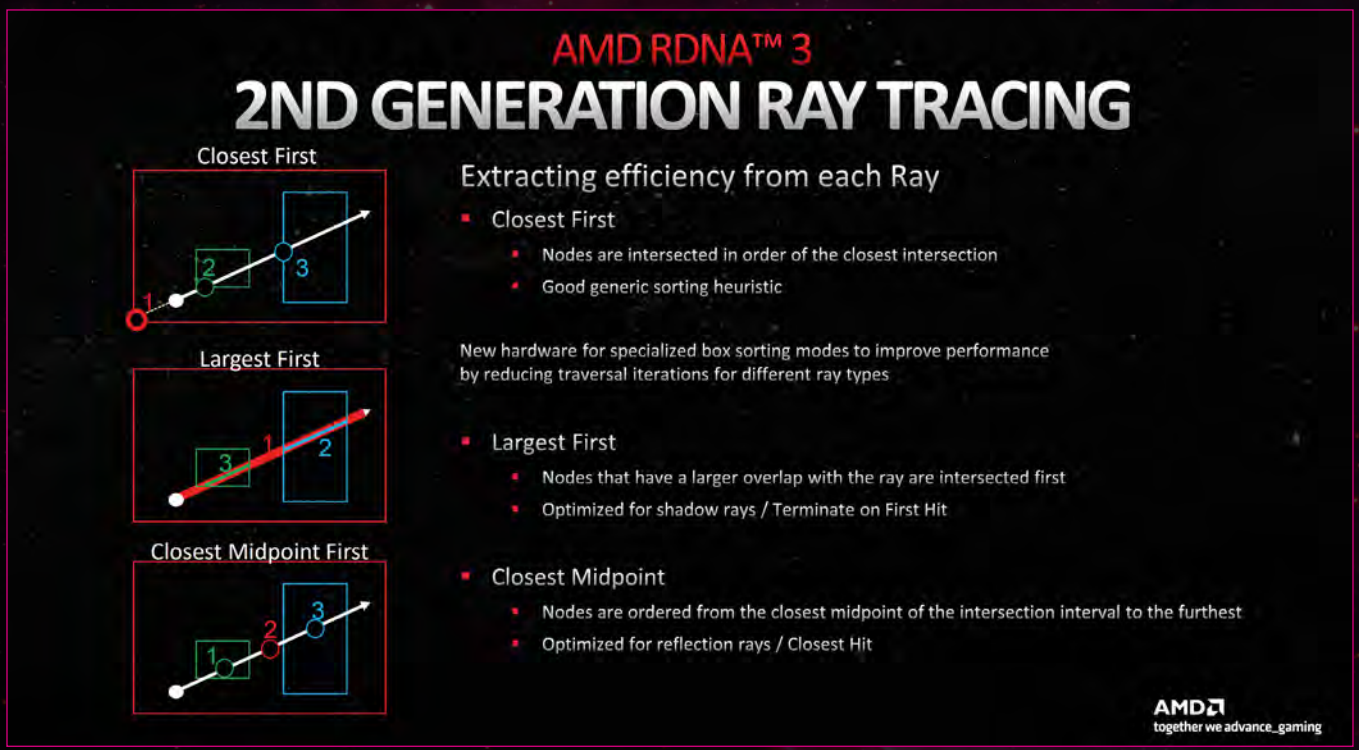
As we just mentioned, the L0 cache of each CU vector unit has seen a doubling in size from 16KB to 32KB, but this is only part of an overhaul of RDNA 3's cache structure compared to its predecessor. The L1 caches – housed alongside and dedicated to each block of eight dual compute units inside each shader engine – have also doubled in size from 128KB to 256KB. while the L2 cache that's shared across the whole GPU is 50 per cent larger, up from 4MB to 6MB.

An interesting twist on this theme of increasing cache sizes is that the L3 or Infinity Cache has actually dropped in size from 128MB to 96MB, compared to RDNA 2. This is particularly intriguing given the offloading of Infinity Cache onto the MCD chiplets. Intuitively, you might expect that having space on a separate die would open up the opportunity to have an even larger cache, but clearly, AMD feels it's not needed.

2ND-GEN RAY TRACING CORE

For many users, the most appealing part of RDNA 3 will be its significantly bolstered ray tracing performance, which AMD claims has improved by up to 80 per cent for some tasks when compared to RDNA 2. In our tests, while Nvidia still maintains a strong lead on this front thanks to its RTX 4000-series GPUs based on the new Ada architecture, the Radeon RX 7900 XTX does trade blows with Nvidia's Ampere-based GeForce RTX 3000-series cards, including the top-end RTX 3090 Ti.

If you're calculating ray traced shadows you can prioritise volumes that are largest first



Powering that improvement is an RT accelerator that offloads some of the overall ray tracing workload, while also incorporating several improvements to existing accelerated tasks. Specifically, the new ray tracing accelerator now incorporates a degree of hardware bounding volume hierarchy (BVH) sorting and traversal, a feature that was previously fully performed on the GPU's general shader hardware in RDNA 2 designs. This move can reduce shader instruction count requirements by up to a factor of 15x.

Other enhancements include more efficient ray calculation culling, eliminating any unnecessary work as early as possible. New algorithm options for calculating ray/volume intersections also allow for optimisation of the workflow, depending on the type of ray tracing function being performed. If you're calculating ray traced shadows, for instance, you can prioritise volumes that are largest first, while reflection ray functions can prioritise the closest midpoint, or the default of using the closest intersection can be used.

Also of significant help to overall ray tracing performance are all those increased cache sizes we mentioned earlier. The larger VGPR in particular enables 50 per cent more rays to be in flight at once, greatly reducing the need to drop to slower, higher-level caches in order to find the required data.

THE NITTY-GRITTY

Along with its several large, obvious changes over its predecessor, RDNA 3 also incorporates a host of tweaks to the underlying architecture of the rest of the GPU. The first of these is improved handling of primitives via a new Multi-Draw-Indirect accelerator.

Primitives are the fundamental shapes used to construct the surfaces in a 3D scene – most often triangles – and initial handling of them is undertaken by the CPU. As such, the new accelerator looks to take a load off the processor, reducing CPU and driver overhead in the process.

Primitive culling – the act of reducing the number of triangles to pass on for further calculations by establishing whether they're no longer needed (because they're obscured by another object in the scene, for instance) – is also accelerated, helping to again reduce potential CPU/software culling overhead.

Long a weak point of AMD GPUs, RDNA 3 brings much improved video encoding and decoding to the table

Other changes include a claimed 50 per cent increase in rasterisation performance, with up to six peak primitive and 192 peak pixels of rasterisation per clock cycle – this should be particularly beneficial for running games at very high resolutions. RDNA 3 also adds out-of-order exports from the pixel shader, which allows for tasks to be more efficiently kept running through the GPU, and not held up while one task is waiting to be completed.

DISPLAY AND MEDIA ENGINES

One of the areas where AMD has been trailing Nvidia lately is video encoding and decoding, and that's an area the company is hoping to improve with the new media engine of RDNA 3. It supports the latest AV1 compression encoder and boasts improved H.264 (AVC) and H.265 (HEVC) encode/decode performance, with simultaneous encode/decode of the latter.

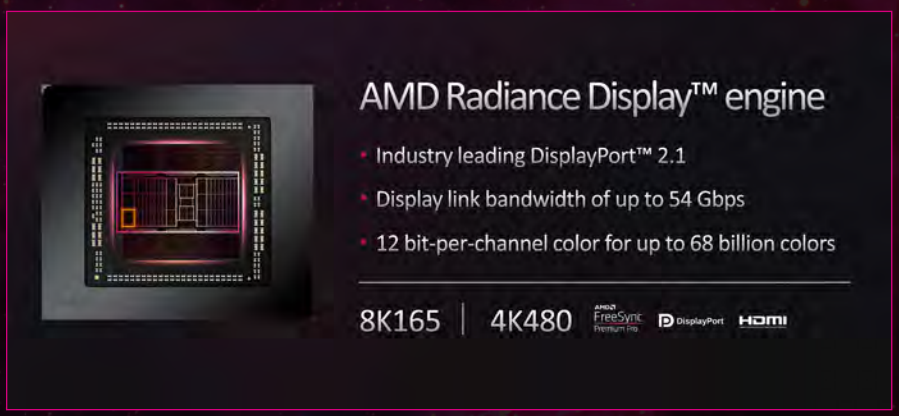
These improvements come in part from taking advantage of the new AI accelerators, while the whole media engine runs at 1.8x the frequency of RDNA 2.

Another key area of improvement is support for DisplayPort 2.1 with ultra high bandwidth support, which enables the GPU to output a display at ridiculous resolution/refresh rate combinations, such as 8K at 165Hz or 4K resolution at 480Hz.

Such futureproof connections might look good on paper, but good luck trying to get any games to run at those settings. Along with two of these DisplayPort 2.1 ports, the reference card designs also include an HDMI port and a USB Type-C output, providing a wide range of output configurations. CPC

ANOTHER KEY AREA OF IMPROVEMENT IS SUPPORT FOR DISPLAYPORT 2.1 WITH ULTRA HIGH BANDWIDTH SUPPORT

The addition of DisplayPort 2.1 supports opens up the possibility of 4K at 480Hz and even 8K at 165Hz



2023 THE YEAR AHEAD

REECE BITHREY FILTERS THROUGH THE RUMOUR MILL, AND CHECKS THE ROADMAPS, TO FIND WHAT'S LIKELY TO HAPPEN FOR PC ENTHUSIASTS IN THE COMING YEAR

PCI-E 5 SSDs TURN UP

AMD's Ryzen 7000-series launch a few months ago brought with it the associated teaser of PCI-E 5 SSDs from a wide range of manufacturers, including Crucial, Corsair and Sabrent. Corsair claimed that its forthcoming MP700, for example, was capable of sequential read speeds of up to 10,000MB/sec. Once the CPUs were available, we expected the drives to follow, but that hasn't been the case. Instead, Phison, maker of the E26 controller that was supposed to power a lot of these new drives, announced that it's been delayed.

That hasn't prevented manufacturers from announcing their forthcoming drives though. CFD Gaming, a Japanese manufacturer, announced its drives recently, featuring active cooling with a massive heatsink and fan. Prices have been seen at Japanese retailer Kataku, which lists them at the following prices: the 1TB model is ¥57,420, which equates to £342, while the 2TB model sits at ¥114,840 yen (£684) and the 4TB model is ¥229,680 (£1,369). In short, if those prices are at all representative, PCI-5 SSDs are going to be very pricey indeed.

We've got motherboards and even heatsinks for them, but we're still waiting to see some actual PCI-E 5 SSDs

As for general specs, the PCI-E 5 interface doubles the theoretical bandwidth of PCI-E 4, with potential speeds of up to 16GB/sec available, although hardware limitations may well limit maximum speeds. For reference, these CFD gaming drives claim speeds of up to 10GB/sec read and 9.5GB/sec write, as well as 1,500K IOPS, which looks to represent a significant generation-on-generation boost from PCI-E 4.

Samsung has also announced that it has begun production of its 8th-gen V-NAND memory; when paired with the right controller, this should be able to work with PCI-E 5 SSDs to provide speeds of 12GB/sec and upwards. We're expecting PCI-5 SSDs to land at some point in 2023, with especially lofty performance. As Antony Leather discusses in Customised PC this month (see p86), they're expected to run pretty hot and require a hefty amount of active cooling too.

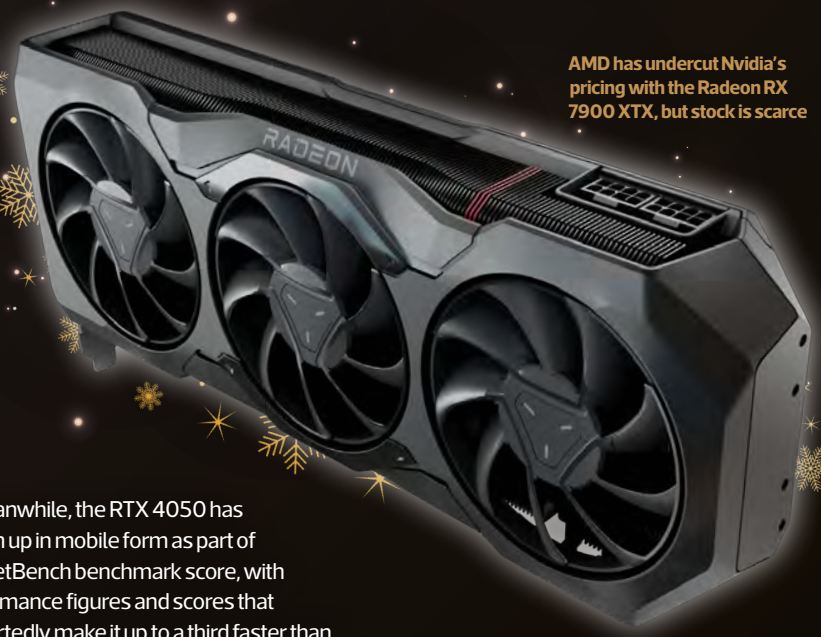
THE PCI-E 5 INTERFACE DOUBLES THE THEORETICAL BANDWIDTH OF PCI-E 4, WITH POTENTIAL SPEEDS OF UP TO 16GB/SEC AVAILABLE

GPUs FOR EVERYONE?

We're expecting 2023 to be the year that Nvidia and AMD pack their new GPU ranges full of cards, with prices hopefully starting to look more sensible by the end of the year. If EEC trademark filings from July 2022 are representative of plans, Nvidia has decided to go as low as the RTX 4050 and 4050 Ti with its new Ada line-up, even if there's no official word of those cards existing as yet.

On the green side of the GPU market, the RTX 4090 and 4080 are out in the wild, while the previously announced RTX 4080 12GB has been 'unlaunched' by Nvidia. Since then, a listing of an RTX 4070 Ti, miraculously with 12GB of VRAM, has been spotted at an Italian retailer with a 5 January, 2023 release date, suggesting Nvidia might be starting the year

Nvidia's GeForce RTX 4090 is an amazingly powerful GPU, but its price is extremely high



AMD has undercut Nvidia's pricing with the Radeon RX 7900 XTX, but stock is scarce

off with a bang, and almost confirming that the old RTX 4080 12GB has been turned into a 4070 Ti.

In addition, images have been shared in the online rumour mill showing supposed renders of the RTX 4070 Ti Founders Edition, with similar coaxial fans, and a thick black and silver shroud to other FE cards. Also, board partner Gigabyte has filed its own EEC listings for varying forms of the RTX 4070 and 4070 Ti, which provides us with a stock of evidence that the card is coming.

Going a little further down the chain is where the situation becomes muddier. There are conflicting reports about the RTX 4060, given that Nvidia is reportedly updating the RTX 3060 Ti to offer 19Gbps DDR6 memory, while board partners phase out the older generation, leaving little to no room for a new card – presumably the 4060 – for a while.

Despite this, we anticipate the SKU for the GeForce RTX 4060 to be based on the AD106 GPU, going from the naming patterns for existing cards. The only major recent gossip here concerns the fact that Nvidia may scale back the initial specs of the GeForce RTX 4060 in a bid to offer a souped-up Ti version. Specs for the RTX 4060 are only at the guessing stage now, so of course should be taken with a pinch of salt.

Meanwhile, the RTX 4050 has shown up in mobile form as part of a PugetBench benchmark score, with performance figures and scores that purportedly make it up to a third faster than the existing mobile RTX 3050, in a laptop with an Intel Core i7-13700H processor and 16GB of 6800MHz RAM.

In terms of a more general look, these so far unannounced RTX 4000-series cards should be bringing support for DLSS 3's AI frame generation tech with them, which has shown to provide a massive performance boost in our own tests on the RTX 4080 and 4090.

Moving onto AMD, both the Radeon RX 7900 XTX and 7900 XT have broken cover already, and while stock is scarce, AMD is clearly focused on offering better bang per buck than Nvidia at the moment.

There isn't too much information flowing around about the next cards in the line-up, apart from months-old leaks from reputable leakers, but we're expecting the 7800-series chips to be based on AMD's Navi 32 die, with up to 60 compute units, 3,840 stream processors, a 256-bit memory bus and 16GB of GDDR6 memory.

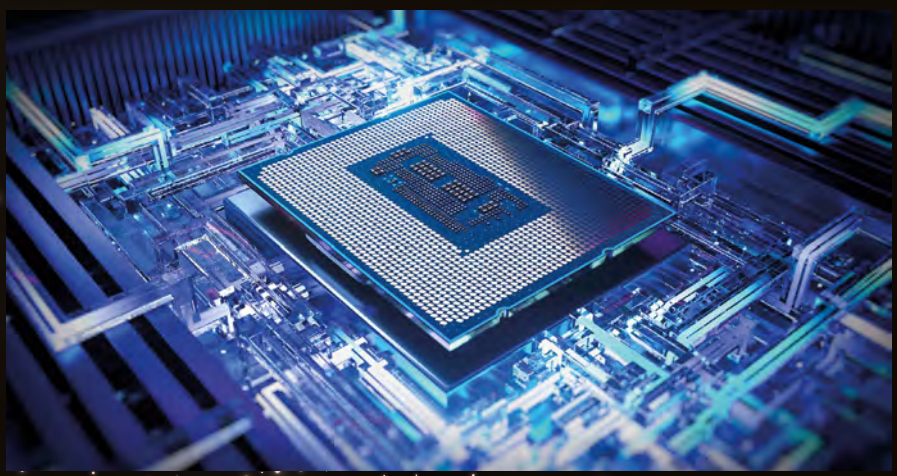
Moving down the stack, we come to the unannounced Navi 33 GPU. This chip is expected to have 32 compute units with 2,048 stream processors, if recent leaks based on information found in an update to AMD's ROCm general-purpose GPU software are correct.

This, combined with the expectation of a 128-bit wide memory bus, constitutes a downgrade when compared with the 6700 XT's 192-bit bus and 2,560 stream processors, but would make it comparable with the Radeon RX 6600 XT.

A RAPTOR LAKE REFRESH?

We've heard a few rumours that Intel may push back by a year its 14th-gen Meteor Lake processors, originally scheduled for 2023, and instead focus on a refresh of its new Raptor Lake CPUs. Official comment from Intel back in July 2022 denied these rumours, with Meteor Lake being full steam ahead for a 2023 release, but recent leaks have resurfaced reiterating a refresh on Intel's current line-up of chips.

The general consensus concerns a potential Q3 (July-September) 2023 launch, with processors based on an optimised 10nm node, which will apparently allow for Intel to squeeze an extra 100-200MHz clock speed out of these processors, with the same core counts. These new processors are said to be



There are rumours that Intel may be refreshing Raptor Lake later in 2023, and postponing its forthcoming Meteor Lake launch

The first DDR5 memory kits, such as Corsair's Dominator Platinum, were overly expensive, but we're starting to see more affordable DDR5 memory options now

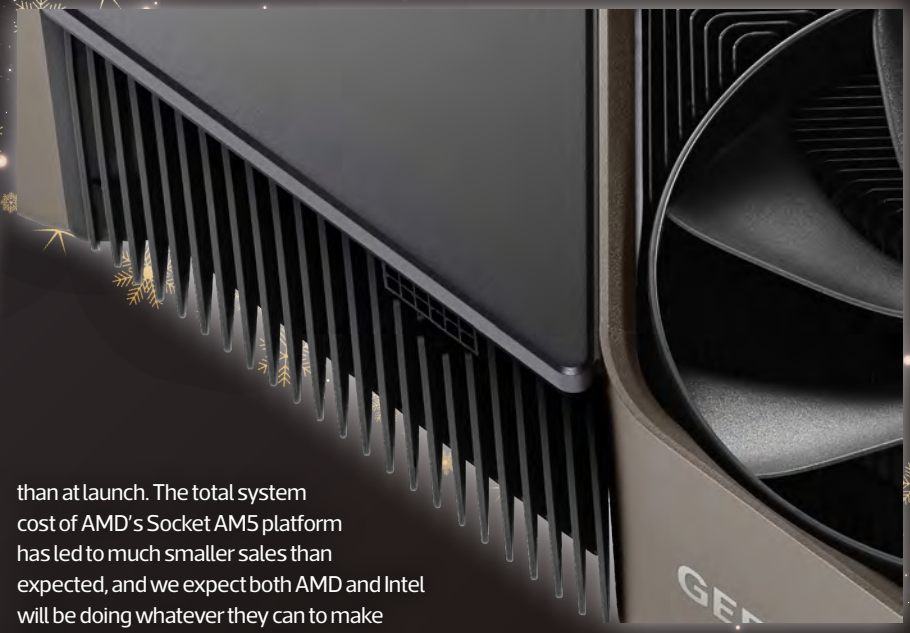
compatible with the existing LGA1700 socket, giving some extra longevity to the platform.

Intel is also going to be launching a new flagship processor in early 2023, the Core i9-13900KS. It's expected to be the world's first official 6GHz chip, as Intel said when announcing its 13th-gen processors back in September, and may bring similar incremental boosts to power limits too. However, the performance gains are reportedly smaller than the ones AMD is bringing with its Ryzen 7000 X3D chips, which are slated for the same 'early 2023' time frame.

DDR5 PRICE DROP

DDR5 memory may well have been out for over a year now, but the fact remains that it's still pretty expensive. However, the Amazon Prime Day and Black Friday/Cyber Monday sales, as well as general markdowns from retailers, have thrown up some decent discounts and deals on DDR5 memory, and it would make sense for the prices to fall further to more affordable levels in the coming year.

With the release of Intel's Alder Lake CPUs in 2021, DDR5 RAM was scarce and expensive, as there wasn't much demand for them, but as 2022 has rumbled on, we've seen the launch of AMD's Ryzen 7000-series processors, which are now much cheaper than at launch. The total system cost of AMD's Socket AM5 platform has led to much smaller sales than expected, and we expect both AMD and Intel will be doing whatever they can to make DDR5 memory more affordable.



Nvidia's latest GeForce RTX 4080 and 4090 cards require a 16-pin 12VHPWR power cable

16-PIN 12VHPWR CABLES FAIL TO BECOME STANDARD

A potentially contentious matter for 2023 is what's going to happen to the 16-pin 12VHPWR cables and adaptors that are required to work with Nvidia's RTX 4090 and 4080 GPUs. Since the GPUs launched earlier this year, there have been reported cases of the plugs melting, which has now caused a consumer class lawsuit in California for one owner against Nvidia, for an allegedly 'defective and dangerous power cable plug and socket', as detailed in the lawsuit's documentation.

Numerous photos of melted cables and subsequently ruined cards have appeared online, and the GamersNexus YouTube channel (**custompc.co.uk/CableMelt**) even managed to recreate the problem in its lab, putting it down to a number of factors, including manufacturing debris inside the cable connectors, as well as improper installation.

Different parties have come out with different solutions. Nvidia itself advises to simply make sure the adaptor is plugged into the socket securely first, before connecting any other cables, while Asus, at least in China for the time being, is offering owners of its Strix and Thor (1st-gen) series of PSUs a free official 16-pin power cable for 'more peace of mind'.

The fact is, though, that this is an issue that has to be fully resolved quickly. PCI-SIG, the devisor of PCI-X and PCI E component connectors and adaptors, and Nvidia itself, are reportedly working on a revised design for the 12VHPWR connector. If this goes through, Nvidia may update their RTX 4090 and 4080 cards with this new connector.

Aside from the melting issues, requiring a new cable also clashes with older PSUs,

The GamersNexus YouTube Channel managed to recreate the 16-pin cable melting problem in the lab

AMD has neatly side-stepped any problems with melting power plugs, by sticking with tried-and-tested PCI-E power sockets

Blizzard's Diablo IV is expected to release in 2023

especially if you have an attractively sleeved system, and new ATX 3 PSUs are expensive. While the cards come with a PCI-E adaptor cable, again this will look a bit rubbish if you have custom coloured sleeves for your power cables elsewhere.

Meanwhile, AMD has neatly side-stepped this whole issue by simply kitting out its latest RDNA3 GPUs with standard PCI-E power sockets. This might look a bit backward on the face of it – multiple PCI-E cables seem a bit clunky in these times – but at least you can be sure you can use your existing power cables, and that none of the sockets is going to melt.

NVIDIA ITSELF ADVISES TO SIMPLY MAKE SURE THE ADAPTOR IS PLUGGED INTO THE SOCKET SECURELY FIRST, BEFORE CONNECTING ANY OTHER CABLES

THE BEST OF THE REST

On the software side, there's some big-ol' games expected for 2023. Confirmed releases include the hotly anticipated Dead Space remake for January, as well as Company of Heroes 3 towards the end of February, and the long-awaited zombie-them-up Dead Island 2 in April. Games with unconfirmed release dates are Alan Wake 2, and Assassin's Creed Mirage, with the latter expected to see the series return to its stealthier roots.

We're also very much looking forward to Larian's long-awaited update to Baldur's Gate, which is slated for an August release, while Diablo IV is scheduled to come out in June. Warhammer 40,000: Space Marine 2 is also looking like a fun action game and is set to arrive some time this year, while Cyberpunk 2077 should be getting its Phantom Liberty expansion as well.

Meanwhile, the world of gaming keyboards is likely to see the continued trend of more wireless and smaller offerings coming out, as mainstream manufacturers grapple with the continued rise of the enthusiast space, and the continued rollout of clever switch types, such as ultra-low profile and analogue options, as well as switches with adjustable actuation points. Gaming mice also keep getting lighter, and it would make sense for this trend to continue in 2023.

As for monitors, 2023 may well be the year of the smaller OLED panel, given the big year-end announcement we've seen from LG pertaining to a 27in 2,560 x 1,440 240Hz OLED panel (the UltraGear 27GR95QE-B) that had long been rumoured, and it makes sense for this trend of OLED screens to continue.

There is, of course, the novelty of the bendable OLED screen, and with pre-orders for Corsair's clever curved panel, the Xeneon Flex, now available, maybe more manufacturers will follow this route. **CPC**

Larian's long-awaited Baldur's Gate 3 is slated for an August release

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

The Ultimate Guide to Informed Wearable Technology

Giving a book a title that includes the word 'ultimate' is always a risky proposition, given the necessary breadth of such a publication, but Christine Farion's The Ultimate Guide to Informed Wearable Technology makes a heck of a case for its applicability – with over 500 pages, it's a weighty tome indeed.

Farion's chosen topic is wearable technology, but the book's far from a dry review of the state-of-the-art. Instead, Farion, a post-grad lecturer at the Glasgow School of Art, has opted for a hands-on approach – turning the book into a guide to building a range of projects using Arduino-compatible hardware.

The book opens with an introduction to (and history of) wearable tech

Putting a few LEDs on a sewable circuit wouldn't constitute an 'ultimate guide', though, which is where Farion's academic experience comes into its own. The book opens with a look at exactly how wearable technology is defined, a brief history and even a look at the ethics of wearable designs. It then moves into a beginner's guide to electronics, working from the first principles of how electricity works and flows in a circuit.

From there, Farion goes into the use of e-textile technologies, using the Arduino IDE (Integrated Development Environment) with an Adafruit Gemma M0 microcontroller board, and then moves onto the rather more complex task of adding inputs and outputs, including sensors and displays.

For a beginner's book, that would probably be enough, but the 'ultimate guide' has more to offer. It covers moving from beginner-friendly, wearable-specific boards such as the Gemma M0 to a generic Espressif ESP32 board, prototyping through the Houde and Hill model, and self-described 'quick and dirty methods' including foam models. It then walks into the creation of a 'hyper-body system' – a wearable electronics platform that combines three or more of the user's five senses – touch, sight, hearing, smell and taste.

Christine Farion's book makes a good case for being the 'ultimate guide' to wearables for beginners

While it's an admittedly low-fidelity example of the field, the hyper-body system would be a great conclusion to the book.

Code snippets are printed, but you need to head to GitHub for complete listings

However, Farion still has around 140 pages left to go by the time the project's complete. The remainder of the book looks at the human-centred design process, introduces the 'Message Bag' project as a solution to human fallibility, and then takes a look at best practices and the potential future of wearable technology in general.

The book's contents alone are evidence enough that Farion has worked to justify the 'ultimate' in the title, but the book isn't just broad yet shallow. The topics are covered in enough depth to make it worth the effort of working your way through each chapter in turn, and Farion strikes a good balance between making the concepts accessible to readers without prior electronics or programming experience, while also not talking down to you.

The last bit of the book introduces the 'Message Bag' project as a solution to human fallibility

That's not to say there aren't areas of the book that could be improved. In common with a disappointingly large number of technical tomes, imagery is sometimes reproduced from elsewhere without proper attribution. Those expecting an academic tone may take issue with Farion's use of the first person throughout, and the print edition reproduces all graphics in greyscale, albeit with a link to download colour imagery if preferred. The publisher, Pakt, provides a free PDF download for all print purchases too.

For those eager to get their hands dirty – or as dirty as conductive thread, fabric and a little soldering will allow – each project in the book includes a full parts list, while an appendix suggests suppliers in the UK and USA. There's nothing particularly unusual to be found in the parts lists, and there's no reliance on components hit by the ongoing supply chain issues creating havoc throughout the electronics industry. However, some projects do assume access to relatively niche hardware, such as a Brother Scan and Cut, or a Cricut machine.

All project source code is available on Farion's GitHub repository, at **github.com/cmoz/Ultimate**, and while it would have been good to see complete code listings printed in the book for those working away from a reliable internet connection, it would have bloated the book beyond its already hefty 500-plus page count. Likewise, it's hard to identify any of the content as superfluous – there's little that could be removed without giving lie to the 'ultimate' claim of the title.

For anyone curious about building their own wearable devices, or simply looking for an introduction to the topic, The Ultimate Guide to Informed Wearable Technology is easy to recommend – although at £41.99 in print with free a PDF download, or £32.99 electronically (inc VAT), it's just a smidge beyond impulse-buy pricing. For students of the subject, it's a price well worth paying, and the review questions at the end of each chapter help to drill the topic home.

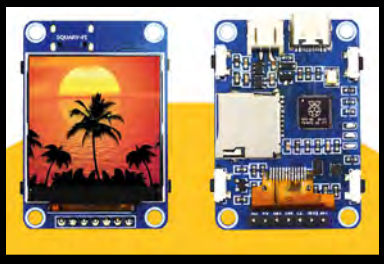
The Ultimate Guide to Informed Wearable Technology is available from **packtpub.com** now, or it can be ordered in from your favourite bookseller under ISBN 978-180323059-7.

NEWS IN BRIEF

SB Components unveils square Roundy cousin

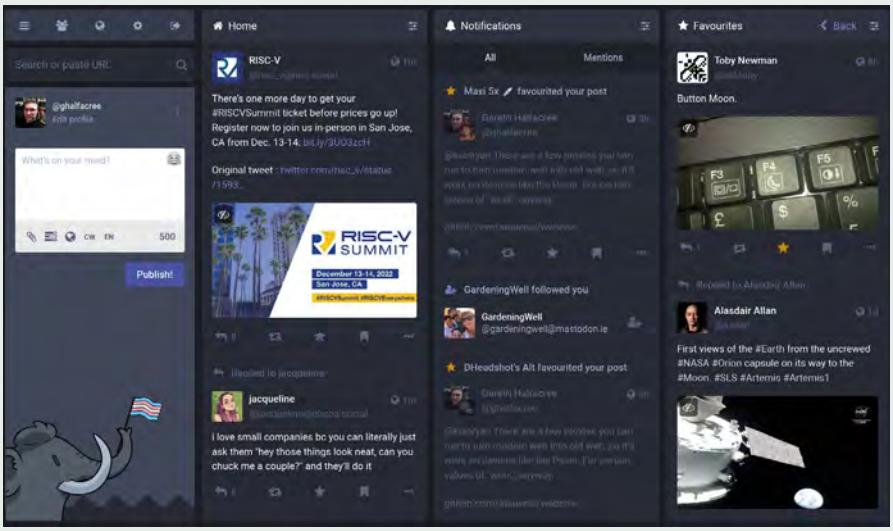
SB Components has launched a follow-up to its RoundyFi and RoundyPi smart circular displays, reviewed back in Issue 226, and this time the company has decided it's hip to be square. SquaryFi and SquaryPi are compact 240 x 240 colour displays with either a Wi-Fi-equipped Espressif ESP8266 or Raspberry Pi RP2040 microcontroller and micro-SD storage slot.

The square display panels aren't the only change – the new boards also include support for an optional battery and USB Type-C connection. The boards should be available on **sb-components.co.uk** when this issue hits shelves, with pre-launch crowdfunding pricing set at £23–£25 inc VAT.



ANALYSIS

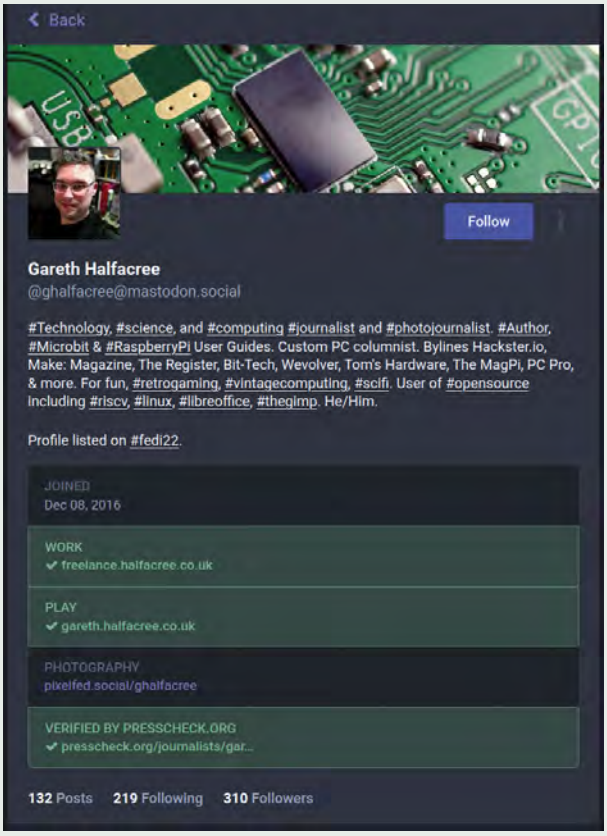
The Fediverse



More than just a Twitter alternative, the Fediverse is a throwback to a more community-driven internet

A major shake-up at microblogging social network Twitter, courtesy of a controversial and rather reluctant new owner, has shone a light on an interesting and effectively anti-corporate portion of the modern web: The Fediverse.

A portmanteau of 'federated' and 'universe,' it's a slice of the web as was – before it became dominated by a surprisingly small number of extremely large companies, such as Twitter and Facebook parent Meta. It's a place where individualism is key, and community is the watchword. It's a place driven by its users, and it's growing faster than ever before.



With no central authority, account verification is handled with simple link-backs

A BRIEF HISTORY

The Fediverse is the name given to websites and services built atop the ActivityPub specification, adopted as an official standard by the World Wide Web Consortium (W3C) in 2018 but dating to years earlier. Originally designed by Evan Prodromou as a successor to OStatus, ActivityPub – originally ActivityPump – is designed to allow cross-publication between sites.

It's this cross-publication that makes the Fediverse federated – any ActivityPub-based service can, in theory, talk to any other ActivityPub-based service. It's closer to email – in which thousands upon thousands of independent servers agree to communicate using a set protocol – than the walled-garden social networks most modern web users would recognise.

It's also not limited to a single service. The Fediverse is made up of a number of open-source ActivityPub-compatible platforms, offering a range of experiences: Frendica, a Facebook-like social network; Mastodon and its spin-offs, which attempt to bring back what people originally liked about Twitter: PeerTube, a YouTube-like video streaming platform; Pixelfed, an alternative to Instagram or Flickr; and more, including event planners and file hosting services.

COMMUNICATION IS KEY

The key to the Fediverse is that all these services can communicate with each other – a feature that makes it stand entirely apart from commercial alternatives. A Mastodon user can, for example, follow someone on PeerTube and be notified when a new video is posted – then reply within Mastodon and have it published on PeerTube as a video comment.

There are few barriers in the Fediverse bar technical ones. Pixelfed, for instance, allows for up to ten images to be attached to a single post, but only four will be visible to Mastodon followers without having to visit the Pixelfed page directly.

WHAT'S OLD IS NEW

Readers of a certain vintage may be feeling some déjà vu at the idea of a federated social networking service, as that's almost exactly how newsgroups got their start – being copied from server to server on a schedule using the UUCP protocol. Universities, ISPs and sufficiently technical individuals could run their own newsgroup servers and choose the peers with which they communicated, and messages would wind their way through the network to other servers hop by hop.

The Fediverse is certainly similar, although more community-driven. As its services are

NEWS IN BRIEF

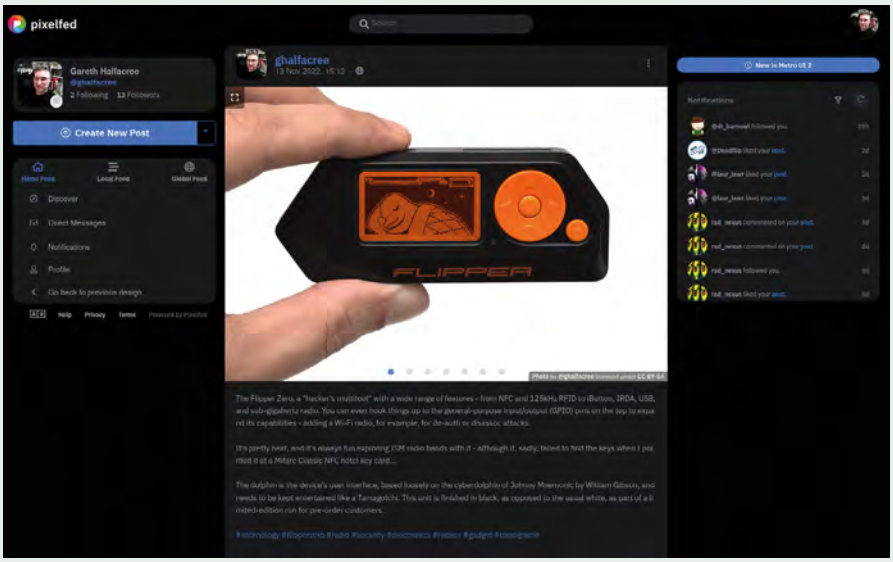
LibreOffice gets RISC-V port

With two affordable quad-core 64-bit RISC-V single-board computers just around the corner – the StarFive VisionFive 2 and the PINE64 Star64 – an increasing number of large-scale software projects are turning their attentions to supporting the architecture, with LibreOffice being the latest to receive a port.

The popular productivity suite, forked from OpenOffice which in turn was based on StarOffice, has now received a patch set that introduces full RV64 support. At the time of writing, this had yet to be reflected in binary availability, but it brings the architecture one step closer to being usable as a daily driver for desktop-class systems.

open-source, setting up a server, known in Fediverse terms as an 'instance', isn't only possible but recommended.

Cross-instance communication is also barely more challenging than writing an email – complete with remembering to put the domain name of the instance after the ultimate 'at' symbol.

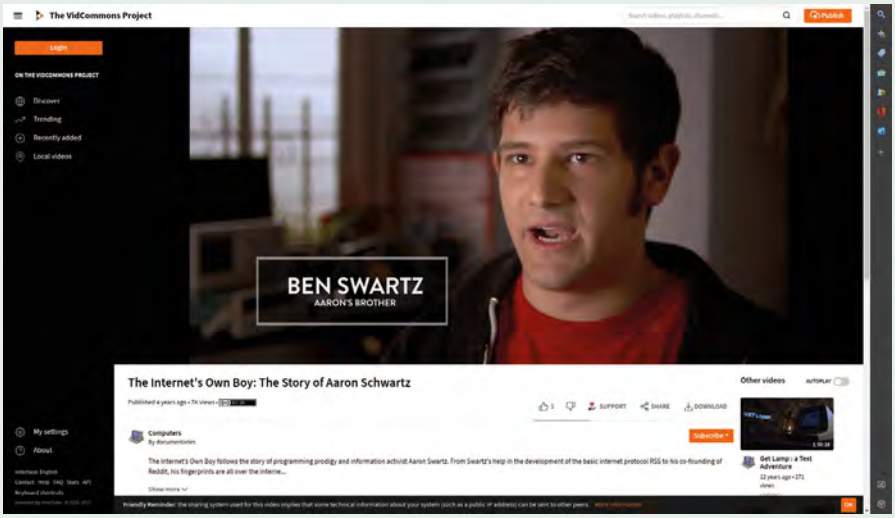


Pixelfed is an ActivityPub-based alternative to photo-sharing sites such as Instagram and Flickr

COMMUNITY RULES

The Fediverse goes a step further than the newsgroups of old, however. The peering agreements between instances, which allow messages to pass between them, are subject to revision. If an instance is known as a source of abuse, it will likely find itself defederated, with other instances refusing their communications.

Defederation provides a way for instance operators to remove abusers communicating from different instances, but at the cost of potentially encouraging echo-chamber behaviours. That's not been a problem so far, but with the Fediverse experiencing explosive growth since the Twitter takeover – primarily by users signing up to Mastodon – it's an issue of which operators should be aware.



There are Fediverse alternatives to most commercial services, from social networking to peer-to-peer video hosting

FINDING FRIENDS

Perhaps the most interesting aspect of the Fediverse comes from the way most implementations handle the concept of instances, splitting content into user, local and federated streams. The user's stream is filled with content from those they follow, like any other social network. The local stream is a firehose of posts from all other users on the same instance. The federated stream, meanwhile, is a barrage of messages from every federated instance – it's interesting to dip into it from time to time, but it's too chaotic for regular reading.

The local stream, though, is a valuable resource. Pick an instance matching your interests – there are instances for gamers, crocheters, programmers, lawyers and even one exclusively available to former Twitter staff – and you'll see posts of interest from people you might not otherwise have found.

The Fediverse isn't like any commercial platform. There's no advertising, and there's a community that values accessibility features such as alt-text and content warnings. It's a place out of time, and one worth checking out. Interested parties can learn more and find Fediverse instances on **fediverse.info** CPC

ANTONY LEATHER'S

Customised PC

Case mods, tools, techniques, water-cooling gear and everything to do with PC modding

The benefits of AMD's Eco mode

AMD has usually offered some sort of Eco mode with its processors, which works by limiting power consumption and cutting temperatures. This usually results in reduced performance, but seeing as undervolting has become popular with some Ryzen CPU owners, especially those with small form factor PCs, trimming power consumption and operating temperatures is a relatively common activity among some enthusiasts.

As we saw in our Ryzen 9 7950X review, the 65W and 105W Eco modes dramatically cut power consumption, but still give the CPU enough headroom to outperform previous AMD flagships. For example, even at its 65W Eco mode, the 7950X was still faster than the Ryzen 9 5950X and Core i9-12900K in heavily multi-threaded tests, which is testament to its efficiency, especially at lower power levels.

In these times of sky-high electricity prices, I wouldn't blame anyone for wanting to trim their PC's power consumption and you can do this in a variety of ways, potentially shaving hundreds of watts off your PC's load draw. This could save up to a kilowatt hour of electricity every couple of days if your PC is regularly under high loads in content creation work, saving up to £10-15 a month at current prices.

That's not what I'm here for today, though, as these lower TDPs are now the target of coolers, particularly low-profile models and coolers at the lower end of the price spectrum. For example, Noctua's L9a low-profile cooler is only compatible with AMD's Ryzen 5 7600X when it comes to Zen 4 CPUs, with every other AM5 chip out of bounds due to heatloads drastically reducing performance.

Similarly, cheap coolers such as ARCTIC's Freezer A13X aren't usually geared towards high-end CPUs, but AMD's Ryzen 7000-series CPUs are so efficient at lower power limits, that I thought that using them in space-limited cases with small coolers usually limited to 65W or 105W TDPs could be possible using one of the Eco modes.

I decided to put this to the test, using a Ryzen 9 7950X and Noctua L9a low-profile cooler with a Socket AM5 adaptor kit, along with a Lian Li Q58 mini-ITX case and Asus ROG Strix X670E-I Gaming WiFi motherboard.

Reducing the power limits of Ryzen 7000-series CPUs enables them to be tamed by surprisingly small coolers

At stock settings, the CPU instantly hit 95°C in Cinebench, with boost frequencies quickly falling below 4.8GHz and ending up closer to 4.6GHz at most by the end of a relatively quick multi-threaded test.

Its score of 33,149 was quite a bit lower than we saw in our review too, due to the limited cooling, and after a couple of runs this score fell to 30,512 as the CPU continued to throttle.

Applying the 65W Eco mode saw the score fall to 27,487 – still a match for Intel's Core i9-12900K and faster than the Ryzen 9 5950X – but the CPU temperature fell to just 75°C under load, with these figures not budging much after several benchmark runs.

Despite the slower than stock performance, it was great to see a tiny low-profile cooler dealing with a 16-core monster and outperforming the flagship CPUs from the last generation.

The really interesting test came with the 105W power limit, which I set using limits of 142,000 PPT, 110,000 TDC and 170,000 EDC in the motherboard's BIOS. Not only did this result in similar boosting frequencies across small numbers of cores, but the CPU was also able to maintain higher all-core boost frequencies and higher scores in Cinebench across all the benchmark runs I completed.

This is the sweet spot, reining in power limits enough to reduce temperatures to a point where the CPU could maintain slightly higher frequencies, bit without cutting performance like the 65W mode. Clearly, I wouldn't recommend using a Ryzen 9 7950X with a Noctua L9a cooler in any situation other than extreme circumstances. This was just a fun test to see what would happen. After all, Noctua itself says the cooler and CPU are incompatible due to the modest cooling on offer.

If you're limited to low-profile air coolers, though, and are restricted to especially small ones due to motherboard heatsinks, then you can still get performance that outstrips every other AMD mainstream desktop CPU and cool it effectively with a tiny cooler. More impressively, it really showcases the sheer efficiency of AMD's new CPUs at lower power settings.

Antony's 2023 wish list

We may have only just got the big CPU and GPU launches out of the way at the end of 2022, but I've also got my eye on quite a few bits and pieces lined up for the coming year, particularly when it comes to small form factor systems. Quite a few items have been delayed, or aren't available in great quantities recently due to the usual issues, and others are promised to be on the way.

One product that could revolutionise water cooling, especially in small cases, is EK's Quantum Velocity² 4.2 DDC PWM D-RGB combined waterblock, pump and reservoir. My sample is inbound, so I'll hopefully be taking a look at it here soon, with plenty of projects planned for it. The ability to do away with reservoirs and pumps and strap all the gear to your motherboard sounds great, as long as vibration isn't an issue.

More SFX PSUs are inbound too. I can't say much yet, as they're under embargo, but they offer much more power than the SFX units we've seen so far, which hopefully means they'll be quieter too – noise is an issue for many SFX PSUs. Speaking of power, I'm also hoping for cheaper GPUs. Even though I've only recently got shot of my ancient-feeling Radeon RX 5700XT, I'm still hoping the rest of Nvidia's stack and AMD's new RDNA3 graphics cards will be cheaper than recent GPU prices, readily available and able to give everyone the upgrade for which they've been waiting.

Finally, there are PCI-E 5 SSDs on the horizon. Several SSD launches I've covered this year were expected to be PCI-E 5-related, but only turned out to be yet another flagship PCI-E 4 SSD. That was certainly the case with Samsung's 990 Pro. I've seen a PCI-E 5 SSD in action, and at the time a company that shall remain unnamed was rushing around a demo hall trying to find a heatsink big enough to cool it and prevent it from thermally throttling.

I've seen enough motherboards bundle extra-large heatsinks in the last few months to want to know what the fuss is about. All signs point at these new SSDs being toasty, but I'm hoping they'll be extremely fast too. CPC

EK's Quantum Velocity² DDC 4.2 PWM D-RGB (right) stands only a little taller than a waterblock with barbs, but there's a waterblock, pump and reservoir inside

Where are all the PCI-E 5 SSDs?!

Antony Leather is Custom PC's modding editor @antonyleather

How to Water-cool an RTX 4090 or 4080

Antony Leather shows you how to remove the cooler from Nvidia's new Founders Edition cards, and fit a waterblock

TOTAL PROJECT TIME / 2 HOURS

Waterblock manufacturers are already offering blocks for Nvidia's latest RTX 4080 and 4090 Founders Edition cards, but this is quite a complicated job. Water-cooling Nvidia's previous RTX 3000-series FE cards was an involved job, with you having to deal with all sorts of cables, screws, magnetic covers and tiny latches in order to remove the stock cooler, and while the process is less involved with these new cards, it's still quite fiddly.

In this guide, we'll show you how to water-cool Nvidia's RTX 4090 Founders Edition with EK's Quantum Vector^2 waterblock, with the steps also applying to the RTX 4080 model, as well as similar partner cards. There are thermal benefits to cooling these cards with water, but the biggest boon is getting rid of the enormous cooler, meaning the card takes up far less space.

TOOLS YOU'LL NEED

GeForce RTX 4090 waterblock
overclockers.co.uk

Micro screwdriver set including T5, T6 and T7 Torx and crosshead bits
amazon.co.uk

Plastic pry tool
amazon.co.uk

Thermal paste cleaner or isopropyl alcohol
amazon.co.uk

Scissors
Most hardware stores

1 / UNLOCK THE BACKPLATE

The backplate secures using a single locking mechanism, which is released using a latch at the end of the graphics card. We've inserted a point-tip plastic pry tool into the hole to release the backplate. This will prevent you from scratching the cooler.

2 / LIFT THE BACKPLATE

The first part of the backplate will now lift up. Do this gently and take care not to bend it, as inner sections will be held in place using pins towards the fan. Lift it gently and allow these sections to release.

3 / PUT SCREWS IN A CONTAINER

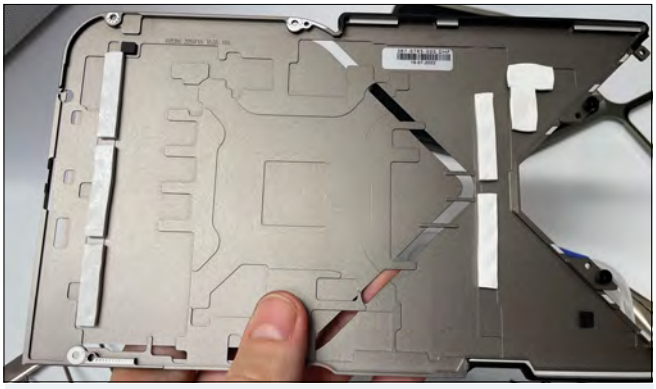
Before you start removing screws, grab a container to ensure they don't get lost. You may well want to reinstall the cooler at some point, so it's essential to keep these screws safe.

4 / REMOVE CROSSHEAD SCREWS

You need to deal with three different types of screw types, so you'll need a mini screwdriver that includes all the bits you need. Start with a crosshead bit, which you can use to remove the four screws next to the backplate fan.

5 / REMOVE TORX HEAD SCREWS

You'll need a T5 Torx bit for the next set of screws. These are located around the lighter area of the backplate next to the expansion slot bracket. Once you've removed these screws, place them in your container.

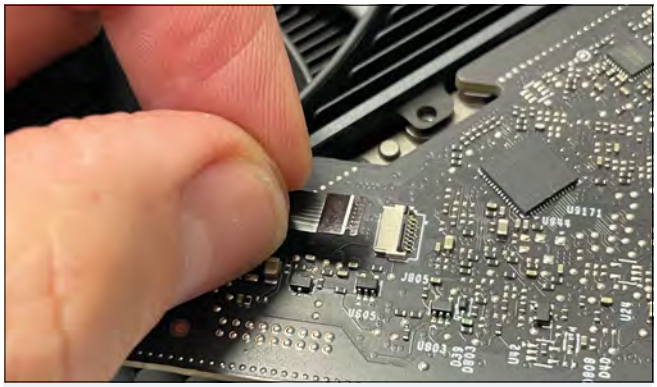


6 / REMOVE BACKPLATE

The backplate should now lift away easily, but it does have thermal pads underneath it that could be a little sticky. Remove the backplate carefully, so you don't tear these pads – you'll need the pads intact if you ever want to refit the stock cooler in the future.

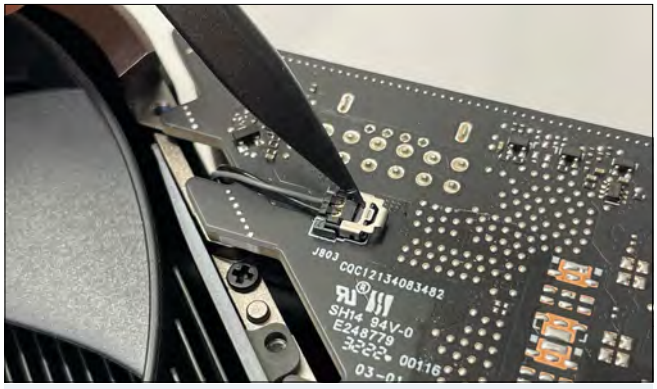
7 / LIFT CABLE LATCH

There are two small ribbon cables on the rear of the PCB, which need to be detached. This can be done using the small pointed end of the plastic pry tool, lifting the end of the black plastic latch upwards.



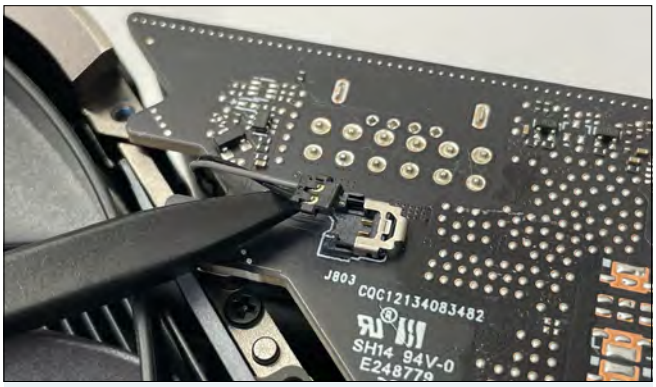
8 / REMOVE RIBBON CABLE

The ribbon cable should now pull out easily. Don't force it out, as it can tear easily. If it refuses to come away, try raising and lowering the latch again, then wiggling the cable from side to side.



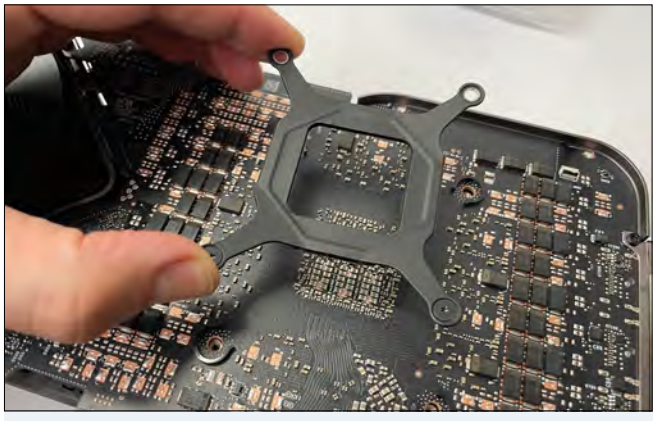
9 / OPEN CONNECTOR CAP

With the two ribbon cables removed, it's time to deal with the last connector. This has a small metal cap that needs to slide away from the connector. Again, you can use the pointy end of the plastic pry tool for this job. The black connector will then be fully revealed.



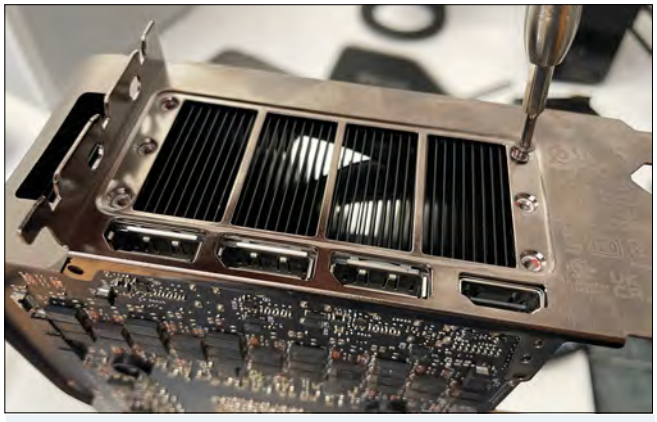
10 / REMOVE CONNECTOR

The connector will lift out vertically, and you can again use the pointy end of the plastic pry tool to lift it from the end with the cables protruding. This job needs very little force.



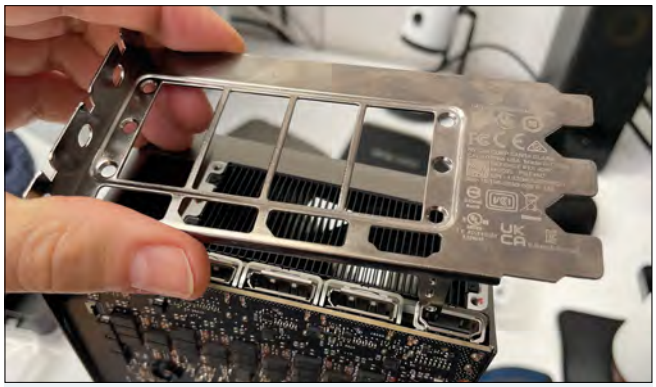
11 / REMOVE CORE SCREWS

The four screws surrounding the GPU core have T6 Torx heads, so use the correct bit to remove them. Start by loosening each screw by three turns, then fully remove them and lift away the metal bracket.



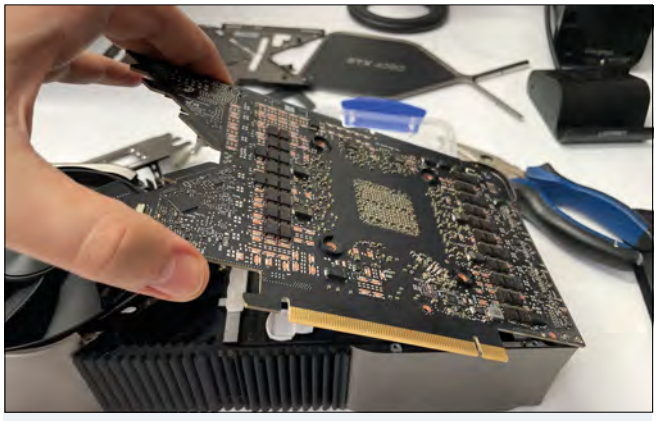
12 / REMOVE BRACKET SCREWS

There are seven Torx screws securing the expansion slot bracket, one of which is at the end of the PCB. These screws require a T7 Torx bit this time, which is larger than before. Remove the screw on the PCB then deal with the six at the end of the card above the output ports.



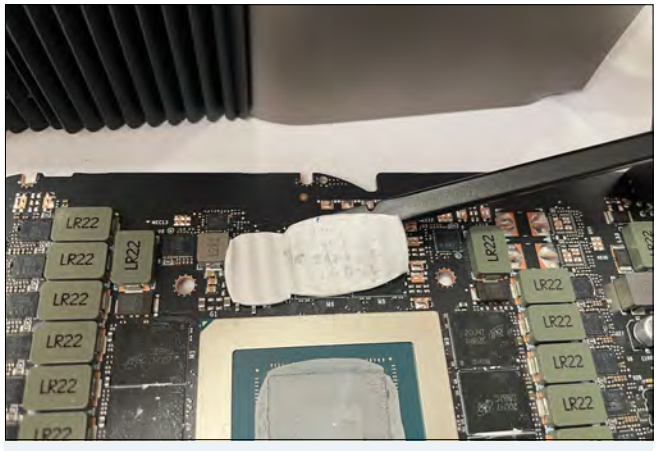
13 / REMOVE BRACKET

You'll now be able to remove the expansion slot bracket, which will pull out from the end of the card. If it doesn't, check that all seven Torx screws have been removed, along with the screws on the PCB.



14 / REMOVE PCB

The PCB should now lift up from the fan end of the card. It may need some persuasion, as the thermal paste and thermal pads underneath will have sat between the PCB and heatsink.

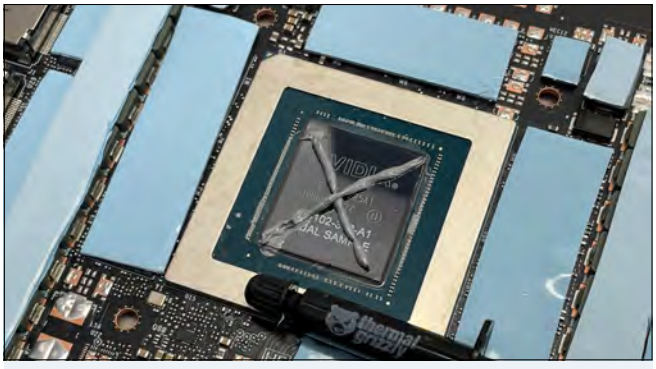


15 / REMOVE STOCK THERMAL PADS

If any thermal pads get left behind here, or on the rear of the card, use the flat end of the plastic pry tool to lift them carefully off the PCB, then replace them back onto the heatsink.

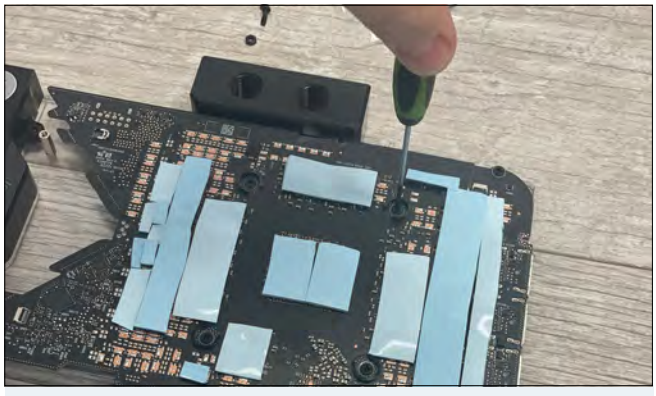
16 / REMOVE CARDBOARD INSERT

The waterblock includes a cardboard section that needs to be removed before you fit it. Unscrew any screws holding it in place, remove the card and then replace those fittings afterwards. The card also provides a QR code you can use to grab the latest instructions for the waterblock.



17 / APPLY THERMAL PADS AND PASTE

Apple a thin cross-shape of thermal paste to the GPU core, then follow the instructions for applying the thermal pads to the PCB on both sides. You need to deal with three thicknesses of pads. Installing them is a simple process if you follow the instructions – you just need a pair of scissors.



18 / SECURE PCB TO WATERBLOCK

Place the waterblock so that the underside is facing up, then place the PCB with the GPU core facing downwards. You can then secure the PCB to the waterblock according to the instructions using the included crosshead screws.

19 / FIT EXPANSION SLOT BRACKET

The waterblock includes a single-slot bracket that you'll need to put in place. You can then lay the new backplate down on top of the PCB.

20 / SECURE BACKPLATE

Ensure that all six backplate screws have corresponding threaded nuts on the waterblock, as they can occasionally come loose. Each backplate screw needs a plastic washer on it too. Secure the backplate with a crosshead screwdriver, tightening each screw three turns before moving around the plate until they're all fully tightened.

21 / ATTACH BLANKING PLUGS

With the waterblock and backplate secured, you now just need to attach blanking plugs to the ports on the waterblock before plumbing it into your loop. CPC

Retro tech

ATI RAGE

Stuart Andrews examines how ATi went from dodgy 'Free-D' graphics to creating some of the fastest chips on the block

The 3D Rage and 3D Rage II were typical Free-D chips, with decent 2D and video performance but only basic 3D. Photo own work by Toggomusic, CC-by-SA 3.0

ATi's Rage graphics accelerators saw the firm rise over a four-year period to become one of the key graphics hardware manufacturers. Its products didn't break new ground like those of 3dfx and Nvidia in the same period, but they consistently delivered the latest 3D features in products that more of us could afford.

The first Rage 3D products were typical of early 2D/3D graphics chips. Keen to jump on the 3D bandwagon as buzz grew around the first 3dfx and VideoLogic 3D-only cards, ATi combined the 2D Windows accelerator tech behind its popular Mach64 chips with 3D tech it picked up from acquiring the design team from Kubota Graphics, a small division of an industrial and construction giant, specialising in high-end graphics workstations.

The new chip was launched at the Comdex trade show in the winter of 1995, and was originally going to be called the 264GT. However, at the last minute, Product Manager Phil Eisler caught wind that S3 was planning to announce its own 2D/3D accelerator, the S3 ViRGE, which clearly had a cooler name. Eisler hijacked the Rage branding from an arcade graphics board on which ATi was working, and the Rage 3D was born.

Launched in early 1996, the 3D Rage, the S3 ViRGE and Matrox's new Mystique cards were all sold at a price not much higher than you (or a PC manufacturer) would pay for a standard 2D graphics card. That was a big deal when 3D-only cards cost upwards of £200. Pundits described the new cards as 'Free-D'.

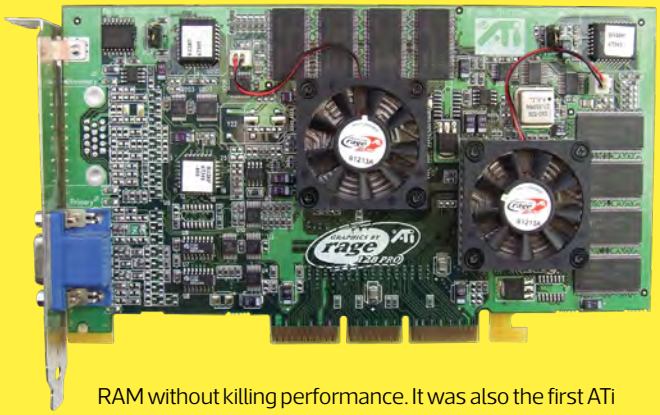
Of course, you got what you paid for. All these early 3D cards were basic, with a single pixel shader, one texture-mapping unit (TMU) and one raster operations pipeline (ROP). The more powerful, two-processor design of the 3dfx Voodoo, which also handled the depth-buffering and shading, left them in the dust. What's more, where 3dfx had its own GLide API – and developer support from the likes of id Software – ATi was designed to accelerate Microsoft's Direct 3D, which Microsoft hadn't even finished at the time of launch.

While the 3D Rage was successful, it wasn't a great 3D graphics accelerator. The titles that ran best were those designed or ported to run on ATi's tech, while issues with the depth buffer, blending operations and mipmapping meant that many early Direct3D titles ran at poor frame rates or with visual artefacts – or simply didn't run at all. ATi's follow-ups, the Rage II and Rage II+, improved speeds and fixed bugs but didn't give 3dfx much in the way of competition. If ATi wanted to stay in the game, it needed to get serious about 3D.

GOING PRO

That's just what it did. Launched in 1997, the Rage Pro had several advantages over the Rage II+, promising a 3x improvement in 3D performance. The big one was that this was the first ATi chip with a built-in, floating-point setup engine, capable of processing up to 1.2 million triangles per second. This took work from the CPU and accelerated it, meaning the CPU could focus on core 3D geometry and lighting transformations. The Rage Pro also included enhanced support for alpha-blending features, such as fog and transparency effects, along with specular lighting, single-pass trilinear filtering and texture compression.

Just as crucially, the Rage Pro brought benefits beyond the chip itself. It was the first ATi chip to fully support Intel's AGP (Accelerated Graphics Port) interface, which dramatically improved read/write speeds between the graphics card and the motherboard chipset, and through that to the CPU and system RAM. You could actually read textures directly from



ATi's Rage Fury Maxx gave you two Rage 128 Pro chips on a single card, rendering alternate frames. Photo own work by Trio 3D, CC-By-SA 3.0

RAM without killing performance. It was also the first ATi graphics card to use 100MHz SGRAM, giving you much faster video memory on-board.

Sadly, ATi still had a problem. While the Rage Pro was a significantly better 3D accelerator, the competition was moving even faster. Nvidia's Riva TNT featured two texture mapping engines for speeds that rivalled 3dfx's mighty Voodoo 2. Even though the TNT didn't have the Rage Pro's triangle setup engine, the Rage Pro fell behind it in both Direct 3D and Quake II benchmarks, with the Nvidia cards sometimes doubling frame rates. ATi risked looking like an also-ran. It needed to take itself up another level.

TAKING ON THE TNT

Launched at the end of 1998, the Rage 128 seemed hell-bent on one purpose: destroying the Riva TNT. It helped that it was the first Rage chip to be fabricated on a new process, with ATi moving from 350nm to 250nm tech. In theory, this meant the Rage 128 could be run at higher clock speeds without overheating.

ATi also added both a pixel cache and a texture cache to improve efficiency, and followed Nvidia in implementing single-pass multi-texturing, with dual texture-mapping pipelines that enabled Rage 128 to render two bilinear filtered pixels, or one bump-mapped pixel, per clock.

Bump mapping itself was seen as a major new feature, enabling games to render more realistic surfaces with the impression of relief, although only a few showcase games, such as Rage Software's Expendable, actually used it. Perhaps the biggest plus with the Rage 128, however, was that it was the first 3D chip to operate in 32-bit colour without a huge performance penalty – less than 10 per cent against the TNT's 40 per cent.

Neither the existing Voodoo 2 nor the upcoming Voodoo 3 even supported 32-bit 3D, and at a time when more games were coming out with 32-bit colour options, and with a noticeable visual difference, this was a real feather in ATi's cap.

Embarrassingly, though, as with the Riva TNT before it, clock speeds had to be reduced before launch to avoid overheating, with the first cards launching at 90MHz rather than 100MHz. Worse, delays getting into stores meant the Rage 128 came up against the new TNT2 and Voodoo 3 chips within months of launch.

Still, it did enough. Benchmarks showed similar and sometimes better performance than the TNT and Voodoo 2, while the chip's triangle setup engine meant performance remained steady when partnered with lower-end CPUs. The Rage 128 was the best card out there if you moved to 32-bit colour, although issues with Super Socket 7 chipsets made it a non-starter if you rocked an AMD or Cyrix CPU.

The Rage 128 was inevitably followed one year later by the Rage 128 Pro, with an enhanced triangle setup engine and higher clock speeds, plus the Rage Fury MAXX, which incorporated two Rage 128 Pro chips, rendering alternate frames. Both helped ATi to remain competitive as the graphics hardware industry evolved.

Sometimes, that's enough. ATi's investment in 3D tech kept it in the picture at a time when other graphics hardware companies were beginning to find the costs too high and the competition too hot. Aggressive pricing helped, while ATi continued to win big OEM contracts from the likes of Compaq and Apple.

Throughout the Rage line's lifespan, ATi also created different variants to reach different areas of the market. ATI captialised on its strength in video and DVD decoding through its All-in-Wonder line, which combined Rage II+, Rage Pro or Rage 128 processors with a TV tuner and composite and S-Video outputs. The Rage Pro, meanwhile, was initially sold in two formats, as the Xpert@Work, aimed at business users, and Xpert@Play, aimed more at gamers. The only difference between the two was that the latter had an S-Video output as well as VGA.

As time went on, the company followed the lead of Nvidia and 3dfx in building closer relationships with games developers, and its Rage tech provided a solid platform on which it could build, with the Rage 6 chip that was to succeed the 128 Pro morphing into ATi's first Radeon GPU. As the list of contenders became ever smaller, ATi remained in the game. **CPC**

ATi showcased the power of the Rage 128 with the Rage Dawning demo. The people who coded these demos loved reflections and glowing light a little too much

Readers' drives

Ex-Box One S

Using an AMD APU and a super-compact water-cooling system, Aaron Howe converted an Xbox One S into a fully functional PC

SEE THE FULL PROJECT LOG AT custompc.co.uk/ExBox

/MEET THY MAKER

Name Aaron Howe

Age 35

Occupation Computer technician

Location Camas, WA, USA

Main uses for PC Portable LAN PC

Likes You'll mainly find my Instagram (@draelren) chock-full of pictures of food, cats, cars and computers, depending on what I'm feeling at the time. I love playing Magic the Gathering, and I'm fairly nerdy overall. I'm also a huge foodie! It doesn't matter if I'm going out or making food at home, I love all tasty treats!

Dislikes Beans and dying (been there, done that before – 0/10, do not recommend)

CPC: What inspired you to build a PC into an Xbox One S?

Aaron: I hadn't seen it done before! I had previously built an air-cooled PC inside an Xbox 360 and, using that experience, I wanted to take the idea of converting consoles to computers an extra step forwards, adding complexity and pushing boundaries.

CPC: How did you plan this build?

Aaron: It started with pen and paper and then moved to MS Paint of all things. I then got out a ruler and just started laying down general sizing to see what the box would take. I then made an initial concept build using J-B Weld and some aluminium to cold-weld a frame together, but the hardware inside was just too hefty. It kept breaking apart in a few weak spots, just from holding it and moving the system around.

I used the measurements of that original prototype to design an internal chassis in 3D software, which I ended up 3D-printing in one solid piece that just slides into the Xbox One S. It's flexible in the right places, so it can bend where necessary, and it's rigid in other places to keep strength.

CPC: What's the side window made from, and how is it attached to the chassis?

Aaron: It's not tempered glass; it's just a glass piece from Home Depot. The idea for the glass panel was that I wanted the console to have a 'sleeper' look if it was faced downwards, but if it was vertical, it would show off its true nature.

To attach it, I used mirror clips that you would usually use to hang mirrors on a wall, which also act as feet if the console is laid down horizontally. The clips themselves are hung on with 'extreme' double-sided adhesive tape, which has more than enough strength to hold it up.

CPC: We're intrigued by that tiny radiator at the bottom and the little fans on top of it. What fans and radiator did you use?

Aaron: It's the Alphacool XT45 50mm dual radiator, with two Gelid Solutions Silent5 50mm fans. Initially I tried to use the triple-radiator version, but I realised quickly that it would leave no room for the pump or reservoir, so I had to scale back the cooling. It's powerful enough to keep the machine in the mid-60s (°C) while gaming, using stock clock speeds and an undervolt to 1.1V on the CPU. I've occasionally seen it go higher, but it's rare.

CPC: Why did you use soft tubing instead of hard tubing?

Aaron: To be honest, this was my

first custom loop ever, and I wanted to nail the basics of a custom loop first before I tried to add the complexity of making hard tubing bend like that. I might take the leap one day and transition the build to hard tubing, but for now it's staying with soft tubing.

CPC: Take us through the rest of the water-cooling loop.

Aaron: While researching my size constraints, there was really only one pump and reservoir choice that would work for me. It's the Alphacool Eisstation 40 DC-LT reservoir paired with its DC-LT 2600 ceramic pump. The super-compact form factor and perfect sizing, paired with Alphacool's XT45 radiator, really allowed the system to be small.

The fittings are made by Bitspower, and I mainly used them for aesthetic reasons. I liked the way they look, especially with the black finish, and the green O-ring makes a call back to the original Xbox design scheme. The waterblock I used wasn't my first choice. I went through multiple different versions, partially because I went through several motherboard ideas and various ways to try to make the build work as efficiently as possible.

> I might take the leap one day and transition the build to hard tubing

I eventually landed on the ASRock Phantom Gaming X570 ITX/TB3 motherboard because of its feature set. Not only does it enable you to install a Ryzen APU with (what was at the time) the world's best iGPU, the Ryzen 7 4700G, but it also gives you a Thunderbolt port at the rear, with which you can use an external GPU. I end up using it paired with a Radeon RX 5700 XT a lot of the time at LAN parties, which is housed inside a Razer Core V2 external GPU box.

Once I'd decided to use that motherboard, I found out there was a company that made a monoblock for it, and it was the same company from which I'd already bought my fittings. It really almost did feel like fate, as if this hardware was made specifically for my case – I just had to buy it.

CPC: Where is the PSU, and what model is it?

Aaron: The power supply you can see just to the right of the motherboard is an HDPLEX 400W DC-ATX unit. It uses a laptop charging brick for input power, and then outputs all of the standard 24-pin, 8-pin EPS and SATA power cables you typically find in a computer.

What's great about this PSU is that it's also fully modular – I don't have SATA or a discrete internal GPU, so I was able to only run two

cables inside the system. The build uses a 1in ATX 24-pin connector that was built by a friend of mine, Heath from Tek by Design, and the 8-pin EPS connector was built by Michael over at MB Custom Sleeving. They're good people and I wanted to include some work from both of them in my build.

CPC: What's the stand underneath the machine with the four USB 3 ports, and does it interface with the PC?

Aaron: It's actually a vertical stand designed to convert the One S to a standing position, from Best Buy's Insignia brand. It cost a total of $20 US. As for how it interfaces with the computer, that's a massive rabbit hole I went down to try to get it to work. Since it's designed for a One S, there are no drivers for it for a computer, of course.

I went deep into trying to find a driver that would work for it – I checked the Hardware ID info and tried repeatedly to get it to function, but it sadly wasn't meant to be. I ended up snipping off the end of the USB cable, and it's now just used to help keep the console upright, and allow more airflow into the base for the radiator.

CPC: What spec did you choose and why?

Aaron: It really came down to wanting a tiny powerhouse for LAN parties. I frequent PDXLAN here in the Portland, Oregon area, and wanted a PC I could easily carry to a few events each year. As such, the main choice I made was to go with the fastest APU available at the time.

It also has 16GB of 4800MHz memory. I tried out multiple different kits for this build, at varying speeds from 3200MHz all the way up to 4800MHz, and the faster memory did make a difference to frame rates when using the iGPU, so I kept the higher-speed kit.

CPC: Is there any way you could have squeezed a half-height graphics card in there, or is it just too tight?

Aaron: I actually get asked that a lot, but no, sadly there's just no room. There is around a 1x 1in rectangular shape below the motherboard but above the radiator where I could fit something, but that space isn't large enough to accommodate any kind of graphics card. The motherboard heatsink, I/O cover and the radiator/fans leave no room between themselves and what was originally the bottom of the One S console.

SYSTEM SPECS

CPU AMD Ryzen 7 4700G

GPU External XFX Radeon RX 5700 XT

Storage WD SN750 1TB SSD

Memory 16GB G.Skill Trident Z RGB 4800MHz

Motherboard ASRock Phantom Gaming X570 ITX/TB3

PSU HDPLEX 400W DC-ATX with Dell 330W laptop power brick

Cooling Bitspower ASRock X570 ITX/TB3 monoblock, Bitspower G1/4in to 3/8in 90-degree rotary barb fitting, Bitspower G1/4in 15mm extender fitting 15mm, Bitspower G1/4in-to-3/8in barb fitting, 3m of EKWB EK-DuraClear 10/13mm clear soft tubing, Alphacool DC-LT 2600 ceramic 12V pump, Alphacool Eisstation 40 DC-LT reservoir, Alphacool NexXxoS XT45 Full Copper 50mm dual radiator, GELID Solutions Silent5 FN-SX05-40 50mm fans

CPC: What's the performance like from the iGPU?

Aaron: It actually works out really well for me. Around 90 per cent of my gaming time is typically spent playing either StarCraft or StarCraft II, so I can almost max out the settings and still have great frame rates. As far as modern gaming, I wouldn't rely on it too hard.

When I use the Radeon RX 5700 XT eGPU, I set any games settings that rely on CPU performance to low or medium, and if I'm relying on the iGPU, all the settings are set to low. I've so far tested out StarCraft and StarCraft II, Diablo 3, BattleTech, Mechwarrior 5, Horizon Zero Dawn, Forza 4 and 5, and a few other smaller titles.

If I don't have the CPU performance items set to low, eventually the system will succumb to heat soak, and temperatures will climb and climb until it just locks up. The 100mm radiator sadly doesn't have enough cooling headroom for the system to run at full tilt

CPC: Did you come across any difficulties?

Aaron: One huge problem was finding a waterblock that would fit in the small space between the CPU socket and the glass screen. I had tried a few variations of hardware, and multiple integrated pumps, but eventually, I ended up going with a plain block, and then integrating the pump and reservoir lower down, instead of trying to use a triple radiator.

Trying to find a Ryzen 7 4700G was also super-hard – at the time, AMD wasn't selling the chips at retail, as it ended up doing with the Ryzen 5000-series APUs. I ended up having to buy an entire HP prebuilt system to get the chip, and then sell the rest of the system for parts.

The last real hardship is that, whenever I have to do maintenance, the pump wiring is really delicate, and I can end up breaking the pump just by pulling the computer apart.

CPC: How long did it take you to complete this build?

Aaron: It took three years almost to the day to complete, my first post on **overclock.net** was on 19 July 2018, and I finished it in mid-June 2021. The main reasons for this were just budgetary concerns, waiting for a 3D printer, only having weekends due to work, and health issues. It was well worth the time though, and I'm proud of the work I've done on it so far.

CPC: Are you completely happy with the end result, or do you wish you'd done some of it differently in retrospect?

Aaron: Yes, and there are many improvements planned! I really want to get proper Start and Reset buttons wired up, and then figure out a way to for an Xbox One controller to turn on the PC, as you do with an Xbox. I've also thought about using a tempered glass screen, and redesigning the internal chassis around the pump to make sure it doesn't get damaged during future maintenance. There are a few other ideas I have in my head too, but I'm keeping those under wraps for now. 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

WORTH £151

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Corsair Hydro X Series XC7 RGB CPU Water Block

WORTH £70

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WORTH £55

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.

JAMES GORBOLD / HARDWARE ACCELERATED

A FLASH IN THE PAN

It doesn't matter if you've got a competitive GPU if nobody can actually buy it, argues James Gorbold

So here we are in the closing days of 2022 (as I write this), and after the multitude of product launches over the past few months, one brand has decided to squeeze another launch into the year. However, unlike the other launches, this one has been frustratingly marred by the stock problems that we'd hoped had been relegated to the past.

It feels a perhaps a little harsh to stick the knife into the new AMD Radeon 7900-series GPUs after the editorial team spent so much time and words covering the products in this issue. After all, the GPUs themselves are very competitive, providing similar performance to the Nvidia GeForce RTX 4000 series in rasterised games.

AMD still lags behind Nvidia when it comes to ray-tracing performance, which is of growing importance as more games support fancy ray-traced graphics. AMD also lacks any tech quite as ingenious as DLSS 3, but FSR 2 does seem to be gaining a lot of traction with game developers, and should prove to be a useful tool to extend the life of graphics cards as more graphically demanding games are released.

> Barely a trickle of cards made it into UK stores at the time of the launch

However, the competitive performance and pricing are all moot if you can't actually buy a Radeon 7900-series graphics card. Unfortunately, that's exactly the situation – again – with barely a trickle of cards making it into UK stores at the time of the launch. What's worse, once again, there are no detailed stock forecasts for retailers, meaning nobody sensible will want to take the risk of taking pre-orders either.

I say 'again' because AMD made the same mistakes with the Radeon 6000 series when they launched in December 2020. Two years on, AMD doesn't appear to have learned a lesson, and I can confidently predict that the result will be the same – a tiny flash in the pan of day one sales that does nothing for AMD's market share or brand awareness.

It's unlikely to have a significant impact on the Nvidia juggernaut, even after the self-imposed hiccup around the RTX 4080 launch. Some people might point to Nvidia already dropping the price of the RTX 4080, but this is more to do with weak sales than losing market share to AMD.

What's particularly disappointing about this pathetic situation is that AMD is more than capable of executing solid product launches. The company's other two most recent launches, Ryzen 7000-series desktop CPUs and EPYC 9004-series server CPUs, were both well-managed affairs with great marketing, good availability and detailed stock forecasts.

Yes, AMD may have shot itself in the foot slightly with some technical decisions around the Ryzen 7000 series, which means the platform costs too much, but overall, it was a good launch. Intel also learned how to launch products properly in 2022 by making sure there were good numbers of 13th-gen CPUs available.

I can only speculate why AMD felt it necessary to proceed with such a meaningless GPU launch in December 2022. Perhaps a sense of vanity, as it can pat itself on the back and say it launched before the end of the year. Alternatively, perhaps it just felt the need to report something positive to shareholders after a dismal year.

Either way, despite the Radeon 7900-series GPUs themselves having quite a few merits, the launch, if one can even call it that, is a damp squib. It would have had a much better chance of disrupting the market if it occurred in early 2023 with good availability. 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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