

AFFORDABLE GAMING MICE 10 SUB-£40 RODENTS REVIEWED



# CUSTOM PC

THE BEST-SELLING MAG FOR PC HARDWARE, OVERCLOCKING, GAMING & MODDING / ISSUE 232

## INTEL RAPTOR LAKE

24-CORE CPUs, 5.8GHz CLOCK SPEEDS AND A NEW CHIPSET, BUT CAN IT TAKE ON AMD'S ZEN 4?

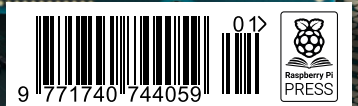
- CPU REVIEWS
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# Welcome

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Custom PC Issue 232

/ FROM THE EDITOR

## Affordable upgrades

**T**his autumn's new hardware bonanza is now well underway, and it's an exciting time to be a PC enthusiast, as long as you have a well-endowed bank account. If you want to play Cyberpunk 2077 at 4K with full ray tracing, you can hand two and a half grand to a scalper on eBay for a GeForce RTX 4090 (see p28). Want a new super-fast CPU? How about a new fully featured X670E motherboard for £600, some new DDR5 memory and an £800 16-core Ryzen 9 7950X?

I don't want to take credit away from Nvidia or AMD here – Zen 4 and Ada Lovelace are stunning technical architectural achievements, but the total platform cost for AM5, and the high price and scarcity of the GeForce RTX 4090, makes for a depressing situation in a cost of living crisis. Even the cheapest B550-based AM5 boards cost at least £210 at Scan.

With that in mind, I wanted to inject a bit of optimism into proceedings, largely thanks to Intel's Raptor Lake launch (see p14). Zen 4 generally still has the edge when it comes to raw performance, but in terms of platform cost for upgraders, Intel has won this round hands down.

There's no need to splash out on a brand-new motherboard or DDR5 memory. If you don't have an LGA1700 board already, you could get a £150 B660 board, flash the BIOS and drop in one of the new CPUs, while reusing your old DDR4 memory. You might not be able to overclock your CPU, but you'd still get an awesome-performing system for a really good price.

Meanwhile, in the graphics world, shelves are full of unsold last-gen GPUs, now out of favour with crypto miners, and going for surprisingly reasonable prices. The store at [nvidia.com](https://www.nvidia.com) has the GeForce RTX 3060 Ti, a fantastic GPU that can genuinely handle ray tracing with decent settings, going for its original price of £369 inc VAT. If you want to step up to 2,560 x 1,440 with ray tracing, the GeForce RTX 3070 Ti is in stock for £569 inc VAT.

There's no longer a severe shortage of GPUs across the board, and there are ways to make your money go further if you have the right knowledge. Despite the worrying prices of some new kit, now is actually a good time to upgrade your system. **PCB**



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### ISSUE 232



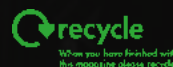
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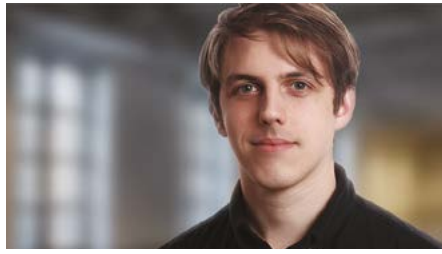
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**RICHARD SWINBURNE** / VIEW FROM TAIWAN

# TEMPTED BY AMD'S RYZEN 7000 CHIPS?

Wait a little longer, advises Richard Swinburne, as the upgrade path has many new considerations

**A**MD's Ryzen 7000-series CPUs have just hit the shelves, but unless you're a hardcore AMD fan and early adopter, you'll want to keep a hold on that itchy buying finger for a little while longer. Without exception – and I say this as someone who used to review motherboards and work for a company that makes them – on every previous AMD platform launch, back to the mid-2000s, there have always been BIOS issues that need a couple of months to iron out. With a new socket and new memory to support, this isn't likely to change this time either.

On the whole, performance of Zen 4-powered CPUs looks great, but the first wave of X670/X670E motherboard prices start at over £300, with many sitting on the wrong side of £500. This is a major price increase versus last-gen boards. And let's not forget, for that weight of purchase, the big four motherboard makers still only offer, at most, a three-year warranty. To top that off, even with this year's price correction, a fast DDR5 kit will still cost you at least twice as much as the DDR4 equivalent.

That said, if the entry-level X670 (non-E) boards turn out to be reliable, they should have enough features to satisfy most people's builds. X670 offers a PCI-E 5 M.2 slot ready for a new generation of SSDs, and the latest Nvidia GeForce RTX 4000-series GPUs still use PCI-E 4, so you don't need a 16x PCI-E 5 slot yet. There are also some advantages to running these new CPUs at lower than maximum TDP, so the VRM capability should be less of a concern as well.

The only serious shortcoming is the basic Realtek audio chips, but that's been a trend on all platforms for a few years

now. Ironically, we've now come full circle with on-board audio, with entry-level codecs now commonplace on £300+ boards again. I'd argue that it's now time to consider using a dedicated PCI-E audio card, USB audio dongle or even a desktop soundbar that will last through several upgrades.

Meanwhile, the new AMD B650 chipset was due in 2023 but has been brought forward to this year, with board prices that could possibly even dip to £150. This time you should think of the B650 chipset as analogous to X570, because the boards offer a similar level of PCI-E 4 slots and SSD M.2 options – a key advantage over B550, which was stuck with PCI-E 3.

But that's a double-edged view – if you're upgrading to unlock more gaming performance, the Ryzen 7 5800X3D keeps up with Ryzen 7000-series chips, and if an X570 motherboard provides a similar experience and price to B650, as well as support for cheaper DDR4 memory, why go with AMD's new platform?

What's more, we also have Intel's 13th-gen CPUs now (see p14), which you can pair with a last-gen Z690 motherboard, rather than a new and expensive Z790 board, and you don't necessarily have to buy expensive DDR5 memory for them either. Upgrading to Raptor Lake looks like a much more tempting upgrade prospect in these times.

The 13th-gen CPUs are built using the Intel 7 process, which isn't as power-efficient as the TSMC 5/6nm process used to make the new Ryzens, but there are clearly a lot of factors at play here. Whether you're building a whole new PC, or upgrading your existing one, you're not just looking at the performance and price of CPUs, but also the cost of the whole platform. **GPC**

This time you should think of the B650 chipset as analogous to X570

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

# IS META ON ITS LAST LEGS?

Tracy King takes a highly sceptical look at recent claims about the future of the metaverse, including the use of VR in clinical settings

**M**y favourite meta joke is ‘what does the “B” stand for in Benoit B Mandelbrot? Benoit B Mandelbrot’. My least favourite is Mark Zuckerberg’s ongoing folly, the metaverse, about which I have written before. In January 2022 I said, ‘Zuckerberg’s vision of the metaverse relies on a successful marriage of physical tech with digital culture, and that won’t happen if the physical tech is a virtual reality headset’, and nothing I’ve seen since has changed my mind.

Still, the Zuck keeps trying, despite his net worth dropping 70 per cent (according to a Bloomberg report) and Meta’s stock dropping 57 per cent. None of this is helped by headlines that are meant to bolster support for the metaverse but instead attract criticism or even derision.

For example, the company recently announced ... legs. During a Connect broadcast, Meta revealed that avatars would soon sport a lovely pair of lower limbs. Embarrassingly, it turns out the legs in the video were actually animated using motion capture rather than tracking in VR, rendering the whole announcement inauthentic at best.

VR seems to prompt all sorts of silly or exaggerated claims. I noticed that on 22 September, Meta put out a tweet containing a fancy video, which claimed ‘in the future medical students will be able to use virtual reality to practise hundreds of times, before operating on patients in real hospitals. The metaverse may be virtual but the impact will be real’.

I’ve done a lot of work in the healthcare sphere, and let me tell you, this is already happening. I advised on a VR surgery simulator (a real one, not the excellent but definitely not medically approved game Surgeon Simulator) a decade

ago. There are companies that provide VR (and AR) medical training systems already, and the Royal College of Surgery-approved surgery training platform, Fundamental Surgery, has been around since 2018.

Here, I think Meta is trying to slap a brand onto existing practices – it’s a bit like saying ‘in the future surgeons will be able to train wearing a hat with our logo on it’. That would be fine (if meaningless) unless a significant percentage of surgeons were unable to wear a hat. VR motion sickness isn’t quite as bad as it was in the early days, but it’s still an issue for a great many people, without a clear understanding of exactly why.

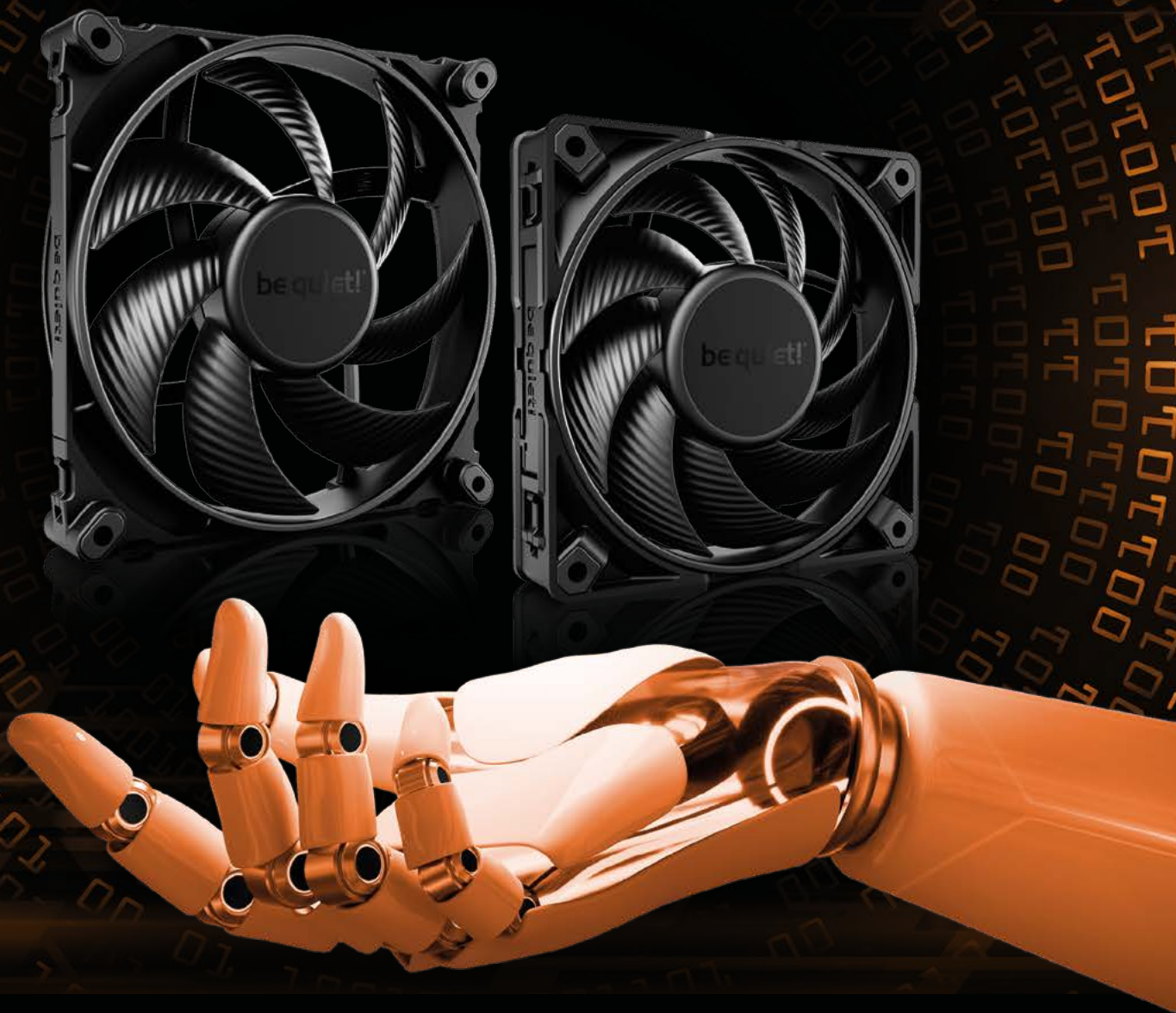
That’s why I was alarmed to see a metaverse-adjacent story about the use of virtual reality in a clinical setting on patients, presented by multiple media outlets. The study claims that patients using VR during hand surgery needed less anaesthetic. Gee, I wonder who funded the study. Ah yes, a VR healthcare company, which is perhaps why the results of the study (on a mere 34 patients) are being reported as a benefit of VR rather than one of the many other factors that could explain it, such as placebo effect.

The patients were fully aware of the conditions of the study, which can cause all sorts of biases, both positive and negative. If the effect is real, and replicable, it’s also possible it could be induced without the VR at all, for example with music or a screen of nice images. However, no VR company is going to fund a study disproving its own technology. It’s left to others to spend time and money pointing out the issues. Like Zuckerberg and his fake virtual legs, I for one am not going to stand for it. **GPD**

I wonder who funded the study. Ah yes, a VR healthcare company

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





# LEAP IN INNOVATION

## SILENT WINGS 4

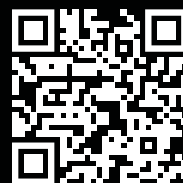
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# Incoming

When's the next issue out?

**CUSTOMPC**

Issue 233

on sale Thursday, 1 December



## Letters

Tell us what you think of the mag, ask us questions and suggest your own tips and tricks for other readers! Send all your correspondence to [custompc@raspberrypi.com](mailto:custompc@raspberrypi.com)

## INTEL ARC GPUs FINALLY LAUNCH

Intel has finally launched its Arc A750 and A770 gaming graphics cards, giving the GPU market a third competitor. However, stock appears to be scarce and only one UK retailer ([ebuyer.com](http://ebuyer.com)) is stocking them at the time of going to press.

The Arc A750 is currently going for £330 inc VAT, and comes with 8GB of GDDR6 memory and a 2050MHz boost clock, while the A770 has 16GB of GDDR6 memory and a 2100MHz boost clock.

The cards support real-time ray tracing and Intel's Xe Super Sampling technology, which the company says will soon be supported by over 20 titles. Some board partners have also announced

cards based on the new GPUs, including ASRock and Acer, marking the latter's first entry into the gaming card space.

We haven't been able to get a sample of either GPU to test yet, but we'll run them through their paces as soon as one lands in the labs.



## THERMALTAKE ATX 3 PSUs FOR SALE

Thermaltake is one of the first PSU manufacturers to get ATX 3 power supplies available in the UK, with Scan, Overclockers UK and Ebuyer all now listing the company's new Toughpower GF3 units, although only for pre-order at the moment. Designed for heavy loads, the new PSUs all feature 80 Plus Gold certification and are available with whopping power ratings of up to 1650W.

The PSUs have native support for the new 12VHPWR 12-pin+4-pin power cable, which is used on Nvidia's latest GeForce RTX 4090, plus compatibility with the ATX 3 spec. They're not cheap, though, with the 1650W version costing £400 inc VAT, and the 1200W unit coming in at £260 inc VAT from [overclockers.co.uk](http://overclockers.co.uk). You can read our full feature on ATX 3 on p78.

## CORSAIR SYNCs UP WITH NANOLEAF

Corsair has teamed up with smart lighting firm Nanoleaf to enable its wall-mounted light-up shapes to synchronise with your PC's lighting, via iCUE.

According to Corsair, in addition to giving you the ability to synchronise lighting effects on Nanoleaf devices, iCUE will also be able to 'display system temperature indicators on them, putting your room on red alert when your PC is running hot, to a calm green when systems are stable'.

Nanoleaf Light Panel support will be coming to iCUE later in 2022.

## NVIDIA 'UNLAUNCHES' 12GB GEFORCE RTX 4080

Nvidia has quickly backtracked on its plan to release two GPUs under the GeForce RTX 4080, by rebranding the 12GB version. 'The RTX 4080 12GB is a fantastic graphics card, but it's not named right. Having two GPUs with the 4080 designation is confusing,' admitted the company on its website, saying it was now 'pressing the "unlaunch" button'.

Two versions of the RTX 4080 were originally announced – a 16GB version for £1,269 and a 12GB model for £949 inc VAT. However, as the prices suggest, the differences went much further than the memory, with the 12GB RTX 4080 only having a 192-bit wide memory interface, compared to the 256-bit wide interface on the 16GB card. The cheaper card also only had 7,680 CUDA cores,

compared to 9,728 on the pricier model. We assume we can now expect the 12GB RTX 4080 to be called the RTX 4070 or 4070 Ti.

We hope to test the RTX 4080 in our next issue, but meanwhile you can check out our full review of the GeForce RTX 4090 on p28.





# Wireframe

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# Reviews

## LGA1700 CPU

# INTEL CORE i9-13900K / £700 inc VAT

SUPPLIER [scan.co.uk](https://scan.co.uk)

**W**e're not sure we can remember a period of CPU launches landing quite so close together, intermixed with graphics cards

too, but as Intel's Raptor Lake CPUs have finally landed, this is the real comparison everyone wants to see. The Core i9-13900K is retailing for a lot more than we initially expected, with a price of £700 inc VAT at [scan.co.uk](https://scan.co.uk), but that's still around £100 less than AMD's flagship Ryzen 9 7950X.

The two CPUs couldn't be more different though. AMD hasn't increased core counts and is instead relying on high frequencies, a new architecture

and boosted cache amounts in order to compete with Intel's 13th-gen CPUs. The Core i9-13900K, though, has had a top to bottom refresh compared with its predecessor. The most significant change is the addition of eight extra E-Cores, giving you 16 in total, alongside the same eight powerful P-Cores with which the Core i9-12900K was equipped.

That gives you 24 cores in total, meaning the Core i9-13900K has the highest core count on an Intel desktop CPU ever, on both mainstream and HEDT platforms. It can execute 32 concurrent threads, rather than 48, as its 16 E-Cores lack Hyper-Threading, so only contribute one thread each. It's a far cry from the small incremental updates that we've come to expect from Intel from the last few launches.

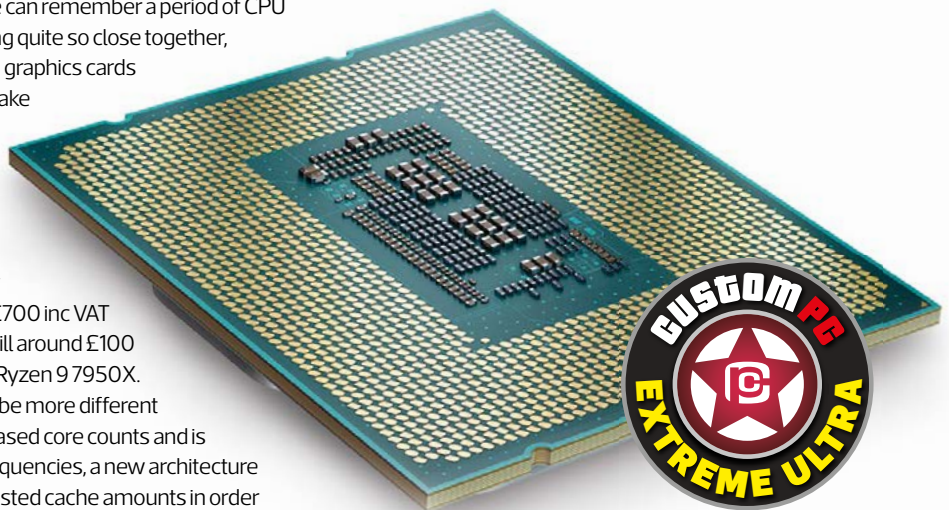
Under the hood, the amount of L2 cache has also increased to 2MB per P-Core and 4MB per cluster of four E-Cores. That move, along with the increased core count, results in a huge increase in the total amount of L2 cache, going from 14MB in the

Core i9-12900K to 32MB in the Core i9-13900K. Meanwhile, the L3 cache has increased from 30MB to 36MB as well. According to Intel, this new cache setup alone results in a 16 per cent performance boost over the Core i9-12900K in some applications.

The base power remains the same as that of the Core i9-12900K at 125W, but that's far lower than what you'll typically see, with the maximum rated turbo power increasing from 241W to 253W and we'd say that's still quite conservative. Meanwhile, its internal fabric runs 900MHz faster than on its predecessor and its 10nm Raptor Cove P-Cores, built on the Intel 7 manufacturing process, see a 600MHz boost over their predecessor in terms of peak boost frequencies.

There have been improvements to the software ecosystem too, including some updates to Thread Director – Intel's link between those E-Cores and P-Cores and software. Intel claims software developers are now more in tune with tapping into the hybrid core architecture, and Windows 11 has received performance-boosting updates too.

While Intel has a Core i9-13900KS waiting in the wings that will hit 6GHz, the Core i9-13900K is no slouch, with its peak boost frequency topping out at a massive 5.8GHz,



## SPEC

### Base frequency

P-Core 3.5GHz, E-Core 2.6GHz

### Max boost frequency

P-Core 5.8GHz, E-Core 4.3GHz

### Core

Raptor Lake

### Manufacturing process

10nm (Intel 7)

### Number of cores

8 P-Cores, 16 E-Cores, (32 threads)

### Hyper-Threading

Yes

### Cache

36MB L3, 32MB L2

### Memory controller

Dual-channel DDR4 and DDR5

### Packaging

LGA1700

### Maximum turbo power

253W

### Features

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



which we saw it hit occasionally in benchmarks too. The highest all-core frequency we saw during benchmarking was 5.5GHz, although this can quickly wind down depending on temperatures and the way the motherboard is configured. However, that's still 300MHz higher than the absolute highest frequency you'd see from a Core i9-12900K, and that CPU's peak boost frequency was a massive 600MHz lower than the 5.8GHz peak boost of the Core i9-13900K.

## Performance

We were a little disappointed to see that the Core i9-13900K wasn't able to match the AMD Ryzen 7000-series CPUs in our image editing test, which stresses single-threaded performance, as Intel had made big gains here with Alder Lake. Its score of 87,278 is still great, being well in front of the 80,155 score from the Core i9-12900K, but this result was bettered by the 93,724 scored by the Ryzen 9 7950X.

The Intel CPU clawed back ground in our heavily multi-threaded Handbrake video encoding test, though, with a score of 1,409,689, which just beat the Ryzen 9 7950X's score of 1,397,365, while massively outstripping the Core i9-12900K's score of 1,061,918. AMD took the crown in the multi-tasking test by a slightly wider margin, with the Core i9-13900K in second place, all of which handed the Ryzen 9 7950X a narrow win in the overall RealBench system score, with the Core i9-13900K adding nearly 100,000 points to the Core i9-12900K.

Cinebench was Intel's domain this time, however, with the Core i9-13900K claiming the top spot and the Core i5-13600K not doing badly either, while the 13th-gen flagship also claimed the crown in the single-threaded Cinebench test with a score of 2,246 compared to 2,050 for the Ryzen 9 7950X.



It was also able to beat the Ryzen 7 5800X3D in Far Cry 6, being noticeably quicker than the Ryzen 9 7950X when using our GeForce RTX 3070 test GPU. The overall situation was much tighter in Watch Dogs: Legion, with the top ten CPUs delivering similar performance, but the Core i9-13900K ultimately came out in second place.

Power efficiency isn't the Core i9-13900K's strong point, though, with our system drawing 546W under load with all the P-Cores running at 5.5GHz and E-Cores at 4.3GHz. That's over 150W more than with the Ryzen 9 7950X. However, this result was hit with our Asus Z790 motherboard running at its default settings, which did seem to open the taps on power consumption.

Setting a limit of 1.4V and pushing the P-Cores up to 5.7GHz saw the peak power draw fall to 525W, with temperatures falling from the high to mid-80s in centigrade, so it's clear that more performance and certainly lower power consumption can be achieved with a little tweaking. This overclock didn't always result in better performance, though, as the stock peak boost frequency is a little higher. The Cinebench score rose from 40,444 to 41,015, but it was tit for tat elsewhere.

## Conclusion

Considering it costs around £100 less than the AMD Ryzen 9 7950X, the Core i9-13900K does well, bettering its rival in some tests, matching it in others and only losing in a select few instances. The Ryzen 7 5800X3D is still a thorn in its side for gaming, offering similar frame rates for far less cash, but it's destroyed everywhere else by this 24-core behemoth. Intel's LGA1700 socket may have a short lifespan now, but if you get a Core i9-13900K, you won't be needing an upgrade for a very long time.

ANTONY LEATHER

## VERDICT

Not quite a clean sweep over AMD's flagship, but it's still monstrously fast.

### F-22 RAPTOR

- + Blisteringly fast at multi-threaded work
- + Excellent lightly threaded performance
- + Cheaper than Ryzen 9 7950X

### CESSNA

- Ryzen 7 5800X3D matches it in games
- Very high power draw
- Limited overclocking

### PERFORMANCE

48/50

### FEATURES

14/15

### VALUE

26/35

### OVERALL SCORE

88%

## LGA1700 CPU

INTEL CORE  
i5-13600K / **£380** inc VAT

SUPPLIER scan.co.uk

**I**ntel is keeping up the Raptor Lake momentum at the cheaper end of the scale, as the new Core i5-13600K isn't just a boring incremental bump over the excellent Core i5-12600K, which retails for around £300 these days. As with the Core i9-13900K, the Core i5-13600K doesn't just have higher clock speeds than its predecessor but it has more cores too, even if they are only the lower-power E-Cores, rather than full-fat P-Cores.

Its price of £380 inc VAT might not be super-cheap, but it's competitive at today's prices, sitting between the price of AMD's Ryzen 5 7600X at £326 and the Ryzen 7 7700X at £430.

Out of the box, it will hit a peak frequency of 5.1GHz, giving it a 200MHz advantage over its predecessor, and our sample hit this boost clock across all of its P-Cores too in multi-threaded workloads. With the Core i9-13900K hitting 700MHz higher than this, there's an obvious question about overclocking potential too, which we'll come to later. Meanwhile, the Core i5-13600K's E-Cores went up to 3.9GHz and maintained this frequency in multi-threaded workloads too.

Comparatively, the venerable Core i5-12600K had six P-Cores and four E-Cores, so while it offered far more multi-threaded grunt than Intel's Core i5-11600K, for example, that lack of E-Cores compared with the higher echelons of Intel's product stack meant it lagged behind. Even so, it was one of the best all-rounders that Intel has produced and that's exactly a Core i5 CPU's purpose.



With the Core i5-13600K, Intel adds another four E-Cores to the equation, massively bolstering its multi-threaded clout. In fact, this means it's only two cores short of the Core i9-12900K's core count in total. Like its more expensive sibling, it's received a generous helping of extra cache from Intel as well. The L3 cache rises from 20MB to 24MB, while the L2 cache doubles from 9.5MB to 20MB. This should help to cut latency, along with offering other performance improvements, as the CPU won't need to reach out to system memory as frequently.

The CPU also has a lower maximum turbo power of 181W than the other 13th-gen chips, although this is 30W more than its predecessor so it's unlikely to run cooler or be more power-frugal. It has a lot to live up to, then, and the competition is extensive, with the Ryzen 5 5600X costing half the price, the Ryzen 7 5800X3D retailing for around £50 more and the Core i7-12700K sitting just £20 above this new Core i5 chip's price as well.

### Performance

As with the Core i9-13900K, the Core i5 13600K's result in our image editing test, which stresses single-threaded performance, was disappointing. It still beat the Core i7-12700K and Core i9-12900K in this test, and was significantly faster than the Core i5-12600K and all Ryzen

### SPEC

#### Base frequency

P-Core 3.5GHz, E-Core 2.6GHz

#### Max boost frequency

P-Core 5.1GHz, E-Core 3.9GHz

#### Core

Raptor Lake

#### Manufacturing process

10nm (Intel 7)

#### Number of cores

6 P-Cores, 8 E-Cores, (20 threads)

#### Hyper-Threading

Yes

#### Cache

24MB L3, 20MB L2

#### Memory controller

Dual-channel DDR4 and DDR5

#### Packaging

LGA1700

#### Maximum turbo power

181W

#### Features

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

### AIRCRAFT CARRIER

- + Excellent overclocking potential
- + Fantastic gaming and content creation performance for the cash
- + Reasonable temperatures

### RUBBER DINGHY

- Power-hungry, depending on motherboard power limits
- Ryzen 7 5800X3D can be cheaper for gaming
- Still quite expensive

5000-series CPUs too, but every Ryzen 7000-series CPU was noticeably better here.

Thankfully, that was a rare blip, as the Core i5-13600K managed to beat the Ryzen 7 7700X in our heavily multi-threaded video encoding test, nearly matching the performance of the 16-core Ryzen 9 5950X and stopping just short of the Core i9-12900K too.

The multi-tasking test was more of a challenge, but it still beat the Ryzen 9 5950X, Core i7-12700K and Ryzen 5 7600X in this test, which is about right for its price. The overall RealBench system score of 372,186 saw the Core i5-13600K beat the Ryzen 7 7700X and Core i7-12700K as well, which are two huge scalps, and it added nearly 90,000 points to the score of the Core i5-12600K.

Cinebench was another strong showing, with the Core i5-13600K's score of 24,268 beating that of the Core i7-12700K, Ryzen 7 7700X and Ryzen 9 5900X, with its new Raptor Lake architecture and additional E-Cores really shifting performance up a gear. It was no slouch in the single-threaded Cinebench test either, beating the Ryzen 7 7700X and narrowly missing the Ryzen 9 7950X's result, while adding over 100 points to the score of the Core i5-12600K.

In games, it performed well too with its 101fps 99th percentile frame rate in Far Cry 6 putting it in third place behind the Ryzen 7 5800X3D and Core i9-13900K, beating every Ryzen 7000-series CPU, as well as the Core i9-12900Ks. It was quick in Watch Dogs: Legion too – there are only small variations here, but the Core i5-13600K was still in the third slot overall.

However, power consumption was fairly high, with a total system draw of 331W, which was nearly 60W more than with the Ryzen 7 7700X and 80W more than the Core i7-12700K. Of course, overclocking only made this worse, but if you have a decent PSU, the Core i5-13600K can be a very willing participant, with our sample hitting 5.7GHz on all of its P-Cores with a vcore of 1.4V. This saw the



power consumption increase to 381W for the system, but temperatures only rose from the mid-70s to the mid-80s in degrees centigrade.

Performance was spectacular after overclocking, though, with the clocked-up Core i5-13600K claiming the third highest image editing score of any stock or overclocked CPU we've tested, adding more than 10,000 points to its score. The score in our video encoding test rose as well, although not as much as we hoped, but the system score of 390,305 was enough to beat the Ryzen 9 5950X and Ryzen 7 7700X.

The Cinebench score rose from 24,268 to 25,657 after overclocking as well, leapfrogging the stock speed Ryzen 9 5950X and Core i9-12900K, while also claiming one of the highest scores we've seen in Cinebench's single-threaded test and Watch Dogs: Legion. It also claimed the top spot in Far Cry 6 when overclocked.

### Conclusion

Finally, there's a CPU that can excite us about overclocking again. The Core i5-13600K isn't only fast once overclocked, but it's also a match for AMD and Intel's previous flagships in many tests at stock speed too. Critically, it's cheaper and faster than the Ryzen 7 7700X and Core i7-12700K in a lot of tests, and keeps up with the Ryzen 7 5800X3D in games, while smashing it in application tests.

This is a fantastic CPU, and the only fly in the ointment is the high power consumption on our Asus test motherboard – otherwise, the Core i5-13600K is absolutely brilliant.

ANTONY LEATHER

### VERDICT

Excellent stock speed performance, plenty of overclocking headroom and a reasonable price.



PERFORMANCE  
**45/50**

FEATURES  
**14/15**

VALUE  
**31/35**

OVERALL SCORE

**90%**



## SOCKET AM5 PROCESSOR

AMD RYZEN 5  
7600X / £326 inc VAT

SUPPLIER overclockers.co.uk

If there was one issue with the Ryzen 5 5600X it was its price compared with its predecessor. At launch, there was no sign of the Ryzen 5 5600 and 5500 either, and it looked as though AMD's high value 6-core predecessors were potentially gone forever, as the company levelled up to Intel and realised it could demand premium prices. Likewise, the new Ryzen 5 7600X isn't cheap, but at least it doesn't retail for significantly more

than its predecessor and is roughly the same price as the latter a year ago.

At £326 inc VAT, the current cheapest Ryzen 7000-series CPU costs around £60 less the Core i5-13600K, while it's also £40 more expensive than the 8-core Ryzen 7 5800X, which will remain on sale to bolster AMD's offerings at the lower end. However, the Ryzen 7 5800X3D costs around £100 more, and is a speed demon in games, so it will be interesting to see how it fares against the new flagship 6-core CPU. In this price arena, it's also worth keeping an eye on Intel's Core i7-12700K, which costs £70 more than the Ryzen 5 7600X.

The Zen 4 architecture under the hood has brought numerous benefits to AMD's new chips, including a smaller 5nm manufacturing process, increased socket power and other refinements that enable Ryzen 7000-series CPUs to hit higher frequencies than their predecessors. The Ryzen 5 5600X could reach a peak boost frequency of 4.6GHz, but that officially rises to 5.3GHz with the Ryzen 5 7600X and we even saw boost speeds of 5.5GHz in our testing. That's a massive increase in one generation and the all-core boost clock is higher too.



The latter sat at 4.4GHz with the older Zen 3 CPU, but the new kid on the block hits 5.25GHz across all cores in multi-threaded workloads. This should mean the new chip can offer sizeable gains across the board.

That's just as well because AMD hasn't increased core counts on any of its CPUs, putting it at odds with Intel, which has added more cores to all its latest Raptor Lake CPUs. The Core i5-13600K, for example, now has a total of 14 cores. AMD has also doubled the L2 cache from 3MB to 6MB compared with the Ryzen 5 5600X, although the new chips has the same 32MB L3 cache.

One other change is that we're now dealing with a CPU that has a thermal design power of 105W, rather than 65W, and the Ryzen 5 7600X doesn't have a cooler in the box either, unlike the Ryzen 5 5600X. You'll need a powerful cooler for it as well, as it didn't run much below 90°C in our tests, even with our custom water-cooling loop.

## Performance

In our RealBench image editing test, which stresses single-threaded performance, the Ryzen 5 7600K managed a score of 88,908, which was high enough

## SPEC

**Base frequency**  
4.7GHz

**Max boost frequency**  
5.3GHz

**Core**  
Zen 4

**Manufacturing process**  
5nm

**Number of cores**  
6 x physical (12 threads)

**IGP**  
AMD Radeon Graphics

**Simultaneous Multithreading**  
Yes

**Cache**  
32MB L3, 6MB L2

**Memory controller**  
Dual-channel DDR5, up to 5200MHz

**Packaging**  
AMD Socket AM5

**Thermal design power (TDP)**  
105W

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

## SIX FEET TALL

- + Excellent lightly threaded performance
- + Fast out of the box
- + More power-efficient than the competition

## SIX FEET UNDER

- Core i5-13600K is quicker in a lot of tests
- Struggles in multi-threaded workloads
- Limited overclocking headroom



for it to claim third place, ahead of Intel's Core i9-13900K, which is a great result.

However, its multi-threaded performance wasn't quite as potent as we hoped, with the Ryzen 5 5600X failing to better the Core i5-12600K in our heavily multi-threaded video encoding test, even if it did beat the Ryzen 7 5800X here, which has two more cores at its disposal. It did reasonably well in our multi-tasking test, but overall, it only just beat the Core i5-12600K and Ryzen 7 5800X in the system score, trailing the Core i7-12700K and Core i5-13600K.

Cinebench also saw the Ryzen 5 7600X struggle, failing to beat the Ryzen 7 5800X and falling a huge amount short of the Core i5-13600K's performance, which managed 24,268 points in the multi-threaded test, compared to just 15,309 for the Ryzen CPU. It was reasonably quick in the single-threaded test, though, bettering all Ryzen 5000-series CPUs, as well as the Core i7-12700K.

Likewise, Far Cry 6 saw the Ryzen 5 7600X better the performance of all the standard Ryzen 5000-series CPUs, as well as Intel's Core i9-12900K, with a 99th percentile frame rate of 100fps, although it was still a way off AMD's Ryzen 7 5800X3D here. In Watch Dogs: Legion, it was again not far from the top of the chart either, with only Intel's 13th-gen CPUs and the Ryzen 7 7700X able to better it.

Power consumption, meanwhile, was nearly 70W higher under load than with the Ryzen 5 5600X, but also significantly lower than our test system with the Core i5-13600K installed, and around the same as a Ryzen 7 5800X system, which it outperformed in many tests.



Overclocking wasn't particularly fruitful, though, with the Ryzen 5 7600X hitting an all-core frequency of 5.4GHz with a vcore of 1.2V, adding 150MHz to the stock all-core boost, but trailing the peak single-core boost by 100MHz.

Unfortunately, by comparison, the Core i5-13600K overclocked like a trooper and was able to overhaul the Ryzen 5 7600X in the image editing test and extend its lead in the system score, as well as in Cinebench's multi-threaded and single-threaded tests. Also, the fact that overclocking the Ryzen 5 5600X means it loses some peak lightly threaded boost frequency compared with stock speed, means it was slower in some tests after overclocking too.

## Conclusion

The Ryzen 5 7600X is a solid performer, especially in games and lightly threaded applications, where it often beats the Ryzen 7 5800X and Core i7-12700K. Unlike the Core i5-13600K, this is definitely a CPU that's best left at stock speed, perhaps with some power tuning to cut peak thermals and power consumption using AMD's Curve Optimiser or a manual undervolt. It's well priced for this reason, at least until Intel releases cheaper 13th-gen CPUs.

Its main weakness is multi-threaded workloads, where Intel's extra cores give its Core i5-13600K an advantage, even though AMD has made big strides compared with the Ryzen 5 5600X. Intel also has the benefit of compatibility with cheaper DDR4 memory and slightly cheaper motherboards. If you're building a whole new system, though, as an out-of-the-box CPU for gaming and light content creation, the Ryzen 5 7600X is still a solid CPU for the money.

ANTONY LEATHER



## VERDICT

Excellent lightly threaded and gaming performance for the cash, but it struggles in multi-threaded scenarios.

PERFORMANCE  
**43/50**

FEATURES  
**14/15**

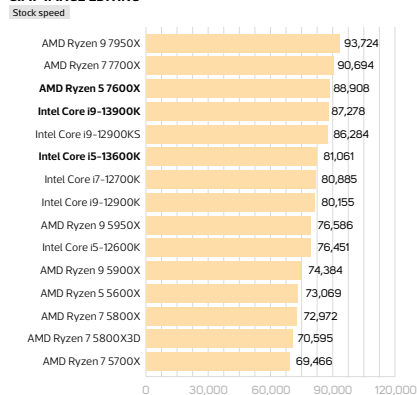
VALUE  
**28/35**

OVERALL SCORE

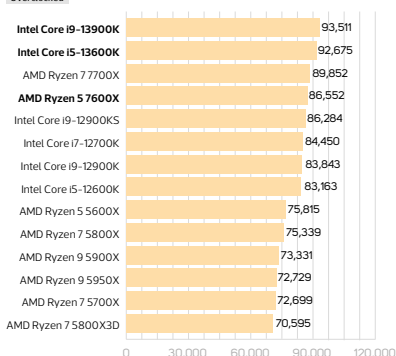
**85%**

## INTEL AND AMD CPU RESULTS

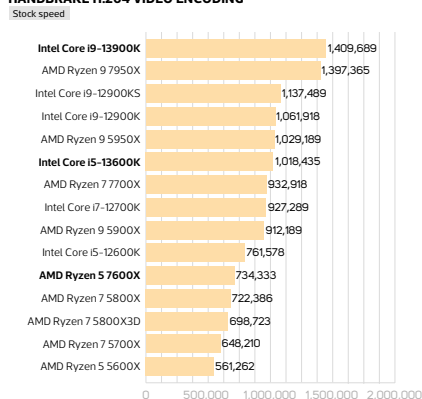
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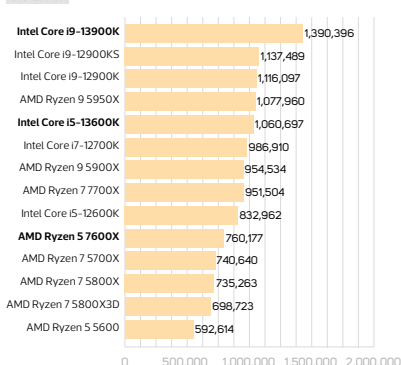
#### Overclocked



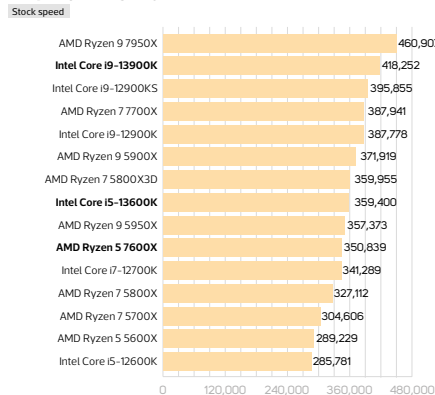
### HANDBRAKE H.264 VIDEO ENCODING



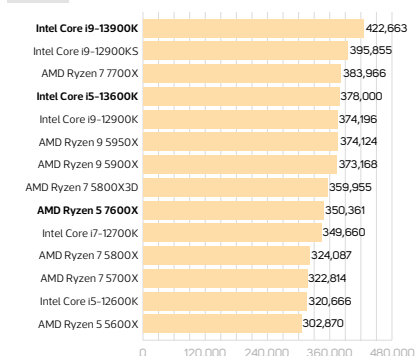
#### Overclocked



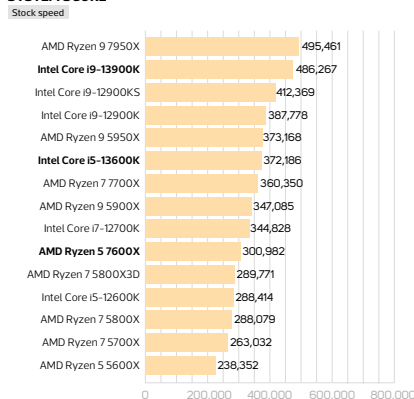
### HEAVY MULTI-TASKING



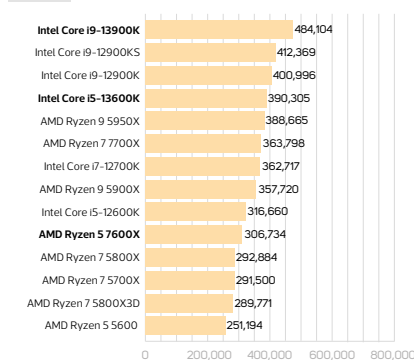
#### Overclocked



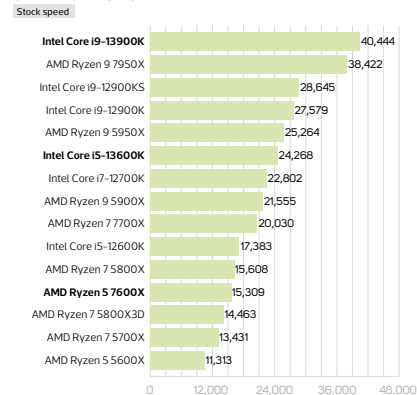
### SYSTEM SCORE



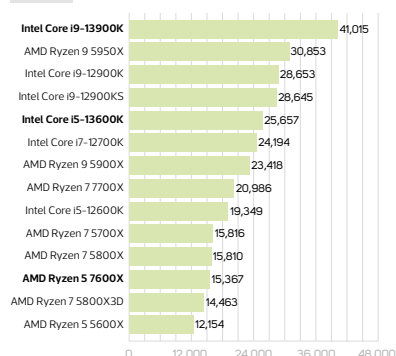
#### Overclocked



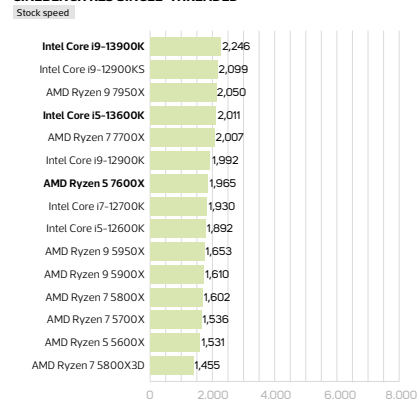
### CINEBENCH R23 MULTI-THREADED



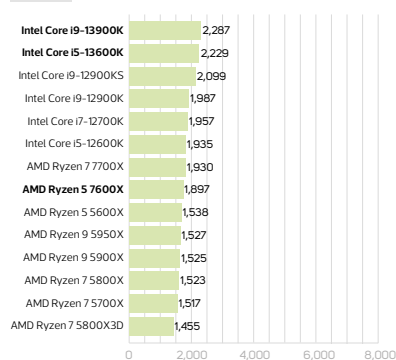
#### Overclocked



### CINEBENCH R23 SINGLE-THREADED



#### Overclocked

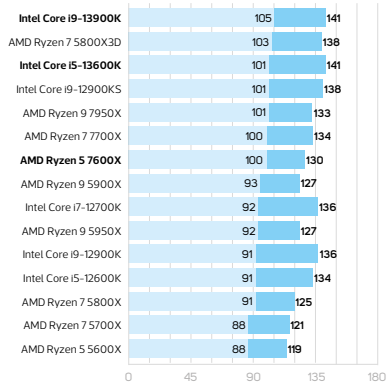




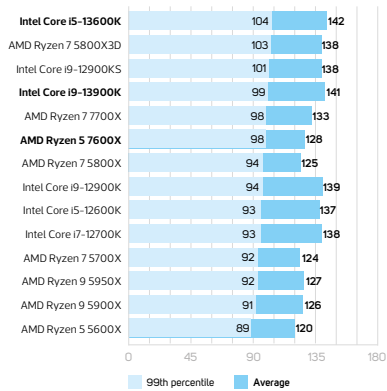
## INTEL AND AMD CPU RESULTS

### FAR CRY 6 (FPS)

Stock speed, 1920 x 1080, Ultra settings

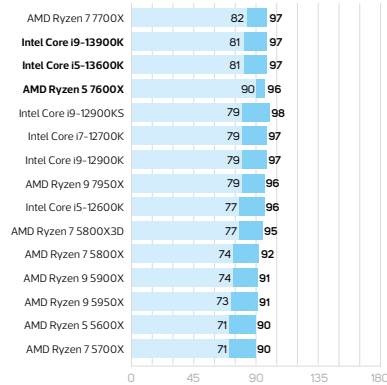


Overclocked, 1920 x 1080, Ultra settings

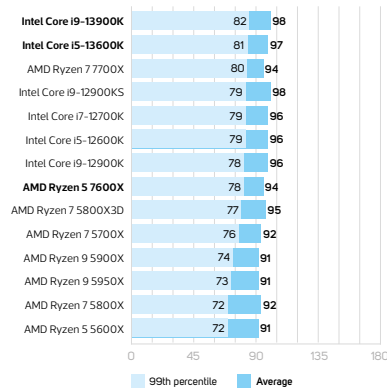


### WATCH DOGS: LEGION (FPS)

Stock speed, 1920 x 1080, Ultra settings

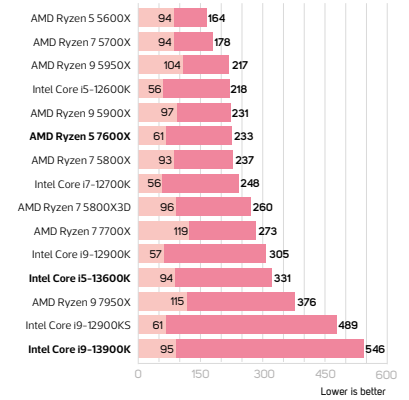


Overclocked, 1920 x 1080, Ultra settings

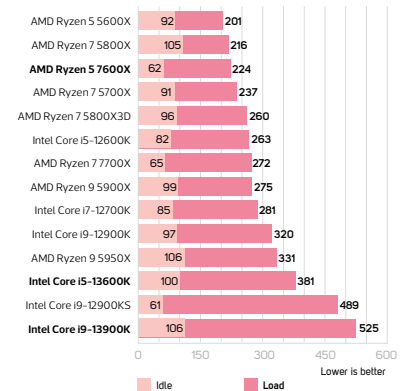


### TOTAL SYSTEM POWER CONSUMPTION (WATTS)

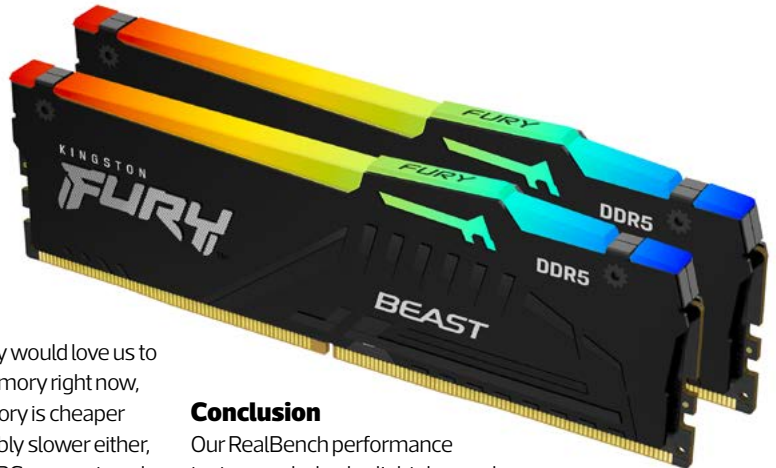
Stock speed, Windows desktop / Prime95 smallFFT



Overclocked, Windows desktop / Prime95 smallFFT



# WHICH RAM TO USE WITH RAPTOR LAKE



**W**hile several firms in the PC industry would love us to all be upgrading to new DDR5 memory right now, the simple fact is that DDR4 memory is cheaper and, from our experience so far, isn't noticeably slower either, at least not in games and most typical tasks PC enthusiasts.

That's not particularly helpful if you're building an AM5 system, where DDR5 is your only option, but Raptor Lake continues what Intel started with Alder Lake, with support for both memory standards. This gives Intel an advantage when it comes to platform cost, and there are plenty of DDR4 LGA1700 motherboards available, including models based on the new Z790 chipset.

Whether you want to transplant your existing DDR4 memory, or splash out on a new DDR5 kit, even just so you can get the Z790 chipset motherboard of your dreams, we've put together the data below to help you make that choice. We've used two popular speeds of DDR5 memory, as well as a 3600MHz kit of DDR4 memory, to see what you can from using faster memory in a Raptor Lake system, and to see if DDR5 is really worth the extra cost.

## Conclusion

Our RealBench performance tests revealed only slight drops when moving from high-speed to low-speed DDR5 or, on occasions, from DDR5 to DDR4. In fact, in some situations the DDR4 kit was a little faster than DDR5, but overall, the results are within the margin of error.

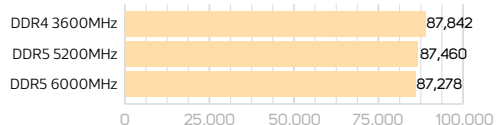
Cinebench's multi-threaded test presents a clearer case for DDR5 memory, as the DDR4 kit was slowest here, although there wasn't much difference between the two DDR5 kits. However, the slower DDR5 kit was still behind the DDR4 kit in the single-threaded Cinebench test. The differences in gaming performance were also minimal.

In short, it really doesn't seem to matter which speed of memory you choose for a new Raptor Lake system, or whether you opt for DDR4 over DDR5 if you want to save yourself some cash. With Raptor Lake, at least, you should go for whatever best suits your budget and your system.

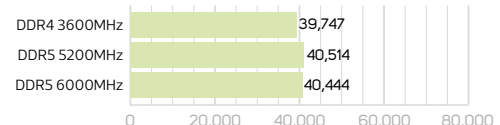
ANTONY LEATHER

## BENCHMARK RESULTS

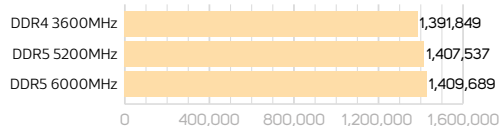
### GIMP IMAGE EDITING



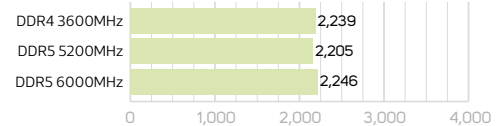
### CINEBENCH R20 MULTI-THREADED



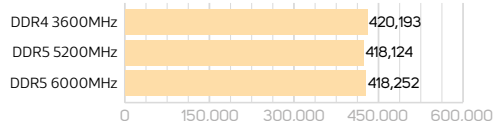
### HANDBRAKE H.264 VIDEO ENCODING



### CINEBENCH R20 SINGLE-THREADED

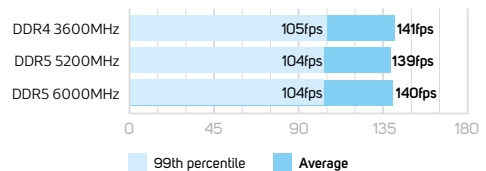


### HEAVY MULTI-TASKING

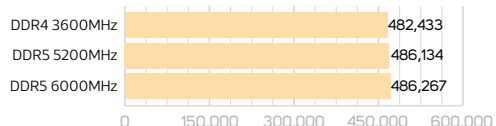


### FAR CRY NEW DAWN

1,920 x 1,080, Ultra settings



### SYSTEM SCORE



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# OVERCLOCKING RAPTOR LAKE

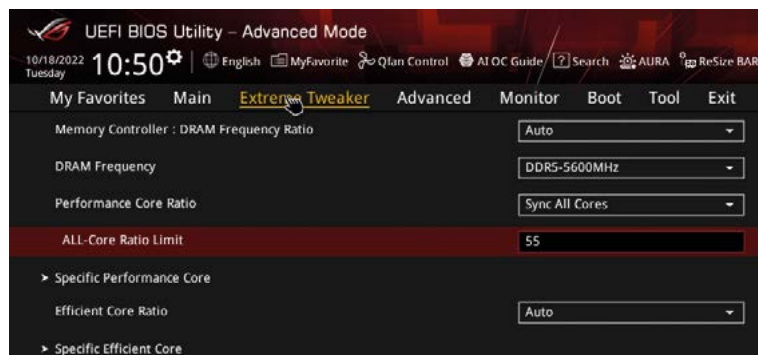
**T**here haven't been many CPUs you'd want to manually overclock recently, simply because so many are already pushed close to their limits out of the box that there's not much overclocking headroom left. In addition, manually overclocking can also mean you lose peak boost frequencies. Intel CPUs do at least allow for per-core overclocking, which is one way around that issue, but with Raptor Lake, Intel offers a degree of overclocking headroom that's worth exploiting.

We're focusing on the Core i5-13600K here, as it proved to be an excellent overclocker. Even better is that it's compatible with Z690 and motherboards, as well as DDR4 memory, making it a potential winner from a value point of view too. In this guide, we'll look at applying a basic manual overclock and how to ensure it's stable. You'll need a good heatsink or AIO liquid cooler in order to attempt this overclock.

## Check your temperatures

Start by checking your temperatures. Intel's CPUs don't run as hot as AMD's Ryzen 7000-series chips, but you'll still need to check you have sufficient headroom. You can also use CPU-Z to check your CPU's boost frequencies and voltage, to see whether you need to apply loadline calibration in order to reduce vdroop, where the CPU voltage can fall under load.

Run Prime95's smallfft test with AVX disabled ([mersenne.org/download](https://mersenne.org/download)), along with CPU-Z ([cpuid.com](https://cpuid.com)) and CoreTemp ([alcpu.com/CoreTemp](https://alcpu.com/CoreTemp)). Our Core i5-13600K was sitting at 5.1GHz across all its P-Cores, and temperatures were mostly below 70°C after our ten-minute stress test, leaving plenty of headroom for an overclock. Head to your motherboard's EFI by restarting your PC and pressing the Del key when an image appears on the screen.



## Set the clock

Start by loading the XMP profile for your memory. This will ensure it's running at the correct frequency, timings and voltage. This is important, as running it at stock settings can result in lost performance and simply setting the rated frequency yourself can result in stability issues.

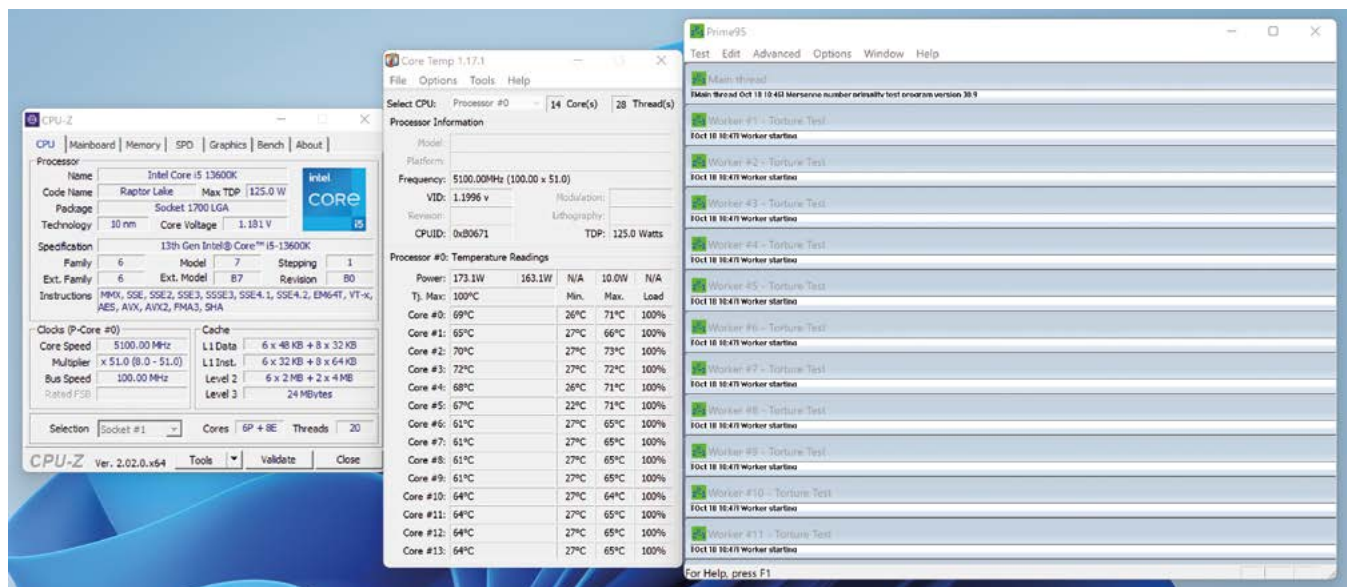
We managed to hit an all-core overclock 5.7GHz with our Core i5-13600K, but we'll be aiming for a lower frequency that should be achievable on most systems with good cooling. Start by locating the Performance Core (P-Core) settings. We only want to adjust these, as the E-Cores often don't overclock very far and the overclock also has a smaller impact here. Set the Performance Cores to sync all cores, and set the ratio to 55 in order to give you an all-core overclock of 5.5GHz.

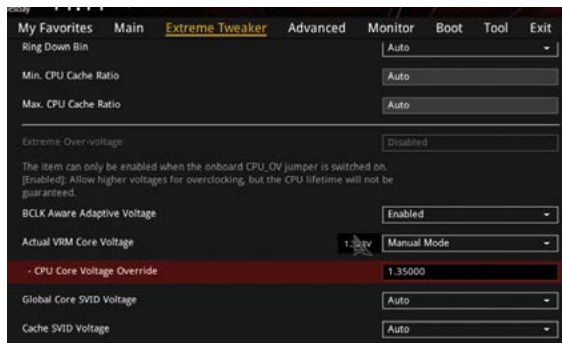
**Set the P-Core ratio to 55 in order to give you an all-core overclock of 5.5GHz**

## Voltage tweaks

This frequency is 400MHz higher than any boost frequency we saw at stock speed, so both lightly- threaded and multi-threaded applications will benefit from this tweak. Your next

**Use Prime95 and Core Temp to get an idea of how hot your CPU gets before you start**





Enter a voltage of 1.35V to give your CPU enough power to safely hit its faster clock speed

step is to adjust the voltage (vcore). We used a vcore of 1.4V to hit 5.7GHz for our review, but we can start at a lower point here with a lower frequency. Locate the CPU core voltage or vcore setting, set it to manual or fixed, and enter a voltage of 1.35V – the correct field is called CPU Core Voltage Override on our Asus board.

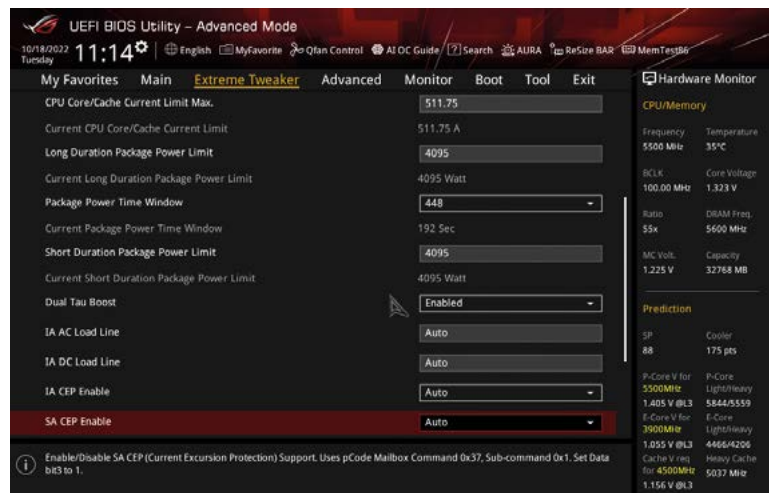
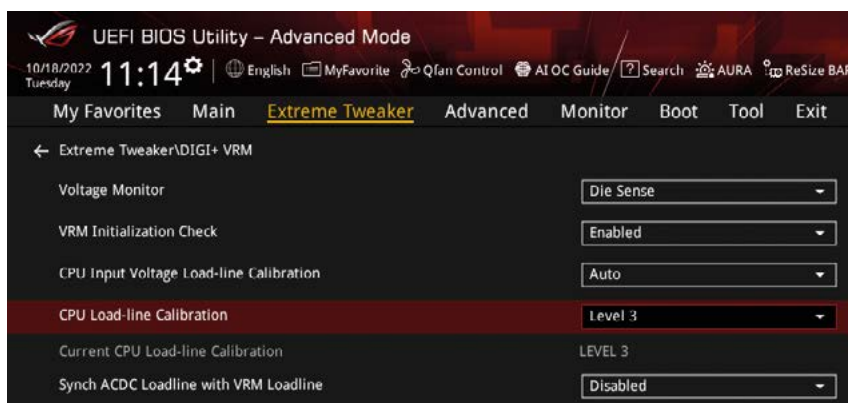
As we encountered a fair bit of vdroop during stress testing with our overclock, we recommend acting to counter this now with safe settings, and then you can always reduce your settings if your system is stable.

In order to limit vdroop, head to your CPU VRM settings, in this case under the DIGI+ VRM on our Asus motherboard, and locate the option for loadline calibration. We've set this to Level 3.

To allow more power to get to the CPU under sustained loads, we also need to open the taps a little. On our Asus motherboard, these options are located in the CPU power management section. You're looking for power and current limits, which need to go up to their maximum settings.

This should equate to 511A for the CPU core/cache current limit, 4,095W for the long duration package power limit, 448 seconds for the package time window and 4,095W for the short duration package power limit. You can now save your settings and exit. If you have issues rebooting the PC, dial down the CPU frequency by 100MHz and raise the vcore by 0.01V to 1.36V.

#### Adjust the loadline calibration in order to counter vdroop



#### Fine tuning

Now it's time to recheck your settings and fine-tune your overclock. We've used a voltage we know works and should be stable on most systems, but you should always try to lower this voltage as much as possible. Similarly, you may find that higher frequencies are achievable at this voltage too.

Firstly, we need to check if our overclock is stable, so run Prime95's smallfft test with AVX disabled again for a ten-minute stress test, checking the temperatures with Core Temp. If the system freezes or exhibits strange behaviour, try lowering the frequency by 100MHz or slightly raising the voltage, for example to 1.36V. We saw a peak temperature of 77°C, so there's scope here for pushing your overclock further with higher voltages and frequencies.

From here, it's worth playing some of your favourite games and using your most-used programs to check stability. Prime95 is a good stress-testing tool, but occasionally stability issues can occur in other programs even if Prime95 appears fine. Next, head back to the EFI and begin lowering the voltage in the smallest increments your motherboard allows. After each drop, save the settings then

perform the Prime95 stress test again.

Eventually, your system will freeze or crash and that's its way of telling you it needs more voltage. At this point, head to the EFI again and raise the voltage by two steps. This should prove stable and give you a decent overclock, but without using more power and generating more heat than necessary.

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Increase the current and power limits to open up the power taps

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The image displays three covers of Custom PC magazine. The first cover on the left features a blue background with abstract light patterns and a Kingston Fury memory module. The middle cover has a green background and shows an AMD processor. The third cover on the right has a red background and features an Intel Raptor Lake processor (Core i9-13900K). A white mug with a yellow star logo and the text 'CUSTOM PC BEVERAGE APPROVED' is positioned in front of the third magazine cover. A yellow circle with a red plus sign is next to the mug. A yellow banner at the bottom right contains the text 'FREE CUSTOM PC BEVERAGE APPROVED MUG WITH 6-MONTH AND 12-MONTH SUBSCRIPTIONS!'.

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# NVIDIA GEFORCE RTX 4090 / ~£2,400 inc VAT

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**O**h scalpers, how we'd missed you. Just when the GPU market had settled back into some sort of normality, you've stepped back into our world to make buying a GeForce RTX 4090 as stressful as possible. Yes, there's no stock of the RTX 4090 already. Yes, there are lots of them now on eBay going for around £2,400. On the other hand, though, the RTX 4090 was already priced very high in the few minutes it was still available at the standard retail price.

The Founders Edition we're reviewing here launched a day before the partner cards for a price of £1,699 inc VAT. Some of this premium is down to the drop in value of the pound, of course, but there's no getting away from the fact that this is a very expensive card, wherever you buy it. If you're going to spend that sort of money on a graphics card, then it really needs to deliver on its promise.

In this case, the RTX 4090 needs to be the fastest gaming GPU ever, by a long way. It needs to make 4K gaming in demanding games with ray tracing a real possibility. After all, not even the RTX 3090 Ti could play Cyberpunk 2077 properly using the Medium ray-tracing preset at 4K, even with DLSS on Balanced. Can the RTX 4090 finally make such a goal achievable? The answer is a definite yes.

## Lovelace and Babbage

The GeForce RTX 4090 is the first GPU out the doors to use Nvidia's new Ada Lovelace architecture. In this case it's based on the A1 revision of the AD102 GPU, a 608mm<sup>2</sup> die containing 76,300 million transistors, and fabricated on TSMC's latest 4nm manufacturing process.

Sometimes it's difficult to visualise these numbers when they get so big, but that's basically 48 billion more transistors than the top-end GA102 GPU from the Ampere line-up – this is a really sophisticated piece of silicon. Not only that, but the RTX 4090 isn't even a fully enabled chip – there's room for at least one more top-end GPU to come out at a later date, based on the same AD102 chip.

We're going to do a full deep dive into the new architecture in Issue 233, by which time we also hope to have the first RTX 4080 cards, but we'll

skim some of the basics here. Let's start with the basic structure of the GPU, which sees Nvidia use a similar block layout as before, with the various processors combined into streaming multiprocessor blocks (SMs), two of which make up a texture processing cluster (TPC).

The TPCs are then grouped into graphics processing clusters (GPCs). Fully enabled GPCs contain six TPCs, but Nvidia can also disable them so that some GPCs only have five, for example. A fully enabled AD102 GPU contains 12 GPCs, each containing six TPCs (which in turn contain two SMs), giving you 18,432 CUDA cores. The RTX 4090 only has 11 GPCs enabled, though, and two of them only have five TPCs rather than six. That means the RTX 4090 has 16,384 basic CUDA cores, so there's still a good bit of headroom for improvement from a fully enabled GPU in the future.

The AD102 GPU also shared a huge 98MB pool of L2 cache between all the GPCs, compared to just 6MB in the GA102. We've seen AMD adopt a similar approach of laying on as much cache as possible with its RDNA2 GPUs, using its Infinity Cache system.

In the case of AMD, the headroom provided by this massive increase in the amount of high-speed, quick-access memory effectively negated the need for the main memory interface to get wider than 256 bits.

That's not an issue for the RTX 4090 anyway. Not only does it have loads of cache, but it also has a 384-bit memory interface. Couple this with a whopping 24GB total of 1,325MHz (21.2GHz effective) GDDR6X memory and you end up with a total memory bandwidth that surpasses the 1TB/sec barrier, at 1,018GB/sec.

## Trace those rays

Nvidia has also taken this opportunity to revise the design of its RT cores, one of which is found in each SM. You would get 144 3rd-gen RT cores in a fully enabled AD102 chip, and you get 128 of them in the RTX 4090. We'll explore the new RT cores in much more depth in our future deep dive, but



## SPEC

### Graphics processor

Nvidia GeForce RTX 4090, 2235MHz base clock, 2520MHz boost clock

### Pipeline

16,384 CUDA cores, 176 ROPS

### RT cores

128 (3rd-gen)

### Tensor cores

512 (4th-gen)

### Memory

24GB GDDR6X, 1325MHz (21.2GHz effective)

### Memory interface

384-bit

### Card interface

16x PCI-E 4

### Bandwidth

1,018GB/sec

### Power connectors

1x 16-pin / 4x 8-pin

Nvidia has focused on several areas in order to accelerate ray-tracing performance.

The first is ray-triangle intersection testing throughput; as its name suggests, this is calculating the effect of a ray intersecting with a triangle, which is very computationally expensive when compared with a ray being behind, parallel to or in front of a triangle. Nvidia claims that the 3rd-generation RT core found in Ada Lovelace doubles the throughput of this work compared with the 2nd-generation RT cores found in Ampere GPUs.

Next up is the Opacity Micromap Engine, which is designed to alpha-test geometry on the new RT cores. This process is often used to cut down on the number of triangles used to describe translucent objects or those with complex shapes (Nvidia uses the example of a leaf or a flame) and instead relies on the alpha channel in the object's texture to capture the shape.

However, this puts strain on the CUDA cores, and Nvidia says that the ability to move this process to the RT cores means 'developers can very compactly describe irregularly shaped or translucent objects, like ferns or fences, and directly and more efficiently ray trace them'.

Another big jump with ray tracing is what Nvidia calls Shader Execution Reordering (SER), a feature that the company's CEO Jensen Huang described as being as revolutionary as out-of-order processing on CPUs. We'll explore this feature in more depth in our deep dive next month, but the idea behind it is that it tidies up the often chaotic mess that occurs with ray tracing, when various different threads are executing shaders, or code paths within shaders, and all these threads are accessing various memory resources all over the place.

SER is basically a new scheduler that takes all this shading work and reorders it on-the-fly into a uniform pipeline, which is optimised for efficiency and directing work to the nearest resources.

## DLSS3

Finally, the other big new introduction is Nvidia's latest form of DLSS, which is a very different beast to the previous versions. Again, we'll explore this in more depth next month, but the main takeaway here is that DLSS 3 isn't just using AI to upscale the resolution anymore. The new string in its bow is frame generation, relying on AI to predict how some future frames will look and generate them according to this information, rather than fully rendering them, and massively improving performance.

The process is based on several data inputs, including depth and motion vector information from the game engine to track geometry. There's also Nvidia's new Optical Flow Accelerator system, which takes a look at a pair of sequential frames in a game and works out an 'optical flow field' between the two frames – how fast the pixels are moving and the direction in which they're travelling from one frame to the other.

According to Nvidia, the two-pronged attack of resolution scaling and frame generation effectively means that DLSS 3 reconstructs seven eighths of the pixels displayed on your screen. The resolution scaling effectively transforms a 1,920 x 1,080 scene into a 4K scene in one frame, meaning only a quarter of that frame is produced with a standard render, and then frame generation can create the next frame entirely on its own.

## Performance

Let's be frank here, the GeForce RTX 4090 is a phenomenally fast gaming GPU. Let's start off with 4K performance, as that's what you really want from a graphics card at this price. At this resolution, it simply battered the competition and its predecessors.

For starters, its 108fps average in Assassin's Creed Valhalla is way in front of the 75fps from the Sapphire Nitro+ Pure 6950 XT, and this game was previously a

### LOVELACE

- + Amazing 4K ray-tracing performance
- + DLSS 3 has great potential
- + Fastest GPU ever

### SHOELACE

- Ridiculously expensive
- High power draw
- No stock





stronghold for AMD. One of the benefits of Nvidia's latest driver update is massively improved performance in this game, and Nvidia is now the clear winner by a long way.

Play a less demanding game such as Doom Eternal and the frame rates just rocket up. The RTX 4090 clocked up an average of 414fps in this game (at 4K), while the RTX 3090 Ti could 'only' average 256fps. When 4K monitors start to be equipped with super-fast refresh rates, this GPU will see you in good stead. Even adding ray tracing to the mix couldn't stop it, with the RTX 4090 managing a 276fps average and 179fps 99th percentile result – it looked amazing on our 144Hz AOC U28G2XU 4K test monitor.

Cyberpunk 2077 was also a pushover for the RTX 4090. The Medium ray tracing settings have previously been a struggle at 4K, even on the mighty RTX 3090 Ti with Balanced DLSS enabled, but the RTX 4090 not only makes this setting smoothly playable, but also hits our framerate target (60fps average; 45fps 99th percentile) with Ultra ray tracing and DLSS set to Quality.

Nvidia also gave us access to a pre-release build of this game so that we could test DLSS 3, and the results were incredible. We were able to max out all the ray-tracing settings at 4K, and the game then averaged a massive 118fps, with an 89fps 99th percentile result. It looked stunning with all the ray-traced lighting eye candy in action, and it was super-smooth in play. You would never guess it was based on 1,920 x 1,080 frame data – it looks really sharp.

The only slight downside we spotted were a few perspective artefacts, such as shimmering as you drive over textured road surfaces quickly, but in all honesty, you don't really notice this in action – it's a price that's well worth paying for the enormous uplift in visual quality and framerate.

It goes without saying that this card is also really quick at 2,560 x 1,440, although you don't gain much of a performance benefit moving down to 1,920 x 1,080 as you start to hit the CPU limit of a lot of games here. Buying this card for gaming at sub-4K resolutions is a false economy though – it's really only worth considering for gaming at high resolutions.

### Power needs

Aside from the lack of stock and high price, the other downside to the RTX 4090 is its power draw. The Founders Edition we tested uses the new 16-pin connector (see our ATX3 feature on p78 for more information), and comes with a cable to split this into four 8-pin PCI-E power sockets.

The power draw of our Ryzen 9 5900X test system was also highly variable with the RTX 4090 installed, and really starts eating watts when you're gaming at 4K with ray tracing enabled. Using our standard Metro Exodus 2,560 x 1,440 power draw test, our system maxed out at 535W with the RTX 4090 installed, but this went right up to 619W running the same test at 4K.



On the plus side, this is less power than our system drew with the RTX 3090 Ti installed, but the RTX 4090 is still clearly a thirsty customer. You'll want at least an 850W PSU if you want to run this GPU.

We also have to take our hats off to Nvidia for the design of its Founders Edition card. It's a massive, three-slot brick, but most of that space is occupied by heatsink fins and large fans. Assuming you use it in a case with a standard airflow layout, the flow-through system works well. The GPU temperature peaked at 67.5°C, with a 77.6°C peak hotspot temperature, and the fan noise never became annoyingly loud. The GPU was also consistently able to boost to 2745MHz in our tests – a good 225MHz higher than the quoted boost clock.

### Conclusion

The GeForce RTX 4090 shows how 4K gaming should be done. It annihilates the competition and its predecessors, making settings that were previously impossible achievable. We never thought we'd be discussing 240fps+ frame rates at 4K with ray tracing, but the RTX 4090 has brought us to that world.

Meanwhile, Nvidia's new DLSS 3 tech has the potential to make demanding games such as Cyberpunk 2077 run at over 100fps with settings that look incredible. This tech is already lined up to be supported in several big titles, including Microsoft Flight Simulator and A Plague Tale: Requiem, and if it ends up being supported by many games then this will be huge for Nvidia, as it really opens up high frame rates in demanding games with ray tracing.

This flagship card isn't for everyone, of course. Few people will be able to afford one, even if you could find one at its original retail price, but Nvidia has shown that it's once again the king of the castle at the very top end. If you have plenty of cash in the bank and want to play games at 4K, this is undoubtedly the card to get.

BENHARDWIDGE

### VERDICT

4K with ray tracing done properly, and DLSS 3 has great potential. It's just a shame the price is so high, and the stock so low.

PERFORMANCE  
49/50

FEATURES  
20/20

VALUE  
3/30

OVERALL SCORE

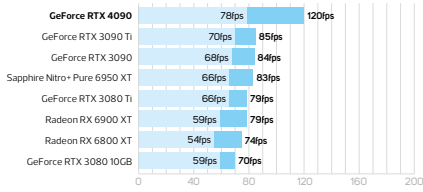
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# NVIDIA GEFORCE RTX 4090 RESULTS

## CYBERPUNK 2077

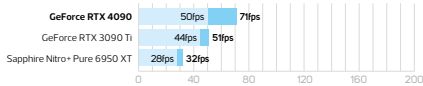
2,560 x 1,440

Ultra preset, no ray tracing



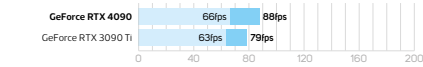
## 2,560 x 1,440 - MEDIUM RAY TRACING

Medium ray tracing preset, DLSS disabled



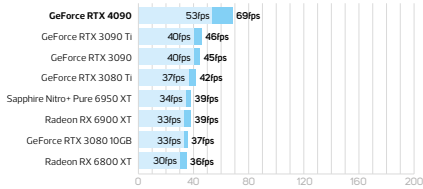
## 2,560 x 1,440 - MEDIUM RAY TRACING + DLSS

Medium ray tracing preset, DLSS Balanced



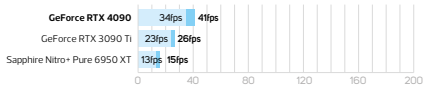
## 3,840 x 2,160

Ultra preset, no ray tracing



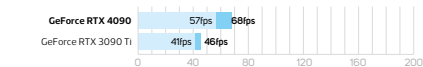
## 3,840 x 2,160 - MEDIUM RAY TRACING

Medium ray tracing preset, DLSS disabled



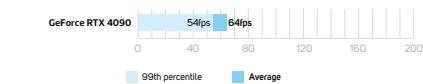
## 3,840 x 2,160 - MEDIUM RAY TRACING + DLSS

Medium ray tracing preset, DLSS Balanced



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

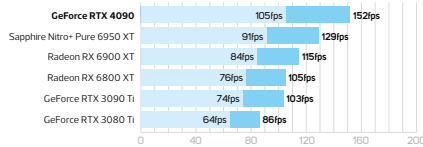
Ultra ray tracing preset, DLSS Quality



## ASSASSIN'S CREED VALHALLA

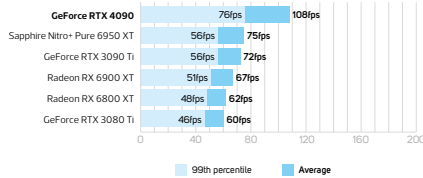
2,560 x 1,440

Ultra high settings, High AA



## 3,840 x 2,160

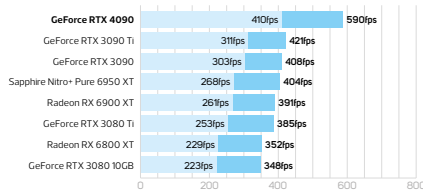
Ultra high settings, High AA



## DOOM ETERNAL

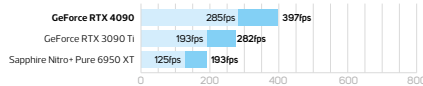
2,560 x 1,440

Ultra Nightmare settings



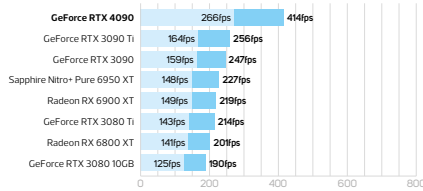
## 2,560 x 1,440 - RAY TRACING

Ultra Nightmare settings, ray tracing enabled



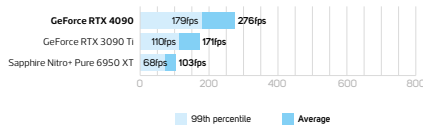
## 3,840 x 2,160

Ultra Nightmare settings



## 3,840 x 2,160 - RAY TRACING

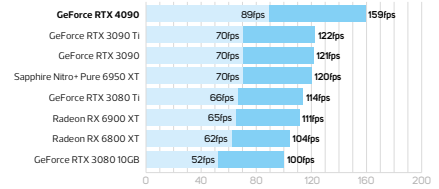
Ultra Nightmare settings, ray tracing enabled



## METRO EXODUS

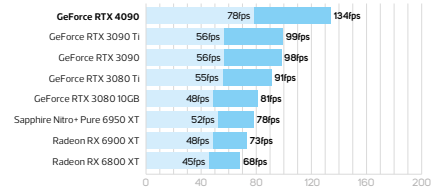
2,560 x 1,440

Ultra settings, HairWorks off, PhysX off



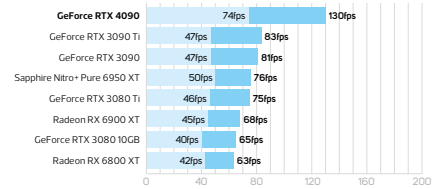
## 2,560 x 1,440 - RAY TRACING

Ultra settings, HairWorks off, PhysX off, High ray tracing



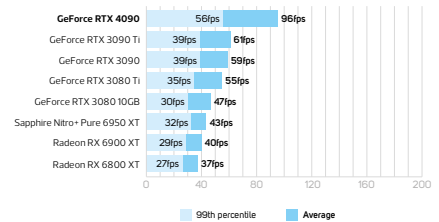
## 3,840 x 2,160

Ultra settings, HairWorks off, PhysX off



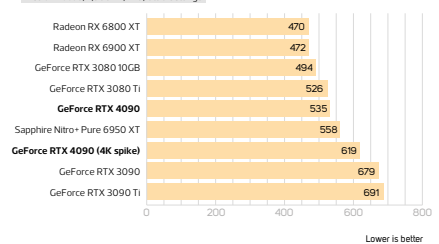
## 3,840 x 2,160 - RAY TRACING

Ultra settings, HairWorks off, PhysX off, High ray tracing



## PEAK TOTAL SYSTEM POWER CONSUMPTION (WATTS)

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



Lower is better

## ATX Z790 MOTHERBOARD

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MAXIMUS Z790  
HERO / £669 inc VAT

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**W**ith Intel launching its most core-laden desktop processor ever in the form of the Core i9-13900K, it's not surprising to see some suitably high-end and extreme motherboards lining up as potential suitors. Once a brand that sat at the budget end of the ROG line-up, the new Hero won't leave you with much change from £700. However, on paper at least, the Asus ROG Maximus Z790 Hero seems to be utterly droolworthy. For starters, it looks fabulous, with a huge RGB display above the enormous heatsink sitting on top of the I/O panel. It's not too garish either, instead adding a premium feel to the board that looks classy. The rest of the PCB is covered in

huge heatsinks, both for the 20+1 teamed power stages and three M.2 ports, with all of the latter cooling both sides of the SSDs you install. The M.2 ports in this area only support PCI-E 4 SSDs, which might seem like you're short-changed given the huge price tag.

However, Asus hasn't just included a large heatsink for a PCI-E 5 M.2 SSDs, but has also provided an entirely separate expansion card that offers a single PCI-E 5 port and one more PCI-E 4 M.2 connector. This is equipped with a massive heatsink, so if PCI-E 5 SSDs do end up being as hot-running as we suspect, this is the best cooling method we've seen so far, and it can be installed in either one of the two 16x PCI-E 5 slots on the board. This also means that you get a grand total of five M.2 ports on the Hero, in addition to six SATA 6Gbps ports.

Connections are a big feature with the Z790 chipset, and Asus has gone all-out here, putting a pair of Thunderbolt 4 ports on the rear I/O panel, as well as 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

output up to 60W of power for you to charge phones, tablets and laptops, as long as you hook up a 6-pin PCI-E connector into the slot next to it.

The usual 802.11ax Wi-Fi connection is here too, and with the addition of Wi-Fi 6E support as well – perhaps the only fly in the ointment is the lack of 10Gbps Ethernet, with just the usual 2.5 Gigabit Ethernet adaptor included. The audio system looks top-notch too – the Realtek ALC4082-based ROG SupremeFX audio setup offers an ES9218 Quad DAC, as well as a USB interface to offer up to 32-bit/384kHz audio.



## SPEC

## Chipset

Intel Z790

## CPU socket

Intel LGA1700

## Memory support

4 slots: max 128GB DDR5 (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, 1x 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, 2 x Thunderbolt 4, 1x USB 3.2 Gen 2 Type-C, 1x USB 3.2 Gen 2x2 Type-C header, 3 x surround audio out

## Dimensions (mm)

305 x 244



## HERO

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

## ZERO

- Expensive
- Teething issues with 6400MHz memory
- Did we already mention it's expensive?

If you want to add a custom water-cooling loop to your PC then there's practically every feature you need as well. There are 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 too, which is more than enough power for DDC and D5 pumps. There are eight 4-pin fan headers in total, which are located on the very top and bottom end of the PCB for easy cable routing.

It's certainly a densely packed PCB, and in these situations, we'd usually be worried about releasing your

graphics card without mangling your fingers, but the board is equipped with the same quick-release button we've seen on other premium boards, which is great.

The PCB also sports on-board power and reset buttons, an LED POST code display, support for USB BIOS FlashBack and a clear-CMOS button too. The rear I/O panel is fairly standard, with a generous tally of nine Type-A USB ports, all of which are USB 3 or faster, plus there's a USB 3.2 Gen 2 Type-C port in addition to the two Thunderbolt 4 ports, and an HDMI output if you plan on just using your CPU's integrated graphics.

## Performance

To get the audio system performing as it should, we had to download Realtek's audio console from the Microsoft store, which allowed the already installed Asus software to fire up and provide some extra tweaking. This procedure finally returned the results we were looking for in RightMark's Audio Analyzer software, with a noise level of -113.7dBA and dynamic range of 111.7dBA, along with a super-low THD of 0.002 per cent, which are some the best results we've seen from on-board audio.

For testing M.2 temperatures, we used the large heatsink at the base of the PCB and here our toasty WD SN850 SSD hit a peak of 62°C, which was a good 15°C or so away from throttling, so there's no need to use the expansion card's massive heatsink for PCI-E 4 SSDs if you're worried about overheating.

There's no fan on the VRM heatsinks but the Hero's peak software-reported temperature of 51°C was excellent considering it was dealing with our Core i9-13900K. We used a vcore of 1.4V to overclock our CPU to 5.7GHz too, although this was 100MHz short of the single-core stock speed peak boost frequency.

Not surprisingly, this added performance in most places and actually saw the peak power draw fall a little, thanks to a voltage lower than stock speed being used. One problem, however, was that we had issues hitting 6400MHz on our DDR5 memory, and we had to run our memory at 6000MHz instead, but this hasn't been an isolated incident.



## Conclusion

It's a shame such a fantastic motherboard will also leave such an impressive dent in your wallet, because if we could take our pick of a Z790 motherboard, so far, the Asus ROG Maximus Z790 Hero would be it.

You get Thunderbolt 4 support, and a high-power Type-C header for your case that can even charge the latest laptops, as well as smartphones and tablets. Plus, you also get loads of water-cooling and testing features, an excellent EFI and plenty of rear USB ports.

The VRMs and M.2 SSDs are kept cool, and the expansion card will certainly offer a comfortable home for a future PCI-E 5 SSD too. If you have deep pockets and want a droolworthy home for your shiny new Core i9-13900K CPU, or even a Core i9-13900KS if and when it arrives, the ROG Maximus Z790 Hero is a hugely expensive but excellent choice.

ANTONY LEATHER

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## VERDICT

Hideously expensive, but it's so great we can't help but want one.

PERFORMANCE  
**32/35**

FEATURES  
**33/35**

VALUE  
**15/30**

OVERALL SCORE

**80%**

# ATX Z790 MOTHERBOARD

## ASUS ROG STRIX Z790-A GAMING WIFI D4 / £400 inc VAT

SUPPLIER scan.co.uk

There's no getting round the fact that motherboards are going up in price, and if you want the latest chipsets you're going to have to pay down the nose for them. Even here, with the Asus ROG Strix Z790-A Gaming WiFi D4, we're looking at a £400 motherboard. Despite being a few hundred pounds cheaper than the admittedly lustworthy ROG Maximus Z790 Hero on p32, that's still a lot of money. These are the prices we have to pay at the moment, though, and if you can afford it, the Strix has a lot going for it.

For starters, it looks fabulous in its white and silver colour scheme, complete with a large ROG logo illuminated with RGB lighting in the I/O shroud. It definitely has more of a fun, cheerful look to it than the Hero, but it still packs a punch as you'd expect given its price. That said, to get the price down to £400 in these times, not surprisingly, Asus has had to cut back a few features compared with the Hero.

There's no Thunderbolt 4 support, for example, and while the Strix's Type-C USB 3.2 Gen 2x2 header has a decent amount of power on tap, it's only 30W as opposed to the 60W of the Hero. More importantly, there's no PCI-E 5 SSD support, with just one 16x PCI-E 5 slot catering for the new standard. The accessories are rather thin too, with no M.2 expansion card, but there are four PCI-E 4 M.2 ports, all of which are adorned with heatsinks, with the top slot also offering double-sided cooling.

The power delivery system is less lavish, but still includes a 16+1 phase design with 70A for each VRM, and it's all cooled by two separate heatsinks rather than the enormous linked array on the Hero. Still, Asus has done a good job of dressing this up with the large plastic top and RGB lighting.

There's also Wi-Fi 6E support, with an antenna included in the box, and 2.5Gbps Ethernet, so all your networking needs are

covered. The same is true for the audio, which uses the Realtek ALC4080 codec and you get the full complement of audio outputs, including an optical port. You get four SATA 6Gbps ports, as opposed to six with the Hero, but this is likely to be enough for most people unless you're transplanting a stack of hard disks.

Meanwhile, the rear I/O panel offers a USB 3.1 Gen 2x2 Type-C port and another Type-C port with just USB Gen 2 support. There are also two USB 3.2 Gen 2 Type-A ports, four USB 3 ports and two USB 2 ports, bringing the total of Type-A ports to eight. Asus has squeezed USB BIOS FlashBack and CMOS-clear buttons into this area as well, which is good to see, although you only get the basic debug LEDs on the PCB, and there are no on-board power and reset buttons, or LED POST code display.

One feature we were super-pleased to see on the Strix, though, is the PCI-E quick release button that's also present on the pricier Hero – it's great to see Asus bringing this excellent feature further down its product stack. Also included are its tool-free M.2 clips, which we absolutely love and, while we're here, we'd certainly appreciate tool-free M.2 heatsinks too. How about it Asus?

There's not much in the way of extra features for custom water-cooling systems, but there is a thermal sensor, which allows you to hook up a thermal probe and use its temperature input to control radiator fans, for example, based on coolant temperature. This is arguably more useful for water cooling than flow sensors and pump



### 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, 3 x surround audio out

#### Dimensions (mm)

305 x 244

### Z790

- + Attractive design
- + Good feature set
- + DDR4 support

### Z-LIST

- Still pricey
- VRMs get a little warm
- No PCI-E 5 M.2 support



headers, so at least Asus has its priorities right. The BIOS and software also allow you to select the VRMs, chipset and motherboard as the temperature source to control fans, rather than the CPU.

## Performance

The ROG Strix Z790-A Gaming's audio performance was excellent, and on par with the ROG Maximus Z790 Hero, with a noise level of -114dBA, dynamic range of 115.5dBA and THD of 0.0016 per cent, meaning you'd need to buy an expensive discrete sound card to get noticeably better audio quality.

Meanwhile, the M.2 temperature of 54°C with our toasty WD SN850 was actually a few degrees cooler than on the more expensive Asus board. This could be down to the SSD being single-sided, and the Hero offering double-sided thermal pads on its largest heatsink, potentially improving airflow, as would a less cramped PCB, and the heatsink is slightly larger here too.



The Asus ROG Strix Z790-A Gaming WiFi D4 couldn't match its pricier sibling's VRM temperatures, though, with the software reporting a peak temperature of 63°C after our ten-minute stress test, which was a little over 10°C warmer.

Overclocking was just as easy, though, with our CPU hitting a 5.7GHz all-core boost frequency with a vcore of 1.4V, though exhibiting quite a bit of vdroop. This saw the image editing score rise from 87,842 to 93,025 and Cinebench multi-threaded score from 39,747 to 41,140.

## Conclusion

If you want to assemble a Raptor Lake system on a tight budget, then it's fair to say this board isn't for you – you'd be much better off getting a 600-series chipset board and updating the BIOS. With that out the way, though, if you're in the market for motherboard that's a little newer and more premium, but you can't afford the big bucks for the ROG Maximus Z790 Hero, then keep reading, as the Asus ROG Strix Z790-A Gaming WiFi D4 is in many ways every bit as good as its pricier sibling.

You get top-notch audio, excellent M.2 cooling and it can overclock just as well too. Only expensive features such as Thunderbolt 4 and PCI-E 5 M.2 support are missing, plus a few little extras such as overclocking and testing tools. It looks great, performs well and has an excellent EFI, but it still manages to include plenty of premium features. It's still very expensive, but with support for DDR4 memory, there are savings to be found too.

In that light, this is a sensible option for those that already have some decent DDR4 memory they can transplant from an old system, and are looking for a Z790 motherboard with cutting-edge features. It's a shame there's no PCI-E 5 M.2 support, but otherwise, the ROG Strix Z790-A Gaming WiFi makes much more financial sense than the ROG Maximus Z790 Hero.

ANTONY LEATHER

## VERDICT

A sensible yet desirable choice to jump on the LGA1700 bandwagon, although it's still a tad pricey.

PERFORMANCE  
**31/35**

FEATURES  
**29/35**

VALUE  
**22/30**

OVERALL SCORE

**82%**



## ATX X670E MOTHERBOARD

ASUS TUF GAMING  
X670E-PLUS WIFI / £327 inc VAT

SUPPLIER cclonline.com

**A**sus' TUF-branded motherboards used to represent the company's value-focused range, but with a price over £300, you would have a tough time describing the TUF Gaming X670E-Plus WiFi as cheap. It also costs around £60 more than the Z690-based equivalent, which benefits from also having DDR4 memory support, whereas using any AMD Socket AM5 motherboard required you to buy new

DDR5 memory.

It's also a little disappointing to have no USB 4 support, as well as a general lack of on-board overclocking and testing tools. Thankfully, though, in most other areas, this is one of the most feature-packed TUF motherboards we've seen. You get a quartet of M.2 ports, with the primary connector sporting PCI-E 5 support, two ports capped at PCI-E 4, and the final one catering for PCI-E 3 and SATA M.2 SSDs. The primary 16x PCI-E slot is also PCI-E 5 compatible. You get a fair amount of futureproofing, then, especially as Socket AM5 is likely to have a reasonably long lifespan too.

There are some cooling-focused features too, such as a dedicated custom water-cooling pump header that can dish out up to 36W of power, and there are eight 4-pin power headers in total. What's more, three of the four M.2 ports offer heatsinks.

You even get a thermal probe input. This can be used with 2-pin thermal probes to tell your motherboard EFI (or fan control software) to adjust fan speeds based on a temperature input, rather than the CPU or VRM temperatures. This is useful if you're water-cooling your system, enabling you to control fan speeds based on

the coolant temperature, or if you're adding extra fans to your graphics card cooler, as we did in this month's How To guide on p88. The EFI also lets you change the temperature inputs for case fans to your graphics card.

Meanwhile, two large heatsinks cool the VRMs, which are made up of a 14+2 array of teamed power stages rated at 70A, although there's no heatpipe linking them or additional fans. Over the back of the VRMs, on the rear I/O panel, you'll find connectors for 2.5 Gigabit Ethernet, 802.11ax Wi-Fi and a handy tally of eight Type-A USB ports, all of which are USB 3 or faster. While there's no USB 4 support, you do get a pair of Type-C ports offering USB 3.2 Gen 2x2 speeds, and another one that's limited to just USB 3.2 Gen 2 speed.

Unlike the mini-ITX Asus ROG Strix X670E-I Gaming WiFi (see p38), which we've also reviewed this month, there's a near-full array of audio ports from the Realtek-based S1220 on-board audio on the back too, although there's no optical output. You also get DisplayPort and



## SPEC

## Chipset

AMD X670E

## CPU socket

AMD Socket AM5

## Memory support

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

## Expansion slots

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

## Sound

8-channel Realtek S1220A

## Networking

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

## Cooling

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

## Ports

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

## Dimensions (mm)

305 x 244



HDMI outputs for tapping into the on-board graphics with Ryzen 7000-series CPUs too. Should you buy the board in future and want to drop in a future CPU that's not supported by the original BIOS, you can also update the board without a compatible CPU using the included USB BIOS FlashBack feature, which can be very handy.

One small complaint is that we would have liked to see six SATA ports on the PCB instead of four, but if you're jumping on the Socket AM5 bandwagon you're more likely to be making use of the M.2 ports, and four is still plenty for most people. There's also a tiny amount of RGB lighting emanating from the bottom right of the board, which hasn't been a focus of TUF boards in the past, and there are both 3-pin and 4-pin RGB headers on the board to expand your lighting system further.

## Performance

After our ten-minute load test with a Ryzen 9 7950X, the X670E-Plus WiFi's VRMs hit a reasonable temperature of 66°C, although after a few minutes, the CPU did drop from an all-core boost frequency of over 5GHz to around

4.9GHz, where the temperature stabilised. The M.2 temperature with our Kingston Fury Renegade PCI-E 4 SSD using the largest heatsink at the bottom of the board was a reasonable at 66°C, after handling lengthy back-to-back runs of CrystalDiskMark, which is well away from thermal throttling, although we have seen cooler results.

Our system drew a peak of 358W from the wall with this motherboard installed, which was about 15W less than the ASRock X670E Taichi. Meanwhile, the RealBench system score at stock speed was nearly identical to that of the Asus ROG Strix X670E-I Gaming WiFi at 489,953 points.

One highlight of this board is also the performance of the on-board Realtek S1120A audio system, which recorded a noise level of just -111.1dBA in RightMark Audio Analyzer along with a dynamic range of 111.3dBA and total harmonic distortion (THD) of 0.0057.

Setting up the board in the EFI was a simple process as well, with Asus' system providing easy-access options for enabling Resizable BAR, for example, plus it fired up first time when we enabled the AMD EXPO profile for our DDR5 6000MHz memory. However, as with most Socket AM5 boards, you'll need to sit through lengthy black screen boot times at first, while the board sets itself up for your particular hardware configuration.

## Conclusion

At a cost of £327 inc VAT, the Asus TUF Gaming X670E-Plus WiFi is still an expensive motherboard compared with previous motherboard prices, and if you're looking for a cheaper upgrade path, the Intel route presents a cheaper option. However, if you're keen to jump on the Socket AM5 bandwagon, the TUF Gaming X670E-Plus WiFi has a slightly better feature set than the pricier ASRock X670E Steel Legend, as well as a better EFI and software. The Asus board's M.2 and VRM temperatures weren't quite as low as those of the ASRock board, but they're still fine, and the Asus also offers some handy cooling features if you're planning to use a custom water-cooling loop.

ANTONY LEATHER

## VERDICT

Awash with cutting-edge features for such a small board, but it's hugely expensive.

## CROWD SURFING

- + Good feature set compared with similarly priced X670E boards
- + PCI-E 5 graphics and storage support
- + Plenty of cooling-related features

## TOUGH CROWD

- Expensive
- Comparatively high VRM and M.2 temperatures
- No USB 4 support



PERFORMANCE  
**31/35**

FEATURES  
**31/35**

VALUE  
**23/30**

OVERALL SCORE

**85%**

## MINI-ITX X670E MOTHERBOARD

ASUS ROG STRIX  
X670E-I GAMING  
WIFI / £470 inc VAT

SUPPLIER scan.co.uk

**D**espite its fair share of naysayers, it's clear that mini-ITX is here to stay now, and Asus has been an avid supporter of the form factor, offering both AMD and Intel platforms since Ryzen first appeared on the scene. Luckily for small form factor fans, there are now mini options for both Socket AM5 and LGA1700 available, although going the Intel route appears to be noticeably cheaper given that the ROG Strix X670E-I Gaming WiFi we're reviewing here is set to retail for nearly £500 inc VAT.

Even if you consider its imposing specifications, that's still a huge amount of money and it makes the Asus ROG Strix X670E-I Gaming WiFi easily the most expensive mini-ITX motherboard we've reviewed. Thankfully, Asus hasn't been idle when it comes to innovation here, which is part of the reason why the price is so high, even compared with its Z690 sibling.

For starters, the ROG Strix X670E-I Gaming WiFi is the first mini-ITX board to have a separate external sound device, called the ROG Strix Hive. This has been done for a couple of reasons, the first being to make room for a beefy stacked heatsink array for its two M.2 ports, so the board can cater for toasty PCI-E 5 M.2 SSDs. This has also had the effect of enlarging the CPU socket area, which may mean better clearance for some coolers. This has certainly been an issue with previous Asus mini-ITX boards, so any improvements here are welcome.

The ROG Strix Hive hooks up to the motherboard using a dedicated USB port on the I/O panel, but it's not just a featureless box. It has a hefty metal volume wheel, a FlexKey button that defaults to the reset function

but can perform other tasks, an AMD Precision Boost Overdrive button and LED status indicators. It even allows you to perform USB BIOS FlashBack with a further button and USB 2 port on the side. In addition, there's also a USB 3.2 Gen 2 port, as well as microphone and audio jacks, with the former doubling as an S/PDIF output.

We're not sure rarely used features such as BIOS FlashBack are more useful here than on the back of the motherboard, and Asus could have made the Hive more useful on an everyday basis, given it will be sitting on your desk, but it certainly delivers on the audio spec. Inside it is a Realtek ALC4050 audio codec, along with an ESS Sabre 9260Q DAC, while the unit sports a strong magnet should you want to fix it to your PC case instead of sitting it on your desk.

The small vertical ROG FPS-II card also makes a return to this board, bringing USB 2 headers, the front panel headers, a clear-CMOS header and two SATA 6Gbps ports off the PCB to save additional space, although there's still a 2-pin power button header on the PCB should you wish to ditch the card for a cleaner look.

However, it's when you delve into the M.2 heatsink stack and VRM heatsink that you see where the R&D budget has been allocated for this board. The M.2 heatsinks are large and multi-layered, and Asus has thoughtfully included a spare thermal pad should you damage one during upgrades.

The lower slot has the larger heatsink and is the one designed to cater for PCI-E 5 SSDs. This is fixed to the



## SPEC

**Chipset**  
AMD X670E

**CPU socket**  
AMD Socket AM5

**Memory support**  
2 slots: max 64GB DDR5  
(up to 6400MHz)

**Expansion slots**  
One 16x PCI-E 5

**Sound**  
6-channel Realtek ALC4050

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

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

**Ports**  
2x SATA 6Gbps, 1x M.2  
PCI-E 5, 1x M.2 PCI-E 4, 2x  
USB 4 Type-C, 5x USB 3.2  
Gen 2, 3x USB 2, 1x USB 3.2  
Gen 2 Type-C header, 1x  
audio out, mic, S/PDIF out

**Dimensions (mm)**  
170x170



### USB 4 PORT

- + Excellent feature set
- + External audio saves CPU socket space
- + USB 4 and PCI-E 5 support

### PARALLEL PORT

- Expensive
- M.2 and VRM temperatures could be cooler
- Disappointing audio performance

PCB, but the upper slot, which supports PCI-E 3 and 4 SSDs, needs to be removed in order to access the lower slot. Thankfully, this process is fairly painless, but it involves unscrewing several small screws that could easily get lost, so make sure you keep them safe. Amazingly, Asus has squeezed an M.2 cooling fan into the arrangement too, which appears to spin at a fixed speed and draws in air through the rear I/O panel – thankfully, it's also quiet, and wasn't audible above the rest of our water-cooled test system.

There's a second tiny fan lodged among the VRM heatsink array as well, which can be controlled or completely disabled in the EFI. Under full load, this fan took a while to spin up and still wasn't audible above the rest of the system, so there's nothing to worry about here from a noise perspective.

Meanwhile, the rear I/O panel is reasonably well stocked with ports, including two USB 4 Type-C ports, which offer similar specifications to Thunderbolt 4. There are eight Type-A ports with five of these being USB 3.2 Gen 2, a 2.5 Gigabit Ethernet port, connectors for the 802.11ax Wi-Fi aerial and an HDMI output should you wish to use the new integrated graphics on your Ryzen 7000 CPU.

## Performance

Firing up the board for the first time saw it take a minute or two to before any image appeared on the display, but it had no problem booting with our 6000MHz EXPO memory first time. The packed nature of the PCB seemed to have a negative impact on thermals, though, with the VRMs hitting a toasty (but perfectly safe) 68°C with our Ryzen 9 7950X.

Of more concern were the SSD temperatures. The lower slot saw our Kingston Fury Renegade PCI-E 4 SSD hit 70°C, which just about avoided throttling, but a hotter-



running WD SN850 reached 80°C. The lower heatsink became extremely hot, so it was definitely doing its job, but we do have concerns if PCI-E 5 SSDs end up running much hotter.

Meanwhile, the best performance we could coax out of the Realtek ALC4050 external audio setup was a dynamic range of 99dBA and signal to noise ratio of -99.5dBA, which are reasonable, but not as good as the best Realtek audio we've seen. Application and gaming performance were fine, though, with the RealBench system score of 491,497 being on the money, if a tad slower than the ASRock X670E Taichi we reviewed last month.

## Conclusion

While the M.2 and VRM temperatures are a tad disappointing, the rest of the Asus ROG Strix X670E-I Gaming WiFi shows stunning attention to design and cutting-edge features.

Whether you want a suitable small home for a Core i9-7950X or PCI-E 5 and USB 4 support, it has practically every feature you could want, and it even comes with a handy desktop audio control hub with USB ports and more. However, £470 is a huge amount of cash for a mini-ITX motherboard, meaning we can only recommend it to those with very large budgets.

ANTONY LEATHER

## VERDICT

Awash with cutting-edge features for such a small board, but it's hugely expensive.



PERFORMANCE  
**30/35**

FEATURES  
**33/35**

VALUE  
**19/30**

OVERALL SCORE

**82%**



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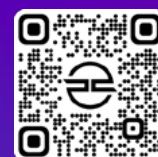
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# GAMING LAPTOP

# CHILLBLAST DEFIANT / £1,879 inc VAT

SUPPLIER [custompc.co.uk/ChillblastDefiant](http://custompc.co.uk/ChillblastDefiant)



**T**he Defiant is the first of Chillblast's brand-new laptop range to break cover, and for £1,879, you get an RTX 3070 Ti GPU and Core i7-12700H processor. This RTX 3070 Ti runs with the GPU's peak power limit of 150W, and Intel's CPU is another known quantity with a top turbo speed of 4.7GHz.

The inclusion of 32GB of dual-channel DDR5 memory is great for the money too, as is 1TB of NVMe storage. The supplied Samsung 980 drive only uses the PCI-E interface, but it still topped out with a decent read speed of 3,451MB/sec, with a slightly disappointing 2,760MB/sec write speed. These speeds are fine for most people's

needs in everyday use though. Internally, it's easy to access the SSD, along with a spare M.2 socket and the SODIMM memory slots.

The Defiant also comes equipped with a solid 16in display – its 2,560 x 1,600 resolution is crisp and the 16:10 aspect ratio provides more vertical space than the usual 16:9 screens. It's an IPS panel that runs at 165Hz, which is fine for most gamers' needs, although it doesn't support G-Sync.

In other areas, the Defiant is more ordinary than exceptional. The gunmetal body looks plain, and there's a sturdy base but too much flex in the lid behind the screen. The 31mm body is thicker than most laptops too, and its 2.5kg body isn't light – especially with a 978g power brick.

You get a decent range of connections, though, including three full-sized USB ports, and around the back you'll find a Thunderbolt 4 socket, HDMI 2.1 and DisplayPort 1.4 outputs and Gigabit Ethernet. For wireless comms, you also get 802.11ax Wi-Fi and Bluetooth 5.2 support. Don't expect much from the quiet, tinny speakers, though, and there's no card reader or biometric login.

Meanwhile, the keyboard has crisp, comfortable keys that hammer into a solid base, and it has a numberpad too. However, its buttons, including the Return and Backspace keys, are small. The typing unit's RGB LED lighting is only three-zone as well, and the trackpad's clicking action is too soft.

While the Chillblast isn't perfect, though, it offers a lot of hardware for the money. It has a great warranty as well, with five years of parts and labour cover for the core spec, the first two years of which have a collect and return service.

## Performance

At 2,560 x 1,600, the Defiant struggles to play games at top settings. In Assassin's Creed Valhalla, it returned a 99th percentile result of 35fps, and 38fps in Cyberpunk 2077. These results are playable, but you'll need to reduce the settings if you want smooth gameplay. There's plenty of power for running less demanding games at decent frame rates, though, as demonstrated by the Doom Eternal 99th percentile result of 117fps at this resolution.

If you're happy to drop to 1,920 x 1,080, though, the Defiant is great, hitting our frame rate targets in both Assassin's Creed Valhalla and Cyberpunk 2077. This isn't the fastest RTX 3070 Ti laptop we've tested though – the

## SPEC

### CPU

2.3GHz Intel Core i7-12700H

### Memory

32GB 4800MHz DDR5

### Graphics

Nvidia GeForce RTX 3070 Ti 8GB

### Screen

16in 2,560 x 1,600 IPS 165Hz

### Storage

1TB Samsung 980 M.2 SSD

### Networking

Gigabit Ethernet, dual-band 802.11ax Wi-Fi, Bluetooth 5.2

### Weight

2.5kg

### Ports

1x Thunderbolt 4/USB Type-C/DisplayPort, 1x USB 3.2 Gen 2, 2x USB 3.2 Gen 1, 1x audio, HDMI 2.1, mini-DisplayPort 1.4

### Dimensions (mm)

360 x 282 x 31 (W x D x H)

### Operating system

Windows 10 Home 64-bit

### Warranty

Five years parts and labour, two years collect and return, then return to base

## SISKO

- + Solid gaming pace
- + High-quality screen
- + Decent warranty
- + Great price

## DUKAT

- Occasionally intrusive fan noise
- Gets hot
- Poor battery life
- Underwhelming design



Asus ROG Strix Scar 15 G533ZW is pricier than the Defiant at £2,199, but it was consistently quicker.

The Defiant delivered mixed performance in application tests too. Its heavily multi-threaded Handbrake score of 813,959 beat the Asus, but its single-threaded image editing score of 59,958 lagged behind. Generally, though, there's clearly plenty of mobile CPU power on tap here. Don't expect much longevity from the Defiant's small 64Wh battery though – it delivered just 54 minutes of gaming time and four hours when working.

One area where the Chillblast excels, though, is with its screen. Its delta E of 1.69 and colour temperature of 6,360K are excellent, ensuring great colour accuracy, and the panel rendered 97 per cent of the sRGB gamut. The contrast ratio of 1,332:1 is another good result and means you get lots of depth alongside great colours. That said, the Defiant's display can't handle the Adobe RGB or DCI-P3 gamuts, and its peak brightness of 333cd/m<sup>2</sup> isn't ideal for outdoor use.

Chillblast's laptop dithers in thermal tests too. In its default Gaming Mode, the GPU pulls 125W and delivered moderate fan noise, but while the underside stayed cool, the area above the keyboard was too hot to touch.

Switch over to the High Performance mode and the RTX 3070 Ti pulled 150W, but the fan noise was distractingly loud in challenging games and our test results only improved by a few frames per second.

It's a bit trickier on the processing side. In application benchmarks, the Defiant was never loud, but the i7-12700H didn't blow us away with its speeds – even in High Performance mode, its respective single and multi-core frequencies



## BENCHMARK RESULTS

59,958

GIMP IMAGE  
EDITING

813,959

HANDBRAKE H.264  
VIDEO ENCODING

264,861

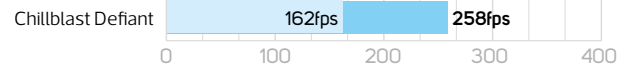
HEAVY MULTI-  
TASKING

292,977

SYSTEM  
SCORE

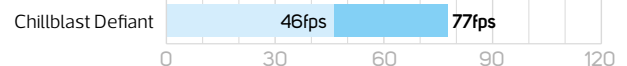
### DOOM ETERNAL

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



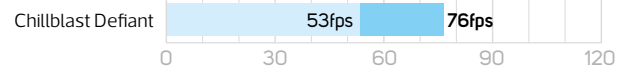
### ASSASSIN'S CREED VALHALLA

1,920 x 1,080, Ultra High settings, High anti-aliasing



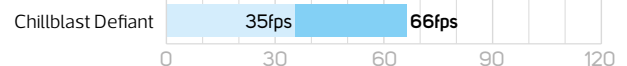
### CYBERPUNK 2077

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



### METRO EXODUS

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



99th percentile Average

of 4.1GHz and 3.1GHz are short of the chip's potential maximums, and the chip hit toasty delta Ts between 71°C and 76°C before throttling.

## Conclusion

Chillblast's sub-£2,000 laptop delivers solid mainstream speed, a high-quality display and a comfortable keyboard. Crucially, it's cheaper than rivals with equivalent specifications and it has a great warranty. This involves some compromises though. Alternative (albeit pricier) machines have sleeker and more practical designs, and you'll find improved thermal and battery performance elsewhere.

The situation is no better if you pay £2,399 for an RTX 3080 Ti model, and its RTX 3060 rigs aren't much cheaper than equivalent laptops from different brands. We can recommend the Defiant if you want an RTX 3070 Ti laptop with a good screen and warranty for the lowest price possible, but don't expect much beyond those core areas.

MIKE JENNINGS

## VERDICT

Reasonably quick, with a good screen and a low price, but don't expect much finesse.

PERFORMANCE  
20/25

DESIGN  
17/25

HARDWARE  
19/25

VALUE  
22/25

OVERALL SCORE

78%

# Custom kit

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

## GARMEE CUP WARMER / £25.99 inc VAT

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

The Garmee Cup Warmer brings a new level of complexity to keeping a hot drink warm. It has a pressure-operated glass plate that's activated by the weight of your cup, or any other object that might happen to be pressing down on it. It also has a simple interface and display and three temperature settings – low, medium and high; as any scientist will tell you, these are the three different heats available.

You pick the temperature or switch it off with the on button, which is very simple and easy with the basics indicated by clear white lights. In terms of its effectiveness,



your mileage will vary based on the mug or cup that you use, but having abandoned ordinary-sized mugs of tea on it for 15-minute increments, I always came back to a drinkable cup of tea each time.

As with most mains-powered hot plates, it gets potentially hot enough to hurt you, and you need to be careful with it. If you're the sort of person who prefers to keep a forgotten cuppa on life support, rather than make a new one, though, the Garmee does its job pretty well.

Low ●●●●● High

## KKM MAGNETIC WIRELESS CHARGER / £16.99 inc VAT

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

Instead of passively sitting on a table like a regular charger, the KKM Magnetic Wireless Charger wants to get stuck in, or rather stuck on, and does its job while attached, via a magnet on the base.

The magnet itself is fairly weak though. The KKM manages to just about cling onto a phone with no case, but it's not strong enough to be useful. It will slide around and eventually fall off, and if you have a case on the phone, or any other device, there's no chance it will stick.

That said, the charging system still works through a case, and the small size of the pad is a plus point. With larger wireless charging pads there can be a bit of fuss involved with finding the sweet spot where the charging happens, and the petite KKM avoids this issue by simply not having room for wasted space.



Repelling ●●●●● Attracting

## WINEDON GAMEPAD / £23.99 inc VAT

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

The Winedon Gamepad packs an Xbox button pattern into a lightweight pad that's slightly smaller than usual. It's not much smaller, but it takes a while to get used to it in action – the buttons don't feel as if they're located where you would expect them. It's not much to look at either, and while nobody expects serious wow factor from a budget gamepad, there's an unflattering retro quality at work with the textured plastic grips and drab colour accents.

Functionally, it all works to the acceptable standard for a budget pad, but it doesn't deliver any pleasant surprises in this regard – the sticks are quite unyielding, resulting in imprecision, while conversely, there's a significant amount of play in the triggers.

The vibration works well enough though. This isn't a bad gamepad – it's functional enough for the cheap price, but there are better alternatives to be found.



Perfunctory ●●●●● Perfection

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and journalist

.....



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# How we test

## MOTHERBOARDS

### TEST PROCESSORS

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

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

All CPUs are cooled by a Corsair Hydro-X water-cooling loop with two XR5 240mm radiators, an XD3 RGB reservoir and an XC7 RGB waterblock. We test with our RealBench suite and Far Cry 6 on Windows 11. We test each board's M.2 ports with CrystalDiskMark, and record the noise level and dynamic range of integrated audio using RightMark Audio Analyzer.



## MONITORS

We test image quality with an X-Rite iDisplay Pro colorimeter and DisplayCal software to check colour accuracy, contrast and gamma, while assessing more subjective details such as pixel density and viewing angles by eye. For gaming, we test a monitor's response time with an Open Source Response Time Tester, and use Blur Busters' ghosting UFO test to check the sharpness of a display in high-speed motion.



## PROCESSORS

### TEST MOTHERBOARDS

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

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

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

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



## CPU COOLERS

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

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

### TEST KIT

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

### INTEL LGA1700

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

### INTEL LGA1200

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

### AMD AM4

Ryzen 7 5800X overclocked to 4.6GHz with 1.25V vcore, or Ryzen 5 5600X overclocked to 4.6GHz with 1.25V vcore on low-profile coolers, MSI MEG X570 Unify motherboard.



## GRAPHICS CARDS

We mainly evaluate graphics cards on the performance they offer for the price. However, we also consider the efficacy and noise of the cooler, as well as the GPU's support for new gaming features, such as ray tracing. Every graphics card is tested in the same PC, so the results are directly comparable. Each test is run three times, and we report the average of those results. We test at 1,920 x 1,080, 2,560 x 1,440 and 3,840 x 2,160, using an AOC U28G2XU monitor.



### TEST KIT

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

### GAME TESTS

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

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

**Doom Eternal** Tested at Ultra Nightmare settings, with resolution scaling disabled. We run a custom benchmark in the opening level of the campaign, and record the 99th percentile and average frame rates with Nvidia FrameView. This test requires a minimum of 8GB of graphics card memory to run, so it can't be run on 6GB cards.

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

### POWER CONSUMPTION

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



## CUSTOM PC AWARDS



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### 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.

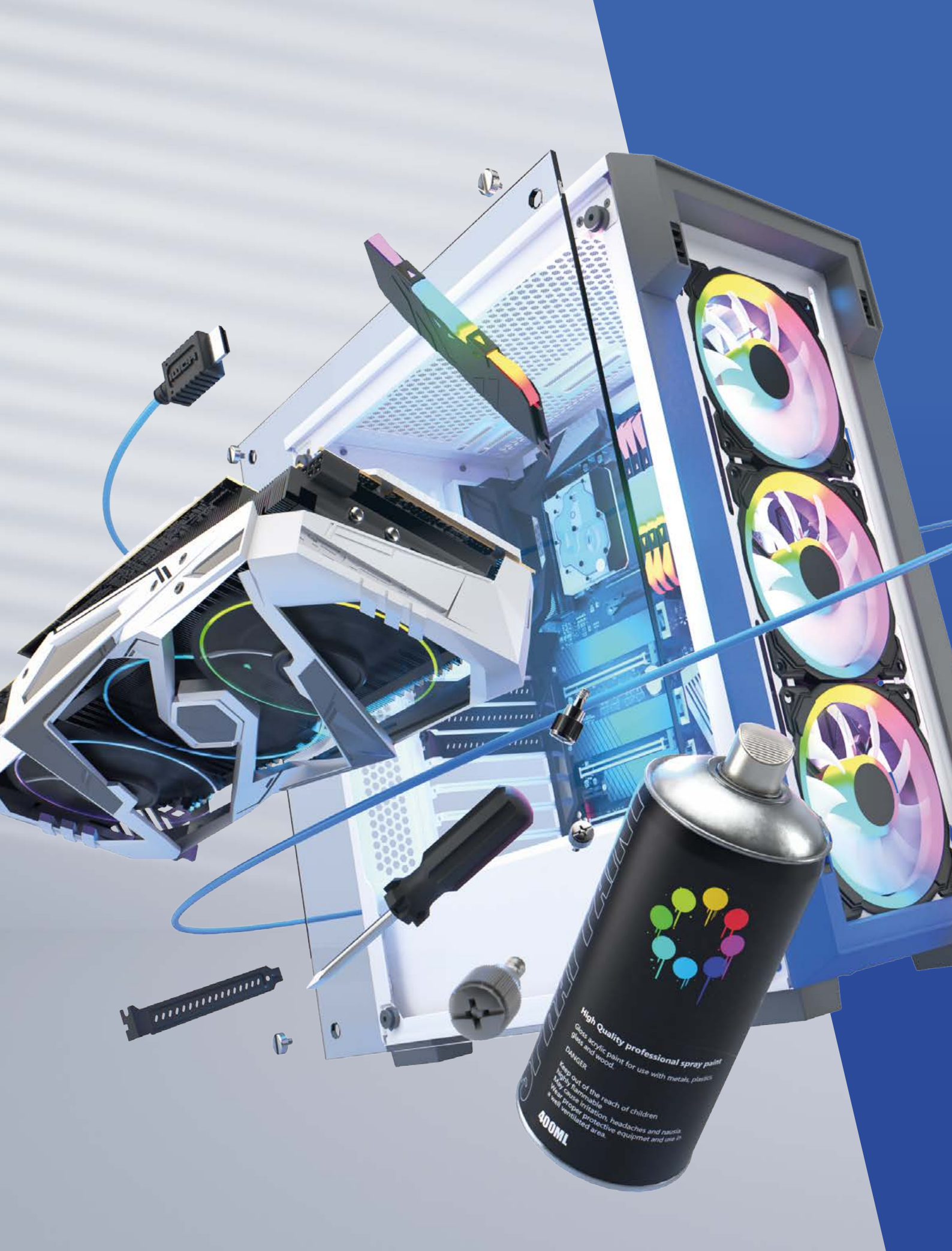
### LUXMARK OPENCL

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.







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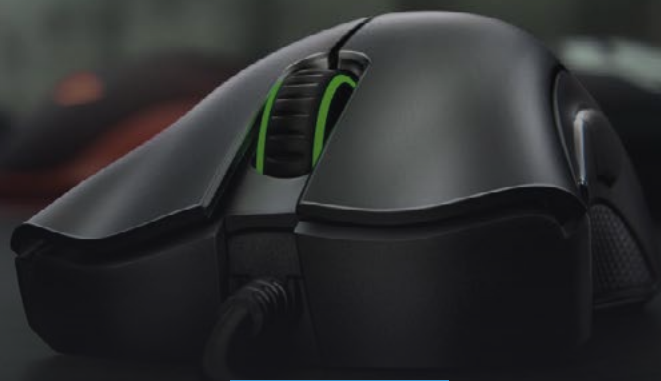
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## LABS TEST

# Penny pinching pointers

Edward Chester puts ten sub-£40 gaming mice through their paces, proving that you don't have to spend big to get decent gaming performance

## How we test

**N**ot surprisingly, budget mice simply tend to have fewer features than their pricier alternatives, so the addition of any extra buttons, RGB lighting or even just the ability to program the mouse via software are notable at this price range.

The shape, build quality and addition of extra physical features, such as the latest highly flexible lightweight braided cables, are all areas where some cheap mouse designs make compromises. At this price, you won't find any reputable brands offering a wireless option, so a cable that doesn't push back against your movements is a major plus point.

The modern trend for gaming mice to shed a fair bit of weight, using perforated cases or the latest lightweight materials, is also a rarity at the budget end, so lightweight models particularly stand out in this price range.

We tested our selection of gaming mice looking for all these above factors, while also using the mice during intensive gaming sessions, focusing on first-person shooters, where the ease with which you can grip the shape of the mouse, as well as the placement and accessibility of buttons, are so crucial. This also enables us to test the tracking ability of the sensors.

## Contents

- › AOC Gaming GM530 / p51
- › Cooler Master MM711 / p52
- › Corsair Sabre Pro Champion Series / p52
- › Endgame Gear XM1r / p53
- › Glorious Model O / p54
- › Logitech G203 Prodigy / p54
- › NZXT Lift / p55
- › Razer DeathAdder Essential / p56
- › SteelSeries Rival 3 / p56
- › Trust GXT 981Redex / p57



# AOC GAMING GM530 / £25 inc VAT

SUPPLIER amazon.co.uk

**A**s a relatively new entrant to the mouse market, we've only previously looked at one of AOC's gaming mice, the ultra-budget GM500, which retails for under a tenner. It had decent main switches and a good sensor but a basic shape, comparatively heavy weight and dull design. With a price more than double that of the GM500, the GM530 is understandably a considerably more capable offering.

The most obvious advantage of the GM530 over the GM500 is its greatly improved shape. The slightly concave curved rubber sides, with their Y-shaped texture, provide fantastic grip, while the scalloping on the two main buttons similarly helps your fingers to nestle into their centre.

It's similar in shape to the Razer DeathAdder, with a sloped right side and full body for providing proper palm support. However, despite this palm grip-centric shape, it still works well for other grip styles thanks to its middling size and quite narrow middle section. The only downside is its relatively heavy weight of 101g, which isn't far off double the weight of some of the mice on test this month.

It's a smart enough looking mouse, with a particularly classy-looking matt black coating, a neatly integrated RGB strip on the rear and a DPI indicator on the top. The AOC logo is a little

on the dull side compared with the likes of Razer's branding, but that's not a big deal when it only costs £25.

When it comes to buttons, the AOC offers the standard left, right, back, forward and scroll wheel/middle buttons, plus there are two DPI buttons behind the scroll wheel. The latter are quite large buttons, but they sit low, so they aren't easy to knock accidentally. Meanwhile, the scroll wheel is metal but not weighted, instead offering a precise notched feel that makes it easy to roll the wheel accurately. It's also easy to press the middle button without rolling the wheel.

AOC has employed Kailh switches, which are rated to a massive 80 million-click lifetime for the left and right buttons. They're loud and require a bit more force than the buttons on some mice, but they feel precise and positive in action.

A top-notch PixArt PMW3389 sensor is also used, providing maximum tracking figures of 16,000 DPI, 400 inches per second (IPS) movement speed and 50G acceleration. Those figures are right up there with the best gaming mice available, and sure enough, this mouse performed flawlessly in our gaming tests.

Conversely, the cable is of the stiff braided style, so there's noticeable cable pushback when you move the mouse, which we found a little distracting. Modern lightweight braided cables interfere far less with your movements.

On the underside of the mouse, there's also a profile switch, which saves having to jump into software to switch between settings. Four small glide pads sit in the corners, and while they provide smooth movement, they're so small that they're more likely to wear out quicker than larger pads.



## SENSORY

- + Top-end sensor
- + High-end switches
- + Great shape

## CENSORIOUS

- Not the sleekest design
- Stiff cable
- Heavy by modern standards

## Conclusion

AOC has done an excellent job with the GM530. The inclusion of a top-of-the-line sensor and high-endurance switches means it really has the gaming performance chops to compete with much more expensive mice. Its shape is very accommodating too, with the addition of rubber sides making it effortless to grip. On the downside, it's also comparatively heavy, and its cable is quite stiff, so it's not quite a home run. Its impressively capable for the price though.

## VERDICT

A high-end sensor, high-endurance switches and great shape put this mouse above many rivals at its surprisingly low price.

## SPEC

**Weight** 101g

**Dimensions (mm)** 55 x 125 x 42 (W x D x H)

**Sensor** PixArt PMW3389 - 16,000 DPI, 50g acceleration, 400 IPS

**Buttons** 7 (left, right, scroll wheel, back, forward, two top-mounted DPI)

**Cable** 1.8m, braided

**Extras** RGB lighting, profile switch

DESIGN  
14/20  
PERFORMANCE  
26/30

FEATURES  
14/20  
VALUE  
28/30

OVERALL SCORE  
**82%**

# COOLER MASTER MM711 / £30 inc VAT

SUPPLIER [box.co.uk](http://box.co.uk)

**C**ooler Master's MM711 sneaks into our sub-£40 price bracket thanks to it being several years old, leading to discounted current pricing. Originally priced at £50, it can now widely be found for just £30 inc VAT. It takes the recent trend of weight-reducing holes to the extreme. Almost the entire unit, other than the front two thirds of the sides and the main left and right buttons, are perforated.

## SPEC

**Weight** 60g

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

**Sensor** PixArt PMW3389 - 16,000 DPI, 50g acceleration, 400 IPS

**Buttons** 6 (left, right, scroll wheel, back, forward, top-mounted DPI)

**Cable** 1.8m, lightweight braided

**Extras** Internal RGB lighting

Add in its short shape and it's one of the lightest mice around, weighing just 60g. Dust can get into the holes, but the inside has a water-resistant coating to keep the electronics relatively safe. This shorter shape means you don't get much palm support, making this mouse suited to fingertip grip for most hand sizes, although it could work for claw and palm grip for smaller hands. The glossy or matt surfaces provide good purchase too, helped by the grip provided by the holes.

Styling is neat, with the holes mimicking Cooler Master's hexagonal company logo, and the same shape is also picked out in an RGB-lit ring on the rear. Features are basic, with just one extra DPI button sitting behind the scroll wheel being the only addition - it's easy to reach when

needed here, while otherwise staying well out the way.

Meanwhile, the main left and right buttons use 20 million click-rated Omron switches. They respond crisply, and while they're fairly light and quiet, they still provide a precise feel. The other buttons feel reasonably crisp



# CORSAIR SABRE PRO CHAMPION SERIES / £40 inc VAT

SUPPLIER [overclockers.co.uk](http://overclockers.co.uk)

**T**he full-fat £55 Corsair Sabre includes RGB lighting, but this non-RGB version costs just £40 inc VAT and its 69g weight is 5g lighter than the RGB version. It's fairly large, with a tall, bulbous back section that fills the area under your palm. It's ideal for palm grip use with small and medium-sized hands, but it also works well for other grip styles with medium to large hands.

Its plain black styling is simple without looking cheap, and its relatively coarse matt outer surface provides decent grip, even for dry hands - it's helped here by the tall sides, which provide plenty of surface area for your thumb and outer fingers.

You don't get any extra top-mounted buttons, but there's a DPI button on the underside with an RGB LED showing your

current DPI setting. DPI, polling rate and button assignments can be changed in iCUE, where you can set up to five DPI levels but annoyingly can't opt for fewer than three.

The Sabre uses 50 million-click Omron switches for the left and right buttons. They feel snappy yet light, as do the back and forward thumb buttons. The middle button is also easy to press without moving the wheel, and the wheel has a satisfyingly knobbly rubber grip. Meanwhile, the fixed, lightweight



## SPEC

**Weight** 69g

**Dimensions (mm)** 70 x 129 x 43 (W x D x H)

**Sensor** PixArt PAW3392 - 18,000 DPI, 50G acceleration, 450 IPS

**Buttons** 5 (left, right, scroll wheel, back, forward)

**Cable** 2.1m, lightweight braided

**Extras** RGB lighting skirt, DPI button on underside

## SABRE RATTLING

- + Comfortable palm grip design
- + Lightweight
- + Solid gaming performance

## TIN CAN RATTLE

- Quite bulky
- Baggy-looking cord braiding
- No RGB

## HOLES IN YOUR MOUSE

- + Very light
- + Fantastic value
- + Great overall performance

## HOLES IN YOUR ARGUMENT

- Short shape won't suit everyone
- Holes can let in grime

too, while the scroll wheel has well-defined notches and it's easy to press the middle button without rolling the wheel. The PixArt PMW3389 sensor provides flawless tracking too, and the lightweight braided cable provides minimal pushback.

At its current £30 inc VAT price, the MM711 is an absolute steal, assuming you don't mind the slightly stubby mouse shape. It's incredibly light, comfortable and has flawless performance.

## VERDICT

Light, easy to use and currently very well priced.

DESIGN 18/20	FEATURES 16/20	OVERALL SCORE <b>86%</b>
PERFORMANCE 26/30	VALUE 26/30	

2.1m braided cable has minimal pushback, but the outer braided sleeve is loose and oversized, looking a little messy.

Corsair's Axon processor powers this mouse, providing up to an 8kHz polling rate and on-board setting recall, so you don't need Corsair's software to keep your mouse settings. Meanwhile, the PixArt PMW3392 sensor proved flawless in our gaming tests.

The Sabre is quite large, but light, comfortable and capable when it comes to gaming. It's not ideal for those with smaller hands or that prefer a fingertip-centric mouse design, but if you like a hand-filling mouse shape, the Sabre delivers the goods for a reasonably low price.

## VERDICT

A capable budget gaming mouse for palm grip users, or those with medium to large hands.

DESIGN 16/20	FEATURES 14/20	OVERALL SCORE <b>80%</b>
PERFORMANCE 28/30	VALUE 22/30	

# ENDGAME GEAR XM1R / £40 inc VAT

SUPPLIER [overclockers.co.uk](http://overclockers.co.uk)

**T**he Endgame Gear XM1r is a simple mouse with just five main buttons and a scroll wheel on its top.

However, on its underside, it also has a button and two LEDs that combine to select and indicate the polling rate and DPI.

A tap of the bottom button cycles through the four available DPI settings (400, 800, 1,600 and 3,200) with the LEDs changing colour accordingly (blue, green, yellow and red). Meanwhile, a long press switches between 125Hz (left LED), 500Hz (right LED) and 1000Hz (both LEDs) polling rates. It's a neat system.

Also on the underside are the surprisingly thick but wonderfully smooth glide pads. Smaller pads are fitted by default, but larger pads are included in the box.

## XMP

- + Excellent tracking
- + Decent value

## EX-MP

- Mushy-feeling side buttons
- Basic feature set
- No software yet

## SPEC

**Weight** 68g

**Dimensions (mm)** 66 x 122 x 38 (W x D x H)

**Sensor** PixArt PAW3370 - 19,000 DPI, 50g acceleration, 400 IPS

**Buttons** 5 (left, right, scroll wheel, back, forward)

**Cable** 1.8m, lightweight braided

**Extras** DPI and polling rate control button on underside

Inside, the XM1r uses the excellent PixArt PAW3370 sensor. In theory, it can deliver up to 19,000 DPI, configurable in steps of 50 DPI but, without software to configure this yet, you only get the default options for now. Kailh GM 8 switches are used for the left and right buttons, and they're rated to 80 million clicks. They provide a more pronounced click than some alternatives, but the back and forward buttons feel a little mushy.

Meanwhile, the scroll wheel is very lightweight with subtle notches and a quite stiff middle button. We found this combination resulted in us often rolling the wheel when just trying to press the middle button. In terms of shape, the XM1r is quite short and wide, so it's not particularly well suited to small hands but works well for medium to large hands. At 72g, it's not a record setter but still quite light.

The Endgame Gear XM1r is a no-frills gaming tool that delivers excellent sensor performance and all the essentials for a reasonable price. However, its side buttons feel a tad mushy and its scroll wheel is too easy to accidentally roll.

## VERDICT

A capable mouse for its price, although it's pipped to the post by some finer choices.

DESIGN 12/20	FEATURES 14/20	OVERALL SCORE <b>76%</b>
PERFORMANCE 26/30	VALUE 24/30	





# GLORIOUS MODEL O / £40 inc VAT

SUPPLIER [overclockers.co.uk](http://overclockers.co.uk)

**T**he Glorious Model O has maintained a slot on our Elite List for years, thanks to its great design and impressively low price. Now widely available for just £40 inc VAT, it still impresses. Its long, gently sloped and symmetrical shape is comfortable for most grip styles with a wide variety of hand sizes – and if it is too large for you, there's the smaller

Model O-. It's also impressively light for a mid-size mouse, at just 67g. The sides could be flatter, but largely this mouse's shape is excellent.

Styling is another plus point, assuming you don't mind the weight-saving perforated look. RGB lighting is neatly integrated around the sides of the scroll wheel and in stripes down the sides, while the simple black or white finishes keep the look attractively clean and simple.

The only downside is the cheesy company logo on the sides of the mouse. You can also order replacement cables in different colours to add some pizzazz, and replacement glide pads are available too.



## SPEC

**Weight** 67g

**Dimensions (mm)** 66 x 128 x 38 (W x D x H)

**Sensor** PixArt PAW3360 - 12,000 DPI, 50g acceleration, 250 IPS

**Buttons** 6 (left, right, scroll wheel, back, forward, top-mounted DPI)

**Cable** 1.8m, lightweight braided

**Extras** RGB lighting, replaceable cables

Along with the scroll wheel and left, right, back and forward buttons, there's a tiny DPI button behind the scroll wheel that's easy to tap when needed.

## MODEL STUDENT

- + Fantastic shape
- + Lightweight
- + Excellent performance

## HIGH SCHOOL DROP OUT

- Silly company graphics
- Older sensor than some rivals

# LOGITECH G203 PRODIGY / £30 inc VAT

SUPPLIER [overclockers.co.uk](http://overclockers.co.uk)

**T**he G203 has been Logitech's budget wired gaming mouse option for years, and while that longevity could be seen as testament to a good design, Logitech could do with issuing an update now. It's a petite mouse, measuring around 10mm shorter and

3–4mm narrower than many rivals. Its lozenge-like shape is much less contoured to the curves of your hands too.

The left and right buttons have slight dips in their middle to help centre your fingers, but otherwise it's a largely convex shape. It's also surprisingly heavy for its size, weighing 85g. Despite this not overly accommodating shape and weight, the G203 is still easy to use and works well for fingertip grip with most hand sizes, and even works for palm and claw grip with small hands.

You get just the one extra button – a DPI button behind the scroll wheel. It's large enough to be pressed with the base of the



middle finger when required but

otherwise doesn't get in

the way. Logitech doesn't state the type of switches used in the G203, but they feel reasonably crisp and responsive. However, they're loud, producing a hollow, echoey noise that doesn't evoke the hefty engineered feel of the Kailh switches and belies the petite size of this mouse.

On the underside is the optical sensor and four tiny glide pads that will wear down quicker than larger pads. The former is basic by today's standards but we didn't notice any major hiccups during our gaming sessions. More of a concern when gaming

## SPEC

**Weight** 85g

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

**Sensor** Logitech optical - 8,000 DPI, 25g acceleration, 200 IPS

**Buttons** 6 (left, right, scroll wheel, back, forward, top-mounted DPI)

**Cable** 2.1m, rubber coated

**Extras** RGB lighting

The Model O uses the PixArt 3360 sensor, which is a little older than the sensors on some mice in this test but still proved flawless in our testing.

Meanwhile, Omron switches are used for the left and right buttons. They have a lighter feel than the Kailh switches and are only rated to 20 million clicks, but they still feel precise and responsive.

Despite being a few years old and not having the very latest sensor, the Model O remains an excellent mouse. Its shape is accommodating, it's lightweight, its sensor works well and its buttons feel great and fall to hand in the right places. If you can afford to step up to £40, this is a great buy.

## VERDICT

An excellent mid-sized mouse for its current price.

DESIGN 17/20	FEATURES 14/20	OVERALL SCORE <b>83%</b>
PERFORMANCE 26/30	VALUE 26/30	

## THE PRODIGY

- + Reasonably comfortable shape
- + Neat RGB lighting
- + Functional overall design

## 2 UNLIMITED

- Heavy by modern standards
- Older sensor than some rivals
- Relatively stiff cable

is the cable. It's slim but still has significant, distracting pushback compared with modern lightweight braided designs.

Compact, cheap and reasonably stylish, the G203 is fine as a small mouse design. However, it could do with an update to include a modern lightweight cable, lighter overall build and better sensor.

## VERDICT

A capable small mouse but other cheap mice offer more for your money.

DESIGN 12/20	FEATURES 12/20	OVERALL SCORE <b>66%</b>
PERFORMANCE 20/30	VALUE 22/30	



# NZXT LIFT / £40 inc VAT

SUPPLIER scan.co.uk

**T**he Lift has a seriously slick design. It comes only in matt black or white and uses a clean, symmetrical shape with the NZXT logo subtly picked out in glossy text on the rear. RGB lighting strips run down each side, providing a gentle under glow. For an extra £20, you can also opt for the scroll wheel, buttons, underside and cable to come in one of five accent colours.

The shape is very reminiscent of the Glorious Model O, with a long, gently sloped rear, with slightly flared left and right buttons and heavily contoured sides. It's a very comfortable shape for a variety of grip styles and hand sizes, although the sides could be just a little taller and flatter. The surface also isn't the grippiest in dry conditions but the light 67g weight is excellent, as is the fixed

lightweight braided cable, which provides minimal pushback.

The Lift incorporates five main buttons, with the addition of a small DPI button behind the scroll wheel. The latter balances staying well out the way for normal use but is easy to find with your index finger when required. The left and right buttons use Omron switches that feel decently snappy and are rated to 20 million clicks. The other buttons all feel crisp too. The knobby rubber scroll wheel surface is also very grippy and the wheel has well defined notches, plus it's easy to press the middle button without rolling the wheel.

Meanwhile, the underside is featureless other than the very large and smooth glide pads. The Lift's sensor is also the excellent PixArt 3389, with a maximum DPI of 16,000. It performed flawlessly, and you can configure it and the polling rate, lift of distance and more in NZXT's excellent CAM software.

NZXT has nailed it first time with the Lift. It looks smart, it has decent features, well-integrated RGB lighting, a comfortable shape, superb performance and a competitive price.

## LIFT

- + Slick design
- + Decent features
- + Great performance

## STAIRS

- Not the grippiest outer surface
- Needs flatter sides

## SPEC

Weight 67g

Dimensions (mm) 67 x 127 x 38 (W x D x H)

Sensor PixArt PAW3389 - 16,000 DPI, 50g acceleration, 400 IPS

Buttons 6 (left, right, scroll wheel, back, forward, top-mounted DPI)

Cable 1.8m, lightweight braided

Extras RGB lighting skirt

## VERDICT

A clear winner for style, features and performance at this price.

DESIGN 18/20	FEATURES 16/20	OVERALL SCORE <b>87%</b>
PERFORMANCE 27/30	VALUE 26/30	



# RAZER DEATHADDER ESSENTIAL / £25 inc VAT

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

**R**azer has surprised us in this test by offering a variant of one of its flagship mice at a price that doesn't just sneak under our price limit but sails clear below it. All the current DeathAdder models sport the same core shape but the Essential skimps on most other aspects.

For a start, the extra DPI buttons behind the scroll wheel of the V2 Pro are gone, plus the

sensor is a far more basic unit with a maximum DPI of 6,400, tracking speed of 220 IPS and maximum acceleration of 30g, compared to 20,000 DPI, 500 IPS and 50g for the V2 Pro.

Weight is another compromise, with the Essential tipping the scales at 96g. That's 14g heavier than the V2 Pro and it's some 20-30g heavier than several other mice in this Labs test. Despite this, the Essential still feels fantastic to use, thanks to its wonderfully contoured shape and rubber side grips. It suits most grip styles for medium to large hands, and is great for palm and claw grips with medium and small hands.

## SPEC

**Weight** 96g

**Dimensions (mm)** 62 x 127 x 43 (W x D x H)

**Sensor** Razer optical - 6,400 DPI, 30g acceleration, 220 IPS

**Buttons** 5 (left, right, scroll wheel, back, forward)

**Cable** 1.8m, lightweight braided

**Extras** Green lighting

## EVERYDAY ESSENTIALS

- + Smart styling
- + Comfortable shape
- + Great value

## ESSENTIALLY USELESS

- A little heavy
- Basic sensor
- Stiff cable

# STEELSERIES RIVAL 3 / £25 inc VAT

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

**S**teelSeries' Rival 3 is similar to Logitech's G203 Prodigy in that it's notably compact and cheap, and also includes RGB lighting, while featuring a relatively modest sensor. However, where the Logitech had notable drawbacks, such as its weight and stiff cable, the Rival 3 has fewer issues.

Its shape is quite narrow where you grip the sides, so it isn't ideal for larger hands, but then it also splays out towards the back,

resulting in your fingers sliding forwards. It works if you grip the mouse with only your little finger but feels awkward if you use your ring finger too.

With a weight of 77g, the Rival 3 is far from the lightest mouse but it's trimmer than the Logitech. Plus, although the rubber-coated cable arrives kinked, it's more flexible than that of the Logitech, making for less pushback. With its RGB-lit skirt and SteelSeries logo, the Rival 3 also looks smart, especially with its high-quality black finish.

The Rival 3 includes five standard buttons plus a top-mounted DPI button. The latter is small but tall enough that you could hit it accidentally in gaming, although this didn't happen to us in testing. Meanwhile, the



## SPEC

**Weight** 77g

**Dimensions (mm)** 67 x 121 x 38 (W x D x H)

**Sensor** SteelSeries TrueMove Core - 8,500 DPI, 35g acceleration, 300 IPS

**Buttons** 5 (left, right, scroll wheel, back, forward)

**Cable** 1.8m, rubber coated

**Extras** RGB lighting

## UNRIVALLED

- + Good sensor and switches
- + Smart design with RGB lighting
- + Good value

## UNRAVELLED

- Divisive shape
- A little heavy for its size



The left and right button switches are only rated to ten million clicks, which is low by modern standards, but they still feel precise and responsive. Similarly, the 6,400 DPI sensor has low headline figures but still held up in our tests.

The Essential doesn't have RGB lighting, but the rear Razer logo and scroll wheel sides light up in green. Meanwhile, the cable is braided but it's the older stiff style of cable, so there's quite a bit of cable pushback.

There are definite compromises to the DeathAdder Essential. Its sensor and switches aren't up to the level of plenty of other mice in this Labs test, and its cable is quite stiff. However, at just £25 inc VAT, it's very cheap for what's still a very comfortable and capable mouse.

## VERDICT

A little heavy, and with a stiff cable, but this is still a capable and great-value gaming mouse.

DESIGN 18/20	FEATURES 10/20	OVERALL SCORE <b>78%</b>
PERFORMANCE 22/30	VALUE 28/30	

notches on the scroll wheel aren't the most distinct but we had no issues pressing the middle button without nudging the wheel.

Although it's only rated to 8,500 DPI, the SteelSeries TrueMove Core sensor has reasonable ratings of 300 IPS movement speed and 35g acceleration, putting it well ahead of the Logitech. Moreover, it performed flawlessly in our tests. Impressively, its main two switches are also rated to a massive 60 million clicks.

The Rival 3's shape isn't ideal for larger hands, but if you can get on with its design then it otherwise delivers the goods. It looks smart, has a good sensor and switches, and it's not too heavy either.

## VERDICT

A slightly more divisive shape than some rivals, but performance is good for the price.

DESIGN 12/20	FEATURES 14/20	OVERALL SCORE <b>77%</b>
PERFORMANCE 24/30	VALUE 27/30	



# TRUST GTX 981 REDEX / £28 inc VAT

SUPPLIER [argos.co.uk](http://argos.co.uk)

**T**he GTX 981 Redex is markedly small, being 12mm narrower and 15mm shorter than the NZXT Lift, for instance. It weighs only 74g but considering its size that makes it relatively dense by modern standards. As a result, it's best suited to those with smaller hands, although its shape is surprisingly accommodating to larger paws. The gentle inward curve of the sides centres the fingers well, while the relatively high, flat sides provide room for your fingers to grip.

In terms of styling, the backlit GXTrust writing on the rear isn't the most alluring, and the overall design lacks the sleekness of some other options, but you do get software-

programmable RGB lighting around the scroll wheel and illuminating the rear.

For features, the Trust is very similar to most of the other mice on test, with just the one extra DPI button sat behind the scroll wheel. Like the SteelSeries, the button is small but sits proud enough that it could be knocked accidentally, although we didn't find this an issue in our tests. On the underside, there's a slider for setting the polling rate too.

This mouse uses Kailh switches rated to 80 million clicks for its left and right buttons, and its sensor tops out at 10,000 DPI. However, the latter is only rated to 20g acceleration and 100 IPS, so it's well behind some other mice on test for these measures, even if we didn't notice the difference when gaming.

The Trust GTX 981 Redex is a viable option for a small gaming mouse. It's easy to get on with its shape, and while its sensor isn't up there with the best, it performs well. However, the Cooler Master MM711 has a similar price with a better sensor and a much lighter weight.

## TRUSTED

- + Comfortable shape
- + Decent feature list for the price
- + 80 million-click Kailh switches

## BUSTED

- Relatively heavy for its size
- Small size limits appeal
- Low maximum sensor specs

## SPEC

Weight 74g

Dimensions (mm) 54 x 112 x 39 (W x D x H)

Sensor PixArt PMW3325 - 10,000 DPI, 20g acceleration, 100 IPS

Buttons 6 (left, right, scroll wheel, back, forward, DPI, lighting)

Cable 1.8m, braided

Extras RGB lighting

## VERDICT

Impressively petite and perfectly capable but spending just a tiny amount more gets you a lighter build and better sensor.

DESIGN 12/20	FEATURES 14/20	OVERALL SCORE <b>70%</b>
PERFORMANCE 20/30	VALUE 24/30	

## 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	£260
CPU COOLER	AMD Wraith air cooler included with CPU	N/A	#218 p20	£0
GRAPHICS CARD	AMD Radeon RX Vega 8 integrated into CPU	N/A	#218 p20	£0
MEMORY	16GB (2 x 8 GB) Corsair Vengeance LPX Pro 3200MHz (CMK16GX4M2B3200C16)	scan.co.uk	#218 p78	£62
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	£51

**Total £478**

### 1,920 x 1,080 gaming

#### 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	cclonline.com	#227 p51	£186
CPU COOLER	ARCTIC Freezer i13X	scan.co.uk	#224 p76	£23
GRAPHICS CARD	Nvidia GeForce RTX 3060 Ti	nvidia.com	#228 p90	£369
MEMORY	16GB (2 x 8 GB) Corsair Vengeance LPX DDR4 3200MHz (CMK16GX4 M2B3200C16)	scan.co.uk	#224 p76	£62
MOTHERBOARD	Gigabyte B660 Gaming X DDR4 (ATX)	scan.co.uk	#224 p50	£153
STORAGE	1TB WD Blue SN570 (M.2 NVMe)	scan.co.uk	#222 p20	£77

**Total £870**

#### UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 3070 Ti	nvidia.com	#228 p90	£549
SWAP STORAGE	1TB WD Black SN850	scan.co.uk	#225 p27	£130

## 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	£380
CPU COOLER	ARCTIC Liquid Freezer II 240 RGB (240mm AIO liquid cooler)	scan.co.uk	#226 p49	£90
LGA1700 ADAPTOR	ARCTIC Liquid Freezer II Upgrade Kit	scan.co.uk	#226 p49	£5
GRAPHICS CARD	Nvidia GeForce RTX 3070 Ti	nvidia.com	#228 p90	£549
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz DDR4 (CMW16GX4 M2D3600C18)	scan.co.uk	#230 p47	£80
MOTHERBOARD	Gigabyte Z690 Gaming X DDR4*	scan.co.uk	#222 p46	£220
STORAGE	1TB WD Black SN850	scan.co.uk	#225 p27	£130

**Total £1,454**

#### UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	ebuyer.com	#166 p54	£85
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\*This motherboard will need its BIOS updated in order to recognise the new CPU. This new BIOS can be downloaded online from [custompc.co.uk/GigabyteBIOS](http://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	£380
CPU COOLER	ARCTIC Liquid Freezer II 240 RGB (240mm AIO liquid cooler)	scan.co.uk	#226 p49	£90
LGA1700 ADAPTOR	ARCTIC Liquid Freezer II Upgrade Kit	scan.co.uk	#226 p49	£5
GRAPHICS CARD	Nvidia GeForce RTX 3080 Ti	nvidia.com	#226 p78	£929
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz DDR4 (CMW16GX4M 2D3600C18)	scan.co.uk	#230 p47	£73
MOTHERBOARD	Asus ROG Strix Z790-A Gaming WiFi D4	scan.co.uk	#232 p34	£400
STORAGE	1TB WD Black SN850	scan.co.uk	#225 p27	£130

**Total £2,014**



# 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	£429
CPU COOLER	Corsair iCUE H150i Elite LCD (360mm AIO liquid cooler)	scan.co.uk	#226 p78	£230
GRAPHICS CARD	Nvidia GeForce RTX 4090	ebay.co.uk	#232 p28	£2,400
MEMORY	32GB (2 x 8GB) G.Skill Trident Z5 Neo DDR5 6000MHz EXPO (F5-6000J3636 F16GX2-TZ5N)	memoryc.co.uk	#231 p21	£220
MOTHERBOARD	Asus TUF Gaming X670E-Plus WiFi	cclonline.com	#232 p36	£327
STORAGE	1TB WD Black SN850	scan.co.uk	#225 p27	£130
Total £3,736				

## 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	£800
CPU COOLER	Corsair iCUE H150i Elite LCD (360mm AIO liquid cooler)	scan.co.uk	#226 p78	£230
GRAPHICS CARD	Nvidia GeForce RTX 3060 Ti	nvidia.com	#220 p53	£369
MEMORY	32GB (2 x 8GB) G.Skill Trident Z5 Neo DDR5 6000MHz EXPO (F5-6000J3636 F16GX2-TZ5N)	memoryc.co.uk	#230 p54	£220
MOTHERBOARD	ASRock X670E Steel Legend	scan.co.uk	#222 p50	£380
STORAGE	2TB WD Black SN850	scan.co.uk	#225 p27	£300
Total £2,299				
UPGRADES				
SWAP GRAPHICS CARD	Nvidia GeForce RTX 4090	ebay.co.uk	#232 p28	£2,400

# 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)
<b>Intel Z690</b> (LGA1700)	Gigabyte Z690I Aorus Ultra Plus	amazon.co.uk	#228 p46	£352
<b>Intel B660</b> (LGA1700)	Gigabyte B660I Aorus Pro DDR4	scan.co.uk	#228 p47	£220
<b>AMD X670</b> (AM5)	Asus ROG Strix X670E-I Gaming WiFi	scan.co.uk	#232 p38	£470
<b>AMD B550</b> (AM4)	Asus ROG Strix B550-I Gaming	cclonline.com	#228 p39	£232

### Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>ALL-PURPOSE</b>	Cooler Master MasterBox NR200P	scan.co.uk	#206 p18	£100
<b>TOWER</b>	Ssupd Meshlicious	overclockers.co.uk	#225 p51	£105
<b>HIGH AIRFLOW</b>	Fractal Design Torrent Nano	scan.co.uk	#225 p45	£120
<b>PREMIUM</b>	Streacom DA2 V2	quietpc.com	#214 p51	£199

### Other components

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

## ATX cases



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>BUDGET RGB</b>	Antec DF700 Flux	cclonline.com	#214 p26	£88
<b>SUB-£100 AIRFLOW</b>	Corsair 4000D Airflow	scan.co.uk	#222 p56	£110
<b>COMPACT</b>	Fractal Design Meshify 2 Compact	scan.co.uk	#215 p20	£125
<b>HIGH AIRFLOW</b>	Fractal Design Meshify 2	scan.co.uk	#212 p45	£160
<b>PREMIUM HIGH AIRFLOW</b>	Fractal Design Torrent RGB TG	scan.co.uk	#225 p20	£250
<b>LUXURY</b>	Corsair iCUE 5000T RGB	scan.co.uk	#224 p22	£350

## Micro-ATX



### Motherboards

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

### Cases

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

## Networking



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>BUDGET ROUTER</b>	Belkin RT3200-UK	amazon.co.uk	#216 p52	£86
<b>ROUTER</b>	Asus RT-AX68U	scan.co.uk	#216 p51	£177
<b>MESH ROUTER</b>	Asus ZenWiFi AX Hybrid XP4	amazon.co.uk	#226 p59	£260
<b>WI-FI ADAPTOR</b>	TP-Link Archer TX3000E	overclockers.co.uk	#196 p58	£60
<b>DUAL-BAY NAS BOX</b>	Synology DS220j	box.co.uk	#200 p22	£159
<b>DUAL-BAY MEDIA NAS BOX</b>	Synology DS218play	box.co.uk	#174 p34	£209
<b>2.5 GIGABIT DUAL-BAY NAS BOX</b>	QNAP TS-231P3	box.co.uk	#212 p25	£307

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

# Monitors



## Up to 25in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>24IN, 144Hz, IPS, 1,920 X 1,080, F, G</b>	AOC 24G2U	cclonline.com	#214 p28	£150
<b>25IN, 240Hz, IPS, 1,920 X 1,080, F, G</b>	Acer Predator XB253Q	box.co.uk	#209 p57	£220
<b>25IN, 360Hz, IPS, 1,920 X 1,080, F, G</b>	Asus ROG Swift PG259QN	box.co.uk	#212 p20	£703

## Up to 28in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>27IN, 144Hz, IPS, 1,920 X 1,080, F, G</b>	AOC 27G2U	overclockers.co.uk	#201 p53	£170
<b>27IN, 165Hz, IPS, 2,560 X 1,440, F, G</b>	LG UltraGear 27GP850	currys.co.uk	#229 p48	£379
<b>27IN, 165Hz, VA, 2,560 X 1,440, F, G</b>	AOC CQ27G3SU	overclockers.co.uk	#223 p45	£290
<b>27IN, 240Hz, TN, 2,560 X 1,440, F, G</b>	AOC AG273QZ	overclockers.co.uk	#202 p27	£590
<b>27IN, 240Hz, IPS, 2,560 X 1,440, F, G</b>	Alienware AW2721D	dell.com	#212 p21	£620
<b>28IN, 144Hz, IPS, 3,840 X 2,160, F, G</b>	AOC U28G2XU	overclockers.co.uk	#221 p29	£569

## Over 28in

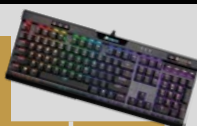
CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>31.5IN, 60Hz, VA, 3,840 X 2,160, F</b>	iiyama ProLite XB3288UHSU	scan.co.uk	#205 p43	£370
<b>32IN, 144Hz, VA, 2,560 X 1,440, F, G</b>	iiyama G-Master GB3266QSU	scan.co.uk	#224 p30	£320
<b>32IN, 165Hz, IPS, 2,560 X 1,440, F, G</b>	LG UltraGear 32GP850	currys.co.uk	#220 p38	£449
<b>34IN, 144Hz, IPS, 3,440 X 1,440, W, F</b>	iiyama G-Master GB3461WQSU	overclockers.co.uk	#206 p53	£370
<b>38IN, 144Hz, IPS, 3,840 X 1,600, W, F, G, HDR</b>	LG UltraGear 38GN950	currys.co.uk	#208 p30	£1,349
<b>32IN, 240Hz, VA, 3,840 X 2,160, F, G, HDR</b>	Samsung Odyssey Neo G8	scan.co.uk	#229 p17	£1,299
<b>55IN, 165Hz, VA, 3,840 X 2,160, F, G, HDR</b>	Samsung Odyssey Ark	samsung.com	#231 p34	£2,599

## Non-gaming

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>27IN, 75Hz, IPS, 2,560 X 1,440, F</b>	LG 27QN880	amazon.co.uk	#210 p26	£385

# Peripherals and audio

## Gaming keyboards



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>BUDGET TKL</b>	SteelSeries Apex 3 TKL	currys.co.uk	#221 p59	£50
<b>MECHANICAL 65 PER CENT</b>	Ducky One 3 SF	overclockers.co.uk	#230 p26	£120
<b>MECHANICAL TKL</b>	NZXT Function MiniTKL	cclonline.com	#226 p32	£104
<b>PREMIUM TKL MECHANICAL</b>	Corsair K70 RGB TKL	scan.co.uk	#214 p31	£150
<b>PREMIUM MECHANICAL</b>	Corsair K70 RGB Pro	overclockers.co.uk	#225 p30	£150
<b>PREMIUM WIRELESS MECHANICAL</b>	Razer BlackWidow V3 Pro	overclockers.co.uk	#208 p60	£230

## Gaming mice



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>BUDGET GAMING</b>	NZXT Lift	scan.co.uk	#232 p55	£40
<b>FIRST-PERSON SHOOTER</b>	Glorious Model O	overclockers.co.uk	#232 p54	£40
<b>AMBIDEXTROUS</b>	Razer Viper 8K	currys.co.uk	#215 p59	£80
<b>MULTI-BUTTON</b>	Roccat Kone XP	roccat.com	#225 p60	£80
<b>WIRELESS</b>	Razer Viper Ultimate	currys.co.uk	#217 p54	£100
<b>PREMIUM WIRELESS</b>	Razer DeathAdder V2 Pro	scan.co.uk	#210 p28	£120
<b>ULTRA LIGHTWEIGHT</b>	Cooler Master MM711	box.co.uk	#232 p52	£30
<b>PREMIUM LIGHTWEIGHT WIRELESS</b>	Logitech G Pro X Superlight	amazon.co.uk	#217 p52	£109



# Peripherals and audio cont ...



## Game controllers



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>RACING WHEEL</b>	Logitech G29 Driving Force	currys.co.uk	#202 p50	£269
<b>BUDGET GAMEPAD</b>	PowerA Spectra Infinity Xbox Series X	amazon.co.uk	#228 p55	£40
<b>MID-RANGE GAMEPAD</b>	Sony DualSense	scan.co.uk	#228 p58	£60
<b>PREMIUM GAMEPAD</b>	Scuf Instinct Pro	scufgaming.com	#228 p57	£200
<b>BUDGET FLIGHT STICK</b>	Logitech Extreme 3D Pro Joystick	currys.co.uk	#207 p52	£48
<b>FLIGHT STICK</b>	Thrustmaster T.16000M FCS HOTAS	scan.co.uk	#207 p56	£130

## Gaming headsets

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>BUDGET STEREO</b>	Roccat Elo X Stereo	scan.co.uk	#210 p56	£40
<b>STEREO</b>	EPOS GSP 300	amazon.co.uk	#210 p54	£40
<b>WIRELESS</b>	Corsair Virtuoso RGB Wireless	ebuyer.com	#204 p50	£146
<b>PREMIUM WIRELESS</b>	EPOS H3Pro Hybrid	currys.co.uk	#231 p47	£220

## Speakers

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

## Non-gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>WIRELESS 84-KEY ELECTRO-CAPACITIVE</b>	Niz Mini 84 Pro	keyboardco.com	#220 p29	£132
<b>BUCKLING SPRING MECHANICAL</b>	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)
<b>BUDGET GAMING</b>	PC Specialist Prism Nova	Intel Core i5-12400F	Nvidia GeForce RTX 3060	custompc.co.uk/PrismNova	#229 p30	£1,199
<b>WATER-COOLED ULTIMATE PERFORMANCE</b>	CyberPower Hydro-X Infinity RTX	Intel Core i9-12900K	Nvidia GeForce RTX 3090 Ti	custompc.co.uk/CPHX	#228 p26	£4,084

## Laptops



CATEGORY	NAME	CPU	GPU	SCREEN	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>MID-RANGE GAMING</b>	Asus ROG Strix Scar 15 G533ZW	Intel Core i9-12900H	Nvidia GeForce RTX 3070 Ti Laptop	15.6in 2,560 x 1,440 IPS 240Hz	custompc.co.uk/AsusScar15	#227 p40	£2,200
<b>HIGH-SPEED GAMING</b>	Alienware x17 R2	Intel Core i7-12700H	Nvidia GeForce RTX 3080 Ti Laptop	17.3in 1,920 x 1,080 IPS 360Hz G-Sync	custompc.co.uk/AlienwareX17	#227 p38	£2,449

# Games



RICK LANE / INVERSE LOOK

## LEAK DETECTING

The growing number of video game leaks are a consequence of an industry being stretched to breaking point, argues Rick Lane

**I**n September, over 90 videos of an early version of Grand Theft Auto 6 were leaked online, the most significant game leak since Half-Life 2's source code was stolen. The GTA 6 leak resulted from a hack, with the footage allegedly stolen from the developer's Slack channel.

It's an extraordinary example of a phenomenon that's becoming increasingly common. Countless studios have seen information, screenshots or footage of their games leak prematurely online. This year alone, Stalker 2, Assassin's Creed Mirage, a reboot of Silent Hill 2 and an expansion to Cyberpunk have leaked online in one form or another before their developers were ready to reveal them. Leaks are becoming so frequent that, on the same day as the GTA 6 leak, Blizzard saw a huge chunk of Diablo 4 test-footage appear online.

Leaks can happen for multiple reasons, from external hacks to developers accidentally or deliberately revealing information prematurely. They've been a controversial feature of the industry for decades, but this recent surge in both size and frequency of leaks points to mounting infrastructural problems within the AAA games industry.

One cause is simply the size of modern game development studios. In the year 2000, The Creative Assembly, developer of the Total War series, employed fewer than 100 people, compared to over 800 today. This massive growth in team size makes it much harder for studios to oversee how their employees share and distribute game code and information, while also increasing the chance of employing someone with fewer scruples than their colleagues.

Another issue is security. The past 20 years have made it much easier to share information online, while the past two years have made such sharing a necessity. With many studios switching to a work-from-home structure due to the pandemic, in-development games are more vulnerable to both malicious actors such as hackers, as well as simple human error.

But there's also a third, less obvious factor at play. Over the past two decades, game development production cycles have ballooned. Where once upon a time games could be turned around within a year, today's average development cycle is approximately four years, and can stretch far longer than that.

This means game developers, who are highly creative people, are often prohibited from showing off their work for years on end. In extreme cases, they never get to show it. It's not uncommon for entire games to be cancelled at

the drop of a hat, meaning years of work can disappear into a void of corporate non-disclosure agreements.

All these factors combined create increasing pressure in an increasingly porous container. Even if developers keep their games safe from hackers and human error, it only takes one disgruntled employee to prematurely burst the bubble.

None of the above is a justification for leaks, which causes considerable grief for developers and, in cases where source code is leaked, can be legally and financially problematic for entire studios. However, due to the way the game industry has evolved structurally, it's hard to see how developers can prevent leaks without making significant changes. **CPC**

Game development  
production cycles  
have ballooned

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



# ARCADE PARADISE / £15.99 inc VAT

DEVELOPER Nosebleed Interactive / PUBLISHER Wired Productions

**A**rcade Paradise is a nostalgic love letter to coin-ops, 8-bit graphics and chiptune soundtracks. You play a teenage layabout tasked with running a laundrette owned by your wealthy, workaholic father. After discovering a handful of old stand-up gaming machines in a dingy back room, your character decides to convert the laundrette into a thriving arcade.

You divide your time between management simulation and retro-gaming. Converting the laundrette into an arcade requires money. A basic income is provided by the laundrette, where you fill and empty washing machines and tumble dryers, pick up litter and occasionally take a plunger to the toilet. Cleaning clothes provides you with a small amount of cash that lets you buy new arcade machines, each of which helps to increase your passive income.

Each arcade machine is also a fully functioning retro-styled game that plays on classic arcade archetypes. These include Woodgal's Adventure, a blend of Zelda-style exploration and match-3 puzzling, a Towers of Hanoi-style game called Stack Overflow, and Racer Chaser, a mashup of

Pac-Man and Grand Theft Auto where you collect bundles of cash on a maze of roads while being chased by police cars.

There are over 35 games, and while some are undoubtedly better than others, they're all fun enough to occupy the quiet moments when you're not tending to the laundrette or musing your next arcade machine purchase.

It's an intriguing blend of ideas that works well for the most part. Balancing profit maximisation with spending time on the machines makes for an enjoyable plate-spinning challenge, while a constant drip feed of new features accompanies your arcade expansion, such as daily work challenges that provide a second type of income, which can then be used to purchase efficiency-boosting upgrades.

Not only does each arcade game look and feel authentic, but the daily grind of the laundrette is also viewed through an arcade lover's lens. Every work chore is presented as a minigame, from tossing bin bags into the dumpster to pulling discarded chewing gum off surfaces.

After a novel first few hours, though, the daily grind of the laundrette sets in, and there isn't sufficient breathing space to appreciate the arcade games – you're snatching a minute here, 30 seconds there. Annoyingly, you're also ordered to go home after a certain time, with the potential punishment of your character passing out. It needs a solid chunk of downtime somewhere in each day, where you can do more than scratch the surface of the game you've chosen to play.

This aside, Arcade Paradise is a fascinating hybrid, especially if you have a soft spot for the 8-bit era. It will also please aficionados of industrial washing machines, although that's probably not why you're reading this magazine.

RICK LANE

## PARADISE

- + Interesting concept
- + Fun hybrid play
- + Wonderful suite of knock-off arcade games

## PAIR OF DICE

- Laundrette element lacks depth
- Too strict on your time

## / VERDICT

A pleasant slice of management and nostalgia, although it's slightly undermined by its workaholic attitude.

## OVERALL SCORE

75%





# Immortality / £15.49 inc VAT

DEVELOPER Sam Barlow, Half Mermaid / PUBLISHER Half Mermaid



**M**arissa Marcel starred in three films – a 1968 gothic horror, a detective drama two years later and a glitzy thriller filmed just before the millennium. Then she disappeared. None of the movies was ever released commercially, and between her second and final project, Marissa spent most of her life in seclusion.

The details of her life and career were a mystery, until an archive of footage from all three films was unexpectedly discovered. Unedited and disorganised, the footage represents a jigsaw puzzle of a life in forgotten stardom, a jigsaw puzzle that you're tasked with assembling.

This is the premise for *Immortality*, which is simultaneously the most ambitious full-motion video (FMV) game ever made, and a wild experiment in modern filmmaking. Combining a remarkable eye for period detail with sharp, authentic writing and some of the best acting you'll ever see in a game, *Immortality* is a spellbinding example of interactive storytelling.

Directed by Sam Barlow, *Immortality* is structurally similar to his previous game *Her Story*, with players piecing together a coherent narrative from a large archive of short video clips. However, there are two key differences.

Firstly, *Immortality* introduces a new mechanic through which the video clips are connected. Each clip has multiple interactable objects within it, ranging from actor's faces to inanimate objects within the scene, such as windows, paintings, jewellery, furniture, clothes and so on.

Clicking on any highlightable object in a single video will trigger a 'match-cut', with the in-game camera zooming in on that object, then zooming out on a similar object from a new clip, which is added to your archive and can now be explored. In this way, you assemble a non-linear but symbolically connected story that charts Marissa's career across her three film projects.

This brings us to the other key difference – the scale at which *Immortality* plays. Whereas *Her Story's* police interview took place in one room and focused on a single character, *Immortality* sees you deciphering clues within what are essentially three full-length feature films. And it isn't only the final footage you explore either. The archive includes behind-the-scenes footage, rehearsals, casting auditions, script readthroughs and personal videos filmed by the cast.

This scope can make *Immortality's* initial hour slightly bamboozling, as a match-cut on Marissa's face takes you from a rehearsal scene for 1968's *Ambrosio* – a fake film based on a real 18th-century gothic horror novel titled *The Monk* – to a script reading for 1999's *Two of Everything*, a darkly modern take on *The Prince and the Pauper*, in which a world-famous pop star trades places with a talented but anonymous lookalike.

Indeed, *Immortality's* most significant flaw is that the match-cut system provides little deductive agency. Unlike *Her Story*, where you could search the archive for new clips

## IMMORTAL

- + Smart, involving story
- + Superb performances
- + Distinctive match-cut mechanic

## IMMORAL

- Lacks proper deductive systems





based on words and phrases uttered in previous clips, the match-cut system's connections are all made automatically. As such, while you can mentally deduce what's going on in the broader story, you can't apply any of that knowledge to solving the mystery in the game itself.

However, *Immortality* compensates for its lack of deductive systems with its storytelling and presentation. The inability to search the archive for new clips is frustrating, partly because all three of the game's faux films are riveting stories in their own right.

The detective story *Minsky* is a wonderful pastiche of 1970s cop thrillers, in which a handsome sleuth falls for Marissa's femme fatale while investigating the murder of a renowned artist. Meanwhile, *Two of Everything's* direct-to-DVD drama is the most fun of the three for puzzling, as you try to figure out which of Marissa's identical characters is which in every scene.

But it's the first film, *Ambrosio*, that stands out. Not only is *Ambrosio's* religious tale of sin and seduction the most satisfying film of the three, it also perfectly captures the period of cinema in which it's supposedly filmed. *Ambrosio* looks exactly like an Italian horror movie from the late 1960s – the sets, costumes, music and even the particular quirks of the camera.

Although *Immortality* blends horror, crime and domestic drama, it's ultimately a romance that occasionally verges upon becoming an erotic thriller. Not only is sex a running



theme in all three of *Immortality's* cinematic fabrications, but it's also a constant factor behind the scenes of those films too. Each of Marissa's projects is dominated by crisscrossing relationships, affairs and love triangles between actors, directors and other members of the cast.

*Immortality's* hypersexuality nods to the inherent grottness of both low-budget genre filmmaking and early FMV games, but intermingled within that is a secondary theme of female emancipation.

Each of the three films is acutely attuned to society's attitude towards women, from the frequent sexist comments of *Ambrosio's* Hitchcock-like director, to the more contemporary gender politics of *Two of Everything*, where Marissa's socially liberated pop star still can't escape the unwanted attention of powerful men. The game also reflects heavily upon the concept of the male gaze, particularly in *Minsky*, wherein the film's murdered artist was obsessed with 'perfecting' the physical form of Marissa's muse.

Crucially, this all works, in no small part thanks to the superb performances of everyone involved. Manon Gage, who plays Marissa is obviously the standout, but the lead actors in both *Ambrosio* and *Minsky* are also excellent, and there are several superb performances amid the smaller roles.

One of the best individual scenes in the game is a clip of casting footage for *Ambrosio*, in which a young actress performs a Lauren Bacall scene from *Hold Her Tight*. Set against a beige backdrop playing a fake actress doing a fake audition for a fake film, it's one of the most absorbing scenes you'll see in a game this year.

*Immortality* is a cinematic jigsaw puzzle that uses its intricate structure and powerful performances to pull you into its world, ratcheting your attention as you slowly unveil the plots of the three films, and the broader story of Marissa's obscure fate. It's one of the best games of this year, and one of the best films of this year, a thoroughly engrossing multimedia hybrid.

RICK LANE

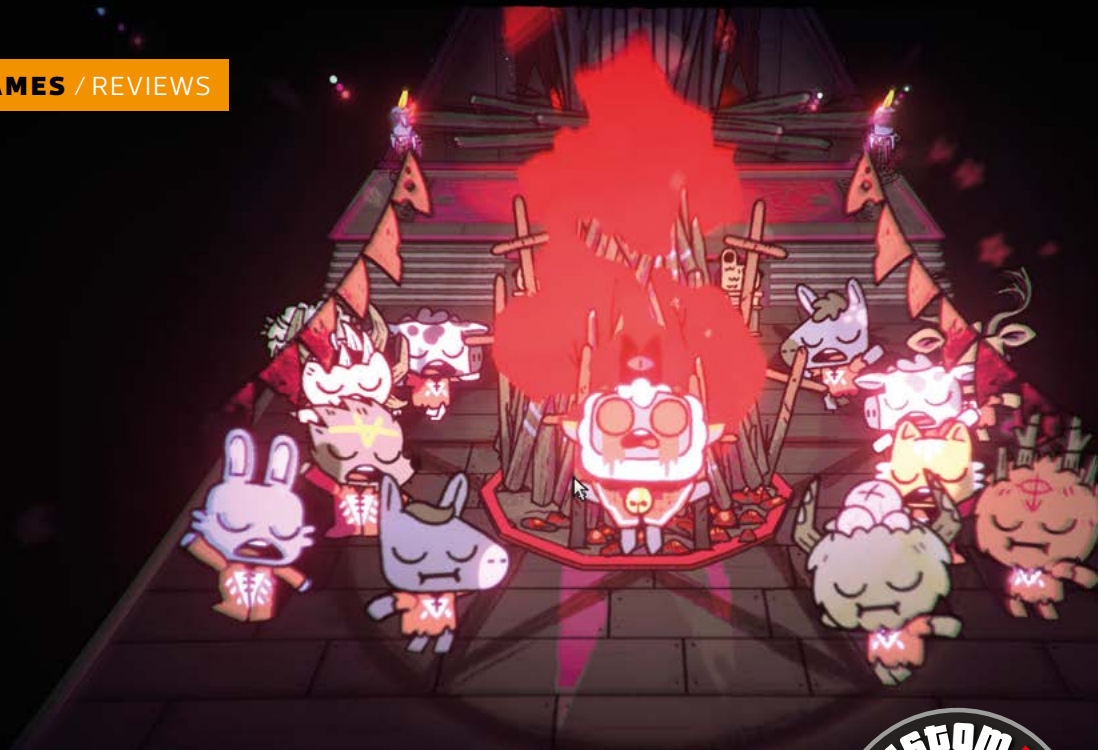
## / VERDICT

Thrilling, provocative and endlessly clever, *Immortality* is a masterful experiment in interactive cinema.

OVERALL SCORE

90%





# CULT OF THE LAMB / £19.49 inc VAT

DEVELOPER Massive Monster / PUBLISHER Devolver Digital



## LAMB OF GOD

- + Incredible visuals
- + Great colony simulation
- + Good combat
- + Delightfully twisted

## LAMB TO THE SLAUGHTER

— Er... no mint sauce?

## / VERDICT

A superb blend of settlement-building and fast-paced dungeon crawling, Cult of the Lamb is a faith we urge you to follow.

## OVERALL SCORE

90%

**I**t would be fitting if Cult of the Lamb lured players with false promises of enlightenment before revealing itself to be a tedious, soul-destroying grift, but it's actually bloody brilliant. A dazzling mix of settlement building, 2D brawling and twisted social simulation, Massive Monster's magnum-opus is marvellous and malevolent.

You play a literal sacrificial lamb who, after being ritually murdered to appease one god, is pulled from the afterlife by a rival deity to serve as their messiah. Returned to the mortal plain, you're tasked with building a religion dedicated to your mysterious saviour, gathering followers, constructing a settlement, and destroying the heretics who originally sacrificed you in a campaign of righteous vengeance.

Play is divided into two roughly equal halves. The first half is the colony simulation, where you build the physical and metaphysical infrastructure of your cult. Each new follower you recruit must be fed, watered and housed, in exchange for which they provide you with their devotion.

This can be used to unlock buildings ranging from farms, outhouses and other basic amenities, to more eclectic

structures such as demon-summoning circles. Followers can also be summoned to your cult's church, where you can feed on their faith for character upgrades, dictate tenets that alter the slant of your cult and perform a range of stat-boosting rituals.

The other half of the game concerns Crusades, which see your lamb depart into the wilderness to track down the leaders of your rival religion. These take the form of randomly generated dungeons where you battle enemies with weapons such as swords, axes and spells that range from fireballs to demonic tentacles that rise up from the ground. It's strongly reminiscent of The Binding of Isaac, albeit nowhere near as difficult. While combat is highly twitchy, a generous dodge-roll and frequent health pickups mean that progress is more consistent than in other, more dedicated roguelikes.

Cult of the Lamb is also comfortably one of the best-looking 2D games ever made. Its gorgeous pop-up-book art style is rendered with sharp lines, bold colours and slick, expressive animations. Moreover, this cartoony art style brilliantly juxtaposes the game's pitch-black themes.

The game lets you build a relatively benign cult if you want, but you can also revel in darker excesses, from enforcing bruising fasts on your cultists to participating in ritual murder and even cannibalism. It brilliantly evokes the influence a charismatic cult leader can have on their believers, and the terrible consequences that can result.

By focusing on a particular type of community, Cult of the Lamb moulds familiar ideas into a fresh and unique game. Add in refined systems and buckets of style, and Cult of the Lamb will brainwash even the most sceptical minds.

RICK LANE





# SAINTS ROW

£49.99 inc VAT

DEVELOPER Volition / PUBLISHER Deep Silver

**S**aints Row was supposed to lead this month's game reviews section, but it's such an unmitigated stinker that we couldn't justify giving it two pages. A reboot of the anarchic series of Grand Theft Auto clones, Saints Row is a virtual car crash of bugs, bad design and a lack of interesting ideas.

Taking place in the new, Las Vegas-inspired city of Santo Ileso, Saints Row sees you play a new Boss leading a new crew of fast-talking renegade gangsters. After losing his job as a security officer for a private military company, your Boss and his flatmates decide to form their own criminal empire, competing against several other gangs in Santo Ileso.

Saints Row exhibits problems from its opening mission, in which your private military employers assault an Old West-style theme park overrun with gangsters. It's an action-packed introduction, but it's also riddled with bugs – glitching ragdolls, floating objects and a physics engine so elastic, it practically propels exploded enemies into orbit. The broader game also frequently encounters technical issues, such as NPCs stuck in T-poses and lines of dialogue playing at the wrong time.

These bugs are annoying and unsightly, but they're ultimately surface symptoms of more chronic issues. The tone of the game is downright bizarre, simultaneously trying to be edgy with scattergun swearing and zany scenarios, while also being terrified of offending anyone.

Your Saints will murder people by the dozen in one scene, then be cloyingly mindful of their flatmates' lifestyle



## SAINT

- + Nice city
- + Decent driving

## SINNER

- Derivative
- Insincere
- Extremely buggy
- Terrible shooting
- Generally bad

choices in the next. It's not impossible to balance these two ideas – Saints Row 4 did a reasonable job of it. The problem is that both elements are performative and insincere – a thoroughly corporate attempt to please everyone without giving players a story or characters worth caring about.

Saints Row is best when you're freely driving around the open world. The sun-drenched desert city is pleasing on the eye and architecturally diverse, while vehicle physics are sufficiently robust. Activities are divided between lengthy main story missions and a host of side-missions, such as wingsuit flying and stealing armoured cars with a helicopter and a magnet. Nothing here is particularly new or innovative, but you can see a moderately enjoyable experience teetering on the horizon.

Unfortunately, Saints Row never arrives there because the game's primary mechanic – combat – is abominable. Movement is sludgy, weapons are tinny and impacts feel hollow and unsatisfying. The game inexplicably has no cover system, with health regained by performing executions on enemies that are so over-elaborate, they break the flow of combat. There are games ten or 15 years old that have better shooting, such as GTA IV, Gears of War and even Spec Ops: The Line.

In short, Saints Row is unpolished, unimaginative, expensive tripe. For the same price, you could buy all three of the other games reviewed on these pages and enjoy an infinitely more rewarding experience.

RICK LANE

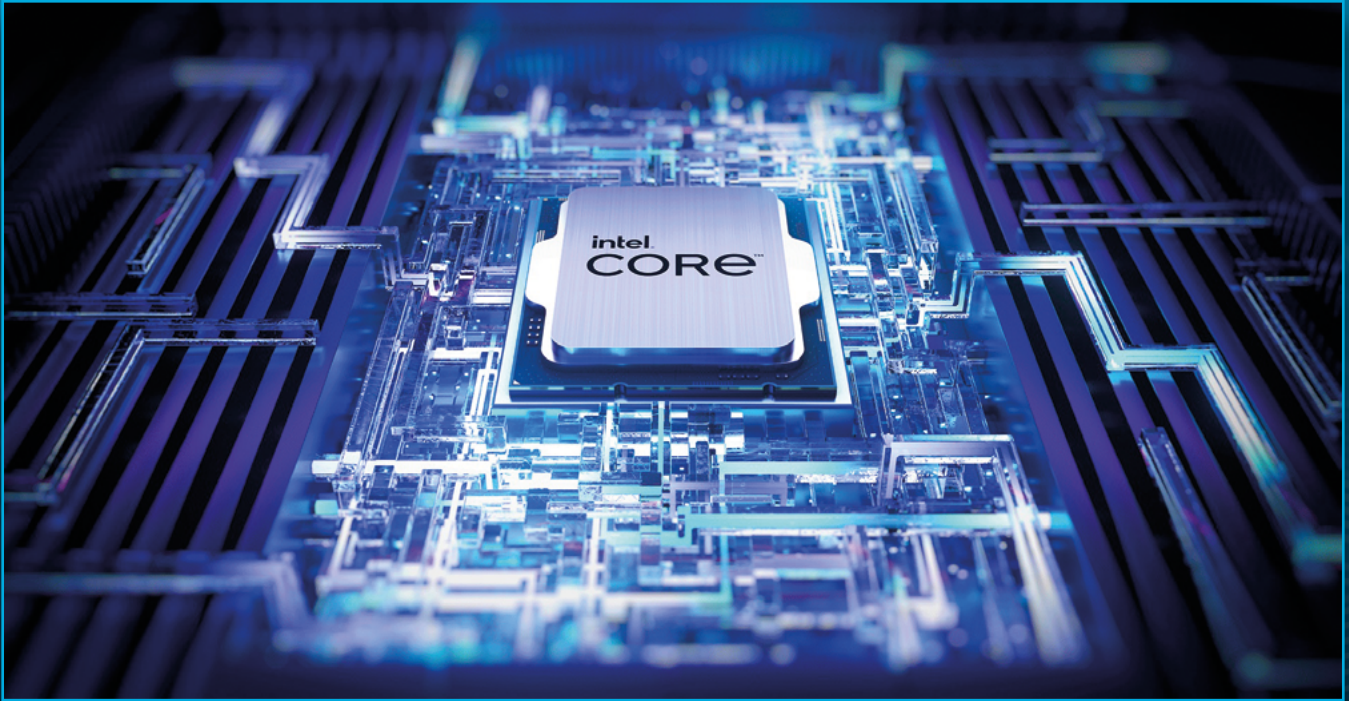
## / VERDICT

Volition's Saints Row reboot is a honking mess with few redeeming qualities.

## OVERALL SCORE

35%





# VELOCIRAPTOR

**INTEL'S 13TH-GEN CORE PROCESSORS HAVE ARRIVED, BRINGING IMPROVED CLOCK SPEEDS, MORE E-CORES AND SEVERAL UNDER-THE-BONNET CHANGES. EDWARD CHESTER EXPLAINS ALL YOU NEED TO KNOW ABOUT THE NEW CHIPS**

**I**t's been a mighty back-and-forth battle between AMD and Intel for CPU supremacy in recent years. AMD's first Ryzen processors revolutionised the market in terms of value and core count, but struggled when it came to raw clock speed, while Intel offered high clock speeds but relatively few cores.

As the years have gone on, AMD has steadily become more and more competitive on the speed front, while Intel has responded when it comes to core count and value, culminating in AMD comprehensively winning the performance crown with its 5th-generation Ryzen 5000 processors, only for Intel to sneak ahead at the end of last year with its 12th-gen Core processors, codenamed Alder Lake.

Just last month we saw the tables turn again with AMD's Ryzen 7000-series processors offering big clock speed boosts over the Ryzen 5000 series, and overall performance that again leapt ahead of Intel. All of which brings us to the launch of Intel's 13th-gen Core processors, codenamed Raptor Lake.

In some ways it's a relatively modest launch, with Intel not revolutionising its architecture – as it did with the introduction of E-Cores with its 12th-gen products – or shifting to a completely new manufacturing process. For those sorts of changes, you'll have to wait until next year's Meteor Lake launch.

However, as Antony's reviews prove (see p14), performance is solid thanks to decent

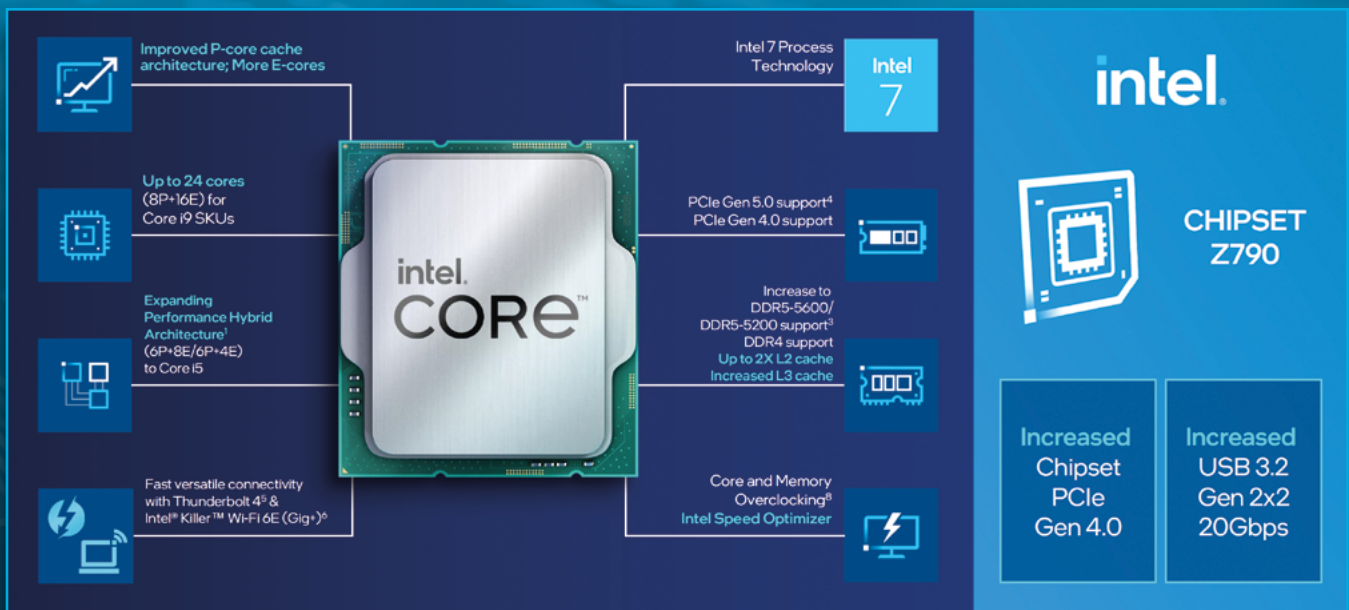
bumps in clock speed, an increase in L2 cache and core counts technically increasing by 50 per cent thanks to a doubling in the number of E-Cores, so there's plenty to unpack.

## THE LINE-UP

The full line-up of 13th-gen processors will expand over time, but at launch there are three main options – the Core i9-13900K, the Core i7-13700K and the Core i5-13600K – each with a K and KF variant. The K suffix denotes that the chips are all multiplier unlocked for easier overclocking, while the F variants have their integrated graphics disabled.

Top of the trio is the Core i9-13900K (£700 inc VAT), which packs eight P-Cores and 16 E-Cores in to one chip, making for a





mammoth total core count of 24. Given that the P-Cores also support Hyper-Threading, that means the Core i9-13900K can handle up to 32 application threads at a time – the highest ever from an Intel desktop CPU.

As with its 12th-gen processors, though, the E-Cores are significantly slower than the P-Cores. As such, while the Core i9-13900K can work on a ludicrous number of threads simultaneously, the rate at which it chews through each of them will be significantly slower than if it had 24 P-Cores.

This E-Core/P-Core arrangement makes it tricky to do direct comparisons with AMD's rival processors, as AMD's designs only employ the equivalent of P-Cores. So, while

**The Alder Lake line-up introduced a hybrid core model, which Raptor Lake refines ahead of next year's Meteor Lake launch**

the AMD Ryzen 7950X (£800 inc VAT) packs in 'only' 16 cores compared to the Core i9-13900K's 24, it has double the number of high-performance cores.

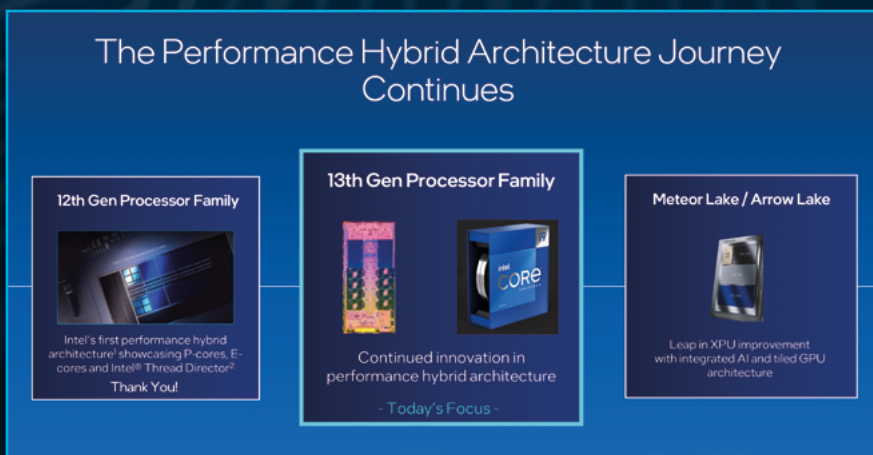
Also, because every one of those cores can process two threads at once, thanks to simultaneous multi-threading (SMT), the Ryzen 9 7950X matches the Core i9-13900K for the total number of threads it can handle at once. This is a situation we see borne out in our Core i9-13900K benchmarks, with its heavily multi-threaded performance just about matching (rather than significantly surpassing) that of the Ryzen 9 7950X.

Clock speed is another area that has seen significant change when comparing the Core i9-13900K with the older Core i9-12900K. The latter topped out at 5.2GHz, while the Core i9-13900K trots along at 5.8GHz.

**The Intel 13th-gen Core processor line-up includes more E-Cores, higher clock speeds and a new chipset**

However, that's still 200MHz short of the 6GHz that a few months ago Intel hinted would be possible with this architecture, and moreover it's only 100MHz faster than the Ryzen 9 7950X. Considering Intel's long-held clock speed advantage since the original Ryzen line-up's launch, it's significant that Intel's lead is close to being eroded.

We can expect to see this architecture hit that 6GHz figure with the subsequent Core i9-13900KS launch in the coming months. However, given that Intel's next generation of chips is set to arrive in the middle of next year, the company doesn't have a great deal of time to fit in the launch of an even faster variant of Raptor Lake before it's made to look rather irrelevant.





## INTEL 13TH-GEN CPU COMPARISON

	CORE i9-13900K	CORE i7-13700K	CORE i5-13600K
<b>MAX TURBO FREQUENCY</b>	Up to 5.8GHz	Up to 5.4GHz	Up to 5.1GHz
<b>INTEL TURBO BOOST MAX 3 FREQUENCY</b>	Up to 5.7GHz	Up to 5.4GHz	N/A
<b>P-CORE MAX TURBO FREQUENCY</b>	Up to 5.4GHz	Up to 5.3GHz	Up to 5.1GHz
<b>E-CORE MAX TURBO FREQUENCY</b>	Up to 4.3GHz	Up to 4.2GHz	Up to 3.9GHz
<b>P-CORE BASE FREQUENCY</b>	3GHz	3.4GHz	3.5GHz
<b>E-CORE BASE FREQUENCY</b>	2.2GHz	2.5GHz	2.6GHz
<b>HYPER-THREADING SUPPORTED</b>	Yes	Yes	Yes
<b>NUMBER OF P-CORES</b>	8	8	6
<b>NUMBER OF E-CORES</b>	16	8	8
<b>TOTAL NUMBER OF CORES</b>	24	16	14
<b>TOTAL NUMBER THREADS</b>	32	24	20
<b>L3 CACHE SIZE</b>	36MB	30MB	24MB
<b>TOTAL L2 CACHE SIZE</b>	32MB	24MB	20MB
<b>GRAPHICS DYNAMIC FREQUENCY</b>	1650MHz	1600MHz	1550MHz

All six of the processors available at launch can peak at clock speeds over 5GHz and include at least four extra E-Cores

Also, when it does arrive, expect it to be pricey and toasty. The Core i9-13900K has a base power rating of 125W, but this is wildly out of tune with the figures users will see when the chip is under load. Instead, the rated peak turbo power consumption figure of 253W is a more representative number, which is a 12W increase over the Core i9-12900K.

Moving on to the next chip in the 13th-gen line-up, the £500 (inc VAT) Core i7-13700K sees the addition of four E-Cores over the Core i7-12700K. That brings the core count to eight P-Cores and eight E-Cores, for a total of 16 cores that can process 24 threads at a time.

Peak clock speed has also jumped from 5GHz to 5.4GHz. Depending on whether you compare the Core i7-13700K with the 8-core 5.4GHz Ryzen 7 7700X (£430 inc VAT) or the 12-core 5.6GHz Ryzen 9 7900X (£590 inc VAT), that puts the Core i7-13700K either on level pegging or 200MHz behind the clock

speed of its main rivals, again highlighting the close competition between the current generation of chips. The Core i7-13700K retains the same base power and max turbo power as the Core i9-13900K despite its lower core count and clock speed.

Rounding out the initial line-up is the Core i5-13600K (£380 inc VAT), which again adds four E-Cores compared with its 12th-gen

overclocking potential, so the default clock speeds don't tell the whole picture. The Core i5-13600K has the same 125W base power as the other two chips but a lower 183W max turbo power figure, although total power when overclocked jumps up significantly. There's likely a reasonable amount of overclocking wiggle room with the Core i7-13700K too but we've yet to test that chip.

## WE CAN EXPECT TO SEE THIS ARCHITECTURE HIT THAT 6GHz FIGURE WITH THE SUBSEQUENT CORE i9-13900KS LAUNCH IN THE COMING MONTHS

equivalent the Core i5-12600K, bringing its total core/thread count to 14/20 with six P-Cores and eight E-Cores. With a top clock speed of 5.1GHz, the Core i5-13600K sits well below the 5.4GHz clock speed of the 6-core Ryzen 7 7700X, although this is also reflected in its lower price.

However, as shown in our review (see p16), the Core i5-13600K has significant

### ON THE SHOULDERS OF GIANTS

Intel has confirmed that the baseline architecture of its Raptor Lake chips is no different to Alder Lake, with the P-Cores and E-Cores, integrated graphics and other building blocks sporting essentially the same design. As such, to get an understanding of Raptor Lake, we'll need to look back at what Alder Lake can do.



Starting from the very top, the first factor to note about both Alder and Raptor Lake is that they're aimed at production on a single piece of silicon, rather than the multiple chiplets used to build up AMD's latest Ryzen processors.

This monolithic approach comes with the advantage of making it easier to interconnect all the components on the chip rather than having to rely on external interconnects between chips.

However, it's a more expensive, riskier approach to produce any one chip than AMD's approach, as any defects can ruin entire CPUs, rather than just one smaller part of the CPU.

What's more, you're forced to use the very latest manufacturing process for the whole CPU, whereas using a chiplet approach allows you to use cheaper, older or differently optimised processes for some of the components, such as AMD's I/O die.

It's for these reasons and more that Intel is set to adopt a chiplet approach for its upcoming Meteor Lake CPUs. That launch is also set to see the debut of the company's Intel 4 manufacturing process, and will use TSMC's latest 3nm process to produce the 'integrated' graphics chips.

Getting back to the overall design of Alder Lake and Raptor Lake, the big addition with Alder Lake was the introduction of a power-efficient E-Core (the design for which is codenamed Gracemont) for taking on low-priority background tasks and providing extra parallel processing capability with minimal power consumption.

**The introduction of a small E-Core allowed Alder Lake and Raptor Lake to pack in four cores in the same space as a single conventional performance core**



With a design that was top-to-bottom optimised for reduced power consumption rather than peak performance, the E-Cores run slower than the P-Cores and do away with power-hungry elements, such as micro-op caches and support for complex AVX-512 instructions (indeed the E-Cores don't even support true 256-bit AVX instructions, as these are split into two 128-bit operations).

The upshot of this pared-down approach is a core that not only gently sips power compared with conventional high-performance cores but takes up less silicon too. Each cluster of four E-Cores takes up

**A wider execution port arrangement, new AMX execution units and larger data structures were introduced in the Alder Lake P-Core**

roughly the same die space as a single P-Core. Those P-Cores use a core design codenamed Golden Cove and they're largely an iteration of the Sunny Cove and Cypress Cove cores used in Intel's 10th and 11th generation Core processors. That said, Intel did introduce a few tweaks with Golden Cove.

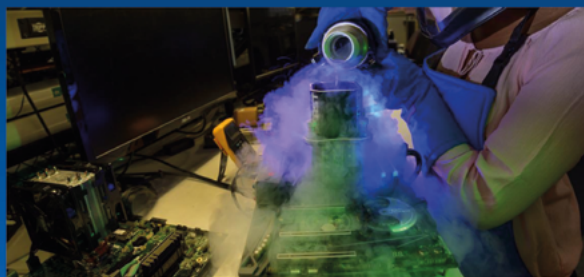
The front end uses a 50 per cent wider micro-op decoder and a micro-op cache that's nearly twice as large as that on the older Cypress Cove design. Other optimisations included doubling the translation lookaside buffer, a larger micro-op queue and a more than doubling of the branch target buffer (BTB).

The front end of a processor core is all about decoding large instructions into smaller micro-ops that are passed to the processor, optimising the order in which instructions are executed and predicting the outcome of branches in code. As such, the larger micro-op decoder, micro-op caches and BTB ensure the CPU can keep as many potential pieces of work in flight as possible. This keeps the execution engine portion of the chip – where those micro-operations are performed – fed with work as efficiently as possible.





# Intel's Highest Overclocked Frequencies



## Liquid Nitrogen (Extreme Cooling)

- P-Cores reaching well **beyond the 8 GHz** threshold!
- DDR5 speeds in excess of **10,000 MT/s**
- Anticipating numerous new OC World Records



## Liquid Cooled

- Higher OC frequencies with headroom similar to 12th Gen
- DDR5 XMP memory speeds ranging to 6,600 MT/s and beyond.

Higher frequency for Beginner, Intermediate, and Extreme Overclockers!

Our overclocking results with conventional cooling were modest, but with cryogenic cooling, Intel expects the Core i9-13900K to hit 8GHz

Then we come to the execution engine, where Intel has slightly increased the number of execution ports, from ten to 12, and significantly increased the reorder buffer (ROB – used to store the outcome of instructions for use by other instructions) from 352 entries in Cypress Cove to 512 entries in Golden Cove. This compares to just a 256-entry ROB in the E-Cores and a 320-entry ROB for AMD's latest Zen 4 architecture.

The execution ports themselves use a fused arrangement where both floating point and integer operations are performed by several of the ports, allowing the scheduler to dynamically optimise which operations to perform on which ports. This is in contrast to AMD's latest Ryzen architectures, which use a separate arrangement of integer and floating point ports with separate schedulers.

A notable change from Intel's previous architectures is that, while the execution engine of Alder Lake and Raptor Lake's P-Cores is able to process 512-bit AVX instructions, Intel has actually disabled this feature in both architectures.

This is because the E-Cores don't support the feature and it has proved troublesome to manage how the Thread Director (the on-board microcontroller that monitors

thread load and communicates thread priorities to Windows) deals with these instructions. Ironically, AMD has only just got around to adding decent support for these instructions in its latest CPUs.

Also new to Alder Lake was the introduction of dedicated matrix multiplication hardware, akin to the Tensor cores on Nvidia's GPUs. These advanced matrix extension (AMX) components are also present on Intel's new Intel Arc graphics cards. Such hardware is seen as key for future applications as machine learning relies heavily on matrix multiplication.

The upshot of these P-Core changes was an average 19 per cent uplift in instructions per clock compared with Cypress Cove chips, while the E-Cores could deliver Intel Skylake (Intel's 6th-gen Core processor design) levels of performance while using

40 per cent less power. Alder Lake also saw the introduction of support for DDR5 memory, while maintaining DDR4 support, plus the use of an integrated graphics module based on the company's Xe (Gen12) graphics architecture.

The Z690 chipset was also introduced, with support for 20 PCI-E 5 lanes and the new LGA1700 socket that the new CPUs would use. Raptor Lake retains most of these features, although it introduces a new chipset, which we'll discuss more in a moment.

## THE ARCHITECTURE TWEAKS

Having established the baseline architecture of Alder Lake, we can now explore more deeply the changes made for Raptor Lake,

Iterative improvements to Intel's latest manufacturing process have allowed for faster clock speeds and/or lower power consumption on Raptor Lake

### Upgraded Intel 7 Process

3<sup>rd</sup> gen Intel SuperFin transistor  
Significantly better channel mobility

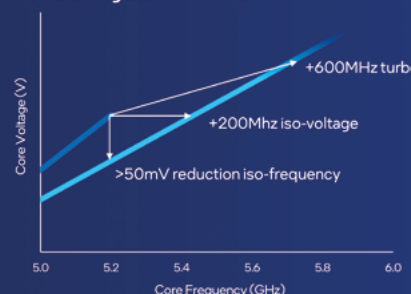
### Faster 'Raptor Cove' Core

Updated design with improved speed paths  
Up to 600MHz faster

### Larger L2 Cache

2MB L2 cache per core  
New dynamic prefetcher algorithm "L2P"

### Shifting the V-F Curve





## Raptor Lake Double the Efficient-Cores<sup>1</sup>

### Wider

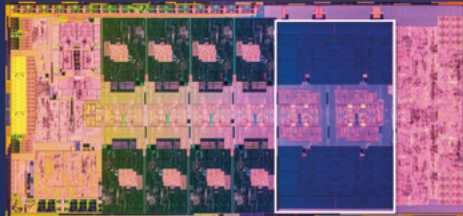
Up to 16 E-cores  
4MB L2 per cluster

### Faster

Up to 600MHz faster (ACT)  
Up to 4.3GHz turbo

### Smarter

Significantly optimized  
prefetcher algorithm



**All Raptor Lake processors include more E-Cores than their Alder Lake counterparts, and they run faster too**

which although not numerous, do add up to significant performance gains across the board.

For a start, these 13th-gen chips are using the latest iteration of the Intel 7 manufacturing process. Improvements to the channel mobility – the rate of electron flow through the transistor's gate – have allowed for higher clock frequencies at reduced voltages, opening up these chips to run up to 600MHz faster than their predecessors.

Despite these gains, we're not seeing a revolution in power efficiency or in maximum power consumption. As Intel's turbo max power figures and our own tests show, these

chips still consume a significant amount of power (and have a resultant high heat output) when under full load. AMD's latest chips also demand top-notch cooling and a quality power supply, but the likes of the Core i9-13900K push the envelope even further.

If power consumption and long-term usability aren't a concern though, Intel is making some bold claims about the overclocking headroom of these chips. With extreme cryogenic cooling, Intel expects frequencies over 8GHz to be possible. With conventional cooling, the story isn't quite so dramatic. We saw good results with the slower-clocked Core i5-13600K but there's not a lot of headroom for the higher-end processors such as the Core i9-13900K.

When it comes to E-Core clock speeds, Raptor Lake brings with it up to a 600MHz increase in all-core turbo (ACT) speed over 12th-gen chips, while single-core turbo speeds max out at 4.3GHz, compared to the 3.9GHz on its 12th-gen chips.

Another key change from Alder Lake to Raptor Lake is an increase in L2 cache size. The P-Cores now have 2MB each, up from 1,280KB. Meanwhile, the E-Cores get double the L2 cache per cluster of four E-Cores, up from 2MB to 4MB, giving the Core i9-13900K a total of 32MB of L2 cache.

That's double the amount of L2 cache AMD includes in its Ryzen 9 7950X – despite AMD doubling the size of its L2 caches when moving from Zen 3 to Zen 4 – but again the P-Core/E-Core situation means it's not overly meaningful to compare total L2 cache amounts.

Meanwhile, when it comes to L3 cache, or last level cache (LLC) as Intel calls it, the Core i9-13900K packs in 36MB. This is far less than the Ryzen 9 7950X's 64MB, which continues a trend we've seen for a while, with AMD's architecture relying heavily on large L3 caches. The Ryzen 7 5800X3D remains blisteringly fast in games, for example, thanks to its dedicated L3 cache die stacked right on top of the CPU.

**Raptor Lake comes with faster-clocked Compute Fabric, a larger L3 cache and support for faster DDR5 RAM than Alder Lake**

## Raptor Lake Better Memory Latency & Bandwidth

### Faster DDR5<sup>3</sup>

Up to 5600 MT/s with 1DPC  
Up to 4400 MT/s with 2DPC

### Faster Fabric

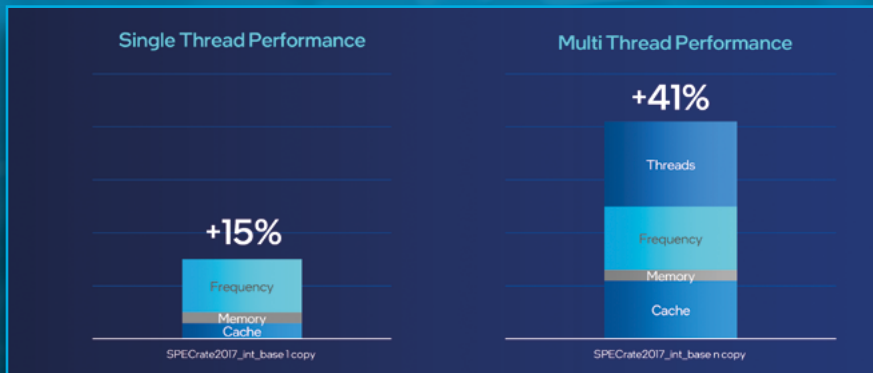
Up to 900MHz faster (ACT)  
Up to 5.0GHz max turbo

### Larger LLC

Up to 36MB shared L3  
New dynamic inclusive/non-inclusive "INI"







Continuing the theme of using generally faster and larger components in Raptor Lake, the compute fabric that runs down the middle of the processor and manages communication between the cores and caches has seen its maximum clock speed bumped to 5GHz, up from 4.7GHz, while its ACT speed is up to 900MHz faster. Although this won't directly increase performance in and of itself, it will ensure the faster-running cores aren't starved of the data they need.

according to Intel's figures. Roughly 70 per cent of this improvement comes from the increased frequency, with around 15 per cent each of the remaining increase coming from the faster memory and caches.

Notably, none of the performance increase is attributed to an improvement in instructions per clock (IPC), as you'd expect given the lack of architectural changes. This contrasts with the introduction of Alder Lake, which brought with it a 19 per cent IPC increase over Rocket

## WHILE IPC MAY NOT HAVE IMPROVED WITH RAPTOR LAKE, THE OTHER TWEAKS DO PROVIDE AN IMPROVEMENT IN PERFORMANCE PER WATT

This internal speed increase is matched by support for faster DDR5 memory. While Alder Lake officially topped out at 4,800MT/sec memory for one DIMM per channel (1DPC) and 4000MT/sec for 2DPC, Raptor Lake pushes this to 5,600MT/sec and 4,400MT/sec respectively. In contrast to most of AMD's Ryzen generations, Intel's recent architectures haven't been overly reliant on high memory speed for optimal performance, but the extra headroom certainly can't hurt.

The final publicly stated tweak Intel has made to transform Alder Lake into Raptor Lake is to change its prefetcher algorithm. This deals with prefetching instructions or data from memory or slower cache stores and moving them to faster caches, ready to be next in the operation queue.

### PERFORMANCE UPLIFT

The net result of all these changes is a claimed 15 per cent increase in single-threaded performance when comparing the Core i9-12900K with the Core i9-13900K,

**Higher clock speeds and more E-Cores lead to significant single-threaded and multi-threaded performance gains with Raptor Lake**

applications. It even beat the Ryzen 9 7950X in some scenarios here too, though it wasn't a clean sweep. Meanwhile, the Core i5-13600K that we tested comfortably beat its predecessor but fell behind the AMD competition until overclocked.

As for multi-threaded performance, here Intel claims a 41 per cent increase due in large part to those extra E-Cores. This is again a claim we saw borne out in our testing, with a big improvement when going from the Core i9-12900K to the Core i9-13900K, although ultimately multi-threaded performance was on par with the 16-core Ryzen 9 7950X.

Frequency is the next largest factor for improved multi-threaded performance, while the cache changes also make up a significant chunk, which shows the importance of having large and fast enough data structures to efficiently move data around these many-cored processors.

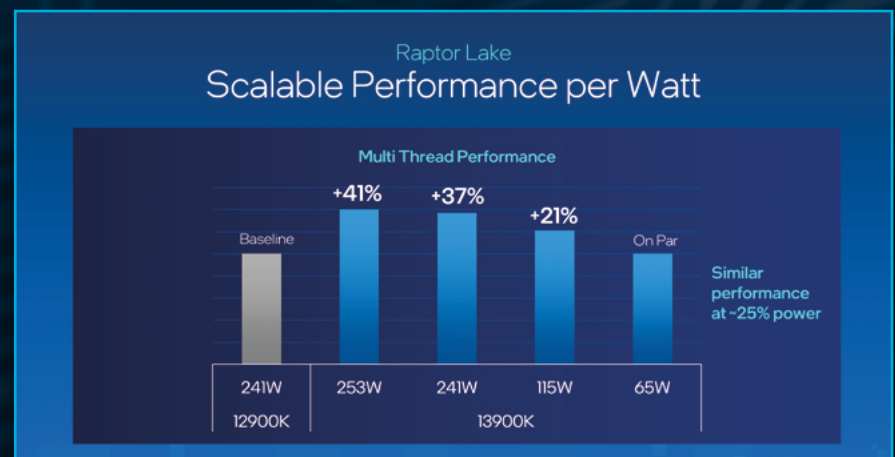
While instructions per clock may not have improved with Raptor Lake, the other tweaks do provide an improvement in performance per watt. Although total power consumption under load has increased when going from the Core i9-12900K to the Core i9-13900K, you're getting a 41 per cent increase in multi-threaded performance for just a 5 per cent increase in power consumption.

As well as hardware improvements, Intel has also been working hard on improving its Thread Director system. Using machine learning, Intel has calculated new boundaries for each class of thread, making the Thread

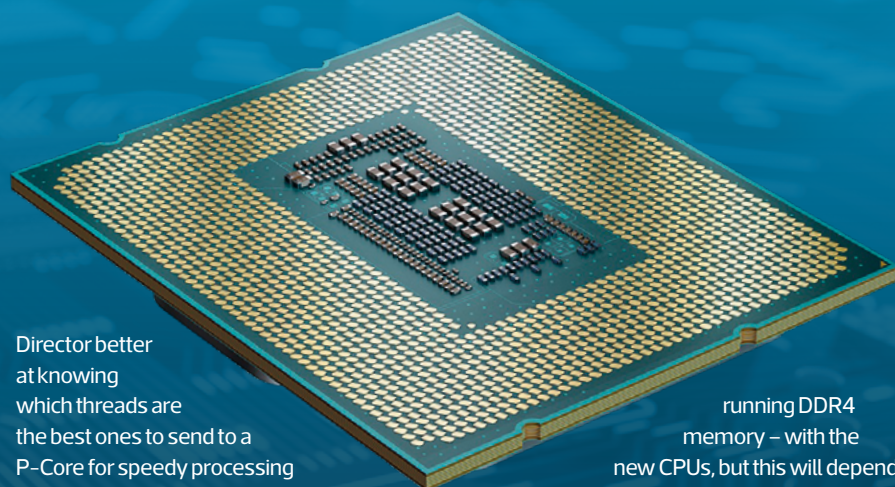
**An improved manufacturing process leads to better performance per watt than Alder Lake**

Lake and AMD's Zen 4, which introduced several architectural changes that amounted to a 13 per cent improvement in instructions per clock over Zen 3.

Regardless of the lineage of the performance uplift, the net result was evidenced in our testing with the Core i9-13900K significantly outstripping the Core i9-12900K in single-threaded







Director better at knowing which threads are the best ones to send to a P-Core for speedy processing and which can chunter along on E-Cores. Thread prioritisation has also been made faster and more efficient in Windows 11's 22H2 update.

In addition, overclocking has been made easier thanks to improvements to Intel's Extreme Tuning Utility (XTU). There's now a one-click Speed Optimizer feature with a compact view, or if you want to get more granular you can now tune on a per-core basis for both P-Cores and E-Cores separately.

## NEW CHIPSETS, MEMORY AND SOFTWARE IMPROVEMENTS

Raptor Lake is launching alongside a new motherboard chipset, Z790, but the CPUs use the same LGA1700 socket as Alder Lake. This opens up the possibility of using older Z690 and B660 motherboards – even those

running DDR4 memory – with the new CPUs, but this will depend on motherboard manufacturers issuing BIOS updates for the older boards.

Assuming your board is compatible, this makes for a surprise upgrade victory for Intel. Not only do you get an easy path to slotting in a faster CPU if you already have a Z690 or B660 motherboard, but you can also hold onto your old DDR4 RAM if you're looking to buy a new CPU and motherboard.

There are also a few Z790 motherboards that support DDR4 memory, but if you want to save some cash, you could buy an older Z690 board at a cut-down price, keep your existing DDR4 memory and slot in a brand-new CPU. In contrast, AMD's newest CPUs use a new socket and only support DDR5, compelling you to invest in new memory and a new motherboard all at once, if you're upgrading from an older AM4 AMD platform – that's a lot of money at today's prices.

This upgrade path is all the more tempting as Z790 doesn't include a great deal when it comes to extra features. You get four extra PCI-E 4 lanes and one extra 20Gbps USB 3.2 2x2 port and that's your lot.

## THE WRAP-UP

All told, while Raptor Lake may not be the most exciting CPU launch when it comes to big headline numbers, in actuality, it has proven to be quite compelling. Increases in overall core count significantly boost multi-threaded performance where needed, while up to eight P-Cores is ultimately sufficient for the vast majority of uses, and is certainly enough for gaming.

Power consumption remains high, but overclocking of the Core i5-13600K in particular is very impressive, opening up the option of buying a cheap processor and getting big performance gains by cranking up those voltages. Considering how little overclocking headroom we've tended to see in recent CPUs, it's great to see a return of proper manual overclocking wins.

Add in the backwards compatibility options available, thanks to the continued use of the LGA1700 socket and support for both DDR4 and DDR5 memory, and Raptor Lake becomes a very tempting proposition, especially given the relatively competitive retail prices. **CPG**

**Intel has added more granular settings to its Extreme Tuning Utility**

Per-Core Tuning

Performance Cores

Ratio	Monitors
P-Core 0	P-Core 1
60x	60x
P-Core 2	P-Core 3
60x	60x
P-Core 4	P-Core 5
60x	60x
P-Core 6	P-Core 7
60x	60x

Selected Core

Performance Core 0

Ratio Multiplier60.000 x

Voltage ModeStatic

Voltage Override1.449 V

Voltage Offset0.000 V

Intel® Thermal Velocity Boost

Temperature0.000 °C

Ratio OffsetDisable

Temperature #20.000 °C

Ratio Offset #2Disable

Per-Core Tuning

Efficient Cores

Ratio	Monitors		
E-Core 0	E-Core 1	E-Core 2	E-Core 3
45x	45x	45x	45x
E-Core 4	E-Core 5	E-Core 6	E-Core 7
45x	45x	45x	45x
E-Core 8	E-Core 9	E-Core 10	E-Core 11
45x	45x	45x	45x
E-Core 12	E-Core 13	E-Core 14	E-Core 15
45x	45x	45x	45x

Selected Core

Efficient Core 0

Ratio Multiplier45.000 x

Voltage ModeStatic

Voltage Override1.449 V

Voltage Offset0.000 V



# WHAT'S NEW WITH ATX 3 POWER SUPPLIES?



ATX 3 PSUs ARE ALREADY APPEARING IN STORES, AND THEY BRING A NEW 16-PIN POWER CONNECTOR WITH THEM, BUT DO YOU NEED ONE AND WHAT ARE THEIR BENEFITS?

**RICHARD SWINBURNE DELVES INTO THE SPEC**

**Y**ou might have already seen a couple of ATX 3 power supplies turning up on the virtual shelves of online stores, with Thermaltake in particular pushing hard into the UK market, and including both SFX and ATX options already. The new standard was inked in February this year, and more will arrive as we hit 2023. Let's state upfront that you don't need one if you're upgrading, so don't worry. However, if you're building a high-end rig with a next-gen GPU, it's worth considering making the jump to ATX 3, especially if you want to avoid using ugly connector adaptors.

To put ATX 3 in context, let's step back for a minute and look at its origins. Launched by Intel in 1995, the first ATX standard replaced the archaic AT plug system with a unified 20-pin connector for the motherboard, plus strongly fitting 4-pin Molex plugs for hard drives and optical drives, as well as a smaller 4-pin connector expressly for floppy drives. This standard was superseded by ATX 2 in February 2003, so it's been nearly 20 years since we saw an uptick of the big number.

ATX 2 was primarily introduced to formalise the changes needed to accommodate the CPU drawing power from a more efficient 12V source, instead of 5V, which was itself a response to the rapid increase in CPU TDPs

from Pentium 4 CPUs. Sounds familiar? ATX 3 again reflects the needs of recent hardware changes, where graphics cards and CPUs now need a lot more power, and they need it reliably.

The ATX standard served as a minimum to make a safe and legal power supply for PCs, but not necessarily a good-quality power supply. In the interim 20-year period, the 80 Plus certification scheme was introduced, and while it's not perfect, it has pushed the industry to improve power efficiency and quality to a greater extent.

So what does ATX 3 bring to the table? Firstly, you might see ATX 3 power supplies advertised as being PCI-E 5-ready. This is because the PCI-E 5 standard design guidelines include power provision, and that has overlapped with ATX 3 to make sure both standards tie in together.

This power provision is more important for server and industrial applications, which must adhere to stricter power limits and reliability requirements than desktop gaming PCs, and Nvidia has already shown with its PCI-E 4-based RTX 4000-series GPUs that you don't need to make an add-in card with PCI-E 5 signalling to use the ATX 3 standard.

The interweaving of PCI-E 5 and ATX 3 is complicated in other areas too, as the former includes support for a new 48V power rail, and 48VHPWR cable, which isn't present in ATX 3. Both standards support the same maximum power output, but higher voltages can provide better power efficiency. In fact, adopting 24V or 48V instead of 12V has been

**The 16-pin 12VHPWR connector theoretically supplies up to 600W, but if the sideband channel is absent, that signal is left 'open' and the 12VHPWR cable is limited to 150W**

Sense0	Sense1	Initial permitted power at system power up	Maximum sustain power after software configuration
Gnd	Gnd	375W	600W
Open	Gnd	225W	450W
Gnd	Open	150W	300W
Open	Open	100W	150W



Power excursion percentage of PSU rated size Sense1		Time for power excursion (TE)	Testing duty cycle
PSU ≤ 450W and PSUs without 12VHPWR connector	PSU > 450W and 12VHPWR connector present		
100 per cent	100 per cent	Infinite	--
110 per cent	120 per cent	100ms	50 per cent
135 per cent	160 per cent	10ms	25 per cent
145 per cent	180 per cent	1ms	20 per cent
150 per cent	200 per cent	1µs	10 per cent

quietly discussed in the industry for many years already, but as the recently launched 12VO standard (which ditches 3.3V and 5V rails) has shown, a big change won't see mass adoption in a market that only ever sees iterative updates.

Enterprise-grade equipment has different build pressures – efficiency being one of them, so this change will be more readily adopted there, but don't expect these higher voltages to be regular features of our desktop power supplies soon.

## FINALLY, A PSU THAT TALKS TO THE SYSTEM

Power supplies have generally always been dumb boxes. They aren't aware of what's going on in the PC to which they're connected. Instead, a classic desktop PSU is like a reservoir into which the PC hardware sticks a straw and guzzles power. ATX 3 takes the smallest of steps to verify that a graphics card isn't too thirsty.

The standard recommends that power supplies rated over 450W include the new 12VHPWR (high-power) cable, which replaces the 6 or 8-pin PCI-E cable used by almost every graphics card made in the past 18 years. 12VHPWR was 'sort of' introduced by Nvidia via

**The new 16-pin 12VHPWR cable, seen here plugged into a Thermaltake SFX Toughpower unit, is intended to replace the existing 6-pin and 8-pin PCI-E connectors**



a 12-pin connector on the RTX 3090 Founders Edition card in 2020, but ATX 3 has gone further, adding four smaller pins that sit on top of the main 12-pin connector, creating a 16-pin connector that allows the graphics card to talk to the PSU directly, so the PSU and GPU can negotiate a safe power draw.

The standard also requires the cable to use a thicker 16AWG gauge wire, up from 18AWG used previously. This 16-pin 12VHPWR connector supplies, in theory, up to 600W.

## FOUR SMALLER PINS SIT ON TOP OF THE MAIN 12-PIN CONNECTOR, ALLOWING THE GRAPHICS CARD TO TALK TO THE PSU DIRECTLY

However, if the sideband channel is absent, that signal is left 'open' and not tied to ground, and the 12VHPR cable is limited to only 150W.

Because ATX 3 power supplies are generally launching later to market than the first wave of Nvidia RTX 4000-series GPUs that use them, adaptors that combine four 8-pin PCI-E power cables into a single 16-pin connector have been provided in graphics card boxes instead.

The Nvidia-designed adaptor actually has some safety brains built into it, with a chip that senses if the first and last +12V pin in the four 8-pin plugs are present before it says 'yes, that cable is correctly installed'. You can still run the graphics card using only three of the four cables, but the chip will send a 450W (open + ground) signal instead, telling the software to limit the amount of power that can be drawn.

Alternatively, Corsair is the first brand to provide a replacement 12VHPWR cable for some of its existing power supplies. It plugs into two modular connectors on the rear of its PSU, which might seem foolhardy

**Without a 12VHPWR cable, a PSU's power excursion capabilities – accommodating momentary peak loads beyond the max wattage of the power supply – are slightly limited**

compared to the Nvidia adaptor needing four 8-pin PCI-E power cables to provide 600W safely, but with the fatter 16AWG gauge wire, fewer connectors are needed to provide the same power.

Since only a ground + ground signal is required from the first two pins of the sideband

connector, Corsair attaches those to the ground wires, making it 600W-capable with no extra chip needed.

These are all good ways to use older ATX 2-era power supplies with new gear, but you might have seen a potential issue. The sideband signalling is elementary, and it's deadly easy to hack. By hooking these two pins to a ground on the power supply, you can bypass this safety limiter and unlock the full power, regardless of how it's been plugged in. It doesn't take a stretch of the imagination to think that cheap adaptors advertising a capability of '600W full power' could be sold with intentional bypasses, and the average buyer would be none the wiser.

Also, even with the ATX 3 stamp, a power supply can even be sold without the 12VHPWR connector entirely. That's because not every PC build uses a graphics card, giving ATX 3 power supplies the option to omit the 12VHPWR cable. The only regulation here is that its power excursion capabilities – accommodating momentary peak loads



beyond the maximum wattage of the power supply – are slightly limited.

Power excursions well beyond the rated wattage of the graphics are important to consider, because even current-generation graphics cards cause them, and without supporting them, it can cause a power supply to simply shut off as over-current and over-power protection kicks in.

### CLEARING UP CONFUSION

All this confusion stems from the language used in the ATX 3 documentation, which is expressly strict on some areas, while being hand-wavey on others. For example, the document says it's expected that a power supply has the 12VHPWR cable. That doesn't mean it's required. If the cable is

If you do go out shopping especially for a new ATX 3-stamped power supply, the bottom line is that you'll need to read the reviews and look at the product page closely before you buy. Don't only look for the ATX 3 stamp on the box, don't buy one without the 12VHPWR cable included if you intend to use a graphics card, and don't buy unverified adaptors or cables.

### MULTI-RAIL IS DEAD, LONG LIVE MULTI-RAIL

In the early to mid-2000s, the power needs of average PCs grew greatly as CPUs and GPUs rapidly became more demanding. To meet that need, power supply manufacturers started adding more 12V rails to their designs in order to scale their performance.



Corsair offers a £20 16-pin cable for its PSUs, which plugs into two PCI-E modular power connectors

much current under a certain workload, causing a fire.

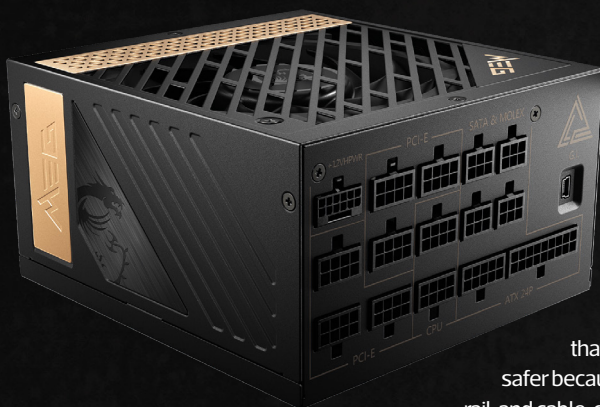
ATX 3 defines four 12V power rails – 12V2 supplies the CPU expressly, 12V3/V4 share duties for the 12VHPWR cable, and 12V1 is divided among the other components.

## BY HOOKING THESE TWO PINS TO A GROUND ON THE POWER SUPPLY, YOU CAN BYPASS THIS SAFETY LIMITER AND UNLOCK THE FULL POWER

present, it's required to be a 16-pin (12+4-pin arrangement), but it's optional for the power supply itself to support the 4-pin sideband signalling from the graphics card.

Intel recommends, but doesn't require, labelling the connector with the maximum wattage, so the user knows exactly what the 12VHPWR cable can provide. This leaves the door open to legitimate ATX 3-stamped power supplies being sold without a 12VHPWR cable at all, or with a cable, but you don't know how much power it can provide. It's messy.

**MSI's MEG Ai 1300P ATX 3 PSU gives you the option to use software to switch between a single 45.5A 12V rail, or multiple rails capable of delivering different amounts of current**



This worked, but the argument against it was you'd never have access to all the rated power on the box unless you used every rail evenly, which really depended on the build – a single-GPU system with multiple hard drives didn't have the same power requirements as a multi-GPU system with just one hard drive.

As a result, the trend changed, and power supply brands began to design monster single 12V rails that could supply all the power of the unit, no matter what you plugged into it. It deferred the safety check element to the components, such as a graphics card opting for one, two or three 8-pin power connectors to split its power needs without going beyond the rated max of each cable.

That hands-off approach is now over. The consequence of the current situation, where a single graphics card with tens of billions of transistors needs insatiable amounts of power, and then adds a layer of enormous power excursions on top, means

that multi-rail designs are now safer because they ensure that no single rail, and cable, can be required to draw too

### TO THE EXTREME

In order to accommodate spikes of extreme, sudden power demand, the nominal voltage of the 12V rail is also being boosted to up to 12.2V to compensate for voltage drops on sudden, huge power excursions.

It's not just graphics cards that are connected to the 12V rails though. Intel appears confident that a modern motherboard VRM will sufficiently control the precise voltage for the CPU, not to mention add-in equipment such as NVMe drives, SATA drives, old optical drives or even niche hardware that might still be used, which still has to withstand the persistent slight increase in voltage.

An ATX 3 power supply also must accommodate a 5x higher slew rate than previously. Slew is the rate at which the voltage or current changes for 12V transient loads. With an RTX 4090 nearly trebling the transistor count over the previous RTX 3090 Ti, tens of billions more of tiny, sensitive transistors suddenly firing up or turning off during a scene change, map changes or many other scenarios during gaming or everyday PC use, can create unpredictable load patterns, so more stringent power control is required.

As a result, power supplies fitted with the 12VHPWR connector are required to support a 2x greater change in current draw per microsecond than those without one.

### POWER EFFICIENCY

If a power supply designer isn't interested in meeting Energy Star or CEC legal requirements, which are US-centric, the ATX 3





standard also requires minimum efficiencies at 20/50/100 per cent load of just 65/72/70 per cent respectively. In terms of meeting the minimum spec, it's basically a shoulder shrug and a missed opportunity to enforce less wasteful products on a global scale.

Thankfully, every reputable PSU brand commits to selling a single design that includes the US market, so also commits to CEC and Energy Star requirements, in addition to a marketable 80 Plus certification. As a minimum, this standard requires efficiency at 230V of 88/92/88 per cent for 20/50/100 per cent loads, which is a shade below 80 Plus Gold standard.

Looking across the power supply market today, 80 Plus Gold has effectively become the minimum spec of high-power units already, so ATX 3 will continue this trend.

The standard also states that the minimum efficiency for power supplies over 500W should be 70 per cent at 2 per cent of max-rated capacity. For example, this means a 750W power supply will need to be at least 70 per cent efficient at 15W output.

This basically covers situations when your PC is in a soft-off state or in standby, but you still have mice, keyboards or gamepads

connected, and still sipping power, some RGB bling is still blaring, or phones are charging from specific USB ports. In this case, ATX 3 even goes beyond 80 Plus, which doesn't mandate a sub-20 per cent load efficiency unless it's 80 Plus Titanium – its highest rated specification – so it should encourage a higher quality design.

### WAKY WAKY

Sticking with the subject of low power states, one of the PC's new power states is Alternative Low Power Mode (ALPM), which has replaced Alternative Sleep Mode (ASM). Windows 10/11 calls ALPM 'Modern Standby', but unlike every other power state that simply requires a BIOS switch or in-OS option checkbox, Windows must be entirely reinstalled in order to support Modern Standby.

Modern Standby is S0 – a low-power state between 'screen off but still awake' and S3 standby. As with your smartphone, this allows your PC or laptop to wake up instantly at the touch of a button. This has a knock-on effect on power supply design, because Alternative Low Power Mode (ALPM) leans on the +5VSB standby rail. This rail is usually only designed to carry 3A and could previously be considered

**Right, I'm just taking my ATX 3 PSUs down to the gym. Back in a bit**

less important than 12V rails, so it's often supplied from a separate circuit inside the power supply.

The problem is that many people charge their smartphones from their PC or laptop, with quick charging able to draw the full 3A using 5V, so the +5VSB rail must be resilient enough to wake up the system even in these scenarios.

The ATX 3 spec suggests it supports up to 3.5A for half a second before overcurrent protection kicks in, and it also provides a target (but not minimum) power efficiency of 75 per cent from ~18 per cent loads and upwards.

### PUSH THE BUTTON

Finally, the ATX 3 standard requires a power supply to achieve a minimum of 175,200 power cycles, which equates to 48 years of use if you turn it on ten times a day. That's plenty. Although notably, it doesn't include the fan in that requirement, which as a mechanical item will certainly fail much sooner, but probably not in the time before you're upgrading anyway. By then, we'll probably be looking at ATX 4. **GPB**





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

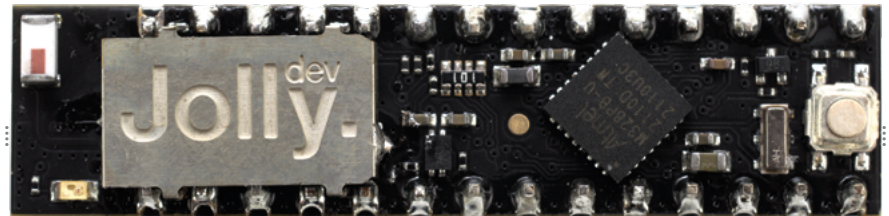
### Jolly Module

**R**eleased more than a decade ago, the Arduino Uno rapidly rose to become the go-to development board for a wide range of microcontroller projects. With integrated USB programming capabilities, pulse-width modulation (PWM) support, and both analogue and digital inputs, the Arduino Uno delivered plenty of features at a low cost and absolutely deserves its position in history.

In 2022, though, its feature set feels a little lacklustre. Its successors and competitors,



The module fits where the ATmega328P chip would usually sit, although it stands proud of the headers



from Arduino and beyond, offer more powerful processors, additional connection options and more. It's a situation that's ended up with many makers hiding their Unos away in a desk drawer, having followed the siren song of more modern microcontroller boards.

That's where the Jolly module enters the fray. Developed by Gianluca Martino, one of the cofounders of Arduino, the Jolly is a drop-in upgrade for the Arduino Uno and compatibles. Simply pop the bulky DIP-packaged Microchip ATmega328P out of its socket on the Uno, push the Jolly Module home, and you'll get all the features you're used to, along with the addition of 2.4GHz Wi-Fi.

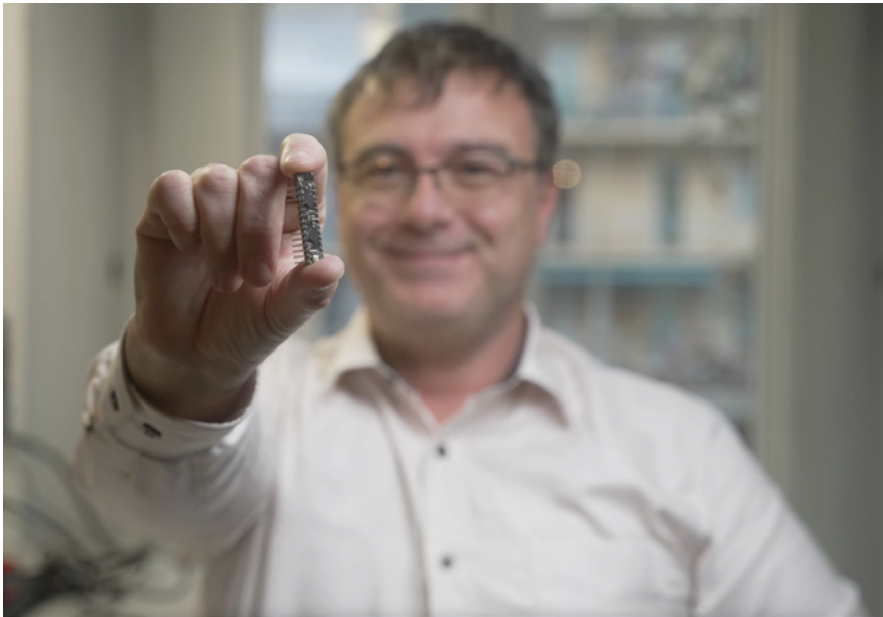
The secret behind the Jolly module is a move to an ATmega328PB – the name is a single letter away from the original microcontroller driving the Uno, but this chip comes in a considerably smaller surface-mount package. Shrinking the main microcontroller provides room for a second

**Surprisingly compact, the Jolly module is a drop-in upgrade for Arduino Uno boards**

one – an Espressif ESP8285H16, a system-on-chip that has its own Tensilica L106 Diamond microcontroller core, along with an 802.11b/g/n Wi-Fi radio.

Having performed the necessary electronic surgery to upgrade an Arduino Uno board with a Jolly, there's little change in everyday operation. Add the board definition URL to the Arduino IDE settings and a Jolly core appears in the Board Manager, installed in seconds with just a couple of clicks.

Once the core is installed, almost any program written for the original Arduino Uno can be compiled and flashed onto the Jolly module – operating identically to the original chip. There are only minor exceptions – an Arduino port of the Dhrystone benchmark, known for riding at the very edge of free memory on an unmodified Uno, failed to finish its run on the Jolly module, but that was the only program on test to show any difficulties.



If you're only running Uno-compatible code, though, there's no reason to get a Jolly. Martino and colleagues have included code samples with the core toolchain, offering a hands-on quick start to handling the Wi-Fi radio. From scanning for networks to connecting, acting as a web client, or running an on-device web server that reads values from the Arduino's analogue inputs, clear examples make it easy to integrate the Jolly into a connected project.

A boot button on the module itself – distinct from the reset button on the Arduino Uno board – provides a means to switch from flashing your code on the ATmega328PB to the ESP8285. For most makers, there's little reason to do so beyond potentially upgrading

**The module was designed by Arduino co-founder Gianluca Martino**

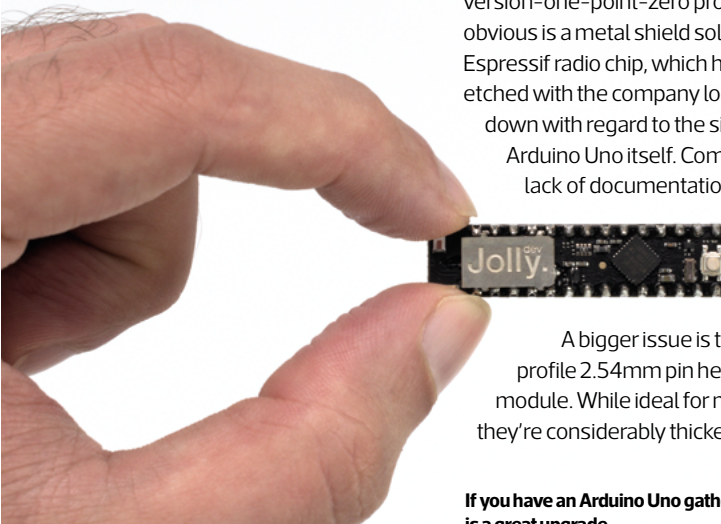
the firmware that handles the networking; for advanced users, it provides a second core that can run alongside the ATmega328.

There's another trick up the Jolly module's sleeve too. While it's designed for installation in an Arduino Uno or pin-compatible carrier, it's also capable of standalone operation – with castellated solder pads for its pins providing a means of attaching it as a surface-mount module to custom carrier boards. At the time of writing, however, the modules being shipped came with 2.54mm male pin headers already soldered into place.

The Jolly module is an undeniably clever design, but there are definite signs it's a version-one-point-zero product. The most obvious is a metal shield soldered over the Espressif radio chip, which has been laser-etched with the company logo, but is upside down with regard to the silkscreen on the Arduino Uno itself. Combine this with the lack of documentation and it's all too

easy to install the module backwards in the socket.

A bigger issue is the use of square-profile 2.54mm pin headers on the module. While ideal for motherboards, they're considerably thicker than the legs



**If you have an Arduino Uno gathering dust, the Jolly is a great upgrade**

## NEWS IN BRIEF

### Framework launches Chromebook variant

Modular laptop specialist Framework has announced a new model, the Framework Laptop Chromebook Edition which, as the name suggests, comes preloaded with Google's ChromeOS. 'We designed the Framework Laptop Chromebook Edition to maximise longevity and minimise impact on the planet,' the company claims.

The machine 'is built with the Titan C security chip and receives automatic updates through June 2030, all to keep your Chromebook fast and secure.' UK pricing and availability haven't been announced yet, with pre-orders opening in the US at \$999 US (around £890 ex VAT) for December delivery.



of the ATmega328 originally installed in the Arduino Uno. As a result, the socket 'stretches', making it impossible to revert the upgrade and go back to the original ATmega328. The legs are also a touch too long, leaving the module standing proud of the Arduino Uno's female pin headers.

On the software front, the Wi-Fi firmware defaults to providing an unauthenticated webserver offering manual pin control, a system that really should be made optional for security.

The Jolly module is available to buy now at [jolly-dev.com](https://jolly-dev.com) for €15 (around £13 ex VAT), a price which makes it hard to recommend over a self-contained device such as the Raspberry Pi Pico W (see Issue 229) at £6 inc VAT. However, the Jolly module does offer an affordable way to offer dusty Arduino Uno shields a second, network-connected life.





## REVIEW

# Shareware Heroes

**R**ichard Moss is a man with a love for vintage gaming. His first book, *The Secret History of Mac Gaming* (see Issue 196), was a walk through the history of games on a machine that's most associated with serious business. His second book, *Shareware Heroes*, holds no such ties to a specific platform.

Moss' latest book isn't quite as lengthy, at 338 pages plus 16 colour plates in the book's centre, compared to 416 for the first book, but that by no means indicates a lack of content. Shareware Heroes is absolutely packed to the gills, yet by Moss' own admission, it can't even attempt to offer a truly comprehensive look at what was for years the most popular way to distribute, buy and sell games, as well as other computer software.

The book opens in the 1970s, when most independent software authors gave away their wares for free – being forbidden from using the ARPANET, the government precursor to what would become the Internet, for commercial purposes.

Even this early into the book, there's information likely to surprise many people,

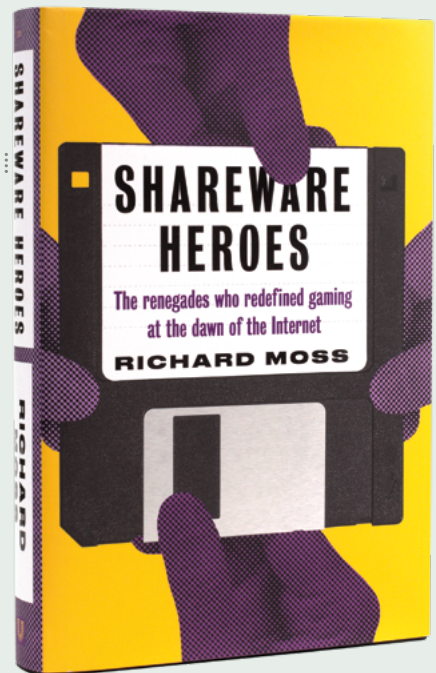
**Imagery is reproduced in greyscale, bar a number of colour plates at the book's centre**

such as the origins of the term 'shareware', and how it beat out the rather misleading and ironically trademarked 'freeware' and verbose 'user-supported software'.

For readers unfamiliar with shareware, here's a brief aside. In the days when a magazine such as the one you're reading now would have come with a floppy disk glued to the cover, and when home internet connections were effectively unavailable, shareware was king. Authors encouraged the copying and free distribution of their software, and asked a small fee for 'registration' in order to unlock additional features, receive a printed manual or simply to reward the author for a job well done.

At the time when Andrew Fluegelman began distributing his PC-Talk communications software under these terms, it seemed outlandish that anyone would voluntarily pay. When millions of dollars began arriving at his door, though, it was clear he was on to a big idea.

As you might expect from the author of a book on retro gaming, there's a heavy focus on shareware games rather than business software. It goes from 3D Pac-Man clone 3-Demon, released in 1983, to turn-of-the-



## Shareware Heroes highlights the rise and fall of the shareware/freeware/user-supported software industry

century titles such as Tread Marks and, of course, the work of noted shareware giants, such as Apogee Software, id Software and Epic MegaGames.

There are no guest chapters this time around, and while Moss has interviewed as many shareware developers and distributors as possible, he admits there are gaps in the research. The biggest one is the loss of CompuServe's forums from the 1980s, where so much shareware was traded and discussed that the company would launch a middleman service in order to tack registration fees onto subscribers' monthly bills.

The book also handles its citations in an unusual way. There's no printed bibliography, although there is a short glossary of terms



**For some reason, even the PDF is greyscale – and missing the colour plates**

## NEWS IN BRIEF

### DevTerm gets a CM4 upgrade

Clockwork Pi's DevTerm retro-futuristic portable computer (reviewed in Issue 222) has a new model, based around the Raspberry Pi Compute Module 4. Using the same injection-moulded chassis, compact keyboard and trackball, and ultrawide display as the original, the new DevTerm RPI-CM4 Lite comes with a bundled Raspberry Pi Compute Module 4 10400 Lite with quad-core Arm Cortex-A72 processor, 4GB of RAM and integrated Wi-Fi and Bluetooth connections. The kit is available at [clockworkpi.com](http://clockworkpi.com) for \$279 US (around £250 ex VAT) including a CM4 module. However, the company warns that delivery could take up to 60 days.



at the back, with Moss instead placing the bibliography online on the book's official website. There's also a separate database of online sources, which acts as a great companion for anyone looking to do a deeper dive into the topic after (or while) reading the book.

The text pages – in a comfortable serif font this time, rather than the tiring sans-serif, oddly spaced layout of *The Secret History of Mac Gaming* – are broken up with full-page and occasional inline images, typically using a blow-up screenshot or pattern as a background, with smaller screenshots overlaid on top of them. These are all, sadly,

None Contents Sources Reviews Links

>> Shareware Heroes: The renegades who redefined gaming at the dawn of the Internet

A really awesome book about cool people and things.

About the book

From the author of *The Secret History of Mac Gaming*, *Shareware Heroes* tells the story of the developers and games from the 1980s and 90s that dared to be different – relying not on flashy marketing but rather on making great games that speak for themselves, and that were distributed across the nascent internet for anyone to enjoy (and, if they liked it enough, pay for).

Written by Richard Moss. Made possible by 970 crowdfunding backers. Published by Unbound.

Out now in the UK and online; US trade paperback to follow in January 2023 (but Kindle edition available now)

Buy your copy

Hardback or DRM-free ebook Amazon UK (Paperback or Kindle)

US/Canada Kindle edition Book Depository (Paperback)

US/Canada paperback preorder (Amazon)

>> Full description <<

\*Shareware Heroes\* takes readers on a journey through a critical yet long overlooked chapter in video game history: the rise and eventual fall of the shareware model.

As commercial game distribution professionalised in the 1980s, independent creators with scant resources or contacts were squeezed out of the market. But not entirely. New technologies and distribution concepts were creating a hidden games publishing market – one that operated by different rules and that, at least for the first several years, had no powerful giants.

It was a land of opportunity and promise, and a glimpse of the digital-first future. This is the story of the games and developers who relied on nascent networking technologies combined with word-of-mouth marketing in an era before social media.

Building on deep archival research and featuring interviews with creators, developers and other heroes of the shareware age, Richard Moss – author of *The Secret History of Mac Gaming* – once again brings to light a forgotten but all too important era of game development.

About the author

Richard Moss is an award-winning journalist, writer, and historian based in Melbourne, Australia. He has written for more than 38 games, technology, and science publications, including *Ars Technica*, *Edge*, *EGM*, *Game Developer*, *Hyper*, *MacLife*, *PC Gamer*, *Polygon*, *Ruck Paper Shotgun*, and *Vice Motherboard*. His specialties are long-form reporting on the future and the past of technology and in-depth looks at niches within the games community.

Richard's first book, *The Secret History of Mac Gaming*, is rated 4.27 on Goodreads and was called a "fascinating read" by *Retro Gamer* Magazine as well as "a great book" by *Hyst* co-creator Robin Hillier and "packed with info" by Macformat. It is now available [in an expanded edition from Wiley Books](#).

Richard is also co-writer and producer on CREATORC's upcoming documentary *WPS: First Person Shooter*, and he creates the narrative podcasts *Lightside* and *The Life & Times of Video Games*.

You can find him on Twitter [@mossrhc](#).

WEBSITE STILL WIP – STAY TUNED FOR MORE

>> Progress: <<

(While you wait, you can play with the Classic Mac-themed website for my other book.)

The companion website, themed around an old DOS interface, includes the bibliography

reproduced in greyscale – even in the digital copy, losing impact in the process.

Those picking up the digital copy will find themselves a little short-changed too. The 16 colour plates in the print edition – which range from images of boxed shareware and floppy disks to behind-the-scenes photographs – are completely absent from the PDF.

It's the text that draws the reader into the book, though, and this is where Moss definitely delivers. As with his previous book, a passion for the topic comes through loud and clear, and a great balance between factual info-dump (with a small number of forgivable errors) and entertaining narrative is drawn. However, the chapters for which a willing interviewee was available unarguably flow better than those written from the outside looking in.

For anyone who was around in the glory days of public-domain libraries, Fish Disks and cover mounts, *Shareware Heroes* is a walk down Nostalgia Lane, whether you were a Mac user, an Amigan, a DOS gamer or a Windows clicker.

For others, particularly those who came to gaming after digital distribution via the Internet, and two-hour refund periods made user-driven distribution and trial runs all but obsolete, it's a window into how different the independent software market was back then, and some of the successes and failures that led us to the world of today.

*Shareware Heroes* is available now from [unbound.com](http://unbound.com) for £30 (no VAT) in hardback format, or for £10 inc VAT if you want to pick up a DRM-free PDF download. **CPC**



ANTONY LEATHER'S

# Customised PC

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

## Start saving for your next motherboard

It's been a pretty frantic 12 months for PC enthusiasts, what with the tail end of the pandemic and the war in Ukraine both impacting economies worldwide. It's taken a while for the real toll of this situation to be revealed on retail prices, but combined with the pound hitting some devastating lows, it's going to be expensive to build or upgrade your PC.

Older hardware such as AMD Ryzen 5000-series CPUs, and Intel 10th and 11th-gen CPUs, plus their respective motherboards and memory, usually get some tasty retail price cuts just before major launches, but this time around, those discounts have been pretty conservative.

Even if you turn to eBay for your hardware, you're unlikely to see the influx of older gear you would normally expect following new hardware launches, as people are hanging on to their old PCs to save cash. We've seen exactly the same happening in the car industry, which I found out at my own

cost when I had to get another car a few months ago.

What's more, the drop in value of the pound is making new gear even more pricey for us, as it has to be imported, unlike existing stock of old gear. On the plus side, you don't need a flagship motherboard in order to run AMD's Ryzen 9 7950X at stock speed, but even the cheapest X670E board will set you back over £300, and you'll need to buy DDR5 memory for it as well.

The price of motherboards is the biggest issue for me here. I love having an all-singing, all-dancing model, with loads of fan headers, USB ports, big heatsinks and premium features. Ideally, I want Thunderbolt or USB 4 too. I was glad to see a lot of these features appearing on AMD's Socket AM5 motherboards, but I probably won't get any change from £400 if I buy one.

I hate to say it, but I'm actually considering going for a Z590 system,



**The latest X670E motherboards offer some very high-end features, but they're also extremely expensive**

or maybe waiting for Z690 prices to drop. I've had my Socket AM4 system for a couple of years now and I want a change, as well as to start another modding project in a mini-ITX case.

However, the cost of buying a new Socket AM5 system, with the need for a pricey motherboard and DDR5 memory, is a real turn off, especially in the UK. If I go for older hardware, I could start building my new setup now, but if it features new hardware, then I (like many others out there) will need a few months to save for it.



# A trip to Intel's Israel fab

**L**ast month I was lucky enough to be invited on a trip of a lifetime to see Intel's current semiconductor fabrication plant (fab) in Israel. It was the first time it had opened its doors to journalists and allowed them inside Fab 28's sterile clean rooms, where the company's Alder Lake and Raptor Lake processors are currently being made.

The fab I visited is huge, but the company is building even bigger ones as it aims to boost its own production capabilities, as well as tap into the massive demand for microchips, offering its services to third parties. In fact, one such plant is already being built in Israel. The new Fab 38 is where Intel's Foveros-based CPUs

**CPUs are individually tested in a live binning process that sets voltages for each chip's capabilities**



will be made, which feature 3D chip stacking tech.

This technology is coming to mobile silicon first but will appear on desktop CPUs soon, and Intel is also increasing its production capacity both for itself and in order open up its services to third parties in the wake of massive demand for microchips. It's an aggressive and innovative time for a company that has spent a lot of the last 15 or so years without CPU competition and languishing with incremental updates.

Anyway, back to the Fab 28 visit, which is where the current magic happens. Automated ceiling robots ferry silicon wafers around enormous rooms filled with machines in CD changer-style stacks, with these robots sporting evil robot-like red lights and whizzing around, all aware of each other and slowing or speeding up accordingly. On one particularly long stretch that seemed to go on for hundreds of metres, the line of red lights from dozens of robots coming towards me did make me want to run the other way.

As incredible as it was to be in the same room as seconds-old Alder Lake and Raptor Lake CPUs, the testing



**Automated ceiling robots ferry silicon wafers around the facility**

and quality-control areas were just as eye-popping, with hundreds of water-cooled testing stations ironing out bugs and issues on a massive scale.

CPUs are individually tested too, in a live binning process that sets voltages for each chip's capabilities. If you own an Intel CPU, it will have been tested in one of these machines before it leaves the factory. Seeing this in action, with CPUs being picked up from trays and dropped into motherboard sockets, it didn't surprise me that I've never had an Intel CPU die on me.

Other amazing rooms featured microscopic error checking processes, which could zoom right into individual sections and traces on a CPU to see areas that needed corrections, and then fix them in real time to create a different stepping of a CPU. In the past, these revisions have occasionally improved performance or increased overclocking potential too.

It's an interesting time for Intel, with its hybrid core architecture, increased production capacity and plans for more innovative CPU designs in future, as well as fierce competition from a resurgent AMD. It's mightily impressive to see the manufacturing process in action, and the next few years are going to be very interesting indeed. **GPC**

**Hundreds of water-cooled testing stations iron out bugs and issues on a massive scale**

# How to Boost your GPU's cooling

**Antony Leather** shows you how to change your graphics card's thermal paste and rig up some extra cooling fans

**TOTAL PROJECT TIME / 2 HOURS**

**L**ike it or not, that huge cooler on your graphics card probably isn't that good, or there's certainly room for improvement. The slim fans used on many GPU coolers lack the static pressure and airflow needed to fully take advantage of the heatsink beneath them. It's little wonder that fan manufacturer Noctua recently teamed up with Asus to create a graphics card with its PC fans that has incredible cooling.

Thankfully, there's a way to dramatically drop your graphics card's temperatures in the same way, by using standard case fans to replace its stock cooler. It doesn't take up much more space, and replacing the thermal paste at the same time can help to drop temperatures further. With extra cooling, your card could hit higher GPU boost frequencies, overclock further and run cooler and quieter too. Here's how you do it.

## TOOLS YOU'LL NEED



2-pin thermal probe  
overclockers.co.uk



Microfibre cloth  
Most hardware stores



Thermal paste  
overclockers.co.uk



Cable ties  
Most hardware stores



120mm fan  
overclockers.co.uk

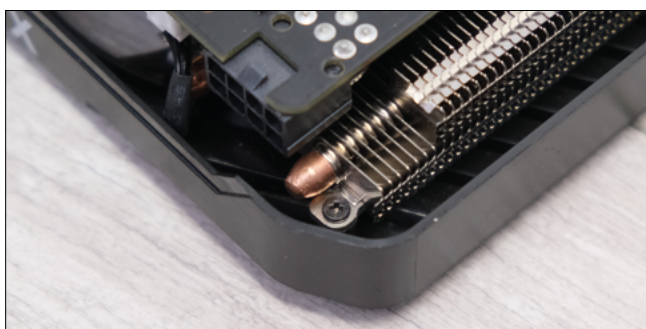


Thermal paste cleaner  
overclockers.co.uk



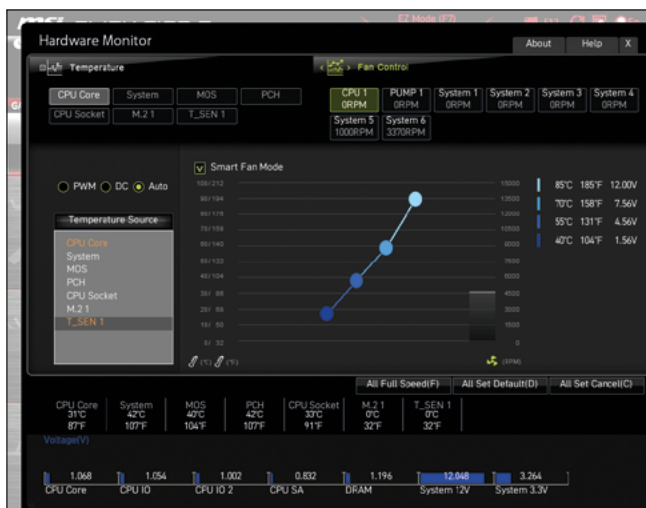
### 1 / CHECK YOUR WARRANTY

Be aware that removing your graphics card's cooler can void your warranty, so check if you still have one and if you're prepared to lose it.



### 2 / IDENTIFY COOLER SCREWS

Your graphics card's cooler is held on with screws, and you'll need to identify them, so you can start to work out how to remove it. If your card has a backplate, this may also hide the screws and will need to be removed first or during the process.



### 3 / CHECK MOTHERBOARD EFI

Your graphics card controls its own fans based on the GPU temperature, but this won't work if you use your own fans connected to your motherboard, as it may be controlling them according to the CPU temperature instead. Head to your motherboard's EFI to see if you can select the GPU or a thermal probe as a temperature input.





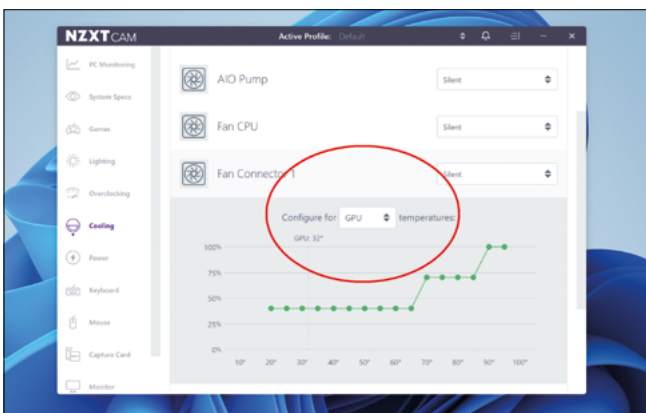
#### 4 / USE A THERMAL PROBE

If you can select the GPU then you're all set, but alternatively you can use a thermal probe attached to your graphics card to tell the motherboard when it needs to spin up the new fans.



#### 5 / OPTIONAL: USE ARGUS MONITOR

Using software is another option for fan control. Argus Monitor ([argusmonitor.com](http://argusmonitor.com)) isn't free but it's a great program to control your system fans, allowing you to link them to GPU temperature as well.



#### 6 / OPTIONAL: USE AN NZXT MOTHERBOARD

NZXT's motherboards use the company's CAM software to control fans, offering another way to control your GPU fans using fan headers while linking their speed to the GPU temperature. CAM can switch to the GPU for temperature input for fan headers, so it's perfect for this task.



#### 7 / TEST CURRENT TEMPERATURES

Check your current GPU load temperature and peak boost frequency to see the benefit of your work, using GPU-Z ([techpowerup.com](http://techpowerup.com)) to record the peak temperature while running the 1080p Extreme Benchmark mode in Unigine's Superposition ([benchmark.unigine.com](http://benchmark.unigine.com)).



#### 8 / CHECK CLEARANCE IN YOUR CASE

Adding 120mm fans to your graphics card will make it thicker and wider, so you'll need to make sure your case can accommodate these dimensions. Line up the fans on the heatsink to assess the width, then add the depth on top of the heatsink and see if your case has room for these measurements.

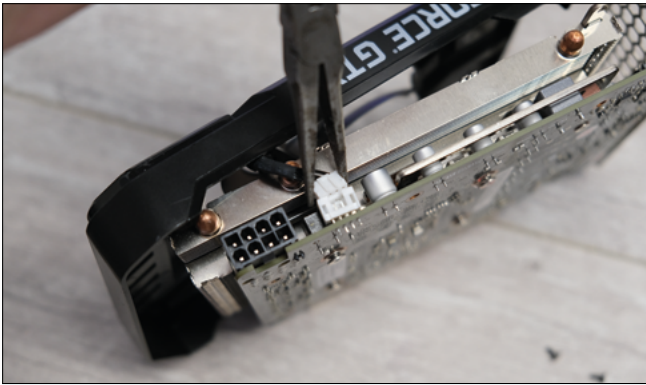


#### 9 / REMOVE COOLER

Your goal is to remove the fans and their shroud from your graphics card, leaving just the heatsink. Remove any necessary screws and gently lift the fans off the heatsink. You may need to detach the heatsink as well in order to do this, but if you can't separate the heatsink from the fans then your card is incompatible with this mod.





**10 / DETACH COOLER CABLES**

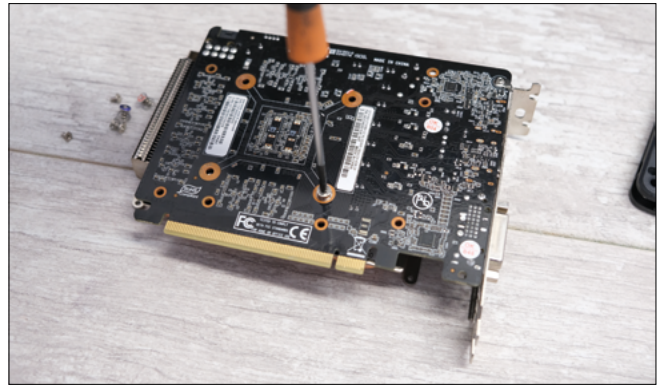
Once you've separated the fans and shroud from the heatsink, detach the power cables for the fans and any RGB lighting. You may need to use needle-nose pliers for this job, but be careful to only pull on the connector and not the cables, while also taking care not to scrape the PCB.

**11 / OFFER UP 120MM FANS**

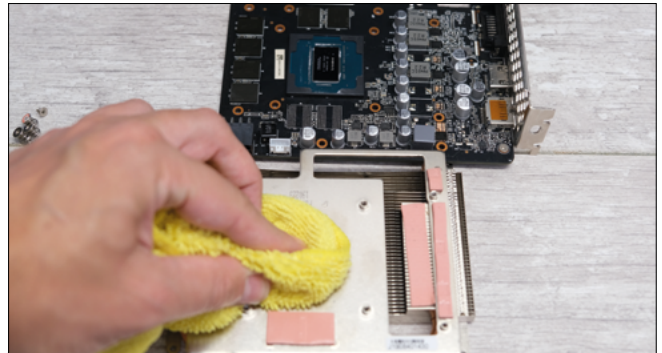
With the heatsink exposed, line up your fans so that they cover the entire heatsink. Make sure that any gaps in the airflow are as small as possible.

**12 / CONSIDER SLIM 120MM FANS**

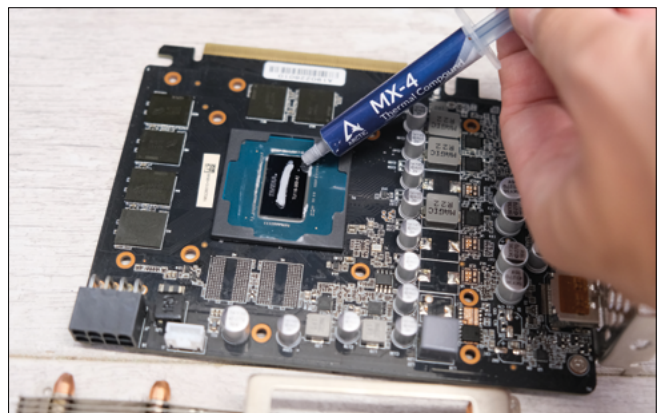
If you're struggling to deal with the added depth from the fans, you can consider using slim fans. These are available in 120mm and 140mm sizes from the likes of ARCTIC and Noctua, and can shave 10mm off the depth of a normal fan, while still providing more static pressure than typical GPU fans.

**13 / REMOVE THE HEATSINK**

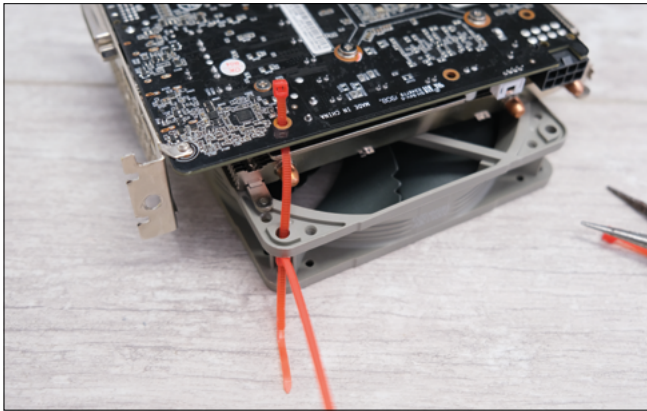
Before you install the fans, remove the heatsink from your GPU, so you can apply fresh thermal paste. This can reduce your temperatures by several degrees and is an easy job to perform at the same time as this process.

**14 / REMOVE OLD THERMAL PASTE**

With the heatsink removed, clean the old thermal paste off the GPU core and base of the heatsink. You can do this with a microfiber cloth and either thermal paste cleaner or isopropyl alcohol too. Leave any thermal pads in place.

**15 / APPLY HIGH-PERFORMANCE THERMAL PASTE**

Apply thermal paste to any areas that had it before, using a drop in the centre of the core that's the size of a grain of rice. Don't use liquid metal paste for this job, but instead use a ceramic, non-conducting paste such as ARCTIC MX-4.



## 16 / IDENTIFY FAN-MOUNTING POINTS

There are numerous ways to mount the fans, but using cable ties to secure them onto the heatsink is the easiest and cheapest option. Test-fit the ties through these holes and see if they'll reach back to the fans.



## 17 / INSTALL THE FANS

Place the fans onto the heatsink, line them up so that the whole of the heatsink is covered and then secure them in place with cable ties, extending them if necessary. You can tie two fans together for support.



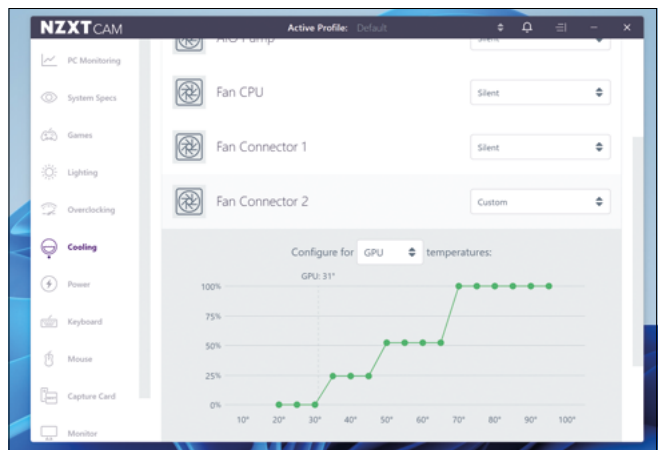
## 18 / CONNECT FANS TO POWER HEADERS

Now connect the fans to the power headers on your motherboard. Most ATX motherboard have plenty of fan headers in various locations, but if not, you'll need to buy fan extension cables to ensure your new graphics card fans can reach the headers.



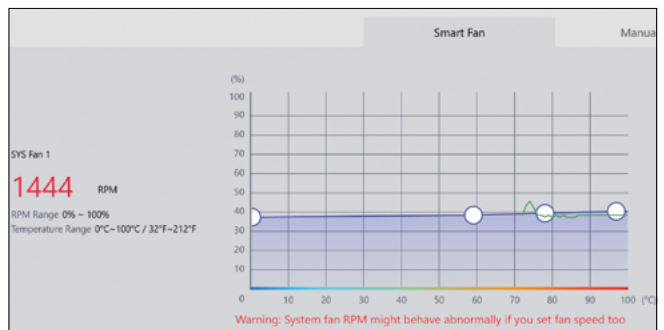
## 19 / SECURE THERMAL PROBE

If you decide to use a thermal probe, you need to make sure it stays in the same position – otherwise your fans might not spin up when needed. Use a cable tie to anchor it in place. Don't use tape, as this can heat up and come loose.



## 20 / USE THE EFI OR SOFTWARE

In your EFI or fan control software, select the GPU as the temperature source and set the fans to run at full speed when your GPU core temperature hits 70°C. From there, you'll need to fine-tune the rest of the fan curve so that the fans spin slower at lower temperatures. The latter will depend on your heatsink and fans.



## 21 / SET FANS TO MINIMAL SPEED

Alternatively, you can set a fixed fan speed that can cope with gaming. Don't use full speed, as the fans will be much louder than necessary. Find a speed that offers enough cooling power while remaining quiet – this will depend on the fan model and your GPU, but you can monitor it using the same technique as step 7. Retesting showed our GPU core temperature fell by 7°C. **GPC**



# Retro tech

## FULL-MOTION VIDEO

FMV is responsible for some of the worst artistic crimes in video game history. **Rick Lane** charts the teething problems in the 1990s and the technique's more recent redemption

**F**ew PC gaming technologies have been quite so maligned as full-motion video (FMV). Originally appearing in the early 1980s and throughout the 1990s, FMV formed the basis of some truly abysmal interactive movies. You may have heard some of the names – Night Trap, Phantasmagoria and The 7th Guest. These are the good ones, which had (relatively) decent production values and a rather coherent idea of their purpose.

Beneath these games are dozens of interactive movies so bad they make Phantasmagoria look like The Shining. Interactive movies did so much damage to the reputation of FMV that it more or less disappeared from games the moment real-time graphics became detailed enough to render a half-decent cutscene.

But FMV itself is neither good nor bad. It's merely a tool, and the history of that tool goes a long way to explaining why interactive movies were once so bad, and why more recent efforts to revive the genre have been more successful.

The fate of FMV was in many ways preordained by the limitations of physical media, and the evolutionary status of the game industry itself. Although we referred to FMV

as a technology earlier, the term refers specifically to the technique of using live action or animated footage in a video game. However, the quality and viability of FMV has historically been heavily dependent on several PC technologies, particularly the physical media upon which it was stored, and the format with which it was encoded.

### LASERDISC BEGINNINGS

The earliest FMV games were made possible by the invention of LaserDisc, massive LP-sized optical discs that were primarily used for watching movies. The extra storage size and improved image quality provided by LaserDisc compared with video tape, alongside the ability to store and retrieve data on them in a non-linear fashion (unlike VHS), meant that, for the first time, video footage could be used as the basis for video-game graphics.

The first LaserDisc FMV game was Astron's Belt in 1982, an arcade space shooter where players controlled a sprite-based ship in front of rolling FMV footage of asteroids and other hazards. Thanks to the use of this pre-rendered footage, FMV arcade games looked visually light years ahead of their real-time counterparts, the most famous example being 1983's Dragon's Lair.

Cinematronics' animated dungeon crawler still looks striking today, so it's easy to imagine its impact when it was released almost 40 years ago (Ed: I remember it well! It looked absolutely stunning, like nothing else we'd seen before – a proper cartoon that you could actually play. We all really wanted to play it, and then ended up being disappointed by the limits of the actual game).

But the pre-rendered footage that made FMV games so attractive also severely limited their capacity for interaction. Consequently, the popularity of FMV arcade games quickly dwindled as players realised there wasn't much going on beneath their glossy exteriors. Arcade FMV games resurged a second time in the late 1980s and early 1990s, with games such as Mad Dog McRee and Who Shot Johnny Rock? However, the interactivity problem once again meant the fascination with them was short-lived.

Thanks to the use of pre-rendered footage on LaserDisc, early FMV arcade games such as Dragon's Lair looked visually light years ahead of other games. Screenshot via MobyGames







**Sierra's big FMV game Phantasmagoria was released on seven CDs**

## DELIVERED ON EIGHT CDs

The heyday (if it can be called that) of FMV gaming was heralded by the arrival of the CD-ROM. Capable of holding around 700MB of data, CDs made games that used FMV footage a viable prospect on home computers. It was only just viable, however, and as the decade progressed, FMV games would require an increasingly absurd number of discs. 1995's Phantasmagoria, for example, was released on seven CDs, while one of the last FMV games from the era, Black Dahlia, was released on eight of them.

The delivery mechanism provided by CDs is only half the story. There also came the question of how exactly you render FMVs on desktop monitors. Many developers of FMV games created their own video formats. Sierra, for example, used the file format VMD (Video and Music Data), which was used in Phantasmagoria as well as Gabriel Knight 2. Command and Conquer developer Westwood Studios, meanwhile, had its own FMV format known as VQA, or Vector Quantized Animation, based on a specialised video compression technique that was optimised for the storage space on a CD.

These bespoke file formats hint at the first major problem that FMV games encountered. Although it was technically possible to squeeze hours of video footage onto a CD, that didn't mean the result would be any good. The limited file size combined with the limited processing power of mid-1990s PCs meant that image quality was generally poor.

The resolution was generally low, and the image was highly pixelated, suffering from all manner of visual artefacts. Even the best examples of FMV in games, such as the cutscenes in the space combat simulator Wing Commander 3, struggled with such technical problems.

This quality issue was compounded by the fact that interactive movies essentially combined the arts of game development and filmmaking. In the 1990s, the latter was vastly more expensive than the former. At the time of its release, Wing Commander 3 was one of the most expensive video games ever made, with a budget of \$4 million US.

Compare that with the budget of a blockbuster movie such as Terminator 2, which cost \$110 US million to make three years before Wing Commander 3 was released. Making an FMV game required the developer to hire actors, build or locate sets, create or hire costumes, and have access

to filmmaking equipment, on top of all the other people required to make a game, such as programmers, artists and sound designers.

Consequently, the games often ended up looking and sounding incredibly cheap, casting B-movie actors with simple costumes and basic sets (if they had sets at all). Combine that with compressed, low-resolution video playback, and the results were nowhere near the quality needed to compensate for the limited interactivity that FMV inevitably mandated.

That isn't to say that all FMV parts of games from the era are beyond redemption. Command & Conquer's FMV cutscenes are fondly remembered, although this is mainly because they're short and lean heavily into the B-movie style. Then there's Wing Commander 3, which is probably the best example of FMV storytelling from that era. Even then, though, it has the feel of a low-budget 1970s sci-fi movie.

## A NEW ERA

In short, the technical and budgetary hurdles that interactive movies faced during the 1990s were insurmountable. It's clear this is the case because, recently, developers have started making FMV games again, most notably Sam Barlow's work on games such as Her Story and Immortality (see p66).

These new games are vastly improved over their 1990s' counterparts. Not only is high-quality video playback a trivial affair to process on modern PCs and gaming devices, but games and films are now also more evenly matched in budgetary terms. It's now possible to create a full motion video game that looks as good as expectations.

There's also a crucial advantage of modern FMV games that isn't related to tech. Developers have figured out how to make video in games such as Her Story feel interactive, putting you in the role of a detective searching through an archive of short video clips, or giving you sufficiently branching narratives that it doesn't feel like you're trapped watching a linear movie.

Sam Barlow's games have solved the fundamental design problem that interactive movies have struggled against since the days of Dragon's Lair and, as a result, FMV no longer needs to be consigned to the historical bin of shame. **CPC**

**New games such as Her Story have properly grasped how to make FMV games feel interactive**



# Readers' drives

## HYDROPOWER

Using iron piping, aluminium sheets and some genuine 1940s electrical components, Dante Mutti created this stunning retro-industrial build

**GPC:** What inspired you to build HYDROPOWER – what were your design inspirations and what look were you trying to achieve?

**Dante:** I've always gravitated towards retro/industrial aspects in the design of my mods, and for this

mod I wanted to stay with this theme, with a focus on water and electricity. I wanted to build something that didn't look like a computer, while focusing the design around the liquid-cooling components.

**GPC:** How did you plan out this build? Did you use CAD, good old-fashioned pen and paper, or a mix of approaches?

**Dante:** I initially used hand drawings for the general design. I find it handy to have a sketching notebook in which I can quickly draw up a design with a pencil when I have ideas for mods. Eventually, some of

these ideas will get transferred to a 3D model using SketchUp. I use these models for a general direction of the build, but I never end up building exactly what I design, as I get most of my ideas during the building process.

**GPC:** Is the basic chassis a scratch build? What materials did you use, and what tools and machinery did you use to construct it?

**Dante:** It is indeed a scratch-built chassis. I used to work mainly with existing cases, but once I did my first scratch build, it quickly became my preferred method of building due to the freedom you have around the design.

The mod is mainly made out of pine wood, which I stained black (as opposed to using paint) so that you could still see the wood grain up close. The main structure is held together by black iron pipes and fittings from my local hardware store.

Every component is then mounted on the chassis on aluminium sheet platforms, which were cut to the exact size needed and then mounted on the chassis. The main tools I used in the fabrication process were power saws, clamps, a hand drill and a drill press.

**GPC:** The piping at the front would be right at home in someone's head in an early Valve intro! Tell us all about it.

**Dante:** The piping at the front is actually a custom electrical switch rig that I made using black iron pipes and new red valves, which I distressed with multiple paint colours. It's only attached to the front, although I positioned it so that it looks like it's internally attached to the pipes in the upper panel. The iron pipes don't carry any liquid, but I wanted them to look like they did. So from the front, it looks like it's all interconnected.



### /MEET THY MAKER

Name Dante Mutti,  
aka retro PC mods

Age 47

Occupation Database  
administrator

Location Oregon, USA

Main uses for PC Gaming

Likes Star Wars, grilling  
and woodworking

Dislikes I'm not a fan  
of closed software  
ecosystems





Whenever I build a mod, I love to find a clever way to turn on the PC. I had the idea of building a pipe rig with several taps, and wiring electrical switches to each of the taps, so turning the taps would turn an electrical switch and visually do something to the PC. The left-most tap turns on the PC when you turn it, while the centre and right-most taps control four different lighting zones as you turn them.

**GPC:** What valves did you use and how are they powered?

**Dante:** The valves (also called vacuum tubes in the USA) are one of my favourite points of interest. I love vintage electronics and what's perceived as post-apocalyptic tech. Valves are a big part of that style – even if people don't know what they do, most of us instantly recognise them and associate them with 'old' technology, so they're perfect for the types of mods I like to build.

In this mod they're only used for aesthetics. Each valve has an individual hand-wired LED under it, and around 30 per cent of them have flickering LEDs. So when you turn them on (using one of the taps), you see random movement within the lighting of the valves.

They're a matching pair from 1947 – 75 years old and still in perfect working condition

**GPC:** How are all the PC components and monitor mounted to the chassis?

**Dante:** After I built the chassis, I cut some aluminium sheets and mounted them onto the chassis. This gave me a solid foundation to mount my PC components, but also gave me somewhere I was able to hide the wiring behind each component. The monitor is mounted on the top panel of the

monitor stand using a standard display mount, which allows the screen to move in all directions.

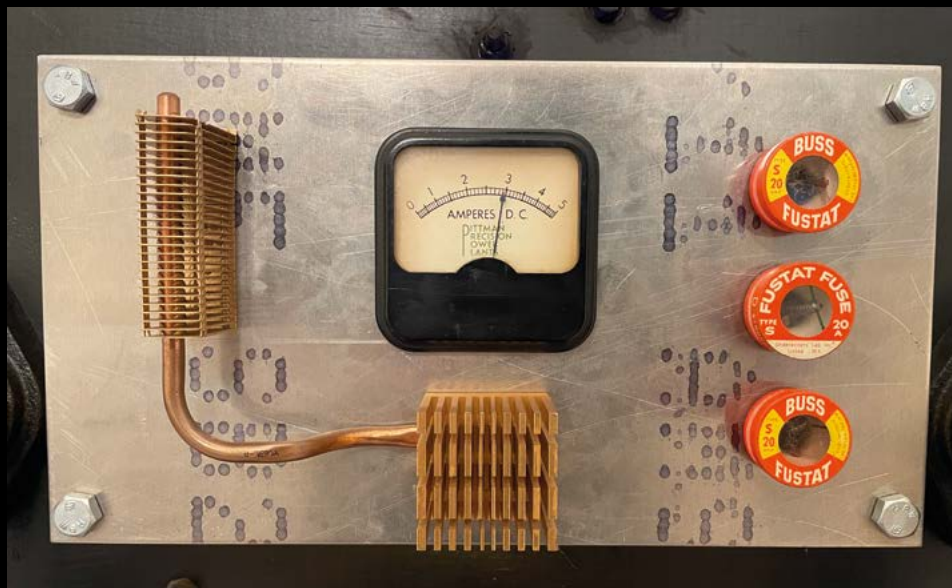
**GPC:** How did you make that custom panel for the rear I/O panel and wire it up?

**Dante:** Due to the shape of the PC, I didn't want to have to plug any devices into the rear of the motherboard or graphics card, because these areas were positioned on the top of the computer. I purchased panel mount connectors that you typically use for marine vehicles and campers, and used these for the custom rear I/O panel. The panel itself is made out of aluminium, the same type as I used to make the platforms that mount the PC components.

**GPC:** How did you create that mesh effect all over the system?

**Dante:** For this mod, I consciously decided to have all the pieces made from the same materials. Whether





you look at the PC, the monitor stand or the board with the mouse and gamepad, they all match because of the materials they all have in common, and the mesh is a key factor that ties them all together. I think adding metal mesh to any electronics automatically gives them an industrial retro look, which is exactly what I wanted to achieve.

**GPG:** That's some immaculate cable tidying considering how many wires must be running between the various bits and pieces. Where are all the wires hidden?

**Dante:** This was one of the biggest challenges, due to the open nature of the design. Mounting the PC components on platforms was a

huge help here, as it meant I was able to initially tuck the cables under the platforms. From there, all the cables are run from the top panel, down to the base of the PC through the iron pipes, terminating at the power supply and the rear I/O panel. To have an open chassis of this type and have hardly any cables visible was a huge accomplishment for me, and the cables that you do see are deliberately visible.

**GPG:** Are those yellow and black PSU cables custom made?

**Dante:** Yes, I made them myself. I wanted custom cables, but I wanted to stick with the retro industrial look, so nylon-sleeved cables were out. I picked these cables in particular because of their vintage look, and exposed them deliberately on the rear of the PC. Having them look like a controlled mess really adds character to the whole look of the PC.

**GPG:** Where did you get the analogue voltage needle displays, and what do they do in this build?

**Dante:** I purchased the voltage and ampere gauges on eBay. They're a matching pair from 1947 – 75 years old and still in perfect working

condition. They're wired to the power supply and they spring to life when the PC is turned on. However, getting the ampere gauge to cooperate was one of the biggest difficulties in this build – I couldn't get it to register a reading, and to be honest, that was because I really didn't know how it worked. That required some research. In the end, I wired up a small board that's meant for a battery charger to it, which allows you to adjust the current.

**GPG:** How long did it take you to complete this build, from start to finish?

**Dante:** I worked on this mod over the course of two years. The original plan was to build just the PC, and enter it into the PDXLAN Case Mod Contest, which is sponsored by Nvidia and EK Water Blocks. Unfortunately, this was right at the start of the pandemic and the event was postponed multiple times over the course of two years.

During that time, I decided to keep modding and then built the monitor stand, the board with the mouse and game pad, and the stand for the controller. By the time PDXLAN came back to being an in-person event again, this mod took first place in the Case Mod Contest.





**GPG:** What part of this build are you most proud of?

**Dante:** One of the things I'm most proud of as a modder is the modded PCI-E riser cable, because I've not seen anyone else do this before. When I first installed the graphics card, I really didn't like how the riser cable looked compared with the other parts I had carefully assembled, so I had the idea of wrapping it in the metal mesh and it came out looking fantastic.

**GPG:** Are you completely happy with the end result, or do you wish you'd done some of it differently?

**Dante:** Because there was such a long span of time between work

starting on it and the mod being finally finished, the original parts were rather outdated by the end. I upgraded the GPU from a Titan X (Pascal) to an EVGA GeForce 3080 Ti FTW3 Ultra, and I also upgraded the memory and SSDs.

The only thing I wish I'd done differently is making upgradability easier, by putting the mounting platforms on hinges that allow them to flip up.

When it was time to upgrade the GPU, it took a large amount of time and effort to fit the new card – I almost had to do a full disassemble of the machine, as most of the cables weren't movable or reachable. **GPG**

## 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](mailto:ben.hardwidge@raspberrypi.com). Fame isn't the only prize; you'll also get your hands on some fabulous prizes, courtesy of Corsair.

### Corsair Hydro X Series XD3 RGB Pump/Reservoir C

The Corsair Hydro X Series XD3 RGB Pump/Reservoir Combo features a high-performance DDC PWM pump, integrated RGB lighting and in-loop temperature sensor to drive even the most compact custom cooling systems. It has a high-performance Xylem DDC PWM pump controlled via PWM to deliver the perfect flow balance for your loop. There are also 16 individually addressable RGB LEDs, which light up the pump head to produce stunning, customisable lighting effects to match your build.

WORTH  
£151



### Corsair Hydro X Series XC7 RGB CPU Water Block

The Corsair Hydro X Series XC7 RGB CPU Water Block combines premium construction, vivid RGB lighting and extreme cooling performance to become the centrepiece of your water-cooling loop. It has a nickel-plated copper cold plate and more than 60 high-efficiency micro-cooling fins, which efficiently draw heat away from your CPU, lowering operating temperatures and allowing for maximum overlocks. You can choose a version for Intel or AMD CPU sockets.

WORTH  
£70



### Corsair Hydro X Series XR5 240mm Radiator

The Corsair Hydro X Series XR5 240mm Water Cooling Radiator delivers extreme custom cooling performance, with a 30mm radiator thickness and premium copper core. Its dual 120mm fan mounts on each side are ready for your most ambitious custom cooling build, and its 25 micron-thick cooling fins offer a high thermal transfer rate.

WORTH  
£55







JAMES GORBOLD / HARDWARE ACCELERATED

# 15 MINUTES AND COUNTING

James Gorbald tracks the success of the GeForce RTX 4090 launch

**A**s you'll have already seen on p30, the GeForce RTX 4090 is already out now, with the RTX 4080 set to follow in mid-November. The RTX 4090 and its siblings use a whole new architecture; continuing with Nvidia tradition, this is named after the pioneering 19th-century mathematician and computer scientist Ada Lovelace.

The new Ada architecture builds on the foundations laid by the two previous GeForce architectures, Ampere and Turing, with a renewed focus on increasing ray tracing performance. That comes from a combination of more cores, higher clock speeds and new technologies: the Opacity Micromap Engine, Displaced Micro-Mesh Engine and Shader Execution Reordering, plus an AI-powered frame generation engine in the form of DLSS 3.

Starting at £1,699 and upwards, depending on which specific card you want, the RTX 4090 also sets a whole new price point for a gaming graphics card, and that's just for the card itself. You also need at least an 850W PSU, preferably a PCI-E 5 one, as well as a 4K or UW-QHD monitor in order to do it justice.

So how was the launch of this new graphics card? As the largest retailer of Nvidia graphics cards in Europe, Scan was in the fortunate position to have the biggest allocation of RTX 4090 cards in the UK. I'm not at liberty to give a specific number, but we had a significant, triple-digit number of cards in stock for launch day, many more than we had for some of 2020's infamous GPU launches that went awry.

As an online retailer, system integrator and physical retailer, we split these cards into three pools to ensure that each type of customer had an equal opportunity to get their hands on a GeForce RTX 4090.

The challenge this time is the dollar rate, which remains highly volatile

Despite the new high price of these cards, the anticipation and hype around the RTX 4090 was still sufficient to severely slow or crash many retailer's websites. As this column is at the risk of sounding like a puff piece rather than providing some insight, I'll admit that Scan underestimated the demand for some of those 2020 launches, such as the RTX 3080.

However, the Scan website coped well with the RTX 4090 launch, as a huge amount of dev time has been spent in the past two years creating new systems and processes for major product launches such as this one. To give an idea of the scale of interest, the number of active users on the website increased by more than 300 per cent five minutes before the launch and lasted for around 30 minutes afterwards.

That 30-minute figure doesn't provide the full picture, though, as the majority of SKUs sold out much quicker than that, with most of the launch stock gone in the first 15 minutes. However, despite this rapid sell-out, and ongoing demand for more cards, we decided not to enable pre-orders once we had sold the launch stock.

This isn't because we don't know when the next batch of RTX 4090s will arrive; we have visibility of four waves of inbound cards. The challenge this time is the dollar rate, which remains highly volatile thanks to the chaos at the top of UK politics, meaning we can't price up cards until shortly before they land in the country.

When those cards do land, however, we expect them to sell extremely quickly. Several days after the launch, the most popular page on the whole Scan website is still the RTX 4090 category, with six of the other top ten pages being specific 4090 SKUs. Despite the high price, Nvidia is clearly onto another winner here. **GPC**

James Gorbald has been building, tweaking and overclocking PCs ever since the 1980s. He now helps Scan Computers to develop new systems.





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