

GRAPHICS CARDS **9 GPUs** REVIEWED AT REALISTIC PRICES

CUSTOM PC

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INTEL ALDER LAKE

**THE FULL STORY ON INTEL'S
REVOLUTIONARY CPU DESIGN**

- ✓ NEW CPUs REVIEWED
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DEEP DIVE

- ✓ BIG AND LITTLE CORES –
INSIDE INTEL'S NEW CPUs
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Welcome

Custom PC Issue 220

/ FROM THE EDITOR **Alder quake**

Wow, we were wondering if we'd ever see this day again, but Intel has finally stopped flailing around and launched an all-out assault against AMD. Alder Lake not only brings us the company's first 10nm desktop processors, but also an interesting new CPU design. These hybrid chips contain two different types of CPU cores – performance-orientated P-Cores and power-efficient E-Cores.

We'll admit that we were sceptical about this approach at first. We wondered how eight 'big' cores and eight 'little cores' could compete with the 16 'big' cores in the Ryzen 9 5950X. Also, while it's great to see Intel finally moving from 14nm to 10nm fabrication, AMD has been using TSMC's 7nm process for years.

As it turns out, Intel's new CPU design is so good that a chip with eight P-Cores and eight E-Cores can indeed outperform AMD's Ryzen 9 5950X, thanks to some clever thread direction. Intel has finally pulled a winner out of the bag, and with competitive pricing too.

You can read all about the CPU design in our deep dive on p78, and check out the reviews on p16. However, while we've worked tirelessly to bring you this coverage at the time of launch, that's not easy for a print magazine, and there was some information we simply couldn't get before we went to press. DDR5 memory pricing and availability information is one, and the pricing of Z690 motherboards is another.

We've given you all the other information you need, though, including performance tests of two DDR5 memory kits (see p26) and a first look at an Asus Z690 motherboard (see p22). You can also read our DDR5 deep dive on p86 to see what's new with this latest memory standard.

Even so, while we can wholeheartedly say that Intel's Alder Lake CPUs are fantastic, we weren't able to gauge the complete platform cost of building an Alder Lake system, which is why our Elite list still largely features AMD Zen 3 hardware. We'll continue to look at accompanying Alder Lake hardware in our next issue, but in the meantime, we hope you enjoy reading all about Intel's bombastic new CPU design. **GPC**



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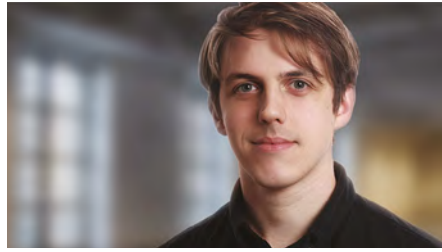
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RICHARD SWINBURNE / VIEW FROM TAIWAN

SMALL DELAYS, BIG UPGRADES

Richard Swinburne looks at what's coming with AMD's forthcoming AM5 CPUs, including PCI-E 5 and DDR5 support

In a recent video celebrating five years of Ryzen, AMD CMO, John Taylor, and Technical Director, Robert Hallock, discussed the rise of Ryzen. It segued into discussing AMD's upcoming 3D V-Cache tech for Zen 3 CPUs, and then they leaked the specs of AMD's next-gen platform. While nuggets of new info aren't unwelcome, it was rather a strange and low-key place to reveal it.

If you're new to AMD's 3D V-Cache, grab Issue 216 of **Custom PC** to read my discussion about it just after it was announced. Despite CEO Lisa Su stating the technology would arrive 'later this year' when she made the announcement via a Computex livestream in June, AMD now admits it's been slightly delayed until 'early 2022'.

But at least it's still on the road map. In the video, AMD admits that AM4 is now end-of-life, so dropping a new Zen 3 AM4 CPU with 3D V-Cache now is still throwing existing AMD Ryzen users a bone. It should offer a decent upgrade too – AMD claims that the new CPUs offer a 5 per cent average performance boost in gaming expected over existing Ryzen 5000-series CPUs.

The video then discussed the upcoming AM5 platform. Beyond the commitment to DDR5 memory, AMD also revealed that its new AM5 CPUs will also support PCI-E 5. While AMD won many fans with Zen over the past five years, that was in a period when Intel suffered long-term trouble in its fabs and only brought out years' worth of rehashed Skylake CPU designs. AMD going toe-to-toe while Intel is on its front foot is an entirely different situation, and it's going to be extremely exciting.

Support for DDR5 and PCI-E 5 means the I/O die (which works in conjunction with up to two CPU dies) is being upgraded, potentially in addition to other tweaks elsewhere,

such as the Infinity Fabric. AMD is also likely to shrink the manufacturing node of the I/O die from its current 12nm down to 7nm/6nm-class, saving quite a lot of power.

In addition, AMD respectfully discussed the hybrid design of Intel's new Alder Lake CPUs (see p16), noting that the approach may work for others. However, AMD says it has chosen to focus on optimising a single architecture – Zen – for all its applications, and is instead complementing that approach with other strengths, such as 'frequency, architecture, process, packaging ... and this idea of accelerators, or non-CPU core performance enhancements'.

AMD's Robert Hallock gave examples of machine learning and AI as 'non-CPU' here, but didn't directly detail whether AMD was planning to add dedicated AI cores – as found in smartphones, or whether it would use GPUs or even an AMD FPGA (since it recently completed the purchase of the industry's biggest FPGA designer, Altera).

Lastly, despite AMD's commitment to a single Zen core architecture, its new laptop CPUs – also launching in 'early 2022' – will feature unique design tweaks (hardware and firmware) focused on power efficiency. AMD is working on fine-grained control over in-chip elements and introducing more power states.

In addition, a new Power Management Framework will be 'situational aware', so instead of selecting a 'Balanced' or 'High Performance' profile from the power management menu, the CPU will have many firmware-based power management algorithms that adapt according to how the laptop is being used – whether you're watching a video, working on a document or playing a game, for example. It will be interesting to see how successful AMD's strategy will be here compared with Intel's big/little design. **GPC**

AMD going toe-to-toe while Intel is on its front foot is entirely different

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

UNWELLNESS

Tracy King digs into some of the pseudoscientific aspects of Razer's new esports wellness program

On my gravestone it will say 'I told you I was ill, and underneath in brackets it will say 'but I still don't want your quack cure'. I've covered gaming and tech-related health claims in this column a few times over the past decade, but health and medicine have become a central focus since the pandemic, which has created new markets for the wellness industry.

My thoughts on wellness as a market are well documented, but the short version is: 'don't exploit health anxiety for profit'. Humans are both scared of dying and notoriously bad at estimating risk and evidence, which leads to a lot of anxiety. The cure is education, good, well-communicated research and a properly funded national health service. However, as those elements are often lacking, the anxiety is vulnerable to attack. Enter wellness, my personal final boss in the game of debunking.

That's right, the gurus are coming for gamers. It was inevitable that wellness would try to grab some of the billions that gamers spend. We're a generous demographic and I've watched the wellness industry increasingly trying to frame gaming as an entire lifestyle rather than a hobby, in a way that doesn't happen for film, TV or other media. Part of this is because there are now so many gamers, and part of it's because the word 'wellness' is everywhere. The evidence for many of the claims made by wellness practitioners ... well that's not anywhere, unfortunately.

Razer has launched an esports wellness program to capitalise on the current vogue for health anxiety. I like Razer – it sells cool stuff and its commitment to ergonomics (and making gaming comfortable) is commendable. However, while being sedentary or using a mouse for long periods

can undoubtedly lead to health issues, there's also only so much a fancy chair and peripheral set can do.

Really, we need to stand up and walk around every hour, get regular exercise to stay fit and all that stuff that's either free or incredibly hard work. I get arthritic pain in my wrists, exacerbated by long stretches of gaming, and it goes away entirely if I do weight training at the gym. Strengthening and exercising your muscles can do more for you here than using an ergonomic mouse.

So with a heavy heart I read Razer's press release, assuming the worst, and, well okay, some of it's fine. The scheme covers areas such as eye health and sleep hygiene (although the answers to those involve similarly hefty lifestyle changes, such as not using screens in bed, which if you're anything like me is just never going to happen).

However, there's also a lot of pseudoscience in there, and that worries me. For example, Razer has hired a chiropractor. Chiropractic is a pseudoscience, although it does its very best to hide that, and it's not supported by rigorous scientific evidence. Back pain is often a self-limiting condition – it comes and goes by itself, so it's very susceptible to exploitation.

Instead of a chiropractor, Razer should hire a medical doctor, but they would be generally less interested in selling you long courses of unnecessary back-cracking. There are also links to wellness gurus, whose blogs contain a slew of unverified claims, from supplements to nonsense about 'superfoods', each of which contains a link to a product for sale. Under all the SEO-friendly blurb about mind and body and wellness, there's money to be made and health anxiety to exploit. Strip away every part that isn't supported by evidence and the wellness industry looks a little sick. **GPG**

Humans are both scared of dying and notoriously bad at estimating risk

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Letters

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Truth to power

In response to James Gorbould's column about the importance of power efficiency, there are some things I want to check in case I'm gravely mistaken about the power consumption of my own PC. I think this is a deeply important aspect of our usage of these systems that needs to be properly understood. Perhaps it would be worth spending time on a longer feature?

My understanding is that, at any given time, an ATX power supply will draw the power equivalent to the power required by components, plus power lost due to PSU inefficiency. This is important, because power is basically heat and drawing the maximum capacity of your PSU at all times means you need to shed a lot of heat.

I believe I can demonstrate this with MSI Afterburner and Rivatuner Statistics Server. I'm using a Core i5-7600K, with an MSI Z270i Pro Carbon motherboard, an undervolted GeForce RTX 3070 and

When's the next issue out?

CUSTOM PC

Issue 221

On sale on Thursday, 2 December



GPU	57 °C	72 %	2025 MHz	65 %	152.2 W
MEM	7801 MHz				
CPU	62 °C	88 %	4191 MHz	49.9 W	
D3D12	115 FPS				

Battlefield V pushes the GPU power draw up to 152W

a 750W Corsair RMx PSU. In Hades, which hardly stresses modern gaming PCs, the CPU only draws 28W, while the GPU only draws 47W. Comparatively, in Battlefield V at high settings with no ray tracing, the GPU power draw is a lot higher at 152W, as a result of the higher core frequency.

My understanding is that, in the first instance, my system must be drawing power equal to 47.3W plus 28W plus some amount for other system components.

In the second instance, the power draw is higher, due to the heavier load that BFV represents in comparison to Hades.

Where temperatures are concerned, I didn't run the games for long enough to reach steady state temperatures on either the CPU or GPU. BFV tends to run in the upper 60s on the GPU and around 65° on the CPU. If the PSU was drawing 750W all the time, the bulk of that power draw has to go somewhere and the sole fan in the PSU isn't really sufficient to shift a huge heat load like that, so my PC would surely be running hot all the time?

Assuming I'm correct about the function of PSUs, there are a number

of measures people can take to reduce the power consumption of their systems in a meaningful way. As James said, a non-K CPU would go some way here, as would undervolting your GPU. Also, am I right in thinking that a K-series CPU doesn't inherently draw more power in all situations, it just *can* draw more power?

Other options people can implement today are limiting your maximum frame rate in the Nvidia control panel to a sensible value – I've chosen 119fps, as my monitor operates at 120Hz and this should keep G-Sync engaged at all times. If you have a high-end system, your CPU and GPU will be working extra hard to deliver potentially hundreds of frames per second you can't see, as your monitor can't display them.

If you're using an Intel CPU, you could also set your power settings to Balanced or modify the High Performance profile. The High Performance setting defaults to a minimum processor active state of 100 per cent, resulting in extra power draw, unnecessary heat and unnecessary work from your cooler, plus extra noise.

The Balanced profile sets the minimum to 5 per cent and leaves the maximum at 100 per cent – this won't impact system performance, as the CPU speed will still ramp up when it's needed. You can also set your hard disk to turn off after one minute (great if you only use it for photo storage, but you'll want a longer window if you use it for applications). You can also set the display to turn off after a sensible window, such as ten minutes.

Your components will only draw the current they require, so an 850W PSU won't always pull 850W from the mains





With all these tweaks taken into account, I estimate that most systems would have an idle power draw of just tens of watts. Even under high load, I would expect the draw to be rather less than the 750W my PSU can deliver.

The added benefit of all this, besides lower energy bills and a smaller climate impact, is that with careful tuning and decent fans, you can make your PC almost silent in any situation other than high load. I've specifically set the fan curves on my PC to only use the lower intake fans when the GPU hits 70°C (rarely), and the GPU's fans spin up at 60°C and are relatively quiet anyway.

Meanwhile, the CPU cooler fans run at low RPM until the CPU goes above 65°C, and the upper intake and exhaust fans spin up slowly from around 60°C. In normal operation, with the hard drive off, my PC is basically inaudible.

ALEC WILBY

Ben and Edward: Thanks for a really interesting letter, Alec, you've brought up some important points. You're right to say that the components plugged into your PSU will only draw the current they need, so your PSU will draw much

less than its rated wattage if you're running low-power components at low loads although, as you say, there will also be some inefficiency.

As an example, our Watts Up? Pro meter shows that our graphics test rig only draws around 70W from the mains when it's idle, and that's with a Ryzen 9 5900X and often a high-end GPU running inside it. James' PC only draws 700W while it's running at full load – the 'constantly' in his column was just a humorous way of saying he spends too much time playing games.

While there is usually a correlation between thermal power and electrical power, though, they're not the same, and remember that your PSU is only powering the components that create the heat (and have their own cooling systems). It will output heat when it's running but not 750W worth. Instead, the heat generated is related to the efficiency of the power supply.

A 95 per cent efficient PSU will only dump 5 per cent of converted energy out as heat (in ideal load conditions), whereas an 80 per cent efficient PSU will dump 20 per cent as heat. Either

Our graphics test rig only draws 258W from the mains with a Radeon RX 6600 running at full load

Rogue-like dungeon crawler Hades barely taxes the GPU in Alec's system



way, that will still only amount to a few tens of watts, so you won't need a monstrous cooling system to shift the thermal energy from your PSU at full load – its fan and ventilated box should be perfectly up to the job (although we don't advise running a PSU at full load anyway).

To answer a few of your other questions. Even if they're not overclocked, Intel's K-series CPUs usually have a higher base clock than non-K CPUs, so they generally draw more power, although the difference isn't huge at stock speed. Today's CPUs also have their own built-in, fine-grain voltage and frequency controls – unless you've forced an all-core overclock in the BIOS, they'll only run at their full frequency when it's needed, with various multiplier steps in between, depending on the load.

Different games will also indeed require different amounts of power. We see quite different levels of total system power consumption between various games when we're testing GPUs and CPUs, although Hades barely uses the GPU, so it's not surprising that the clock frequency and power draw is so much lower here.

Your GPU will generally push itself as hard as possible in order to maximise the frame rate in the game it's running, so limiting your frame rates can help here – there's no point in churning out more frames per second than your monitor can display, as you say.

You can certainly help your system consume less power by turning off your hard drives and monitor when they're not needed, and changing the Windows power profiles. However, the areas that will have the biggest impact are your choice of graphics card (this is the main one) and the clock speeds (and voltages) at which you run your CPU and GPU. Our graphics test rig draws just 258W from the mains at full load (in Metro Exodus with ray tracing) with a Radeon RX 6600 installed, but this climbs all the way to 690W with a GeForce RTX 3090.

It's definitely a complex topic. A more in-depth feature could indeed be interesting in the future. **CPC**

Incoming

CORSAIR COOLERS GET DISPLAYS

Corsair is the latest company to integrate a display into a pump/waterblock unit, with its new iCUE Elite LCD models featuring a 2.1in screen. Corsair describes the display as 'ultra-bright' and says they can show system data such as fan speeds and temperatures, as well as custom images and animated GIFs.

The display is also surrounded by a ring of 24 individually addressable RGB LEDs, which are programmable in the company's iCUE software.

The Elite LCD cooler will come in 240mm (pictured), 360mm and 420mm flavours, and be equipped with Corsair's MLRGB Elite fans with magnetic levitation bearings, each of which has a further count of eight individually addressable RGB LEDs. Corsair also says the coolers' mounting system will support a variety of CPU sockets, including AM4, TRX4, LGA1700, LGA2066 and LGA115x.

Corsair's iCUE Elite LCD coolers are available to pre-order now from corsair.com/uk now, with prices starting at £220 inc VAT for the 240mm H100i, and going up to £270 inc VAT for the 420mm H170i.



ASUS AND NOCTUA TEAM UP ON GRAPHICS CARD

Asus and Noctua have unveiled a new GeForce RTX 3070 graphics card that has a cooling system co-engineered by Noctua, complete with its 'Granny's tights' brown and beige colour scheme.

The Asus GeForce RTX 4070 Noctua Edition is based on Asus' TUF Gaming RTX 3070 card, but makes a number of changes to the cooler design. First up, the TUF card's three 92mm fans have been swapped out for a pair of 120mm Noctua NF-A12x25 fans. The heatsink has also been enlarged, adding 10mm to the height and 12mm to the width, as well as increasing the gap between the heatpipes by 3.7mm.

The result is a huge graphics card that occupies four slots, but can also run its fans at slower speeds than before, massively reducing noise and in some cases reducing temperatures too. According to Noctua, the noise level goes from 36.8dBA at medium fan speed on the original TUF

card (2,250rpm), to just 21.1dBA with the Noctua cooler (1,350rpm), with no change in temperature.

At maximum fan speed, Noctua also claims there's a drop from 42.4dBA (3,200rpm) on the standard TUF cooler to 33.3dBA (2,000rpm) on the Noctua cooler, as well as a drop of 1°C in temperature from using the latter.

The card is available in both stock speed and overclocked editions, with a UK MSRP of £750 inc VAT.



Rumour control

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NEXT-GEN AMD APU APPEARS

A mysterious benchmark result has been recorded on a 'Corsair XENOMORPH' system on userbenchmark.com, with the system apparently using an engineering sample of an AMD APU. The system is shown to have a Socket FP7 8-core CPU with 16 threads and a turbo clock of 3.9GHz, while the integrated GPU has 512MB of allocated memory. The system is also equipped with a 16GB 4800MHz SODIMM, suggesting DDR5 support.

The benchmark results themselves aren't outstanding, with a CPU score of 71 per cent (a Core i9-9900K scores 100 per cent), while the Radeon GPU gets just 24.1 per cent (a GeForce RTX 2060 Super scores 100 per cent). However, that isn't surprising for early silicon and drivers, and comparably, Intel's Iris Xe graphics scores just 18.4 per cent, with the GeForce GTX 1050 getting 27.1 per cent.



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Reviews

INTEL LGA1700 CPU

INTEL CORE i9-12900K / £579 inc VAT

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It's been a long time coming, but Intel has finally taken a giant leap forwards in terms of architecture, CPU design and manufacturing – Alder Lake is here at last. We're finally dealing with a desktop 10nm CPU from Intel now and, rather than just using it to add more cores, Intel has made some interesting changes to its CPU design.

There are now two different types of cores in this hybrid CPU design, with Intel attempting to provide more performance at lower power levels and have different cores designed to different tasks. There are P-cores and E-cores

– the former deal with high-performance tasks, and the latter aid lower-power and background tasks, while providing a general boost to multi-threaded workloads.

If you think this sounds a nightmare in terms of thread management in Windows, you'd be right, but Intel has worked with Microsoft to enhance the thread scheduling capabilities in Windows 11, and its 12th-gen CPUs also now include a feature called Thread Director.

This intelligently manages workloads to improve performance and lower power consumption based on priorities, pushing demanding workloads onto P-cores and lighter tasks onto others. This should work independently of Windows 11, but Intel says that Windows 11 will definitely offer additional performance compared with other operating systems, for now anyway.

There are quite a few differences between the cores too. E-cores lack Hyper-Threading, so even though the Core i9-12900K has 16 cores made using a 10nm manufacturing

process under the hood, only the P-cores feature Hyper-Threading. As a result, the Core i9-12900K has a total of 24 rather than 32 threads. This core differentiation extends to overclocking too, as both P-cores and E-cores can be overclocked separately and have very different limits.

This flagship CPU also retails for £579 inc VAT, which is a fair bit less than the current price of AMD's mighty 16-core Ryzen 9 5950X, but a little more than the 12-core Ryzen 9 5900X. The Intel CPU can hit 5.2GHz using Turbo Boost Max technology on its P-cores, but only 3.9GHz on its E-cores.

We didn't see the P-cores top 5.1GHz in CPU-Z, but we were using very early drivers and BIOS versions. The E-cores appeared to run at their maximum 3.9GHz most of the time, though, and unlike the P-cores, this was across all cores too. The P-cores fell to 4.9GHz in multi-threaded workloads, though, while the E-cores dropped down to 3.7GHz.

Memory support is another major tweak and you'll be glad to know that both DDR4 and DDR5 are supported, with



SPEC

Base frequency

P-core 3.2GHz, E-core 2.4GHz

Max boost frequency

P-core 5.2GHz, E-core 3.9GHz

Core

Alder Lake

Manufacturing process

10nm

Number of cores

8 x P-cores, 8 x E-cores,
(24 threads)

Hyper-Threading

Yes

Cache

30MB L3, 14MB L2

Memory controller

Dual-channel DDR4 3200MHz
and DDR5 4800MHz

Packaging

LGA1700

Thermal design power (TDP)

125W

Features

Turbo Boost Max Technology 3,
Turbo Boost 2, FMA3, F16C, SHA,
BMI / BMI1 + BMI2, AVX-512,
AVX2, AVX, AES, SSE4a, SSE4,
SSSE3, SSE3, SSE2, SSE, MMX

plenty of DDR4 motherboards from which to choose. This CPU officially supports the latter at 3200MHz, while DDR5 support starts at 4800MHz. The Core i9-12900K also sports a massive 30MB L3 cache, along with 14MB of L2 cache, plus PCI-E 5. What's more, the K-series Alder Lake CPUs also get Intel UHD Graphics 770, which is based on Intel's Xe architecture.

Performance

The Core i9-12900K's performance is stellar. It's the first CPU to crack 80,000 points in our image editing test and it even beat the 16-core Ryzen 9 5950X in our heavily multi-threaded video encoding test, with a massive score of 1,117,658 compared to 1,061,730 for the AMD CPU – it's also in a different league to the Ryzen 9 5900X in this test. The Handbrake result nearly doubles the score from the Core i9-11900K too. The system score was just short of 400,000 points, with a clear lead over the 5950X and miles ahead of the Core i9-11900K, which only managed 263,567.

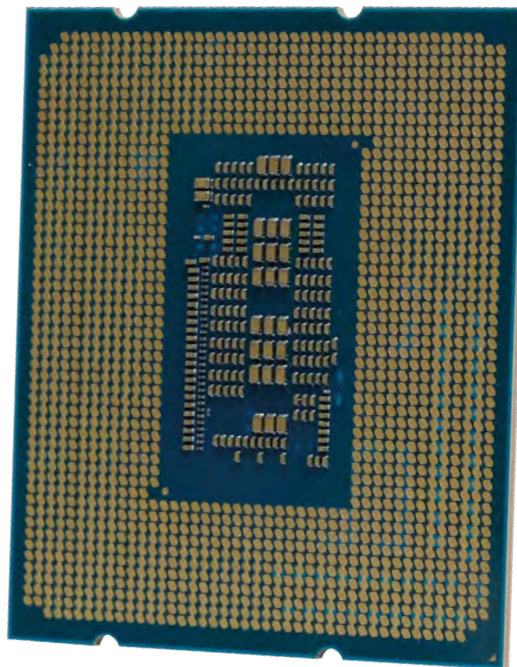
The 12900K also smashed Cinebench R23 with a multi-threaded score of 27,579, which was again nearly double the score of the Core i9-11900K and faster than the Ryzen 9 5950X by a few thousand points. As if stellar multi-threaded performance wasn't enough, it had a huge single-threaded score of 1,992 as well – hundreds of points faster than any older CPU.

It's even blisteringly fast in games, adding up to 10fps to the average frame rate of any AMD CPU in Far Cry 6, but for some reason it was a little behind the other two 12th-gen CPUs on the 99th percentile results. It was faster than any AMD chip in Dirt 5 as well.

Meanwhile, power consumption has been a sore topic for Intel lately, but the Core i9-12900K was restrained at stock speed, hitting 248W at load, which was barely any more than the Ryzen 7 5800X, although this was a little higher than AMD's flagship Ryzen 9 5950X. Still, it's a vast improvement compared to the 360W the Core i9-11900K drew at stock speed.

We didn't have much time to overclock the Core i9-12900K before we had to get the magazine printed, but we found the 12900K has similar overclocking potential to 10th and 11th-gen CPUs on the P-cores, with us ending up at a stable all-core frequency of 5.1GHz with a 1.36V vcore. We could only get the E-cores to stick at their maximum 3.9GHz frequency across all cores, which was at least a 200MHz boost above the all-core stock frequency we observed.

These tweaks saw the 12900K gain an extra 2,000 points in the image editing test, which went up to 82,361, and it held its lead in the video encoding test, with a higher score of 1,120,269 compared to the Ryzen 9 5950X's overclocked score of 1,113,608. The system score sat at 399,954, again more than a match for the AMD CPU and a long way ahead of the Core i9-11900K. Overclocking also benefited games, with the minimum 99th percentile



in Far Cry 6 hitting 108fps, which was over 10fps higher than any AMD CPU and its average of 143fps leading the pack. Overclocking did result in our system drawing 320W from the mains at load, but that's still 11W less than with an overclocked Ryzen 9 5950X.

Conclusion

We honestly weren't sure what to expect from Alder Lake, but the proof is in the pudding and the Core i9-12900K is an absolute monster while remaining relatively power-frugal too, especially compared with previous generations.

In games, it proved to be significantly faster than AMD anywhere that was remotely CPU-bound, although in our test games it didn't offer much benefit over the other two 12th-gen CPUs on test, which clearly offer better value for gamers. In content creation, the 12900K absolutely flies, matching or bettering the Ryzen 9 5950X in multi-threaded tasks and offering much more performance in any single or lightly threaded tasks. This is despite it costing less than the AMD CPU, which was still retailing for close to £700 at the time of writing.

If you're just gaming and dabbling occasionally in content creation, then the Core i5 or Core i7 12th-gen CPUs offer better value and still provide great multi-threaded performance. However, if you need the best multi-threaded grunt for a mainstream desktop PC, the Core i9-12900K is for you and as a bonus it's also a fantastic CPU for gaming. Welcome back, Intel.

ANTONY LEATHER

VERDICT

A devastatingly fast CPU across the board – it's faster and better value than any CPU AMD currently offers.

ALDER LAKE

- + King of the hill in games
- + Superb multi-threaded performance
- + Costs less than £600

LAKE PLACID

- Overclocked Ryzen 9 5950X faster in some tasks
- Requires new motherboard
- CPU socket needs new cooler or adaptor

PERFORMANCE
49/50

FEATURES
14/15

VALUE
32/35

OVERALL SCORE

95%

INTEL LGA1700 CPU

INTEL CORE i7-12700K / £419 inc VAT

SUPPLIER scan.co.uk

SEVEN WONDERS

- + Fantastic gaming performance
- + Faster and cheaper than Ryzen 9 5900X
- + Much cheaper than Core i9-12900K

SEVEN OAKS

- Limited overclocking headroom
- Core i9-12900K faster at multi-threading
- New motherboard and socket

SPEC

Base frequency
P-core 3.6GHz, E-core 2.7GHz

Max boost frequency
P-core 5GHz, E-core 3.6GHz

Core
Alder Lake

Manufacturing process
10nm

Number of cores
8 x P-cores, 4 x E-cores, (20 threads)

Hyper-Threading
Yes

Cache
25MB L3, 12MB L2

Memory controller
Dual-channel DDR4 3200MHz and DDR5 4800MHz

Packaging
LGA1700

Thermal design Power (TDP)
125W

Features
Turbo Boost Max Technology 3, Turbo Boost 2, FMA3, F16C, SHA, BMI / BMI1 + BMI2, AVX-512, AVX2, AVX, AES, SSE4a, SSE4, SSSE3, SSE3, SSE2, SSE, MMX

After the Core i7-11700K proved almost as potent as the Core i9-11900K, but for much less cash, Alder Lake sees Intel's mainstream Core i7 chip go back to basics.

It has a lower core count than the 12900K, but also a much lower price, retailing for £150 less than the Core i9-12900K.

It actually has the same number of P-cores as the Core i9-12900K, which should give it serious clout across the board. These can hit a peak of 5GHz at stock speed, which is 200MHz lower than the Core i9-12900K, but it did hit this frequency regularly. In fact, we saw an all-core boost of 5GHz regularly in multi-threaded workloads too.

The E-cores usually sat at 3.6GHz in our tests, but according to Intel they can reach 3.8GHz, which is a 100MHz climb down from the flagship. It actually has fewer E-cores than the 12900K too, at four compared to eight, so in total it has 12 cores. The result is a CPU that has

20 threads, which is just four short of the Core i9-12900K. You get a little less cache too, with 25MB L3 and 12MB L2, but other specifications are the same.

The 12700K's score of 78,744 in the image editing test saw it outperform every AMD CPU by a few thousand points, and it was also much faster than the Core i9-11900K while not sitting too far behind the Core i9-12900K. Meanwhile, our heavily multi-threaded video encoding and Cinebench tests saw it outgun the Ryzen 9 5900X, which cost £110 more at the time of writing, and the 12700K was only a couple of thousand points behind the Ryzen 9 5950X.

The single-threaded test in Cinebench saw it come close to matching the massive score of the Core i9-12900K, and it was miles ahead of older CPUs. Its minimum 99th percentile frame rate of 105fps in Far Cry 6 was the fastest on test and a good 10fps higher than any AMD CPU, while in Dirt 5, the 12700K again had an edge over AMD and closely matched the Core i9-12900K.



Overclocking saw us hit an all-core frequency of 5GHz on the P-cores, but we decided to leave the E-cores alone, partly due to running out of time, but also as they didn't seem to offer much of a boost with its bigger sibling. This tweak still saw the Cinebench R23 multi-threaded score rise to 24,168, which again bettered the overclocked Ryzen 9 5900X's result, while 3fps was added to the 99th percentile frame rate in Far Cry 6.

What's more, our system drew just 248W at stock speed with the 12700K installed – that's just a little higher than the Ryzen 9 5900X and this figure only rose by 30W after overclocking.

Conclusion

The 12700K is the best Core i7 CPU we've seen since the Core i9 brand first landed on the mainstream desktop in the Coffee Lake era. The Core i9-12900K still has its place with noticeably better multi-threaded performance, but the Core i7-12700K still offers superb lightly threaded grunt and top gaming performance. If you need a CPU for gaming and a fair amount of content creation, but can't stretch your budget to the Core i9, it's a fantastic alternative that also offers better value than AMD's current options.

ANTONY LEATHER

VERDICT

A fantastic CPU for a reasonable price – it's unbeatable in games and no slouch in content creation too.

PERFORMANCE
47/50

FEATURES
14/15

VALUE
33/35

OVERALL SCORE

94%

INTEL LGA1700 CPU

INTEL CORE i5-12600K

/ **£289** inc VAT

SUPPLIER scan.co.uk

Thanks to supply shortages, AMD's Ryzen 5 5600X has often been a tad too expensive to offer a viable alternative to Intel's Core i5 chips, and it now has its work cut out even further, with Intel's latest Core i5-12600K coming in at just £289 inc VAT. Like its pricier siblings, the Core i5-12600K has a mixture of high-performance P-cores and power-efficient E-cores with six of the former, compared to eight for the other two CPUs on test this month.

Meanwhile, the count of E-cores stands at four, which is the same as the Core i7-12700K, giving it 16 threads in total. It's equipped with 20MB of L3 cache and 9.5MB of L2 cache while the frequencies are a tad slower than those of the Core i7. The lack of Turbo Boost Max Technology 3 means the peak boost frequency for the P-cores is 4.9GHz, and we did see it hit this clock speed on occasions. Under heavy multi-threaded workloads, this drops to 4.5GHz, but the E-cores stayed at their peak of 3.6GHz in these loads and rarely (if ever) dropped lower.

It all makes for a potent setup at this price though. The Core i5-12600K matched the Ryzen 7 5800X in our image

editing test, which stresses single-threaded performance, while also outpacing the Core i9-11900K. It was noticeably slower than the Core i7-12700K in our heavily multi-threaded video encoding test and in Cinebench R23's multi-threaded test, proving that it's the P-cores doing the majority of the number crunching here.

Still, its Cinebench multi-threaded score of 17,340 was faster than that of the Core i9-11900K and much quicker than the Ryzen 7 5800X, which cost £60 more at the time of writing. As with its siblings, it has massive



single-threaded performance in Cinebench, offering far more grunt than any AMD CPU. It was also quicker in Far Cry 6, with a 99th percentile of 102fps compared to 97fps for the Ryzen 7 5800X and it was a little quicker in Dirt 5 too.

When it came to overclocking, we managed to hit 5GHz across all P-cores with a voltage of 1.36V, but couldn't go any higher, and we also decided to leave the E-cores at stock speed. This saw the image editing score rise more than 2,000 points, enabling it to outpace the competition from AMD – and only the two new Alder Lake CPUs were faster.

Overclocking did wonders for the 12600K's multi-threaded performance as well, enabling it to sit squarely between the Ryzen 7 5800X and Ryzen 9 5900X, and it was substantially faster than the former in Cinebench. Gaming performance didn't improve much, but thankfully, the total system power consumption, which already sat at a low 180W at stock speed, only rose to 245W when overclocked – both results are lower than those of the Ryzen 7 5800X.

Conclusion

The 12600K is Intel's best Core i5 CPU since the legendary Core i5-2500K. It might not have incredible overclocking headroom, but it's great for other reasons. It has stellar gaming performance out of the box and enough multi-threaded clout to see off AMD's more expensive Ryzen 7 5800X. If you need a gaming or general-purpose CPU for under £300, this is the one to get.

ANTONY LEATHER

VERDICT

Fulfills the role of a Core i5 chip exactly. The 12600K offers stellar gaming performance and it's faster than AMD's Ryzen 7 5800X in multi-threading too.

SANDY BRIDGE

- + Excellent gaming performance
- + Faster and cheaper than Ryzen 7 5800X
- + Very reasonable price

PRESCOTT

- Limited overclocking headroom
- Core i7-12700K faster at multi-threading
- New motherboard and CPU socket

PERFORMANCE
45/50

FEATURES
14/15

VALUE
34/35

OVERALL SCORE

93%

SPEC

Base frequency

P-core 3.7GHz, E-core 2.8GHz

Max boost frequency

P-core 4.9GHz, E-core 3.6GHz

Core

Alder Lake

Manufacturing process

10nm

Number of cores

6 x P-cores, 4 x E-cores,
(16 threads)

Hyper-Threading

Yes

Cache

20MB L3, 9.5MB L2

Memory controller

Dual-channel DDR4 3200MHz
and DDR5 4800MHz

Packaging

LGA1700

Thermal design Power (TDP)

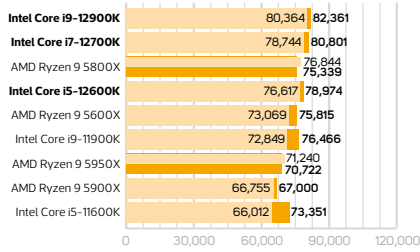
125W

Features

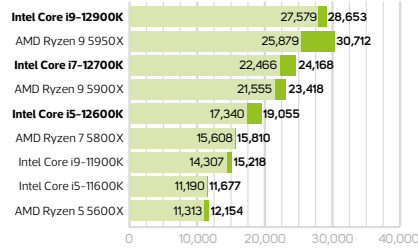
Turbo Boost 2, FMA3, F16C, SHA,
BMI / BMI1 + BMI2, AVX-512,
AVX2, AVX, AES, SSE4a, SSE4,
SSSE3, SSE3, SSE2, SSE, MMX

INTEL ALDER LAKE BENCHMARK RESULTS

GIMP IMAGE EDITING

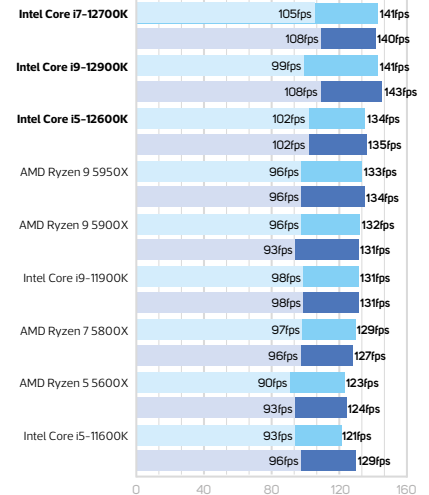


CINEBENCH R23 MULTI-THREADED

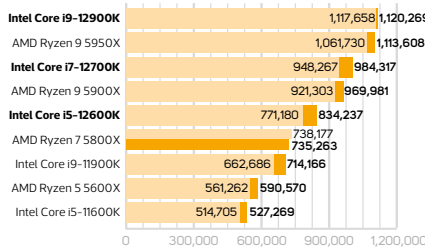


FAR CRY 6

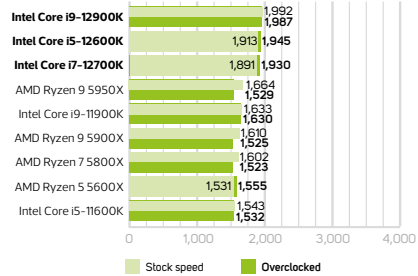
1,920 x 1,080, Ultra settings



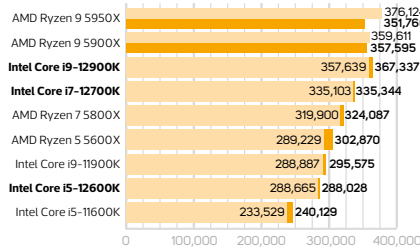
HANDBRAKE H.264 VIDEO ENCODING



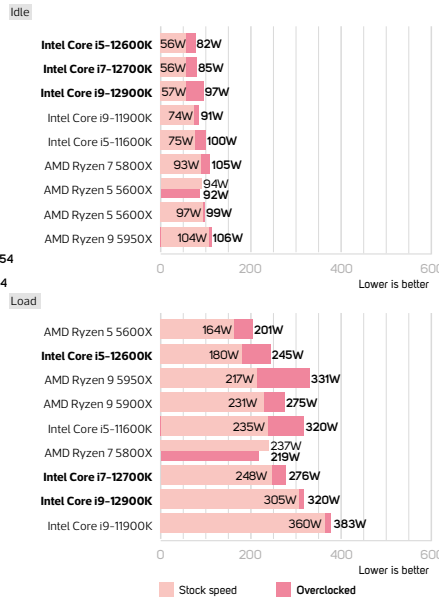
CINEBENCH R23 SINGLE-THREADED



HEAVY MULTI-TASKING

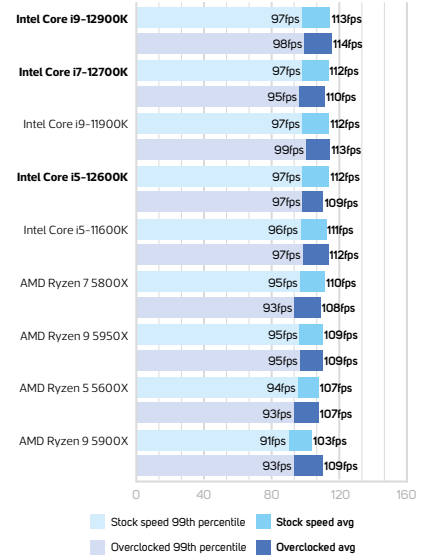


TOTAL SYSTEM POWER CONSUMPTION

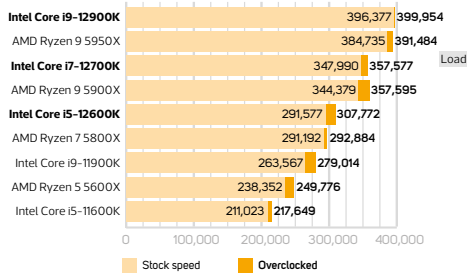


DIRT 5

1,920 x 1,080, Ultra settings, DX12



SYSTEM SCORE



OVERCLOCKING ALDER LAKE

While Alder Lake uses a vcore and multiplier to overclock your K-series CPU just like other CPUs, the process is now complicated by having the ability to overclock both the performance-orientated P-cores and more power-efficient E-cores. They're clocked differently and won't hit the same speeds when tweaking their multipliers, so you'll need to adjust each type separately to find their limits.

At the time of writing, it looks as though it's just the frequency that differs, as there's just a single vcore input. Due to print time constraints, we had to write this guide prior to receiving the lowdown from Intel and motherboard manufacturers, but if necessary we'll do a more comprehensive guide in future with more details.

1 To start, check your stock speed temperatures using Prime95 ([mersenne.org](https://www.mersenne.org)) and Core Temp ([alcpu.com](https://www.alcpu.com)). Run Prime95's smallest FFT test, disabling all AVX options at the bottom. Leave the test to run for five minutes and then check your CPU temperature. If it's above 80°C, we recommend getting a better cooler.

2 Head to your motherboard's EFI and locate the overclocking section, sometimes called the Advanced or Tweaker section, and find the P-core or Performance core ratio settings. Sync all cores, so the same frequency is applied to all cores at the same time.

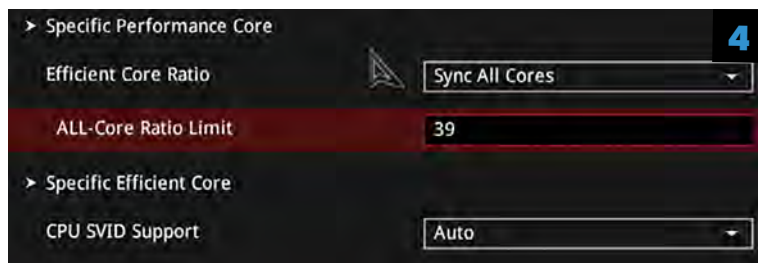
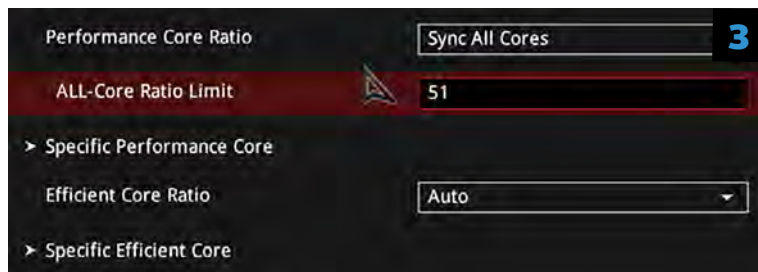
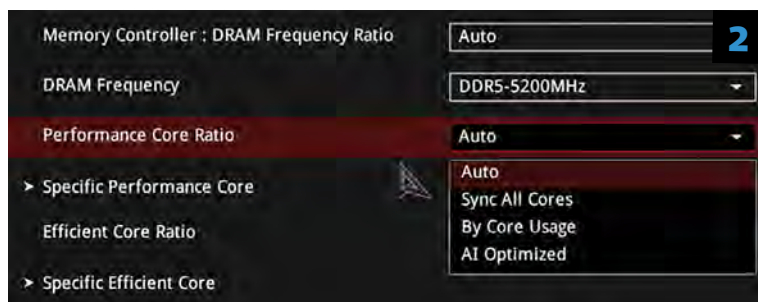
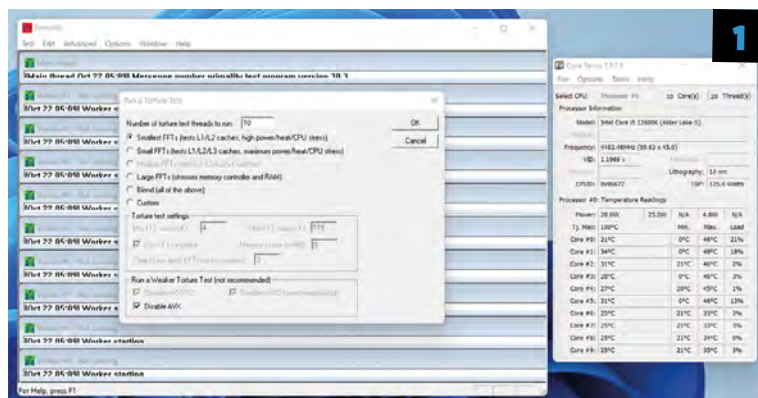
3 We suggest trying 51 to get you to 5.1GHz with the Core i9-12900K, and 50 to get you to 5GHz for the Core i7-12700K and Core i5-12600K. These are good starting points, but all CPUs vary. Some may go higher while others may struggle.

4 Next find the E-core or efficient core options and, again, select 'sync all cores' – if you have the Core i9-12900K, we found 39 (for 3.9GHz) was an easy target, but it struggled to go further. For this reason, and due to time constraints, we didn't test E-core overclocking on the other CPUs, although our testing showed that overclocking them didn't add much performance anyway.

5 We've used a vcore of 1.36V here, but you can try more if your cooling allows. Equally, you may find you need less for your final frequency and it's always a good idea to use as little as possible.

6 Head back to Windows and run Prime95 again. In CPU-Z and Core Temp, the P-cores are much hotter and have higher frequencies than the E-cores, so keep an eye on the former. Check your CPU temperatures under load in Prime95 for ten minutes – if they stay below 90°C then you're done.

ANTONY LEATHER



Z690 MINI-ITX MOTHERBOARD

ASUS ROG STRIX Z690-I GAMING WIFI

SUPPLIER scan.co.uk

Asus' mini-ITX motherboards usually get released a few weeks after a major chipset launch, but this time around Asus has seen fit to get its new Z690 dinky offering out the door on day one. The ROG Strix Z690-I Gaming WiFi looks absolutely stunning, and Asus has also thrown in some funky engineering to make the most of the smaller form factor.

Sadly, we couldn't persuade Asus to let us in on the expected launch price at the time of going to press, so we can't come to a firm

conclusion nor offer scores or awards, but our usual testing and keen eyes will hopefully still give you some insight, especially given the fantastic performance of Intel's Alder Lake CPUs in our reviews (see p16). We expect this board to demand a premium, though, as is usual for Asus' ROG Strix-branded motherboards.

As we said earlier, the ROG Strix Z690-I Gaming WiFi does look stunning, although you'll be disappointed if you're a fan of RGB lighting. Unlike previous models, the large stack of circuitry, which culminates in an M.2 heatsink beneath the CPU socket, no longer has an embedded RGB lighting array. However, this does make the design more compact, while also making it easier to dismantle the board and install M.2 SSDs, plus there are two RGB headers on the PCB for some extra illumination if you need it.

Looking at the board, you might also wonder why there are two male USB Type-C ports, and you'll find out when you delve into the accessory box – it turns out Asus has yet more additional PCB real estate you can add to the board, this time in the form of a vertical riser card. This adds four SATA ports to the equation, as well as a full front

panel, 3-pin digital RGB connector and speaker header, all of which are absent from the main PCB to save space.

The front panel speaker cable is, thankfully, located on the M.2 heatsink stack, and there's a single 2-pin power button header on the main PCB, so you can use the board without the riser card if you don't need any of the extra paraphernalia. Meanwhile, two of the SATA ports are angled at 90 degrees and will face the front of your case with a normal layout, but the other two face upwards, so using them could look unsightly. Sadly, the connectors are also the wrong way around to use angled SATA cables, as the cables would then trail over the motherboard.

The triple-decker PCB for M.2 SSDs also makes a return, and this time, both the upper and lower portions of the M.2 SSDs are cooled using thermal pads and heatsinks. You get Asus' M.2 Q-Latch feature as well, which does away with those pesky annoying tiny M.2 screws and instead uses a tool-free locking mechanism to fix your SSDs in place. Also sitting above the PCI-E 5 slot on the PCB stack is a USB 2 header, and Asus includes a splitter cable for this header, enabling you to connect two USB 2 devices, such as AIO liquid coolers.

Meanwhile, the 11-phase power circuitry is hidden under two large heatsinks, which are connected via a heatpipe, making for a setup that does a decent job – the VRM temperature didn't top 50°C while the board and our Core



SPEC

Chipset

Intel Z690

CPU socket

Intel LGA1700

Memory support

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

Expansion slots

One 16x PCI-E 5

Sound

8-channel Supreme FX
7.1 Realtek ALC4080

Networking

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

Cooling

Three 4-pin fan headers,
VRM heatsinks

Ports

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

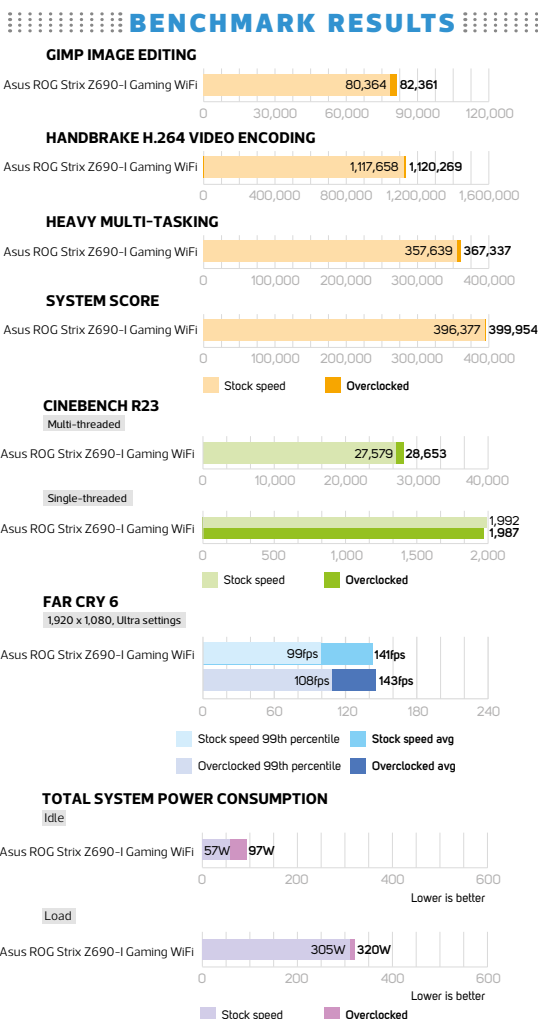
Dimensions (mm)

170 x 170



i9-12900K test CPU were under full load in our ten-minute stress test.

Move around the back and you'll find seven Type-A USB ports on the rear I/O panel, which is a generous amount for a mini-ITX motherboard, plus you get two Thunderbolt 4-compatible Type-C ports too. If you don't fancy outputting the Intel UHD Graphics 770 over these ports then there's also an HDMI port. In addition, the rear I/O panel sports three audio minijacks that can be configured as inputs or outputs using software, and Asus has also included a separate optical S/PDIF output.



There are USB BIOS FlashBack and clear-CMOS buttons as well, although there are no other significant overclocking and testing tools other than diagnostic LEDs on the PCB. These LEDs can be useful, but they can also often be hidden by the 24-pin ATX cable and are tricky to read, as they're so small. The board comes with a standard networking setup too, with an Intel 2.5Gbps Ethernet port as well as 802.11ax Wi-Fi.

When it comes to tweaking, Asus' software is usually pretty good for controlling fan speeds and we're glad to see that the GPU has now been added as a temperature source to control fan speed, alongside VRMs and various other hot spots on the PCB.

There are the standard trio of 3-pin fan headers for cooling, but the downside is that Asus has removed the thermal probe header, which was useful for controlling radiator fans in water-cooling systems using the coolant temperature. Asus was the only motherboard manufacturer to include this feature on its mini-ITX boards, making this omission a shame.

Performance

We don't have any comparison numbers for other Z690 boards yet, so our comments here will be limited. However, the Realtek ALC4080-based audio performed excellently, with a dynamic range of 118dBA and noise level of -118dBA. The M.2 performance was up to usual speeds as well, with a read and write speed of 4,959MB/sec and 4,209MB/sec respectively using a Sabrent Rocket PCI-E 4 SSD, which the board's heatsink kept below 60°C in our stress test.

We also managed to use this board to overclock our Core i9-12900K's P-cores to 5.1GHz with a vcore of 1.36V and the E-cores to 3.9GHz across all of them. This resulted in some noticeable gains in our benchmarks, but as this frequency was close to the CPU's all-core boost anyway, only bigger overlocks will likely be worth it.

Conclusion

There's little doubt that the Asus ROG Strix Z690-I Gaming WiFi is a great-performing motherboard. It kept our PCI-E 4 SSD cool with its large heatsinks, the VRMs were kept in check under load, plus it handled our Core i9-12900K with ease. It looks fantastic and has nearly every feature you need to build all kinds of awesome mini-ITX PCs using Intel's fantastic new CPUs.

There are a couple of flies in the ointment, such as the removal of a thermal probe header and some awkwardly placed SATA ports, but as long as the price is right, this board will make a great dinky home for a shiny new Alder Lake CPU.

ANTONY LEATHER

VERDICT

One or two small niggles, but this is otherwise a fantastic mini-ITX board for Intel's new CPUs.

ROG

- + Attractive design
- + Excellent M.2 and VRM cooling
- + Innovative layout

RAG

- No thermal probe input
- Cramped PCB
- Few overclocking and testing tools



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PCSpecialist

DDR5 MEMORY KIT

CORSAIR DOMINATOR PLATINUM RGB / ~£250 inc VAT (32GB, 5200MHz, two modules)

SUPPLIER scan.co.uk

iCUE

- + Brilliant lighting
- + Customisable software
- + Software overclocking in future

I QUEUE

- Alder Lake also supports DDR4
- Very tall

At the complete opposite end of the spectrum to the Kingston Fury Beast DDR5 opposite is Corsair's Dominator Platinum RGB DDR5 kit; as its name suggests, it certainly does have RGB lighting and a whole lot of aesthetic prowess besides. The modules themselves have a matt finish, which looks fantastic, and the heatsinks themselves are enormous.

This should mean they're more than up to the task of dealing with any extra heat load from the DDR5 memory's additional circuitry for voltage regulation, as well as overclocking. The downside to the heatsinks is their size. At a height of 55mm, the Dominator Platinum RGB modules are extremely tall, so you'll need to factor this height into your PC build, especially if you're using an air cooler that overhangs the DIMM slots or a setup that otherwise has limited memory clearance.

Outside the PCB and memory dies, the modules appear to be mostly identical to Corsair's current DDR4 Dominator Platinum kits, with 12 Capellix RGB LEDs embedded at the top of the heatsink and shining through small square openings, as well as Dominator logos. It looks less funky than Corsair's Vengeance RGB modules, but if you like your RGB lighting to look clean and a tad more restrained than the Vengeance kits, then Dominator modules are the way to go.

The lighting colours can be fully customised in Corsair's iCUE software, where you can pick the colour of each LED, or apply presets of lighting effects, as well as create your own. You can change the default hardware-stored RGB profile

too, so if you want to set a specific colour or effect and not have the software installed all the time, that's certainly an option. The LEDs are also the best we've seen in a memory module, with highly vivid, bright and accurate colours, even with whites and yellows, which can be hit or miss on RGB memory.

Sadly, the new XMP 3.0 feature wasn't available in the version of iCUE we were given at the time of writing. This feature will allow you to create your own XMP profile for your memory, altering timings, frequency and voltage, partly thanks to the fact that, with DDR5, the voltage regulation circuitry is now on-DIMM and not on your motherboard.



Delving into the EFI, we managed to get the kit to boot at 5600MHz, but could only get the system to boot into Windows at 5400MHz. It's likely you'll be able to get it higher with some more tweaking, but we'll have to wait until Corsair's new version of iCUE becomes available in order to play more.

Conclusion

Corsair's current 32GB kit of dual-channel Dominator Platinum RGB modules retails for around £230 for a 3600MHz kit, and that's only £20 less than the approximate price of £250 we were given before we went to press for the new DDR5 kit. However, prices may have changed by the time you read this, so it's entirely possible that the difference will be higher at launch. We suggest waiting to see the benefits of DDR5 in the real world with reviews after Intel's launch – we'll be looking at this in more detail in our next issue.

Thankfully, Corsair has similar kits available in DDR4 format, and we've been told that there will be plenty of DDR4-based motherboards at launch too, with some manufacturers offering both DDR4 and DDR5 variations of the same model. However, we're also intrigued by Corsair's additions to its iCUE software relating to XMP 3.0. We had no information about it at the time of writing, so we sadly can't comment further, but if you want a smart-looking set of DDR5 modules that include some restrained RGB lighting with heaps of customisation, this is a great kit.

ANTONY LEATHER

VERDICT

Massive modules, but they're elegant and have fantastic RGB lighting

SPEC

Memory standard
DDR5

Effective frequency
5200MHz

Timings
38-38-38-84

Voltage
1.25V

Height (from base)
55mm

Lighting
Yes (RGB)

DDR5 MEMORY KIT

KINGSTON FURY BEAST 5200MHz DDR5

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

There has been a flurry of DDR5-related press announcements over the past few months, and Kingston has been quite forthcoming about its approach, as well as contributing to our DDR5 memory feature this month, discussing the pros and cons of DDR5 (see p86). This Kingston Fury Beast kit was also the first DDR5 memory to pass through our doors, and while we don't have pricing information yet, we've put the 32GB Kingston Fury Beast 5200MHz kit through its paces on our new Alder Lake test system.

On the surface, this Fury DDR5 set looks like a standard DDR4 memory kit, and for anyone needing some low-profile memory to sit under a large air cooler, or in a cramped small form factor build, the Fury modules stand just 35mm tall. This should mean the modules sit under any potential obstructions, as the heatsinks protrude just a few millimetres above the modules' PCBs. However, this comes at the expense of visual pizzazz, as there's no RGB lighting anywhere on the modules, which may or may not please you, depending on whether or not you're a fan of lighting.

We couldn't drag any of the information about the types of dies used out of the modules using our usual software, so we'll have to try another way over the next few weeks when the usual software gets updated to support Alder Lake systems.

What we can tell you is that these modules have timings of 40-40-40-40, as well as an effective frequency of 5200MHz for our kit, which is 400MHz higher than the

maximum effective frequency supported with no overclocking on Intel's 12th-gen Alder Lake CPUs. As we discuss in our deep dive, DDR5 memory can have two channels per module, and CPU-Z did report that this two-module DDR5 kit was operating in quad-channel mode.

The modules certainly got a bit warmer than DDR4 kits we've used, but not to a worrying level, and this could easily be down to the smaller heatsinks used here, rather than because the voltage

controller is now integrated on the DIMMs instead of on the motherboard. We didn't have any access to software offered by Kingston when we did this preview, but upping the DDR voltage in the EFI of our motherboard from 1.25V to 1.3V did see us hit an effective frequency of 5400MHz with ease.

The next step up was 5600MHz, but this proved too much for the Fury modules, with several failed boots and a reset EFI facing us a few restarts later. Even upping the voltage to 1.35V didn't help here – we might have been able to get higher, but we were reluctant to increase the voltage further until we had more information about what was safe.

Conclusion

It remains to be seen whether DDR5 memory is going to be a must-have, or whether DDR4 will do the job fine for Alder Lake systems. When we went to press, we were hearing reports that DDR5 memory was looking very thin on the ground for launch, so it may well be better to opt for DDR4 anyway if you want to get straight into the Alder Lake action.

As a result, we strongly suggest waiting to see how the situation evolves with regards to pricing and performance before splashing out on a Z690 motherboard and memory. As we didn't have firm pricing when we went to press, we're unable to give a firm conclusion here.

However, we can say that the Kingston Fury DDR5 kit performed well and offered a small amount of overclocking headroom. Its low-profile stature will also be a boon for anyone with restricted memory clearance, and these modules will also be right up your street if you're not a fan of RGB lighting.

ANTONY LEATHER

VERDICT

Super-low profile DDR5 memory if you need a no-nonsense approach to DDR5.



FURIOUS BEAST

- + Super-low profile modules
- + Clean, RGB-free design
- + Overclocks to 5400MHz

FURY BEAST

- No lighting
- Timings are a little higher than other kits
- No software

SPEC

Memory standard
DDR5

Effective frequency
5200MHz

Timings
40-40-40-40

Voltage
1.25V

Height (from base)
35mm

Lighting
No

360MM AIO LIQUID COOLER

THERMALTAKE TOUGHLIQUID
ULTRA 360 / £240 inc VAT

SUPPLIER scan.co.uk



While there are some very reasonably priced all-in-one liquid coolers available that offer decent cooling for your cash, there's definitely a trend towards pushing performance and features, and of course the price tag, much higher than we've seen in the past. In fact, the cost of numerous liquid coolers has topped the £200 mark in the past year, and the latest to do so is Thermalright's Toughliquid Ultra 360. It will set you back £240 inc VAT, and at face value, it doesn't seem to justify its price tag.

Combining a 27mm-thick 360mm radiator and powerful pump, there's clearly some scope for serious cooling as with most cooling systems based on 360mm radiators, although you can certainly buy similar coolers in terms of what's in the box for a lot less money.

However, the feature that impressed us the most about the Toughliquid Ultra 360 was its trio of 120mm fans. The new Toughfan 12 Turbo fans look and feel remarkably similar to Noctua fans, with a degree of heft that suggests some very high-quality manufacturing and materials. They sport hydraulic bearings and speeds up to 2,500rpm, which Thermalright claims dishes out nearly 4mm H₂O of static pressure, which is right up there with some of the best-regarded fans on the market.

This is exactly what you need for shunting air through a radiator, especially one with a very tight fin spacing, such as the 360mm radiator used here, which is attached to the pump section with braided, low-evaporation tubes. The fans also have built-in anti-vibration mounts, but if you were hoping for RGB lighting, which isn't

unreasonable given the lofty price tag, the only illumination you'll see is on the pump housing.

This sports a 480 x 480 pixel display that can show various aspects of system data, such as coolant or CPU temperature, as well as CPU load, but it can also show custom JPEG and GIF files. The display is particularly bright and vivid, although not quite as large as the one on the Asus Ryujin II 360. It can also be rotated so that it sits horizontally, depending on how you mount your motherboard – our only complaint being the USB cable that powers the display is sat right at the top edge of the pump housing, so it's clearly visible.

Sadly, there's no software control here, as you would find on high-end NZXT or Corsair coolers, as well as the Asus Ryujin II 360, which is a tad disappointing given the price tag. We'd also like to have seen support for AMD's Threadripper sockets given the enlarged contact plate, but this cooler only supports LGA2066 and mainstream desktop CPU sockets.

SPEC

Intel compatibility
LGA115x, LGA1200,
LGA2066, LGA2011

AMD compatibility
AM4, AM3+

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

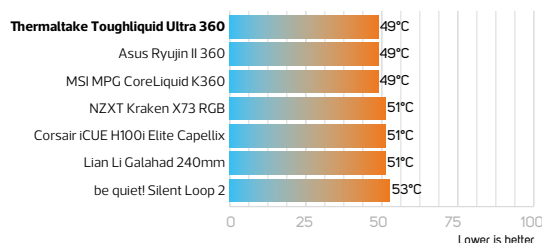
Fans
3 x 120mm

Stated noise
28dBA

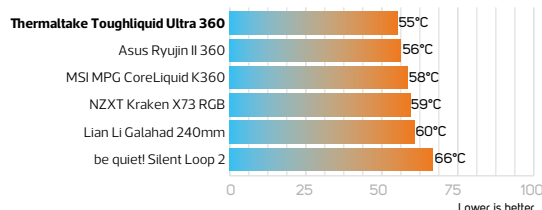


TEMPERATURE RESULTS

AMD SOCKET AM4 DELTA T



INTEL LGA1200 DELTA T



As with the NZXT Kraken X73 (see p30), Thermaltake only provides enough screws to cater for the included trio of 120mm fans. Again, you'll often find additional screws for extra fans with other coolers. You do get a daisy-chain fan connector, though, so you can power all three fans from a single 4-pin fan motherboard header.

Meanwhile, there's a tube of thermal paste included rather than being pre-applied, so you'll get a couple of re-mounts without having to buy more. The mounting mechanism is easy to use, and while you have to contend with a fair few pieces, the fact that the backplate has components that hold the pump section to your motherboard while you install it means you shouldn't need to remove your motherboard to install this cooler.

Sadly, there are no LGA1700 mounting components in the box, but Thermaltake, like most other cooler manufacturers, will send you one free of charge if you plan on upgrading to one of Intel's new 12th-gen Alder Lake CPUs.

Performance

The Thermaltake's fans were reasonably loud at full speed, but the noise was nowhere near as loud and irritating as some coolers we've tested recently, and the noise retreated to practically inaudible levels at low speeds under PWM control. The fans shift a lot of air too, so we have no doubts about their excellent airflow-to-noise ratio. Thankfully, the pump was also extremely quiet at full speed, generating a low thrum with no evidence of the high-pitched whine that can plague some liquid coolers.

The combination appeared to work well in our test systems too. Starting with our Core i9-11900K, the CPU

TOUGH SKIN

- + Great cooling
- + Premium fans
- + Quiet pump

TOUGH LUCK

- No RGB lighting
- No software control
- Expensive



delta T of 55°C was the best result we've seen, beating the Asus Ryujin II 360 and MSI MPG CoreLiquid K360. Our overclocked AMD Ryzen 7 5800X was kept at similarly chilly levels with the CPU delta T of 49°C being the joint lowest result we've seen, matching the Asus Ryujin II 360 and MSI MPG CoreLiquid K360, although that's only a modest gain over the better 240mm liquid coolers we've tested.

Conclusion

The asking price of £240 for the Thermaltake Toughliquid Ultra 360 is a lot for an all-in-one liquid cooler, and there are a few areas of concern in terms of features and value. The lack of software control is one, especially as Thermaltake offers it with other coolers, and the lack of RGB lighting is disappointing at this price too.

The unsightly USB cable that controls the snazzy display is also a shame, and there's no getting away from the fact that you can build a custom water-cooling loop for not much more money. However, many premium 240mm liquid coolers already demand more than £150 and have less cooling capacity.

In addition, the Thermaltake's display is crisp and smart, while being easy to configure. Installation is also simple and the powerful yet quiet pump and premium fans helped to propel the Toughliquid Ultra 360 up to the top of our cooling charts while making much less noise than most other coolers we've tested.

The exceptional cooling and supremely low noise at lower loads means that, while the Toughliquid Ultra 360's price is slightly eye-watering, if you're not fussed by RGB lighting, you like the screen and want a very capable cooler for both Intel or AMD sockets, it's just about worth the cash.

ANTONY LEATHER

VERDICT

Superb cooling at reasonable noise levels, but there's no RGB lighting or software control and the price is very high.



Socket AM4

COOLING
39/40

FEATURES
14/20

DESIGN
17/20

VALUE
13/20

FITTING
EASY

OVERALL SCORE

83%



LGA1200

COOLING
39/40

FEATURES
14/20

DESIGN
17/20

VALUE
13/20

FITTING
EASY

OVERALL SCORE

83%

360MM AIO LIQUID COOLER

NZXT KRAKEN X73 RGB / £189 inc VAT

SUPPLIER cclonline.com



The range of NZXT's all-in-one liquid coolers can be a little confusing, but there are some clear differences between the latest models as well as their predecessors if you delve into the specs. The company now uses the latest 7th-generation Asetek pump design, but it's the lighting, software control and fan speed that differentiates them, with the NZXT Kraken X73 RGB sitting in the middle of the pack.

It has a 360mm radiator and three 120mm fans, but unlike the current Z-series models, it lacks software control for fan speed, so you'll need to hook them up to your motherboard. That's easily done, as the Kraken X73 RGB includes a splitter cable, so you just need one spare fan header.

Unlike the fans, the pump can be software controlled, although we found it quiet enough to run at full speed without being audible above the noise made by the rest of our system. Besides, it will ramp up to full speed anyway under load, even on the Silent mode setting.

To make sure the fans don't get overly noisy, NZXT limits their speed to 1,500rpm. This means the fans more of a low thrum compared with the racket made by the monstrous 2,500rpm fans on the Thermaltake Toughliquid Ultra 360 (see p28), but it does mean there's less airflow to deal with the radiator's dense array of fins.

The AER RGB 2 120mm fans also feature digital RGB lighting, which can be controlled using NZXT's CAM software. Each of the eight individual LEDs can be controlled using the full RGB colour palette and, as usual, there

are various preset lighting effects from which to choose, including a funky rainbow mode. The lighting is vivid, but also cleanly diffused thanks to large opaque rings surrounding the fans.

Hooking up all the cables for a trio of RGB fans can be a nightmare, but NZXT has made this job a little easier by installing input and output ports for the lighting control, with shortened cables daisy-chaining across the fans, instead of each fan needing to connect to a splitter or hub individually. The cable spaghetti is drastically reduced as a result, but we wonder why NZXT didn't go the whole nine yards and do the same with the fan power cables too.

Our white sample costs a little more than the black model, but it does look fantastic, especially with the black fan corner inserts. Stepping up to a Z-series model bags you a snazzier display on the pump/waterblock unit with a temperature

SPEC

Intel compatibility
LGA115x, LGA1200,
LGA2066, LGA2011

AMD compatibility
AM4, AM3+, TRX4, TR4

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

Fans
3 x 120mm

Stated noise
33dBA



GIANTSQUID

- + Good cooling
- + Low noise
- + Excellent RGB lighting
- + Looks fantastic

CALAMARI

- No software fan control
- Competition offers similar credentials for less money
- Aging design in some areas

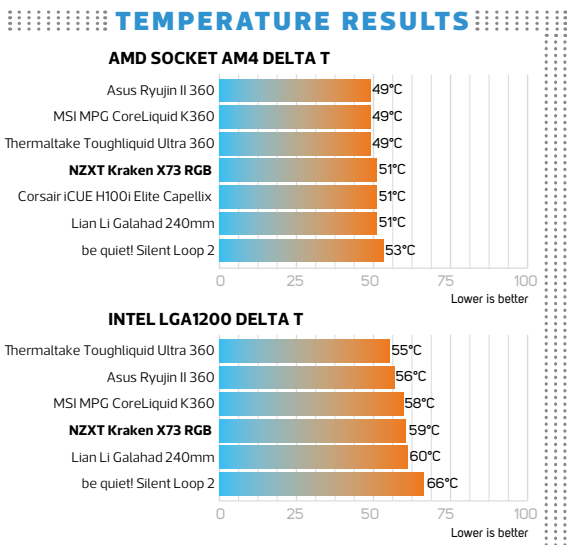
control readout, but the infinity mirror effect pump top, which is colour-customisable, still looks great on this model, if a little dated. Thankfully, unlike Thermaltake, NZXT has also kept the power and USB cable ports well below the top of the pump housing, so they're not as clearly visible.

Meanwhile, the mounting kit is your typical Asetek affair, but doesn't yet include adaptors for LGA1700, so you'll need to request them from NZXT when they're available. There's a backplate for Intel systems, but it makes use of the stock backplate on AMD motherboards. Either way, all CPU sockets will require mounting plates to be fitted to the pump section before securing it with thumbscrews. It's very simple, although the thermal paste is pre-applied, so you'll need to keep the protective cap on the pump/waterblock unit until you're ready to mount the cooler, and buy more paste if you ever swap CPUs.

With a thin 27mm-thick radiator, there's not much point adding another row of fans, as they're £20 a pop and won't improve performance much. As such, NZXT hasn't included additional screws, only providing what you need to mount the included trio of 120mm fans.

Performance

With a subdued set of fans offering reduced airflow compared with other 360mm liquid coolers, it wasn't a surprise to see the Kraken X73 RGB drop a little way down the graphs when squaring up against louder competitors such as the Thermaltake Toughliquid Ultra 360, Asus Ryujin II 360 and MSI MPG CoreLiquid K360. All these coolers managed a CPU delta T of 49°C in our AMD system, cooling



an overclocked Ryzen 7 5800X, while the NZXT cooler managed 51°C, but while making less noise.

The Kraken X73 was further behind the competition when dealing with a Core i9-11900K with Adaptive Boost Technology enabled, sitting at a CPU delta T of 59°C under full load, compared to 55°C for the Thermaltake Toughliquid Ultra 360, although it was only 1°C behind the MSI MPG CoreLiquid K360. Surprisingly, the likes of the 240mm Lian Li Galahad weren't far behind at all in this test, and they cost a lot less money. Again, though, the NZXT Kraken X73 RGB managed this with far less noise.

Conclusion

The NZXT's price is certainly a little more reasonable than that of the Thermaltake Toughliquid Ultra 360, and the white version looks stunning, helped by some fantastic RGB fans and aesthetic details. If you're building a white-themed PC, this is a great cooler that's reasonably quiet and performs well on both AMD and Intel systems.

The lack of software control is a bit of a letdown considering NZXT's CAM software is actually very good, but we can appreciate NZXT's reasoning for this omission. It enables the company to provide a cheaper cooler for those who don't want to use its software and instead make use of their motherboard's EFI control.

The competition is fierce, though, with the likes of Corsair's iCUE H150i Elite Capellix retailing for £40 less, but offering full software control via an included fan and lighting hub, as well as RGB fans and pump top, plus it's available in white for under £150. Still, if you prefer your RGB lighting to sit in rings rather than on the blades, or prefer to use NZXT's software for pump and fan control, then the Kraken X73 RGB is a good (though not outstanding) low-noise cooler with decent cooling capacity.

ANTONY LEATHER

VERDICT

Snazzy RGB lighting and decent cooling at low noise levels, although it's a tad pricey.



Socket AM4

COOLING
36/40

FEATURES
16/20

DESIGN
16/20

VALUE
15/20

FITTING
EASY

OVERALL SCORE

83%

LGA1200

COOLING
34/40

FEATURES
16/20

DESIGN
16/20

VALUE
15/20

FITTING
EASY

OVERALL SCORE

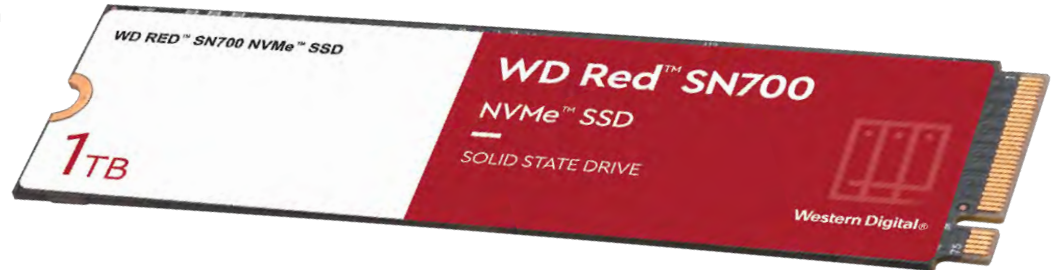
81%

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- + High capacities available

RED FLAG

- High load temperatures
- Slower than similarly priced SSDs
- PCI-E 4 SSDs can be bought for less money

We're used to WD's SSDs either offering great value for money, such as the Blue SN550, or extreme speeds, as we saw with the Black SN850, which topped 7,000MB/sec when we reviewed it. However, not only is the company's new SN700 the first Red-branded NVMe SSD from WD, but it's also not actually aiming to appeal in terms of either value or performance. Instead, the Red SN700 is all about reliability.

Its key asset is its TBW rating – the number of terabytes you can write to the SSD and still have it covered under the warranty. The endurance of SSDs has been an issue in the past, but with most SSDs now offering many hundreds of terabytes on their TBW ratings, endurance is unlikely to be an issue for most people unless you're regularly writing a heck of a lot of data. In fact, most SSDs will last for the lifetime of an average PC.

Still, if you regularly swap out massive games, or huge stores of video and photo files, endurance might be more of a concern. Of course, WD is also aiming at NAS users, as it did with its Red hard disks, as many high-end NAS enclosures now make use of SSDs to boost speeds.

In these cases, the 2,000TBW rating for our 1TB sample and mind-boggling 5,100TBW rating for the 4TB model will certainly give you that peace of mind. Other 1TB SSDs only offer an endurance rating of around 600TBW, so WD is more than trebling this figure.

In terms of specifications, the Red SN700 uses an in-house WD controller and 3D TLC NAND along with SLC caching like most TLC-based SSDs. Its claimed read and write speeds are typical for a 4x PCI-E 3 SSD at 3,400MB/sec and 3,000MB/sec respectively for our 1TB model, and these figures don't rise by much even for the 4TB model. What's more, the claimed performance figures were bang on, being matched by our own performance tests.

There's no heatsink on the SSD, though, and no option to buy it with one, unlike the Black SN850. While the SSD performed as expected without one, the peak temperature of a toasty 83°C did raise our eyebrows. Needless to say, we'd definitely suggest using a heatsink on this drive if your system can accommodate one, as there's not a lot of headroom here before the drive is likely to begin throttling in order to reduce the temperature. That's clearly not what you want if you're regularly reading and writing lots of data.

Not surprisingly, the 32-queue-depth random 4K speeds were some way off the mighty WD Black SN850's results of 1,021MB/sec and 897MB/sec, instead hitting 853MB/sec and 675MB/sec. Likewise, the random 4K single-queue-depth, single-thread results were noticeably slower, but these speeds are all still decent for a PCI-E 3 SSD, and you're unlikely to notice much difference in real-world use.

Conclusion

For most of us, the typical 600–800TBW ratings offered by cheaper SSDs are enough, and the likes of the ADATA PCI-E 4 XPG Gammix S50 Lite are faster, cheaper and still offer decent warranties. Endurance isn't a typical selling point for SSDs, but there is a definite market for people who really hammer their storage systems with regular large data transfers.

If that's you, and you want the peace of mind that's bought by a huge endurance rating, then the Red SN700 offers an unmatched endurance rating for the cash and is also available in huge capacities.

ANTONY LEATHER

VERDICT

A hardy drive that's worth considering for high-end NAS boxes, or if you regularly hammer your storage system.

PERFORMANCE
42/50

FEATURES
19/20

VALUE
20/30

OVERALL SCORE

81%

SPEC

Full capacity
1TB

Formatted capacity
931GB

Heatsink
No

NAND
TLC

Controller
WD in-house

Endurance
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Warranty
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PHILIPS

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SCAN

PCI-E 3 M.2 SSD

ADATA XPG SPECTRIX S40G /

1TB **£118** inc VAT; 512GB (reviewed) **£85** inc VAT; 256GB **£46** inc VAT

SUPPLIER amazon.co.uk



SPLASH OF LIGHT

- + Fantastic RGB lighting
- + Reasonable price
- + Simple software

SPLASH OF MUD

- No 2TB model
- PCI-E 4 drives are faster

Our recent M.2 group test in Issue 215 saw some of the cheaper PCI-E 4 offerings such as ADATA's own S50 Lite offer decent bang for your buck, although in real-world use you're unlikely to see noticeable benefits by jumping from PCI-E 3 to PCI-E 4 unless you regularly shift multiple terabytes of data around your storage system. As a result, cheaper PCI-E 3 SSDs can still provide excellent performance while saving you some cash or, in the case of the ADATA XPG Spectrix S40G, you can spend a little bit more money and get an RGB-equipped SSD instead.

Yes, you heard us right – this PCI-E 3 SSD has its own RGB lighting array – a feature that's usually only found in slower 2.5in SATA SSDs. What's more, the lighting isn't just fixed in a cycling rainbow effect – it's fully controllable on a per-LED basis using ADATA's software. Whether you want to take advantage of one of this drive's preset lighting modes, go all-out with the usual rainbow effect or set a specific colour to match the rest of your system's lighting, the XPG Spectrix S40G is a good match if you like to illuminate as much of your PC's interior as possible.

The XPG Spectrix S40G also has a small heatsink sandwiched among the RGB paraphernalia and, prior to updating the firmware, its temperatures were reported to be reaching 90°C. However, after we'd updated the firmware, these temperatures fell to below 70°C, so this is well worth doing, especially as ADATA's software will enable you to install the new firmware in just a couple of clicks.

While many PCI-E 4 SSDs are based on Phison controllers, we see far more variation in the controllers used in 4x PCI-E 3 SSDs, and in this case, the XPG Spectrix S40G uses a Realtek RTS5762 controller along with Micron triple-level cell (TLC) NAND flash and a portion of single-level cell (SLC) flash reserved for a write cache, which boosts the otherwise slow write speeds associated with TLC memory. Continually writing data to the SSD saw this cache run out once we started writing between 350GB and 400GB,

so this is unlikely to be an issue unless you'll be dropping hundreds of gigabytes onto the drive regularly.

Our 512GB sample has a claimed write speed of 2,400MB/sec while the 1TB can hit 3,000MB/sec, and this was generally borne out in the benchmarks. We recorded a read speed of 3,540MB/sec, which even slightly outstrips the claimed 3,500MB/sec, but sure enough, it sat just short of 2,500MB/sec in our tests, hitting 2,461MB/sec. The 4K random speeds were reasonable, with a single-queue-depth, single-thread read result of 52MB/sec, and its 190MB/sec 4K write result was noticeably quicker than that of the WD Red SN700 we also reviewed this month (see p32). Meanwhile, the 32-queue-depth performance of 502MB/sec for reads and 724MB/sec for writes are fine, but not outstanding.

Conclusion

Ultimately, you won't see much real-world difference between most PCI-E 3 and 4 SSDs, especially outside of sequential workloads, and the Spectrix S40G is certainly fast enough for most people's needs, even if it only uses the PCI-E 3 interface. Price and features are far more important differentiators, and here the ADATA XPG Spectrix S40G keeps pace with most PCI-E 3 SSDs, but throws RGB lighting into the mix for around an extra tenner, although bear in mind the range tops out at 1TB, with no 2TB model available. The lighting is certainly a gimmick, but it does look great if you like to light up as much of your PC as possible.

ANTONY LEATHER

VERDICT

If you want to light up as much of your PC as possible, the RGB-enabled ADATA XPG Spectrix S40G offers great lighting without bumping up the price too much.

PERFORMANCE
42/50

FEATURES
18/20

VALUE
24/30

OVERALL SCORE

84%

SPEC

Full capacity
512GB

Formatted capacity
476GB

Heatsink
Yes

NAND
TLC

Controller
Realtek RTS5762

Endurance
640TBW

Warranty
Five years

Wireframe

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on video games



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32IN GAMING MONITOR

LG ULTRAGEAR
32GP850 / £399 inc VAT

SUPPLIER overclockers.co.uk

BIG SCREEN

- + Great overall image quality
- + Excellent gaming performance
- + Low cost for its size
- + Superb OSD system

BIG SCENE

- Can't really do HDR
- Contrast is a touch low
- Comparatively pixel density

SPEC

Screen size
32in

Resolution
2,560 x 1,440

Panel technology
IPS

Maximum refresh rate
165Hz (180Hz overclocked)

Response time
1ms

Max brightness
350cd/m² (SDR)

Backlight zones
1

Contrast
700:1

Adaptive sync
FreeSync and G-Sync

Display inputs
1x DisplayPort 1.4, 2x HDMI 2

Audio
Headphone out

Stand adjustment
Height, tilt, rotate

Extras
100 x 100mm VESA mount, 2-port USB hub

Available for under £400, the LG UltraGear 32GP850 provides a large 32in screen size and a rapid 165Hz (overclockable to 180Hz) refresh rate. What's more, it uses LG's Nano IPS panel technology for class-leading response time and what should be solid image quality.

It's an attractive-looking bit of kit, if a little on the plain and plastic side. There's no RGB or extra gaming hardware, such as a headset hook, but it's a simple, classy-looking unit. The stand is reasonably elegant, although the long pointy leg design is a little less practical than a flat square base. It offers height and tilt adjustment, as well as rotation, although there's no swivel option.

Around the back, the ports face directly outwards rather than downwards. It's easier to plug cables into the monitor this way, but it's less tidy when it comes to cable management. The external power supply helps to keep the display slim, but you'll have a power brick to tidy away somewhere.

Those ports consist of one DisplayPort and two HDMI inputs along with a 2-port USB 3 hub and headphone jack. There are no speakers, but the headphone jack

sounds good, unlike the ones in some cheap displays. A single mini D-pad/joystick on the underside of the panel controls the on-screen display menus and the setup process works superbly, while the selection of options is comprehensive for tweaking both image quality and gaming performance.

An important addition for many users will be the sRGB mode for reducing the colour gamut and, unlike on many monitors, in this case this mode doesn't lock the brightness. By default, the display offers a high colour gamut (100 per cent DCI-P3, 140 per cent sRGB) for an HDR-like colour range, but there are no contrast boosting technologies for proper HDR.

When it comes to image quality, this display's 2,560 x 1,440 resolution on a 32in panel makes pixels look quite large, so fans of



ultra-sharp panels will have to look elsewhere. However, we found it enjoyable for gaming and video. LG only rates the contrast of this panel at 700:1, but in our tests it delivered over 900:1. As a result, it didn't obviously suffer the slightly washed-out look of some Nano IPS screens we've tested.

In both high gamut and sRGB modes, the display provided excellent image quality out of the box, with accurate colour temperature (6,384K in high gamut, 6,597K in sRGB), good colour accuracy (0.12 average delta E in both) and decent gamma response (2.16 high gamut, 2.31 sRGB). This means you shouldn't need to tweak any image quality options to get the best from this display, other than changing brightness and opting for the sRGB mode if desired.

For gaming, the native 165Hz refresh rate along with a snappy 1ms response time makes for an impressively responsive experience. You've also got FreeSync and G-Sync support for image tearing and stutter removal, and the option to overclock to 180Hz, although the latter didn't make much of a discernible improvement in our tests.

Conclusion

If you want a big screen without a huge cost and the need for an expensive 4K-capable GPU, the LG UltraGear 32GP850 is an ideal compromise. Its IPS panel offers great overall image quality and solid gaming performance. There are a few competitors in this general price range, but the LG is among the cheapest options yet lacks nothing in terms of performance.

EDWARD CHESTER

VERDICT

An ideal balance of screen size, image quality, gaming performance and price.

IMAGE QUALITY

26/30

GAMING

26/30

FEATURES

16/20

VALUE

18/20

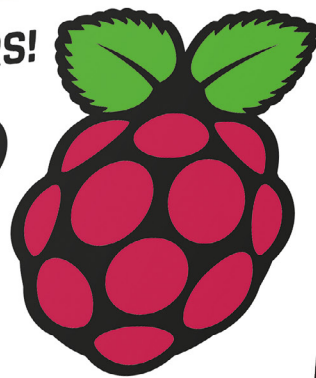
OVERALL SCORE

86%

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WIRELESS GAMING MOUSE

CORSAIR M65 RGB ULTRA WIRELESS / £110 inc VAT

SUPPLIER scan.co.uk



The Corsair M65 is a stalwart of the gaming mouse market, but its shape and weight make it an outlier when the current trend is to make gaming mice lighter. There are two variants of the new M65 – a wired and a wireless version. They share the same overall shape and dimensions, but the wired version is slightly lighter at 97g, while the wireless version starts at 110g and can go up to 128g once its weights are added.

When the latest lightweight FPS-targeted mice weigh in the region of 70g or lower, you can see why the M65 is such a different beast. The weights system consists of three 4g weights and three 2g screws to affix them. They're arranged in a triangle on the underside of the mouse, so you can use them to balance the mouse to your liking.

Meanwhile, the shape and build of the M65 Ultra Wireless is intriguing. It's fairly wide and tall with a flared-out left edge, plus of course it's heavy. That generally bulky feel suggests this mouse is best used with a palm grip but then the back of the M65 tapers inwards quite sharply, leaving little support for the palm of the hand.

The sides are also a little slippery and the sniper thumb button slightly gets in the way for fingertip grip. It's a well-built, weighty unit, but the shape can make the M65 uncomfortable to hold in your hand and we found we didn't really get on with it. If you liked the shape of previous M60-series mice, then you'll probably like this one too, but it's definitely divisive.

Joining the standard left, right, middle/scroll wheel, back and forward buttons are two DPI buttons behind the scroll wheel and that sniper thumb button. The latter is designed to be used as a quick DPI-lowering button for sniping. We've also found it can be rather useful in some desktop software, such as Photoshop, and it's fully programmable button, so you can use it for any purpose.

Both of the new M65 RGB Ultras include Corsair's latest Marksman optical sensor. There's also a six-axis gyro system that lets the mouse know when it has been picked

up, minimise lift-off-distance and offer programmable tilt gestures. Meanwhile, the wireless version uses the company's excellent Slipstream wireless technology that has a latency of just 0.9ms, and you can connect it over Bluetooth too.

The tilt gestures are an intriguing addition that certainly elevates the mouse above most others for utility. They work quickly and intuitively, and it's one less shortcut or macro you'll have to assign to your keyboard.

In general, performance was as excellent, as we've come to expect, with flawless tracking accuracy, great button feel and no discernible lag from the wireless mode, plus battery life proved impressive too. Corsair claims up to 90 hours over wireless and 120 hours via Bluetooth, and we certainly had no issues with the mouse running out over a week of use.

Conclusion

The M65 RGB Ultra Wireless is a hugely capable gaming mouse that's packed with features. None of the extras are essential, but most of them can be useful. It's not cheap, but it's competitively priced for a wireless mouse. However, its shape can make it uncomfortable to hold – we recommend trying it before buying it, and it's also heavy for an FPS mouse.

EDWARD CHESTER

VERDICT

A divisive shape and weight, but this is a solid update to a venerable gaming mouse.

MARKSMAN

- + Loads of features
- + Solid performance
- + Reasonable value

MARKED MAN

- Heavy
- Odd shape

SPEC

Weight
110g

Dimensions (mm)
77 x 117 x 39 (W x D x H)

Sensor
Corsair Marksman, 26,000 DPI, 50g acceleration, 650 IPS

Buttons
8 (left, right, scroll wheel, back, forward, two DPI, sniper)

Cable
1.8m, USB Type-C

Stated battery life
90 hours wireless, 120 hours Bluetooth

Extras
Dongle stowage on underside, weights system, tilt gestures

DESIGN
14/20

FEATURES
18/20

PERFORMANCE
26/30

VALUE
16/30

OVERALL SCORE

74%

HackSpace

TECHNOLOGY IN YOUR HANDS

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GAMING LAPTOP

RAZER BLADE 14 / £1,799 inc VAT

SUPPLIER razer.com

RYZEN

- + Rapid 1080p gaming
- + Great CPU
- + Excellent display
- + Sleek chassis

FALLING

- Middling battery life
- Expensive
- Slightly cramped keyboard

The Blade 14 sees Razer equipping its laptops with AMD CPUs for the first time, and Razer hasn't messed around, cramming a Ryzen 9 5900HX inside this compact machine. The 5900HX has eight SMT-enabled cores (16 threads) alongside base and boost speeds of 3.3GHz and 4.6GHz, so it's ideal for creative workloads as well as gaming.

The rest of the spec is good too, with graphical grunt provided by an Nvidia GeForce RTX 3060 Laptop GPU. Its TDP here ranges between 90W and 100W, which is mid-range for this particular GPU core. That translates to a modest base clock of 900MHz and a better boost speed of 1425MHz.

The Blade 14 also has 16GB of DDR4 memory alongside a 1TB Samsung PM981a SSD, which delivered solid read and write speeds of 3591MB/sec and 2111MB/sec respectively. Dual-band 802.11ax Wi-Fi 6E and Bluetooth 5.2 complete the internals.

This Blade doesn't just break ground with the processor – it's also Razer's first 14in laptop. This form factor has become increasingly popular lately, with other machines such as Asus' ROG Zephyrus G14 offering a compact alternative to bulky 15.6in machines. The Blade weighs

1.78kg and it only measures 16.8mm thick, so it's far slimmer and lighter than your average 15.6in laptop. Its weight virtually matches the Asus, and the Razer is slimmer.

Aside from the shrinking body, Razer's chassis design hasn't changed. As usual, the Blade 14 uses CNC-milled aluminium, and its sleek lines and black finish will be familiar to any Razer fan. It looks mature, and the body is sturdy. It will easily stand up to frequent transport, although you'll want a sleeve to protect its good looks.

The Razer has pairs of full-sized and Type-C USB 3.2 Gen 2 ports, with the smaller connectors also handling DisplayPort and power delivery. Razer's machine also has an HDMI 2.1 port, which is futureproofed with support for 8K/120Hz outputs. The RTX 3060



will only handle some esports games at that resolution and refresh rate, but it's welcome nonetheless.

Overall, the connection options are better than those of the Asus, which has slower full-sized USB ports and no HDMI 2.1, although an equivalent spec of the Asus only costs £1,499. The Blade's 720p webcam supports Windows Hello login too, but this smaller machine doesn't have card or fingerprint readers, and there's no Gigabit Ethernet. Users can't upgrade the memory either, and there's no Thunderbolt support.

Meanwhile, the keyboard has per-key RGB LED lighting and n-key rollover, and its keys have a fast and consistent action, with the speed and regularity required for mainstream gaming. On a 14in laptop, though, there are expected compromises; there's no numberpad, the Return and cursor keys are small, and larger machines have bigger, heavier keys. The trackpad is large and its built-in buttons are snappy, but a USB mouse always provides a better experience for gaming.

Performance

The RTX 3060 GPU played Assassin's Creed Valhalla and Cyberpunk 2077 with 99th percentile minimums of 38fps and 39fps, and its Cyberpunk score improved marginally with ray tracing and DLSS enabled, so it has the speed to tackle single-player games – drop the settings a little, and you can easily run games smoothly.

SPEC

CPU

3.3GHz AMD Ryzen 9 5900HX

Memory

16GB 3200MHz DDR4

Graphics

Nvidia GeForce RTX 3060 Laptop 6GB

Screen

14in 1,920 x 1,080 IPS 144Hz

Storage

1TB Samsung PM981a M.2 SSD

Networking

Dual-band 802.11ax Wi-Fi 6E, Bluetooth 5.2

Weight

1.78kg

Ports

2 x USB 3.2 Gen 2, 2 x USB 3.2 Gen 2 Type-C/DisplayPort, 1 x audio, 1 x HDMI

Dimensions (mm)

320 x 220 x 17 (W x D x H)

Operating system

Windows 10 Home 64-bit

Warranty

One year parts and labour return to base



Its 87fps 99th percentile result in Doom Eternal gave way to a 154fps average, which is fine, but it shows that even undemanding games won't be able to make the most of the Razer's 144Hz display. The Razer is quicker than the Asus, though, which runs its RTX 3060 with a TDP between 60W and 75W.

The processor is quick. Its single-threaded GIMP image editing score of 68,585 is rock-solid, and it scored 535,106 in our heavily multi-threaded Handbrake benchmark. Those results mean you can run any everyday task on this machine alongside photo and video editing tools. That image editing score squeaks ahead of Intel's Core i7-11800H, and the Handbrake result is miles better.

The Blade is a mixed bag in thermal tests though. It's fine when running CPU-based workloads – the CPU's delta T of 59°C is solid, noise levels were modest and the exterior remained cool. That's true during less demanding games too, and the GPU's delta T of 46°C is decent. However, if you push the GPU in challenging games, the machine's underside becomes uncomfortably warm and the metal above the keyboard is too hot to touch. Noise levels are moderate here, though, and no worse than most larger gaming machines.

Meanwhile, the battery offers no surprises. The Razer's unit lasted for more than seven hours while working and ten hours while playing video, but only managed 87 minutes of gaming. Comparatively, the Asus lasted half an hour more during gameplay.

You get a great screen with the Razer, though, with the 1080p 144Hz panel offering excellent quality. Its brightness level of 323cd/m² is fine for both indoor and outdoor use, and the 0.17cd/m² black point is tremendous, providing serious depth. The contrast ratio of 1,900:1 is as good as it gets for an IPS display, and it serves up fantastic vibrancy. The delta E of 1.66 is great too.

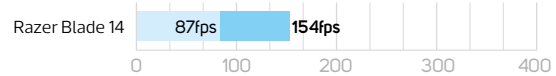


BENCHMARK RESULTS



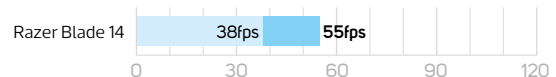
DOOM ETERNAL

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



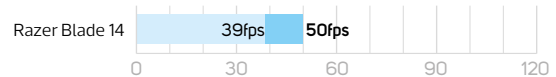
ASSASSIN'S CREED VALHALLA

1,920 x 1,200, Ultra High settings, High anti-aliasing



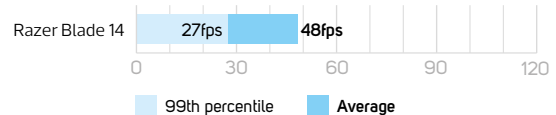
CYBERPUNK 2077

1,920 x 1,200, Ultra preset, no ray tracing



METRO EXODUS

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



The colour temperature of 7,348K is slightly on the cooler (bluer) side and the sRGB gamut coverage of 93.2 per cent could be better, but those figures aren't wayward enough to cause serious issues. This is a bold, bright gaming screen. The speakers are reasonable too, with a surprising amount of bass and a crisp, clear top end.

Conclusion

Razer's first 14in laptop gets plenty right – the RTX 3060 is a rock-solid mainstream gaming chip, and the AMD processor is quick and versatile. The familiar design is robust and good-looking, the keyboard is crisp and connection options are good.

The Blade isn't infallible though. Battery life is middling, larger keyboards are more satisfying, and the Blade is pricier than the marginally slower Asus. These compromises aren't surprising in this form factor, though, and they're not deal-breakers. This is an excellent small laptop, and well worth buying if you want a compact, portable gaming machine.

MIKE JENNINGS

VERDICT

Slick performance and design combine to deliver a great experience, although you have to pay for it.

PERFORMANCE
23/25

DESIGN
23/25

HARDWARE
22/25

VALUE
21/25

OVERALL SCORE

89%

AMD B550 GAMING PC

CCL HORIZON 5 3060 Ti GAMING PC / £1,499 inc VAT

SUPPLIER cclonline.com

CCL's Horizon costs £1,499 inc VAT, and that's a rock-solid price considering the Nvidia GeForce RTX 3060 Ti graphics card and AMD Ryzen 5 5600X processor – systems with this hardware usually cost more. The RTX 3060 Ti has 4,864 stream processors, which is 1,280 more than the conventional RTX 3060, and it has a solid 8GB of memory. In this case, it's a Gainward Ghost model, but it's not overclocked, so its base and boost speeds remain at 1410MHz and 1665MHz.

There are no surprises from the CPU either – the

Ryzen 5 5600X remains a rock-solid option thanks to six SMT-enabled Zen 3 cores alongside a turbo speed of 4.6GHz. There's impressive hardware elsewhere too. The 16GB of dual-channel memory runs at 3600MHz, and the 1TB ADATA SSD delivered sensational read and write speeds of 7,469MB/sec and 6,381MB/sec. That's fantastic speed and plenty of space, but be aware that there's no secondary hard disk for large media file storage.

ADATA also supplies this PC's case and CPU cooler. The radiator for the XPG Levante liquid cooler sits in the roof with two RGB LED fans and doesn't intrude on the rest of the build, while the XPG Starker case is white and filled with RGB LEDs – you can't miss it.

The chassis is robust and has a tempered glass side window with CCL's Horizon logo, while the front panel easily pops away for access to the removable dust filter. On the inside there's neat cabling and a PSU shroud. You only get room for two 2.5in drives and a single 3.5in hard disk, but the Starker is good in every other area.



You get a B550 motherboard too, in the form of MSI's MAG B550 Tomahawk. It has four memory slots, two M.2 connectors and several PCI-E slots, while the rear serves up USB 3.2 Gen 2 Type-A and Type-C ports alongside a USB 3.2 Gen 1 connection. The board has attractive heatsinks and some RGB LEDs, and it has 2.5Gbps Ethernet and decent Realtek ALC1200 audio as well. Only its primary PCI-E and M.2 connectors support PCI-E 4, though, and there's no Wi-Fi or Thunderbolt connection either.

Meanwhile, the Corsair RM650 power supply is 80 Plus Gold certified and fully modular. The warranty is excellent too – this PC has three years of on site coverage for both parts and labour.

Performance

The RTX 3060 Ti is well suited to single-screen gaming at mainstream resolutions. At 1080p, it played Assassin's Creed Valhalla at a 99th percentile minimum of 54fps, and it played Cyberpunk 2077 with a 99th percentile result of 58fps, which increased to 59fps with Medium ray tracing and DLSS applied in Balanced mode.

With the resolution increased to 2,560 x 1,440, the RTX 3060 Ti remained playable, with minimums that ranged between 32fps and 46fps across our tests. You'll be able to play any single-player game on a mainstream display with this GPU, but you won't be able to play games at 4K.

SPEC

CPU

3.7GHz AMD Ryzen 5 5600X

Motherboard

MSI MAG B550 Tomahawk

Memory

16GB ADATA D60G 3600MHz DDR4

Graphics

Gainward GeForce RTX 3060 Ti 8GB

Storage

1TB ADATA XPG Gammix X70 M.2 SSD

Networking

2.5Gbps Ethernet, Gigabit Ethernet

Case

ADATA XPG Starker

Cooling

CPU: ADATA XPG Levante 240 with 2 x 120mm fans; GPU: 2 x 80mm fans; front: 1 x 120mm; rear: 1 x 120mm

PSU

Corsair RM650 650W

Ports

Front: 1 x USB 3.2 Gen 1, 1 x USB 3.2 Gen 2 Type-C, 2 x USB 3.2 Gen 1, 2 x USB 2.0, 1 x PS/2, 1 x optical S/PDIF, 5 x audio

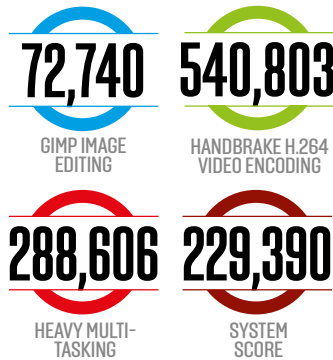
Operating system

Windows 10 Home 64-bit

Warranty

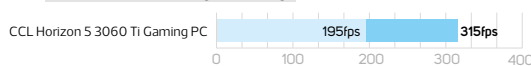
Three years on site parts and labour

BENCHMARK RESULTS



DOOM ETERNAL

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



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



ASSASSIN'S CREED VALHALLA

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



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

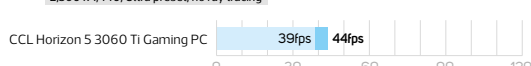


CYBERPUNK 2077

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

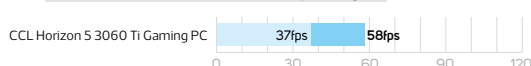


2,560 x 1,440, Ultra preset, no ray tracing

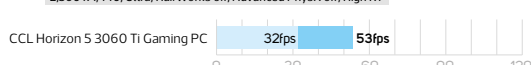


METRO EXODUS

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



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



99th Percentile Average

It's a capable GPU for high frame rates too – it zipped through Doom Eternal with average frame rates of 315fps and 234fps at 1080p and 2,560 x 1,440 respectively. There's easily enough pace to run undemanding games and esports titles with high refresh rates.

There's a comfortable gulf between the RTX 3060 Ti and the standard RTX 3060 – the CCL's GPU is around 9fps quicker in Cyberpunk at 1080p, and 8fps faster in Assassin's Creed Valhalla. That's great, but the RTX 3070 and RTX 3080 are still significantly quicker, and you'll need to spend more for one of those GPUs if you want to get smooth frame rates in demanding games at 2,560 x 1,440.



SUNRISE

- + Great 1080p gaming speed
- + Tidy, good-looking case
- + Fast memory and SSD
- + Excellent warranty

SUNBURN

- Few enthusiast features
- Can't handle 4K games
- Little room for extra storage

Meanwhile, the 5600X proved adept in application tests. Its result of 72,740 in our single-threaded image editing benchmark is around 4,000 points faster than Intel's equivalent Core i5-11600K, and the its score of 540,803 in Handbrake is great for this price too. This is an excellent CPU for a broad range of tasks – it scythes through content-creation tools and multi-tasked workloads.

CCL's machine delivers good thermal performance as well. The CPU and GPU delta T figures of 37°C and 46°C are great, and fan noise is reasonable – there's a constant hum from this rig when playing games or running creative software, but it's quieter than most gaming PCs and easy to drown out with speakers or a headset.

Conclusion

CCL's is one of the best mid-range gaming PCs we've seen for ages. The RTX 3060 Ti delivers rock-solid 1,920 x 1,080 gaming pace, the AMD processor is a great affordable CPU, and the CCL has fast memory and storage, a decent motherboard and a solid case. It's all protected by a generous warranty too.

This PC doesn't have enthusiast-level motherboard features, loads of space for extra storage or 4K gaming ability, but no PC at this price nails those tougher elements. You won't find many better desktop gaming PCs for £1,499 inc VAT.

MIKE JENNINGS

VERDICT

Great speeds, good features and a keen price – a rock-solid affordable gaming PC.

PERFORMANCE

21/25

DESIGN

22/25

HARDWARE

21/25

VALUE

22/25

OVERALL SCORE

86%

AMD APU GAMING PC

STORMFORCE ONYX
RYZEN 5600G / £699 incVAT

SUPPLIER stormforcegaming.co.uk

Stormforce's Onyx is the second system we've seen with one of AMD's latest APUs, enabling the company to make a PC for just £699. It's effectively one of the cheapest gaming PCs you can buy right now in the era of GPU shortages and price inflation.

The mid-range Ryzen 5 5600G used here has six SMT-enabled Zen 3 cores alongside a Radeon GPU with 448 stream processors. The CPU core has base and boost speeds of 3.9GHz and 4.4GHz, and the GPU runs at 1900MHz, but it doesn't have its own memory and needs to share system RAM. However, while this new APU uses AMD's latest Zen 3 CPU microarchitecture, the GPU uses

AMD's much older Radeon RX Vega hardware rather than RDNA silicon, and the APU doesn't support PCI-E 4 either.

The conventional Ryzen 5 5600X doesn't have an integrated GPU, of course, and its base speed of 3.7GHz is modest, but it has a better boost peak of 4.6GHz, and its 32MB of L3 cache is twice as much as that of the 5600G.

The rest of Stormforce's specification isn't surprising for a budget build. There's 16GB of dual-channel DDR4 memory running at 3200MHz and a 500GB WD SN550 SSD. That drive is big enough for an entry-level drive with a few esports titles installed, it will get cramped after you've installed a few large single-player titles.

On the plus side, it's relatively quick, with its 2,431MB/sec read speed being a long way in front of SATA SSDs.

It all plugs into an Asus Prime A520M-K micro-ATX motherboard



with a basic specification – its two memory slots are both occupied, it doesn't have a second M.2 connector and there's no PCI-E 4 support. You do get Gigabit Ethernet and Stormforce has added dual-band 802.11ax Wi-Fi, but elsewhere there's basic audio and no USB Type-C ports. The four USB 3.2 Gen 1 ports top out at a sedate speed of 5Gbps, and there are only three audio jacks. It's fine for basic everyday computing, but it only really covers the bare minimum.

On the plus side, the Cooler Master MB320L case looks good, with a stylish curved front panel and a couple of fans with RGB LEDs. It also has a tempered glass side panel, a PSU shroud and decent build quality.

It's not too big either. Stormforce's cabling is tidy, and throughout the case there's room for four 2.5in drives and two 3.5in hard disks. It's easy to work inside, but don't expect high-end features – those drive bays don't have caddies or cages and you don't get a USB Type-C port on the front, or buttons to alter the lighting.

The Cooler Master MWE power supply isn't modular either – it only has a standard 80 Plus efficiency rating and a 500W peak output, although that gives you a little headroom for a modest GPU upgrade later.

The £699 Stormforce rig does have a good warranty, though, with three years of parts and labour coverage alongside collect and return service.

That's a notable area where this rig outpaces its main rival from our reviews. Last month's PC Specialist Lotus Elite R

SPEC

CPU

3.9GHz AMD Ryzen 5 5600G

Motherboard

Asus Prime A520M-K

Memory

16GB Crucial CT8G4DFRA32A
3200MHz DDR4

Graphics

AMD Radeon RX Vega 7

Storage

500GB WD Blue SN550 M.2 SSD

Networking

Gigabit Ethernet, dual-band 802.11ax Wi-Fi

Case

Cooler Master MasterBox MB320L

Cooling

CPU: Stock AMD cooler with 1x 80mm fan;
front: 2 x 120mm fans; rear: 1 x 120mm fan

PSU

Cooler Master MWE 500W

Ports

Front: 2 x USB 3.2 Gen 1, 2 x audio;
rear: 4 x USB 3.2 Gen 1, 2 x USB
2.0, 1 x PS/2, 3 x audio

Operating system

Windows 10 Home

Warranty

Three years collect and
return parts and labour

BENCHMARK RESULTS

67,579
GIMP IMAGE EDITING

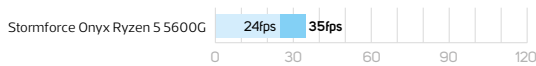
538,931
HANDBRAKE H.264 VIDEO ENCODING

233,268
HEAVY MULTI-TASKING

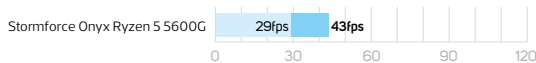
211,501
SYSTEM SCORE

DOOM ETERNAL

1,920 x 1,080, Vulkan, High settings

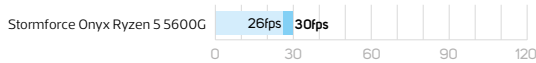


1,920 x 1,080, Vulkan, Medium settings



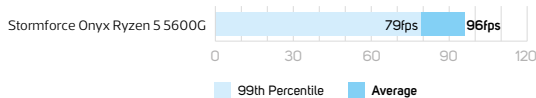
DIRT 5

1,920 x 1,080, Low settings, DX12



RAINBOW SIX SIEGE

1,920 x 1,080, Low settings



(see Issue 219, p32) deployed the same APU in a £699 PC, but that system had a much better motherboard, a quicker SSD and a superior PSU, albeit with slightly slower memory.

Performance

The Ryzen 5 5600G is a decent performer in mainstream applications. In this machine, the APU scored 67,579 in our single-threaded image editing benchmark and 538,931 in our heavily multi-threaded Handbrake test. The former score is only slightly behind AMD's proper desktop CPUs, and the latter is around 15,000 points slower than the 5600X. For everyday computing, those are solid.

Look beyond that, though, and the Stormforce is more ordinary. Its scores are a tad slower than the PC Specialist, and the 8-core Ryzen 7 5700G APU is miles faster in heavily multi-threaded applications. The 6-core Ryzen 5 5600X was far quicker in our multi-tasking test too.

The Stormforce fought back a little against the PC Specialist in our 1080p gaming benchmarks. When playing Doom Eternal at Medium and Low settings, its 99th percentile minimums of 29fps and 33fps were 1fps quicker, and its 26fps result in Dirt 5's Low benchmark was 2fps faster, most likely thanks to the quicker memory. The Stormforce's best results came in the esports title Rainbow



Six Siege, where it delivered 99th percentile and average frame rates of 79fps and 96fps respectively at Low settings – easily playable, and the same as the PC Specialist.

Indeed, esports games are this APU's wheelhouse – you'll be able to play most of them at solid speeds, but this PC will struggle with today's best single-player games at modest quality levels. If you want to play the latest single-player games, you really need to stump up for a discrete GPU.

The Stormforce system had no temperature issues, but it produced a modest but noticeable high-pitched fan noise in game and work benchmarks. It's not loud, but the PC Specialist was almost silent in comparison.

Conclusion

The Stormforce is an affordable and tidy PC that has the power to handle 1080p esports games and everyday computing tasks, so it's ideal for an everyday workhorse and undemanding games. The warranty adds security too.

In several departments, though, this rig falls behind its main rival; its motherboard, SSD and power supply can't compete with the PC Specialist, and that machine is quieter too. The performance of the on-board GPU is also disappointing – it might be quicker than Intel integrated graphics in games, but it's still based on yesterday's GPU tech and struggles in even undemanding single-player games.

The low price, great warranty and reasonable everyday computing power make the Stormforce a decent option for esports gaming and affordable computing, but the PC Specialist is better option if you can't afford to go any higher.

MIKE JENNINGS

VERDICT

AMD's APU supplies entry-level speed in an affordable PC, but you can get a better balance for the same money elsewhere.

SEMI-PRECIOUS

- + Good for esports and everyday use
- + Affordable
- + Excellent warranty
- + Good-looking, tidy case

SYNTHETIC

- Weak GPU performance
- Conventional CPUs are quicker
- Entry-level motherboard
- Basic power supply

PERFORMANCE

16/25

DESIGN

17/25

HARDWARE

16/25

VALUE

20/25

OVERALL SCORE

69%

Custom kit

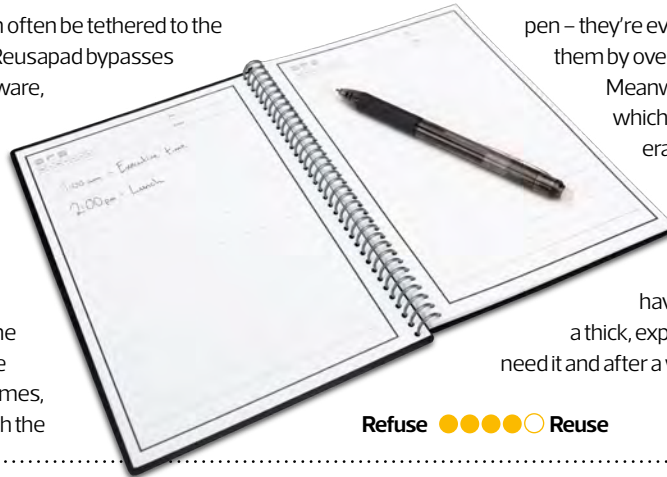
Phil Hartup checks out the latest gadgets, gizmos and geek toys

REUSAPAD / £19.99 inc VAT

SUPPLIER amazon.co.uk

The smartness of smart notepads can often be tethered to the software that comes with them. The Reusapad bypasses this problem by not using its own software, instead relying on Microsoft Lens to handle the smart part of the equation. This allows you to scan, store and organise photographed pages easily into compatible formats.

The notepad itself is a spiral-bound A5 affair with 56 pages, half of which are lined and half of which are plain. The paper quality is high, and the pages are durable enough to be used plenty of times, as long as you don't press too hard with the



pen – they're even waterproof, so you won't ruin them by overcleaning.

Meanwhile, the pen is a Pilot FriXion, which sports an eraser in the cap that can erase its words even off regular paper, although there's a microfibre cloth supplied for cleaning up the pad itself, which is much quicker and easier. The Reusapad doesn't have the substantial weightiness of a thick, expendable notebook, but it doesn't need it and after a while, it doesn't miss it. Very smart.

Refuse ●●●●○ Reuse

MIONIX ALIOTH / £9.99 inc VAT

SUPPLIER amazon.co.uk

The Alioth is a substantial mousepad that measures 46 x 40cm. It employs a water-repelling fabric surface and a textured rubbery underbelly to help anchor it to your desktop. As you might expect with a fabric mousepad, the Alioth has some of the usual minor drawbacks. For example, it takes a while to settle completely, so that it properly uncurls on a perfectly flat surface. This impacts on portability, even if the Alioth itself is quite light and folds up small.

The surface itself is great – it's a little bit textured but still comfy, with reinforced stitching around the edges, so it won't fray. Although it's light, the size aids the base in gripping, so it doesn't move easily when in place. With a thickness of just 3mm, you're also unlikely to bump the edge accidentally. Visually, it's a smart black mousepad that screams MIONIX in big but tasteful letters, successfully navigating that difficult balance between nondescript and a feast for the senses in mousepad form. For a big, inexpensive mousepad, it delivers on all fronts.



Over-egged ●●●●○ Understated

GC101 GAME CONTROLLER /

£29.99 inc VAT

SUPPLIER amazon.co.uk

The GC101 brings all the usual expectations from a wired Xbox-pattern gamepad, wrapped up in a package as nondescript as a surveillance van. Despite the uninspired visuals, however, the GC101 is surprisingly good to use. It has adjustable levels of vibration, controlled via the Turbo button and D-pad, and it's positively unruly at the maximum vibration level.

The control sticks are perfectly fine too. The shoulder buttons are very sensitive and have a lot of pull, so you get very granular control if you need it. The Turbo function works by holding down the Turbo button and whichever button you want to work at rapid speed, but it's not that easy to set up under duress. It might look quite bland, but the GC101 does deliver the goods for a reasonable price



Bland ●●●●○ Grand

BOOMPODS ZERO / £24.99 inc VAT

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

The Boompods Zero is a Bluetooth speaker that packs a number of surprisingly smart features into its tiny egg-shaped body. The aforementioned egg body is quite solid, the device has an IPX6 waterproof rating and it's drop-tested as well.

The battery provides up to five hours of playback and is charged via a USB Type-C connector behind a sealed rubber cover on the bottom. Even a small USB Type-C port takes up a fair bit of room on this tiny egg, but the Zero can also charge wirelessly on charging pads. Given that the charging port cover is so often a long-term weakness on these types of speakers, the fact that you can get away without ever using it is a huge plus.

The speaker is easy to set up, since it only has the one button on the base, and it gives you clear audio cues when it's switched on or off. That button can also answer calls, hang up and also trigger the



camera remotely. Sound quality is good for its size, as long as you understand that this is a very small speaker, and you can also pair them up. The Boompods Zero executes a lot of clever ideas in an impressively small package.

Dog egg ●●●●○ Fabergé egg

TIMOVO 2 IN 1 HEADSET HOOK / £19.95 inc VAT

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

At first glance, the sheer audacity of putting a cup or can full of potentially device-destroying drink close to headphones seems unwise, but the TiMOVO headset hook makes this work. The hook attaches to the desk by a clamp and the cup holder part of the arrangement screws in above it.

The use of a clamp is smart in this instance, because while double-sided tape can usually hold headphones in place for a while, it would be a risk with the extra weight, so it needs to be as secure as possible. The cup holder has a partial rim around 4cm above the plate, so the cup or can it holds is quite well protected from being knocked over. Given that drink spillage is a relatively common way to gunk up hardware, this is quite a clever idea, especially if it keeps the cup off your mousepad.

The cup holder isn't big enough for mugs, which is unfortunate, and it can also be a bit fiddly getting headphones onto the hook, as the gap between the two parts isn't big enough. The hook itself can be rotated through 360 degrees, although its clamp installation means this is rarely useful, as you generally want to get as much clearance



from the desk as possible. The same goes for the notches to hold cables, which make for a crowded space when they're in use. The TiMOVO lacks finesse, but it does its job.

Canned laughter ●●●●○ Canned drink

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

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LABS TEST

Graphic equaliser

Ben Hardwidge rounds up nine sub-£1,000 graphics cards, and finds out which ones offer the best bang per buck at current prices

How we test

Wobbly stock levels and sky high prices have made the graphics card market harder to understand than Season 2 of *Twin Peaks*. The boom in cryptocurrency mining saw Nvidia RTX rocketing on price on eBay, but Nvidia has responded with low hash-rate cards. Low stock of all GPUs, coupled with low demand, has also seen speculative scalpers making a mint out of the latest GPUs. Cards have gradually started to appear back on retailers' shelves over the past few months, but only in dribs and drabs, and usually at high prices.

Where does that leave us now? If you can afford to buy a new graphics card, which one should you buy for gaming at current prices? In order to make sense of the situation, we've rounded up nine sub-£1,000 GPUs, listed at the cheapest prices we could find them at UK retailers, and tested them in a number of games. None of them is an award winner at these prices, but our testing and analysis will show you which cards are worth buying if you can afford them, and which ones to look for if you're buying a new system.

Cyberpunk 2077 is a high-profile and challenging game for even the latest GPUs. We run our own custom benchmark, which incorporates a 60-second drive around Night City recorded with FrameView. We run it at the Ultra preset with no ray tracing, and with

the Medium Ray Tracing preset. You ideally want a 99th percentile result above 45fps with an average above 60fps.

Our second new test is the epicly awesome *Assassin's Creed: Valhalla*. We run the built-in benchmark at the Ultra High preset with resolution scaling at 100 per cent, recording the results with FrameView. Again, a 99th percentile result above 45fps, with an average over 60fps, will do the job.

Meanwhile, *Doom Eternal* is an undemanding game that scales superbly with more GPU power, making it great for monitors with a very high refresh rate. Again, we record the frame rate with FrameView. Finally, we run *Metro Exodus* with and without ray tracing, with the latter set to High.

All the tests are conducted on an AMD Ryzen 9 5900X test rig with 16GB of Corsair Vengeance RGB Pro SL 3600MHz DDR4 memory, an Asus ROG Strix B550-E Gaming motherboard and Windows 10 Professional 64-bit.

Finally, we measure the total system power consumption of the whole test rig at the mains with each graphics card installed, while the GPU goes through three runs of our *Metro Exodus* ray-tracing benchmark at 2,560 x 1,440. We record the peak power draw of the whole system.

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- AMD Radeon RX 6600 /p52
- AMD Radeon RX 6600 XT /p53
- Nvidia GeForce RTX 3060 /p54
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- AMD Radeon RX 6800 /p59
- Results graphs /p60

NVIDIA GEFORCE RTX 2060 / £363 inc VAT

SUPPLIER alphabeta pc.com

Wait, what, sorry, why is this Labs test kicking off with a GeForce RTX 2060 at the end of 2021? The answer is because it's made a reappearance in the shops, with new cards being made. As a response to the huge stock shortages of Nvidia Ampere GPUs, the RTX 2060 was rushed back out to fill in the gaps and get some cards back on the shelves. There are even rumours of a 12GB version coming out in the near future.

In the meantime, though, it's the 6GB RTX 2060 that's appearing in affordable PCs from a number of system builders at the moment, and also retailing in the shops for more than its original launch cost of £329 inc VAT – remarkable for a GPU that's nearly three years old. When it first launched, we were impressed by the RTX 2060's average of 75fps in Battlefield V with Low ray tracing, but that was back when ray tracing was in its infancy. How does a three-year-old card hold up now?

Not surprisingly, the answer is 'not brilliantly'. Testing got off to a bad start when the GeForce RTX 2060 wouldn't even run our Doom Eternal test because it didn't have enough memory – 6GB just isn't enough any more, even for gaming at 1,920 x 1,080.

SPEC

Graphics processor Nvidia GeForce RTX 2060, 1365MHz base clock, 1680MHz boost clock

Pipeline 1,920 stream processors, 48 ROPS

RT cores 30 (1st-gen)

Tensor cores 240 (2nd-gen)

Memory 6GB GDDR6, 1750MHz (14GHz effective)

Memory interface 192-bit

Bandwidth 336GB/sec

Power connections 1x 8-pin

The RTX 2060 also really shows the difference between Nvidia's Ampere and Turing architectures, particularly the improvement in ray-tracing performance. We might criticise AMD's ray-tracing performance, but the Radeon RX 6600 still beat the RTX 2060 in our ray-tracing tests, albeit with frame rates that were just as unplayable.

The RTX 2060's average of 18fps in Cyberpunk 2077 is poor, and almost half the 36fps clocked up by the Ampere-based RTX 3060, and even that result isn't smoothly playable. It might have 'RTX' in its name, but you don't want to buy a GeForce RTX 2060 in 2021 for ray tracing – it can't do it.

The RTX 2060 struggles when it comes to raw shader power too. It was just in front of the Radeon RX 6600 in Cyberpunk 2077 at 1,920 x 1,080, although only by 1fps and it still wasn't smoothly playable at these settings. It was a good 7fps behind the Radeon in Metro Exodus at the same resolution as well, and a huge 25fps behind it in Assassin's Creed Valhalla. Its power draw is also nearly 50W higher than that of the Radeon RX 6600.

Being a last-gen Turing GPU, the GeForce RTX 2060 doesn't supportResizable BAR either, so there's no way to boost performance further beyond overclocking it. The RTX 2060 does support DLSS with its 2nd-gen

AMPERE

- + Cheaper than new GPUs
- + Enables system builders to make affordable PCs

TURING

- Only 6GB of memory
- Outpaced by Radeon RX 6600
- Rubbish ray-tracing performance



Tensor cores, but we advise against running DLSS at 1,920 x 1,080, as you end up with a blurry image. Besides, even enabling DLSS only pushed up the average frame rate to an unplayable 30fps in Cyberpunk 2077 with Medium ray tracing – less than half the frame rate of the RTX 3060 at the same settings.

Conclusion

Rereleasing the GeForce RTX 2060 may have helped system builders to get some PCs out the door, and replenish shop shelves, but we don't recommend buying one right now, particularly at the current pricing. It only has 6GB of memory, it can't catch the 8GB Radeon RX 6600 in most tests and it can't handle ray tracing in the latest games. At this price, you'll be better off buying the 8GB Radeon RX 6600 or, even better, saving a bit more cash and getting the Radeon RX 6600 XT.

VERDICT

The GeForce RTX 2060 has had its day – don't be tempted to pick one up in 2021, especially at its current price.

PERFORMANCE

27/50

FEATURES

14/20

VALUE
19/30

OVERALL SCORE
60%

AMD RADEON RX 6600 / £390 inc VAT

SUPPLIER ebuyer.com

AMD's latest RDNA2 desktop GPU is the Radeon RX 6600, which takes the same Navi 23 die used in the Radeon RX 6600 XT and cuts down the spec. It has 28 compute units enabled, compared to 32 on the XT model, giving it 1,792 stream processors and 28 Ray Accelerators.

Meanwhile, the 8GB of GDDR6 memory runs at 1750MHz (14GHz effective), compared to 2GHz (16GHz effective) on the XT model. It's connected to a 128-bit wide memory interface, giving it a total memory bandwidth of 224GB/sec, although AMD has also equipped the GPU with 32MB of Infinity Cache.

The standard Radeon RX 6600 also has much lower clock speeds than the XT model, with a quoted game clock of 2044MHz, compared to 2359MHz for the XT – a deficit

AFFORDABLE

- + Beats GeForce RTX 2060
- + Under £400
- + 8GB of memory

CHEAP

- Can't get smooth frame rates in all tests
- Poor ray tracing
- Overpriced for performance on offer

SPEC

Graphics processor AMD Radeon RX 6600, 1626MHz base clock, 2044MHz game clock, 2491MHz max boost clock

Pipeline 1,792 stream processors, 64 ROPS

Ray Accelerators 28

Memory 8GB GDDR6, 1750MHz (14GHz effective)

Infinity Cache 32MB

Memory interface 128-bit

Card interface 8x PCI-E 4

Memory bandwidth 224GB/sec

Power connections 1x 8-pin



of over 300MHz. You can find overclocked cards that push this higher, but the stock spec is pretty lowly.

These cuts have a significant impact on performance. For example, in Metro Exodus at 1,920 x 1,080, the Radeon RX 6600 averages 66fps with a 39fps 99th percentile result, compared to 78fps and 44fps on the XT card – a drop of over 15 per cent on average, although the Radeon RX 6600 still beats the GeForce RTX 3060 in this test. The average dropped similarly in Cyberpunk 2077, going from a respectable 59fps with a 47fps 99th percentile result to 50fps and 41fps respectively.

On the plus side, this GPU's performance in Assassin's Creed Valhalla is superb, even beating the GeForce RTX 3060 Ti, with a storming average frame rate of 76fps backed up by a 56fps 99th percentile. If you enable Resizable BAR, you can even get it running at 83fps.

However, the Radeon RX 6600's Doom Eternal performance shows its comparable lack of shader power. Its average of 221fps is fast enough, but it's a fair way behind the 260fps of the 6600 XT or the 332fps of the RTX 3060 Ti. You'll be able to run undemanding games smoothly on a 120Hz monitor, but you'll need more power if you want to play at 200Hz.

Not surprisingly, the Radeon RX 6600's ray-tracing capabilities are largely redundant on this GPU. It could only average 22fps in Cyberpunk 2077 at 1,920 x 1,080, and 47fps in Metro Exodus. The latter figure isn't disastrous, and to be fair, the RX 6600 does beat the aging GeForce 2060 in these

tests, but none of the frame rates is smoothly playable. Then again, you really need to step up to the GeForce RTX 3060 Ti if you want to enable ray tracing anyway.

With the market in its current bizarre state, the GeForce RTX 2060 is the Radeon RX 6600's main competitor at the moment. The RTX 2060 occasionally edges in front of the Radeon RX 6600 by 1fps, but the latter is otherwise quicker, plus its extra 2GB of memory means you can run games at higher settings. The Radeon RX 6600 is also extraordinarily power-efficient, with our system drawing just 258W from the mains at load during games.

Conclusion

With a sub-£400 price, the Radeon RX 6600 is mightily tempting in these times. It might be overpriced for a 1080p gaming GPU, but it's more powerful than the bizarrely similarly priced GeForce RTX 2060. If you can't afford to go above £400, this is the card to buy, but you'll need to drop down from top settings to get smooth frame rates. If you can afford it, we advise stepping up to the XT model if you can.

VERDICT

Respectable 1,920 x 1,080 gaming performance for under £400, but it couldn't achieve smooth frame rates in all our tests.

PERFORMANCE

31/50

FEATURES

15/20

VALUE
21/30

OVERALL SCORE

67%

AMD RADEON RX 6600 XT / £470 inc VAT

SUPPLIER ebuyer.com

While pricier GPUs have doubled in price since their launch, AMD's Radeon RX 6600 XT is still contentedly sitting below the £500 mark. The current going rate of £480 is still utterly silly for a 1,920 x 1,080 gaming GPU, of course, but it's only climbed by £80 since we first reviewed it in Issue 218, which gives it an edge over its nearest competitor, the GeForce RTX 3060.

Like the GeForce RTX 3060, the Radeon RX 6600 XT is based on a new, small GPU die, rather than a cut-down version of an existing die used by pricier cards. In this case, it's AMD's 237mm² Navi 23 die, with the Radeon RX 6600 XT giving you 32 RDNA2 compute units that divide into 2,048 stream processors with 32 Ray Accelerators for ray tracing.

Cards are also equipped with 8GB of GDDR6 memory attached to a 128-bit wide interface. With a memory clock of 2GHz (16GHz effective), that gives you a memory bandwidth of 256GB/sec, which is a fair bit lower than the GeForce RTX 3060's 360GB/sec (thanks to its 192-bit wide memory interface), but AMD has equipped the GPU with 32MB of Infinity Cache to help close the gap.

SPEC

Graphics processor AMD Radeon RX 6600 XT, 1968MHz base clock, 2359MHz game clock, 2589MHz max boost clock

Pipeline 2,048 stream processors, 64 ROPS

Ray Accelerators 32

Memory 8GB GDDR6, 2GHz (16GHz effective)

Infinity Cache 32MB

Memory interface 128-bit

Card interface 8x PCI-E 4

Memory bandwidth 256GB/sec

Power connections 1x 8-pin



AMD has targeted this GPU at 1,920 x 1,080 gaming, and it delivers on this front. If you enable Resizable BAR, it will play Assassin's Creed Valhalla at Ultra settings with a 99th percentile result of 64fps and average of 88fps, with the latter figure being 26fps faster than the RTX 3060.

While it didn't quite hit our 60fps average target in Cyberpunk 2077 at Ultra settings, it was only 1fps off, and the GeForce RTX 3060 was no better. Meanwhile, its Metro Exodus average of 78fps is a great result – nearly 14fps quicker than the RTX 3060. It can even rack up an average of 260fps in Doom Eternal, showing scope for playing undemanding games on monitors with high refresh rates.

The downside, as with all current AMD GPUs, is ray tracing. The Radeon RX 6600 XT actually outperformed the RTX 3060 in Metro Exodus with High ray tracing at 1,920 x 1,080, although its 35fps 99th percentile result is only borderline playable.

Not surprisingly, the GeForce RTX 3060 is much quicker in Cyberpunk 2077 when you enable Medium ray tracing, but not fast enough to be smoothly playable, so the point is largely irrelevant.

There is, however, a potential performance issue from the Radeon RX 6600 XT's 8x PCI-E 4 interface. That's not a problem if you have a PCI-E 4 motherboard and CPU, but it results in a small drop in performance if you're using a PCI-E 3 setup, such as an Intel Comet Lake CPU or an AMD X470 motherboard, as it still only uses eight lanes. If you drop to PCI-E 3 mode, you see a drop of 2-3fps, which isn't huge, but worth bearing in mind.

Conclusion

The AMD Radeon RX 6600 XT is as close as we've got to an award winner in this month's Labs test. It's still overpriced, but it really delivers the goods when it comes to gaming at 1,920 x 1,080. Its ray-tracing performance is poor, but realistically the RTX 3060 isn't that great at ray tracing either. In all our other 1080p tests, the Radeon RX 6600 XT beats the RTX 3060 and offers decent frame rates, making it the best entry point for 1080p gaming.

VERDICT

Beats the GeForce RTX 3060 despite costing less money, and delivers decent 1080p frame rates. It's still overpriced, but it's the best 1080p entry point.

IN THE NAVI

- + Beats RTX 3060 in meaningful tests
- + Decent 1,920 x 1,080 frame rates
- + Under £500

IN THE NAVY

- Only 8x PCI-E interface
- Still overpriced for a 1080p card
- Poor ray-tracing performance

PERFORMANCE

34/50

FEATURES

15/20

VALUE
21/30

OVERALL SCORE

70%



NVIDIA GEFORCE RTX 3060 / £540 inc VAT

SUPPLIER awd-it.co.uk

There was a brief moment where Nvidia's GeForce RTX 3060 was a half-decent buy. It was regularly available in stock for a few months, and we even managed to squeeze one into our £1,099 'beat the scalpers' build in Issue 217. Recently, however, it's been increasingly hard to find and steadily going up in price, while AMD has returned fire with the Radeon RX 6600 XT.

Despite having very similar nomenclature to the GeForce RTX 3060 Ti, the standard RTX 3060 is quite a different GPU. It's based on Nvidia's 276mm² GA106 die, rather than the GA104 die used in the 3060 Ti. At full strength, this chip has 3,840 stream processors cores and 30 RT cores. However, the GeForce RTX 3060 has two of its Streaming Multiprocessor blocks disabled, giving you 3,584 stream processors and 28 RT cores. It's quite a step

SPEC

Graphics processor Nvidia GeForce RTX 3060, 1320MHz base clock, 1777MHz boost clock

Pipeline 3,584 stream processors, 48 ROPS

RT cores 28 (2nd-gen)

Tensor cores 112 (3rd-gen)

Memory 12GB GDDR6, 1875MHz (15GHz effective)

Memory interface 192-bit

Card interface 16x PCI-E 4

Memory bandwidth 360GB/sec

Power connections 1x 8-pin

down from the 38 RT cores and 4,864 stream processors in the RTX 3060 Ti.

That wouldn't be a problem if the RTX 3060 were cheap, but with the Radeon RX 6600 XT currently going for £480 and outperforming the £540 GeForce RTX 3060 in every meaningful test, there's simply no reason to pay the extra £60 for the RTX 3060 at the moment. What, even in ray tracing, you may ask? Yep, even in ray tracing. At 1,920 x 1,080, the Radeon RX 6600 XT outperforms the RTX 3060 in Metro Exodus with High ray tracing, with the same average but a higher 99th percentile result.

The GeForce RTX 3060 is much quicker in Cyberpunk 2077 with ray tracing enabled, and it's around twice the speed of the last-gen RTX 2060, but the point is moot because its average of 35fps and 99th percentile result of 31fps isn't smoothly playable. You can get a playable frame rate by enabling DLSS, but it looks unpleasantly blurry at 1,920 x 1,080. With this level of hardware, you'll want to play this game without ray tracing, and at non ray-traced Ultra settings, there's barely a sliver of bog roll between the two GPUs' performance.

With Nvidia's key competitive weapon out the way, the GeForce RTX 3060 really struggles to compete with AMD's Radeon RX 6600 XT. The latter's 58fps 99th percentile and 79fps average in Assassin's Creed Valhalla dwarfs the RTX 3060's respective 43fps and 58fps results. Enable Resizable BAR and the difference expands to 26fps when it comes to average frame rates.

Likewise, the Radeon's 99th percentile of 44fps is substantially higher than the RTX 3060's result of 35fps in Metro Exodus at 1,920 x 1,080. The Radeon is quicker in Doom Eternal too, although not by a huge amount.

TRACING RAYS

- + Decent 1,920 x 1,080 performance
- + Much faster ray tracing than RTX 2060
- + DLSS support

TRACING PAPER

- DLSS looks horrible at 1,920 x 1,080
- Uncompetitive price
- Largely outperformed by Radeon RX 6600 XT

Don't get us wrong – the GeForce RTX 3060 is clearly a capable 1,920 x 1,080 gaming GPU that can handle playable frame rates – if you've already bought one, it will continue to do the job fine. If you're buying a ~£500 GPU now, though, it's clearly been superseded.

Conclusion

Don't be confused by the name – the GeForce RTX 3060 is significantly less powerful than the RTX 3060 Ti, and its current pricing makes it uncompetitive. AMD's Radeon RX 6600 XT is also still overpriced at £470, of course (remember when 1,920 x 1,080 gaming GPUs used to cost around £200?), and the GeForce RTX 3060 is still a decent 1080p gaming GPU, but if you're looking to buy a new card in this price range, the Radeon is now the better option.

VERDICT

Still a capable 1,920 x 1,080 gaming GPU, but it's now soundly beaten by the cheaper Radeon RX 6600 XT.

PERFORMANCE

32/50

FEATURES

18/20

VALUE
17/30

OVERALL SCORE

67%

NVIDIA GEFORCE RTX 3060 Ti

£630 inc VAT

SUPPLIER cclonline.com

Despite being based on the same GA104 Ampere GPU as the RTX 3070, the RTX 3060 Ti currently undercuts the RTX 3070 by £170, offering substantially better value, even if it still costs way more than the original £369 launch price. In terms of stock, the GeForce RTX 3060 Ti was practically non-existent after it launched, but it's recently started reappearing on the shelves, providing some fierce rivalry for the Radeon RX 6700 XT.

The 3060 Ti only has 38 of the GA104 GPU's potential maximum of 48 streaming multiprocessors (SMs) enabled, compared to 46 on the RTX 3070. That still gives you 4,864 stream processors, though, along with 38 2nd-gen RT cores for ray tracing and 152 3rd-gen Tensor cores.

TAKE STOCK

- + Can handle ray tracing at 2,560 x 1,440 with DLSS
- + Storming 1,920 x 1,080 performance
- + Back in stock

TAKE STOCK AWAY

- Radeon RX 6700 XT has more shader power
- Much more expensive than Radeon RX 6600 XT
- Can't play all games smoothly at 2,560 x 1,440

SPEC

Graphics processor Nvidia GeForce RTX 3060 Ti, 1410MHz base clock, 1665MHz boost clock

Pipeline 4,864 stream processors, 80 ROPS

RT cores 38 (2nd-gen)

Tensor cores 152 (3rd-gen)

Memory 8GB GDDR6, 14GHz effective

Memory interface 256-bit

Card interface 16x PCI-E 4

Bandwidth 448GB/sec

Power connections 1x 12-pin (FE) / 1x 8-pin



Like the RTX 3070, it also comes equipped with 8GB of GDDR6 memory as standard, running at an effective clock of 14GHz. That's not as much as the 12GB on the Radeon RX 6700 XT, but the RTX 3060 Ti's memory is attached to a 256-bit wide memory interface, giving it a solid total memory bandwidth of 448GB/sec – the same as the RTX 3070.

Like the Radeon RX 6700 XT, the RTX 3060 Ti can handle a fair bit of gaming smoothly at 2,560 x 1,440, but not all of it. Its 49fps average in Cyberpunk 2077 at this resolution was 11fps off our 60fps target at this resolution, and its 99th percentile result dropped down to 39fps in Metro Exodus. However, its average Assassin's Creed Valhalla frame rate was only 1fps off 60fps, and it will be fine in this game, even if it's 10fps off the pace of the Radeon RX 6700 XT.

Where the RTX 3060 Ti really excels is at 1,920 x 1,080. At this resolution, it nailed all of our test games, hitting or exceeding our targets, and racking up an average of 332fps in Doom Eternal – if you want to play undemanding games on a 1,920 x 1,080 monitor with a high refresh rate, this card is ideal.

There's also scope to enable ray tracing, although the RTX 3060 Ti is on the edge here. Its average of 75fps in Metro Exodus with ray tracing at 1080p is perfectly fine, and 9fps ahead of the Radeon RX 6700 XT, although it dropped down to a 99th percentile result of 41fps while the Radeon only dropped down to 42fps.

However, The RTX 3060 Ti struggled with Cyberpunk 2077 with ray tracing enabled at 1,920 x 1,080 unless you enable DLSS, and the game looks blurry and horrible at these settings. It's faster than all the Radeon cards here, but not fast enough to average 60fps. Thankfully, enabling DLSS with ray tracing at 2,560 x 1,440 brought the average up to 58fps with a 99th percentile result of 50fps, which is perfectly playable, if not as smooth as the RTX 3070.

Conclusion

It hasn't been an easy ride for the GeForce RTX 3060 Ti, with laughable stock levels making it a non-starter shortly after launch. However, with new stock now appearing at £60 less than the Radeon RX 6700 XT, it's now a decent card if you can run to £630. Its 1,920 x 1,080 performance is superb, it can cope with some 2,560 x 1,440 gaming and it offers superior ray-tracing performance to the Radeon RX 6700 XT.

VERDICT

Fantastic 1,920 x 1,080 performance, respectable 2,560 x 1,440 abilities and entry-level ray tracing make the RTX 3060 Ti a decent card if you can afford it.

PERFORMANCE

38/50

FEATURES

18/20

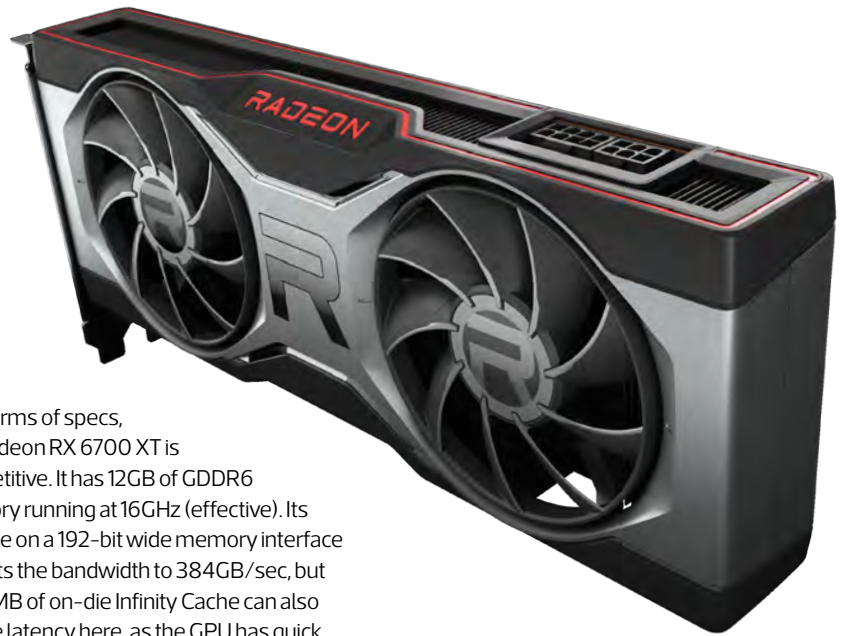
VALUE
14/30

OVERALL SCORE

70%

AMD RADEON RX 6700 XT / £690 inc VAT

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



We've been fans of the Radeon RX 6700 XT over the past few months, not necessarily because it's the best-performing GPU in its ostensible price range, but simply because it's been in stock. The cheapest card we could find cost £690 at [overclockers.co.uk](https://www.overclockers.co.uk), which is much higher than it should be, but it's a good £110 cheaper than the RTX 3070.

Despite the '7' in its name, though, the Radeon RX 6700 XT is more like a competitor to the GeForce RTX 3060 Ti. The latter has previously been impossible to find in stock, but is now readily available for £630. Where does this leave our venerable mid-range favourite of the past few months?

INFINITY CASH

- + Faster shading performance than 3060 Ti
- + Superb Assassin's Creed Valhalla performance
- + Generally available in stock

INFINITY CRASH

- Struggles with ray tracing above 1080p
- No direct DLSS equivalent
- Overpriced at the moment

SPEC

Graphics processor AMD Radeon RX 6700 XT, 2321MHz base clock, 2424MHz game clock, 2581MHz max boost clock

Pipeline 2,560 stream processors, 64 ROPS

Ray Accelerators 40

Memory 12GB GDDR6, 2GHz (16GHz effective)

Infinity Cache 96MB

Memory interface 192-bit

Card interface 16x PCI-E 4

Memory bandwidth 384GB/sec

Power connections 1x 6-pin, 1x 8-pin

In terms of specs, the Radeon RX 6700 XT is competitive. It has 12GB of GDDR6 memory running at 16GHz (effective). Its reliance on a 192-bit wide memory interface restricts the bandwidth to 384GB/sec, but its 96MB of on-die Infinity Cache can also reduce latency here, as the GPU has quick access to a large pool of memory that's much faster than GDDR6.

Meanwhile, the GPU is based on AMD's RDNA2 Navi 22 die, and comes equipped with 40 compute units (2,560 stream processors) with 40 corresponding Ray Accelerators. AMD quotes a game clock of 2424MHz for the GPU, which is massively higher than the 1815MHz game clock of the Radeon RX 6800.

It's a setup that works pretty well in practice. The Radeon RX 6700 XT outpaced the GeForce RTX 3060 Ti in all our non-ray-traced game tests, with solidly playable results at 2,560 x 1,440 in Metro Exodus, and it even beat the RTX 3070 Ti in Assassin's Creed Valhalla at this resolution. It didn't hit our 45fps 99th percentile and 60fps average target in Cyberpunk 2077 at this resolution, but its respective results of 42fps and 52fps are still pretty good – dropping the settings will easily make this smoothly playable.

The Radeon RX 6700 XT also excelled in our Doom Eternal test, with an average of 341fps at 1,920 x 1,080 and 254fps at 2,560 x 1,440 – ideal for playing undemanding games such as esports titles on a monitor with a high refresh rate.

As with the other Radeon cards on test this month, the main area where the Radeon RX 6700 XT falls down is ray tracing. However, it isn't quite as uncompetitive as the Radeon RX 6800 here, as the lower-spec GeForce cards can only manage ray tracing at lower resolutions, and you wouldn't want to enable

DLSS at 1,920 x 1,080 on them anyway, as it makes games look blurry. With this in mind, the Radeon RX 6700 XT's 99th percentile and average results of 42fps and 66fps in Metro Exodus at 1,920 x 1,080 with High ray tracing aren't terrible – the RTX 3060 Ti is only a little bit in front without DLSS.

However, the Radeon's frame rates in Cyberpunk 2077 with Medium ray tracing aren't even playable at 1,920 x 1,080, while the RTX 3060 Ti can average 58fps with a 50fps 99th percentile at 2,560 x 1,440 with DLSS.

Conclusion

When RTX 3060 Ti stock was practically non-existent, the Radeon RX 6700 XT was the obvious choice at this price, but it now struggles to compete. It's faster in terms of raw shading power, but the GeForce RTX 3060 Ti's superior ray-tracing performance, DLSS support and lower price means it offers a better balance.

VERDICT

Decent shading power and a regular supply of stock, but the Radeon RX 6700 XT's poor ray-tracing performance puts it at a disadvantage.

PERFORMANCE

38/50

FEATURES

15/20

VALUE
12/30

OVERALL SCORE

65%



NVIDIA GEFORCE RTX 3070 / **£800** inc VAT

SUPPLIER cclonline.com

At the end of last year, Nvidia's GeForce RTX 3070 gave us our first glimpse of the company's GA104 chip, along with a nostalgically low launch price of £469 inc VAT. Like other Nvidia Ampere GPUs, it's since fallen victim to stock shortages, speculation and insatiable demand, and the cheapest price we could find now was £800. That's not far off double the original price, and only £65 less than the Ti version.

Unlike the RTX 3070 Ti, the original RTX 3070 has two streaming multiprocessors disabled, giving it a total of 5,888 stream processors, plus 46 RT cores for ray tracing, and it also has a slightly lower clock speed than the Ti. In addition, it lacks the Ti card's GDDR6X memory, with its 8GB of standard

GDDR6 memory attached to a 256-bit wide interface and running at an effective speed of 14GHz. This arrangement gives it a total memory bandwidth of 448GB/sec, which is a bit quicker than the Radeon RX 6700 XT's 384GB/sec. However, the Radeon benefits from AMD's Infinity Cache technology and also has 4GB more memory, while the RTX 3070 Ti improved the total memory bandwidth to 608GB/sec.

It's an overall lower spec than the Ti, but the differences aren't colossal, and the RTX 3070 isn't far off the pace of the 3070 Ti. In general, you're looking at a difference of 6fps or under between the two GPUs in demanding games such as Assassin's Creed Valhalla, Metro Exodus and Cyberpunk 2077. The RTX 3070's frame rates are still perfectly playable in these games at 2,560 x 1,440, though, and the 3070 will also happily play Cyberpunk 2077 at Ultra settings at 1,920 x 1,080 with a superb 99th percentile result of 68fps.

As with the other GeForce GPUs on test, it can't keep up with the Radeons in Assassin's Creed Valhalla, with even the Radeon RX 6600 XT beating it at 1,920 x 1,080, but again the RTX 3070's 2,560 x 1,440 frame rate is perfectly playable.

The RTX 3070 is also adept at handling ray tracing – it beats the pricier Radeon RX 6800 in all our ray-tracing tests, and DLSS can enable you to play at 2,560 x 1,440 with all the gorgeous reflections and lighting that

ray tracing provides. With DLSS, the RTX 3070 achieved a cracking average of 64fps in Cyberpunk 2077 with Medium ray tracing at 2,560 x 1,440, with a solid 55fps 99th percentile result.

Conclusion

It's a shame the price of the RTX 3070 is so bananas, as it would be a fantastic upper mid-range GPU. It's great for gaming at 2,560 x 1,440, and its DLSS support means you can enable ray tracing at this resolution and still get playable frame rates. Meanwhile, its shader power beats the Radeon RX 6700 XT in most of our non-ray-traced tests, with its 370fps average at 1,920 x 1,080 in Doom Eternal, showing great potential for gaming on monitors with high refresh rates.

The exception is Assassin's Creed Valhalla, but the RTX 3070's results are still fine in this game. However, the price difference between the 3070 and the 3070 Ti is only £65 – if you're already spending £800 on a GPU, you may as well pay the extra money and get a little more headroom. If you really can't go above £800, though (and let's face it, £800 is already a tough ask), the RTX 3070 remains a cracking 2,560 x 1,440 gaming card.

SPEC

Graphics processor Nvidia GeForce RTX 3070, 1500MHz base clock, 1725MHz boost clock

Pipeline 5,888 stream processors, 96 ROPS

RT cores 46 (2nd-gen)

Memory 8GB GDDR6, 1750MHz (14GHz effective)

Memory interface 256-bit

Card interface 16x PCI-E 4

Bandwidth 448GB/sec

Power connections 1x 12-pin (FE) / 1x 8-pin

£469

- + Decent ray-tracing performance
- + DLSS support
- + Solid 2,560 x 1,440 gaming performance

£800

- Only an extra £65 for Ti
- Massively overpriced
- Beaten by Radeons in Valhalla

VERDICT

A cracking 2,560 x 1,440 gaming card, but at this price, you might as well pay the extra money for the RTX 3070 Ti.

PERFORMANCE

42/50

FEATURES

18/20

VALUE
9/30

OVERALL SCORE

69%

NVIDIA GEFORCE RTX 3070 Ti / £865 inc VAT

SUPPLIER scan.co.uk

Like the Radeon RX 6800, Nvidia's GeForce RTX 3070 Ti started life with an almost-sensible price of around £530, but has since found itself rocketing around the land of ridiculous money. RTX 3070 Ti cards were recently going for over a grand on eBay, but they now seem to have settled at £865 at retailers. That might be well over £300 higher than the launch price, but it's also well below the price of the Radeon RX 6800.

There isn't much to separate the RTX 3070 Ti from its non-Ti sibling in terms of core GPU spec. They're both based on the GA104 Ampere chip, but the RTX 3070 Ti has all 48 streaming multiprocessors enabled, compared to 46 on the standard RTX 3070. This gives the RTX 3070 Ti an extra 256 stream processors and two more RT cores, which isn't much, but it provides a little bit of a boost. The 3070 Ti also has a slightly higher boost clock of 1770MHz, compared to 1725MHz on the 3070.

The 3070 Ti also improves the memory setup over the standard 3070. It still has 8GB of memory attached to a 256-bit wide interface, but the 3070 Ti has GDDR6X



memory running at 19GHz (effective), while the standard 3070 only has GDDR6 memory running at 14GHz (effective), boosting the memory bandwidth from 448GB/sec to 608GB/sec.

Thankfully, the small difference in GPU spec is matched by a small difference in price. There's currently just £65 separating the RTX 3070 Ti from the standard 3070, which isn't huge when you're already paying £800 for a card.

In terms of performance, the RTX 3070 Ti rules the roost at 2,560 x 1,440. It generally can't quite catch the Radeon RX 6800 for raw shader power at 1,920 x 1,080 and 2,560 x 1,440, but it isn't far behind, and it currently costs a lot less money.

It can't catch the Radeon RX 6800 (or even the RX 6700 XT) in Assassin's Creed Valhalla, but its 67fps average and 50fps 99th percentile frame rates at 2,560 x 1,440 are still perfectly playable. Also, now that Nvidia supportResizable BAR, you can get those figures up to 73fps and 55fps respectively if you have a supporting motherboard.

Where the RTX 3070 Ti really fights back against the Radeon is with its ray-tracing performance, especially with DLSS at its disposal. This combo enables the RTX 3070 Ti to average 68fps with a 57fps 99th percentile in Cyberpunk 2077 with Medium ray tracing – a fantastic result. One area where it falls behind the Radeon is power draw – the 3070 Ti was the most power-hungry card on test, with our system drawing 465W from the mains – 50W higher than with the Radeon. Not surprisingly, the 3070 Ti

TITANIUM

- + Better value than Radeon RX 6800
- + Great ray-tracing performance
- + Superb 2,560 x 1,440 gaming

TIN

- Not much faster than RTX 3070
- Comparatively high power draw
- Still expensive

isn't far in front of the RTX 3070 in any of our tests, usually only adding a few frames per second to its figures.

Conclusion

There's a price difference of around 8 per cent between the RTX 3070 and 3070 Ti at the moment, which is about right for the performance difference on offer. It's not a huge amount faster, but that extra cash buys you a bit more headroom. If you can afford it, and you want to play games at 2,560 x 1,440 with high settings, this is the best sub-£1,000 card you can buy at the moment, striking a decent balance between shader performance and ray-tracing capabilities.

VERDICT

Still mightily overpriced, but in the current market, it offers the best balance of shader and ray-tracing performance for 2,560 x 1,440 gaming.

SPEC

Graphics processor Nvidia GeForce RTX 3070 Ti, 1575MHz base clock, 1770MHz boost clock

Pipeline 6,144 stream processors, 96 ROPS

RT cores 48 (2nd-gen)

Tensor cores 192 (3rd-gen)

Memory 8GB GDDR6X, 1188MHz (19GHz effective)

Memory interface 256-bit

Card interface 16x PCI-E 4

Memory bandwidth 608GB/sec

Power connections 1x 12-pin (FE) / 2x 8-pin

PERFORMANCE

43/50

FEATURES

18/20

VALUE
8/30

OVERALL SCORE

69%

AMD RADEON RX 6800 / £999 inc VAT

SUPPLIER ebuyer.com



AMD's Navi 21 GPU just squeezes into this sub-£1,000 Labs test, courtesy of the Radeon RX 6800, which currently goes for £999 inc VAT. It comes equipped with a massive 16GB of memory – more than any other card on test this month. The memory is clocked at 16GHz (effective) and it's GDDR6, so it's not as quick as the 19GHz GDDR6X memory on the RTX 3070 Ti. It's attached to a 256-bit wide memory interface, giving you a total memory bandwidth of 512GB/sec, compared to 608GB/sec on the RTX 3070 Ti.

Meanwhile, the GPU itself has 60 of the Navi 21 GPU's 80 compute units enabled, each of which contains 64 stream processors, adding up to a total of 3,840. Each compute unit also contains a dedicated Ray Accelerator, so you get 60 of them in this GPU to handle ray tracing in games that support it. However, while AMD's

SUPER RESOLUTION

- + Great raw shader power
- + Loads of memory
- + Good power efficiency

BROKEN RESOLUTION

- Struggles with ray tracing
- High price
- No direct equivalent of DLSS

SPEC

Graphics processor AMD Radeon RX 6800, 1815MHz game clock, 2105MHz max boost clock

Pipeline 3,840 stream processors, 96 ROPS

Ray Accelerators 60

Memory 16GB GDDR6, 2GHz (16GHz effective)

Memory interface 256-bit

Card interface 16x PCI-E 4

Bandwidth 512GB/sec

Power connections 2x 8-pin

ray-tracing hardware can accelerate bounding box and triangle intersections, unlike Nvidia's RT cores, they can't accelerate ray traversals, and they're also slower in games.

There's no equivalent of Nvidia's Tensor cores here either, and although AMD's FidelityFX Super Resolution tech (see Issue 217, p84) can scale gaming resolutions to massively improve frame rates in supported titles, it can't compete with the image quality of DLSS.

Where the Radeon RX 6800 excels is in raw shader power. In tests without ray tracing, it tops the graphs this month in every game at 1,920 x 1,080 and in most of them at 2,560 x 1,440, there's only a 1fps difference between the Radeon RX 6800 and GeForce RTX 3070 Ti in Cyberpunk 2077 at this resolution.

The Radeon RX 6800 doesn't quite have the power for smooth 4K gaming though. It can handle Doom Eternal fine, and there's potential to get this card playing Metro Exodus and Assassin's Creed Valhalla at 4K if you drop the settings a little, but there's little performance difference between the RTX 3070 Ti here – that extra memory clearly doesn't offer a tangible benefit over the 8GB RTX 3070 Ti.

Like the other AMD GPUs on test, the Radeon RX 6800 stormed our Assassin's Creed Valhalla test, being the only GPU to play this game at 2,560 x 1,440 without dropping below 60fps and to average over 100fps at 1,920 x 1,080. If your motherboard and CPU will enable you to enable Resizable BAR, which AMD calls Smart Access Memory, it will go even faster here too.

Where the Radeon RX 6800 struggles is with ray tracing. Its performance in Metro

Exodus wasn't too bad, with a respectable average of 59fps at 2,560 x 1,440. However, that's still a fair way behind the 68fps from the RTX 3070 Ti, and even further behind the 76fps from the latter when you enable DLSS. Cyberpunk 2077 was a bigger struggle, with the Radeon RX 6800 only averaging 26fps at 2,560 x 1,440. The RTX 3070 Ti averages 36fps in this test, and goes right up to 68fps if you enable DLSS.

Conclusion

It's hard to justify the extra £134 for the Radeon RX 6800 over the GeForce RTX 3070 Ti. Yes, the Radeon has double the memory, but the GPU doesn't have enough power to handle the settings where that would really make a difference.

If you're not bothered by ray tracing, then its raw shader power is fantastic, particularly if you play Assassin's Creed Valhalla. However, the GeForce RTX 3070 Ti isn't far behind in other games, it's much cheaper and it can properly handle ray tracing. **GPU**

VERDICT

Awesome raw shader performance, but the price is too high and the GeForce RTX 3070 Ti is much quicker at ray tracing.

PERFORMANCE
44/50

FEATURES
16/20

VALUE
6/30

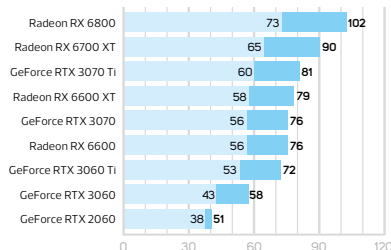
OVERALL SCORE
66%

GRAPHICS CARD BENCHMARK RESULTS

ASSASSIN'S CREED VALHALLA

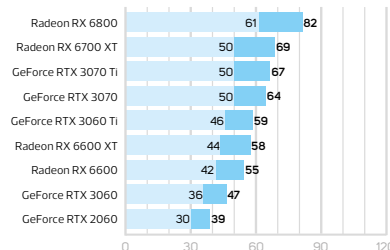
1,920 x 1,080

Ultra high settings, High AA



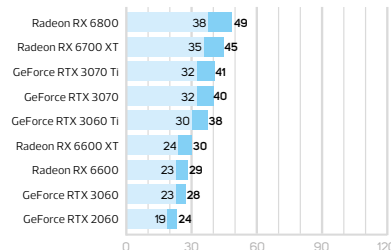
2,560 x 1,440

Ultra high settings, High AA



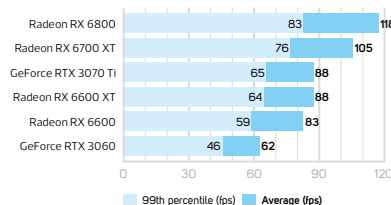
3,840 x 2,160

Ultra high settings, High AA



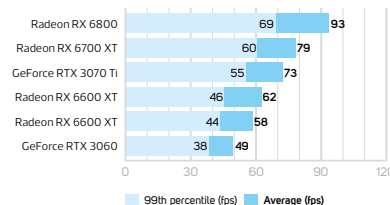
1,920 x 1,080 - RESIZABLE BAR

Ultra high settings, High AA



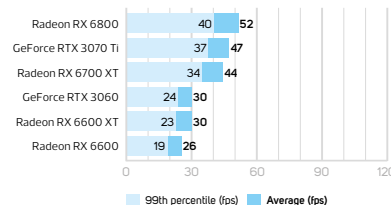
2,560 x 1,440 - RESIZABLE BAR

Ultra high settings, High AA



3,840 x 2,160 - RESIZABLE BAR

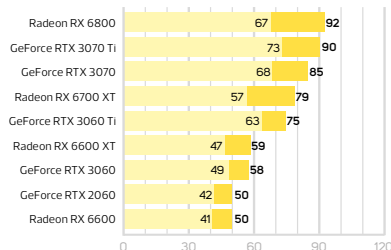
Ultra high settings, High AA



CYBERPUNK 2077

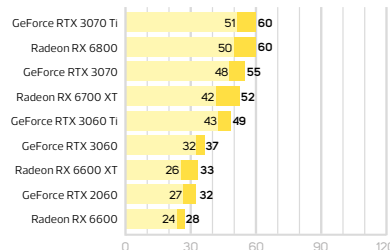
1,920 x 1,080

Ultra preset, no ray tracing



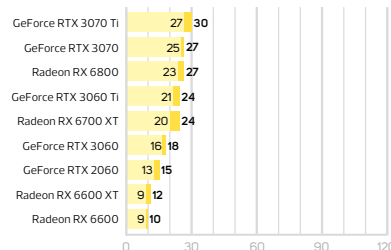
2,560 x 1,440

Ultra preset, no ray tracing



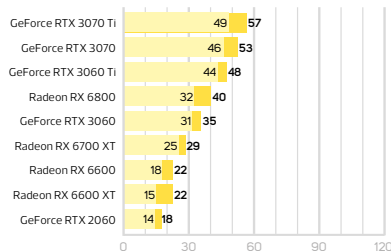
3,840 x 2,160

Ultra preset, no ray tracing



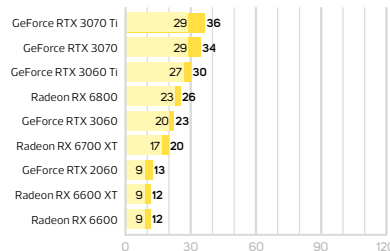
1,920 x 1,080 - RAY TRACING

Medium ray tracing preset, DLSS disabled



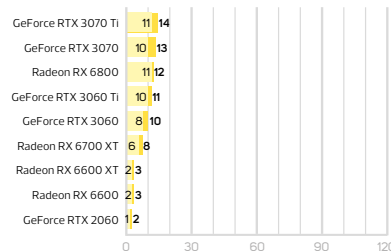
2,560 x 1,440 - RAY TRACING

Medium ray tracing preset, DLSS disabled



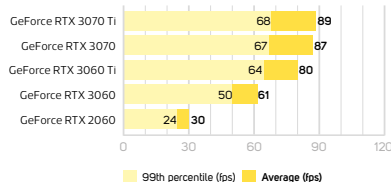
3,840 x 2,160 - RAY TRACING

Medium ray tracing preset, DLSS disabled



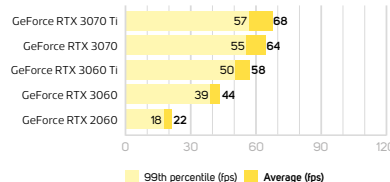
1,920 x 1,080 - RAY TRACING + DLSS

Medium ray tracing preset, DLSS Balanced



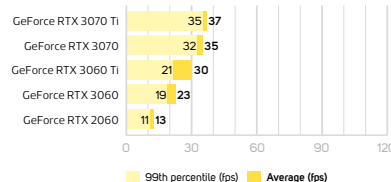
2,560 x 1,440 - RAY TRACING + DLSS

Medium ray tracing preset, DLSS Balanced



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

Medium ray tracing preset, DLSS Balanced

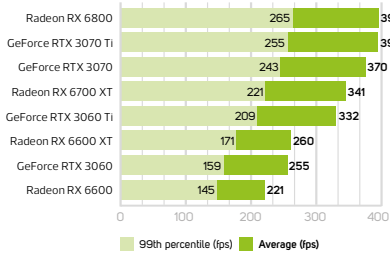


GRAPHICS CARD BENCHMARK RESULTS

DOOM ETERNAL

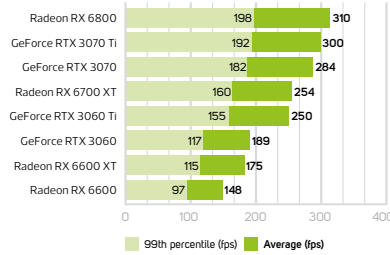
1,920 x 1,080

Ultra Nightmare settings



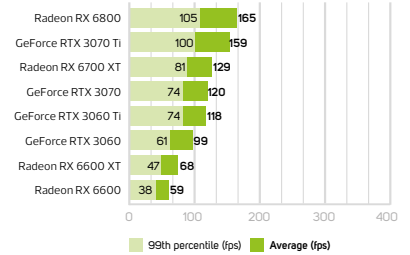
2,560 x 1,440

Ultra Nightmare settings



3,840 x 2,160

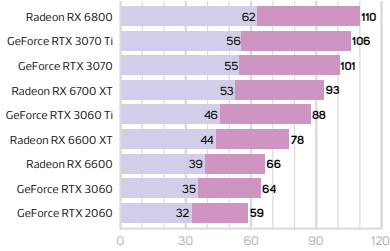
Ultra Nightmare settings



METRO EXODUS

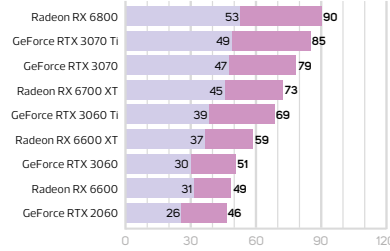
1,920 x 1,080

Ultra settings, HairWorks off, PhysX off



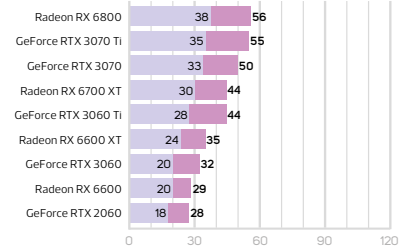
2,560 x 1,440

Ultra settings, HairWorks off, PhysX off



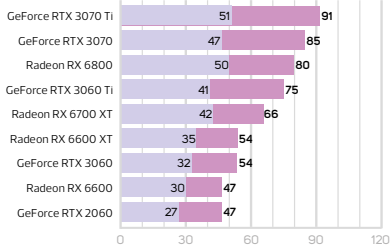
3,840 x 2,160

Ultra settings, HairWorks off, PhysX off



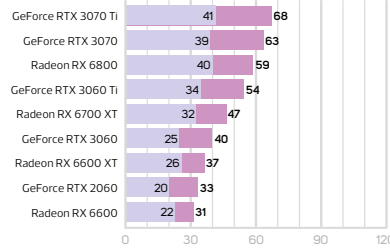
1,920 x 1,080 - RAY TRACING

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



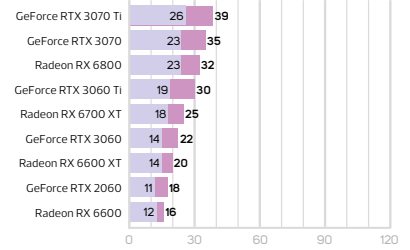
2,560 x 1,440 - RAY TRACING

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



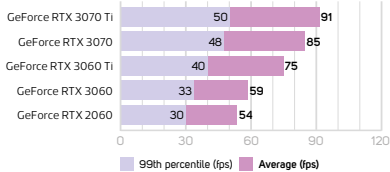
3,840 x 2,160 - RAY TRACING

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



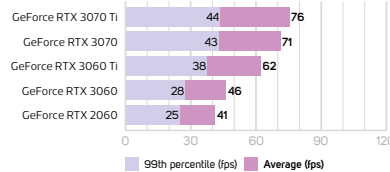
1,920 x 1,080 - RAY TRACING + DLSS

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



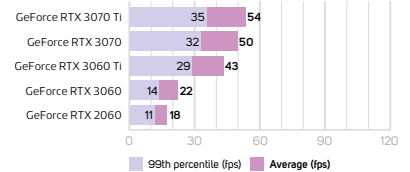
2,560 x 1,440 - RAY TRACING + DLSS

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



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

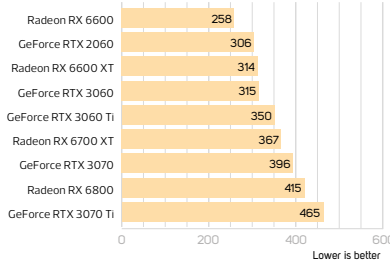
Ultra settings, HairWorks off, PhysX off, High ray tracing, DLSS



POWER DRAW

PEAK TOTAL SYSTEM POWER CONSUMPTION (WATTS)

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



Lower is better

How we test

MOTHERBOARDS

TEST PROCESSORS

- **Intel LGA1700** Intel Core i9-12900K
- **Intel LGA1200** Intel Core i9-11900K
- **AMD AM4** AMD Ryzen 9 5900X

Common gear includes a 2TB Samsung 970 Evo SSD, a 1TB PCI-E 4 Corsair MP600 SSD and an Nvidia GeForce RTX 3070. We use 16GB (2 x 8GB) of Corsair Vengeance RGB Pro 3466MHz DDR4 RAM, or 32GB (2 x 16GB) of Kingston Fury 5200MHz DDR5 RAM, depending on the board. LGA1700 CPUs are cooled by a Thermaltake Toughliquid Ultra 360, while other 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 the M.2 ports, and record the noise level and dynamic range of audio using RightMark Audio Analyzer.



PROCESSORS

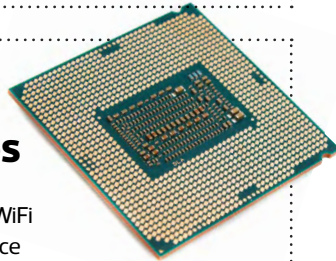
TEST MOTHERBOARDS

- **Intel LGA1700**
Asus ROG Strix Z690-I Gaming WiFi
- **Intel LGA1200** MSI MEG Z490 Ace
- **AMD AM4** MSI MPG Gaming B550 Carbon WiFi
- **AMD AM4 APU** MSI MEG X570 Unify

Common gear includes a 2TB Samsung 970 Evo SSD and Nvidia GeForce RTX 3070 FE graphics card. For LGA1700 CPUs, we use 32GB (2 x 16GB) of Kingston Fury 5200MHz DDR5 RAM and a Thermaltake Toughliquid Ultra 360 CPU cooler. For other systems, we use 16GB (2 x 8GB) of Corsair Vengeance RGB Pro 3466MHz RAM and 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 Dirt 5.

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.



MONITORS

We test image quality with an X-Rite iDisplay Pro colorimeter and DisplayCal software to check for colour accuracy, contrast and gamma, while assessing more subjective details such as pixel density and viewing angles by eye. For gaming, we test a monitor's responsiveness subjectively and then also use Blur Buster's excellent ghosting UFO test to check the sharpness of the display in high-speed motion.



CPU COOLERS

We 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 in order to compensate for any hot spots that might be misleading. AMD's CPUs only report a single temperature reading, rather than per-core readings, so we list what's reported in CoreTemp.

TEST KIT

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

INTEL LGA1200

Intel Core i9-11900K at stock speed with Adaptive Boost enabled, or Core i5-11600K overclocked to 4.8GHz with 1.35V core on low-profile coolers, MSI MEG Z590 Ace motherboard.

AMD AM4

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

INTEL LGA2066

Intel Core i9-9980XE overclocked to 4.2GHz with 1.08V core.



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.



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 HX750 PSU, Cooler Master MasterCase H500M case, Windows 10 Professional 64-bit.

GAME TESTS

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

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

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

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

POWER CONSUMPTION

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



CUSTOM PC AWARDS



EXTREME ULTRA

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



PREMIUM GRADE

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



PROFESSIONAL

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



APPROVED

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



CUSTOM KIT

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

CUSTOM PC REALBENCH

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

GIMP IMAGE EDITING

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

HANDBRAKE H.264 VIDEO ENCODING

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

LUXMARK OPENCL

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

HEAVY MULTI-TASKING

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

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.

Note that some of these bundles will be updated next issue when we've reviewed more Alder Lake gear

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	scan.co.uk	#218 p20	£325
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	£69
MOTHERBOARD	Asus TUF B450M-PLUS II (micro-ATX)*	scan.co.uk	#218 p78	£70
STORAGE	500GB WD Blue SN550 (M.2 NVMe)	scan.co.uk	#204 p24	£45

Total £509

*This motherboard may require a BIOS update in order to recognise the new CPU

1,920 x 1,080 gaming

6-core CPU, 1080p gaming

Needs an ATX case. We recommend a 500W 80 Plus Bronze power supply.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i5-11400F	cclonline.com	#215 p16	£146
CPU COOLER	ARCTIC Freezer 7 X	scan.co.uk	#202 p20	£15
GRAPHICS CARD	AMD Radeon RX 6600 XT	ebuyer.com	#220 p53	£470
MEMORY	16GB (2 x 8 GB) Corsair Vengeance LPX Pro 3200MHz (CMK16GX4M2B3200C16)	scan.co.uk	#204 p74	£69
MOTHERBOARD	MSI MAG B560 Tomahawk WiFi (ATX)	scan.co.uk	#215 p18	£170
STORAGE	500GB WD Blue SN550 (M.2 NVMe)	scan.co.uk	#204 p24	£45

Total £915

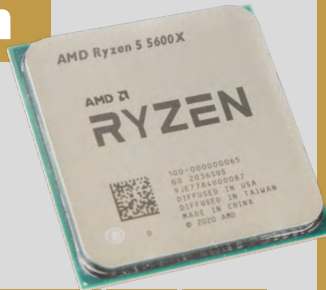
UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 3060 Ti	cclonline.com	#220 p55	£630
SWAP STORAGE	1TB ADATA XPG GAMMIX S50 Lite	cclonline.com	#215 p43	£117
SWAP CPU COOLER	SilverStone Hydrogen D120 ARGB	amazon.co.uk	#217 p43	£48

2,560 x 1,440 gaming system

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

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



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 5 5600X	scan.co.uk	#213 p43	£275
CPU COOLER	SilverStone Hydrogen D120 ARGB	amazon.co.uk	#217 p43	£48
GRAPHICS CARD	Nvidia GeForce RTX 3060 Ti	cclonline.com	#220 p55	£630
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz (CMW16GX4M2Z3600C20)	scan.co.uk	#210 p74	£102
MOTHERBOARD	MSI MPG B550 Gaming Carbon WiFi	ebuyer.com	#210 p74	£180
STORAGE	1TB ADATA XPG GAMMIX S50 Lite	cclonline.com	#215 p43	£117

Total £1,352

UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	#166 p54	£80
SWAP CPU COOLER	Antec Neptune 240	scan.co.uk	#216 p44	£70

Mid-range gaming system

8-core CPU, smooth 2,560 x 1,440 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	AMD Ryzen 7 5800X	scan.co.uk	#213 p44	£370
CPU COOLER	Lian Li Galahad 240mm	overclockers.co.uk	#216 p47	£110
GRAPHICS CARD	Nvidia GeForce RTX 3070 Ti	scan.co.uk	#220 p43	£865
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz (CMW16GX4M2Z3600C20)	scan.co.uk	#210 p74	£102
MOTHERBOARD	Asus ROG Strix B550-XE Gaming WiFi	scan.co.uk	#218 p22	£230
STORAGE	1TB ADATA XPG GAMMIX S50 Lite	cclonline.com	#215 p43	£117

Total £1,794

UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	#166 p54	£80
SWAP CPU COOLER	Corsair iCUE H100i Elite Capellix	scan.co.uk	#216 p46	£150

Core component bundles cont...

4K gaming system

8-core CPU, 4K gaming

Needs an ATX case with room for a 240mm all-in-one liquid cooler. We recommend an 850W 80 Plus Gold power supply.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 5800X	scan.co.uk	#213 p44	£370
CPU COOLER	Corsair iCUE H100i Elite Capellix	scan.co.uk	#216 p46	£150
GRAPHICS CARD	Nvidia GeForce RTX 3080 Ti	overclockers.co.uk	#216 p18	£1,500
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz (CMW16GX4M2Z3600C20)	scan.co.uk	#210 p74	£102
MOTHERBOARD	Asus ROG Strix X570-E Gaming (ATX)*	overclockers.co.uk	#193 p44	£290
STORAGE	1TB WD Black SN850	box.co.uk	#215 p49	£156
Total £2,568				

UPGRADES

ADD SECONDARY STORAGE	4TB Western Digital Blue	overclockers.co.uk	#166 p54	£80
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* This motherboard may require a BIOS update in order to recognise the new CPU

Content creation system

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

Needs an E-ATX case with room for a 280mm 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 5900X	scan.co.uk	#213 p45	£480
CPU COOLER	NZXT Kraken X63 (280mm AIO liquid cooler)	scan.co.uk	#207 p47	£130
GRAPHICS CARD	AMD Radeon RX 6600 XT	ebuyer.com	#220 p53	£470
MEMORY	32GB (2 x 16GB) Corsair Dominator Platinum RGB 3600MHz (CMW32GX4M2D3600C18)	scan.co.uk	#210 p74	£138
MOTHERBOARD	MSI Prestige X570 Creation (E-ATX)*	overclockers.co.uk	#193 p48	£440
STORAGE	2TB WD Black SN850	scan.co.uk	#215 p49	£350
Total £2,008				

UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 3080 Ti	overclockers.co.uk	#216 p18	£1,500
SWAP CPU	AMD Ryzen 9 5950X (16 cores - more multi-threaded power)	scan.co.uk	#213 p46	£700
ADD SECONDARY STORAGE	4TB Western Digital Blue	overclockers.co.uk	#166 p54	£80

* This motherboard may require a BIOS update in order to recognise the new CPU

Mini PCs

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

Mini-ITX



Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Intel Z590 (LGA1200)	Gigabyte Z590I Vision D	scan.co.uk	#214 p18	£270
AMD B550 (AM4 budget)	Asus ROG Strix B550-I Gaming	scan.co.uk	#206 p44	£197

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ALL-PURPOSE	Cooler Master MasterBox NR200P	scan.co.uk	#206 p18	£100
TOWER	Ssupd Meshlicious	overclockers.co.uk	#219 p18	£102
PREMIUM	Streacom DA2 V2	quietpc.com	#214 p51	£190

Other components

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
LOW-PROFILE CPU COOLER	Noctua NH-L12S	scan.co.uk	#219 p54	£50
SFX POWER SUPPLY	SilverStone SX750	scan.co.uk	#219 p72	£130

ATX cases



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Phanteks Eclipse P300 Glass	overclockers.co.uk	#176 p28	£55
BUDGET RGB	Antec DF700 FLUX	scan.co.uk	#214 p26	£75
SUB-£100	be quiet! Pure Base 500DX	scan.co.uk	#202 p39	£99
COMPACT	Fractal Design Meshify 2 Compact	scan.co.uk	#215 p20	£100
HIGH AIRFLOW	Fractal Design Meshify 2	scan.co.uk	#212 p45	£130
MID-RANGE	Phanteks Eclipse P600S	overclockers.co.uk	#202 p44	£139
SUB-£150	Fractal Design Define 7	overclockers.co.uk	#204 p18	£140
PREMIUM	Phanteks Enthoo Evolv X	overclockers.co.uk	#187 p24	£200

Micro-ATX



Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Budget AMD B450 (AM4)	Asus TUF B450M-PLUS II (micro-ATX)	scan.co.uk	#218 p76	£70
AMD B550 (AM4)	MSI MAG B550M Mortar	ebuyer.com	#204 p42	£140

Cases

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

Networking



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET ROUTER	Belkin RT3200-UK	currys.co.uk	#216 p52	£130
ROUTER	Asus RT-AX68U	scan.co.uk	#216 p51	£170
MESH ROUTER	Asus AiMesh AX6100	amazon.co.uk	#196 p54	£334
WI-FI ADAPTOR	TP-Link Archer TX3000E	overclockers.co.uk	#196 p58	£60
DUAL-BAY NAS BOX	Synology DS220j	laptopsdirect.co.uk	#200 p22	£160
DUAL-BAY MEDIA NAS BOX	Synology DS218play	laptopsdirect.co.uk	#174 p34	£208
2.5 GIGABIT DUAL-BAY NAS BOX	QNAP TS-231P3	ebuyer.com	#212 p25	£300

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

Monitors



Up to 25in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN, 144Hz, IPS, 1,920 X 1,080, F, G	AOC 24G2U	box.co.uk	#214 p28	£150
25IN, 240Hz, IPS, 1,920 X 1,080, F, G	Acer Predator XB253Q	amazon.co.uk	#209 p57	£290
25IN, 360Hz, IPS, 1,920 X 1,080, F, G	Asus ROG Swift PG259QN	overclockers.co.uk	#212 p20	£699

Up to 28in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN, 144Hz, IPS, 1,920 X 1,080, F, G	AOC 27G2U	overclockers.co.uk	#201 p53	£170
27IN, 240Hz, IPS, 1,920 X 1,080, F, G	Asus TUF Gaming VG279QM	overclockers.co.uk	#209 p60	£340
27IN, 144Hz, IPS, 2,560 X 1,440, F, G	Asus TUF Gaming VG27AQ	overclockers.co.uk	#201 p54	£460
27IN, 240Hz, TN, 2,560 X 1,440, F, G	AOC AG273QZ	overclockers.co.uk	#202 p27	£480
27IN, 240Hz, IPS, 2,560 X 1,440, F, G	Alienware AW2721D	dell.com	#212 p21	£700
28IN, 144Hz, IPS, 3,840 X 2,160, F, G	Asus TUF Gaming VG28UQL1A	very.co.uk	#218 p56	£749

Over 28in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
31.5IN, 60Hz, VA, 4K, F	iiyama ProLite XB3288UHSU	scan.co.uk	#205 p43	£385
32IN, 165Hz, IPS, 2,560 X 1,440, F, G	LG UltraGear 32GP850	overclockers.co.uk	#220 p38	£399
34IN, 144Hz, VA, 3,440 X 1,440, W, F, G	Cooler Master GM34-CW	ebuyer.com	#215 p30	£550
34IN, 144Hz, IPS, 3,440 X 1,440, W, F, G	iiyama G-Master GB3461WQSU	scan.co.uk	#206 p53	£330
34IN, 144Hz, IPS, 3,440 X 1,440, W, F, G	LG UltraGear 34GN850	currys.co.uk	#206 p55	£779
38IN, 144Hz, IPS, 3,840 X 1,600, W, F, G, HDR	LG UltraGear 38GN950	currys.co.uk	#208 p30	£1,199
32IN, 144Hz, IPS, 3,840 X 2,160, F, G, HDR	Asus ROG Swift PG32UQX	scan.co.uk	#218 p54	£3,299

Non-gaming

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN, 75Hz, IPS, 2,560 X 1,440, F	LG 27QN880	ebuyer.com	#210 p26	£395

Peripherals and audio

Gaming keyboards



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
MEMBRANE	Corsair K55 RGB	amazon.co.uk	#201 p45	£54
OPTICAL ESPORTS	Asus ROG Strix Scope RX	ebuyer.com	#209 p43	£113
MECHANICAL MMO	Corsair K95 RGB Platinum	scan.co.uk	#164 p26	£180
PREMIUM MECHANICAL	Corsair K70 Mk.2 Low Profile	scan.co.uk	#193 p56	£150
PREMIUM TKL MECHANICAL	Corsair K70 RGB TKL	scan.co.uk	#214 p31	£140
LUXURY MECHANICAL	Ducky Shine 7 RGB	overclockers.co.uk	#212 p53	£175
LUXURY WIRELESS MECHANICAL	Razer BlackWidow V3 Pro	overclockers.co.uk	#208 p60	£230

Gaming mice



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET GAMING	Corsair M55 RGB Pro	ebuyer.com	#200 p24	£22
FIRST-PERSON SHOOTER	Glorious PC Gaming Race Model O	overclockers.co.uk	#215 p57	£52
MMO	Razer Naga Trinity	amazon.co.uk	#186 p52	£73
AMBIDEXTROUS	Razer Viper 8K	currys.co.uk	#215 p59	£65
WIRELESS	Razer Viper Ultimate	box.co.uk	#217 p54	£90
PREMIUM WIRELESS	Razer Deathadder V2 Pro	ebuyer.com	#210 p28	£114
ULTRA LIGHTWEIGHT	Roccat Burst Pro	scan.co.uk	#211 p28	£48
PREMIUM LIGHTWEIGHT WIRELESS	Logitech G Pro X Superlight	currys.co.uk	#217 p52	£100

Peripherals and audio cont ...



Game controllers



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
RACING WHEEL	Logitech G29 Driving Force	currys.co.uk	#202 p50	£229
GAMEPAD	Microsoft Xbox One Wireless Controller	currys.co.uk	#191 p56	£55
BUDGET FLIGHT STICK	Logitech Extreme 3D Pro Joystick	currys.co.uk	#207 p52	£37
FLIGHT STICK	Thrustmaster T.16000M FCS HOTAS	scan.co.uk	#207 p56	£140

Gaming headsets

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET STEREO	Roccat Elo X Stereo	scan.co.uk	#210 p56	£40
STEREO	Epos Sennheiser GSP 300	amazon.co.uk	#210 p54	£58
WIRELESS	Corsair Virtuoso RGB Wireless	ebuyer.com	#204 p50	£155
PREMIUM WIRELESS	Razer BlackShark V2 Pro	scan.co.uk	#211 p26	£200

Speakers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
STEREO	Edifier R1280DB	amazon.co.uk	#192 p57	£130

Non-gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
WIRELESS TKL MECHANICAL	Keychron K2 Version 2	keyboardco.com	#208 p57	£84
TKL MECHANICAL	Filco Majestouch Convertible 2 Tenkeyless	keyboardco.com	#203 p55	£140
BUCKLING SPRING MECHANICAL	Unicomp New Model M	keyboardco.com	#219 p26	£129

PCs and laptops



Pre-built PC systems

CATEGORY	NAME	CPU	GPU	SUPPLIER	ISSUE	PRICE (inc VAT)
6-CORE GAMING	CyberPower Infinity X115 GT	Intel Core i5-11400	Nvidia GeForce RTX 3060	cyberpowersystem.co.uk	#217 p32	£1,299
6-CORE GAMING WITH RAY TRACING	CCL Horizon 5 3060 Ti Gaming PC	AMD Ryzen 5 5600X	Nvidia GeForce RTX 3060 Ti	cclonline.com	#220 p42	£1,499
MINI-ITX GAMING	Chillblast Fusion Diablo	AMD Ryzen 5 5600X	AMD Radeon RX 6700 XT	chillblast.com	#215 p34	£2,100
4K GAMING	PC Specialist Infinity LC	AMD Ryzen 9 5950X	AMD Radeon RX 6900 XT	pcspecialist.co.uk	#218 p34	£3,295
WATER-COOLED 4K GAMING	Scan 3XS Absorbere	AMD Ryzen 9 5900X	Nvidia GeForce RTX 3080 Ti	scan.co.uk	#209 p46	£4,383
PREMIUM WATER-COOLED 4K GAMING	Chillblast Fusion Kraken	AMD Ryzen 9 5950X	Nvidia GeForce RTX 3090	chillblast.com	#217 p34	£6,840

Laptops



CATEGORY	NAME	CPU	GPU	SCREEN	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET GAMING	Lenovo Legion 5 (82JU002YUK)	AMD Ryzen 7 5800H	Nvidia GeForce RTX 3070 Laptop	15.6in, 1,920 x 1,080 IPS 165Hz	box.co.uk	#218 p48	£1,399
RTX GAMING	Gigabyte Aorus 15G XC	Intel Core i7-10870H	Nvidia GeForce RTX 3070 Laptop	15.6in, 1,920 x 1,080 IPS 240Hz	cclonline.com	#213 p30	£1,599
ULTRA PORTABLE GAMING	Razer Blade 14	AMD Ryzen 9 5900HX	Nvidia GeForce RTX 3060 Laptop	14in, 1,920 x 1,080 IPS 144Hz	razer.com	#220 p40	£1,799
ULTRA PORTABLE GAMING + EGPU DOCK	Asus ROG Flow X13 GV301	AMD Ryzen 9 5980HS	Nvidia GeForce GTX 1650 Max-Q (laptop) / RTX 3080 Laptop (dock)	13.4in, 1,920 x 1,200 IPS 120Hz	overclockers.co.uk	#219 p28	£2,499
PREMIUM RTX GAMING	Asus ROG Strix Scar G733QSA	AMD Ryzen 9 5900HX	Nvidia GeForce RTX 3080 Laptop	17.3in, 1,920 x 1,080 IPS 360Hz	overclockers.co.uk	#217 p28	£2,999

Games



RICK LANE / INVERSE LOOK

DIFFICULTY OPTIONS

Sometimes there are smarter ways to make games accessible than using easy modes, argues Rick Lane

As well as being brilliant in every other way, *Psychonauts 2* (see p72) has one of the most comprehensive ranges of accessibility options around. Alongside subtitles and colour-blindness compensation, it has several options that help to mitigate the game's challenges. Players can choose to eliminate fall damage, activate 'narrative combat' that helps them deal more damage and even make Raz invincible, shrugging off damage like a Teflon tank.

As a proud advocate of playing games on easy mode if you're tired or busy, I fully endorse *Psychonauts 2*'s approach to accessibility. It works with *Psychonauts 2* because Double Fine's game isn't really about the challenge anyway, but about story, adventure and cool level design. But what do you do when challenge is a fundamental pillar of your design, in games such as *Sekiro*, *Blasphemous* or *Cuphead*?

Purists will say either deal with the challenge or don't play, while others will say that just because a game has an easy mode doesn't mean you have to use it. I'm inclined to agree with the latter, but there are ways to cater to less challenge-orientated players without artificially adjusting the entire game.

Dark Souls recently celebrated its tenth anniversary – it's an infamously tough nut that's often at the centre of debate between players who believe in squaring up to challenge, and those who prefer to play games for more experiential reasons. The irony is that *Dark Souls* has an 'easy mode' built

into the game. Players struggling with a particular boss can 'summon' other players into their game to help them defeat it. You can even summon multiple players, at which point you can often sit back and let them batter a troublesome boss for you.

Crucially, this isn't a side system or a tickbox in the menu, it's fundamentally built into the game's world and story. *Dark Souls* acknowledges that difficulty is a design choice, and rather than compromise on its own vision, it uses a design solution to solve it. Summoning help isn't deemed a 'lesser'

way to play. It isn't framed as taking the easy road, but as a fallback for when you hit a wall you simply can't get past. The core experience never changes, and once the boss is toppled, your summoned companions return to their worlds, leaving you to continue your journey.

There's also a positive message built into the summon system. Rather than pushing players to give up or artificially reduce the challenge by hitting a button, *Dark Souls* instead encourages players to ask for help.

This notion of community and helping each other out is perhaps *Dark Souls*' most significant theme, as well as being the most overlooked. That might be because asking for help can be hard, and instead people will try to brute-force solutions or avoid the problem entirely. In this way, *Dark Souls*' summons system isn't only a great solution for mitigating difficult sections in game, but also sound advice for life that we too often dismiss. **EPG**

**Purists will say either
deal with the challenge
or don't play**

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



Quake Remastered / £7.99 inc VAT

DEVELOPER id Software/Nightdive Studios/Machine Games/ PUBLISHER Bethesda

To celebrate Quake's 25th anniversary, Bethesda Softworks has released a remastered version of the classic FPS. This shiny new version optimises the game for modern machines and even adds a new expansion from Wolfenstein: The New Order developer Machine Games.

In terms of basic quality-of-life features, the remaster adds proper support for full-screen and windowed play, plus widescreen resolutions and FOV scaling. The new graphical features, meanwhile, include anti-aliasing, ambient occlusion, and dynamic lighting and shadows. Quake couples these broader bells and whistles with sharper textures and a complete overhaul of the game's models, making them slightly less lumpy without compromising their distinctive designs.

The Quake that emerges from this makeover is slightly brighter and more vivid, while retaining its moody atmosphere. It's still brown and murky, but its brown murk is a lot clearer now. Most importantly, the Quake remaster smooths out the kinks of the original version, such as its stuttering animations and dodgy performance at higher resolutions, making it easier to appreciate the core game.

With its bloodstained façade wiped clean, Quake is just as fresh and invigorating as it was back in 1996. The slippery movement, the serpentine levels, the meticulously designed weapons and enemies that all combine in different ways, the phenomenal soundtrack by Nine Inch Nails which remains one of the best in all of gaming – it's a marvellous

experience. Quake's iconic multiplayer mode has been given a new lease of life too, with both online matchmaking and P2P support for online deathmatch, and a split-screen feature for both competitive and cooperative multiplayer.

However, the highlight of Quake Remastered is its brand-new expansion, Dimensions of the Machine. This sees you battle across five large, elaborate worlds, each of which comprises multiple levels. In Dimension of the Blacksmith, for example, you explore a Dark Souls-inspired dilapidated fantasy world, with creaking windmills and sunken cathedrals, as you seek to unlock the entrance of a vast iron fortress.

Dimension of the Cultists, meanwhile, juxtaposes imagery of heaven and hell, with the player fighting through a sparkling monastery on a remote, lofty peak, before slowly descending through crypts and undercrofts into a fiery abyssal plain. The whole campaign is brimming with imagination, although it doesn't quite match the ambition of Quake's most spellbinding mod, Arcane Dimensions.

Quake Remastered also contains the two original Quake expansions, Scourge of Armagon and Dissolution of Eternity, plus Machine Games' 20th anniversary expansion, Dimensions of the Past. You can even download the Quake 64 campaign, an entirely separate experience from the PC version made for the Nintendo 64. This, ultimately, is what makes the Quake remaster so special. It isn't simply an update of Quake, it's a celebration.

RICK LANE

QUAKE

- + It's Quake
- + But bigger
- + And better

QUACK

- Quake being 25 makes us feel old

/ VERDICT

Simultaneously a facelift, curation and expansion of id's classic FPS, Quake Remastered is an overhaul that absolutely nails it.

OVERALL SCORE

94%



Psychonauts 2 / £54.99 inc VAT

DEVELOPER Double Fine / PUBLISHER Xbox Game Studios



PSYCHONAUTS

- + Funny
- + Clever
- + Dramatic
- + Emotional
- + Stunning
- + Imaginative
- + Brilliant

PSYCHONAUGHTS

- Boss fights can be repetitive
- Too much collecting
- Some underdeveloped characters

Double Fine Productions is a studio that has hovered outside the exclusive club of 'best game developers' for years but has never quite got past the bouncer. From *Brutal Legend* to *Broken Age*, its games are always brimming with charm, but tend to suffer from unfortunate design decisions or other problems in development. Even the original *Psychonauts* offers as much frustration as entertainment.

Hence, it's a delight to say that *Psychonauts 2* is Double Fine's masterpiece, a spellbinding adventure that not only brings all the humour and imagination you'd expect from a Tim Schafer game, but fixes all the sticky design problems of the original. It also features some of the best level design you'll see all year, and a story that will tickle your tear ducts as much as your diaphragm.

Once more we don the goggles of Raz, a yellow-headed circus runaway who desires to be a Psychonaut, who is a sort-of hybrid between therapists and spies that can project themselves into other people's minds and feng shui their negative emotions and mental trauma. After attending Psychonaut summer camp in the first game, the sequel sees Raz promoted to an apprentice at Psychonauts HQ, where he's tasked with rooting out a mole in the agency believed to be in service of the Psychonauts' most notorious foe, Maligula.

Although *Psychonauts 2*'s plot is framed as a camp spy adventure, the story quickly reveals itself as a deeply

personal tale of grief, regret, forgiveness and making amends for past mistakes. Raz's journey to find the mole takes him into the minds of the Psychonauts' original founders, each of whom has been variously damaged by a historic encounter with Maligula. Finding the mole requires Raz to help the elderly Psychonauts come to terms with their troubled pasts.

It's a story that could easily devolve into mawkish sentimentality, but *Psychonauts 2* avoids this in two ways. The first is also the most obvious – it's very funny. Double Fine's games tend toward charming rather than outright hilarious, but *Psychonauts 2* has multiple laugh-out-loud moments. The game world is filled with amusing asides, with one random Psychonaut responding to Raz introducing himself with 'I'm sorry, I just ... hate children.' Meanwhile, any scene involving dentist turned brain surgeon Doctor





Loboto or the animal obsessed Sam Boole is guaranteed to leave you chuckling.

But arguably more interesting is *how* Psychonauts 2 tells its story. Psychonauts 2 lets its levels do the talking, literally in the case of the introductory mission where you delve into Loboto's orally fixated mind. As with the first Psychonauts, most of the game takes place in other people's heads, with each brain having its own distinctive theme. You'll explore mindscapes made of hair, labyrinthine mental libraries and even a mind themed around the inside of a bowling shoe, where a city populated by germs is blown away by a tsunami of disinfectant spray.

Yet Psychonauts 2 doesn't offer zaniness for the sake of it; each of these mindscapes provides an insight into that person's life and personality, tying their personal tale into the broader story of Maligula and the mole.

One level depicts a Psychonaut's battle with alcoholism as a seafaring adventure in which Raz sails to different islands, home to ship-sized bottles in which Raz must descend to the bottom of each bottle to reveal more about that Psychonaut's past. In another, Raz must bring the near-dead brain of a rockstar Psychonaut back to life, traversing a psychedelic landscape to reunite the five senses for a rocking comeback gig.

As for how this translates into play, Psychonauts 2 is surprisingly similar to the original game. Double Fine has resisted temptation to bow to modern conventions, creating an old-school platformer similar to the Mario games. Progression still mostly relies on Raz's acrobatics, jumping between platforms and swinging across trapezes. Most of the original game's Psi abilities also return, including levitation, Psi blast and clairvoyance.

Unlike the original Psychonauts, the sequel's platforming is consistently fun. The platforming challenges are carefully designed to minimise frustration, while new abilities such as Mental Connection, which lets Raz teleport between diffuse thoughts, help to bake variety into the action.

Combat is also designed to be more creative than challenging. A new dodge ability helps Raz to avoid enemy blows, while abilities such as telekinesis and the new Time Bubble further enable you to minimise taking damage. Enemies are also designed to be weak to specific attacks. For example, Bad Ideas are canine-like creatures that fire explosive light bulbs at you, but Raz can toss back the light bulbs using his telekinesis ability.



There are a few minor issues. The boss battles are visually creative, but mostly fall into the 'do X three times to win' category, while a couple of encounters go on too long. The series also remains obsessed with collectibles, with levels stuffed full of figments, Psi cards, emotional baggage and so on.

Finally, while there are few rough edges, there are some noticeable seams where the game appears to have been cut down from a larger vision. For example, it introduces a whole new group of kids who accompany Raz on early adventures, but they almost completely disappear from the later game, only to suddenly turn up at the end for no real reason. Certain areas of Psychonauts HQ also feel underused – there's a sense that some sizeable chunks of the game were cut out late in development.

Beyond a few underdeveloped side characters, however, this doesn't overly affect the quality of what's there. And what's there is one of the best action-adventure games in years, a spectacularly imaginative and endearing adventure that has heart and soul as well as humour. If Double Fine is a spiritual successor to LucasArts, then Psychonauts 2 is the studio's Grim Fandango. It's been a long time coming, but boy, was it worth it.

RICK LANE

/ VERDICT

A charming, heartfelt and spectacular journey, Psychonauts 2 will crack open your braincase and pour in a bucketful of endorphins.

OVERALL SCORE

92%



TheRealJoWoo

R Whisper

Target Lock

C Drop

Climb Up

Aragami 2 / £29.99 inc VAT

DEVELOPER Lince Works / PUBLISHER Lince Works

Aragami 2 is simultaneously better and worse than its predecessor. It radically changes the mechanics and structure of the original game, emphasising faster-paced, acrobatic stealth and more open-ended missions designed around cooperative play. While the former is by and large an improvement, the latter burdens Aragami 2 with repetition and grind.

The story is where the game most clearly departs from the original, seeing your ghostly ninja whisked away to the home of the Kurotsuba clan in the remote valley of Rashomon. The Kurotsuba are cursed spirits like yourself, and promise to help you find a way to break the spell if you help them to defeat the evil Akatsuchi clan.

Frankly, the story is a confused mess that doesn't really capitalise on its ideas, a phrase that could also summarise the game in general. It's a shame because, mechanically, Aragami 2 is fascinating. Your ninja is far more sprightly than in the first game, being able to jump, flip and lunge forwards in a way that makes them briefly invisible. They can also perform a 'Shadow Leap' that lets them teleport from a distance to any elevated ledge.

Combining these abilities lets you navigate levels extremely quickly, lending Aragami 2 a frenetic pace that's unusual for a stealth game. Zipping through the game's feudal fortresses and temple compounds is highly satisfying, succeeding in making you feel like a ninja.

Aragami 2 also overhauls the combat, borrowing Sekiro's active parrying system in an effort to make swordplay more

skill-based and engaging. Unfortunately, the parry timings simply feel off, while the system is useless for fighting multiple opponents.

When engaged by more than one foe, you're better off running away, using evasion equipment such as smoke bombs or amnesia darts to give enemies the slip. The combat is disappointing, but that's not too much of a problem given Aragami's stealth emphasis.

The same can't be said for the restructured campaign. Although Aragami 2 remains a linear adventure, missions are now accessed from a central hub, many of which require repeated revisits to locations you've already explored. Unfortunately, Aragami 2's levels don't stand up to repeated exploration. They're large and pretty, but also static and lifeless, failing to change enough between missions to make returning to them interesting.

Playing in co-op with one or two other ninjas helps to spice up the game, but the success of Aragami 2's co-op largely depends on playing with like-minded companions. Working together to move through environments silently, performing simultaneous takedowns is great. However, playing stealthily is no fun whatsoever if your teammates approach missions like rampaging rhinos.

Played in short bursts, Aragami 2 is an entertaining distraction. However, if you're looking for a deeper, more fulfilling stealth experience, this sequel is simply too repetitive to stand up to more sustained play.

RICK LANE

NINJA

- + Fast-paced, acrobatic stealth
- + Great art
- + Fun in short bursts

WHINGER

- Disposable story
- Fiddly combat
- Repetitive

/ VERDICT

With great stealth marred by a tedious structure, Aragami 2 is an effective but predictable assassin.

OVERALL SCORE

60%

The Forgotten City

/ £19.49 inc VAT

DEVELOPER Modern Storyteller / PUBLISHER Dear Villagers

Time loop games have become increasingly popular, with games such as *Outer Wilds* and *12 Minutes* challenging you to explore clockwork worlds that repeat the same time frame over and over, and find ways to exploit or change the time loop to solve puzzles. *The Forgotten City* might be the best example yet.

You play an amnesiac protagonist who awakes on the banks of the river Tiber beside some ancient Roman ruins. Exploring those ruins reveals a hidden Roman metropolis in which both its architecture and inhabitants have been miraculously preserved.

Approached by the City's Magistrate, Sentius Sentillus, you're told that the city is a paradise locked into eternity by the Golden Rule. Nobody knows the rule exactly, but breaking it will destroy the city, which will force Sentius to sacrifice himself to restart the day. What's more, he knows somebody plans to break the rule before the end of the day, unless you can find and stop them.

This slightly convoluted premise forms the foundation of an elaborate and intelligent detective story. There are approximately 20 other inhabitants of the city, each with their own backstory and routine. The first hour or so mostly involves conversing with these characters, learning about them, their friends, their rivals, who they think might break the Golden Rule and so on.



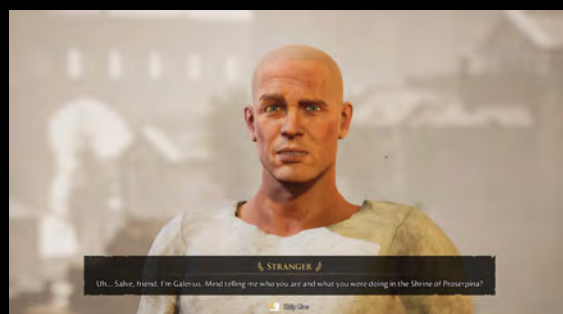
This is also the weakest part of the game. Although the writing is excellent, *The Forgotten City* is based upon a *Skyrim* mod of the same name, and employs a static *Skyrim*-style dialogue system that's unsuited to protracted conversations. Fortunately, when you have enough pieces of the puzzle to start putting them together, the game becomes a lot more entertaining.

Much of the puzzling revolves around exploiting the time loop. Certain actions such as theft and murder will break the Golden Rule, triggering the city's destruction and forcing you to flee to a portal, which will reset the day with any items in your inventory carrying through with you to the next morning. If you need money to complete a quest, you can steal some, reset the day, then steal the same money again until your purse is bursting.

This is only a simple example. The way *The Forgotten City* plays with its time loop is frequently ingenious. One character, named Galerius, is essentially a living savegame. At the start of a new day, you can direct Galerius to complete any major tasks you've already discovered on your behalf, so you don't have to repeat the same actions every time.

Couple this with a superbly told mystery that's capable of being funny, frightening and emotionally affecting and *The Forgotten City* is a highlight of the year.

RICK LANE



FORGOTTEN

- + Ingenious time loop concept
- + Excellent puzzles
- + Great story and characters

FORGETTABLE

- Early stages of investigation can be tedious

/ VERDICT

A masterfully crafted mystery, *The Forgotten City* is the best time loop game so far

OVERALL SCORE

90%

REALITY CHECK

In his latest VR roundup, **Rick Lane** wanders around *Myst*'s puzzle-filled islands and brings us news of a full *Half-Life 2* mod

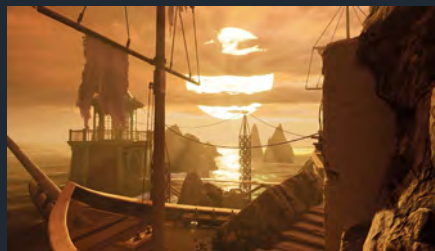
REVIEW

MYST / £22.99 inc VAT

DEVELOPER Cyan Worlds Inc / PUBLISHER Cyan Worlds Inc

There are two kinds of remasters. There are those that seek to update the game, giving it a visual overhaul while keeping the core experience intact, and there are those that seek to modernise it, overhauling both the visuals and the core experience to rectify mistakes in the original design and make the game more accessible to modern audiences. *Myst* belongs to the former group, but it should probably belong to the latter.

That's not to say it's terrible. *Myst* is a classic for a reason. Much like the *Witness*, which was based upon *Myst*, it's about exploring a mysterious, puzzle-filled island while slowly unveiling a fragmented and ambiguous story. To get off the island, you need to retrieve the scattered pages of the book, which means solving puzzles that transport you to further, conundrum-filled islands.



Visually, Cyan Worlds' remake is a triumph. The pre-rendered images of the 1993 original have been converted into fully explorable 3D environments, and beautiful ones at that.

The islands have a slightly Hebridean atmosphere, bracing and moody, while the puzzle rooms are lush, cosy and inviting. That said, the conversion of *Myst* into a flowing, contiguous space also highlights the cramped size of the islands – perhaps it would have benefited from taking a few liberties with scale.

Meanwhile, the puzzles remain identical to the original, and *Myst*'s puzzle design hasn't aged well over the best part of three decades. There's no consistency to the challenge.

One puzzle solution can be obvious, while the next can have you tearing out your hair with frustration. Clues to puzzles are scattered all over the place, and it's easy to become stuck simply because you overlooked a cryptic hint while wandering around.

The addition of a VR mode is a mixed blessing. Being able to reach out and touch the world of *Myst* is a slightly surreal experience, and *Myst*'s atmosphere makes for a relaxing space in which to spend time (at least when you're not gnashing your teeth over a puzzle). However, *Myst* involves a lot

of standing still and thinking, which is fine when you're sat in front of a screen, but less so when you're stood in the centre of the room with a sweaty plastic box on your face.

Moreover, it's also a game where you want to keep a notepad handy, and the VR mode's ability to photograph clues simply isn't a sufficient replacement for good pen and paper.

This isn't *Myst*'s first makeover, and it's past time for a more adventurous overhaul that doesn't simply make *Myst* look prettier, but smooths out the game's flow, makes puzzles more intuitive and the logic more coherent. That said, if you've never played *Myst* and want to try it, this is the version to get. Just be aware that its experience isn't as laid-back as it looks.

MYST

- + Great visual overhaul
- + Chill vibes
- + Some good puzzles

MISSSED

- Some horrible puzzles
- Limited scale
- VR is more a hindrance than a help

VERDICT

The best *Myst* remaster, but it's still not sufficient to bring the classic puzzler into the modern era.

OVERALL SCORE

65%





NEWS

HALF-LIFE 2 VR

Half-Life 2 was one of the first games playable in VR. Back before the official release of the Oculus Rift, a group of modders created a simple VR mod for Valve's classic shooter that made it compatible with the Oculus Developer Kit. However, that mod was incompatible with the Rift itself, meaning VR support for Half-Life 2 dropped off before most people had a chance to play it.

A new, more comprehensive version of the mod was announced in 2017, which included proper support for touch controls, among other features, but the project drifted apart over the following year. Yet it appears there's hope for Half-Life 2 VR.

A new team has rebooted the project, led by well-regarded VR modder Simon 'DrBeef' Brown, who has previously

worked on VR mods for Doom and the original Half-Life. While there's no release date, the team has confirmed that work is active on the mod. According to a statement posted on the mod's Discord community, Brown has 'rewritten all of the VR code' and 'ported the engine's VR implementation to use Vulkan instead of DX9'. Currently, the team is trying to figure out whether to continue developing the mod using the Source 2013 SDK version, or move to the newer engine developed for Counter-Strike: Global Offensive.

Whether or not a Half-Life 2 VR mod is needed now we have Half-Life: Alyx is up for debate, but Half-Life 2 was a surprisingly great VR experience even in the mod's rudimentary state. Let's hope this new team can see the project over the finish line.



NEWS

WANDERER

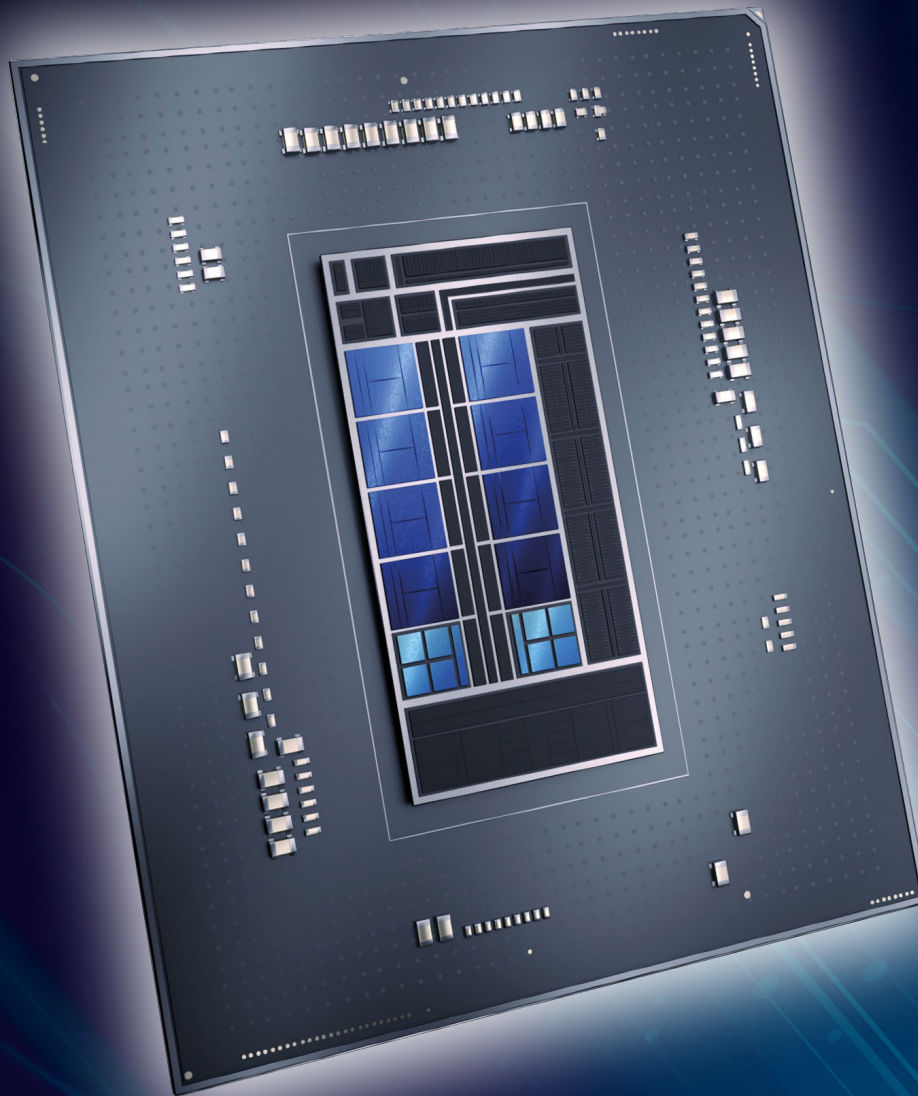
Developed from the ground up for VR, Wanderer is an extremely pretty time-travelling puzzle game that sees you trying to change the fate of humanity. You play Asher Neumann, who exists in an alternate timeline where civilisation has collapsed.

Exploring her grandfather's overgrown apartment, Asher finds a message from him, in which he claims this is not the intended timeline for humanity, and something, *somewhen*, has gone seriously wrong. Oh, and he leaves you a talking wristwatch that can be used to travel through history and fix the timeline, which is more than a little convenient.

Wanderer is an interesting attempt to transform the 'room-scale vignette' experiment into a more cohesive experience. The time-travelling gimmick enables developer M-Theory to string together a wide range of VR experiences into a coherent story without the player having to move.

Locations you'll visit in the game include an Ancient Aztec temple, Nikola Tesla's laboratory and the Moon. The game's temporal themes also allow for broader puzzling. Items from one time period can be stored in the watch and taken to another, letting you skip across history as you repair the timeline.

It's a clever concept, bolstered by first-rate production values. The only minor concern relates to the watch itself, which has its own personality and speaks in a Deep South drawl. It's apparently designed to act as comic relief, but the jokes in the recently released gameplay demo were more cringeworthy than amusing. Wanderer has been delayed from a scheduled release in September 2021, but is still slated to launch later this year. **GPC**



ALDER LAKE

BENEATH THE SURFACE

INTEL'S NEW ALDER LAKE CPUs BRING THE BIGGEST CHANGES IN THE COMPANY'S CPU MICROARCHITECTURE IN OVER A DECADE. **EDWARD CHESTER** EXPLORES THE NEW CHIPS' HIDDEN DEPTHS



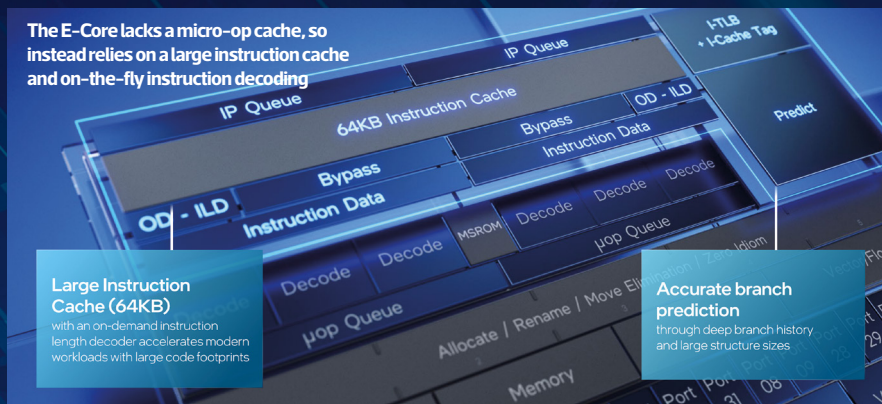
The E-core enables Intel to pack eight extra power-efficient but performant cores into each Alder Lake chip

Intel says that it considers Golden Cove alone to be the biggest microarchitectural upgrade to the Core family in a decade, putting its significance well beyond the launch of Skylake and all the way back to the Sandy Bridge days (2000-series). The result of these changes is a claimed 19 per cent improvement in instructions per clock (IPC) over the Cypress Cove core used in Rocket Lake CPUs.

The last major piece of the puzzle is a move to a new manufacturing node that finally sees Intel move its high-performance desktop CPU manufacturing away from its 14nm-based nodes. The new chips will be manufactured on what Intel now calls its Intel 7 process, which was previously known as its 10nm Enhanced SuperFin (10 ESF) process. It boasts an improvement in transistor density from the 43.5 million transistors per square millimetre (MTr/mm²) of Intel's latest 14nm++ node to 100.76 MTr/mm² on Intel 7.

This change in naming appears to be an attempt to align Intel's technologies more closely with the claimed density of competing technologies, such as TSMC's N7FF technology (96.5 MTr/mm²) and Samsung's 7LPP process (95.3 MTr/mm²). Intel had previously been using a more aggressive scheme for categorising the size of its process nodes, showing that its 10nm and 7nm technologies were smaller/denser than that of competitors. What Intel previously considered its 7nm node is now known as Intel 4, reflecting its status as being closer in density to competitors' 4nm nodes.

A dual 3-wide decoder setup keeps the execution units of the E-Core fed



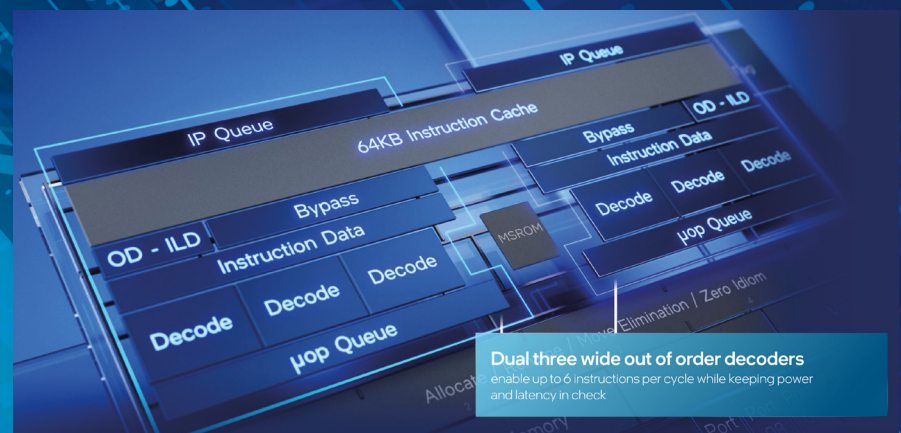
It took nearly six years for Intel to move from its Skylake microarchitecture (Intel Core 6000 Series) to Rocket Lake (11000 Series) earlier this year, and even the latter was still stuck on a 14nm manufacturing process. Since 2015, we saw iteration upon iteration of tweaking the Skylake formula to add more cores, improve performance per core and increase clock speed. However, through Kaby Lake (7000 series), Coffee Lake (8000-9000 series) and Comet Lake (10000 series), the fundamental building blocks of its CPU design have remained largely the same.

That all changed with the launch of Rocket Lake, and sees an even bigger jump with the launch of Alder Lake, the company's brand new CPU microarchitecture. Although there are umpteen small differences between the new architecture and its predecessors, the core changes amount to three key areas.

Firstly, and most intriguingly, Intel has moved to a hybrid CPU design where instead of having several identical cores tasked with being both powerful and energy-efficient, now there are two different types of core aimed at fulfilling each of these tasks.

As well as a more traditional performance core that's akin to the existing cores in current Intel and AMD CPUs, Alder Lake CPUs will come packaged with smaller, energy-efficient cores based on the company's Atom product line. These will be used to perform lower-priority work and background tasks, with the aim of keeping power usage to a minimum while they're in operation.

The second big change concerns the more traditional 'performance' cores, which use a brand-new design codenamed Golden Cove.



Data Execution

**Five-wide allocation
with eight-wide retire**

**256 entry
out of order window**
Discovers data parallelism

**Seventeen
execution ports**
Executes data parallelism



ON THE DOWNLOW

The single biggest change with Intel's new Alder Lake CPUs is undoubtedly the inclusion of a new low-power core (E-Core). It's designed to take on the smaller background tasks your system requires without having to engage its more power-hungry performance cores (P-Core). With an architecture codenamed Gracemont, these new E-cores are a refinement of the most recent Tremont core used in Intel's Atom line of processors.

You only have to glance at the chip layouts for the various Alder Lake variants to see the sheer difference in size between these smaller E-Cores and the P-Cores, with four E-Cores taking up the same space as a single P-Core. This difference in size has a fairly direct correlation with the overarching capability and power consumption of each core, with the

instruction in the order it's given. Meanwhile, performance processor designs could run out of order, choosing to complete whichever instruction it wanted to first, in order to maintain the fastest overall performance.

By doing away with all the extra circuitry at the so-called front end of the processor that was required to manage the organisation and reordering of tasks, the design of these Atom cores could be much smaller than the Core equivalents and use far less power.

In this way, understanding at least one core principle of what limited Atom's performance was quite simple. However, it quickly became evident that in-order execution was too slow to continue with, so modern Atom designs now also use out-of-order execution. This makes them faster, but trickier to see and understand the differences in core design.

The execution stage of the E-Core has a whopping 17 execution units – more than the P-Core

The next obvious difference is in the overall approach to handling instructions. With P-Cores and older Skylake cores, most instructions are received by the processor and then broken down (decoded) into simpler, smaller instructions known as micro-ops, which are then executed further down the line. The micro-ops are rejigged and organised for optimal execution order, and are stored in a micro-op cache. If the same operation is to be performed again, the original instruction then doesn't need to be decoded again.

With E-Cores, though, fewer operations are decoded into micro-ops and there's no micro-op cache, with instructions instead mostly decoded on the fly. Micro-ops can still be rearranged and executed out of order but not to the same extent as on performance cores. This makes for a simpler front end design but one that's far less speedy and responsive.

To alleviate this problem, E-Cores have a fairly large 64KB instruction cache (the P-Core instruction cache is only 32KB and the previous Atom architecture had only a 32KB cache too). This enables them to store as many pre-decode instructions as possible on-chip, rather than having to pull them from the power-hungry memory subsystem, in case they're needed again.

E-Cores also include Intel's first 'on-demand instruction length decoder', which generates pre-decode information for instructions in

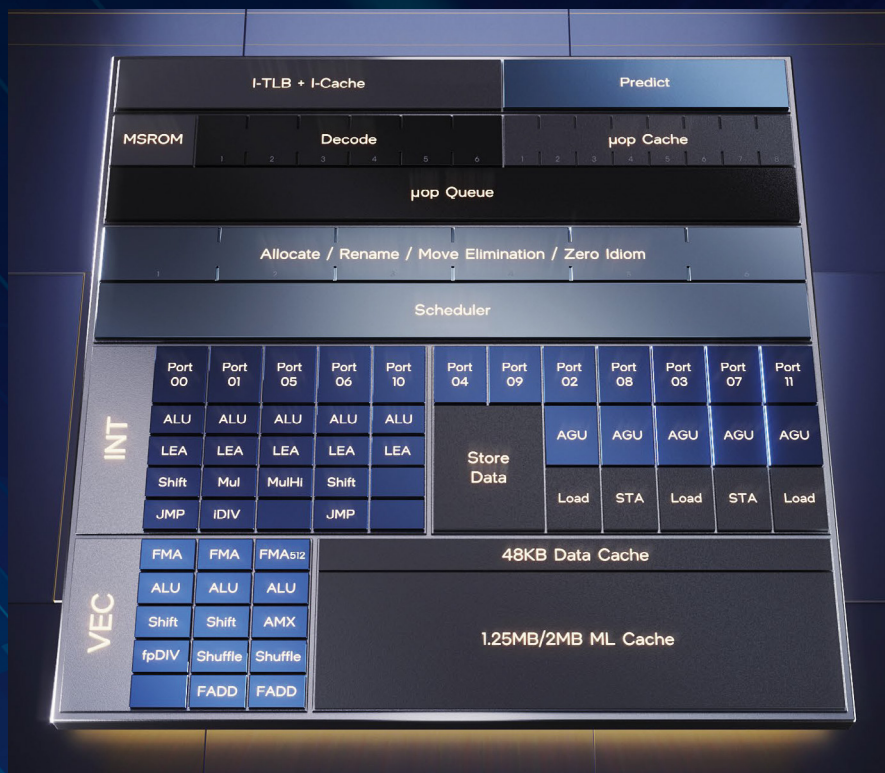
WITH E-CORES, THOUGH, FEWER OPERATIONS ARE DECODED INTO MICRO-OPS AND THERE'S NO MICRO-OP CACHE

E-Cores having fewer and smaller features.

When Atom first launched, there was a clear distinction that could summarise the difference in design between an Atom processor and Core processor. That's because those early-generation Atom processors used an in-order execution system whereby the processor can only perform each task or

One of the first areas where E-Cores differ from existing performance cores and the latest P-Cores is that E-cores don't support Hyper-Threading (although ironically the older in-order cores did support it).

As a result, each core can only handle one thread at a time, compared to the two threads that P-Cores can handle.



Alder Lake's P-Core provides a 19 per cent performance boost over its previous architecture, according to Intel

An analogy is having many fast taxis delivering a constant stream of a few passengers vs the occasional bus delivering many passengers all at once. They both get the job done, but one is far more responsive while the other is more efficient overall.

Other notable aspects of the new E-Core over previous Atom designs are the inclusion of AVX2 support, with two vector ports that support floating point multiply (FMUL) and floating point add (FADD) functions. This means the peak potential performance of the core is significantly higher than that of Tremont. Intel's latest security features are supported too, such as ControlFlow Enhancement Technology (CET) and virtualisation redirects via its VT-rp feature.

Along with all these more obvious building-block-style architectural changes, the other big difference with designing an E-Core vs a P-Core is that every step is taken to ensure power saving is prioritised over performance. There are myriad routes to designing with this priority in mind, but an obvious one is ensuring that voltages are kept as low as possible. That's because the dynamic power of these chips increases with the square of the voltage (power = node capacitance x node frequency x voltage² – $P = C \times F \times V^2$).

Nonetheless, as well as being focused on the efficient yet rapid execution of background tasks, Intel is insisting E-Cores will still play a part in highly threaded performance workloads, thanks to the load balancing

The front end of the P-Core architecture sees a significant increase in its overall width, with extra decoders and a doubling in micro-op cache

order to help speed up the decode process. Once an instruction has been sent off for decoding, it's passed to a decode system that can handle two streams of instructions, with each stream sharing instructions between three decoders, for what's deemed a dual 3-wide decoder setup.

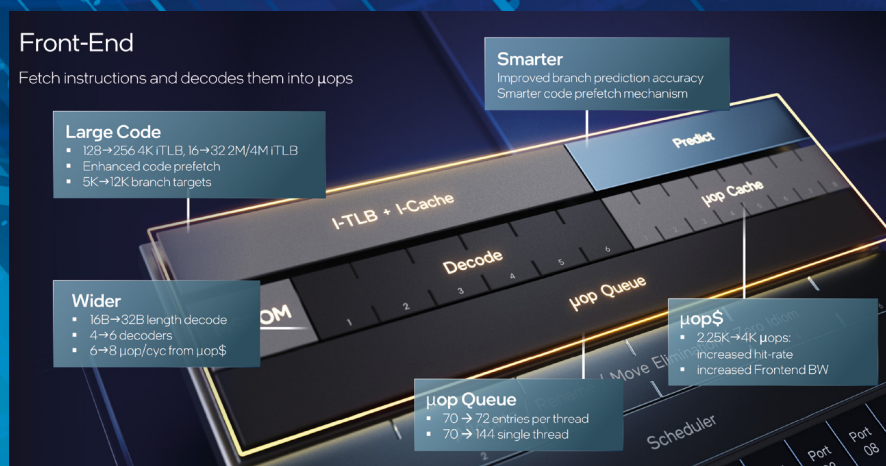
This is narrower than the 6-wide decoder setup for P-Cores (and 4-wide for Skylake-derived designs), although the comparison isn't a direct one given the overarching architectural differences. The decode system will also store a history of previous decodes in the instruction cache, so in some instances where the same decode is required again, the data is already on hand. This is a bit like having a micro-op cache but on a far smaller scale.

Once instructions are decoded, they're passed to the execution engine, which is where we see an even more intriguing situation regarding the performance capability of E-Cores vs P-Cores. Here we see that E-Cores have a whopping total of 17 execution ports (paths into which micro-ops can be fed for execution) compared to just 12 on P-Cores and just eight in the older Tremont Atom core.

However, each unit is less versatile and capable than those on performance cores, and the E-Core design also doesn't share ports for integer and vector operations like the P-Core.

The reason for this very wide but simple execution port is twofold. For one, it makes for a core that can quickly perform a very wide, varied set of work in parallel for any given instruction, and then power down as rapidly as possible.

Also, by segmenting out all the functions, Intel can keep those execution units that aren't needed powered down and save more power. In contrast, performance-focused core designs tend to prioritise keeping the execution units constantly fed in the most efficient manner in order to minimise overall latency and maximise performance.



Out of Order Engine

Track μ op dependencies and dispatch ready μ ops to execution units

Wider

5 $\rightarrow$ 6 wide allocation
10 $\rightarrow$ 12 execution ports

Deeper

512-entry Reorder-Buffer and larger Scheduler sizes

Smarter

More instructions "executed" at rename / allocation stage



provided by its Thread Director (more on this later). Plus, we can expect to see non-consumer variants of these processors that use dozens of these cores for specialist use.

Highlighting just what E-Cores can bring to the table, Intel claims the new efficient core uses 80 per cent less power for the same performance, or 80 per cent more performance for the same power, as the original Skylake implementation. Plus, its latency is 40 per cent lower for the same power compared with Skylake (or power is 40 per cent lower for the same latency). Both those claims represent mightily impressive improvements. Nonetheless, as far as most consumers are concerned, the likely key benefit of the addition of E-Cores will be lower power usage and longer battery life.

GOLDEN WONDER

While the addition of a new efficiency core is an interesting aspect of Alder Lake, particularly when it comes to mobile implementations of the architecture, the biggest deciding factor for gamers and other desktop PC users who value performance over power efficiency, is the capability of the performance cores and their Golden Cove architecture.

In some ways, Golden Cove appears to be a fairly iterative development of the Sunny Cove and Cypress Cove designs used in Intel's previous CPUs, but there's enough that's new here for Intel to make that claim about it being the biggest change in a decade.

Those big changes are most prominent in the front end of the core design, which sees a 50 per cent increase in the decoder machine width, moving from a 4-wide decoder to a 6-wide decoder setup. This change has been a notable point of debate, with AMD recently pointing out the practical drawbacks of going for a wider decoder design as a reason to stick with a 4-wide design in Zen 3.

As x86 instructions can vary so much in length, it's much harder to add more and more decoders than with instructions sets that have more fixed instruction lengths, such as Arm. Regardless, Intel has pushed ahead with this wider decoder setup and correspondingly

The back end of the P-Core sees modest improvements, with two extra execution ports and one extra integer ALU

The branch target buffer has also leapt in size from 5K entries to 12K entries, while Intel has talked up the improvement in the branch predictor, although the company is as secretive as ever about the specifics of those improvements.

Branching refers to the instances in code where there may be several possible outcomes, and predicting these outcomes, so the CPU is ready to execute whichever outcome occurs is a key part of speeding up modern processors.

THE END RESULT ACCORDING TO INTEL'S NUMBERS IS AN AVERAGE 19 PER CENT IMPROVEMENT IN INSTRUCTIONS PER CLOCK

doubled the micro-op cache size from 2.2K entries to 4K entries, in a move similar to AMD when it went from Zen to Zen 2 and doubled the micro-op cache from 2K to 4K.

Elsewhere, we see further increases in the specifications of the new architecture. The instruction translation lookaside buffer (i-TLB) doubles from 128 entries to 256 and the micro-op queue increases from 70 to 72 entries per thread for multi-threaded workloads (two threads per core) and from 70 to 144 entries for single-thread loads (one thread per core).

As we move to the execution portion of the P-Core, the main difference compared with Cypress Cove is the move from a 5-wide allocation and 10-wide execution port arrangement to a 6-wide allocation and 12-wide execution port arrangement. This matches the 6-wide allocation setup of AMD's Zen 3 architecture, although the comparison isn't entirely direct.

However, where Zen 3 uses a reorder buffer (known as a ROB, and used to store the outcome of instructions for use by other

Integer Execution Units

5th Integer execution port /
ALU added

1-cycle LEA on all 5 ports
Used also for arithmetic calculations

The execution units of P-Cores are combined so that integer and vector operations can be passed to the same ports

Intel® Advanced Matrix Extensions (Intel® AMX)

Tiled Matrix Multiplication Accelerator - Data Center

AMX
2048 int8

↑
8x

operations / cycle / core

VNNI
256 int8



AI applications have dedicated acceleration hardware in Alder Lake, courtesy of the P-Core's AMX hardware

instructions) of 256 entries, Golden Cove has a whopping 512-entry ROB, up from the 352 entries used in Cypress Cove. Meanwhile, for comparison, the E-Cores work with a 256-entry ROB.

The overall picture is of evermore potential micro-op work being in-flight at once, increasing the likelihood that the execution ports themselves can be kept constantly fed with tasks and never starved of work.

The counter-argument for just going ever wider and larger in this way is that you get diminishing returns (you can only usefully juggle so many micro-ops before you just need to get on and execute them). However,

clearly Intel feels that it's implemented sophisticated enough techniques for managing the workload that this was the right approach.

As for the execution ports themselves, Intel still uses a fused system for allocating both integer and floating point workloads, compared with the clearly split pipelines used in both its own E-Cores and in AMD's Zen 3 design. The number of ports has increased from ten in Cypress Cove to 12 in Golden Cove.

These additional ports bring extra execution hardware with them in the shape of an extra integer execution port, adding an extra arithmetic logic unit (ALU) and load effective address (LEA) unit, which effectively increases the raw integer processing power over Cypress Cove by 20 per cent.

There's also an additional dedicated port with a load AGU, increasing the possible number of memory loads per cycle from two to three, which puts Golden Cove in line with Zen 3.

Floating point performance has also been boosted via the addition of two dedicated floating point add (FADD) units, which are added to the existing execution port line-up, rather than being attached to any new dedicated ports.

The floating point multiply add (FMA) units have also been given 16-bit floating point (FP16) support, although Intel has actually dropped AVX512 support – a feature it boasted as setting its previous architectures apart from AMD's.

The upshot is a relatively small increase in overall execution (back end) hardware improvement when compared with the large increases in decode and micro-op management (front end) hardware. Regardless, the end result according to Intel's numbers is an average 19 per cent improvement in instructions per clock, although notably, there are some tests where performance drops significantly compared with Cypress Cove, which we wouldn't have expected to see.

As well as tweaks to performance for existing workloads, Golden Cove also introduces dedicated hardware for matrix multiplication and related workloads, with its advanced matrix extensions (AMX). These are used for accelerating machine learning

workloads, in the same way as Tensor cores on Nvidia GPUs and indeed the AMX cores on Intel's new Xe-HPG GPU cores.

INTEL THREAD DIRECTOR

The basic idea of having powerful cores and power-efficient cores is simple enough but unless programs know how to make best use of them, they aren't much use at all. To this end, a system for assigning software tasks (threads) to the right cores is required.

This can be (and is) done to an extent just by assigning threads to cores based on static rules, such as foreground and background software flags. However, this approach doesn't maximise performance, creates overheads for software developers and doesn't account for plenty of scenarios, such as if a thread gets stuck in an unresponsive loop while assigned to a performance core.

Accordingly, Intel has developed a new hardware feature called Thread Director, which sits between the operating system's thread scheduler and the cores of the CPU. The technology works by dynamically analysing the current load of any given thread, looking at its instruction mix, the current state of each core and microarchitecture telemetry, then feeds that information back to the operating system's thread scheduler so that it can better reassign workloads to the appropriate cores.

The Thread Director is Intel's solution to managing which core on Alder Lake takes on which task

It does all this with apparently nanosecond-level timing and precision, so the switching of workloads to appropriate cores should happen very quickly. The whole setup is baked into the CPUs and supported by various operating systems, including Windows 10 and 11, adding a whole new layer of software-independent granularity to thread management.

THE CHIPS ARE UP

We've looked in detail at the two new core designs used in Intel's latest CPUs, but there's plenty more going on under the hood of an Alder Lake CPU, with integrated graphics, memory interfaces and other dedicated acceleration hardware all required to make up a full chip. Indeed, it's striking that Intel has made the design of Alder Lake so modular.

Along with the two cores types, Intel highlights nine main blocks that can be arranged together to form the three initial variants of Alder Lake coming to market. These consist of a display controller block, a PCI-E interface, Thunderbolt 4 controller, a gaussian and neural accelerator (GNA 3) for offsetting applications such as AI speech and noise cancelling, an image processing unit (IPU), display controller, two configurations of the company's Xe-LP graphics (the same as in Tiger Lake but ported to Intel 7 manufacturing), the blocks of four E-Cores, the P-Cores and a memory interface.

Starting with the desktop configuration, these will use up to eight P-Cores (for an

8-core/16-thread maximum setup) along with another eight E-Cores split into two blocks of four. Also included will be the smaller 32 execution unit configuration of the Xe-LP graphics blocks, along with a display controller, GNA 3 block, PCI-E interface and memory interface.

The latter is a universal interface that can support DDR5 at 4800MT/sec (effective MHz), DDR4 memory at 3200MT/sec, LPDDR5 at 5200MT/sec and LPDDR4X at 4266MT/sec, so we can potentially see all sorts of odd motherboard configurations with multiple memory options. What these desktop processors don't include, however, is Thunderbolt 4 support, nor do they get the image processing unit.

For the standard mobile configurations (UP3), we see those Thunderbolt and IPU units included, along with the more powerful 96-EU configuration of Xe-LP graphics, as befits a systems that will more likely rely on integrated graphics and sophisticated external connection configurations. The E-Core count remains the same, as it does for even the lowest-power UP4 configuration, but the P-Core count maxes out at six (for 12 threads).

Finally, the ultra-mobile UP4 configuration includes the same components as the UP3 configuration, but its Thunderbolt port count drops from four to two while its P-Core count maxes out at just two. It's this final configuration that really highlights the benefit of such a hybrid system, as many ultra-mobile

Introducing

Intel Thread Director

Intelligence built directly into the core

Monitors the runtime instruction mix

of each thread and as well as the state of each core – with nanosecond precision

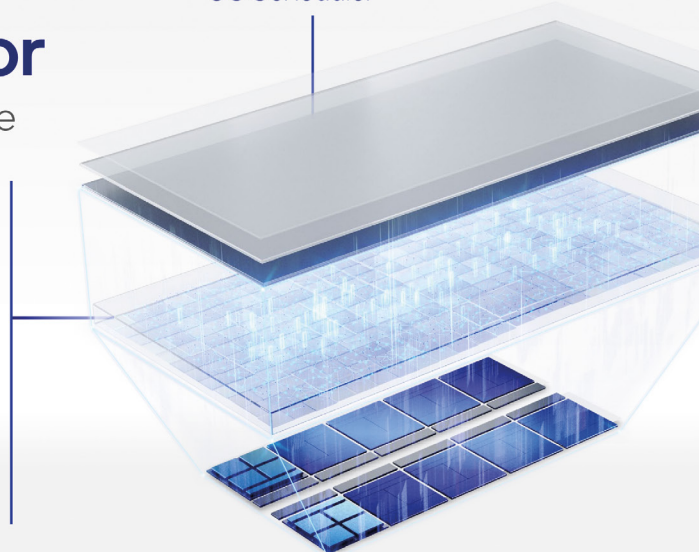
Provides runtime feedback to the OS

to make the optimal scheduling decision for any workload or workflow

Dynamically adapts guidance

based on the thermal design point, operating conditions, and power settings – without any user input

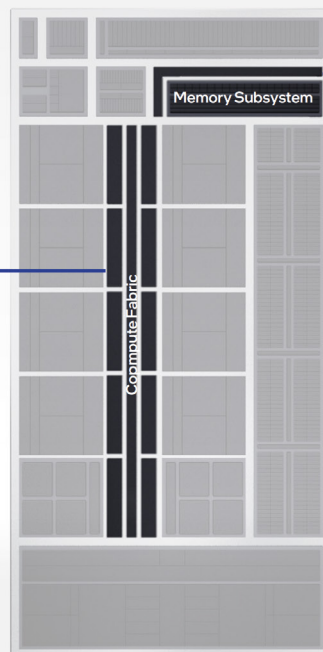
OS Scheduler



Alder Lake Interconnect

Compute Fabric

Up to
1000 GB/s
Dynamic Latency
Optimization



I/O Fabric

Up to
64 GB/s
Real-time, demand-based BW control

Memory Fabric

Up To
204 GB/s
Dynamic Bus Width & Frequency

laptops and tablets do really only need a couple of powerful cores for most tasks, but still need plenty of multi-core power for background tasks.

Regardless of which configuration is used, all Alder Lake CPUs use the same dual-ring, on-chip interconnect (called the compute fabric) to share information between each P-Core and each cluster of four E-Cores. This interconnect provides up to 1,000GB/sec of

Communication between the rest of the chip and the memory interface is handled by the memory fabric/subsystem, which provides up to 204GB/sec of bandwidth and can scale both its bus width and frequency up and down to provide maximum performance only when it's needed.

The third crucial interconnect of these chips is the I/O fabric that handles communication with PCI-E devices and other internal devices.

Alder Lake uses three key internal interconnects to manage communication between the cores, external devices and memory

simply doesn't have a CPU that offers this sort of potential performance and power-saving combination.

Meanwhile, at the top end, even the fact that Intel has limited Alder Lake to eight P-Cores shows where it feels the market is going – for most users, more than eight cores is overkill – and the big core-count push that brought AMD back into prominence in the CPU market just a handful of years ago is providing ever diminishing returns.

Ultimately, we won't get a true sense of how this situation will pan out until AMD's Zen 4 architecture hits the market next year. With it set to use TSMC's latest 5nm manufacturing process, it could leapfrog Alder Lake just based on that advantage alone, not to mention the fact that it's likely to include a larger number of performance cores than Alder Lake, which will appeal to many desktop users.

If Zen 4 can deliver an equally compelling balance of performance and power saving without a hybrid approach – as current rumours suggest it won't use – then we could continue to see AMD make inroads into the mobile market too. Either way, with DDR5 now arriving and plenty of other big changes with Alder Lake and Zen 4, it's going to be an interesting few months. [GPA](#)

WE WON'T GET A TRUE SENSE OF HOW THIS SITUATION WILL PAN OUT UNTIL AMD'S ZEN 4 ARCHITECTURE HITS THE MARKET NEXT YEAR

bandwidth, depending on the number of cores, which should certainly be ample considering the maximum count of eight P-Cores, and the fact that each E-Core block shares its connection anyway, so the shared connection is likely to be the bottleneck before the dual ring becomes a limiting factor.

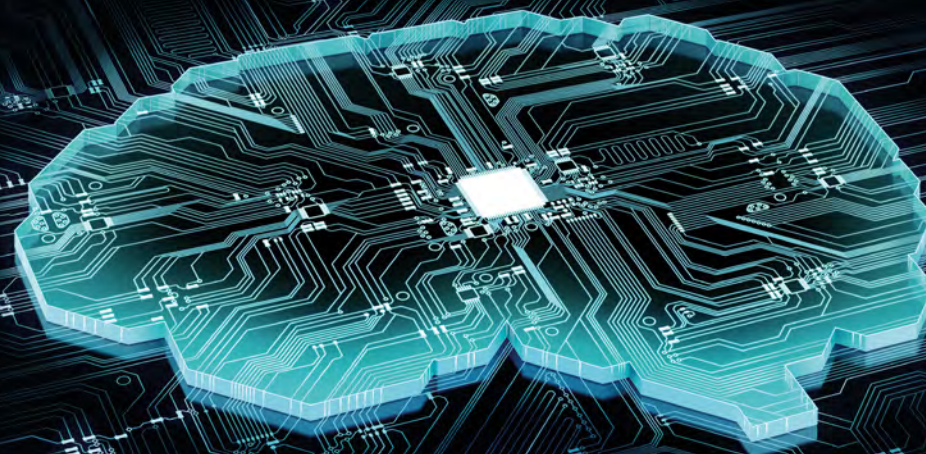
The load on this compute fabric is constantly monitored, and its frequency and operation scaled accordingly.

However, while one of the dual rings can be disabled in low-bandwidth situations, once it's switched on, the ring is fully enabled, which could potentially negate some of the power-saving efforts of the rest of the chip.

This supports up to 16x PCI-E 5 devices and 4x PCI-E 4 devices, with PCI-E 5 doubling the bandwidth of PCI-E 4. The I/O fabric can again scale its speed according to the load on it, without affecting the operation of any single connected device.

RIISING TO THE SURFACE

With stated thermal design power (TDP) ratings of 7W to 125W, it's clear just how wide a range of devices Intel is hoping to capture with Alder Lake. If the hybrid approach works and maximum performance is competitive, it's sure to give AMD plenty to think about. At the low-power end of the market, AMD



INSIDE DDR5

ANTONY LEATHER INVESTIGATES WHAT'S NEW WITH DDR5 MEMORY, HOW IT WORKS AND WHETHER YOU SHOULD UPGRADE

Like it or not, every few years technology advances and our once-shiny new tech becomes old news. Most upgrades are fun, exciting and can improve performance of your PC, but levelling up memory generations is often the least favourable way to upgrade your PC. It invariably means buying a new CPU and motherboard, or is another added cost when upgrading those features.

Upgrading from one type of memory to another frequently doesn't lead to particularly noticeable performance improvements either. There's often increased latencies with newer, faster standards, in addition to higher prices for the same capacity and far fewer kits from which to choose. That said, there are equally as many benefits to memory upgrades, including lower power draw, higher densities, higher bandwidth and higher frequencies.

The first desktop CPU platform to offer DDR5 support will be Intel's Z690 chipset with its new LGA1700 socket and Alder Lake CPUs, although the shift to DDR5 won't be

complete, at least not at first. While high-end motherboards will opt for the new DIMMs, some LGA1700 motherboards, especially the more affordable ones, will support DDR4.

In fact, you'll even see two versions of the same model in some cases, such as MSI's MAG Z690 Tomahawk, which will come in DDR4 and DDR5-supporting flavours. In this

one serving each memory module (DIMM) when used with two modules and each channel shared across two modules when used in a four-module configuration – that's why running four memory sticks doesn't gain you any performance and can in fact reduce performance. Each of these channels provides a single 64-bit interconnect to the

THE TASK OF DEALING WITH VOLTAGE REGULATION WILL FALL ON THE MEMORY MODULES THEMSELVES, THANKS TO A NEW POWER MANAGEMENT INTEGRATED CIRCUIT

article, though, we want to delve into how DDR5 differs from DDR4, explore the benefits and ask if upgrading to DDR5 will be worth it, given the hefty upgrade costs that will likely be involved.

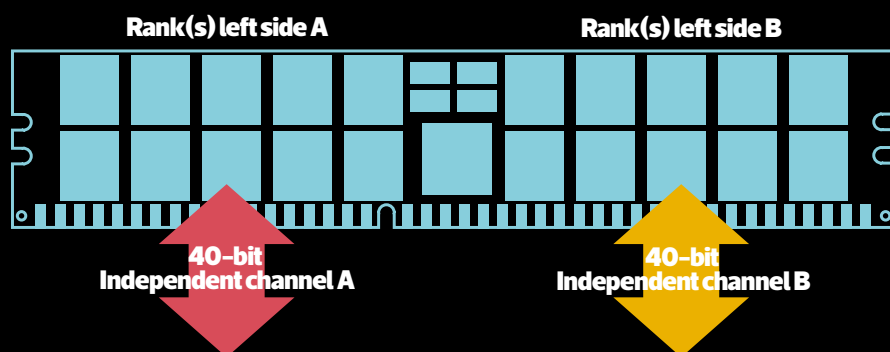
Two channels per module

Current mainstream desktop motherboards have two DDR4 memory channels, with

attached modules. With DDR5, though, each module gains a second channel and now has dual 32-bit channels (actually 40 bits with ECC, which we'll discuss later), so even using two modules can allow for four independent memory channels.

While the overall bandwidth of the channels hasn't changed, the greater versatility in ways to access the modules can make memory

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DDR5 moves from a single 64-bit channel to two 32-bit/40-bit channels

accesses more efficient. This could also mean that high-end desktop motherboards just lost one of their advantages too, which is to offer more than two memory channels.

Other improvements to the overall access pattern of DDR5 include a doubling of the prefetch buffer size that moves from 8n (eight data words per memory access) with DDR3 and DDR4 to 16n with DDR5. Similarly, the burst length – the amount of data that can be accessed in a single read/write command – has risen from eight to 16 bytes. This allows a single burst to access 64 bytes per operation.

Another factor in overall memory performance is the number of ranks (the number of memory banks on a module, generally arranged in a row on one side of the module) on a memory module. Dual-rank modules with chips on both sides generally offer more performance than single-rank modules, especially with modern AMD systems. This situation will remain with DDR5 but the next logical block used to access memory, the bank, will see changes.

To access a memory cell, you must first find the rank (a data block that's 64 bits wide) then define its bank before picking out the column and row the data is on. With DDR5, the number of banks per rank is doubling from 16 to 32 (arranged in eight bank groups each with four banks), increasing the overall

accessible memory per rank. To help alleviate any potential bottlenecks from having an even larger block of data open at one time, DDR5 also introduces the ability to refresh the memory of a bank (DDR memory needs to be constantly rewritten by a refresh command) while still keeping the other banks in each rank accessible. Previously a bank refresh would affect all the banks at once.

On-DIMM power management

Until now, desktop motherboards have had to regulate memory voltage, with plenty of motherboard-side power circuitry on board to handle it. With DDR5, though, the task of dealing with voltage regulation will fall on the memory modules themselves, thanks to a new a power management integrated circuit (PMIC) on each DIMM.

This could have a few upsides, such as motherboard designs being less complicated and potentially cheaper, reduced signal noise and interference, and memory manufacturers



Most new DDR5 modules will include heatsinks, and this time they might actually be required, unlike on most DDR4 modules

being able to cater more for their own modules. Indeed, Corsair now has memory overclocking integrated into its iCUE software and claims it makes for easier, finely tuned and more stable overclocking compared with motherboard control. You can even create your own XMP profiles within the software too, boosting performance when particular apps are loaded.

However, the presence of the PMIC is likely to increase the cost of DDR5 memory, and with higher densities and capacities in addition to the voltage regulator circuitry, waste heat could increase too.

This is something Kingston's Iwona Zalewska all but confirmed to us, saying that while DDR5 memory uses less power than DDR4, the PMICs may run hotter than any components featured on DDR4 modules. Zalewska further explained that it's for this reason that Kingston's overclockable memory will feature heatspreaders to keep them cool when running at extreme speeds, which is something we can also expect from most other manufacturers.

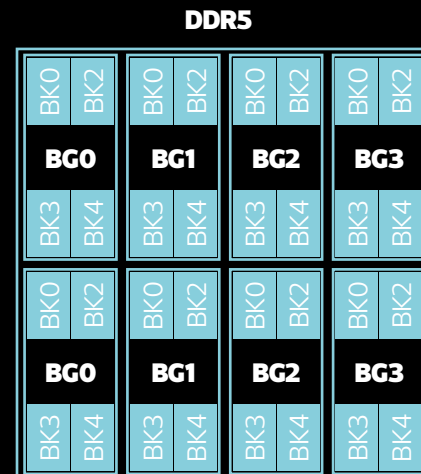
However, considering that many existing DDR4 modules incorporate largely unnecessary heatspreaders – they're often just cosmetic – the net result for buyers will



A cluster of power management circuitry is now a prominent feature on most uncovered DDR5 DIMMs



16 banks

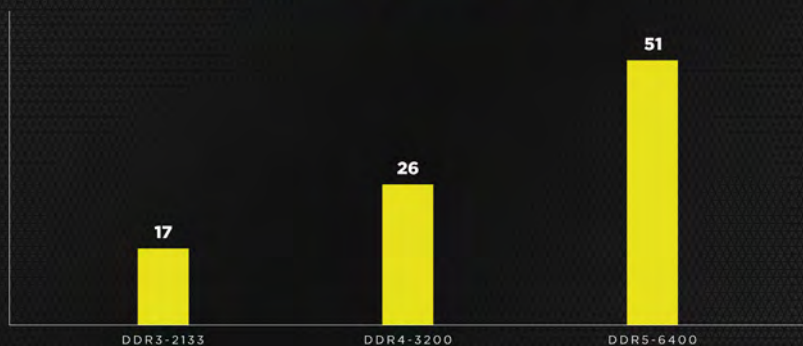


32 banks

DDR5 uses a configuration of eight bank groups of four banks, up from four groups of four with DDR4

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57827681240816623794411761295835564 87 7681240

DDR MEMORY BANDWIDTH (GB/S)



MAXIMUM DRAM UDIMM CAPACITY (GB)



The maximum capacity per DIMM for DDR5 has increased fourfold, although most users will still get by with just 16GB total system RAM

likely be that DDR5 modules aren't any larger, more cumbersome or hotter to the touch than DDR4 modules.

Lower power

Further helping to ensure heat likely won't be an issue with DDR5 memory is that while there will be extra, toasty power regulation circuitry on the PCB, the memory itself will be running at a lower voltage compared with DDR4. As power consumption of memory increases directly with voltage, any reduction in voltage should reduce heat generation.

This is something we saw evidenced when we moved from the 1.5V of DDR3 to the 1.2V of DDR4, with power savings in the region of 25 to 40 per cent. The reduction in voltage with DDR5 isn't as large, though, dropping to just 1.1V or by 8.3 per cent compared to the 20 per cent drop from DDR3 to DDR4. There are other factors at play too, such as frequency and the load on the memory, so it remains to be seen how real-world power usage will be affected.

Also yet to be determined is how the lower voltage will factor into memory overclocking. It's likely the change to an on-board PMIC will be the far bigger factor but a lower voltage could mean more headroom or conversely that even tighter control is required.

We'll be putting this to the test more thoroughly in the future, once we've had more time hands-on with Alder Lake CPUs and LGA1700 motherboards.

Maximum typical bandwidth of DDR5 will see big increases over DDR4 but it will be some time before 6400MHz modules are widely available

memory frequency above 3600MHz seeing diminishing returns.

Much higher frequencies will come as standard with DDR5, though, as 4800MHz is now the new baseline and manufacturers are already offering modules clocked at 5200MHz with faster speeds expected soon. This will result in CPU memory support increasing in order to make the most of the new standard, while overclocked memory will reach even higher speeds.

Higher capacity

Speed, bandwidth and efficiency are undoubtedly the most interesting improvements for PC users when it comes to DDR5 and the most likely to boost performance. However, capacities will also rise, even if 16GB will likely remain the baseline amount of memory for some time, with only high-end gaming or content-creation systems needing to upgrade to 32GB.

With DDR4, the maximum per-module capacity is 32GB, hence 4-slot, dual-channel motherboards are limited to 128GB and 2-slot mini-ITX motherboards are limited to 64GB. With DDR5, the per-module capacity limit rises to 128GB, or even higher in some cases. Clearly, though, seeing as most of us would struggle to push 32GB of RAM to its limit, the higher capacities on offer with DDR5 aren't likely to be as attractive to your typical PC enthusiast as the other benefits.

On-die ECC

You might think all those ones and zeros floating around in the circuits of your PC are transferring data reliably, with data arriving at

WITH DDR5, THE HIGHER DENSITY AND FREQUENCIES OF THE MEMORY HAVE NECESSITATED ECC BECOMING A STANDARD FOR ALL MEMORY MODULES

Higher speeds

Memory speed hasn't been much of a talking point outside of AMD circles, where the fact that the memory clock is tied to AMD's high-speed CPU interconnect called Infinity Fabric means higher speeds can have much more of an impact on performance than with Intel systems. Even then, it has its limits, with any

the other end in the same form it left and not prone to errors being introduced. However, that isn't always the case. High temperatures and even background radiation can all introduce errors. This has always been a problem but with smaller microchips and ever increasing frequencies, it can be trickier to account for these errors.

On-die ECC will bring a degree of extra data integrity to desktop memory but won't match full ECC systems

The tolerances required to create reliable circuits are in part why, for example, Intel has struggled to produce 10nm CPUs on a big enough scale and large enough yields, and has instead had to use its larger 14nm process nodes for several CPU generations.

One such error example is bit flipping, which is where a bit of data in a memory location randomly flips from a one to a zero or vice versa of its own accord. The chances of this happening in a PC are very small but, with ever increasing memory capacities, the chances are ever greater, and certainly once you move to the scale of working in datacentres, it can be a huge concern.

For this reason, Error Correction Code or ECC is used to detect these rare errors that could otherwise cause serious issues.

Previously, ECC memory was only required for those specialist scenarios but with DDR5, the higher density and frequencies of the memory have necessitated ECC becoming a standard for all memory modules. However,



while most or all of the data pipeline – the memory, storage and CPU – is ECC-enabled in areas such as datacentres (to enable full integrity of the data) with DDR5 in a desktop PC environment, the ECC is on-die only.

This means that it will be used to check data stored in the memory when it's there, but not anywhere else. The data isn't checked before it enters the memory and there's no ECC elsewhere either, unless you're using an ECC-

enabled CPU, so you're not getting the same level of error checking – just enough to deal with DDR5's greater susceptibility to errors.

This means that DDR5 will be safe to use, whether it's in a £1,000 gaming PC or £5,000 workstation. What's more, ECC could also help to keep costs down by allowing memory manufacturers to use more memory chips than otherwise might make the cut, improving yields and lowering average chip cost.

KINGSTON TALKS DDR5

WE SPOKE TO IWONA ZALEWSKA, SALES MANAGER, DRAM BUSINESS MANAGER, EMEA REGION FROM KINGSTON ABOUT SOME OF THE BURNING QUESTIONS SURROUNDING DDR5

CPC: What are prices for DDR5 going to be like – will it be significantly more expensive than DDR4?

Zalewska: As with every new memory technology introduction, we can expect there will be a premium for the new memory. Looking back at previous generations, DDR4 was 30 to 40 per cent more expensive than DDR3 when it launched. We can expect the same for DDR5, particularly since it requires more components per module (PMIC, additional DRAM for ECC per 32-bit subchannel).

CPC: What sort of latencies and speeds can we expect from DDR5 at launch, compared with DDR4?

Zalewska: DDR5 will launch with JEDEC standard speed, timings, and voltage of 4800MT/sec, CL40 (CAS Latency) and 1.1V respectively. Some systems may force the

memory to down-clock if multiple DIMMs are installed per channel. The down-clock speed is 4400MT/sec CL36.

The next generation of DDR5 will launch sometime in 2022 at 5200MT/sec CL42. Overclock speeds, timings, and voltages are yet to be disclosed.

CPC: What is the benefit of moving the voltage regulators off the motherboard and onto the DDR5 module? Will this affect the cost of the motherboard and the memory module?

Zalewska: For server class modules, the PMIC uses 12V, and for PC class modules, the PMIC uses 5V. This makes for better power distribution than previous generations, and improves signal integrity and reduces noise.

Moving the PMICs from the motherboard to the memory module also frees up space on the motherboard and potentially reduces

its cost. Conversely having another group of components on the memory module will add to its cost.

Another consequence of the PMIC on the module will be increased heat, which will be a concern for overclocking and effective heat dissipation at high speeds and higher voltages.

CPC: Will there be an uplift in terms of the minimum and maximum capacity of your memory kits, compared with DDR4?

Zalewska: For PCs, there will be 8GB, 16GB, and 32GB DIMMs at launch using 16Gb density DRAM. SODIMMs will follow with 8GB, 16GB, and 32GB sometime later.

In approximately two years, these will increase to 12GB, 24GB and 48GB using 24Gb density DRAM. For servers, there will be 16GB, 32GB and 64GB registered DIMMs at launch. There will also be 128GB and 256GB Load Reduced DIMMs (LRDIMMs). **CPC**



The Thing in its full glory

THE THING

ANTTI VÄISÄNEN GUIDES US THROUGH THE CREATION OF HIS 3D-PRINTED CASE

The Thing is my second 3D-printed case, following the creation of AV3D, a machine I built for the Cooler Master Case Mod World Series (CMWS) 2018 modding competition. That was a bigger ATX case but this time I wanted to try something a little smaller.

The inspiration for this build came one night following a conversation with my wife. I'd said I wanted to make my own mini-ITX case design but didn't know what it should look like, and she assured me I'd figure it out in my sleep.

Sure enough, the next day I woke up and the design had come to me, so I hopped on to my computer and started to draw. It took three

long weeks of drawing and 3D modelling but eventually I came up with the basic design.

At this point, I didn't have any hardware or water-cooling components, so I had a tough time figuring out some of the key case dimensions. Then it hit me like lightning out of a clear sky; I did have something that I could use, but it just happened to be in my current PC.

There was an Alphacool 3 x 80mm radiator that I could measure, so I pulled my computer to pieces and started to design the case to fit the radiator. Then I found out that Alphacool has 3D models for their parts, so I destroyed my current computer for nothing. You live and learn. After I found the 3D models, it was easy

to place all of the water-cooling parts in my model and figure out the final case dimensions.

Although I was able to finalise dimensions for the water-cooling components, I still didn't have a motherboard or graphics card, so I had to use some generic 3D models to figure out the best layout. Thankfully, the key parts such as the mounting screws are standardised and other than graphics card length, there aren't too many other aspects of the design of these components that varies too much.

One of the most prominent features of the case is its fan grilles that cover the front intake fans, the rear exhaust fan and the GPU exhaust on the side. Figuring out what design

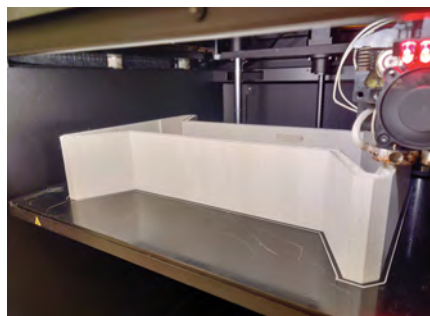
to use for this took a long time and scrolling through hundreds pages of different designs. Eventually I settled on my own pattern based on a repeated three-arrow shape.

One of the most difficult things to figure out was a way to ensure that you don't have to glue any of the case's parts together, and instead everything can be taken apart easily. The front grille, for instance, is attached with recessed magnets while several of the panels are bolted together.

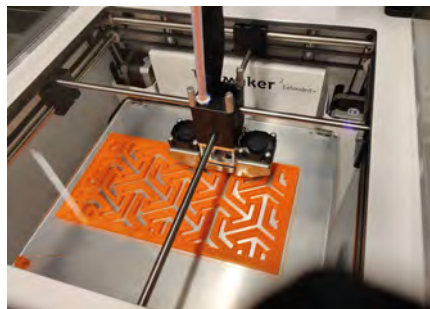
Choosing the colours used in the build was one of the easier choices. White and orange are the colours we've chosen for the interior of our home, so the new PC should fit right in. As for why it's called The Thing, when I started to write my project logs for the build, to document my progress, I didn't know what to call it, so the best I could come up with was The Thing.

PICKING THE PARTS

The basic layout of the case was ready but I still didn't have any hardware to put in it. So, I started to reach out to manufacturers for help with the parts. This took many months but I was so lucky that Gigabyte/Aorus and TeamGroup joined to sponsor this build, providing the GPU and motherboard, and SSD and memory respectively. As for water cooling, I've teamed up with Alphacool many times, so they stepped up to the plate as usual.



The Minifactory Innovator can print big parts



The Ultimaker 2 Extended+ was perfect for printing the smaller parts



Magnets were used to attach the front and side grilles to help with accessing the case

I only really had one key requirement for the components, which was for the GPU length to be just right. Because of the way the GPU sits on the side of the case, I didn't want it to be too small or too big but just right. Thankfully, the Vision RTX 3060 that Gigabyte sent fit both



Almost all of the non-component parts of the build are 3D printed

When it came to the fans, I used ARCTIC P8 PWM PST 80mm models and they work really well in this build. There are three fans on the radiator, which are daisy-chained together, so they use fewer cables, plus there's another fan in the back panel.

MY FIRST PROTOTYPE WAS PRINTED IN PLA PLASTIC BECAUSE IT'S EASY TO PRINT AND WORKS FINE AS A PROTOTYPE MATERIAL

the length requirements and the style of the case perfectly, so I didn't have to change my design for it.

This mod doesn't have extreme hardware but I don't need top-of-the-line components with my daily work and casual gaming. It will be easy to upgrade to a better CPU if needed, and there's one spare M.2 slot for upgrading storage too. That's why I put the 512GB drive in the back slot on the motherboard.

LET THE PRINTING BEGIN

My first prototype was printed in PLA plastic because it's easy to print and works fine as a prototype material. I am so lucky because I can use my workplace's 3D printing gear – there's one bigger printer – the Minifactory Innovator, and two smaller Ultimaker 2 Extended+ printers. For those of you who are interested in 3D printing, for this first print I used a 0.5mm nozzle, 0.3mm layer height, five top/bottom



Test-fitting the water-cooling parts to the case

SYSTEM SPECS

Sponsors Alphacool, Gigabyte, Aorus, TeamGroup

Graphics card Nvidia GeForce RTX 3080 Founders Edition with EK-FE waterblock

Case Custom-made, 3D printed

CPU Intel Core i5-11400F

Motherboard Gigabyte Z590I Aorus Ultra

Graphics card Gigabyte Vision RTX 3060

Memory 16GB Teamgroup Dark Z

PSU SilverStone SST-SX650-G (SFX)

SSD 512GB Teamgroup T-Force Cardea Zero Z340

Cooling Custom water cooling with Alphacool parts

layers, a wall thickness of 1.5mm and 12 per cent infill.

Initially, I wanted to print this case as one big part, with separate covers/grilles for the front and back, but the 3D printing time was over 70 hours, so I split the case in two parts. As I was printing the first part there was a jam at the 3D printer's nozzle, so the print came out 16mm short. This was frustrating, but 3D printing isn't always easy, so I just had to keep moving.

After I finished the front part of the case, I did a test fit of the water-cooling parts and they slotted into place perfectly. Now was the time for the back half of the case and here I took advantage of the missing 16mm from the front. Instead of scrapping that piece and starting again, I simply made an orange spacer to fill the gap. The end result was so good that I incorporated it into the final design.

When I had all of the 3D-printed parts ready, it was time to test-fit everything, and unfortunately, there were so many problems with the cable routing for the motherboard and GPU that I had to do some major changes. I also forgot to add a power button, so it was back to the drawing board for that.

This is the idea for attaching the two halves that came from the viewers on my project log



The use of smaller than usual 80mm fans looks great with this build

At this point, I had a recycling bin full of prototype parts, but that was always going to be likely when designing a 3D-printed case from scratch. One week later, I almost had a working model but I still had to resolve how to secure the two case halves together; thanks to the help of viewers on my worklog, I came up with a plan for what would be easy to implement on the 3D model.

With all the prototyping and testing done, it was time to print the final version of the case. For this I used PETG, because it's easy to print and it can withstand more heat than PLA. The PETG I used was ColorFabb Economy white, which I chose for two reasons: it has a good white colour and there's 2.2kg material per spool, so there's plenty to work with (thanks to all the not-so-good test prints, I used two of these spools). It was a nerve-wracking 36-hour wait for the print, just for the one half of the case, but the print came out nice and I



This was my first go at hardline tubing but only two 90-degree bends were needed

was so happy of the end result. A little more confident, I then set the print going for the other half only to return the next morning to find that the print was so bad I had to bin it. Thankfully, it only took one more attempt to get as good a print as the front part.

The orange parts of the build were easy to print because almost all of the parts were flat and small. I used both PLA and PETG for them, as these parts aren't as structurally important.

THE ASSEMBLY

My plan was to paint the case, but as the print quality and colour was so good, I changed my mind and used the parts as they were. There was some cleaning up to do first, such as removing the support material, which I did with a sharp knife. There's a couple of imperfections on the prints but it didn't bother me too much and more important to me is now you can see the layer lines, so you know it's 3D printed.



The back panel design took several iterations to get just right



The Gigabyte Vision RTX 3060 is perfect for this build

3D PRINTING IS SUCH A GOOD WAY TO GET INTO CASE MODDING BECAUSE NOT EVERYONE CAN ACCESS LASER CUTTING OR METAL SHOPS

Finally it was time to assemble the PC, and I was so nervous that I had forgotten something. Build order for this case was very exact so there was plenty of room for mistakes. First, I added the water-cooling components to the front part of the case. I used soft tubing on the inside because it's easier and I think more secure that way.

Next, the two parts were joined together. Because of where the motherboard is placed, I had to connect all the cables and route them to the back side of the motherboard. The fit was so tight that I had to cut away a piece of the motherboard's metal back panel. Cable management was hard because the case isn't big on the inside, but I eventually managed to neaten the cables, and they don't block airflow.

Hardline tubing was up next, and this was my first time doing hardline tubing, so I was

extra nervous. Thankfully, there were only two 90-degree turns, so there wasn't a lot of difficulty with regards to tube bending. After a successful leak test, I was relieved to be nearing the finishing line for this build.

The next few stages were to fit the front grille and the grille on the back of the graphics card. These are secured with magnets, so it's a nice and easy way to get inside to the case if I need to service anything. Last but not least, the graphics card was put in its place and I'd finished my own 3D-printed mini-ITX case.

THE THING

Building The Thing had its ups and downs, but because it's so easy to make prototypes and change the design when 3D printing, this made the whole process easier. I'm not an expert 3D modeller or 3D printer but I have learned

so much working with this case and got lots of help from viewers on my project log. For this project, I used Autodesk Fusion 360 and Microsoft 3D builder (you may laugh at me using such basic software but it's easy to use for making basic models).

Using 3D printing is such a good way to get into case modding because not everyone can access laser cutting or metal shops capable of making the designs we want. I'm lucky that I can use my workplace 3D printers to do my mods, and they're expensive printers, but even basic printers can get the job done. You just need patience and lots of filament.

Overall, I'm very pleased with the end result of this mod. It has also featured in mod of the month competitions on both bit-tech.net and builds.GG, which I'm very happy about. There are a few things I might do differently next time though. The most obvious one is that I didn't think to add an easy way to drain the water-cooling loop, so that's going to be fun when it comes time to give the system a clean. As for my next mod, I have teamed up with Jonsbo, so something cool is incoming and I am so excited to finally use wood filament. **CPC**



GARETH HALFACREE'S

Hobby tech

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

ANALYSIS

The MNT Reform project

For most laptop manufacturers, the computer is the product, but for MNT, the laptop is merely part of the story.

The MNT Reform (see over) is designed to be open – aggressively so, in fact. From the 3D-printed trackball to the motherboard, the system-on-module, and even the system management controller – both hardware and software – every part that goes into the Reform is published under an open-source licence.



3D-printed parts such as the trackball have already been respun and improved by the community

If you're unhappy with the performance, you can – skills allowing – design a replacement system-on-module using the design files published for the original as a basis. MNT itself is already doing so, in fact, promising both a more powerful Arm variant and investigating the possibility of an even more open design built on a RISC-V implementation. An FPGA add-on design has also been released, although it's not yet available for sale, allowing the use of soft-core processors in place of fixed-purpose silicon.

If the scratchy trackball annoys you, and it probably will, you can print a replacement with steel ball bearings to provide reduced friction and a smoother scroll – and several community members have already done so, publishing STL files for their modifications, so others can easily follow in their footsteps.

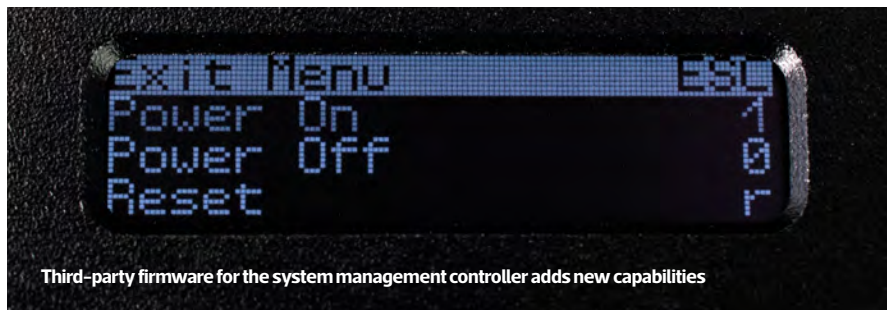
Another group is working on a replacement keyboard, swapping out the aggressive 1.5U



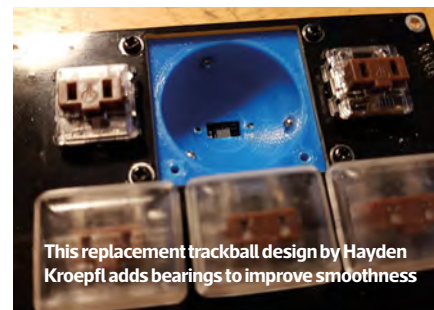
A blocky lump, perhaps, but the MNT Reform is little short of a crowning achievement in aggressive openness

rake of the stock model for an ortholinear fixed-grid design in the name of extreme ergonomics. Even the chassis, which is CNC-milled from bead-blasted black-anodised aluminium, is open source – and while nobody has fired up the mill to make their own replacement quite yet, it's definitely a possibility for those with a suitably equipped workshop.

The Reform is built to be open first, and a laptop second. Seen through this lens, what could be interpreted as a disappointment is a resounding success. In a world where only the biggest corporations design their own laptop hardware, with others relying on rebadging ODM designs and maybe throwing in a branded wallpaper, MNT hasn't only created a truly unique laptop from scratch but also made the



Third-party firmware for the system management controller adds new capabilities



This replacement trackball design by Hayden Kroepfl adds bearings to improve smoothness

designs available for free – as in both ‘speech’ and ‘beer’.

No, the performance of the Reform won’t match (let alone beat) an x86 device from the last decade. No, the battery life won’t get you through a working day before you have to plug in the bundled mains adaptor. No, having to undo ten screws and pull the battery wires if you’re planning to leave the machine

unattended and unplugged for more than a week doesn’t exactly scream user-friendly.

But what could be friendlier than a community built on the concept of radical openness, working together to make and share improvements, modifications and customisations? What could be friendlier than working to design an incredibly complex device and inviting others to join in, rather than hiding

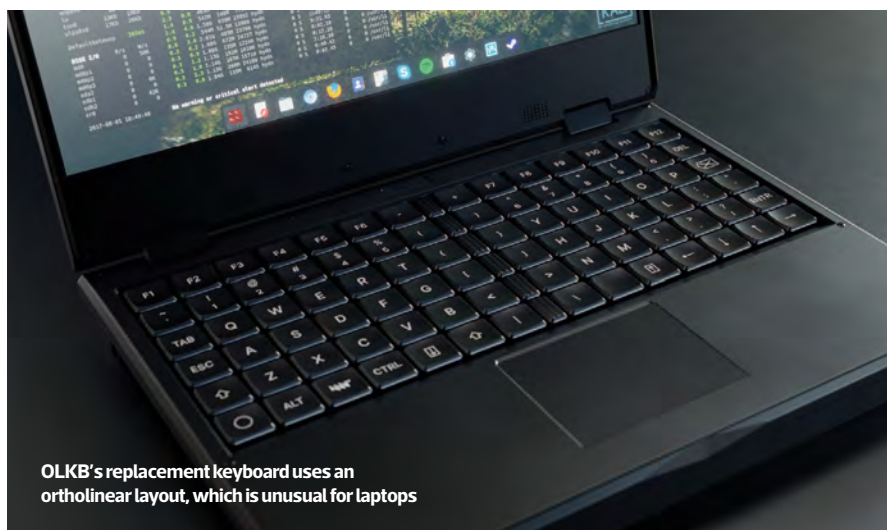
the technology away behind design patents? What could be friendlier than a device that includes full hardware schematics in its manual, in a move once common among electronics companies but that from the 1990s onwards became almost unheard of?

It’s true that MNT isn’t alone in the effort, and that the Reform isn’t the only as open as possible laptop around. PINE64’s Pinebook is probably its biggest competition, and certainly boasts a sleeker – though considerably less eye-catching – design. Its processor is weaker, though, and it has only half the memory. It’s also not as easy to upgrade in the future.

Nobody would argue that the MNT Reform is perfect – particularly those who received early batch models that required a minor modification in order to avoid a short circuit and potential fire. There’s room for improvement in a range of areas, from the flexing keyboard to the antenna bundled with the optional Wi-Fi adaptor, which is by far the worst we’ve tested.

At least some of the bigger flaws are under active investigation. MNT founder Lukas Hartmann has confirmed that tweaks are being made to the firmware for the system management controller in order to dramatically reduce idle power draw, decreasing the risk of draining the batteries below their rated minimum charge. The system management controller is fully open-source in both software and hardware, and it’s already been hacked around by the community to add a few new features for the on-board OLED display.

If you’re not looking for a plug-and-play experience, and you’re not interested in this year’s variant of the same old, same old, if you want to expand your horizons and don’t mind paying to support a worthwhile project when you could pay a lot less for a lot more performance from an off-the-shelf proprietary device, the MNT Reform is likely for you. The community, which congregates on the forum at community.mnt.re, would also be happy to have you.



OLKB’s replacement keyboard uses an ortholinear layout, which is unusual for laptops

NEWS IN BRIEF

Turing Pi project unveils V2

The Turing Pi low-cost cluster computing project has unveiled V2 of its eponymous hardware platform, introducing support for the latest Raspberry Pi Compute Module 4, and its first-ever compatibility with Nvidia’s Jetson module as an alternative.

‘While working on the V2,’ the project maintainers claim of its 2nd-generation four-node design, which adopts the mini-ITX form factor, ‘we have been focused on bringing extensibility, modularity and the possibility of upgrading clusters with new compute modules in the future.’ Go to turingpi.com for more information.



REVIEW

The MNT Reform laptop

Taken on its own, in complete ignorance of the ethos behind the project, the MNT Reform is a confusing device. The 12.5in 1080p IPS display and backlit mechanical keyboard – ignoring the unusual layout with its split spacebar, Hyper key and so on – suggest a modern device perhaps aimed at gamers. The trackball mouse, though, leaves you wondering if this laptop is old stock from the 1980s.

It's the thickness that really strikes you. At 42.5mm, if you include the rubber feet, the MNT Reform is beefy, tipping the scales at just over 2kg. Flip over the laptop and all is revealed – literally, thanks to a transparent acrylic base.

The bulk of the space is taken up by a battery made up of eight individual 18650-size cells (1,800mAh each), each of which are individually replaceable, while the motherboard and the system-on-module it holds are visible just above.

When was the last time you saw a laptop with a trackball fitted?

It's a laptop, Jim, but not as we know it – the MNT Reform is unique

For such a hefty laptop, you might – again, assuming no foreknowledge of the project – expect some impressive specifications. Inside, though, is an NXP i.MX8MQ chip with four Arm Cortex-A53 cores running at 1.5GHz, a Cortex-M4F microcontroller, a Vivante GC7000Lite GPU and 4GB of shared RAM.

If you picked up the DIY variant of the MNT Reform, you'll have a little work – an hour or

two – before it's ready for use. For the pre-assembled version, you'll still need to undo the ten screws holding the base in place, so you can connect the battery wires and install the optional Wi-Fi card and antenna and/or 1TB NVMe SSD.

When it's all wired up, you can pop the micro-SD card into its socket and fire up the laptop. This involves accessing the on-board system management controller by tapping the circle key, navigating the menu that appears on the small but bright OLED panel just above the keyboard, and hitting the Enter

A lot of attention has gone into the Reform, from the packaging to the manual



NEWS IN BRIEF

Home Assistant launches Amber hub

The Home Assistant open-source home automation project has unveiled its first own-brand hardware, Home Assistant Amber, which it pitches as 'a ready-to-use device and the easiest way to run Home Assistant and experience the best home automation in the world'.

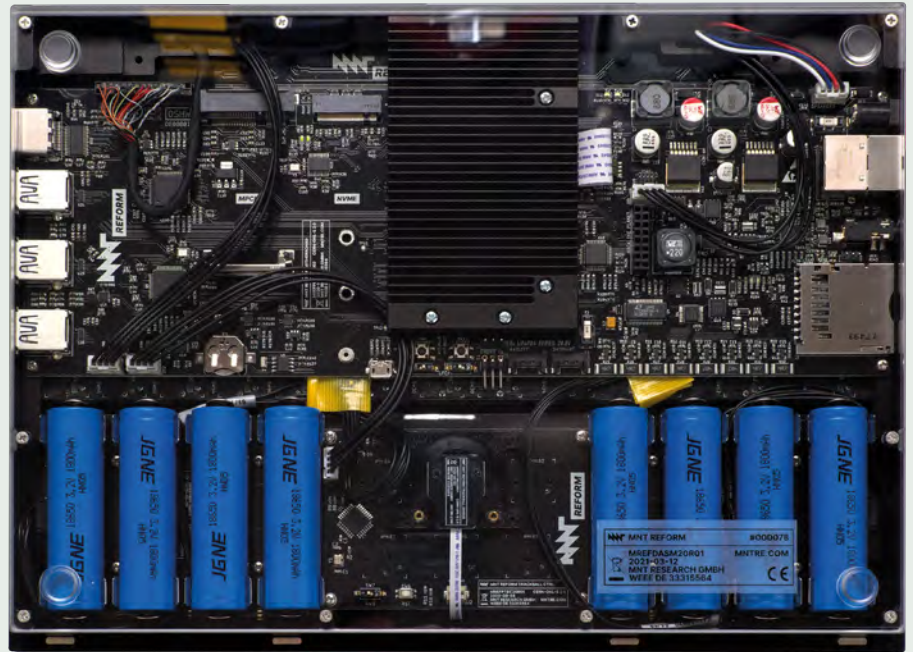
Powered by a Raspberry Pi Compute Module 4, the Amber hub includes Gigabit Ethernet with optional Power-over-Ethernet (PoE) support, a Zigbee radio module and an unpopulated M.2 slot for an SSD or AI accelerator. The Amber hub is being funded on [crowdsupply.com](https://www.crowdsupply.com) starting at \$99 US (around £72 ex vat) for a kit-form variant with no Compute Module 4 included.



key – it then drops you into a customised Debian Linux.

It's clear from this stage that MNT isn't aiming the Reform at absolute beginners, but there's still some help to be found – a quick-start guide appears on login, and commands are provided to load a PDF copy of the user manual or connect the user to the MNT channel on IRC for live community chat.

Every aspect of it is open, including the circuits that drive the Reform



A transparent base reveals the components, but you'll have to unscrew it to get started

Two desktop environments are provided, for those who need them – Sway, an interesting tiled DE, and the more common GNOME Shell. However, using one reveals a secret about the trackball, which can be replaced by a touchpad – it's unpleasantly scratchy, as it's 3D-printed and lacking metal or synthetic ruby contact surfaces

Everything about using the Reform feels anachronistic, and there are few of the niceties you may have come to expect from a 21st-century laptop. There's no lid-close sensor, and at the time of writing the suspend-to-RAM function was unreliable. The Hyper key allows for programmable layers on the keyboard, but it's disabled by default with no dedicated configuration utility. There's no microphone or camera either, which can certainly be spun as a positive from a privacy perspective.

Also, if the batteries run low, the system simply switches off without safely shutting down first. The batteries will run low too, as using individual 18650 cells and LiFePo4 chemistry (safer but with a lower energy density than usual) does have an impact on battery life. In a standard media playback test, the Reform lasted for five hours and six minutes, which falls well short of getting you through a working day on a single charge.

It's not a device that you can just grab and go either. The system management

controller, which is based on an Arm Cortex-M0 core, is constantly drawing power. While it's not much power, it's enough to drain the batteries in around a week or so, while bringing them to a level that's so low they can't be charged in the laptop. When, rather than if, that happens, you need to take off the base, unplug the battery packs, remove the cells and insert them into an external battery charger to bring them back to life.

General performance is, sadly, weak. Both synthetic and real-world benchmarking put the Reform somewhere between a Raspberry Pi 3 Model B+ and Raspberry Pi 4 in every area except 3D-accelerated workloads, where the Vivante GPU lets the Reform pull ahead. A replacement system-on-module, based on a more powerful system-on-chip and with up to 16GB of RAM, is in the pipeline but with no timescale provided.

By all measures, then, the MNT Reform should disappoint. However, there's something about it that will appeal to a certain sort of techie – the sort who doesn't mind delving into configuration files, recompiling kernels or even warming up a 3D printer for some home-brew modifications. For these people, the Reform offers a laptop like no other, even if it comes at a high price.

The MNT Reform is available for pre-order on [crowdsupply.com](https://www.crowdsupply.com) at \$999 US for the DIY kit or \$1,550 assembled (around £730 and £1,130 ex VAT respectively).

REVIEW

Computer Lib / Dream Machines

Ted Nelson's *Computer Lib* is an unusual book, for more than one reason. For a start, it's two books: flip it over and you'll find a companion book called *Dream Machines*. The layout is unique, capturing typewritten material – sometimes squeezed into five columns – on oversized pages accompanied by handwritten notes, black and white photography, and hand-drawn diagrams. It's eclectic, verging on chaotic, and it's not the easiest read.

It's also generally recognised as the first publication that really tried to get a handle on what, at the time of its first printing in 1974, was barely a blip on anybody's radar: personal computing. It has some extremely influential names among its fans. Lee Felsenstein, designer of the Osborne 1 luggage, described the book as a rally cry to 'a rabble of latent crackpots'.

Another fan is Ed Roberts, creator of the famous Altair 8800 and whose copy was stolen by his subordinate David Bunnell, later editor-in-chief of *PC World*.

Other fans include Stewart Brand, creator of *The Whole Earth Catalog* from which would spring pioneering online service the WELL, and Timothy Leary, professor and ardent proponent of psychedelic drugs. Leary said Nelson was the kind of sage who would have spent 'maybe a thousand' years 'up on some magnificent Himalayan mountaintop'.

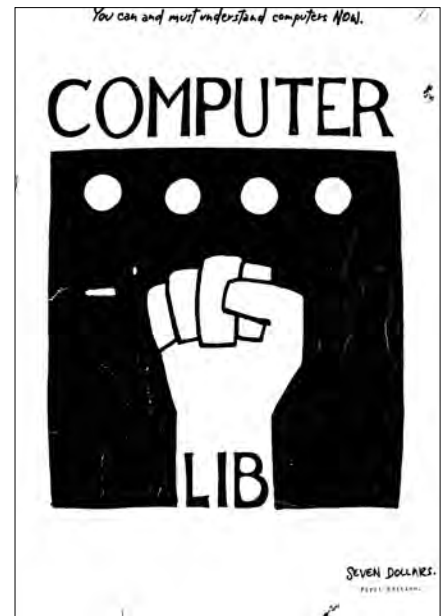
Nelson, somehow, had spotted what very few others would see: that computers were becoming personal. MITS' Altair 8800 wouldn't be launched until early 1975, a year after Nelson's book began circulating; the Apple 1 wouldn't come out until 1976; and IBM's Personal Computer, which

popularised the term and birthed the current generation of 'open architecture' systems, didn't land in stores until 1981.

Generally recognised as the first book about personal computing, *Computer Lib* looks not only at the technology but the politics behind computing. It also brings a sense of urgency with it: 'you can,' Nelson wrote in the book's subtitle, 'and must understand computers NOW.'

The book took a heavy, and at the time still more or less science fictional, topic and made it not only understandable but desirable – a clarion call to understanding computers that accurately predicted the importance computers would have in peoples' lives today.

The subtitle of *Dream Machines*, 'new freedom through computer screens – a minority report,' offered

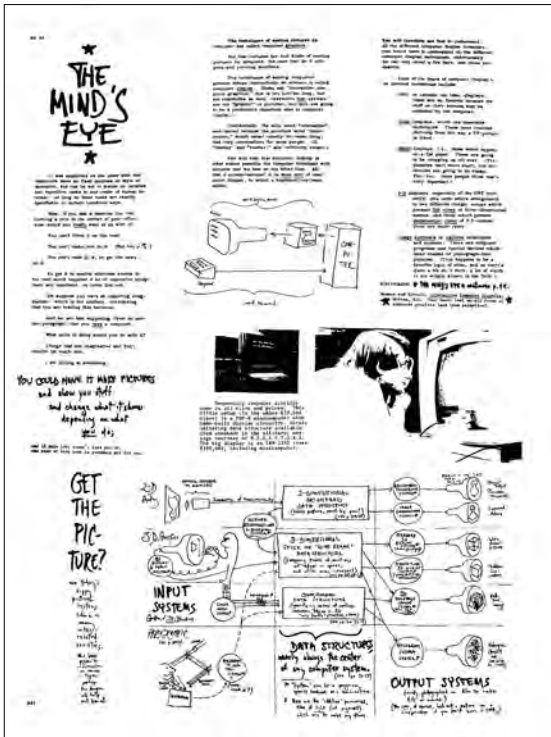


More a zine than a book, *Computer Lib* is recognised as one of the first publications on truly personal computing

more concrete predictions, but from a heavily counterculture perspective. In this half, Nelson explored hypertext and hypermedia – terms he had coined in the 1960s as part of his Project Xanadu, but which had not yet been fully implemented anywhere – as underpinnings for education and personal entertainment.

The section on Project Xanadu itself, meanwhile, sounds very familiar today – a network of machines, accessible through a hypertext interface, on which users can pull up a wealth of information from remote databases and even do their shopping. This in a book that predates the formalisation of the TCP/IP standard by eight years and the World Wide Web by 16.

Today, the specific machines and technologies Nelson discusses are long obsolete, but the core concepts live on. Reading the book is at once both nostalgic and evocative of the future, leaving the reader wondering if computers progressed so far over such a relatively small period – where could they go next? Both the original printing and Microsoft's 1987 second edition are long out of print, but a digital copy of the first edition is available for free download from custompc.co.uk/ComputerLib **GPC**



The content is fascinating, and the layout shows a clear counterculture inspiration

Gareth Halfacree is a keen computer hobbyist, journalist, and author. His work can be found at freelance.halfacree.co.uk @ghalfacree

sinclair



Commodore



the

COMPUTERS



THAT MADE

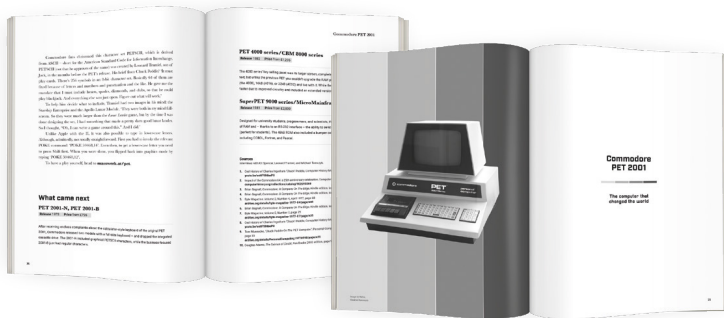
BRITAIN

OUT
NOW

"The Computers that Made Britain
is one of the best things I've read
this year. It's an incredible story of
eccentrics and oddballs, geniuses and
madmen, and one that will have you
pinning for a future that could have been.
It's utterly astonishing!"

- **Stuart Turton**, bestselling author
and journalist

.....



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ANTONY LEATHER'S

Customised PC

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

Hands-on with EK's FLT 80

If you're building a water-cooled PC, your choice of pump and reservoir is often very important. Your decision will dictate the ease with which you can fill the loop, the visibility of your coolant and how you route your tubing around the case, since many combined pump-and-reservoir units have multiple inlets and outlets. They're also a critical choice when it comes to building a small water-cooled PC and can often make or break a plan for a water-cooling system.

It's usually a case of smaller is better when it comes to combo units here, but it can be tricky to integrate a powerful DDC or D5 pump into a small unit while not make gurgling noises and still enabling you to bleed air from the loop. EK's FLT series has generally got this balance right, making them popular in small water-cooled systems – they're small and can be mounted in a range of locations and now there's an even smaller one – the FLT 80.



EK's latest dinky pump/res combo unit measures just 8cm wide and 12cm long

Available in DDC or D5 versions, it's just 8cm wide, 12cm long and the DDC pump-equipped version is just 56mm deep too. This is considerably smaller than the FLT 120 I've been using in my current PC. Amazingly, EK has shoehorned seven G1/4in ports into the FLT 80 with a pair of inlets and outlets – there's one port apiece on the side and front of the reservoir. In addition, there are two fill ports and a drain port too.

This might sound like plenty of ports, but for the purpose it was intended – being used in small, space-starved

cases with awkward tubing routes – more flexibility in the port placement would have been welcome. As it stands, only two of the six surfaces on the reservoir have ports, which limits its flexibility. It's for this reason that I actually tapped a new port into the rear of my larger FLT 120 reservoir in a recent build – I'd have been stuck without it.

There's a PWM connector to control the pump speed, which is important on both DDC and D5 pumps, as they can be a tad loud when they're running at full speed yet rarely benefit cooling running flat out, and there's also a 3-pin digital RGB cable to control the on-board RGB lighting. The pump

is powered with a standard SATA power connector.

I've mounted FLT reservoirs using the included mounting mechanism before, but also with 3M mounting tape using a flat side of the reservoir, which works fine, but the FLT 80 limits the latter, thanks to the protruding ports on the side and front of the reservoir.

Another mounting option is to use the included brackets to mount the reservoir to a 120mm fan mount, fan or 120mm radiator, but doing so will waste space, as the brackets are U-shaped, meaning there's a gap of around an inch between the fan or radiator and the actual reservoir. This isn't an issue in larger systems, but again, that's precious space lost in smaller setups, many of which have already been

limited to using slim fans and radiators.

Despite a few complaints, though, the FLT 80 is one of the best options available for a small, combined pump and reservoir. It might be a tad restrictive in terms of actually plumbing it into your system, especially if your own loop requires the reservoir and pump to be placed in a very specific location. However, similar options from Phanteks and Bitspower are even more restrictive, so EK is definitely onto a winner with the FLT 80.

There's also price to consider, though, and at £150, it's certainly right up there with premium pump and reservoir combinations.

A lot of that budget has clearly been spent on the DDC 4.2 PWM pump, the extensive machining involved and also

The supplied brackets enable you to fit the FLT 80 to a radiator, but only with a sizeable gap between them



the RGB lighting. However, given that this dinky combo unit might make the difference between water-cooling and not water-cooling your PC, it's likely to be popular with small form factor fans.

Beware of LGA1700 cooler compatibility

It's pretty clear that Intel's Alder Lake CPUs represent hefty upgrades for anyone wanting to jump on the bandwagon and get the latest tech. However, you'll not only need to fork out for DDR5 memory for one of these systems, but also a new motherboard.

It's not often that PC enthusiasts have had to upgrade so many parts in one go. It seems an age since I was using DDR3 memory, for example, but while it's a pricey exercise, it's also a good time for a refresh of technology, and see some interesting and much-needed innovation.

That's been lacking on several fronts, with AMD continuing to use aging chipsets over multiple CPU generations and Intel not really adding much new with its last few CPUs. We haven't had a major CPU socket redesign for a while either: AMD's change to Socket AM4 used the same mounting brackets as its predecessor, just with wider-spaced holes, and even Intel's CPU sockets have generally stuck to similar designs.

However, LGA1700 not only changes the hole spacing, but the surface of the CPU heatspreader is now lower too.

This means that, even if you mod your cooler to work with the slightly wider-spaced holes compared with LGA1200 and LGA115x sockets, there's a height difference to consider as well. This lower height could result in poor to zero contact between the CPU and cooler. I was speaking to Corsair this week about its new waterblocks, and it warned me that while the new blocks have LGA1700-compatible mounting plates that have backwards compatibility, you shouldn't use older brackets with Alder Lake, as they won't deal with the change in height.

That's probably not an issue for most people buying a new cooler, but as I have plenty of old brackets lying around, I'm going to make very sure they're hidden away, so I don't use one by mistake. You'll also need to make sure your current cooler is up to the task too. This will mean checking with the manufacturer to see if there's

a mounting kit available. Plenty of manufacturers have already said they're providing compatible mounts, with some such as Noctua offering free upgrade kits, while others such as ARCTIC are charging a small fee.

Some coolers may also ship with the parts needed already, so check your cooler or waterblock's box to make sure or see the manufacturer's website. However, don't be tempted to use old mounting kits with Alder Lake – if in doubt, get a new cooler that's LGA1700-compatible. **GPB**

LGA1700 not only changes the hole spacing, but the surface of the CPU heatspreader is now lower too



How to Change your pump speed

Antony Leather shows takes you through some of the ways you can modify the speed of your water-cooling pump to make it quieter

TOTAL PROJECT TIME / 1 HOUR

While modern water-cooling pumps and extremely powerful, you rarely need to run them at full speed in order to get the best cooling. In fact, tuning them down by 25 or even 50 per cent will often see little to no increase in load temperatures of your water-cooled hardware. However, at full speed, most pumps can be noisy and some make a racket that makes you want to be in a different room from them.

This completely ruins one of the best reasons to water-cool your PC, which is noise reduction. In this guide, we'll show you how to identify your pump and any built-in ways to control its speed, in addition to using software if you can hook it up to your motherboard, as well as modifying your pump's power cable to adjust its voltage and reduce its speed.

TOOLS YOU'LL NEED



3-pin female to 4-pin Molex
male/female adaptor
ebay.co.uk



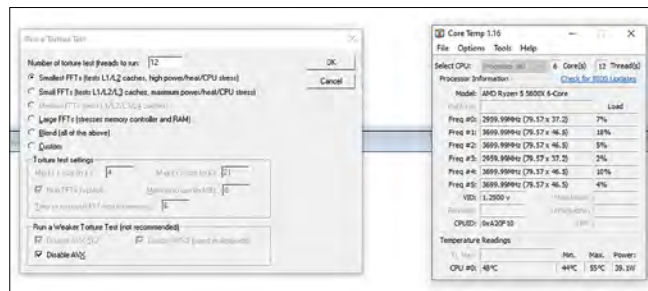
Molex pin remover
scan.co.uk

FIRST STEPS



1 / IDENTIFY PUMP

Start by identifying your pump. This will give an indication of any built-in speed control tools, such as dials or PWM cables. You can also try a Google search to see what other users may have done to adjust their pump speed.



2 / TEST PUMP SPEED

To check whether your pump's lower speed has an impact on temperatures, test it in your loop by running a stress test. Running Prime95's smallfft test with AVX disabled for ten minutes will do this job fine – you can download it from mersenne.org/download

SIMPLE PUMP CONTROL OPTIONS



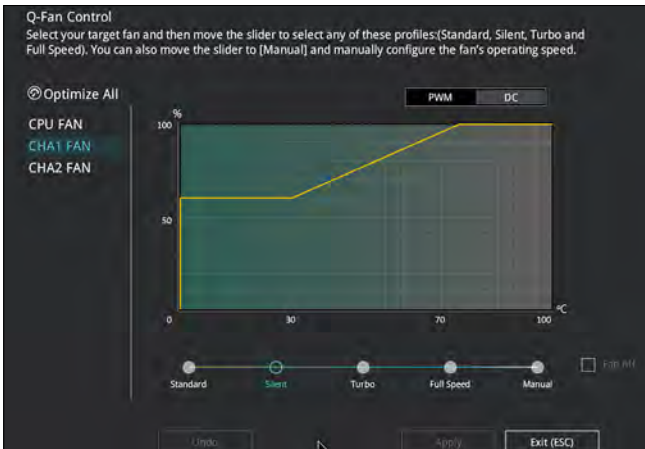
USE ADJUSTER DIAL

The popular D5 pump occasionally comes with an adjuster dial, allowing you to alter the pump speed. Start by dropping the setting to three and seeing if that has an impact on temperatures using the same test above. If it doesn't, try dropping the speed to two, or to wherever the noise drops off, so you can't hear it anymore, then test it again to make sure your load temperatures are still fine.



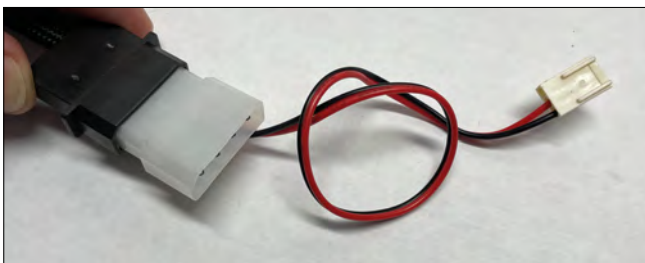
USE PWM CABLE

The PWM cable on some pumps allows you to control their speed using your motherboard's EFI or software. Some motherboards have specific headers for pumps, but these can force it to run at full speed, so look in your motherboard's EFI.



CONTROL USING SOFTWARE OR EFI

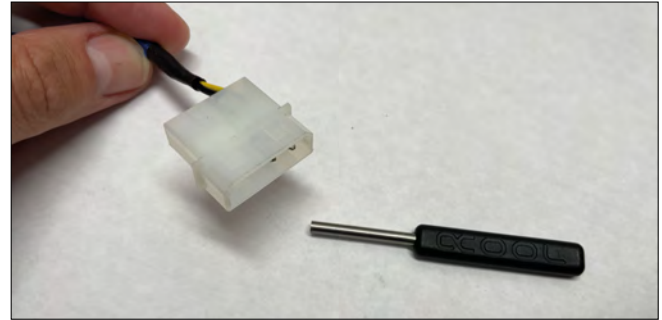
With your pump's power or PWM connector connected to your motherboard, head to the EFI and identify the fan header control. Switch to PWM control for PWM pumps, or voltage/DC control if you've connected a 3-pin power cable directly to your motherboard. You can then set it to alter its speed depending on the temperature.



USE 3-PIN TO MOLEX ADAPTOR

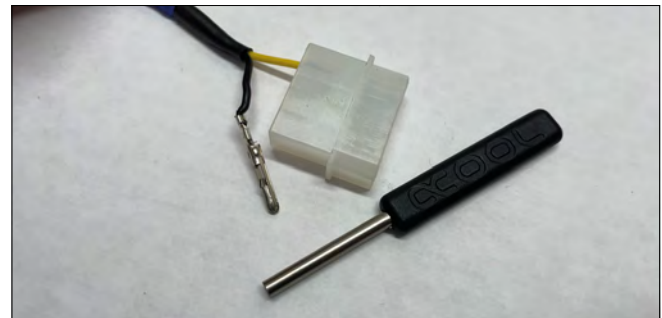
If your pump lacks any kind of speed adjustment, you can still control it using your motherboard. A female 3-pin to female Molex adaptor can power a Molex-equipped pump using a fan header. Just make sure your motherboard's fan header can provide enough power as stated in the manual.

MOLEX VOLTAGE MOD



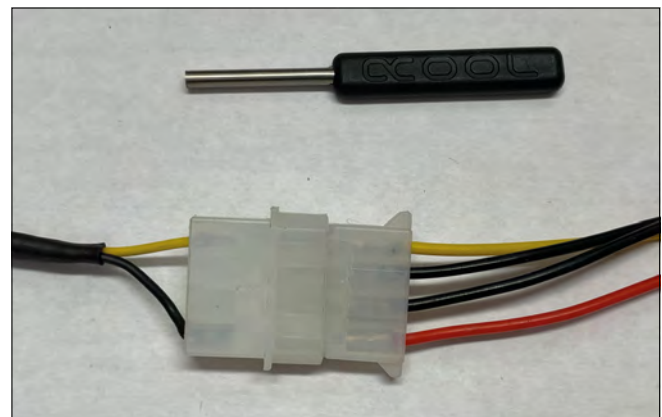
1 / CONVERT YOUR PUMP TO 7V

An alternative way to quickly reduce your pump's speed is to convert the Molex connector to supply 7V instead of 12V. This will in turn reduce its speed, although you'll need to check there's still coolant flowing afterwards, as some pumps might need a higher voltage to start working.



2 / REMOVE BLACK SOCKET PIN

To do this, you need to move the single black cable to the outer socket. Use a Molex pin removal tool to do this part, then pull out the small securing flanges on either side, so that when you reinsert it, the cable will lock itself in place again.



3 / MOVE PIN TO FAR SIDE

Move the cable to the outer socket. This should line up with the red cable if the colours are visible on the other connector, but this won't be the case if your PSU has braided cables. Push the pin into the socket so that it clicks, then connect the power connector to it. Now check that your pump starts up and that your coolant is flowing.

How to Mount a reservoir

Antony Leather shows you how to customise your reservoir's mounting position

TOTAL PROJECT TIME / 1 HOUR

Water-cooling reservoirs are more flexible than ever in terms of their size, number of ports and their ability to use various mounting locations in a typical case. Some can use fan mounts or radiators while others come equipped with their own mounts or can be used with universal mounts included with some cases. However, occasionally, you'll need to get creative.

For example, you might not have space to install your reservoir in a fan mount, and your particular case might not offer an alternative such as a universal pump and reservoir mount. In this month's modding guide, we'll show you how to install a reservoir using a standard radiator and fan mount, but also some sneaky ways of installing them elsewhere in your case too. This can help to make tubing runs easier and also make better use of space in smaller cases, while making the reservoir easier to fill too.

TOOLS YOU'LL NEED



Small spirit level
Most hardware stores



Heavy duty mounting tape
amazon.co.uk



Masking tape
Most hardware stores



Drill and drill bit
Most hardware stores

FIRST STEPS



1 / CHOOSE SIZE AND TYPE OF RESERVOIR

Tube reservoirs can be mounted using fan mounts in cases, or on radiators. In some situations, they also have mounting brackets for use on some pre-drilled case motherboard trays, or holes you've drilled yourself. Square reservoirs can also use fan mounts, but it can be easier to mount them in smaller spaces.



2 / DECIDE ON LOCATION

It's likely you have a specific location in mind for your reservoir, but if not, it's always worth checking to see if mounting it yourself away from fan mounts might free up some space in your case, or make filling and bleeding easier.



3 / IDENTIFY TUBING ROUTES

Once you've worked out roughly where you need to mount the reservoir, you'll need to work out your tubing routes. You might need to install the rest of the hardware in your PC first to check this accurately, especially in smaller cases, and then you can adjust the position of your reservoir if necessary.



4 / MEASURE UP

Once you've decided on the exact location, check there's clearance for the pump if it has one, and make sure you can replace your case's side panels and other PC components once the reservoir is in place. Ensure it can sit level in this position using a spirit level, or it will look unsightly.

FAN AND RADIATOR MOUNTS



1 / USE FAN MOUNTING KIT

Firstly, you may find that using the standard mounting kit suits your needs, so it's always worth trying it first. These kits usually secure to fans, fan mounts or radiators, but sometimes they offer fittings for case pump mounts if your case has them.



2 / INSTALL ON FAN MOUNT OR RADIATOR

Reservoirs don't typically come with screws to secure them to radiators, as they need to be the correct thread size and length. Most reservoirs will come with their own screws to mount directly on fan mounts, though, while standard fan screws will allow you to secure your reservoir to a fan.

SUSPEND YOUR RESERVOIR



1 / CONSIDER A SUSPENDED RESERVOIR

Sometimes there might not be anywhere to mount your reservoir, but all is not lost if that's the case. As a last resort, you can consider using fittings or rigid tubing to hold a small reservoir in place, as long as you won't be moving your PC around.



2 / USE PUSH-TO-SEAL FITTINGS

One way to suspend a reservoir is to use push-to-seal fittings. These fittings come in two separate parts, with rubber O-rings in one section, so they create a seal when they're pushed together. This will allow you to mount the reservoir to a tube port for support, while using rigid tubing can also help to secure it.



3 / FIT RESERVOIR INTO PLACE

With the reservoir donning the push-to-seal fitting, push it onto the other section of the fitting. Ideally, you want these fittings to be at the base of the reservoir in order to support its weight. You can then use tubing cut to the right length to ensure it sits straight.

MOUNTING TAPE



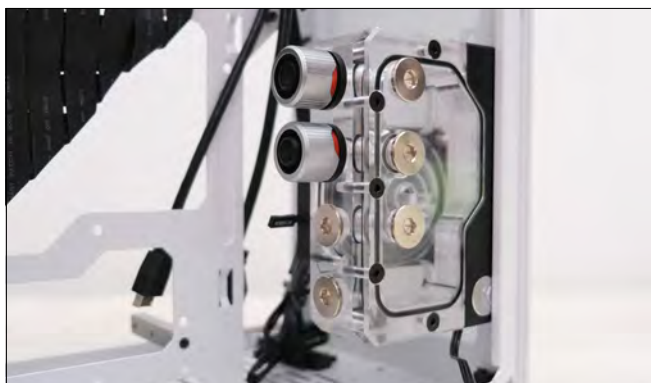
1 / USE MOUNTING TAPE

If your reservoir has a large flat edge, then you can use mounting tape, which is made by the likes of 3M, Scotch and Gorilla, to secure it in place. This is very strong stuff, so be sure on the location. As it's a rubbery material, it also has vibration-absorbing qualities.



2 / APPLY TO RESERVOIR

Cut a strip of mounting tape that's large enough to cover the edge of the reservoir. Peel off one side of protective film, then fix it to the edge, before removing the film on the side to stick to your case. This will only work on smooth metal or plastic surfaces – don't try to stick it to a panel lined with sound-absorbent foam.



3 / FIX IN PLACE

Ensure the reservoir is level, using a spirit level – this is really important, as you won't be able to adjust it afterwards. Press the reservoir firmly into place with a good amount of force to ensure the mounting tape is pressed firmly onto the case.

SCREWS AND CUSTOM HOLES



1 / MARK UP CUSTOM MOUNTING HOLES

Reservoirs usually come with a mounting kit, which you'll need to use in order to mark up your mounting holes. Use the mounting mechanism's screw holes as templates to mark up the surface, having checked that the screws can pass through the surface and out the other side.



2 / USE APPROPRIATE DRILL BIT

Use a spirit level to ensure the holes are straight. Now measure the screw threads to see what size drill bit you need to use, then create the holes. Aim to use all of the screws included with the mount in order to ensure your reservoir is secure.



3 / INSTALL RESERVOIR

Use the screws and nuts to secure the reservoir. Once it's filled with coolant, it will become heavier, so give it a little wiggle to make sure it's held tightly in place. **GPC**

WIN

A MAD CATZ RGB GAMING KEYBOARD

If you're looking to add a touch of flare to your desktop with a splash of lighting, then here's a great opportunity to snag an RGB gaming keyboard with a toughened aluminium faceplate and a load of RGB lighting. Our pals at Mad Catz are offering a S.T.R.I.K.E. 2 keyboard for three lucky Custom PC readers.

MAD CATZ S.T.R.I.K.E. 2

Equipped with RGB lighting and best-in-class durability, the membrane-based S.T.R.I.K.E.2 provides the feel of a genuine mechanical keyboard. The full-sized 104-button key set allows for smooth and reliable gameplay, even during sustained gaming sessions, while the 26-key anti-ghosting feature is ideal for competitive gamers in intensive gaming action.

It features nine variations of RGB lighting effects, all equipped with adjustable speed/brightness, allowing gamers to illuminate their gaming environment the way they wish. The convenient on-the-fly controls allow gamers to change the lighting settings by shortcut, without downloading additional software or exiting their game.

Meanwhile, the 26-key anti-ghosting design makes sure that simultaneous key presses are always registered in-game. The S.T.R.I.K.E. 2 enables gamers to execute complex commands with full precision, accepting multiple key presses at once. Under the keyboard you'll also find a custom-designed 3-way cable management system to keep cables organised and prevent desktop clutter.



SPEC

- 104 keys
- 26-key matrix anti-ghosting design
- 9 built-in RGB lighting effects with adjustable brightness and speed
- Toughened aluminium faceplate
- 12 shortcut keys for multimedia
- Windows Lock feature



SUBMIT YOUR ENTRY AT **CUSTOMPC.CO.UK/WIN**

Competition closes on Friday, 3 December 2021. Prize is offered to participants in the UK aged 13 or over, except employees of the Raspberry Pi Foundation and Trading, the prize supplier, their families or friends. Winners will be notified by email no more than 30 days after the competition closes. By entering the competition, the winner consents to any publicity generated from the competition, in print and online. Participants agree to receive occasional newsletters from Custom PC magazine. We don't like spam: participants' details will remain strictly confidential and won't be shared with third parties. Prizes are non-negotiable and no cash alternative will be offered. Winners will be contacted by email to arrange delivery. Any winners who have not responded 60 days after the initial email is sent will have their prize revoked.

Retro tech

ROLAND MT-32

K.G. Orphanides looks back at Roland's external MIDI synth that revolutionised early PC gaming music

Released in 1987 as a musician's tool, the MT-32 would revolutionise PC gaming audio



A glossy black box with a green LCD invites you to 'Insert Buckazoid' on its screen. A stirring 1980s sci-fi theme blasts glossy-textured synth tones through the speakers connected to it, as you're brought up to speed on the continuing exploits of space janitor Roger Wilco. In 1989, Space Quest III leaned into the highest-quality music available on home computer platforms, an external MIDI audio device that was as prohibitively expensive as it was revolutionary.

When it was released in 1987, the original Roland MT-32 MIDI synthesiser cost £450 in the UK – equivalent to over £1,200 in today's money, and it didn't even come with the MIDI interface card you'd need to connect it to your PC.

Roland primarily marketed its MIDI expander module at amateur electronic musicians: a multi-timbral synth-in-a-box that could be controlled by any MIDI keyboard. It proved popular by being significantly cheaper than most rivals, and by supporting 32-note polyphony across up to eight simultaneous voices.

But the MT-32 would become best known as the pinnacle of IBMPC-compatible gaming audio from the late 1980s to the mid-1990s, and it helped to popularise the fully orchestrated game soundtracks we take for granted today.

WHAT'S IN THE BOX?

In 1987, digital synthesis was still a relatively new technology, developed in the 1970s and popularised in 1983 by Yamaha's DX7 synthesiser. It would become the archetypal sound of the

1980s, with a very different feel to analogue synthesisers' use of control voltages to determine pitch, gate and trigger signals.

The MT-32 used Roland's new Linear Arithmetic (LA) synthesis (see custompc.co.uk/LASynth) technique, first seen a few months earlier in Roland's 61-key D-50 keyboard synthesiser. LA synthesis relies on Partials: fundamental sounds to which it then adds effects in order to produce voices.

These Partials are either stored as pulse code modulation (PCM) sound samples (as used by audio CDs, WAV files and so on) or fully simulated combinations of oscillators, creating the tone. Filters then determine the brightness of the sound by fixing its cutoff frequency, and an amplifier then determines its loudness. The LA chip's pitch and amplitude envelopes act on the PCM sounds, determining the note produced and



The innards of an early MT-32

its attack, decay, sustain and release. This technique enabled the synth to produce a realistic (for the time) reproduction of genuine instruments.

Alongside the LA chip, you'll find a dedicated gate array, a reverb chip, a Burr-Brown PCM54 DAC, a clutch of op-amps, and EEPROMs that hold the MT-32's firmware and PCM sample banks. You can even send custom patches to the MT-32 – specific configurations of effects for the LA synthesis chip to render on a voice from the PCM bank, so you can effectively make new instruments.

Sierra carried the flag for the MT-32, recruiting Supertramp drummer Bob Siebenberg

GETTING INTO PC GAMING

The first IBM PC-compatible game with an MT-32 soundtrack was Sierra's *King's Quest IV: The Perils of Rosella*. Scored for the MT-32 by film and TV composer William Goldstein, the game also supported other audio hardware on release, notably the Yamaha OPL2-based AdLib.

Sierra would carry the flag for the MT-32, recruiting Supertramp drummer Bob Siebenberg to create the soundtrack for *Space Quest III* and even selling the MT-32 and required MPU-401 ISA MIDI interface card for \$550 US (equivalent to around £950 today), with MIDI composition software and two Sierra games of your choice included.

The MT-32's original US retail price was \$695 US (around £1,200 today). It wasn't cheap, particularly compared with the AdLib and CMS Game Blaster cards Sierra also sold, but it was the best way to get what the company's 1989 catalogue describes as 'a symphony orchestra playing in your living room'.

Other companies took up the challenge, some more enthusiastically than others. Origin Systems supported the MT-32 with some excellent soundtracks from 1990's *Ultima VI* and *Bad Blood*, through to *Pacific Strike* in 1994. LucasArts/Lucasfilm Games put most of its MT-32 support into its *Star Wars* titles, such as *X-Wing*, although some adventure games, including *Sam & Max* and the *Monkey Island* titles, received MT-32 MIDI soundtracks. Legend Entertainment, New World Computing and Microprose were also enthusiastic adopters.

UK game development support for the MT-32 included the Bitmap Brothers' *Gods*, Adventuresoft/Horrorsoft's *Elvira* and Simon the Sorcerer games, Team 17's *Alien Breed*, Gremlin Graphics' *Little Devil* and *Plan 9 From Outer Space*, as well as Ocean Software's *Elf*.

Sierra aggressively promoted and supported the MT-32 until the General MIDI standard was published in 1991, which standardised the voice types and program numbers, ensuring that the right instrument sounds were playing the right parts on all compatible devices, although the quality of the voices still depended on your synth.

The music for *Laura Bow II: The Dagger of Amon Ra* (1992) was composed on the MT-32, but released with full support



Uniquely, the MT-32 could be sent SysEx messages to display short text strings – a feature that many games used

for new General MIDI audio devices such as the Roland SCC-1. Other studios supported the MT-32 as late as 1997, with the cover disk demo of Bethesda's *The Elder Scrolls: Daggerfall* (custompc.co.uk/Daggerfall) being among the last.

VERSIONS AND RELATIONS

The MT-32 spawned a host of versions and successors, and became a de facto MIDI standard for other sound card producers before General MIDI was established.

This first 'old' version of the MT-32 is easy to spot, based on its port configuration – it had just a stereo pair of 1/4in TRS outputs. If you connect it to a MIDI interface card on any PC faster than a typical 286, it can produce buffer overflow errors due to an insufficient delay between SysEx messages sent to the device. This could be resolved using the turbo button on 386 and 486 PCs or slowdown utilities on later PCs. This doesn't affect modern PCs using good-quality USB-to-MIDI connectors though – delay SysEx switches are also implemented in a number of popular emulators.

The second 'new' version of the MT-32 introduced a functionally undetectable control CPU switch, along with an additional rear TRS stereo headphone port and reduced noise levels. It also added a ROM playback demo mode and introduced some changes to the gate array and ROM chips. It fixed the buffer overflow error affecting faster computers, but it also rectified some firmware bugs on which some game composers had relied, breaking some soundtracks.

The MT-32's appeal to computer music composers didn't go unnoticed by Roland, and the company followed it with the screenless Computer Music (CM) range of MIDI devices, based on the LA chip. This included, in 1990, Roland's first internal ISA sound card, the LAPC-I, which integrated an MPU-401 interface and MT-32-compatible CM-32L synth.

By 1991, General MIDI was standardised and Roland launched its Sound Canvas range with the SC-55, which used Roland's own GS (General Standard) extension to provide even more voices. A year later an internal version, the Roland SCC-1, was released. Both provided reasonable MT-32 backwards compatibility, but lacked support for custom MT-32 instrument patches.

These MIDI devices, and many to follow, would be popular with musicians for years, but MIDI music in games was on the wane. Full CD audio was clumsy at first, but as disk capacity and audio compression improved, it would be digitally recorded audio that led game music into the new millennium. **GPG**

LISTEN TO THE ROLAND MT-32

Space Quest III custompc.co.uk/SQ3

Frederic Pohl's Gateway custompc.co.uk/FPG

Ultima VI custompc.co.uk/UltimaVI

The Bard's Tale III custompc.co.uk/BT3

Dune custompc.co.uk/dune

Readers' drives

Citrine

Armed with a CNC machine, some acrylic and some top-notch 3D modelling skills, Søren Kirkegaard made this striking build inspired by Citrine crystals

GPC: How did this project start?

Søren: It started out with the idea of putting hard tubing in my current rig. At that point, I already had a soft tube-loop in the same case. I started to draw it all up in 3D, which is what I tend to do when I start a new project. My original idea was to make a new theme based around crystals and their colours. The hard edges, crystal look and the yellow colour all came from the stone I chose for this theme – Citrine!

GPC: What case did you choose and why?

Søren: I chose the InWin 909, which was the case I used in my previous build, and I love the look, size and possibilities for it. There's space for three radiators inside it, which I felt I needed for this amount of hardware. I had been looking at the case for

a year or so, and I imagined different ways to integrate a water-cooling system directly into the case. I created a 3D virtual model first, so I could try out different ideas and see what was actually possible.

GPC: We love the broken rock/crystal effects around the graphics cards and PSU shroud area. How did you achieve this effect?

Søren: All my so-called 'light signs' are custom-designed and made. I started out with my 3D model, trying out different designs. Afterwards, I had the signs cut and laser-etched in 8mm clear acrylic. All the signs have mirror-polished aluminium on them to hide the RGB strips and give them a mirror finish. All these light signs are controlled by the Asus Aura Terminal and then connected to the motherboard, so they can synchronise with the lighting in the rest of the build.

All the etched patterns catch the light, plus you see the light on the clear edges. That's the effect you get when there's only light on the etched parts, and the rest is just clear – it looks damn cool! My brother, who has helped me A LOT in the manufacturing of parts, helped me to 3D-print the RGB brackets and assemble the signs. The light signs have three layers overall – the 3D-printed part, then the acrylic and then the aluminium.

GPC: Did you have to physically modify the case?

Søren: I decided to mount my pump/reservoir combo unit horizontally, on the top of the case, so I was able to see the fluid on the top side. For this, I first designed a pump/res combo. Then my brother and me CNC-machined it, which wasn't easy, plus we had to implement a pump and make



/MEET THY MAKER

Name Søren Kirkegaard
(Nordic 3D Design)

Age 33

Occupation Freelance 3D artist and PC modder

Location Denmark

Main uses for PC 3D rendering and gaming

Likes Music, gaming, 3D printing, designing things, photography and geek stuff such as gaming figurines

Dislikes Losing socks in the washing machine



All the signs have mirror-polished aluminium on them to hide the RGB strips and give them a mirror finish

our own pump bracket. It took some time.

When that was done, we measured the hole we needed to cut out in the top of the case. We used the CNC machine, and very slowly the hole finally got cut out. We then mounted the pump/res combo using 3D-printed brackets and magnets, so it sits in place but can still be removed if necessary.

There are also lots of small 3D-printed parts in this build that you can't see, which I'm pretty happy about. One of them is the stand for the Asus Aura Terminal,

on top of the PSU area. It's designed so that it hides the cables from the PSU and the RGB cables connected to it – it's barely visible; you can just see the Asus logo light up in the bottom.

GPC: How did you plan the cooling system?

Søren: I designed it all in 3D beforehand. I designed the entire PC, with all the hardware, cooling, cables and so on, and then planned my loop in 3D. As a result, I had a plan and a design before I even had the parts in my hands. Of course,

there were always going to be some changes along the way, but the end result came out very close to my original idea. The tubes are acrylic, and they were all shaped and bent by hand.

GPC: That's some neat cabling for a dual-GPU build with so much lighting. Where did you get the custom cables, and how did you plan the cable routing?

Søren: I got my cables from solosleeving.com, a one-man company in the USA. The cables were made as a direct replacement





for the stock cables and I had them made to the exact length I needed, which made it so much easier to manage the 'bigger' cables. All the 'small' cables, for the fans, storage, temperature sensors and so on, are neatly tucked away and guided by cable-combs. I routed all the cables for the RGB lighting (there are a lot in this build) last, so I had easy access to them in case any of the strips failed.

GPG: You don't often see SLI graphics setups these days, more's the pity. What graphics cards are you using here, and what performance do you get from them?

Søren: I have two Asus ROG Strix OC GeForce RTX 3080 Ti cards in this system, in SLI mode (using NVLink), for rendering purposes. I render on my GPUs, and using these cards with ray tracing provided an awesome improvement in render



SYSTEM SPECS

CPU Intel Core i7-8086K
overclocked to 5.2GHz

Case InWin 909 Silver

GPU 2 x Asus ROG Strix OC
GeForce RTX 2080 Ti

Storage 500GB Samsung 960
Evo, 2 x 1TB Samsung 860 Evo

Memory 64GB G.Skill Royal Silver
3600MHz

Motherboard Asus ROG Maximus
XI Formula

PSU Asus ROG Thor 1200W

Cooling EKWB Velocity CPU
waterblock, EKWB Vector GPU
waterblocks, 3 x EKWB radiators
with 8 x InWin Crown fans, 3 x
EKWB Vardar EVO fans

speed over my old GTX 1080 Ti cards. Some games can handle the SLI config, and with others it's best to just disable one of the cards, but the setup does make sense for my work.

GPG: Take us through the water-cooling system.

Søren: This water-cooling system is cooled by three radiators. There's a 60mm-thick 360mm radiator in the back and two 28mm-thick 240mm radiators in the front and bottom. The back radiator is set up in a push/pull configuration, and the two 240mm radiators draw cold air into the case.

This build also has two custom distro plates and the custom res/pump combo unit on the top that I mentioned earlier. Just underneath that sits a distro/res unit that acts

mostly as an aesthetic piece, which says 'InWin' on it. The inside of the case has another distribution plate, which connects all the runs and helps me tidy it all up.

All these custom pieces were designed in Fusion 360 and manufactured on a small CNC machine. My brother and me had to spend some very long nights getting this all right, since it was our first time trying to make parts such as these ones. We had to remake both the distro plates two times, but I'm very happy with the results.

GPG: What coolant did you use, and why did you choose that combination of yellow coolant and white lighting?

Søren: The coolant is EKWB Laguna Yellow, and it sits very well with



the theme colour, which is based on the stone Citrine. The white light is there to help create the complete crystal look I was aiming to achieve.

GPG: What specs did you choose?

Søren: When I built this machine, I pretty much chose the most high-end parts I could obtain. I needed the power for my work, and I like to run my games at max settings – I'm a complete sucker for graphics. It has a Core i7-8086K overclocked to 5.2GHz, 64GB of RAM, two GeForce RTX 2080 Ti cards overclocked to 2100MHz and a 1,200W PSU – it was a very beefy machine at the time it was built.

GPG: What temperatures do you get on the CPU and GPU with that water-cooling setup?

Søren: The maximum temperature on my CPU is 54°C, and my two GeForce RTX 2080 Ti cards max out at 55°C.

GPG: Did you come across any difficulties in the build process?

Søren: The most difficult part of this build was manufacturing the custom acrylic parts. I had to learn

how to integrate a pump into the reservoir (thank god for YouTube). Then I had to learn how to make toolpaths for a CNC machine, and of course learn how to use the CNC machine. Luckily, my brother took care of the last part, and then we helped each other to get it all to work together. It involved a lot of trial and error – this part of the build was without doubt the most time-consuming part, but I learned a lot of skills that I've used in later builds.

GPG: How long did it take you to complete this build?

Søren: From creating my first drawings to the finished build, I'll say roughly six months, but I think it took two months from when we started building it.

GPG: Are you completely happy with the end result, or do you wish you'd done some of it differently in retrospect?

Søren: I'm very satisfied with this build! I got to implement all my ideas into it and I was lucky enough to get the parts that I wanted. I learned a lot in the process, and I'm very satisfied with Citrine. **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. 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

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WORTH
£70

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WORTH
£55



JAMES GORBOLD / HARDWARE ACCELERATED

INTEL STRIKES BACK

James Gorbald celebrates the return of true competition to the CPU market

After months of rumours, speculation and more than a few teasers from Intel itself, the company's latest 12th-gen Core processors based on the new Alder Lake design are finally here.

While there wasn't sufficient time for Scan to submit a system for review this issue, we've had Alder Lake up and running in the 3XS lab for a while now, monitoring closely as the ecosystem around the new CPUs developed. The complexity of this ecosystem shows one of the biggest differences between a CPU and GPU launch, especially in a world ravaged by Covid and still experiencing severe supply issues.

For a GPU launch, it's only the graphics cards themselves and drivers that have to be readied for launch. In contrast, for a CPU launch, not only do the processors need to be bang on, but also the motherboards, CPU coolers and memory. Plus, in the case of Alder Lake, all of this is occurring in the shadow of the recent launch of Windows 11; like any new OS, this has had its own set of issues.

If you haven't already read Antony's reviews on p16, I strongly suggest doing so. However, for the purposes of my column I'm going to summarise by saying that 12th-gen CPUs mark a real comeback for Intel, being significantly faster than the equivalently priced 3rd-gen Ryzen CPUs in practically every workload, whether it's games or content creation applications.

What's more, Intel has managed to pull this off without ram-raiding the power piggy bank, as these CPUs only draw around 20W more than a 3rd-gen Ryzen CPU when gaming. That's a relatively small difference when you're talking about hundreds of watts for the entire system, and that's

Intel has managed to pull this off without ram-raiding the power piggy bank

perfectly tolerable. Perhaps most impressive is the way that ThreadDirector in the CPUs seems to work perfectly in tune with Windows 10 and 11, intelligently allocating threads to whichever part of the hybrid architecture, P-core or E-core, is most appropriate.

I had quite a few doubts about how well this would work, mostly based on looking back to how badly Hyper-Threading worked when it was first introduced, often reducing performance rather than improving it. However, I've yet to see ThreadDirector make the wrong call.

I'm also delighted to report that there are good numbers of 12th-gen Core CPU available, at least at Scan. There aren't as many as I'd like, of course, but a lot more chips than AMD

managed to supply in time for its 3rd-gen Ryzen launch last year. It also shouldn't be forgotten that there's still an ongoing shortage of many components, so stock for any launch is still in constraint.

The one area that's a bit of letdown is DDR5. While the JEDEC standard was finalised in July last year, you're not going to find many DDR5 DIMMs in stock anywhere, at least not until well into 2022. Fortunately, 12th-gen Core CPUs also support DDR4. This potentially means you need to make the decision to go with a DDR4 board for now or get a DDR5 board and run the gauntlet of not finding any memory.

That said, the real-world performance difference between DDR4 and DDR5 is hardly earth-shattering, so if you're considering a Core i5 or i7 CPU then it's a bit of no-brainer to go for DDR4. If you've got your eye on the flagship Core i9-12900K, though, then you're probably better off trying to get hold of some DDR5 memory in order to get the most from the CPU. Your move now, AMD. **CPC**

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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