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Welcome

Custom PC Issue 230

/ FROM THE EDITOR

RAM busters

Memory is one of the least well understood components in the PC. We know that more cores and faster clock speeds generally make CPUs faster, and that more stream processors make GPUs faster, but there are many factors to consider when it comes to memory, and it can be hard to work out their impact on performance.

For example, what does that string of numbers on the back of your memory module actually mean? You might know that one of them is CAS latency, and that a lower figure is better, but what are the others, and how does latency actually impact your PC's performance. Does latency even really matter when your memory is running at a fast clock speed?

There are so many questions people have about memory. Do you really need more than 16GB for gaming? Does running memory in dual-channel mode actually make much difference? Is it really worth spending the extra money on DDR5? With both AMD and Intel's forthcoming CPUs promising support for DDR5, and DDR4 still going strong, we thought now would be a good time to take a deep dive into the world of PC memory.

A really good place to start with this issue is to flip it over and read James Gorbold's column on p114, as it provides a really interesting insight into the sales of DDR5 vs DDR4 memory. From Scan's perspective, DDR5 sales have been eclipsed by DDR4 sales across the board, in some areas by over 500 per cent.

Next you'll want to read our massive ten-page feature on p76, which answers all the above questions and more, explaining exactly how memory works and how the various different specs affect performance, complete with test results. If you think having 32GB of high-speed DDR5 memory will give you a gaming speed advantage over 16GB of DDR4 memory, then you'll want to have a good read of this feature and potentially save yourself some cash.

Finally, when you're all up to speed on how memory works, and you know what you need, take a look at our Labs test on p44, where we test 11 different DDR4 and DDR5 kits to find the best options. Once you've read this issue, you'll be fully versed in the language of memory. CPC

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CUSTOM PC

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ISSUE 230
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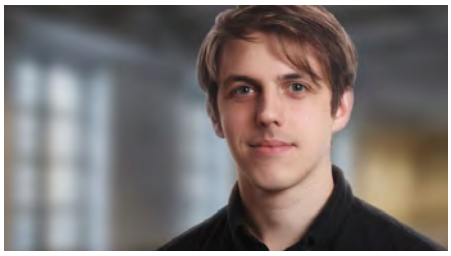

RICHARD SWINBURNE / VIEW FROM TAIWAN

THE STATE OF INTEL GRAPHICS

Intel's GPU division is hemorrhaging billions of dollars, and can't get its cards to market. Richard Swinburne hopes Intel can turn this situation around

The past few months of this year are set to bring us a bonanza of new hardware launches, and one standout from the tsunami of hot new hardware is Intel's Accelerated Graphics Division (AXG), which is currently causing the company to hemorrhage billions as it struggles to launch its Arc graphics cards.

After resorting to a paper launch in the initial Q1 launch window, then missing the Q2 window, the past few months have seen Intel AXG continually struggle to kick a single card out the door. Leaks from graphics card makers and PC system builders appear to tell a story that Arc cards are already made and waiting in warehouses, but the drivers just aren't up to scratch. The delay has got so bad that Intel's own promotional giveaway in March had to give winners CPUs rather than the Arc graphics cards they had won.

Intel has produced some in-house benchmark videos showing its performance advantages in DirectX 12 and Vulkan, but DirectX 9, DirectX 11 and OpenGL games were notably absent, and many of them are still many played regularly. For DirectX 9 games, such as CS:GO, Intel's own support pages admit that Arc doesn't support them natively, and instead uses Microsoft's D3D9On12 interface, which emulates DirectX 9 on DirectX 12.

That tends to seriously weaken performance when compared with cards that have native support, but there should still be enough performance available – DX9-era games aren't exactly demanding. Some graphics enthusiasts are also beginning to endorse the (unproven) theory that Intel is also using a DXVK implementation to convert DirectX 11 games to Vulkan.

In an attempt to streamline driver development, Intel has stopped making drivers for all non-Xe based GPUs, affording them only quarterly security updates for the future. Just focusing on 11th and 12th-gen CPUs, plus Arc GPUs, sounds like common sense, but there are still 10th-gen CPUs being sold right now for PCs, and in laptops that still use older UHD graphics, leaving their owners with potentially months of holes between security fixes.

> The drivers just aren't up to scratch

Following the news of Intel's GPU division shedding billions, longtime graphics analyst and market researcher, Jon Peddie, called it an embarrassment, and suggested Intel should sell or fold the division entirely. Peddie cited the fact that Pat Gelsinger, Intel's CEO, wasn't afraid of making tough decisions after he recently sold and killed off several divisions, including Intel Optane.

Thankfully no one else has joined in the chorus – after all, most of Intel's CPUs benefit from some form of graphics system, and it's not like the driver requirement would go away in that case. Even AMD is now putting a little slice of Radeon in its AM5 CPUs, in order to ensure that PC builders can run the CPUs without discrete GPUs if needed.

Gaming has now propelled the PC market for over a decade, with GPUs taking an ever larger slice of the pie with every new generation. Intel simply *has* to work it out. The head of Intel AXG, VP Raja Koduri, tweeted in response, 'We are very much committed to our roadmap,' and promised 'four new product lines by the end of the year'.

We're on the precipice of having a third option in the graphics market, and after years of grossly inflated graphics card prices, enthusiasts would be worse off without an Intel Arc option in the mix. Let's hope Intel can make it work by 2023 and that Pat Gelsinger keeps his finger off the Eject button. CPC

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

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TRACY KING / SCEPTICAL ANALYSIS

IS THE GAME INDUSTRY REALLY RECESSION-PROOF?

Tracy King takes on recent media reports about the game industry's ability to weather current and future market conditions

Money. I like it, as does my landlord, my Steam wallet and the local café that keeps me supplied in coffee and Wi-Fi. No person or business is unaffected when the economy tanks, and in Britain we're in a cost of living crisis, a weather crisis, a healthcare crisis, an energy crisis, an inflation crisis and a political crisis.

In other words, here comes a recession, and most of us are about to get poorer. If everything gets more expensive – not just products on shelves but every service and element of a country's infrastructure – then prices will go up while disposable income goes down. But will that affect our gaming habit?

There's no such thing as a recession-proof industry, but one or two have historically come close. In the USA, the video game business has previously been able to get through some tough financial times, and some even argue demand for games goes up because of unemployment.

However, some journalists are warning that it might be different this time. In the past two months, I've seen several articles from respected publications claiming that, yes, in the 2008 recession (USA), the industry saw growth, but this time it will be different. Maybe. Possibly. These articles have an air of cautious pessimism, followed by a lengthy series of examples of game companies that are now reporting less revenue or a declining market.

There are lots of them. For example: 'Activision Blizzard reported $1.64 billion net revenue, a $700 million dip in revenue compared to the same time period last year.' However, because the USA currently has a strong labour force (as does the UK), the company claims its workforce has expanded by 25 per cent in the same period, which indicates growth. It's this strong labour market that's scuppering the 'unemployed people buy games' theory of 2008. This time it will be different, the articles claim, because that same level of unemployment doesn't exist now.

> This sort of cherry-picked data doesn't give a true picture

This sort of cherry-picked data doesn't give a true picture, and the behavioural guesswork blurs the image even further. One analyst suggests gaming will decline because people with disposable income are socialising outside again. And that's true, but that will settle into pre-pandemic norms, or even worse, as the recession hits the restaurant and entertainment industry. It's not much fun going out if your friends can't afford it. As such, I have little patience for the consumer behaviour predictions in such articles.

Plus, we're still figuring out post-pandemic culture, whether working from home is here to stay, how long we're now prepared to commute and so on. Each of these factors affects a different aspect of the game market. Less commuting means fewer mobile and handheld games, but more leisure time for gaming at home on a PC or console.

Predicting the behaviour of gamers in the next 12 months based on the past 12 months is wandering into black magic, as is predicting how the game market will perform in a recession based on how it fared in 2008. It's not the same industry now, and while some aspects will probably fare badly (I worry for Twitch and Patreon, for example, which might struggle to adapt their funding models), others will be fine, and evolve or innovate quickly.

So nice try media, I respect you for trying to predict the future under complicated circumstances, but the data isn't there to conclude if the video game industry is recession-proof. CPC

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

PHILIPS

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CUSTOM PC

OCT 6

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Letters

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

GAMER GUM

Never a company to be afraid of branching out, peripheral maker Razer has released its own range of gum. RESPAWN by 5 Gum was developed in collaboration with Mars Wrigley, with Peter Strnad, Senior Manager, Global Portfolio for Mars Wrigley, claiming it was 'designed to deliver mental performance from vitamin B5, to support competitive gamers'.

However, vitamin B5, also known as pantothenic acid, is widely available in many foods anyway, including dairy and eggs, as well as potatoes, tomatoes and mushrooms, and only needs supplementing if you have a deficiency. There's also currently no evidence that it does indeed help mental performance in competitive gaming. It might be nice gum though.

RESPAWN by 5 Gum is available in 15-pellet boxes in cool mint, pomegranate watermelon and tropical punch flavours, at a cost of £8.99 inc VAT for six packs from **amazon.co.uk**

MUGS ARE BACK!

What's better than sitting down to read the latest issue of **Custom PC** when it comes through the door? Doing it while sipping your favourite beverage from a classic **Custom PC** mug, of course! Whether your chosen thirst-quencher is tea, coffee, hot chocolate, Ovaltine or warm Ribena, our **Custom PC** Beverage Approved mug will happily dispense it into your gullet while you read all about the latest PC tech.

Yes, due to popular demand, we've brought back the ever-popular **Custom PC** mug subs gift, and it's exactly the same as the old ones. If you've broken your old mug (and we know from our emails that a lot of you have), then why not take out a new subscription and get it replaced? If you've never owned one of these amazing branded ceramic drinking vessels, then what are you waiting for? See p42 for the full details.

Wireframe

Join us as we lift the lid on video games

Visit **wfmag.cc** to learn more

SAMSUNG ANNOUNCES 'ULTIMATE SSD'

Samsung has lifted the lid on a new high-speed M.2 SSD, promising 'ferocious speed'. The new 990 Pro is still stuck on the PCI-E 4 interface, rather than using the latest PCI-E 5 standard, but Samsung promises that the top-line model will push the theoretical 8,000MB/sec limit of a 4x PCI-E 4 interface to the limit, describing it as the 'ultimate SSD'.

According to Samsung, the 990 Pro can hit a sequential read speed of 7,450MB/sec and a write speed of 6,900MB/sec, compared to 7,000MB/sec and 5,300MB/sec respectively for the WD Black SN850. The drive is based on an in-house Samsung controller, and uses Samsung's TLC V-NAND flash memory. It's available in capacities of 1TB, 2TB and 4TB, with 1GB, 2GB and 4GB of LPDDR4 DRAM respectively.

A version with a heatsink will also be available, which has an angular design that incorporates an RGB LED. The Samsung 990 Pro will be available in October this year. No UK pricing has been announced yet, but the 1TB model has been given a $179 ex tax MSRP in the USA, which works out around £182 inc VAT in the UK at current exchange rates.

CORSAIR SHOWS OFF 'BENDABLE' MONITOR

Corsair has revealed a 45in gaming monitor that allows you to adjust the curvature of its panel. According to Corsair, the Xeneon Flex OLED can go from a fully flat panel to an 800R curve, and anywhere in between, with the adjustment taking a few seconds.

The Flex OLED is the product of a partnership between Corsair and LG, and it features a formidable spec beyond its flexible panel. Corsair claims the OLED panel has a 1,350,000:1 contrast ratio, and brightness of up to 1,000 nits. It also has a 3,440 x 1,440 resolution and a 240Hz refresh rate, along with compatibility with both G-Sync and FreeSync Premium, so the refresh rate can sync with the frame rate output of both Nvidia and AMD GPUs.

'We challenged ourselves to create a game-changing display that delivers an incredible and customisable experience,' said Dennis Jackson, senior director of systems product management & marketing, stating that the Xeneon Flex OLED has 'the literal flexibility to exceed the needs of even the most discerning gamers'.

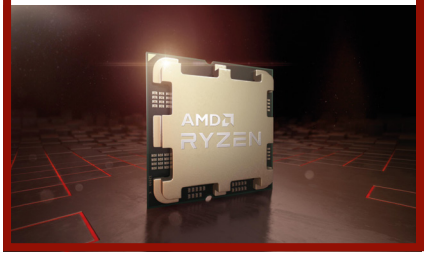
Information about pricing and availability is expected later in the year. Look out for a hands-on preview of the Corsair Xeneon Flex OLED in our next issue.

AMD UNVEILS ZEN 4

In a spectacularly bad piece of timing, this magazine went to the printers two days before AMD was due to lift the lid on its new Zen 4 CPUs on 29 August. With all the details of the new Ryzen 7000-series CPUs being kept thoroughly hush-hush, and the pre-press briefing taking place just a couple of hours before the launch, we're sadly unable to bring you any of those details here.

However, we can share some of what we do already know about Zen 4, which is that the CPUs and motherboards will use a new LGA socket called AM5, and that the new Core Chiplet dies will be manufactured on a 5nm process. Meanwhile, the I/O die will be built on a 6nm process, and will also feature integrated Radeon graphics as standard, along with both DDR5 and PCI-E 5 controllers.

More details of the new CPUs will be available at **amd.com** by the time you read this, and we hope to have reviews of them in the next issue of **Custom PC**.



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Reviews

MINI-ITX CASE

FRACTAL DESIGN MESHIFY 2 NANO / £105 inc VAT

SUPPLIER scan.co.uk

We've seen plenty of interesting additions to the mini-ITX case market over the past year, but until recently, the last dinky case we saw from Fractal was the Era ITX, which was certainly small, but wasn't without its flaws. Fractal has recently broken its silence, though, firstly with the superb Torrent Nano, and now with two new models – the Define 7 Nano and the Meshify 2 Nano here.

The Define 7 Nano, as you would expect, is a mini-ITX version of the Define 7 and Define 7 Compact, but it shares much of the same interior with the Meshify 2 Nano. The company has also added micro-ATX versions of both cases, with 'Mini' instead of 'Nano' at the end of their names.

As its name suggests, the Meshify 2 Nano offers copious amounts of mesh to boost airflow, with the front panel benefitting from a near top-to-bottom mesh section. This is a separate panel to the front panel fascia, allowing you to pull it out to clean it, saving space and volume compared with using a separate dust filter. However, you'll need to remove the fascia in order to get at the front fan mounts too. The roof houses a second mesh area with a large filter-equipped vent in the base as well.

Getting inside the chassis is simple, thanks to the tool-free, pop-off side panels that we've loved on other Fractal Design cases. Even better, the removable roof section has returned, allowing you to completely remove every part of the case between the front and rear of the case with no chassis frame remaining. This gives you a wonderfully open area with which to work, and it's even more useful here than in larger cases.

This isn't a small case, though, and those hoping for a chassis that's not much bigger than a Cooler Master NR200P or Lian Li Q58 will be disappointed, as it's much larger than both of those cases in every dimension. Part of the reason for this is that there's ATX PSU support. Dropping to SFX PSUs could shaved several inches off the width, depth and height of the case.

As the Meshify 2 Nano sticks to the usual case layout of larger models, further reductions in size would also impact on the generous CPU cooler height limit of 167mm and the graphics card clearance of 331mm or 306mm with a fan installed in the front, dropping to around 270mm if you have a radiator there too. Despite the case's size, you're also unable to use a triple-slot graphics card, which is possible in much smaller mini-ITX cases.

It seems strange, then, that Fractal Design has cut space in the roof, removing the official option of mounting a radiator here and, what's more, the roof's space is limited to such an extent that while there are two 120mm or 140mm fan mounts, the latter are limited to slim 15mm fans, which are extremely rare. It would have been far more beneficial to limit the case to SFX PSUs, which would allow for a smaller case or better fan and radiator support.

SPEC

Dimensions (mm)
205 x 396 x 361 (W x D x H)

Material
Steel, plastic, glass

Available colours
White, black

Weight
5.9kg

Front panel
Power, reset, 2 x USB 3, 1 x USB 3.1 Gen 2 Type-C

Drive bays
2 x 2.5in, 1 x 2.5/3.5in

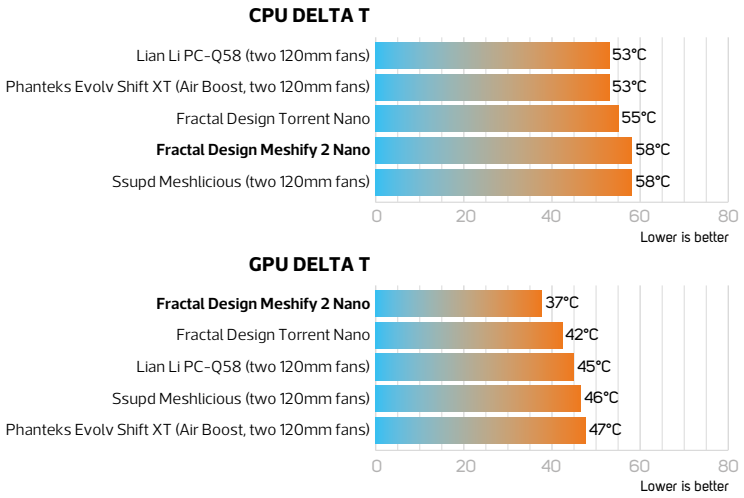
Form factor(s)
Mini-ITX

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

CPU cooler clearance
167mm

Maximum graphics card length
331mm (306mm with front fan)

TEMPERATURE RESULTS



Meanwhile, an interesting addition to the cooling arrangement is an angled duct that directs air from the single 140mm front intake fan diagonally upwards to the graphics card. This has the benefit not just of pointing cool air at your graphics card, but will actually aid its fans rather than shoving air in their vague direction. This is split in two parts, allowing you to benefit from the full duct effect, remove it to install a slim radiator or remove both portions to install a thicker cooling setup.

Another issue we found was the hole for the 8-pin EPS 12V CPU connector. This was too small for our PSU cable to pass through with the motherboard already installed, meaning you need to shove it through the hole beforehand. This is mentioned in the manual, but it did catch us out, requiring us to remove the motherboard. Adding a couple of millimetres to the height of the hole would have solved this issue.

Despite being large for a mini-ITX case, there's also just a single 3.5in hard disk mount, which is disappointing, plus two dedicated 2.5in mounts. Cable tidying is generally excellent, with lots of Velcro anchor straps behind the motherboard tray, as well as cable-routing holes. The case is extremely well made and solid-feeling too, so there are no issues with build quality. The front panel ports are also decent, comprising a USB 3.2 Gen 2 Type-C port, a pair of USB 3 ports and audio mini jacks, plus power and reset buttons.

Performance

The Meshify 2 Nano's CPU delta T of 58°C was decent, but we have seen a little cooler from the likes of the Lian Li PC-Q58. The GPU delta T was exceptional, though, shaving a few degrees off the already good Fractal Design Torrent Nano, most likely thanks to the fan duct funnelling air directly into our RX 6700 XT graphics card's fans. The case fans weren't inaudible, but neither were they loud at full speed, and they shifted a reasonable amount of air.

Conclusion

The main issue with the Fractal Design Meshify 2 Nano is that its large size hasn't yielded any major benefits, which is a problem for a case that's supposed to be small. Some smaller cases offer the same CPU cooler height limit, better radiator support, more hard disk mounts and support larger graphics cards. The added volume and footprint only seem to be there to accommodate a large ATX PSU and large air cooler, and the latter is supported by many smaller cases anyway.

We can't deny that it's reasonably priced, mostly sublime to work with, and offers excellent GPU cooling and cable tidying. It's smaller than an ATX case, but it's also not much smaller than Fractal Design's Compact version, which is much more flexible. Still, if you want an even more compact Meshify case, and are happy with its credentials, it's a solid if bulky mini-ITX case.

ANTONY LEATHER

MESHY

- \+ Excellent GPU cooling
- \+ Removable roof section
- \+ Great cable tidying

MESSY

- – Limited roof clearance
- – Large for a mini-ITX case
- – AIO liquid coolers restrict graphics card size

COOLING 26/30

FEATURES 15/20

DESIGN 23/30

VALUE 16/20

OVERALL SCORE 80%

VERDICT

Impressive GPU cooling and many great features, but its large size doesn't yield any significant benefits.

ATX CASE

THERMALTAKE TOWER 500 / £200 inc VAT

SUPPLIER scan.co.uk

Despite looking like a vivarium for exotic pets, and being huge for a mini-ITX case, Thermaltake's Tower 100 proved to be popular with air and water-cooling enthusiasts. People appreciated its unique design, ample working space and reasonable price. The recently released Tower 500, though, is very different.

Available in black or white, it costs £200 inc VAT, which is twice the price of the Tower 100, and it's much bigger too. It's not as gargantuan as the Tower 900, but it still stands 60cm tall and measures nearly 40cm deep and wide. Strangely, though, it doesn't seem that big on a desk, as its footprint is under 40 x 40cm, with the depth being much shorter than your typical ATX case. It gives you a great view of your hardware as well, benefiting from a top-to-bottom view of the main chamber, with half-width glass panels in the side too.

The motherboard sits on its side with the I/O panel facing upwards, with holes in the rear of the case at the top, allowing you to thread through cables for keyboards, mice and monitors. The front panel is fairly standard, with four USB 3 ports, a USB 3.2 Gen 2 Type-C port, audio jacks, and both power and reset buttons. We expected to see a few more features here, or in the box, which makes the price tag feel a little steep.

One key optional extra is a customisable colour LCD panel. This sits in a replacement panel for one of the lower side vents and includes a 3.9in screen that hooks up to your PC using a USB header. It looks great, but we'd have liked this to be included as standard, and the extra £100 for the panel kit is steep too, given that larger customisable displays cost far less money, and the Tower 500's ample number of flat surfaces can provide plenty of homes for them.

One feature we've loved about the variations of the tower we've seen in the flesh so far is the removable panels. The roof and all four side panels detach, along with the lower vent panels. It's not quite as swish as the fully removable roof you get in some of Fractal Design's cases, but it certainly makes building a PC much easier work than with a typical ATX tower, especially if you're water-cooling your PC.

Speaking of which, unlike its mini-ITX sibling, the Tower 500 is very water cooling-friendly, with space for 360mm radiators in the sides, two 240mm radiators in the base with one sat on its side, and either a 240mm or 280mm radiator in the roof. There's a massive 275mm of CPU cooler clearance and masses of fan mounts too.

The left and right sides of the case each house a trio of 120mm fans, the rear of the motherboard tray offers a home to two 120mm or 140mm fans, and the trio of roof and base radiator mounts add six more 120mm mounts, with the option of two 140mm fans in the roof instead.

SPEC

Dimensions (mm)
388 x 398 x 608 (W x D x H)

Material
Steel, plastic, glass

Available colours
Black, white

Weight
14.8kg

Front panel
Power, reset, 1 x USB 3.2 Gen 2 Type-C, 2 x USB 3, 1 x USB 2, stereo, mic, LED control

Drive bays
6 x 3.5in, 4 x 2.5in, 2 x 3.5in/4 x 2.5in

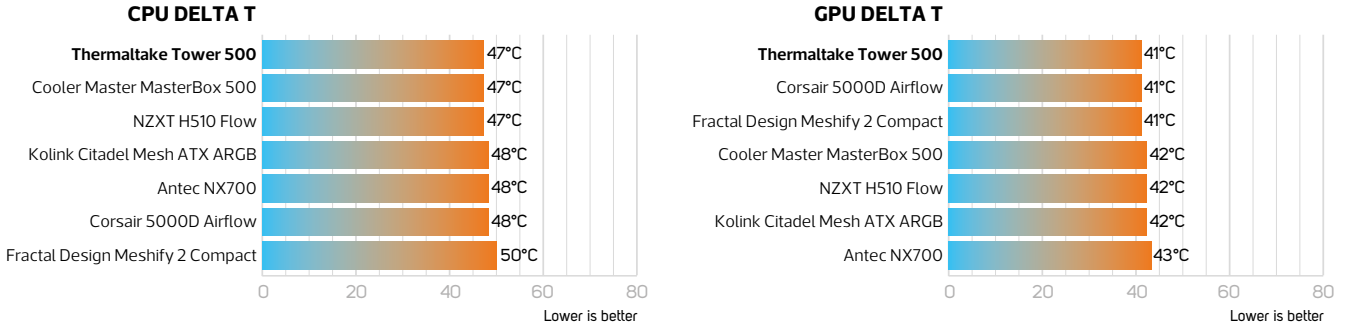
Form factor(s)
E-ATX, ATX, micro-ATX

Cooling
6 x 120mm side fan mounts (fans not included), 2 x 120mm/140mm rear fan mounts (2 x 120mm fans included), 4 x 120mm base fan mounts (fans not included), 2 x 120/140mm roof fan mounts (fans not included)

CPU cooler clearance
275mm

Maximum graphics card length
355mm

TEMPERATURE RESULTS



That's more than enough cooling to handle any system you could house inside this case, which is one advantage it has over your typical mid-sized ATX tower. Out of the box, only two 120mm fans are included, with both acting as exhausts and one drawing air away from the side of the GPU. Again, though, given the price, we'd have liked to see more and perhaps some RGB lighting too.

Of course, the case could be a lot shallower if Thermaltake ditched the rear chamber, but this doubles as an area to stow cables, as well as house up to six hard disks or a mix of up to two hard disks and four SSDs. With eight hard disk mounts in total, that's far more than many ATX cases, which also have far less generous cable stowage, and the entire tray that holds them in place is removable too.

Building a PC in the case, as we've mentioned, is fairly easy, but what's not as easy as many ATX towers is getting inside it. You have to remove the roof section to remove any of the panels that allow you to get at your core hardware, and this setup could get old very quickly if you're a regular tinkerer,

Performance

Buried in the depths of the case, the two 1,500rpm exhaust fans were easily eclipsed by the noise made by the rest of our system. We were surprised to see the GPU delta T sitting at a low of 41°C despite no fans pointing at it, but it does sit within a few inches of the vented side panel. The CPU delta T of 47°C is also on par with the lowest results we've seen, with both these components also benefiting from the huge volume of air inside the case too.

Conclusion

The Thermaltake Tower 500 is very much a blank canvas, as the air or water-cooled PC you could house inside it could be absolutely monstrous – far more so than the case's size suggests. With six hard disk mounts, five radiator mounts (including two 360mm ones), more fan mounts than you can shake a stick at, and essentially unlimited graphics card and CPU cooler clearances, both air and water-cooled system essentially have no limits. We also love the view you get of your hardware through the glass panels – this case will look brilliant with a water-cooling system installed inside it.

While it's great to see unique and interesting case designs such as the Tower 500, though, it's hard to justify its £200 price tag. If you have plenty of money, and can afford to build an eye-catching water-cooled PC, then the Tower 500 will give it an attractive room with a view, but everyone else can get better value elsewhere.

ANTONY LEATHER

VERDICT

Massive air and water-cooling potential in a unique and interesting chassis, but it's overpriced for what you get.

TOWER OF LONDON

- \+ Excellent air and water-cooling support
- \+ Amazing view of your hardware
- \+ Good cooling

TOWER OF WASHING UP

- – Roof needs to be removed to detach side panels
- – Basic accessories and features
- – Expensive for what you get

COOLING	29/30
FEATURES	14/20
DESIGN	26/30
VALUE	12/20
OVERALL SCORE	81%

140MM FAN

ADATA XPG HURRICANE 140 ARGB / £20 inc VAT

SUPPLIER amazon.co.uk

The ADATA XPG Hurricane 140 ARGB's blades wouldn't look out of place on a Formula One car, with loads of vanes and vents. Each blade is equipped with a booster blade, which ADATA claims boosts airflow and static pressure. The fans use simple 4-pin PWM and 3-pin RGB connectors to control the blade speed, and the lighting and can be daisy-chained too.

The RGB lighting looks great, with defined rings around the outer and inner circles of the frame and hub. The lighting on Thermaltake's SWAFAN models is a bit punchier, but the ADATA still produced a pleasant glow of accurate colours. There's no fancy software control, though, and you only get screws in the box to mount them to your case.

A peak airflow of 1.14m/sec at an indicated 1,900rpm compared reasonably well with the 1.61m/sec we saw from the Thermaltake SWAFAN 14 ARGB. When we dialled down to 1,000rpm, though, the airflow of 0.44m/sec paled against the be quiet! Silent Wings 4, which hit 0.55m/sec at 40dBA, compared to 43dBA for the ADATA. At a noise-normalised 40dBA, the ADATA managed 0.34m/sec airflow, while the Silent Wings 4 sped along at 0.55m/sec.

The ADATA XPG Hurricane 140 ARGB may offer RGB lighting for just £20, but its funky blade design failed to better the performance from the be quiet! Silent Wings 4.

ANTONY LEATHER

HAWKER HURRICANE
- + Good-looking RGB lighting
- + Daisy-chained cables
- + Reasonably priced

PAPER PLANE
- – Mediocre efficiency
- – No RGB software
- – Higher than average noise

VERDICT
An affordable 140mm RGB fan, but it's not the most efficient.

PERFORMANCE 15/20
EFFICIENCY 38/50
FEATURES 7/10
VALUE 16/20
OVERALL SCORE 76%

140MM FAN

BE QUIET! SILENT WINGS 4 140MM / £20 inc VAT

SUPPLIER cclonline.com

Like it's smaller sibling that stormed our Labs in Issue 229, the Silent Wings 4 140mm comes with push-pin fittings that allow it to be installed in seconds with no tools, but also has replacement corner sections for the included fan screws or radiator screws.

The Silent Wings 4 140mm uses a 6-pole fan motor and fluid-dynamic bearing, and its corner sections all have anti-vibration mounts. Noise quality is superb, with no whine or tone noticeable at any speed.

At its maximum speed of 1,100rpm, the airflow of 0.7m/sec was less than half that of the Thermaltake SWAFAN 14 RGB, but the latter was also spinning twice as fast and was significantly louder.

At 1,000rpm, the Silent Wings 4 140mm offered more airflow – 0.55m/sec – than the 0.46m/sec for the Thermaltake and 0.44m/sec for the ADATA, and was several decibels quieter too. Meanwhile, at a noise-normalised 40dBA setting, it spun faster and offered more airflow than the competition too.

The be quiet! Silent Wings 4 140mm offers modest airflow, exceptionally low noise levels and high efficiency. It also has great sound quality and is easy to install. If you need more grunt, it comes in a faster version too, but both models come recommended, depending on your needs.

ANTONY LEATHER

THE BEATLES
- + Great airflow to noise ratio
- + Good sound quality
- + Tool-free fittings

WINGS
- – Not very powerful
- – No RGB lighting
- – Pricey

VERDICT
A smooth, quiet and supremely efficient 140mm fan.

PERFORMANCE 15/20
EFFICIENCY 49/50
FEATURES 6/10
VALUE 14/20
OVERALL SCORE 84%

120MM FAN

THERMALTAKE SWAFAN 12 RGB / £89 inc VAT (triple pack)

SUPPLIER scan.co.uk

As with its 140mm sibling, the 120mm Thermaltake SWAFAN 12 RGB features a clever reversible fan blade design, as well as software-controlled RGB lighting with the ability to tweak the speed.

The latter can be done using preset profiles, or with the discrete controller's PWM signal based on CPU temperature. However, you can only tweak this slider in increments of ten, with no fan curve adjustment. The lighting control is comprehensive, though, with all the essentials.

Like their larger siblings, these 120mm fans exhibited slightly lower airflow in reverse mode than standard mode, where they were a tad louder too.

When running at 2,000rpm, the Thermaltakes delivered 1.31m/sec of airflow at 67dBA, with the airflow being relatively low for the speed and noise, and not as good as Thermaltake's excellent Toughfan 12. We weren't able to set the fan at exactly 1,000rpm, instead hitting 950rpm where, not surprisingly, it dished out lower airflow than other fans we've tested. At 50dBA, it was again near the bottom of the pack, hitting 0.51m/sec, while the Deepcool FC120 offered double this for the same noise.

We love Thermaltake's innovative reversible fan blades, and the software is good. The 140mm model offers reasonable performance too, but the 120mm version lacks the efficiency of even mid-table fans in our recent Labs test.

ANTONY LEATHER

SWAN

- \+ Innovative reversible blades
- \+ Snazzy RGB lighting
- \+ Software controlled speed and lighting

SWAB

- – Below-par airflow
- – Reversed blades reduce noise quality
- – Poor efficiency

VERDICT

An innovative design, but it lacks grunt and efficiency.

PERFORMANCE 13/20

EFFICIENCY 30/50

FEATURES 9/10

VALUE 12/20

OVERALL SCORE 64%

140MM FAN

THERMALTAKE SWAFAN 14 RGB / £89 inc VAT (triple pack)

SUPPLIER cclonline.com

Thermaltake's SWAFAN 14 RGB comes in a triple pack of digital RGB-enabled fans, including a speed and lighting controller, for £89 Inc VAT. The latter allows for software control courtesy of a motherboard USB 2 header. The software allows you to alter the speed and lighting, which extends to the base of the fan hub and rings on both sides of the frame.

The blades don't have their own LEDs, though, as they're removable, allowing you to switch between standard and reversed blades – great if you want your fans to be visible in all their RGB glory, but with the exhaust side facing you.

The lighting looks fantastic and is easily tweakable in the software, while speed control is either done manually or using a PWM signal based on CPU temperature. The reversed blades managed an airflow of 1.4m/sec at 2,100rpm and, while the noise level of 62dBA was the same with the standard blades, the noise with the latter sounded more pleasant, and the standard blades increased the airflow to 1.61m/sec.

At 960rpm, they produced a fair amount of airflow, but not as much as the be quiet! Silent Wings 4 140mm, which also shifted more air at a noise-normalised 40dBA speed.

The innovative swappable fan blades are a huge boon for those that care about aesthetics, but these fans need to be more efficient at this price, especially in reversed mode.

ANTONY LEATHER

HOT CAKES

- \+ Good maximum airflow
- \+ Snazzy RGB lighting
- \+ Reversible fan blades

HOT TAKES

- – Mediocre efficiency
- – Reversed blades reduce airflow
- – Rather pricey

VERDICT

Innovative reversible fan blades and snazzy RGB lighting.

PERFORMANCE 16/20

EFFICIENCY 40/50

FEATURES 9/10

VALUE 12/20

OVERALL SCORE 77%

Z690 MOTHERBOARD

NZXT N5 Z690 / £209 inc VAT

SUPPLIER scan.co.uk

If you fancied the look of NZXT's N7 Z690, but couldn't quite stretch to its £300 asking price, NZXT has another option for you in the form of the N5 Z690. It retails for just £209, which still isn't exactly cheap, but that's not a horrendous price for a Z690 motherboard. Both boards use DDR4 memory, but how many gubbins has NZXT cut from the feature list compared with the N9 Z690?

Thankfully, you still get 802.11ax Wi-Fi and NZXT's stand-out CAM software control for lighting and fan speed, which we'll get to in a minute. There are four SATA 6Gbps ports and three M.2 ports as well, with all of the latter offering PCI-E 4 support, although only the top one comes with a heatsink. Future graphics cards could benefit from the board's 16x PCI-E 5 slot too, although this new interface is lacking from the M.2 ports.

Dig a little deeper into the specifications and you'll find less lavish audio in the form of Realtek's ALC897 codec, rather than the ALC1220 codec included with its pricier sibling. However, the same Realtek 2.5 Gigabit network controller is used on both boards, and each has both Type-A and Type-C USB 3.2 Gen 2 ports on the rear I/O panel too. Both boards have eight USB ports in total here as well, although the N9 Z690 has a few extra bits on the I/O panel, such as additional audio jacks, including an optical output, and a clear-CMOS button.

SPEC

Chipset
Intel Z690

CPU socket
Intel LGA1700

Memory support
4 slots: max 128GB DDR4 (up to 5000MHz)

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

Sound
8-channel Realtek ALC897

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

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

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

Dimensions (mm)
305 x 244

The main differences between the two boards are found on the top of the PCB itself, with an 8+1 phase power delivery on the N5 Z690 vs 12+1 for the N7 Z690. The N9 Z690 also has the extensive NZXT shroud, which comes in either black or white, while the cheaper board has a largely exposed PCB. However, there are still some white details if you opt for that version, so if you were aiming to use white memory and a white graphics card, your colour choices will still work. The lack of a shroud means easier access to ports as well.

With the M.2 heatsink installed, our PCI-E 4 SSD's temperature didn't rise above 51°C in our stress test, being kept well away from any potential throttling. The VRMs didn't have a digital readout, so we were forced to use an IR probe. They didn't overheat, sitting at 57°C under our ten-minute stress test, although this is a touch higher than the results from some other boards.

Perhaps the biggest difference between NZXT's products and those from other motherboard manufacturers, though, is the way they control your fans. There's no fancy fan control interface in the NZXT's EFI, with features such as fan curves. Here, you'll only find basic, clunky settings within the usual menus, which will make it time-consuming to set up more than a couple of fans.

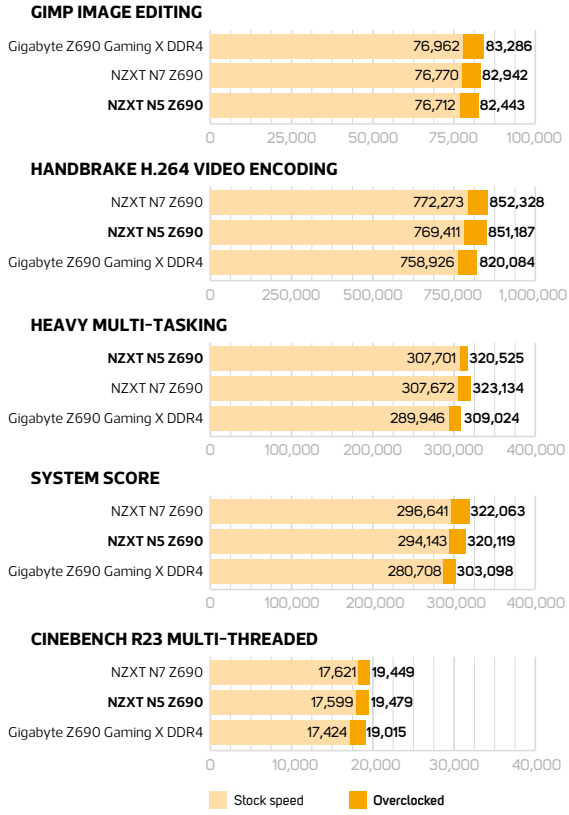
However, NZXT has given this motherboard support in its CAM software, which enables you to tweak fan speeds and RGB lighting from within Windows. This is as good as, if not better, than any motherboard software we've used, although it's not as granular in some areas, such as switching between temperature inputs or DC and PWM control. The downside, of course, is that if you want to ditch any motherboard software and just use the EFI, there's no easy way to fine-tune your fan speeds.

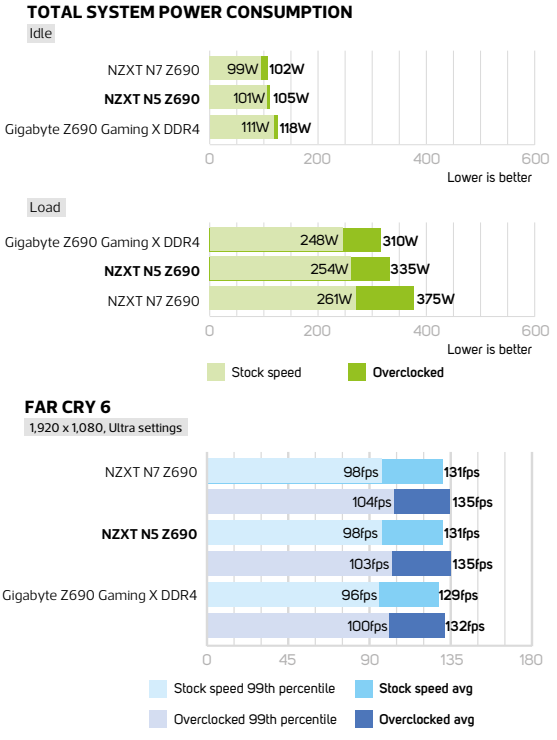
Performance

The N5 Z690's audio performance was surprisingly good, given it only used Realtek's ALC897 codec, and the noise level of -96dBA, dynamic range of 96dBA and THD of 0.001 are solid numbers, although a decent ALC1220-based motherboard is definitely better here. The N7 Z690, for example, hit 110dBA on the dynamic range.

This board is fine for overclocking though. We hit 5GHz across the P-Cores on our Core i5-12600K, with a vcore of 1.36V, as with many other Z690 boards we've tested. This overclock added 7 per cent added to the image editing score and 11 per cent to the Cinebench multi-threaded test score. This shows that both lightly threaded and multi-threaded

BENCHMARK RESULTS





FAN CURVE

- \+ Smart looks
- \+ Decent feature set
- \+ Excellent software control

INFLATION CURVE

- – Lacks aesthetic prowess of other NZXT boards
- – No EFI-based fan control suite
- – Basic audio

workloads can benefit from overclocking, with the N5 Z690 able to provide the necessary boost.

The system scores of 294,143 and 320,119 at stock speed and overclocked respectively weren't noticeably better than any other boards, but given this is one of the cheapest Z690 boards we've tested, this shows it's still competitive. The power consumption was on the money too, although a little higher when overclocked than some other boards.

Conclusion

There's increasing competition at the low end of the Intel Z690 motherboard spectrum, which is good news for potential owners, as it makes affording an Intel 12th-gen PC more affordable. Of course, you could also wait for 13th-gen CPUs to land in the not too distant future and, thanks to the inclusion of USB BIOS Flashback, the N5 Z690 can update its BIOS even without a compatible CPU installed, just in case you buy an example with an older BIOS version.

The specifications are mostly solid too, with plenty of rear USB ports, Wi-Fi, USB Type-C and plenty of M.2 ports, and while the audio could be better, it isn't bad either. The only disappointment is that this board lacks the stand-out qualities of the last collaboration between NZXT and ASRock, which is the large PCB shroud and overclocking and testing tools.

As a result, it's up against other standard motherboards, such as the Gigabyte Z690 Gaming X DDR4, which admittedly lacks Wi-Fi, and MSI's MAG Z690 Tomahawk, which costs around £30 more. The N5 Z690 strikes a good balance of features, aesthetics and value though – as long as you're happy to use its CAM software to fine-tune your system fans, we can certainly recommend it.

ANTONY LEATHER

VERDICT

Smart looks, plenty of features and a reasonable price, but it has rather limited fan control options.

PERFORMANCE **32/35**

FEATURES **24/35**

VALUE **25/30**

OVERALL SCORE **81%**

27IN GAMING MONITOR

AOC AGON PRO AG274QG / £850 inc VAT

SUPPLIER box.co.uk

AOC's Agon Pro AG274QG is one of a handful of new gaming monitors that push the limits of current LCD panel technology, combining a 2,560 x 1,440 resolution with a whopping 240Hz refresh rate. As they use the very latest in panel technology, most of these screens demand quite high prices, but even then, this AOC is particularly expensive.

With its DisplayHDR 600 certification, built-in Nvidia Reflex Analyzer, wired remote control for its on-screen display (OSD) and lots of RGB lights on the back, it certainly does its best to justify its high price though. AOC has seemingly taken a leaf out of Asus' book with the AG274QG. For several years that company's high-end monitors have included RGB lighting on the back and a logo projector in the stand for firing the Asus ROG logo (or a silhouette of your choice, via a replaceable circular mask) onto your desk.

We found the additions to be superfluous on those monitors and it's the same with this monitor, especially as you can't add your own the mask to the logo projector here – you can opt for the Agon logo or Agon name and that's it. The rear lighting, meanwhile, offers a host of built-in patterns and colour options, but doesn't include a Philips Ambilight-style mode for matching the lighting to what appears on the screen.

More useful additions come in the form of an included screen shield, which clips to the top and sides of the display to reduce glare and provide some privacy if you're at a LAN or shared office situation. There's also a slide-out headphone stand on the left edge of the panel.

The stand, with its elegant (though very wide) metal, V-shaped feet, offers a full range of ergonomic adjustments and includes a carry handle at its top. It can also be removed to reveal a 100 x 100mm VESA mount for use with alternative monitor arms and mounts.

Connection options consist of one DisplayPort 1.4 input and two HDMI 2 ports, along with a 4-port USB 3.2 hub. There's also a headphone jack that offers good clean sound quality (not always a given), along with two 5W speakers, which sound treble-heavy, but do at least sound clear and undistorted.

Alongside the headphone jack is the input for the wired OSD remote control. It's a pleasantly weighty little unit, so it isn't tossed around by the strength of its own cable, and it has satisfyingly clicky buttons for navigating the menus and recalling four menu presets.

However, you can't hold down the buttons to adjust settings such as brightness or volume – you have to press these buttons multiple times. Considering the brightness is adjusted on a scale of 40-450 nits, that's a lot of button presses. Otherwise, the menus are controlled via a mini D-pad on the right rear of the panel, and this control does have the option to hold down buttons.

The menus are largely comprehensive, with plenty of colour-tweaking options and game-specific settings, and they're quick to respond. However, navigation isn't as intuitive as on some monitors – sometimes a press of the D-pad is used to select an option and sometimes you select an option by pressing right on the D-pad.

SPEC

Screen size
27in

Resolution
2,560 x 1,440

Panel technology
IPS

Maximum refresh rate
240Hz

Stated response time
1ms

Max brightness
450cd/m² SDR and HDR

Backlight zones
1

Stated contrast ratio
1,000:1

Adaptive sync
G-Sync Ultimate, FreeSync

Display inputs
1 x DisplayPort 1.4, 2 x HDMI 2

Audio
2 x 5W speakers, headphone out

Stand adjustment
Height, pivot, rotation, tilt

HDR standard
DisplayHDR 600

Extras
100 x 100mm VESA mount, 4-port USB 3.2 hub, rear RGB lighting, Nvidia Reflex Analyzer

PERFORMANCE

Getting to the display itself, this monitor's impressively slim-bezelled IPS panel is a bit of a mixed bag. On the one hand, it offers good viewing angles, dazzling colours (140 per cent sRGB colour space coverage) and a decent contrast ratio of 948:1 in our tests. However, its default colour balance is poor, with its 7,372K colour temperature being well above the ideal of 6,500K, and its gamma isn't quite right either, with a measurement of 2.04 rather than 2.2.

It took switching to the User colour mode and adjusting the default 50x50x50 RGB colour values all the way to 50x47x34 to get the colour balance right, while opting for the +0.2 gamma option was needed to correct that figure. There's also noticeable IPS glow in the bottom two corners. One positive is that there's an sRGB colour gamut toggle for reducing the colour gamut to 100 per cent sRGB, and this mode doesn't lock out the other image adjustment settings when it's used, unlike many displays.

The AOC also includes a zoned backlight for boosting contrast, but it's only split up into 32 columns – as soon as any vertical portion of a column is illuminated, so is the whole column. As a result, we didn't record any boost in real-world contrast using the DisplayHDR Test app. Subjectively, there's a little boost in contrast – along with a dazzling peak brightness of over 600cd/m^2 – giving HDR content a little more life than displays with no backlight zoning at all and a lower peak brightness, but it still isn't true HDR.

As for gaming, this is where the AG274QG really comes into its own. The combination of a 240Hz refresh rate and a 2,560 x 1,440 resolution makes for a superbly snappy and sharp-looking image that's ideal for modern-day shooters and other competitive, fast-paced games. Using its default Weak overdrive mode, the display delivered a very nippy 4ms initial response time while producing a minimal amount of colour overshoot, resulting in a fast and clear-looking display.

The response time can drop even further – as low as 3.3ms – at higher overdrive settings but overshoot increases significantly. That said, we would consider using the Medium overdrive setting. Overshoot hits an average RGB value miss of 17 at this setting, which results in a little bit of visible overshoot in gaming, but it's not too distracting and the initial response time drops to 3.55ms.

Sadly, this monitor doesn't have a backlight-strobing blur reduction mode, but it does support G-Sync Ultimate and Nvidia Reflex Analyzer. The latter allows you to plug a mouse into the monitor's USB port, and it then uses an internal detector to measure the lag between your mouse click and on-screen response. It's rather useful, particularly for trying to gauge the impact of Nvidia's own in-game low latency options, but often any change to optimise lag will be reflected in a faster frame rate too, which you can measure without any extra tools.

BELLS AND WHISTLES

+ Fantastic gaming performance
+ Excellent image quality once calibrated
+ Loads of extra features

NEEDLESS FRILLS

– Initial colour balance is poor
– Some unnecessary frills
– Very high price

CONCLUSION

The AOC AG274QG is by and large a fantastic gaming monitor. Its 2,560 x 1,440 resolution, 240Hz refresh rate and low response time combine to make for a superb gaming experience. Once calibrated, its image quality is excellent too, plus some of its extra features are genuinely useful.

However, other extras such as the lighting and OSD remote feel superfluous, it lacks the real-world contrast needed for stellar HDR performance and its out-of-the-box colour balance is off. Given its price, this makes it a hard sell, especially when other 240Hz displays with 2,560 x 1,440 resolutions can be bought for half the price.

EDWARD CHESTER

VERDICT

An excellent display for gaming, but it needs some image calibration and it's monstrously expensive.

IMAGE QUALITY **22/30**

GAMING **28/30**

FEATURES **18/20**

VALUE **9/20**

OVERALL SCORE **77%**

MECHANICAL KEYBOARD

DUCKY ONE 3 SF / £100 inc VAT

SUPPLIER overclockers.co.uk

FORM FROM FUNCTION

+ Great overall build quality
+ Comparatively quiet
+ Hot-swappable switches
+ Wide range of sizes and colours

FORM OVER FUNCTION

– Yellow colour option lacks key backlighting
– No Home or End keys
– Not cheap

Ducky has been making great quality mechanical keyboards for years, and the One 3 is the company's latest main keyboard line-up, coming in all manner of sizes, layouts, colours and hot-swappable switch options. The variant on test is the SF (65 per cent layout), which drops the entire top row of Esc and F keys, the numpad area and most of the Home/End cluster of keys.

However, unlike 60 per cent keyboards, it retains dedicated cursor keys and a small cluster of Del, PgUp and PgDn keys, putting that crucial handful of keys at your disposal. The One 3 is also available in 60 per cent, tenkeyless (TKL) and full-sized variants.

The SF format offers a useful compromise between super-compact 60 per cent layouts and larger formats. The addition of cursor keys and a dedicated Del key are very useful for everyday needs, although we would have preferred Home and End keys over the PgUp and PgDn keys. The sheer number of secondary functions can be a bit confusing though – you'll need to download the manual to get the most from this keyboard.

If our sample's subtle shade of yellow isn't to your liking, there are umpteen other colour options as well, including black, white, translucent black and several multi-colour options. Along with the standard keycaps, each keyboard also includes several replacement keys. For instance, the black and white versions come with a replacement spacebar with a tiger pattern on it and a purple Enter key.

As well as a full set of yellow keys, our review model includes Enter, cursor, Esc and shift keys that are white with red legends. A keycap puller and key switch puller are also included, along with a matching yellow USB Type-C cable (with the socket on the far-left rear of the unit).

We found the white legends on this yellow model difficult to see in dull lighting conditions, as they're not translucent to allow the backlighting through the letters. The white and black versions with their translucent legends are preferable in this respect. Another small gripe is that the white plate, which sits under the keycaps and holds the keyswitches, has a hole between the G and H keys, which mars the clean look.

Otherwise, the build quality can't be faulted. This keyboard is weighty and rock solid and the extra layer of padding below the PCB helps to deaden rattles – you can hear the signature clatter of your chosen mechanical key switches but without the amplifying effect of the chassis.

The doubleshot PBT keycaps also feel great, with a rough texture that really grips your fingertips, and the texture and legends won't wear away as quickly as ABS plastic and printed legends either. Meanwhile, sturdy, two-level flip-down rear feet keep the keyboard in place, and there's a four-toggle DIP switch on the underside. These four switches enable or disable the Windows key, switch between N-key rollover and 6-key rollover, switch between a Ducky vendor ID and a user-defined vendor ID, and switch the right Windows key to a menu key.

SPEC

Dimensions (mm)
335 x 110 x 40 (W x D x H)

Weight
627g with cable

Format
65 per cent – 68 keys

Connections
USB Type-C socket with 2m cable

Switch type
Hot-swappable Cherry MX

Switch life
100 million key presses

Backlighting
Per-key RGB

Polling rate
1000Hz

Keyboard rollover
N-key

Extras
Doubleshot PBT keycaps, hot-swappable switches, keycap and key switch removal tools, replacement keycaps

Conclusion

This particular yellow SF version of the One 3 has niche appeal thanks to its compact size, bright colour and non-translucent key legends. However, as a representative of the quality of the One 3 range, it's rather more impressive. It's a stylish, well-built keyboard that's quiet and available in all manner of configurations.

EDWARD CHESTER

DESIGN 18/20
FEATURES 16/20
PERFORMANCE 26/30
VALUE 22/30

OVERALL SCORE 82%

VERDICT

A stylish and well-built keyboard, but this yellow colour isn't our first choice.

MECHANICAL KEYBOARD

KEYCHRON Q1 V2 / £159 inc VAT (chassis alone)

SUPPLIER keyboardco.com

FLORIDA KEYS

+ Amazing build quality
+ Marvellous typing experience
+ High-quality dye-sub PBT keycaps
+ 75 per cent layout offers good balance

CAR KEYS

– Expensive with the best configurations
– Weight means it's not particularly portable
– RGB doesn't work well with all switches

Keychron is targeting both enthusiasts and prospective keyboard builders with the Q1 V2. You can either purchase it as a preconfigured keyboard with keycaps and switches, or buy it in a barebones form, sourcing the switches and keycaps yourself. The latter option provides immense versatility, with our sample coming with a set of Cherry MX Clears and Keychron's own Mac-Inspired keycaps, which make it look like an old Apple Extended Keyboard from the late 1980s.

The high-quality dye-sub PBT keycaps are superb, and the switches are also hot-swappable, although we recommend picking up a few spare ones just in case you end up accidentally bending some pins if you put one of them in wrong.

The MX Clears' 65g force makes them ideal for typists, with arguably more tactility than you'll find in MX Browns. They act as a reminder of keyboards from yesteryear, when the MX Clears were much easier to find. The only problem is that the MX Clears feature a black housing, so the RGB LED lighting isn't particularly visible compared with clear-housed switches, such as any of Cherry's MX RGB options.

There's some additional software here too, in the form of VIA, which is a powerful suite. It enables you to remap keys and program macros on several function layers, as well as control the aforementioned lighting and test all the switches to make sure they all work.

In terms of layout, the Q1 V2's 75 per cent layout offers a total of 82 keys. It's akin to a tenkeyless keyboard that ditches the numberpad and only offers the standard alphanumeric keys and the navigational key cluster. In this case, that right-hand cluster is squidged into one column, as opposed to two shorter rows, a bit like the Ducky One SF 3 opposite. It offers a good balance of gaining desk space without sacrificing too many features compared with a 60 per cent design.

Its total mass of 1.6kg makes it one of the heavier compact keyboards available, and the CNC-machined 6063 aluminium outer casing means there's no flex – the build quality is exemplary here. There are also a few creature comforts, including a detachable, braided and coiled USB Type-C cable and a selector switch between Windows and Mac modes.

Conclusion

The Keychron Q1 V2 is an excellent keyboard. The build quality of its aluminium case feels military grade, and it offers an intuitive and easy to use layout. Meanwhile, the ability to hot-swap key switches makes for an incredibly versatile range of options, whatever your preference.

The MX Clears used in our sample feel responsive, with great tactility, and are ideal for typing, although they don't work brilliantly with RGB lighting. However, gamers also have the option to equip this well-made keyboard with their own choice of switches and keyboard. There's RGB if you want it, and the bundled VIA software is both simple and effective.

The only downside is the price, which is an immense £159 inc VAT for the chassis, and you then have to add the switches and keycaps – our configuration as reviewed came in at £287.40 inc VAT. That cost is undoubtedly immense, but if you have that sort of money to spend on a keyboard, this is a fantastic model.

REECE BITHREY

SPEC

Dimensions (mm)
328 x 145 x 35 (W x D x H)

Weight
1.6kg

Format
75 per cent layout (82 keys)

Connection
Wired – USB Type-C to Type-A cable

Switch type
Mechanical

Switch life
100 million key strokes (with MX Clears – switch dependent)

Backlighting
RGB (although will only show with the right switches)

Extras
Keycap puller, key switch puller, detachable USB Type-C cable, Mac keys

VERDICT

Sleek looks, great versatility and unparalleled durability makes the Q1 V2 a superb keyboard, but you'll have to pay for it.

DESIGN 24/25
FEATURES 16/25
PERFORMANCE 23/25
VALUE 15/25
OVERALL SCORE 78%

GAMING MOUSE

ROCCAT KONE XP AIR / £150 inc VAT

SUPPLIER roccat.com

BUTTONED UP

+ Masses of easily reachable buttons
+ Convenient charging dock
+ Excellent gaming performance

HANGING LOOSE

– No rubber to aid grip
– Comparatively heavy
– High price

Roccat's Kone XP Air sets aside the current trend for ultra-lightweight mouse design and minimal features, and instead packs in just about every feature you could imagine, including a charging dock, 13 buttons and plenty of RGB lighting.

The regular Kone XP is our Elite-listed multi-button mouse of choice, thanks to the ingenious way it packs in so many buttons without them becoming difficult to hit and without the mouse being unwieldy. Joining the Air's conventional left and right-click buttons is a scroll wheel that tilts left and right and presses down, and behind it is a button that defaults to switching the mouse profile. To the left of the left-click button are two extra buttons for your index finger to tap, which default to switching the DPI up and down.

Above your thumb is a cluster of four buttons, the top two of which default to back and forward functions, then under the thumb is a button that can be activated by tipping your thumb down towards the desk. It defaults to an Easy-Shift mode that acts like a keyboard's Shift button to modify the function of the mouse's other buttons. The whole combination works superbly, putting dozens of functions at your fingertips for genuinely easy activation, with minimal risk of hitting the wrong button.

The overall ergonomics of the Kone XP remain the same as before, with a highly sculpted right-hand-only design. The gap for your thumb could be a bit tight if you have quite thick fingers but it worked fine for us. The lack of any soft-touch or rubber areas to aid grip isn't a problem in the current heat either, but the mouse could prove a little slippery in colder, drier times, especially given it's not all that light, at 99g. That's a low figure for a mouse with this many buttons – and lighter than the standard Kone XP – but 50 per cent heavier than many ultralight mice.

New to the Air version of the XP is wireless connectivity and a charging dock. The latter is a neat little unit with a fetching strip of RGB lighting around its base and a tiny footprint of just 56 x 56mm, yet it's sufficiently weighted to remain stable and not slide around. The mouse easily slides onto the two charging pins and you'll get five hours of game time on ten minutes of charge. Overall battery life is low, though, with a top up required every few days.

The wireless receiver slots into a USB slot on the front of the dock, while the USB Type-C cable plugs into the back. That same cable can be connected to the front of the mouse for charging and wired used, and the USB dongle can be stowed in a slot on the underside of the mouse. The mouse also supports Bluetooth.

Meanwhile, the Roccat Owl-eye sensor tracks flawlessly, keeping up with all our most extreme gaming movements without issue. Likewise, the main buttons all feel crisp and responsive. The only issue is that, even with the clever layout, we still occasionally hit the wrong button or nudged one of the many extra buttons during very fast mouse movements, but you can always disable some buttons during certain games.

SPEC

Weight
99g

Dimensions (mm)
72 x 126 x 40 (W x D x H)

Sensor
Roccat Owl-Eye 19K (based on PixArt PAW3370) optical, 19,000 DPI, 50G acceleration, 400 IPS

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

Cable
1.8m, lightweight braided

Extras
Bluetooth and 2.4GHz wireless connections

Conclusion

The Roccat Kone XP Air is a fantastic do-it-all mouse with its mass of extras buttons, multiple wireless and wired connection modes and a convenient charging dock. It also can't be faulted for gaming performance. It's comparatively heavy, and its price is high, but if you have the money, it's ideal if you want every possible function at your fingertips.

EDWARD CHESTER

DESIGN 14/20
FEATURES 20/20
PERFORMANCE 26/30
VALUE 20/30

OVERALL SCORE 80%

VERDICT

A pricey but very capable multi-button wireless gaming mouse.

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GAMING LAPTOP

ASUS ROG STRIX SCAR 17 SE / £3,999 inc VAT

SUPPLIER scan.co.uk

Asus' ROG products are rarely shy, retiring or affordable, but the ROG Strix Scar SE ups the ante by several notches, with benchmark-breaking internals and a vast £3,999 price. That huge cost is partly justified by the core components. Graphics come from Nvidia's flagship GeForce RTX 3080 Ti mobile GPU, for example, which has 7,424 CUDA cores, and it runs at this GPU's peak power level of 150W, hitting 175W using Dynamic Boost.

Likewise, the Core i9-12950HX is Intel's most powerful mobile CPU, with eight Hyper-Threaded P-Cores that peak at 5GHz and eight E-Cores to bolster multi-threading performance. Support comes from 32GB of dual-channel DDR5 memory and two Samsung PM9A1 SSDs in a RAID 0 array. Networking is similarly high-end, with 2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi and Bluetooth 5.2, while the 17.3in display combines a 2,560 x 1,440 resolution with a 240Hz refresh rate.

Not surprisingly, this powerful hardware sits inside an eye-catching chassis. The base incorporates translucent plastic, and you can customise the hinge with removable plastic. There are also RGB LEDs everywhere. It looks the part, although the weight of 3.1kg is significant, the body is 28mm thick and build quality is inconsistent: the screen and underside are strong, but the metal around the keyboard flexes.

Connection options could be better too. While the Asus serves up two full-sized USB ports, a USB 3.2 Gen 2 Type-C connection and Thunderbolt 4 alongside HDMI 2.1, at this price, we expect faster USB Gen 2x2 ports, and at least a webcam and SD card reader.

Amid that flexible metal you'll find a middling keyboard. It's a chiclet unit with a crisp, fast action that's ideal for gaming, and it has per-key RGB LED lighting alongside extra buttons for volume, microphone and fan control. It has a numberpad, too, but the layout could be better – on a 17.3in rig, there's no excuse for thin numberpad keys, shrunken cursor buttons and a single-height Return key.

This Special Edition model also has some high-end enthusiast credentials. Positively, the interior boasts a new vapour-chamber cooler and Thermal Grizzly Conductonaut Extreme paste on the CPU and GPU. Negatively, other Special Edition features have little practical impact.

The laptop includes a game called Scar Runner, for example, a first-person parkour adventure – and invisible ink on the lid can be revealed using an included UV flashlight to solve in-game puzzles. Playing the game only nets you the chance to enter a prize draw for ROG gear. And, despite Asus' boasts that it took seven attempts to get the ink right, Asus confirms that 'inks on the lid will fade over time' – and the hidden messages are visible in sunlight anyway. It seems like a lot of effort for a short-lived gimmick that adds to the price of the laptop.

SPEC

CPU
2.3GHz Intel Core i9-12950HX

Memory
32GB 4800MHz DDR5

Graphics
Nvidia GeForce RTX 3080 Ti 16GB

Screen
17.3in 2,560 x 1,440 IPS 240Hz

Storage
2 x 1TB Samsung PM9A1 M.2 SSD

Networking
Gigabit Ethernet, Dual-band 802.11ax Wi-Fi, Bluetooth 5.2

Weight
3.1kg

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

Dimensions (mm)
395 x 282 x 28 (W x D x H)

Operating system
Windows 10 Home 64-bit

Warranty
One year parts and labour return to base

It's an awful lot to pay too, considering the hardware. The normal Scar 17 with the RTX 3080 Ti, a 240Hz display and a Core i9-12900H costs £3,399 – and you can spend £3,399 on the Alienware x17 R2 with the RTX 3080 Ti, Core i9-12900HK and a 360Hz display.

PERFORMANCE

Beyond the bluster, the Strix Scar 17 SE is indeed the most powerful laptop we've reviewed. In Assassin's Creed Valhalla and Cyberpunk 2077 at 1080p, the Asus delivered 99th percentile minimums of 59fps and 70fps, with both results marginally outpacing the Alienware.

Cyberpunk remained smooth with DLSS and ray tracing, and the 323fps average in Doom Eternal shows it can easily run undemanding games in sync with the screen's 240Hz refresh rate too. The native 2,560 x 1,440 resolution is no problem either, with an Assassin's Creed Valhalla 99th percentile result of 49fps and a superb 249fps average in Doom Eternal.

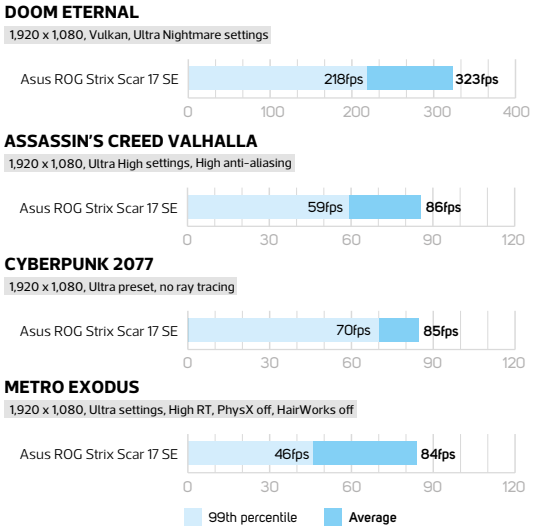
The Core i9-12950HX is similarly impressive. Its single-threaded image editing result of 73,398 easily beat the scores we've recorded from conventional chips, such as the i7-12700H and i9-12900H, and its Handbrake result of 1,004,104 is miles ahead of the competition, thanks to those 16 cores.

Not surprisingly, the Core i9 excels in heavily multi-threaded content creation software too, recording a multi-threaded score of 22,688 in Cinebench R23 with the laptop switched to its Turbo mode. Intel's conventional Core i7 and Core i9 laptop parts tend to be around 4,000 points behind in that benchmark.

The SSD RAID array is also impressively fast, with sequential read and write speeds of 10,632MB/sec and 10,149MB/sec, but remember that RAID 0 means no data redundancy – if one drive fails then you lose everything.

The Scar's upgraded thermal hardware does a sterling job too. In Balanced mode, the Asus was quieter than most gaming laptops. In Turbo mode the fan noise increased, but it was still one of the quietest notebooks we've tested – just as good as the Alienware x17 R2. The respective CPU and GPU delta Ts of 46°C and 50°C are great too, and the exterior panels never became too hot.

BENCHMARK RESULTS



ULTRAVIOLET

- \+ Incredible performance
- \+ High-quality 240Hz screen
- \+ Fast storage
- \+ Impressive cooling performance

ULTRAVIOLENT

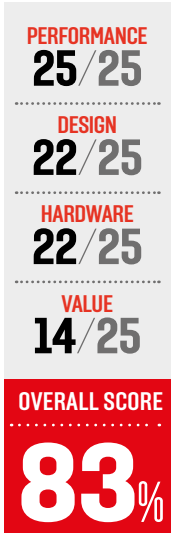
- – Absurdly expensive
- – Misfiring marketing nonsense
- – Middling connection options
- – Heavy, thick chassis

Meanwhile, the display's decent brightness level of 331cd/m^2 contributed to a contrast ratio of 1,068:1, and the delta E of 2.83 and sRGB coverage level of 99.9 per cent ensure a broad gamut of accurate colours. However, while games look great here, they look better on the Alienware's display, which has better contrast and accuracy – alongside 360Hz and 480Hz options. Asus says that a 360Hz model is coming, but not until later in the year. The speakers could be better too – they're loud and bassy, but the mid-range is muddy.

CONCLUSION

The Asus ROG Strix Scar 17 SE is the fastest laptop we've ever tested, and its storage, keyboard and display are all solid too. However, at this colossal price, we expect better connection options, build quality and ergonomics. Alienware's laptop is nearly as fast, cheaper and has a slimmer, sleeker chassis and more customisation options. Unless you're loyal to the ROG brand, or need as much power as possible whatever the cost, cheaper rivals deliver almost all of the grunt and better quality in key areas without all the marketing babble.

MIKE JENNINGS



VERDICT

Record-breaking power inside a bold chassis, but the Scar is just too expensive.

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INTEL Z690 GAMING PC

CHILLBLAST FNATIC PIONEER / £2,299 incVAT

SUPPLIER custompc.co.uk/Pioneer

The Pioneer is the result of a collaboration between Chillblast and Fnatic, and you'll find design touches everywhere that advertise the partnership, including on the tempered glass side panel. The good looks continue with RGB LEDs and a Fractal Design AIO liquid cooler with a slick frosted waterblock.

Fractal's new Pop Air chassis impresses in practical areas too – at the bottom of the front section, there's a hidden drawer to hold USB sticks and other small peripherals. Beneath the PSU shroud, you'll find a pair of drive bays that can simultaneously hold a 2.5in and 3.5in drive, albeit without tool-free installation, and behind the motherboard is space for two extra 2.5in drives. At 454mm tall, the Pop Air won't take up too much space, and Chillblast has kept cable tidying neat throughout. On top there's also a button to alter the RGB LEDs.

The case does have some minor issues. The Fractal Design Lumen CPU cooler impedes the spare memory sockets, while the two USB 3 ports sit alongside space for a USB 3.2 Gen 2 Type-C connector, it's not installed – to use it you'll have to buy Fractal's Model D cable. Also, while Fractal produces this chassis in several colours, the Pioneer is only built in black.

Meanwhile, a Palit's RTX 3070 GamingPro graphics card dominates the interior – a suitable name given the Pioneer's esports branding. The GPU is equipped with 8GB of memory and 5,888 CUDA cores, but its boost clock of 1725MHz isn't overclocked. Likewise, the Core i7-12700F processor runs at stock speed, and can't be multiplier-overclocked, but it's a solid all-rounder, thanks to eight Hyper-Threaded P-Cores with a 4.9GHz boost clock.

The 32GB of 3200MHz DDR4 memory is ample for gaming and content creation too, and the 1TB Seagate FireCuda 530 SSD is large enough to hold plenty of games, and its read and write speeds of 7,043MB/sec and 5,889MB/sec are rapid. It's all powered by a Fractal Ion Gold PSU, which has modular cabling and 80 Plus Gold certification, which is excellent, and the same goes for Chillblast's warranty – a three-year on-site deal with labour and parts coverage for the duration.

All the gear plugs into an Asus TUF Gaming Z690-Plus WiFi D4 motherboard, which covers all the essentials. The inclusion of 2.5Gbps Ethernet, dual-band Wi-Fi 6 and Bluetooth 5.2 gives you great connection options, the top 16x PCI-E slot supports PCI-E 5 and all four M.2 connectors use PCI-E 4.

The board has a Thunderbolt header as well, and at the rear you'll find a 20Gbps USB 3.2 Gen 2x2 Type-C port, a second slower USB Type-C connector and five full-sized USB ports. It's a good board for upgrading – it's only really missing DDR5 support and Wi-Fi 6E.

Chillblast's PC is impressive, but it squares up to strong competition. The CCL Horizon 5, for example, costs £1,972 inc VAT at the moment and gives you a faster RTX 3080 GPU, along with the same warranty standard and the same motherboard as the Chillblast. The CyberPower Infinity X127 Plus (see over) also gives you a more powerful CPU and GPU for under two grand. On the plus side, the Chillblast has double the amount of memory of those machines.

SPEC

CPU
2.1GHz Intel Core i7-12700F

Motherboard
Asus TUF Gaming Z690-Plus WiFi D4

Memory
32GB Corsair Vengeance RGB Pro 3200MHz DDR4

Graphics
Palit GeForce RTX 3070

Storage
1TB Seagate FireCuda 530 M.2 SSD

Networking
2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi, Bluetooth 5

Case
Fractal Design Pop Air RGB Black TG Clear Tint

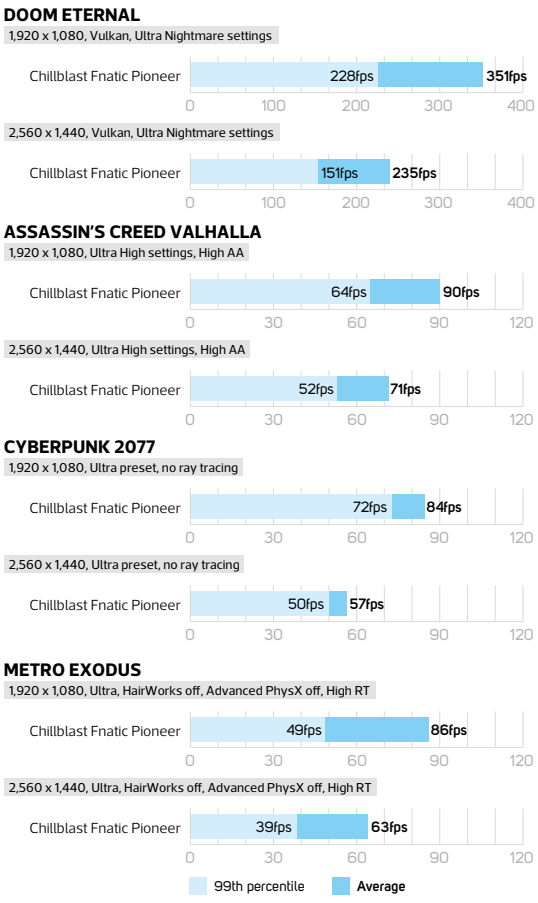
Cooling
Fractal Lumen RGB with 2 x 120mm fans; GPU: 3 x 90mm fans; front: 2 x 120mm fans; rear: 1 x 120mm fan

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

Operating system
Windows 11 Home 64-bit

Warranty
Three years parts and labour on-site

BENCHMARK RESULTS



Performance

The Chillblast's RTX 3070 has plenty of grunt for running undemanding games at high frame rates, which is ideal for esports. At 1080p, the Palit card delivered an average of 351fps in Doom Eternal, and at 2,560 x 1,440, it ran at 235fps – you'll have no trouble running undemanding games in sync with a 240Hz display.

The RTX 3070 tackles mainstream single-player scenarios too – at 1080p, it returned 99th percentile minimums beyond 60fps in Assassin's Creed Valhalla and Cyberpunk 2077, with the latter still eminently playable with Medium ray tracing and DLSS enabled. The Fnatic rig will also handle gaming at 2,560 x 1,440 with decent frame rates, although the CCL's RTX 3080 is much quicker here.

Chillblast's PC fought back in multi-threaded application tests. The Chillblast's Core i7 CPU has two more P-Cores than the Core i5 chip in the CCL, and its Handbrake video encoding result if 905,643 easily beats the CCL's 778,744. However, the CyberPower's result of 898,448 is nearly on par with the Chillblast, and the CyberPower's Core i7-12700K CPU also has stronger single-threaded performance, as demonstrated in its superior result in our image editing test.

On the plus side, the Chillblast's thermal performance is excellent. When gaming, the Pioneer only produced a low hum – you simply won't notice it in most situations. In a single-core benchmark, the Pioneer's noise levels remained the same and the CPU ran at 4.7GHz – almost at its peak pace. The rig's loudest performance came in a multi-core benchmark, but even then the noise remained moderate. In this test, the P-Cores ran at a rock-solid frequency of 4.5GHz, and the CPU's delta T of 59°C was reasonable.

FANTASTIC

- \+ Decent gaming pace
- \+ Good-looking, tidy and accessible case
- \+ Solid motherboard and SSD
- \+ Great warranty

FANATIC

- – Expensive
- – Rivals are faster in games
- – CPU can't be overclocked

Conclusion

The Chillblast Fnatic Pioneer offers ample gaming power, a solid CPU, a tidy build and quiet operation. The motherboard is great for gaming and upgrades, and the chassis has a slick design and decent practicality. At £2,299, though, it's just too expensive when a much cheaper PC will get you more gaming performance, albeit with less memory and slightly slower CPU. If you're a Fnatic fan and love the branding enough to pay for it, then the Pioneer is a well-built and powerful PC, but you can otherwise get better value elsewhere.

MIKE JENNINGS

PERFORMANCE 21/25

DESIGN 22/25

HARDWARE 22/25

VALUE 16/25

OVERALL SCORE 81%

VERDICT

Fast, well built and quiet, but this esports-branded system is too expensive for the spec on offer unless you're a Fnatic fan.

INTEL Z690 GAMING PC

CYBERPOWER INFINITY X127 PLUS / £1,999 inc VAT

SUPPLIER custompc.co.uk/X127Plus

CyberPower's Infinity X127 Plus makes a big mid-range impression thanks to its core components – for one penny under £2,000, you get an MSI GeForce RTX 3080 card with a boost speed overclocked to 1755MHz, alongside a Core i7-12700KF with eight Hyper-Threaded P-Cores that peak at 5GHz.

That's impressive silicon, and elsewhere the Infinity's specification ticks the relevant boxes without pushing. There's a 1TB Seagate SSD with a great read speed of 6,338MB/sec and an acceptable write pace of 3,511MB/sec, plus there's a 2TB hard disk for extra data storage alongside 16GB of DDR4 memory running at 3200MHz.

MSI's MPG A850GF is an 80 Plus Gold-certified modular PSU, which is great, and MSI also makes the motherboard. The Pro Z690-P DDR4 has some welcome practical touches – its two M.2 connectors support PCI-E 4, the top PCI-E slot supports PCI-E 5 and the board has spare memory slots, a Thunderbolt header and a super-fast USB 3.2 Gen 2x2 Type-C connector at the rear. The board also offers 2.5Gbps Ethernet, while 802.11ax Wi-Fi is provided by an add-in card.

In many ways, though, the motherboard is the weakest part of this PC. The M.2 connectors don't have heatsinks, there's no DDR5 support and no visual pizzazz, with no large heatsinks or RGB LEDs. Also, while the board does have that fast USB Type-C connection, there are only four other USB 3 ports and two slower USB 2 connections to make up the numbers. It's a reasonable board, but there's little in the way of frills for enthusiasts.

Happily, the rest of the build makes up for the motherboard's lack of RGB LEDs. The three intake fans, the sole exhaust and the spinners on the MSI MAG CoreLiquid radiator, all glow brightly, and there's a band of synchronised lighting across the graphics card.

The CyberPower Bifrost case is a capable mid-tower too, with a tempered glass side panel, magnetic dust filters and a PSU shroud on the inside. CyberPower has done a great job of keeping the interior tidy as well, and the main areas of the build are accessible. The chassis supports 360mm radiators as well, and it can accept another hard disk and two 2.5in drives, but it also misses some finesse – it has no tool-free storage bays, no USB Type-C connector and no button to alter the lighting.

Indeed, CyberPower's own-brand enclosure isn't as classy as the Lian Li Lancool II used by the CCL Horizon 5, which is our favourite mid-range gaming system. That chassis had hinged doors, a USB Type-C port and more storage space.

That PC also had an Asus TUF Gaming Z690-Plus WiFi D4 motherboard with a better range of connections and more M.2 ports. CCL's PC also used an overclocked RTX 3080, and offered an excellent on-site warranty. At its current price of £1,972 inc VAT, it's also cheaper than the CyberPower – the CCL's biggest weakness is its Core i5-12600K processor, with the CyberPower offering up a substantial upgrade in this respect.

Finally, the Infinity X127 Plus is protected by CyberPower's Gold warranty, which includes five years of labour coverage and two years of parts protection, including two years of collect and return cover. It's a decent deal, and while Chillblast's Fnatic Pioneer warranty is superior (see p34), the CyberPower has a much more competitive price for the spec on offer.

SPEC

CPU
3.6GHz Intel Core i7-12700KF

Motherboard
MSI Pro Z690-P DDR4

Memory
16GB Corsair Vengeance LPX 3200MHz DDR4

Graphics
MSI GeForce RTX 3080 10GB

Storage
1TB WD Blue SN570 M.2 SSD, 2TB Seagate Barracuda hard disk

Networking
2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi, Bluetooth 5

Case
CyberPower Bifrost

Cooling
CPU: MSI MAG CoreLiquid 240R with 2 x 120mm fans; GPU: 3 x 90mm fans; front: 3 x 120mm fans; rear: 1 x 120mm fan

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

Operating system
Windows 11 Home 64-bit

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

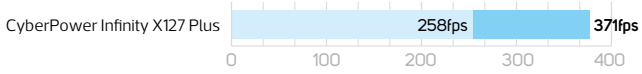
Performance

The CyberPower gets lots of pace out of the aging RTX 3080. It's virtually flawless at 2,560 x 1,440 – its 99th percentile results of 66fps and 68fps in Assassin's Creed Valhalla and Cyberpunk 2077 respectively are among the best we've seen from that GPU, and it still ran beyond 60fps in the latter game with Medium ray tracing and DLSS enabled. A vast 371fps average in Doom Eternal means esports games will run without complaint.

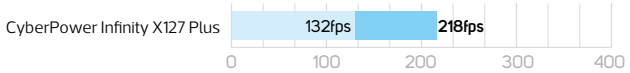
BENCHMARK RESULTS

DOOM ETERNAL

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



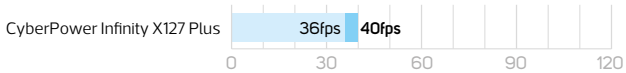
3,840 x 2,160, Vulkan, Ultra Nightmare settings



CYBERPUNK 2077

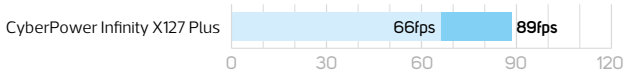
2,560 x 1,440, Ultra preset, no ray tracing

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

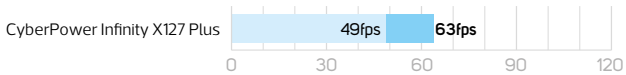


ASSASSIN'S CREED VALHALLA

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

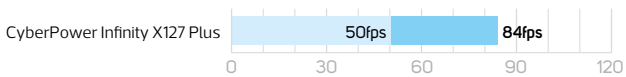


3,840 x 2,160, Ultra High settings, High AA

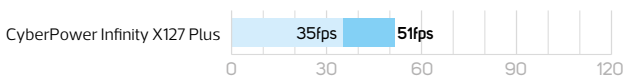


METRO EXODUS

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



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



99th percentile Average

INFINITE LIVES

- \+ Great 2,560 x 1,440 gaming pace
- \+ Powerful processor
- \+ Good storage setup

INFINTE LOOP

- – Can't quite tackle 4K gaming
- – Basic motherboard
- – Underwhelming case

73,880 GIMP IMAGE EDITING

898,448 HANDBRAKE H.264 VIDEO ENCODING

308,907 HEAVY MULTI-TASKING

330,231 SYSTEM SCORE

You'll only struggle if you want to play the trickiest games at 4K and beyond. At this tougher resolution, its 36fps minimum in Cyberpunk is clunky. Still, plenty of less demanding titles will run smoothly at 4K on this machine, and the CyberPower is consistently several frames faster than the CCL.

The Core i7-12700KF is quicker than the Chillblast Fnatic Pioneer's Core i7-12700F and the CCL's Core i5-12600K in application benchmarks too. The Infinity's Handbrake score of 898,448 is more than 100,000 points faster than the CCL, and CyberPower's PC returned an overall score of 330,231 – while the Core i5-based CCL languished with 295,722.

When you're playing tough game titles, the CyberPower will only produce middling noise levels – they're not enough to prove irritating or distracting. The Infinity was no louder in application tests too, and clock speeds were consistently fine. The GPU's delta T of 51°C is great too. The CyberPower's only thermal issue came in our multi-threaded stress test, where the CPU's delta T hit a toasty 77°C before settling at around 72°C. Those high temperatures don't cause throttling or instability, but the CCL is cooler (and quieter) too.

Conclusion

The high CPU temperature, modest motherboard and frill-free enclosure are the CyberPower's biggest weaknesses, but they're not necessarily dealbreakers. Many people won't see those lofty processing temperatures, the motherboard is fine for most people's needs, and the chassis is compact, tidy and has enough room for mainstream upgrades.

Its GPU and CPU are faster than the components in the CCL and the Chillblast, the warranty is lengthy and the Infinity has a competitive price. The CCL's better motherboard and case mean it's better balanced, but the CyberPower's extra CPU power makes it a worthy alternative if performance is a priority.

MIKE JENNINGS

VERDICT

It lacks high-end frills, but this rig delivers pacey performance at a great price.

PERFORMANCE **22/25**

DESIGN **20/25**

HARDWARE **20/25**

VALUE **24/25**

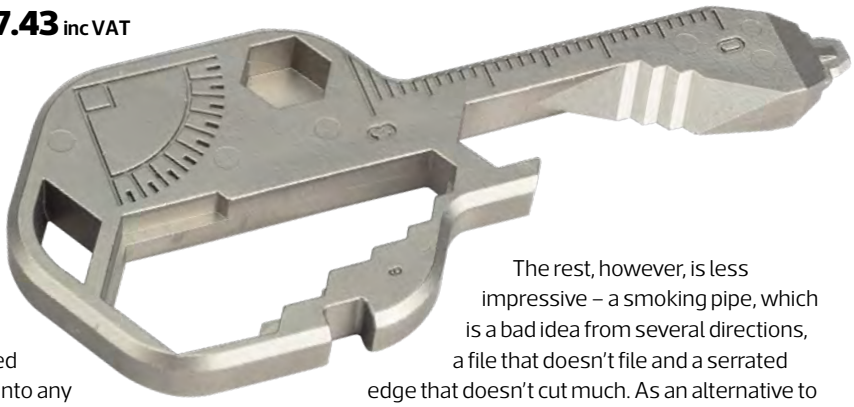
OVERALL SCORE **86%**

Custom kit

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

GEEKEY MULTI-TOOL / £17.43 inc VAT

SUPPLIER amazon.co.uk



The quest for a multi-tool that can be seamlessly fitted into the cluster of items folks take with them when they leave the house continues with the Geekey. It's shaped like a big key made of steel – it's chunkier than a regular key but thankfully lacking any pointy bits, so it's perfectly at home on a keychain.

The array of tools features some well implemented stalwarts – there's a screwdriver head that can't get into any hard-to-reach places but will work in a pinch on flat or cross-head screws. There's also a rudimentary (but functional) closed wrench on which it isn't easy to get leverage, but could tide you over until a real wrench arrives. There's a bottle opener too, because you have to have one of those.

The rest, however, is less impressive – a smoking pipe, which is a bad idea from several directions, a file that doesn't file and a serrated edge that doesn't cut much. As an alternative to a keyring bottle opener that just about gets in the ballpark of nearly doing an array of other jobs, the Geekey isn't terrible, but it's not good either.

Cheeky ●●○○○ **Geeky**

KENSINGTON COMBINATION LOCK / £37.79 inc VAT

SUPPLIER amazon.co.uk

The Kensington Combination Lock is a security device for laptops, specifically ones which have a Kensington Security Slot in the case.

While it's quite possible to have never heard of this feature, a great many laptops do have one, so it's worth checking. You loop the cable around a solid table leg, or some other immovable object if you can find one, pull the lock through the hoop on the opposite end of the cable, then plug the lock into the slot in the laptop case. Once the lock is properly attached, it can't easily be removed without causing damage, making your laptop safe.

The lock is very slim, so it doesn't cause any disruption to the use of the laptop, and it's padded too, so it won't scratch the case when installed. It uses a four-digit combination, which can be changed using a screw on the base. As security devices go, the Kensington Combination Lock isn't substantial – a determined thief with time and tools wouldn't be held off for long, but it will deter or complicate attempts at quick or sneaky thefts of opportunity, and those are often the most common threats for laptops.

Insecure ●●●○○ **Secure**

PDP ELECTRIC / £29.99 inc VAT

SUPPLIER amazon.co.uk

The PDP Electric is a wired game pad rolling into the crowded Xbox and PC pad genre. The layout is clean and tidy, with the start and screenshot capture buttons in the centre, along with the Xbox button, with the rare addition of a mic mute button next to the right-hand stick. This is a nifty little feature that's made niftier still by the fact it's not a simple button, which could be pressed by accident, but thoughtfully also requires a double tap.

Meanwhile, the shoulder buttons are big and flush to the body, the triggers are well constructed, with a long, even pull, and there's plenty of rumble to the feedback. It looks good too – the pairing of a mostly black case with a weird luminous green sounds like a strange idea but it works and improves visibility if you're gaming in dark places. Although the PDP Electric is wired, the 3m cable is also detachable via a micro-USB port. Like many of its contemporaries, the PDP Electric doesn't do much wrong and gets all the fundamentals right.

Squinting ●●●●○ **Staring**

LAZY READERS / £13.49 inc VAT

SUPPLIER amazon.co.uk

The Lazy Readers are glasses that have a prism lens, tilting your viewpoint 90 degrees downwards. This sounds like a strange idea in theory, and it's weird in practice too. There are some benefits offered by having this new angle available to your eyes. For example, you can watch TV lying on your back without having to raise your head, or you can read a book in your lap without having to look down at it, which can be better for your posture. The Lazy Readers are pretty sturdy and big enough for you to just about be able to wear them with glasses if you want.

Prison ●●●○○ **Prison**

KENSINGTON CONTOUR 2.0 PRO / £77.49 inc VAT

SUPPLIER amazon.co.uk

The Kensington Contour 2.0 Pro is a backpack for laptops with up to a 17in screen. The interior is dominated by the large main padded pocket in which a laptop can be snugly stowed. On top of this pocket is a second pocket, which offers a similar level of protection for an accompanying tablet. The pockets are secured via Velcro from the top, which means they can snugly hold any device that fits inside.

Inside there's also a decent amount of room for books, clothes and monster loot, and the pack holds its shape well, so its suitable for work or school gear that you don't want getting dog-eared. There are additional more specialised pockets too – one for a water bottle on the top, one for stationery on the front and an RFID shielded area for a wallet or phone.

Meanwhile, the outside of the backpack is made of ballistic nylon, which is both water-resistant and very tough, although not quite as bulletproof as the name might imply. Overall, the Kensington Contour 2.0 Pro looks good in a very understated way, it's very comfortable to carry and has plenty of room to carry a couple of days' worth of stuff in comfort. It's ideal for taking your laptop out and about.

Sad sack ●●●●● **Bag of holding**

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

How we test

MOTHERBOARDS

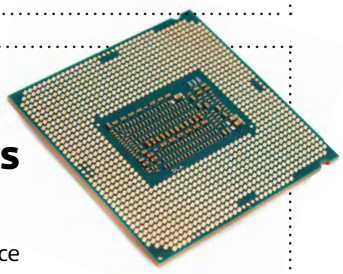
TEST PROCESSORS

- **Intel LGA1700** Intel Core i5-12600K
- **Intel LGA1700 mini-ITX** Intel Core i7-12700K
- **AMD AM4** AMD Ryzen 9 5900X

Common test hardware between our test rigs includes a WD Red SN750 SSD, plus a WD Black SN850 SSD to test the speed of M.2 ports, 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 Corsair 5200MHz Dominator Platinum DDR5 RAM.

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

PROCESSORS



TEST MOTHERBOARDS

- **Intel LGA1700**
  Asus ROG Maximus Z690 Apex
- **Intel LGA1200** MSI MEG Z490 Ace
- **AMD AM4 APU** MSI MPG Gaming B550 Carbon WiFi
- **AMD AM4** 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 colour accuracy, contrast and gamma, while assessing more subjective details such as pixel density and viewing angles by eye. For gaming, we test a monitor's response time with an Open Source Response Time Tester, and use Blur Busters' ghosting UFO test to check the sharpness of a display in high-speed motion.

CPU COOLERS

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

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

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

INTEL LGA1700
Intel Core i9-12900K at stock speed, Asus ROG Maximus Z690 Apex motherboard.

INTEL LGA1200
Intel Core i9-11900K at stock speed with Adaptive Boost enabled, MSI MEG Z590 Ace motherboard.

AMD AM4
Ryzen 7 5800X overclocked to 4.6GHz with 1.25V vcore, or Ryzen 5 5600X overclocked to 4.6GHz with 1.25V vcore on low-profile coolers, MSI MEG X570 Unify motherboard.

GRAPHICS CARDS

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

TEST KIT

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

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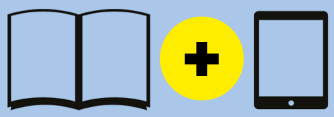

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LABS TEST

RAM raid

Antony Leather tests 11 of the latest DDR4 and DDR5 memory kits to find which ones offer the best bang per buck

How we test

Computer memory is in a state of flux at the moment, with DDR5 memory now becoming mainstream thanks to Intel's 12th-gen CPUs, but venerable DDR4 memory is still supported by plenty of B660 and Z690 motherboards, as well as being the mainstay of AMD's current platforms. While AMD's Zen 4 CPUs, which are due later this year, will support DDR5, the low price of DDR4 memory still makes it an appealing alternative.

With this in mind, this month's memory Labs test had to include both types of memory, as they're equally current and supported by Intel's current platform, while being relevant for AMD's current and future platforms too.

We'll be checking the height of modules for those space-restricted situations with large air coolers or small form factor systems, as well as looking at which memory chips are used. We also look at whether any RGB lighting is easy to control, and how effective it looks, and gauge the temperature of modules where possible, in order to judge the effectiveness of their heatsinks.

We'll also be testing performance using our RealBench suite and AIDA64 Extreme's read, write and latency tests, plus overclocking the modules, as many slower kits still offer plenty of headroom if you're up for some tinkering, which can yield noticeable boosts to performance, especially on AMD systems.

Our systems for memory testing this month comprise an Asus ROG Strix X570i Gaming motherboard with an AMD Ryzen 5 5600X for the DDR4 tests, plus an Intel Core i7-12700K and Asus ROG Maximus Z690 Apex motherboard for the DDR5 testing. Both systems use custom water cooling and Corsair RM850x PSUs, along with Nvidia GeForce RTX 3070 graphics cards.

Contents

ADATA XPG SPECTRIX D45G / £90 inc VAT (2 x 8GB, 3600MHz)

SUPPLIER amazon.co.uk

When it comes to memory, ADATA rarely makes an ugly module and the same is true for all its entries this month. The XPG Spectrix D45G uses a large diffusing bar across its RGB LEDs to present a seamless band of colour that's vibrant and produces accurate colours. However, the lighting here doesn't quite have the punch of the illumination on Corsair and Kingston's modules.

There's no in-house software either, as offered by Corsair, Kingston and G.Skill, but you can control the ADATA's lighting using ASRock, Asus, Gigabyte or MSI motherboard RGB lighting software. They're available in black or white, with the latter being a good match for similar-coloured motherboards, such as Gigabyte's Vision series. Plus, unlike Corsair's towering Dominator modules that also come in white, the XPG Spectrix D45G modules are 1cm shorter, so you're more likely to be able to squeeze them under a large CPU heatsink.

Sadly, we couldn't get a temperature reading from the modules in our testing, but there's ample metal included to keep them cool. Our sample kit used the popular 3600MHz mark as its frequency, which is ideal for both Intel and AMD systems. However, its 18-22-22-44 timings were a little slack compared with other kits. The G.Skill Trident Z RGB Neo and Corsair Vengeance RGB Pro offered slightly tighter timings at the same frequency for similar or less cash.

SPEC

Memory chip Samsung D-die

Effective frequency 3600MHz

Timings 18-22-22-44

Voltage 1.35V

Height (from base) 45mm

Stated software compatibility Asus Aura Sync, Gigabyte RGB Fusion 2.0, MSI Mystic Light Sync, ASRock Polychrome Sync

Interestingly, there were Samsung D-die memory chips under the hood of the XPG Spectrix D45G, while other kits on test used either Samsung B-die or SK Hynix D-die chips, so it will be interesting to see who wins. If you need more than 16GB, or a faster speed, there are also 4133MHz 16GB kits available for £132, and the 32GB version of our 3600MHz kit costs £156.

Performance was average in the AIDA64 Extreme tests, sitting in the middle of the pack, which was expected given its common frequency and similar timings to other kits. This was mimicked in its system score of 226,845 too; while the fastest result on test, it was within the margin of error of all the other scores. We managed to hit the same overclocked frequency of 3866MHz on the ADATA memory as we did with the Corsair Vengeance RGB Pro and G.Skill Trident Z RGB Neo kits, so there's enough headroom if you want to try pushing the fabric clock on AMD systems a little.

That will be essential too, as our standard test with the overclocked frequency saw slower results in our AMD system than at stock speed, highlighting the importance of attention to detail when tweaking AMD frequencies. If you want more headroom, Kingston's Fury Beast DDR4 RGB modules with their SK Hynix dies managed a lofty 4000MHz.

Conclusion

The ADATA XPG Spectrix D45G has a lot going for it, with both black and white modules available, even if they don't have eye-popping lighting, plus the kits have a reasonable price and overclocking headroom. There are a few snags, though, such as a lack of in-house RGB lighting software, which can be useful when avoiding often finicky motherboard software, plus average timings, a lack of frequency and timing options and a slightly higher price than the competition.

Other kits also overclocked further too, such as the Kingston Fury Beast DDR4 RGB, which also had a higher out-of-the-box frequency for the same cash. Of course, the real issue is that Corsair's Vengeance RGB Pro is also available in white for less money and has its own RGB lighting software, so it just pips the XPG Spectrix D45G to the post. If you need shorter white RGB memory modules, though, the ADATA memory is worth considering.

RESPECTED

- \+ Attractive design
- \+ Available in white
- \+ Reasonably priced

SUSPECTED

- – Average timings and overclocking headroom
- – More vibrant lighting available elsewhere
- – No in-house software

VERDICT

Attractive and reasonably priced, but the competition is faster, overclocks further or costs less.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
25/30	31/35	28/35	84%

CORSAIR DOMINATOR PLATINUM RGB DDR4 / £122 inc VAT (2 x 8GB, 3600MHz)

SUPPLIER scan.co.uk

When RGB lighting was first introduced, Corsair was one of the first manufacturers to offer high-speed kits, thanks to its low-power Capellix LEDs, providing more grunt for the memory to hit higher frequencies, while still driving LEDs from DIMM slots with limited power. The Dominator Platinum RGB models are now fairly old, but they remain available in a huge range of speeds and timings, as well as gorgeous white models too.

Here, we're reviewing a 3600MHz kit and, like other modules at the moment, you'll pay a very high price for kits with lower timings. You can get a good compromise, though, with our test kit coming with timings of 18-19-19-39 courtesy of Samsung B-die chips, with the frequency hovering around the sweet spot for AMD Ryzen systems if you want to match the fabric clock to the memory speed for best performance.

Ideally, you want to aim slightly higher, with a kit such us Kingston's Fury Beast DDR4 RGB at 3733MHz, but thankfully, the 3600MHz Dominator Platinum RGB kit still hit 3933MHz with no tweaking required when overclocking, so it should be able to hit high frequencies if you want to get your system running optimally.

Meanwhile, Corsair's iCUE software has full control over the LEDs, with plenty of customisation options. Also, with the Dominator Platinum RGB's individually lit sections, you can set each LED to a different colour with this pixel-like display, rather than having a diffusing light bar.

You can also use some motherboard software to synchronise lighting between components, but you'll need to check your specific motherboard model to confirm compatibility. The lighting is very vivid, with accurate colours, and the ability to set each LED segment to a different colour is a real boon.

The heatsinks are attractive too, especially in white, but while they shaved 3°C off the peak temperature achieved by the Kingston Fury Renegade modules, they're enormously tall at 55mm, so you'll need to take care with clearance with some large heatsinks or in small form factor systems.

The kit offered some of the faster speeds on test in the AIDA64 Extreme memory benchmarks, performing well in terms of both read, write and latency out of the box. As we saw with other modules, if you want to gain performance from an overclock, you'll need to set the fabric clock to the same frequency, otherwise you'll see noticeable performance drops.

Conclusion

Despite its age, Corsair's Dominator Platinum RGB is still one of our favourite memory kits, and the white version is certainly one of the most attractive memory modules out there right now. It looks fantastic in a motherboard with white details, such as Gigabyte's Vision series or NZXT's N-series boards, and if you prefer to play with individual LEDs, rather than a diffusing light bar, then they're your best option.

You'll need to pay careful attention to pricing, frequencies and timings, though, as some are more expensive than they used to be, or have looser timings. However, remember that frequency generally has a much bigger impact on performance than timings, when you're looking for a balance. Thankfully, most options are available and our 3600MHz C18 kit costs just over £120.

For fantastic build quality, Corsair iCUE support, excellent lighting and decent overclocking potential, this is our preferred premium DDR4 kit. However, you're also paying a premium for the frills here. ADATA's XPG Spectrix D45G performs similarly and costs £30 less. Meanwhile, Corsair's own Vengeance RGB Pro is even cheaper and has the benefit of Corsair's Light Enhancement kits too, enabling you to cheaply fill all four slots with two light-up dummy modules – you can't do this with the Dominators. We'd argue the Dominators are worth the extra cash if you can afford them though.

SPEC

Memory chip Samsung B-die

Effective frequency 3600MHz

Timings 18-19-19-39

Voltage 1.35V

Height (from base) 55mm

Stated software compatibility Corsair iCUE

PLATINUM

+ Excellent lighting
+ Great software
+ Decent overclocking headroom

PLATITUDE

− Expensive
− No dummy Light Enhancement modules
− Tall modules

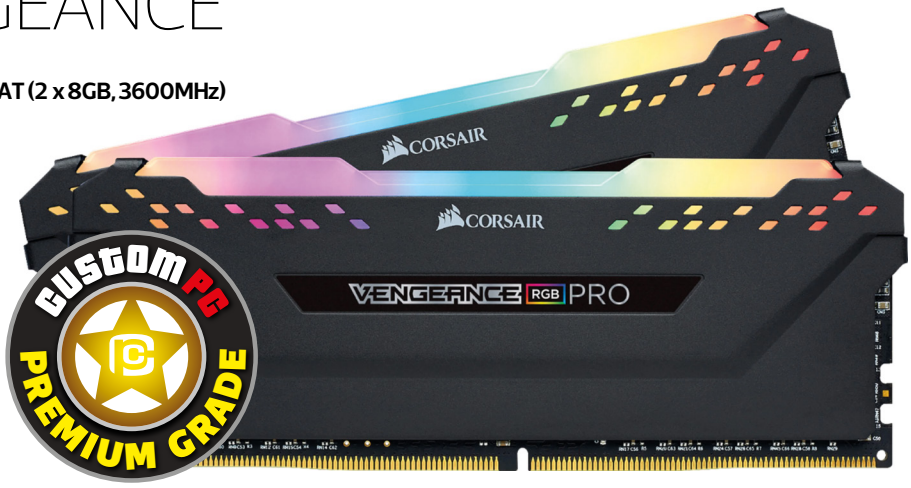
VERDICT

Well-made and attractive RGB memory with cutting-edge LEDs and a decent amount of overclocking headroom.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
26/30	33/35	26/35	85%

CORSAIR VENGEANCE RGB PRO / £74 inc VAT (2 x 8GB, 3600MHz)

SUPPLIER scan.co.uk



We've used Corsair's Vengeance RGB Pro modules in features and systems more times than we've had hot dinners and for good reasons. They're always very well priced, look fantastic and have other benefits too. We're still big fans, and these modules still appear to be good value, with our 16GB (2 x 8gB) 3600MHz test kit retailing for just £74 inc VAT.

It doesn't come with the tightest timings, though, which sit at 18-22-22-42, but other timing options are available, as is a huge range of frequencies. The Vengeance RGB Pro modules look good too, with their towering heatsinks, and they're even more visually appealing once illuminated. The lighting is the Vengeance RGB Pro's party piece, as it's as vibrant and accurate as any other modules on test, but also benefits from full Corsair iCUE software.

The diffusing bars across the tops of the modules do a great job of evening out the photons from the LEDs underneath, with less visible gaps between them than we saw with the Kingston Fury Beast kit. Like any modules, they look best placed together, but that's a tad wasteful if you don't need 32GB of RAM and they only come with a minimum of 8GB per module.

To solve the gaps created with 16GB dual-channel kits on boards with four slots, Corsair also offers Light Enhancement kits of dummy modules, which cost a fraction of the price of real modules, but have lighting that's controlled by its iCUE software to mimic having four modules. It's an advantage that this memory enjoys over every other kit on test, including Corsair's own Dominator Platinum RGB modules.

In terms of thermals, the large heatsinks didn't seem to offer much of an advantage over the smaller G.Skill Trident Z kits, sitting just below 50°C under load too, but were a couple of degrees cooler than the Kingston Fury Renegade, possibly due to its much higher frequency. With the joint lowest frequency on test, as well as average timings, it wasn't surprising to see the Vengeance RGB Pro sit at the bottom of the AIDA64 Extreme results for read and write speeds, and only just short of the highest latency too.

Thankfully, this didn't result in the lowest results in the RealBench tests, where it sat at second overall, albeit largely within the margin of error we'd usually expect. We also managed to push up our 3600MHz modules to 3866MHz by just increasing the memory speed, but couldn't push it further, making it the join lowest overclocked frequency on test.

However, that's still enough headroom to push most motherboards to their limits if you want to synchronise your memory with your AMD CPU's fabric clock. Even without doing that, it saw a small gain in the system score as well as AIDA64 read and write speeds once overclocked, although latency was mostly unchanged.

Conclusion

If you have room for tall memory modules, want top-notch RGB lighting, aren't too fussed about overclocking headroom and have a limited budget, the Corsair Vengeance RGB Pro is a great choice, with our 3600MHz test kit offering particularly good value.

With so many variations of speeds and timings available, it can be a daunting experience picking the right kit, but with this 3600MHz kit now retailing for under £75, now is a fabulous time to pick up some affordable, high-frequency DDR4 modules, especially as we expect AMD Ryzen 5000-series CPUs to see price cuts ahead of the Zen 4 launch later this year. They might be long in the tooth now, but Corsair's Vengeance RGB Pro modules still strike a great balance between performance, value and looks.

VENGEANCE

- \+ Fantastic lighting
- \+ Great software
- \+ Reasonable overclocking headroom

VENGABOYS

- – Might interfere with low-rising CPU heatsinks
- – Lower-latency models can be pricey
- – Aging design

SPEC

Memory chip Samsung B-die

Effective frequency 3600MHz4

Timings 18-22-22-42

Voltage 1.35V

Height (from base) 51mm

Stated software compatibility Corsair iCUE

VERDICT

Still great-looking and superb value for the performance on offer.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
25/30	30/35	33/35	88%

G.SKILL TRIDENT Z NEO / £91 inc VAT (2 x 8GB, 3600MHz)

SUPPLIER watercoolinguk.co.uk

When AMD's first Ryzen CPUs launched in 2017, there was a scramble for compatible memory modules, and any DIMMs based on Samsung's B-die memory chips sold like hot cakes thanks to their enhanced compatibility at speeds beyond 2933MHz. One company rubbing its hands was G.Skill, as its Trident Z memory used these chips, unlike many other memory makers' kits at the time, including those from Corsair.

G.Skill is continuing to sell its new Trident Z Neo modules as Ryzen-optimised now, although Ryzen memory compatibility has since been much improved. Again, the Trident Z Neo modules mainly use Samsung B-die memory chips, although there's no guarantee here – sometimes you get chips from SK Hynix, depending on the date of manufacture and the latency timings you choose. They're not quite as cheap as Corsair's Vengeance Pro RGB modules either, but at under £100, they're still not hugely overpriced.

The main difference between the standard Trident Z kits and the new Neo ones is the heatsinks, with the newer Neo modules offering silver slabs on both sides; not surprisingly, this matched the peak temperature of G.Skill's Trident Z Royal modules at 48°C.

We prefer the look of the newer modules to the old ones, but the lighting is the same as far as we could tell, with a large diffusing bar sitting on top of the LEDs.

SPEC

Memory chip Samsung B-die

Timings 18-22-22-42

Voltage 1.35V

Height (from base) 44mm

Stated software compatibility Asus Aura Sync, Gigabyte RGB Fusion 2.0, MSI Mystic Light Sync, ASRock Polychrome Sync

To control the lighting, you have the option of using G.Skill's own Trident Z software or ASRock, Asus, Gigabyte or MSI's own lighting software, although both Corsair and Kingston's software are superior in terms of features and design.

The lighting looks great, though, and the modules' lighting areas sit very close together, looking great if you can fill adjacent slots. As such, it's a shame G.Skill doesn't sell dummy modules, like the Light Enhancement kits for Corsair's Vengeance Pro RGB memory.

While the Trident Z Neo's performance in our AIDA64 Extreme synthetic tests didn't particularly stand out – for example, the 68.7ns latency was bettered by three other kits on test – it still held its own in our RealBench tests, bettering four other kits with a score of 222,032.

It could only hit an overclocked frequency of 3866MHz, though, matching other kits based on Samsung chips, such as the Corsair Vengeance RGB Pro.

Again, you'll need to dial these higher frequencies into your EFI in order to get the best results in AMD's systems by matching them with the fabric clock, otherwise you'll see slower results despite the higher frequency. Plus, if high-frequency operation is your priority, the Kingston Fury Beast DDR4 RGB kit fared better, hitting 4000MHz.

NEO

- \+ Attractive heatsinks
- \+ Universal motherboard software compatibility
- \+ Reasonable overclocking potential

MR ANDERSON

- – Low-latency kits are hard to find
- – Lighting control can vary between motherboard models
- – Competition is either cheaper or faster

Conclusion

With many kits using dies offering favourable AMD support, and Ryzen memory compatibility improving, G.Skill has lost its advantage and can now only compete on price and features. It's outgunned by cheaper kits such as the Corsair Vengeance RGB Pro, which is noticeably cheaper and offers better software control as well as dummy kits, while the Kingston Fury Beast DDR4 RGB costs the same price, but can overclock further and has a higher out-of-the-box frequency.

This leaves the Trident Z RGB Neo, and the original Trident Z RGB kits for that matter, at the mercy of pricing, and this has fluctuated a lot in recent months.

Ultimately, the Trident Z Neo modules look great, have snazzy RGB lighting and are a good fit with AMD Ryzen systems, as are most modules these days. However, at current pricing, Corsair's Vengeance RGB Pro kits offer much better value.

VERDICT

Still a solid choice, but Corsair's Vengeance RGB Pro kits offer better value at current prices.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
26/30	31/35	26/35	83%

G.SKILL TRIDENT Z ROYAL / £148 inc VAT (2 x 8GB, 3600MHz)

SUPPLIER watercoolinguk.co.uk

The king of bling is still going strong, and the shiniest, flashiest memory out there, also known as G.Skill's Trident Z Royal, is now available with a huge range of timings, as well as both chrome and gold finishes. Sadly, though, any kits with a CAS latency under 18 sees the price skyrocket, with even our 17-18-18-38 kit on test here going for £148 inc VAT at the time of writing.

Thankfully, there are cheaper options, even for a 3600MHz kit. For instance, with 18-22-22-42 timings, the same kit costs just over £110, so we can't be too harsh when making conclusions, especially when latency timings generally make so little difference to real-world performance.

Under the hood of these modules, you'll find Samsung B-die memory chips, and as a result, the Trident Z range has an enviable reputation of working well with AMD Ryzen CPUs. The 44mm-high modules are more compact than Corsair's equivalents, and the Royals still pack a punch in the aesthetic department, with mirror chrome or gold heatsinks that kept our modules at 48°C under load.

They stand up well to dings and knocks too – our test kit in the Labs has survived several system transplants and remained scratch-free. They do pick up fingerprints, but as you likely won't be handling them every day, this isn't much of an issue. Even so, G.Skill includes a microfibre cloth to clean them once your system is built, which is a good premium touch.

The crystal-like effect on top is undoubtedly the more garish feature, and it divides opinion in the mag, but the lighting is excellent. To control the lighting, you have a range of options, such as using G.Skill's own Trident Z lighting control software, or ASRock, Asus, Gigabyte or MSI motherboard software. The former allows for the usual controls, including solid colours and lighting effects, but be aware that while motherboard software is supported, the range of control can vary between boards.

With a decent frequency and the tightest timings of our group of DDR4 modules, the Trident Z Royal top the charts in most tests. It managed a read speed of over 51GB/sec, write speed of nearly 29GB/sec and the lowest latency of 62.3ns too, with the Corsair Dominator Platinum RGB coming second with 64ns. This didn't quite result in the fastest results in our RealBench tests, although it sat close to the margin of error we'd expect to see.

The Royal was also one of only two kits that managed to overclock all the way to 4000MHz, and this again helped it to a win in the AIDA64 Extreme synthetic tests. However, with the Infinity Fabric ratios coming into play on our motherboard, faster isn't always better and this seemed to be the case in RealBench, with most kits performing worse if they pushed past the 3733MHz 1:1 ratio.

Conclusion

We'll start by re-emphasising the fact that, while our particular sample retails for a slightly eye-watering £140, if you opt for slightly looser timings, the price drops dramatically, although even then it's still rather pricey for a DDR4 memory kit.

For example, Corsair's Vengeance RGB Pro costs just £74, Kingston's Fury Beast DDR4 RGB kit is just as compact and sports excellent lighting too, and G.Skill's own Trident Z RGB Neo costs £91 with slightly looser timings.

However, we can't deny the swagger of the G.Skill Trident Z Royal. The gold version might not be to everyone's tastes, but the mirror chrome model has wider appeal, looking good on any motherboard, while remaining compact enough to limit compatibility issues with large CPU coolers.

SPEC

Memory chip Samsung B-die

Effective frequency 3600MHz

Timings 117-18-18-38

Voltage 1.35V

Height (from base) 44mm

Stated software compatibility Asus Aura Sync, Gigabyte RGB Fusion 2.0, MSI Mystic Light Sync, ASRock Polychrome Sync

ALFRED THE GREAT

+ Fantastic lighting and flashy heatsinks
+ Universal motherboard software compatibility
+ Decent overclocking potential

ETHELRED THE UNREADY

− Lower-latency kits are prohibitively expensive
− Lighting control varied between motherboard models
− Aesthetics not to everyone's tastes

VERDICT

Fantastically shiny, but beware of high prices with low-latency models.

PERFORMANCE 27/30 | DESIGN 32/35 | VALUE 23/35

OVERALL SCORE 82%

KINGSTON FURY BEAST DDR4 RGB

£90 inc VAT (2 x 8GB, 3733MHz)

SUPPLIER amazon.co.uk

There have been a few DDR4 sweet spots over recent years with regards to frequency, and a lot depends on price and availability too. Both of these factors have been impacted by the pandemic, but Kingston has found a way to offer one of the faster speeds in this month's group test for under £100. This Kingston Fury Beast DDR4 RGB kits offers a frequency of 3733MHz, which is an easy target for most motherboards if you want to run the memory in a 1:1 ratio with AMD's Infinity Fabric clock.

This can vary from between motherboards, and not all of them are happy run at this speed or faster, but 3733MHz is considered to be the sweet spot in terms of achievability and performance. The Kingston Fury Beast DDR4 RGB gets there with 19-23-23-42 timings and SK Hynix D-die memory chips under the hood. This is plumbed into the XMP profile, and you can also play with the additional 3600MHz profile with slightly tighter timings.

Meanwhile, the lighting is bright and vibrant, but in bright daylight, we could see the slight tell-tale signs of gaps between the LEDs underneath the diffusing strips on top. We couldn't fault the colours, though, which were bold and accurate. Kingston has decent RGB software too, in the form of Fury CTRL, but in addition, the lighting can also be controlled by motherboard lighting software from ASRock, Asus, Gigabyte and MSI.

SPEC

Memory chip SK Hynix D-die

Effective frequency 3733MHz

Timings 19-23-23-42

Voltage 1.35V

Height (from base) 46mm

Stated software compatibility Kingston Fury CTRL, Asus Aura Sync, Gigabyte RGB Fusion 2.0, MSI Mystic Light Sync, ASRock Polychrome Sync

The heatsinks also measure 42mm from top to bottom, so they're certainly low-profile enough to avoid fouling most CPU heatsinks, but for some reason, we couldn't grab a temperature reading using various bits of software. Still, the heatsinks were warm, so were definitely working and we encountered no issues overclocking either.

Here, we pushed the frequency from 3733MHz to a decent 4000MHz without touching the voltage or timings. If you're keen to push the envelope beyond and do some tinkering then it's good to know there's a decent amount of headroom. With only the 3733MHz XMP profile loaded, the peak read speed of 48,559MB/sec was the lowest on test, but like any modules on test, spending extra time and dialling in the same frequency to the fabric clock saw this rise to 51,953MB/sec, making up for the second loosest timings on test.

The overclock also improved the latency, which fell from a poor 76.7ns to 70.9ns, but again, it pays to match the memory's frequency to your fabric clock, as even at stock speed, the latency fell even further to 67.8ns. The lofty overclock also meant the Kingston was one of the few kits to benefit in the RealBench test, with every result gaining a small amount and resulting in the second highest system score.

FURY

+ Low profile
+ Good lighting software
+ Sweet spot frequency

FURRY

- Cheaper overclocked kits can offer similar speeds
- Lighting is good but not the best
- Bland heatsinks

Conclusion

Opting for fast memory with an AMD Ryzen system means nothing without matching your Infinity Fabric clock to it, and even with relatively loose timings, the Kingston Fury Beast DDR4 RGB saw sizeable benefits from its 3733MHz frequency once the fabric clock was set to the same speed. This Kingston kit has plenty of overclocking headroom if you want to push these frequencies further, but critically, most Socket AM4 motherboards should be able to hit 3733MHz on the fabric clock these days, especially with the latest BIOS versions.

With snazzy RGB lighting, decent software, a reasonable price and the ability to easily delve into detailed tweaking, this kit is top of our list if you need low-profile RGB memory. However, if you have room for taller modules, Corsair's Vengeance RGB Pro is noticeably cheaper, and was happy to overclock to 3733MHz and beyond.

VERDICT

Out-of-the-box sweet spot performance with plenty of overclocking headroom.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
27/30	30/35	30/35	87%

KINGSTON FURY RENEGADE DDR4 RGB

/ £153 inc VAT (2 x 8GB, 4600MHz)

SUPPLIER buykingston.co.uk

We've been impressed with Kingston's offerings this month, especially when it comes to its DDR5 kits, but its high-speed Renegade kits actually started in the DDR4 era, and the Kingston Fury Renegade DDR4 RGB kit here can run at 4600MHz straight out of the box. However, it does have to slacken the latency timings of its SK Hynix D-die memory chips to get there.

Our kit used 19-26-26-45 timings, which were the loosest on test, and in an AMD system, you'll either need to make sure this frequency is paired with the fabric clock, or gun for maximum performance in benchmarking with Intel systems, otherwise the extra cash won't be well spent. This high-speed kit will also set you back £153 inc VAT, which is double the price of some of the other DDR4 kits in this month's group test, but slower kits are available too, with a 3600MHz set going for under £100, for example.

The higher speed didn't result in any immediate extra performance in our AMD test system either, with the slack timings seeing relatively low read and write speeds. The former of 49,439MB/sec was bettered by most other kits on test and it had a high latency of 69ns, with a comparatively low RealBench system score too. This was despite having a 1000MHz advantage over most other kits. The Fury Renegade DDR4 RGB also includes a second XMP profile, with lower frequency and tighter timings, sitting at 4000MHz and 19-23-23-42 respectively.

SPEC

Memory chip SK Hynix D-die

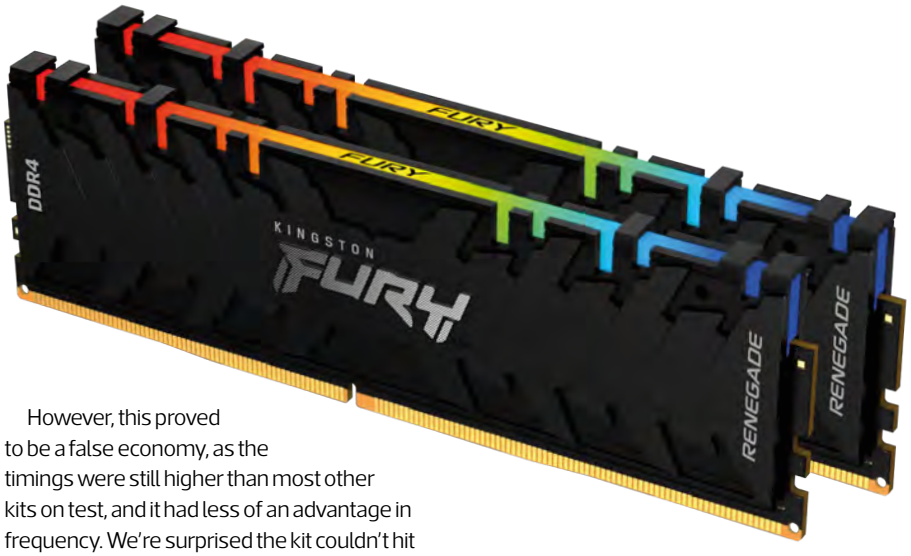
Effective frequency 4600MHz

Timings 19-26-26-45

Voltage 1.35V

Height (from base) 42mm

Stated software compatibility Kingston Fury CTRL, Asus Aura Sync, Gigabyte RGB Fusion 2.0, MSI Mystic Light Sync, ASRock Polychrome Sync



However, this proved to be a false economy, as the timings were still higher than most other kits on test, and it had less of an advantage in frequency. We're surprised the kit couldn't hit tighter timings here, and it would have been an interesting move, giving you the option of a faster every day kit with tight timings, or a frequency monster for benchmarking. In this case, though, it isn't really able to offer either of those benefits without a significant amount of extra tweaking.

Meanwhile, the lighting bars on top of the modules are slimmer than those on the Fury Beast DDR4 RGB modules, but this made the lighting look more intense and these diffusion bars also seemed to iron out the gaps between the LEDs a little more. The side details are an attractive touch too, and as a bonus, the modules are only 42mm tall, making them ideal for use with height-restricted coolers or in very compact systems.

Kingston offers some good in-house RGB lighting software too in the form of Fury CTRL, which offers every setting the casual tweaker would need. The modules are also compatible with motherboard software from ASRock, Asus, Gigabyte and MSI.

PERFECT TIMING

- \+ Low profile
- \+ Good lighting software
- \+ Attractive lighting

LAST MINUTE RUSH

- – Slack timings impact performance
- – Expensive
- – Cheaper kits are faster

Conclusion

We love seeing Kingston gunning for the top spots, and its efforts elsewhere have been justly rewarded. However, the Fury Renegade DDR4 RGB at 4600MHz is overkill for most applications, and unless you know how to use it, you'll end up with slower results, even if you use the second XMP profile with tighter timings. For AMD systems, some slower memory would suffice and cost significantly less money too.

However, we do like the design, lighting, software and low-profile stature, so while this speed demon of a kit might be a waste of money for most people, a more mainstream 3600MHz version for under £100 would be a much better bet for lovers of RGB lighting.

We prefer the heatsink and lighting design of the Fury Renegade DDR4 RGB compared with its sibling Beast kit too, but ultimately, you're better off spending your money a bit more wisely than going for this expensive 4600MHz DDR4 kit.

VERDICT

We love the looks, but 4600MHz is overkill and extremely expensive.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
25/30	32/35	22/35	79%

ADATA XPG LANCER RGB / £242 inc VAT (2 x 16GB, 6000MHz)

SUPPLIER memoryc.co.uk

ADATA has received a few awards in the past for both its memory and SSDs, and we're hoping for more of the same value mixed with decent aesthetics and features with its latest XPG Lancer RGB DDR5 memory too. Under the hood, the kit appears to be identical to the Kingston Fury Beast DDR5 RGB, with both using SK Hynix memory chips, which seem to be the top pick at the moment for 2nd-generation DDR5 modules.

The 6000MHz frequency is also identical, as are the timings of 40-40-40-76, but the ADATA kit's larger heatsinks kept the memory a couple of degrees cooler under load. That said, the heatsinks aren't actually that tall, sitting at a surprisingly low height of 43mm, which is significantly shallower than Corsair's Dominator or Vengeance modules. We also prefer the look of ADATA's heatsinks here too.

ADATA seems to have fewer speed and capacity options available compared with Kingston, and it also offers several speeds of single-module kits. The potential AMD Socket AM5 sweet spot of 6000MHz is what ADATA sent us for the sample, with a dual-channel 32GB kit setting you back just over £240. That's a little more than the Kingston Fury Beast DDR5 RGB, and that kit offers the same frequency and timings as well as more vivid lighting.

The XPG Lancer RGB's lighting wasn't unimpressive, though, as its light bar did a fantastic job of diffusing the RGB LEDs beneath it into a solid block of colour, even when dishing out multiple colours at the same time. However, it was significantly dimmer than the lighting on the Kingston kits we reviewed this month, so it isn't ideal if you want your lighting to be punchy.

Unlike Kingston, ADATA offers no software to control the lighting either, so you're either left with the default rainbow effect or you need to use your motherboard's RGB software, courtesy of ASRock, Asus, Gigabyte or MSI.

The ADATA memory did pip the Fury Beast DDR5 RGB to the post in overclocking, though, hitting 6400MHz as opposed to 6200MHz in our tests, matching the pricey Kingston Fury Renegade DDR5 RGB, albeit with looser latency timings. Still, this tweak was enough for the ADATA to (just) pick up first place in our latency test this month, as well as our RealBench image editing and video encoding tests, but the results were so close, they're within the margin of error.

Conclusion

There's a lot to like about the ADATA XPG Lancer RGB. It has attractive heatsinks, smooth, diffuse RGB lighting, reasonable overclocking headroom and good performance at stock speed and overclocked settings. There are a few negatives, though, such as a slightly higher price tag than the competition and a lack of RGB lighting software.

There's also the issue of its RGB lighting not being that bright compared with the competition. To gauge the difference, we put a stick of Kingston Fury Beast memory in the slot next to an ADATA Lancer module, and the difference in lighting impact was like night and day.

If you want your RGB lighting to make a punchy impact, the ADATA kit isn't for you. If you prefer a less aggressive light show, however, then it's definitely worth considering.

You'll be stuck with few capacity or frequency options with this range of DDR5 memory too, but 32GB and 6000MHz gives you a good balance between capacity, speed and price, especially if future CPUs do indeed make better use of high memory frequency than current chips, as rumoured.

SPEC

Memory chip SK Hynix

Effective frequency 6000MHz

Timings 40-40-40-76

Voltage 1.35V

Height (from base) 43mm

XMP 3.0 support Yes

Stated software compatibility Asus Aura Sync, Gigabyte RGB Fusion 2.0, MSI Mystic Light Sync, ASRock Polychrome Sync

FREELANCER

+ Pleasant, diffuse lighting
+ Universal motherboard software compatibility
+ Reached a 6400MHz overclock

BOIL LANCER

− Lighting isn't particularly bright
− Slightly more expensive than competition
− No in-house RGB lighting software

VERDICT

Attractive and able to overclock, but the lighting needs more punch.

PERFORMANCE 28/30 | DESIGN 27/35 | VALUE 30/35

OVERALL SCORE 85%

CORSAIR DOMINATOR PLATINUM RGB DDR5 / £266 inc VAT (2 x 16GB, 5200MHz)

SUPPLIER scan.co.uk

When it comes to DDR5 memory, Corsair seems to be a little off the pace these days, despite being one of the first manufacturers to have DDR5 products at the start. It's now struggling to offer any products to compete with the likes of Kingston's 6400MHz Fury Renegade DDR5 RGB. Even its slower 5200MHz kits, such as the one on test here, retail for several tenners more than faster competition, such as the ADATA XPG Lancer RGB and Kingston Fury Beast DDR5 RGB.

What's more, it does so with latency timings that are barely any tighter than the higher-clocked competition, at 38-38-38 compared to 40-40-40. The swagger of Corsair's Dominator kits has always demanded a premium, though, and thankfully for Corsair, its DDR5 Vengeance kits are a bit more compelling. It's a shame, then, that the company wasn't able to provide any samples of its cheaper line-ups of DDR5 memory, so we were forced to stick with its DDR5 Dominator kit for this test.

We can't deny its aesthetic prowess, though, with the Dominator Platinum modules offering some fantastic build quality and great-looking heatsinks. However, these stretch to a lofty 55mm in height, so you'll want to make sure your air cooler or other components have the clearance they need. The lighting is superb too, with Corsair using individual Capellix LEDs, rather than diffusing the light into strips. We prefer the vivid diffuse lighting on the Kingston Fury Beast DDR5 RGB, but this is likely to be subjective.

The lighting still looks great, though, with punchy colours, and it has one of the most detailed RGB lighting control suites out there in the form of iCUE too. This works very well indeed, but you can also use some motherboard software to control the lighting, or vice versa, with iCUE being able to control your motherboard's lighting. However, you'll need to check with your particular motherboard as to whether this feature is supported, as not all boards can cooperate with iCUE in this way.

Corsair used Micron memory chips with our 5200MHz test sample, but most faster kits now use SK Hynix dies. We were also not able to push our test kit past 5400MHz with an overclock, which is a shame, as even a couple of hundred megahertz more would have seen it faring better against 6000MHz kits from Kingston and ADATA. Sadly, the Corsair languished in a distant last place in the AIDA64 Extreme synthetic tests, only manage a read speed of 81GB/sec once overclocked, with all the other DDR5 kits on test hitting at least 88GB/sec.

Its latency was higher too, at 79ns compared to the next slowest stock speed result of 68ns. Thankfully, this didn't translate into shockingly low benchmark scores, with a system score that was only slightly off the pace, with multi-tasking suffering the most compared with faster kits. The memory temperature was the lowest on test too, at just 49°C.

Conclusion

While Corsair has more competitive kits in its other ranges, the Dominator range offers particularly poor value right now, which is a shame. We'd only consider the company's Vengeance-branded DDR5 models at current pricing, and even then the likes of Kingston and ADATA often offer better value. There are plus sides here, though, such as low operating temperatures, iCUE lighting and XMP 3.0 control, plus great-looking RGB lighting.

However, Corsair needs to get faster speeds available at much lower prices across the range, particularly with its Dominator series. At the moment, it's hideously expensive compared with the competition. Our advice is to get the Kingston Fury Beast DDR5 RGB, which offers similarly punchy lighting for under £230, compared to £266 inc VAT for these comparatively slower modules.

DOMINANT

- \+ Fantastic lighting
- \+ Effective lighting control software
- \+ Great build quality

SUBSERVIENT

- − Poor speeds compared with competition
- − Limited motherboard lighting integration
- − Expensive

SPEC

Memory chip	Micron
Effective frequency	5200MHz
Timings	38-38-38-64
Voltage	1.35V
Height (from base)	55mm
XMP 3.0 support	Yes
Stated software compatibility	Corsair iCUE

VERDICT

We still love Corsair's Dominator modules, but not at these frequencies or prices.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
22/30	32/35	24/35	78%

KINGSTON FURY BEAST DDR5 RGB / £141 inc VAT (2 x 8GB, 6000MHz); £224 inc VAT (2 x 16GB, 6000MHz)

SUPPLIER cclonline.com

One manufacturer to step up its DDR5 frequencies rapidly, while offering reasonable prices and plenty of stock, is Kingston, and its Fury Beast 6000MHz RGB-enabled kit, comprising a pair of 16GB modules, is available for a little over £220 inc VAT for 32GB. Thankfully, in a rather rare move, Kingston also offers a more affordable way to jump onto the DDR5 bandwagon, with a 16GB kit available too for just £141 inc VAT.

That's still pricier than DDR4 kits, but the 6000MHz modules doing the rounds now might soon be pretty popular, as this frequency is rumoured to be the new sweet spot for AMD's forthcoming Socket AM5 systems. If the rumours are to be believed, these modules would then sit at a 1:1 ratio with Infinity Fabric, just like the 3733MHz upper limit for DDR4 memory. So if you're planning on upgrading to a Ryzen 7000-series CPU, this kit could well end up on your shortlist.

The modules themselves are low-profile, despite being RGB-enabled, and stand just 42mm tall according to our digital vernier callipers at the tallest point. As such, they won't interfere with many CPU coolers, even if you're using a low-profile one. The heatsinks look much the same as those on the DDR4 version of the memory we also reviewed this month, with the Renegade version opposite looking a little snazzier.

The extra surface area on the latter offers slightly better cooling too, shaving 2°C off the temperature of the Fury Beast, although this was still only 62°C under load and didn't cause any issues. The 6000MHz frequency (or 6,000MT/sec as Kingston now refers to it), is backed up by 40-40-40-40 timings, which were the same as the ADATA XPG Lancer RGB, with a similar frequency and the same SK Hynix memory chips too.

The RGB lighting was quite understated, with no large retina-burning LED strips, but instead a diffusing section of plastic on top of the module that offered vibrant colours and an even lighting array. The lighting was much brighter than that of the ADATA DDR5 kit too.

To control the lighting, you can either use the software included with your ASRock, Asus, Gigabyte or MSI motherboard, or you can use Kingston's own Fury CTRL software. This proved to be just as good, if not better, than any motherboard software we've used, and provided ample tweaking and lighting effect presets with which to play.

When it came to overclocking, we were able to add another 200MHz to the Fury Beast RGB's clock speed, but the ADATA kit went up another 200MHz to 6400MHz. Unrestrained by an AMD Infinity Fabric in our Intel Z690 system, this saw some performance boosts too, raising the read speed from 89GB/sec to 94GB/sec, although the latency increased slightly from 68ns to 69ns. Still, there were gains in our RealBench score, which rose from 346,648 to 352,026, but it still couldn't match the mighty 6400MHz Kingston Fury Renegade DDR5 RGB.

Conclusion

Our benchmarks showed marginal gains in real-world tests when shifting up to 6000MHz from the more run-of-the-mill 5200MHz speed of older DDR5 memory kits, but there were clear advantages in synthetic read, write and latency tests.

Perhaps more importantly, the Kingston Fury Beast DDR5 RGB 6000MHz kit sits at the AMD Socket AM5 platform's rumoured sweet spot. We'd wait for concrete evidence of that before purchasing, but with better lighting than the ADATA kit, and a substantially cheaper price than faster Renegade RGB kit, as well as many other DDR5 packages, this is the DDR5 memory to buy.

SPEC

Memory chip SK Hynix

Effective frequency 6000MHz

Timings 40-40-40-80

Voltage 1.35V

Height (from base) 42mm

XMP 3.0 support Yes

Stated software compatibility Kingston Fury CTRL, Asus Aura Sync, Gigabyte RGB Fusion 2.0, MSI Mystic Light Sync, ASRock Polychrome Sync

NUMBER OF THE BEAST

+ Fantastic lighting
+ Universal motherboard software compatibility
+ Reasonable price for DDR5 memory

VIRTUAL XI

− No significant benefit on Intel systems
− Heatsinks lack flair
− Loose memory timings

VERDICT

Well priced for a speedy DDR5 kit with fantastic lighting.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
27/30	28/35	32/35	87%

KINGSTON FURY RENEGADE DDR5 RGB / £305 inc VAT (2 x 16GB, 6400MHz)

SUPPLIER cclonline.com

This speedy kit sits at the top of Kingston's range and has the looks, frequency, timings and price to match. With a price of £305 inc VAT for 32GB (two 16GB modules) running at 6400MHz, this is hugely expensive, but it's worth remembering that many 1st-generation kits cost this much or more when they were first released at the end of last year.

Here, though, you're getting seriously fast SK Hynix memory chips and some of the lowest timings we've seen on a DDR5 memory kit of 32-39-39-80. Despite offering 1200MHz more frequency than many older kits, such as Corsair's 5200MHz Dominator Platinum RGB, the 6400MHz Renegade Fury has similarly tight timings.

The heatsink design is very attractive too, with one black layer sitting on the memory chips and a silver shroud sitting on top of this layer. The heatsinks did a decent job of cooling the memory too, keeping it a couple of degrees cooler than the Kingston Fury Beast RGB kit, and matching the temperature of the ADATA XPG Lancer RGB with its larger heatsinks, despite the extra clock speed.

The RGB lighting is also particularly bright and vivid, easily eclipsing the dimmer ADATA kit here, and while you can use ASRock, Asus, Gigabyte or MSI's software to control it, there's also Kingston's Fury CTRL software, which offers detailed control over colours and effects for each LED on each module. Sadly, there isn't any extra bonus with the lighting compared with the cheaper Kingston Fury Beast RGB kit – the two memory types look near-identical when installed next to each other.

As you'd expect, the synthetic AIDA64 Extreme read and write tests had this kit at the top of the graphs, with a 94GB/sec read speed, 87GB/sec write speed and 63.5nm latency. No other kit got close. It also managed the highest system score in the RealBench test, where its perks seemed to benefit the multi-tasking test the most. Sadly, it seems that 6400MHz is the limit, though, as we couldn't overclock the kit any higher.

Still, this was enough to match or better the highest overclocked results of the other kits, with the Kingston Fury Beast DDR5 RGB managing 6200MHz, but with looser timings, while the ADATA XPG Lancer RGB did hit 6400MHz, but couldn't beat the Fury Renegade DDR5 RGB's performance overall.

Conclusion

If you need the fastest DDR5 memory kit around, and want to splash out on a package that will give you the highest speeds to cater for both Intel and AMD's next-gen CPUs, then the Kingston Fury Renegade DDR5 RGB is for you. It's miles faster than older pricey kits, such as the 5200MHz Corsair Dominator Platinum RGB. However, it's certainly not cheap at £305, and the real-world gains are minimal over the Kingston Fury Beast DDR5 RGB 6000MHz kit, despite the lower timings and 400MHz clock speed advantage.

It also failed to overclock any higher, but was at least perfect stable at its stock 6400MHz speed. For most people, the Kingston Fury Beast DDR5 RGB or ADATA XPG Lancer RGB are much better buys, but it's great to see a recognisable hierarchy forming in what has been a largely disappointing and stock-limited start for DDR5 memory.

For now, at least, Kingston is a front-runner in both the mid-range and high-end sectors of the marker, and with AMD's Socket AM5 just around the corner, it's looking like it's got there just in time.

We'd suggest waiting to see if the Fury Renegade DDR5 RGB's high spec genuinely gives you an advantage with AMD's Socket AM5 CPUs before splashing out though.

SPEC

Memory chip SK Hynix

Effective frequency 6400MHz

Timings 32-39-39-80

Voltage 1.35V

Height (from base) 42mm

XMP 3.0 support Yes

Stated software compatibility Kingston Fury CTRL, Asus Aura Sync, Gigabyte RGB Fusion 2.0, MSI Mystic Light Sync, ASRock Polychrome Sync

RENEGADE

+ Fantastic lighting
+ Universal motherboard software compatibility
+ Good performance thanks to frequency and tight timings

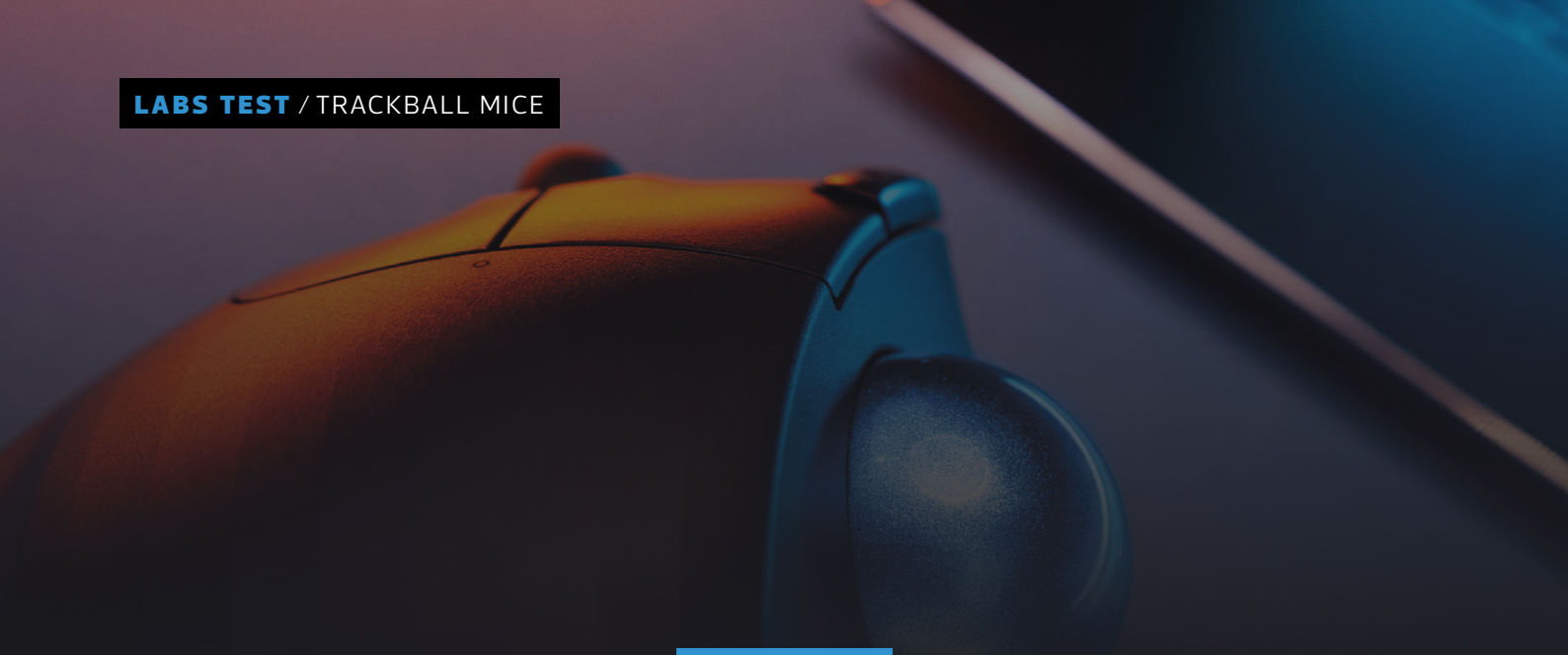
RENE ARTOIS

- Doesn't offer significantly more performance for the cash
- Expensive
- Limited other benefits over cheaper kits

VERDICT

A fabulously fast DDR5 kit, but it demands a hefty premium.

PERFORMANCE	DESIGN	VALUE	OVERALL SCORE
29/30	30/35	25/35	84%



LABS TEST

Rollin' around

Ideal for those with limited desk space or RSI concerns, trackballs are making a comeback. Edward Chester rolls five of them through their paces

How we test

Once a staple alternative to standard mice, trackballs have largely fallen out of favour for average PC users over the past couple of decades. However, with concerns over repetitive strain injuries (RSI) from using mice every day, and ever more of us working from home, they've had a resurgence, offering a more relaxed hand position and less reliance on finger bending and dexterity than normal mice.

Trackballs are also ideal to use if you have a cramped desk space, as you don't need to move the whole unit around a large mat – just 3-4in of desk space is ample to accommodate the width of most trackball pointing devices.

There are two main types of trackball – finger-operated and thumb-operated. The former use a flatter layout with the ball in a more central position, where your index, middle and ring fingers can work together to move the ball – sometimes even your thumb can get in on the act too. Meanwhile thumb-operated designs have the ball off to the side (left side for right-handed designs and vice versa for left-handed designs) where it's only operated by the thumb.

We generally find the finger-style trackballs offer the best tracking accuracy and stability, as your fingers can work together to stabilise each other. In comparison, thumb-operated trackballs have only one digit to provide all the accuracy and stability. The advantage of thumb-operated designs is they have a layout and feature set that's more familiar to mouse users, so make for an easier transition.

For our testing criteria, we looked at the accuracy and stability of the trackballs, gauging how well they worked for delicate tasks, such as picking out individual characters in a document. We tested each trackball briefly in games too, but this wasn't a key focus as they're not a truly viable alternative in terms of speed of motion and accuracy.

We also looked at the features included, such as extra buttons, scroll wheels and connection options. Some trackballs are easier to learn to use than others too, so this was a crucial factor in our testing.

Contents

ELECOM HUGE TRACKBALL M-HT1DRBK / £50 inc VAT

SUPPLIER amazon.co.uk

Elecom offers a wide range of trackballs, including both thumb-operated and finger-operated units in a range of sizes. The M-HT1DRBK is the largest of the lot and is described on the packaging as simply a 'Huge Trackball', a descriptor that's entirely accurate – it is indeed enormous.

The trackball housing measures a whopping 115 x 182 x 57mm and incorporates a lengthy dense foam-padded wrist rest over its rear half. Meanwhile, the ball itself has a diameter of 52mm. The Kensington Expert Mouse Wireless Trackball has an even larger ball, measuring 55mm but the one here is still massive.

While the whole unit and its ball are indeed very large, the same can't be said for the main convex portion that houses the controls, and that your hand envelopes. With the base of my 20cm-long hand nestled into the concave dip of the padded wrist rest, my fingers extended around 1in beyond most of the main controls. In comparison, the much shorter but more bulbous Logitech MX Ergo and ProtoArc EM01 really filled the underside of my hand, putting the controls at my fingertips.

The solution is to just slide back your hand a little – there's still plenty of wrist rest padding further back, but this requires holding up and slightly bending your fingers into more of a claw position to reach the controls. As such, despite its name, this trackball is slightly better suited to those with small to medium-sized hands rather than those with giant mitts.

Crucially, what the large trackball allows is effortless and accurate movement. Your fingers naturally fall onto it, allowing for all three of your longest digits to work together to accurately move and stabilise the ball.

Arranged around the ball is an astonishing array of extra features, considering the modest price. On the top, facing upwards, there are four buttons, with the one immediately to the right of the ball being the default right-click button, and the further three being extra programmable buttons.

On the sloped side, where your thumb naturally rests, are the forward and back buttons, main left-click button and a scroll wheel that includes left and right tilt. Finally, a sliding switch on the base of the unit switches between low (500 DPI), medium (1,000 DPI) and high (1,500 DPI) sensitivity settings.

The button arrangement is certainly logical and efficient, but there's a notable learning curve. We regularly slipped up, hitting the wrong button, even after several days of use. We also found the scroll wheel sits too far back. Again, this is a hand size issue, but even with my hand set further back on the trackball, my thumb still had to bend too much for my liking to reach the wheel.

Most of the larger buttons have just a bit more flex to them than we'd like before the button is pressed as well, although some build quality compromises are to be expected at this surprisingly low price.

Meanwhile, on the underside is a 2 x AAA battery compartment (batteries included), the power switch (with high-speed or low-energy connection modes), a slot for stowing the wireless dongle and a hole for inserting a pencil or similar to pop out the trackball for cleaning.

SPEC

Weight 260g (without receiver)

Dimensions (mm) 115 x 182 x 57 (W x D x H)

Sensor Optical

Buttons 8 (left, right, scroll wheel press, back, forward, three extra programmable buttons)

Connections 2.4GHz USB dongle and Bluetooth

Extras Three extra programmable buttons, tilting scroll wheel, 2 x AAA batteries

Stated battery life 235 hours (low energy mode) or 137 hours (high speed mode) while operating, 1,851 days in standby for both modes

HUMUNGOUS

- \+ Large trackball for easy tracking
- \+ Loads of extra buttons
- \+ Scroll wheel with tilt
- \+ Great value

HUMOURLESS

- – Not ideal for large hands
- – Not the tightest button response
- – Confusing button layout
- – Right hand-only design

Conclusion

The Elecom M-HT1DRBK is a fantastic-value trackball with a brilliantly accurate, easy to use ball and masses of extra features. Getting used to its layout takes some learning time, but it's still an excellent option for this price.

VERDICT

This massive trackball isn't perfect, but it's surprisingly capable for the price.

DESIGN	FEATURES	OVERALL SCORE
12/20	18/20	80%
PERFORMANCE	**VALUE**	
22/30	28/30	

KENSINGTON EXPERT MOUSE WIRELESS TRACKBALL / £103 inc VAT

SUPPLIER amazon.co.uk

From its photos, the Kensington Expert looks like a distinctly modest device, but looks can be deceiving and the Expert is in fact a monster of a trackball. The ball itself has a diameter of 55mm, while the buttons surrounding it are massively oversized, giving the lie to the optical illusion.

But what else does the Expert have going for it, other than size? Well, it's an ambidextrous design, like most of Kensington's extensive trackball range, so it's open for left and right-handed users to adopt. What's more, the Expert includes the company's patented Scroll Ring, which replaces the scroll wheel of most other mice or trackballs. It surrounds the ball, and rotates clockwise and anti-clockwise around the ball to provide down and up scrolling respectively (although this can be reversed).

Combined with the unfamiliar ambidextrous design, you would think it might take a while to get used to the Expert, but that wasn't our experience. The Scroll Ring feels totally natural and is far more comfortable to use than having to bend a finger to roll a scroll wheel, not least because you can use your thumb and fingers together to turn the ring.

Meanwhile, it's equally intuitive to get to grips with the ambidextrous layout with its simple four-button arrangement around the ball. All this and the trackball itself feels superbly accurate and smooth in use. This is partly due to the size of the ball and partly down to the ability to manipulate it with two or even three fingers – you can even get your thumb involved too – making for a precise and stable feel. Notably, though, we still found it easier to precisely move the cursor left and right for long distances using thumb-operated models, as your thumb has a greater range of left-to-right motion.

For all that, we generally are totally won over by the feel, accuracy and approachability of the Expert. However, there's no denying it's rather lacking for features. While the four buttons are big and easy to hit, that's the bare minimum for most desktop users. That's left and right click, back and forward, and that's your lot – you don't even get the middle-click button of a scroll wheel.

However, you can use Kensington's excellent KensingtonWorks software to assign commands to button combinations, as well as remapping the function of individual buttons. Specifically, you can combine the top two buttons or the bottom two buttons to trigger whatever function you like – there are dozens from which to choose.

This wireless version of the Expert includes both a USB receiver-based 2.4GHz wireless mode and a Bluetooth connection, but if you don't need wireless, there's a wired version that costs £20 less than the wireless flavour.

Included in the hefty £103 inc VAT price tag is a rubber wrist rest that attaches to the back of the trackball, and a pair of AAA batteries to power the unit is provided as well.

Conclusion

The Kensington Expert's lack of extra buttons could be limiting for some users, especially given the high price, but we found this limit didn't overly trouble us in daily use. Otherwise, the Kensington Expert is a superb trackball in just about every way. Its large, finger-operated ball design makes for class-leading accuracy and stability, while its simple four-button layout is effortlessly intuitive to use. Add in the equally intuitive Scroll Ring, and this device absolutely nails the core comfort and ease of use aspects required of a trackball.

SPEC

Weight 186g (without receiver or wrist rest)

Dimensions (mm) 63 x 125 x 39 (W x D x H)

Sensor Optical

Buttons 4 (left, right, back, forward)

Connections 2.4GHz USB dongle and Bluetooth

Extras Rubber wrist rest, DPI button on underside, 2 x AAA batteries

Stated battery life Up to 100 days

EXPERTISE

+ Class-leading trackball performance
+ Comfortable design
+ Effortless button operation

BIT OF A TEASE

– A bit large for small hands
– Limited number of buttons
– Expensive

VERDICT

Big, simple and highly effective, but it doesn't come cheap.

DESIGN	FEATURES	OVERALL SCORE
16/20	12/20	82%
PERFORMANCE	VALUE	
30/30	24/30	

KENSINGTON ORBIT WIRELESS WITH SCROLL RING / £43 inc VAT

SUPPLIER amazon.co.uk

With its much more modest price than the Kensington Expert, the Orbit is understandably a smaller unit with a modest feature list. However, it's still a very capable and comfortable device.

Like the Expert, the Orbit's most prominent feature is its ambidextrous central ball design. Here, though, instead of four buttons flanking the ball, there are just two, representing the traditional left and right-click functions. They're just as oversized as on the Expert, making them very easy to hit, even for those with limited individual finger dexterity.

However, having just two buttons feels limiting. After all, you're already missing out on the middle button you'd normally get with a scroll wheel, and you can't even have the back/forward functions for navigating webpages that are now standard. Having to actually click the back and forward buttons in the browser, or use the keyboard shortcut feels like a real throwback. You can combine button presses, but that only nets one extra function here.

SIMPLE

+ Solid trackball performance
+ Comfortable design
+ Great value

BASIC

– Only two main buttons
– Not as stable as larger trackballs

SPEC

Weight 186g (without receiver or wrist rest)

Dimensions (mm) 115 x 139 x 47 (W x D x H)

Sensor Optical

Buttons 2 (left, right)

Connections 2.4GHz USB dongle and Bluetooth

Extras Rubber wrist rest, DPI button on underside, 2 x AAA batteries)

Stated battery life Up to 100 days

Otherwise, the Orbit is largely a delight to use. Its low-slung design and long, gently sloped rubber wrist rest make for a minimum of wrist awkwardness, keeping forearm and finger pain at bay. We also liked using the trackball without the wrist rest (which just clips onto the back of the trackball), as it feels a little more stable without your hand and fingers stretched out.

The trackball has a 40mm of diameter, so it sits between the smaller thumb-operated trackballs on test and the larger Elecom and Kensington Expert designs. The drop in size is surprisingly noticeable, as you have less room to comfortably fit three fingers on the ball. Instead, it's easier to mostly use two at a time, although you can roll the ball sideways from your little finger all the way to your thumb, which you can't do on the Elecom.

Having only two digits on the wheel at a time feels less stable than the larger trackballs (not least because the ball rolls so smoothly), and feels about on par with the thumb-operated units, although the exact difference will depend on the relative dexterity of your fingers and thumb. The Orbit certainly feels more relaxing to use than thumb-operated units, though, as it doesn't rely on the thumb for every movement.

Meanwhile, the two lonesome buttons aren't as snappy as gaming mouse buttons, but they're on par with the other trackballs on test and are responsive enough for desktop use. The Scroll Ring is also as lovely to use as on the Expert, feeling smooth and effortless to rotate and natural to reach with any digit, again reducing the strain on any one finger – it's a much less tiring than a scroll wheel.

Both the wired and wireless versions currently cost the same price, so we'd recommend the wireless version – it's one less cable stretched across your desk. The wireless version can also connect via Bluetooth, making for an easy connection to tablets and other more mobile devices. A switch on the underside slides between Bluetooth, off and 2.4GHz wireless USB receiver modes.

Also on the underside is the DPI button that cycles between four sensibly low DPI settings (400, 800, 1,200 or 1,600), along with the battery compartment that houses two AAA batteries (included).

Conclusion

The Kensington Orbit is a fantastic, low-cost trackball. Its ambidextrous design is very comfortable and its trackball is effortless to use. The Scroll Ring is also a great improvement over a scroll wheel for reducing RSI. The trackball isn't quite as stable and easy to use for finer movements as an even larger unit, but it certainly does the job.

VERDICT

A fantastic ambidextrous trackball for a great price, although it could do with more buttons.

DESIGN	FEATURES	OVERALL SCORE
14/20	9/20	75%
PERFORMANCE	VALUE	
24/30	28/30	

LOGITECH MX ERGO / £77 incVAT

SUPPLIER scan.co.uk

At the top of Logitech's trackball pile is the MX Ergo, which sets itself apart from the rest of the range with its generally premium build quality and support for Logitech's Options+ software. The latter includes features such as Logitech Flow, which lets you copy and paste data between different computers.

The trackball itself is a thumb-operated design, where the whole portion of the trackball that sits under your hand and fingers feels much like a normal, though oversized, mouse. This makes it immediately familiar to mouse users, with the left and right click buttons and the scroll wheel all sitting in their usual places.

The bulbous design is particularly comfortable, with your palm well supported and no need to bend your fingers. The back and right side of the top also has a thick rubber coating that grips your palm, so little effort is required to keep your hand in place. It suits a variety of hand sizes, although those with smaller hands may need to occasionally shift up their hand to reach some of the buttons and other controls.

The Ergo sits on a weighty steel plate, which is rubberised on its underside to grip your desk and magnetically attaches to the trackball. A raised notch in the plate acts as a pivot point, allowing you to tip the trackball either flat against the desk or at a 20-degree angle. The latter is generally considered the better option for reducing RSI and is indeed the one we found more comfortable.

Inside the Ergo is a rechargeable battery that should last up to four months, (depending on how often the trackball is used) and is recharged via a micro-USB socket on the front – a Type-C USB port would be preferable here. There are no features on the underside of the Ergo, such as a stowage area for the USB receiver, which is a shame.

On top of the Ergo there are four buttons. alongside the main left and right click buttons, plus the scroll wheel can be pressed down and tilted left and right. Only six of these can be programmed to perform different functions – the two small buttons to the left of the left click (default to back and forward), the tilt and press buttons of the scroll wheel, and the side button just behind the trackball (defaults to changing DPI). Meanwhile, the button behind the scroll wheel is dedicated to switching between connected devices (one via the receiver and one via Bluetooth).

While the Ergo is comfortable in your hand, though, the relatively small 34mm ball and reliance on only your thumb for movement makes it feel less accurate than trackballs that use multiple fingers to move the ball. Moreover, it's fatiguing for the thumb, with finger-operated trackballs being more accessible for those with dexterity issues.

As for the Options+ software, it's a neat addition that makes it easy to use a single pointer for connecting to any Windows, MacOS or iPadOS device. The Logitech Flow feature allows you to copy and paste files or any other highlighted elements between connected systems, which is very useful for some workflows.

Conclusion

The Logitech MX Ergo is a well-built device that will make for an easy transition for any mouse users thanks to its familiar layout. Its software features are also genuinely useful. However, it can be difficult to make the single small thumb-operated trackball work accurately, and it requires more effort to roll than larger, finger-operated models.

SPEC

Weight 259g (with metal plate, without receiver)

Dimensions (mm) 100 x 133 x 51 (W x D x H)

Sensor Optical

Buttons 8 (left, right, scroll wheel press, back, forward, easy-switch button)

Connections Micro-USB for charging only, 2.4GHz USB dongle and Bluetooth

Extras Wireless connection button, tilting scroll wheel

Stated battery life Up to four months

ERGONOMIC

+ Comfortable shape for most hand sizes
+ Useful software features
+ Can pair with multiple devices at once

IRKSOME

– Thumb ball is tiring for the thumb
– Less accurate than multi-finger trackball designs
– Not suited to small hands

VERDICT

A well-built trackball that feels comfortable in your hand, although the small thumb-operated trackball isn't that accurate in use.

DESIGN	FEATURES	OVERALL SCORE
14/20	16/20	72%
PERFORMANCE	VALUE	
20/30	22/30	

PROTOARC EM01 / £44 inc VAT

SUPPLIER amazon.co.uk

The ProtoArc EM01 has the same core feature set and layout as the Logitech MX Ergo but for a markedly lower price. It misses out on the rubber top and software features of the Logitech pointer, but you do at least get RGB lighting instead.

The lighting is confined to a ring that surrounds the 34mm trackball. It will glow in three different patterns, none of which bears any relation to what's going on with the device, such as indicating the DPI level or the device to which the EM01 is connected, which feels like a missed opportunity.

The EM01 doesn't have the rubberised top section of the MX Ergo either, so those with smaller hands may find their hand slides down the side, away from the controls. Otherwise, for larger hands that can rest partially on the desk, it's equally as comfortable as the Logitech pointer. You also get the same option to tilt the trackball flat or at a 20-degree angle. The tilt platform is rubberised, but not metal, and is fixed to the base, not removable – not that the removable base of the MX Ergo provided any useful features.

For buttons, you get the same standard mouse-style left, middle/scroll wheel, right layout as the MX Ergo, with two back/forward buttons to the left of the left-click button. Meanwhile, behind the scroll wheel is the sync button for switching between the 2.4GHz USB receiver or either of any two devices connected via Bluetooth – you hold down the button to sync Bluetooth devices.

Behind the trackball is the button for cycling through the RGB lighting modes, and behind that is the DPI switching button for changing the ball's sensitivity. It steps between 1,000, 1,600 and 2,400 DPI, and because there's no software these settings can't be changed. We found 1,000 DPI too sensitive for accurate desktop use, so had to reduce the Windows cursor speed setting to make the trackball usable, which we didn't need to do on any other trackball on test.

Once the cursor speed was adjusted, the EM01 proved a very easy to use pointing device. The ball is also a touch smoother than the one on the Logitech, making it effortless to move. This was actually a problem before the cursor speed was reduced, as the reliance on only the thumb to accurately move the ball made the ProtoArc feel too slippery – the slight resistance of the Logitech felt easier to control. However, once cursor speed was adjusted, we preferred the ProtoArc.

Otherwise, the performance of the two trackballs is very similar, although the ProtoArc's main buttons feel a bit mushier, with less of a crisp, distinct click. The EM01 also misses out on a tilting scroll wheel, and that lower price is felt in the overall build quality.

Meanwhile, the rechargeable 900mAh battery should last up to 100 days per charge, which is in the same ballpark as the Logitech. It's charged via a Type-C USB port on the front, which can't also be used to connect the trackball – it's a wireless-only device.

Conclusion

For its modest price, the ProtoArc delivers a decent trackball experience, if you don't mind the slightly less accurate and more fatiguing feel of a thumb-operated trackball. It's comfortable, has plenty of buttons and the ball itself tracks accurately and smoothly – thumb dexterity notwithstanding. Considering it's nearly half the price of the MX Ergo, it's well worth considering, although the Logitech is better built and its software features can be useful too. CPC

SPEC

Weight 186g (with metal plate, without receiver)

Dimensions (mm) 63 x 125 x 39 (W x D x H)

Sensor Optical

Buttons 8 (left, right, scroll wheel press, back, forward, DPI button)

Connections USB Type-C for charging only, 2.4GHz USB dongle and Bluetooth

Extras RGB lighting, RGB lighting button, DPI button, sync button

Stated battery life Up to 100 days

FINISHED PRODUCT

+ Solid thumb-trackball performance
+ Comfortable design
+ Great value

PROTOTYPE

– A bit large for small hands
– RGB lighting pointless
– Lacks rubber grip of Logitech MX Ergo

VERDICT

A great value thumb-operated trackball, although the RGB lighting is wasted.

DESIGN	FEATURES	OVERALL SCORE
12/20	14/20	72%
PERFORMANCE	VALUE	
20/30	26/30	

Elite

Our choice of the best hardware available

Core component bundles

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

8-core system with integrated graphics

8-core CPU, basic gaming

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

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 5700G	awd-it.co.uk	**#218** p20	£280
CPU COOLER	AMD Wraith air cooler included with CPU	N/A	**#218** p20	£0
GRAPHICS CARD	AMD Radeon RX Vega 8 integrated into CPU	N/A	**#218** p20	£0
MEMORY	16GB (2 x 8 GB) Corsair Vengeance LPX Pro 3200MHz (CMK16GX4M 2B3200C16)	scan.co.uk	**#218** p78	£59
MOTHERBOARD	Asus TUF B450M-PLUS II (micro-ATX) with BIOS flash	awd-it.co.uk	**#218** p78	£90
STORAGE	500GB WD Blue SN570 (M.2 NVMe)	scan.co.uk	**#222** p20	£48

Total £454

1,920 x 1,080 gaming

6-core CPU, 1080p gaming

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

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i5-12400F	cclonline.com	**#227** p51	£174
CPU COOLER	ARCTIC Freezer i13X	scan.co.uk	**#224** p76	£20
GRAPHICS CARD	AMD Radeon RX 6600 XT	amazon.co.uk	**#228** p90	£343
MEMORY	16GB (2 x8 GB) Corsair Vengeance LPX DDR4 3200MHz (CMK16GX4 M2B3200C16)	scan.co.uk	**#224** p76	£59
MOTHERBOARD	Gigabyte B660 Gaming X DDR4 (ATX)	scan.co.uk	**#224** p50	£148
STORAGE	1TB WD Blue SN570 (M.2 NVMe)	scan.co.uk	**#222** p20	£74

Total £818

UPGRADES				
SWAP GRAPHICS CARD	Nvidia GeForce RTX 3060 Ti	overclockers.co.uk	**#228** p90	£430
SWAP STORAGE	1TB WD Black SN850	scan.co.uk	**#225** p27	£110

2,560 x 1,440 gaming system

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

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

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i5-12600K	scan.co.uk	**#227** p56	£290
CPU COOLER	ARCTIC Liquid Freezer II 240 RGB (240mm AIO liquid cooler)	scan.co.uk	**#226** p49	£80
GRAPHICS CARD	Nvidia GeForce RTX 3070	overclockers.co.uk	**#228** p90	£500
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz DDR4 (CMW16GX4 M2D3600C18)	scan.co.uk	**#230** p47	£74
MOTHERBOARD	Gigabyte Z690 Gaming X DDR4	scan.co.uk	**#222** p46	£190
STORAGE	1TB WD Black SN850	scan.co.uk	**#225** p27	£110
	Total £1,244			

UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	ebuyer.com	**#166** p54	£86

Mid-range gaming system

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

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

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i5-12600K	scan.co.uk	**#227** p56	£290
CPU COOLER	ARCTIC Liquid Freezer II 240 RGB (240mm AIO liquid cooler)	scan.co.uk	**#226** p49	£80
GRAPHICS CARD	Nvidia GeForce RTX 3080 10GB	overclockers.co.uk	**#228** p90	£700
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz DDR4 (CMW16GX4M 2D3600C18)	scan.co.uk	**#230** p47	£74
MOTHERBOARD	MSI MAG Z690 Tomahawk WiFi DDR4	scan.co.uk	**#222** p48	£245
STORAGE	1TB WD Black SN850	scan.co.uk	**#225** p27	£110
	Total £1,499			

UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	ebuyer.com	**#166** p54	£86

Core component bundles cont ...

4K gaming system

12-core CPU, 4K gaming and ray tracing

Needs an ATX case with room for a 360mm all-in-one liquid cooler. We recommend an 850W 80 Plus Gold power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i7-12700K	scan.co.uk	**#227** p59	£426
CPU COOLER	Corsair iCUE H150i Elite LCD (360mm AIO liquid cooler)	scan.co.uk	**#226** p78	£220
GRAPHICS CARD	Nvidia GeForce RTX 3080 Ti	nvidia.com	**#226** p78	£1,050
MEMORY	16GB (2 x 8GB) Corsair Dominator Platinum RGB 3600MHz DDR4 (CMT16GX4M2 C3600C18W)	scan.co.uk	**#230** p46	£122
MOTHERBOARD	MSI MAG Z690 Tomahawk WiFi DDR4	scan.co.uk	**#226** p78	£245
STORAGE	2TB WD Black SN850	scan.co.uk	**#215** p49	£179

Total £2,242

UPGRADES

ADD SECONDARY STORAGE	4TB Western Digital Blue	ebuyer.com	**#166** p54	£86

Content creation system

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

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

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i9-12900K	cclonline.com	**#227** p62	£599
CPU COOLER	Corsair iCUE H150i Elite LCD (360mm AIO liquid cooler)	scan.co.uk	**#226** p78	£220
GRAPHICS CARD	AMD Radeon RX 6600 XT	amazon.co.uk	**#220** p53	£343
MEMORY	32GB (2 x 16GB) Kingston Fury Beast RGB 6000MHz DDR5 (KF560C40 BBAK2-32)	cclonline.com	**#230** p54	£224
MOTHERBOARD	MSI MEG Z690 Unify	scan.co.uk	**#222** p50	£520
STORAGE	2TB WD Black SN850	scan.co.uk	**#215** p49	£179

Total £2,085

UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 3080 Ti	nvidia.com	**#221** p48	£1,050
ADD SECONDARY STORAGE	4TB Western Digital Blue	ebuyer.com	**#166** p54	£86

Mini PCs

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

Mini-ITX

Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Intel Z690 (LGA1700)	Gigabyte Z690I Aorus Ultra Plus	amazon.co.uk	**#228** p46	£331
Intel B660 (LGA1700)	Gigabyte B660I Aorus Pro DDR4	scan.co.uk	**#228** p47	£213
AMD X570 (AM4)	Asus ROG Strix X570-I Gaming	cclonline.com	**#228** p40	£302
AMD B550 (AM4)	Asus ROG Strix B550-I Gaming	cclonline.com	**#228** p39	£222

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ALL-PURPOSE	Cooler Master MasterBox NR200P	scan.co.uk	**#206** p18	£100
TOWER	Ssupd Meshlicious	overclockers.co.uk	**#225** p51	£105
HIGH AIRFLOW	Fractal Design Torrent Nano	scan.co.uk	**#225** p45	£117
PREMIUM	Streacom DA2 V2	quietpc.com	**#214** p51	£199

Other components

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
LOW-PROFILE CPU COOLER	Noctua NH-L12S	scan.co.uk	**#219** p54	£59
SFX POWER SUPPLY	Phanteks Revolt SFX 750W	overclockers.co.uk	**#228** p74	£130

ATX cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET RGB	Antec DF700 Flux	ebuyer.com	**#214** p26	£85
SUB-£100 AIRFLOW	Corsair 4000D Airflow	scan.co.uk	**#222** p56	£80
COMPACT	Fractal Design Meshify 2 Compact	scan.co.uk	**#215** p20	£125
HIGH AIRFLOW	Fractal Design Meshify 2	scan.co.uk	**#212** p45	£155
PREMIUM HIGH AIRFLOW	Fractal Design Torrent RGB TG	scan.co.uk	**#225** p20	£245
LUXURY	Corsair iCUE 5000T RGB	scan.co.uk	**#224** p22	£330

Micro-ATX

Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
AMD B450 (AM4)	Asus TUF B450M-PLUS II	awd-it.co.uk	**#218** p76	£87
AMD B550 (AM4)	MSI MAG B550M Mortar	scan.co.uk	**#204** p42	£130

Cases

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

Networking

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET ROUTER	Belkin RT3200-UK	amazon.co.uk	**#216** p52	£78
ROUTER	Asus RT-AX68U	scan.co.uk	**#216** p51	£177
MESH ROUTER	Asus ZenWiFi AX Hybrid XP4	amazon.co.uk	**#226** p59	£258
WI-FI ADAPTOR	TP-Link Archer TX3000E	overclockers.co.uk	**#196** p58	£50
DUAL-BAY NAS BOX	Synology DS220j	box.co.uk	**#200** p22	£157
DUAL-BAY MEDIA NAS BOX	Synology DS218play	box.co.uk	**#174** p34	£204
2.5 GIGABIT DUAL-BAY NAS BOX	QNAP TS-231P3	ebuyer.com	**#212** p25	£359

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

Monitors

Up to 25in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN, 144HZ, IPS, 1,920 X 1,080, F, G	AOC 24G2U	cclonline.com	#214 p28	£150
25IN, 240HZ, IPS, 1,920 X 1,080, F, G	Acer Predator XB253Q	box.co.uk	#209 p57	£222
25IN, 360HZ, IPS, 1,920 X 1,080, F, G	Asus ROG Swift PG259QN	ebuyer.com	#212 p20	£659

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, 165HZ, IPS, 2,560 X 1,440, F, G	LG Ultragear 27GP850	currys.co.uk	#229 p48	£299
27IN, 165HZ, VA, 2,560 X 1,440, F, G	AOC CQ27G3SU	overclockers.co.uk	#223 p45	£230
27IN, 240HZ, TN, 2,560 X 1,440, F, G	AOC AG273QZ	overclockers.co.uk	#202 p27	£570
27IN, 240HZ, IPS, 2,560 X 1,440, F, G	Alienware AW2721D	dell.com	#212 p21	£639
28IN, 144HZ, IPS, 3,840 X 2,160, F, G	AOC U28G2XU	overclockers.co.uk	#221 p29	£569

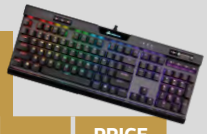
Over 28in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
31.5IN, 60HZ, VA, 3,840 X 2,160, F	iiyama ProLite XB3288UHSU	scan.co.uk	#205 p43	£370
32IN, 144HZ, VA, 2,560 X 1,440, F, G	iiyama G-Master GB3266QSU	scan.co.uk	#224 p30	£320
32IN, 165HZ, IPS, 2,560 X 1,440, F, G	LG UltraGear 32GP850	currys.co.uk	#220 p38	£449
34IN, 144HZ, IPS, 3,440 X 1,440, W, F	iiyama G-Master GB3461WQSU	overclockers.co.uk	#206 p53	£440
34IN, 144HZ, IPS, 3,440 X 1,440, W, F, G	LG UltraGear 34GN850	scan.co.uk	#206 p55	£654
38IN, 144HZ, IPS, 3,840 X 1,600, W, F, G, HDR	LG UltraGear 38GN950	currys.co.uk	#208 p30	£1,099
32IN, 240HZ, VA, 3,840 X 2,160, F, G, HDR	Samsung Odyssey Neo G8	overclockers.co.uk	#229 p17	£1,299

Non-gaming

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN, 75HZ, IPS, 2,560 X 1,440, F	LG 27QN880	amazon.co.uk	#210 p26	£399

Peripherals and audio



Gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET TKL	SteelSeries Apex 3 TKL	currys.co.uk	#221 p59	£40
OPTICAL ESPORTS	Asus ROG Strix Scope RX	amazon.co.uk	#209 p43	£73
MECHANICAL 65 PER CENT	Ducky One 3 SF	overclockers.co.uk	#230 p26	£100
MECHANICAL TKL	NZXT Function MiniTKL	cclonline.com	#226 p32	£100
PREMIUM TKL MECHANICAL	Corsair K70 RGB TKL	scan.co.uk	#214 p31	£150
PREMIUM MECHANICAL	Corsair K70 RGB Pro	overclockers.co.uk	#225 p30	£150
PREMIUM WIRELESS MECHANICAL	Razer BlackWidow V3 Pro	overclockers.co.uk	#208 p60	£230

Gaming mice

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET GAMING	NZXT Lift	scan.co.uk	#226 p32	£40
FIRST-PERSON SHOOTER	Glorious Model O	overclockers.co.uk	#215 p57	£50
AMBIDEXTROUS	Razer Viper 8K	currys.co.uk	#215 p59	£70
MULTI-BUTTON	Roccat Kone XP	roccat.com	#225 p60	£80
WIRELESS	Razer Viper Ultimate	currys.co.uk	#217 p54	£60
PREMIUM WIRELESS	Razer DeathAdder V2 Pro	scan.co.uk	#210 p28	£80
ULTRA LIGHTWEIGHT	Asus TUF Gaming M4 Air	overclockers.co.uk	#227 p36	£48
PREMIUM LIGHTWEIGHT WIRELESS	Logitech G Pro X Superlight	amazon.co.uk	#217 p52	£106

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
BUDGET GAMEPAD	PowerA Spectra Infinity Xbox Series X	amazon.co.uk	**#228** p55	£32
MID-RANGE GAMEPAD	Sony DualSense	scan.co.uk	**#228** p58	£60
PREMIUM GAMEPAD	Scuf Instinct Pro	scufgaming.co.uk	**#228** p57	£190
BUDGET FLIGHT STICK	Logitech Extreme 3D Pro Joystick	currys.co.uk	**#207** p52	£36
FLIGHT STICK	Thrustmaster T.16000M FCS HOTAS	scan.co.uk	**#207** p56	£129

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	£45
WIRELESS	Corsair Virtuoso RGB Wireless	ebuyer.com	**#204** p50	£146
PREMIUM WIRELESS	Razer BlackShark V2 Pro	scan.co.uk	**#211** p26	£155

Speakers

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

Non-gaming keyboards

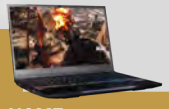
CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
WIRELESS 84-KEY ELECTRO-CAPACATIVE	Niz Mini 84 Pro	keyboardco.com	**#220** p29	£165
BUCKLING SPRING MECHANICAL	Unicomp New Model M	keyboardco.com	**#219** p26	£129

PCs and laptops

Pre-built PC systems

CATEGORY	NAME	CPU	GPU	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET GAMING	PC Specialist Prism Nova	Intel Core i5-12400F	Nvidia GeForce RTX 3060	custompc.co.uk/PrismNova	**#229** p30	£1,199
QUIET GAMING	Gladiator Nocturnal	Intel Core i5-12600K	Nvidia GeForce RTX 3070	custompc.co.uk/Nocturnal	**#225** p36	£1,799
MID-RANGE GAMING	CyberPower Infinity X127 Plus	Intel Core i7-12700KF	Nvidia GeForce RTX 3080 10GB	custompc.co.uk/X127Plus	**#230** p36	£1,999
4K GAMING	PC Specialist Magnus Pro K500	Intel Core i7-12700K	Nvidia GeForce RTX 3080 Ti	custompc.co.uk/MagnusPro	**#225** p34	£2,499
WATER-COOLED ULTIMATE PERFORMANCE	CyberPower Hydro-X Infinity RTX	Intel Core i9-12900KS	Nvidia GeForce RTX 3090 Ti	custompc.co.uk/CPHX	**#228** p26	£4,630

Laptops



CATEGORY	NAME	CPU	GPU	SCREEN	SUPPLIER	ISSUE	PRICE (inc VAT)
ULTRA PORTABLE GAMING	Razer Blade 14	AMD Ryzen 9 5900HX	Nvidia GeForce RTX 3070 Laptop	14in 1,920 x 1,080 IPS 144Hz	custompc.co.uk/Blade14	**#220** p40	£2,120
MID-RANGE GAMING	Asus ROG Strix Scar 15 G533ZW	Intel Core i9-12900H	Nvidia GeForce RTX 3070 Ti Laptop	15.6in 2,560 x 1,440 IPS 240Hz	custompc.co.uk/AsusScar15	**#227** p40	£2,300
HIGH-SPEED GAMING	Alienware x17 R2	Intel Core i7-12700H	Nvidia GeForce RTX 3080 Ti Laptop	17.3in 1,920 x 1,080 IPS 360Hz G-Sync	custompc.co.uk/AlienwareX17	**#227** p38	£3,450

RICK LANE / INVERSE LOOK

STAR BORES

Bethesda claims Starfield is an authentic sci-fi experience, but Rick Lane says its combat is down to Earth in all the wrong ways

Recently, Bethesda showed off the first gameplay footage of Starfield, the studio's first single-player RPG since Fallout 4, and its first entirely new universe in 25 years. It's arguably the most anticipated game currently in development, not least because Bethesda has been reticent about revealing details about the game.

However, the reveal was a mixed affair. Despite running in a new engine, Starfield appeared structurally and functionally similar to Fallout 4 and Skyrim, while Bethesda's claim the game will include over 1,000 explorable planets was met with scepticism regarding the ultimate detail of those planets. But perhaps the most disappointing moment occurred at the start of the reveal. Upon landing on a new planet, the player character instantly pulls out a gun.

Now, first-person combat has always been a feature of Bethesda's RPGs, and it's a sad truth that nothing gets a general audience excited like whipping out a big old boomstick. But it was particularly disheartening to see Starfield resort to this trick so quickly. Given all the possibility for adventure in space, frontloading your sci-fi RPG with a gunfight seems sorely lacking in imagination.

First impressions of combat were hardly promising either. The weapons demonstrated were a highly conventional mix of assault rifles and shotguns, just with extra sci-fi greebles. The actual fighting, meanwhile, seemed to involve mindlessly whittling down enemy health bars in gunmetal prefabs.

Dishearteningly, Starfield's combat makes little consideration for the uniquely dangerous aspects of a gunfight on an alien world. Simply surviving on almost any alien planet would require you to be hermetically sealed inside a spacesuit. A single puncture anywhere in that suit would be immediately life-threatening, either because it allowed the air you need to breathe to escape, or because the change in atmospheric pressure would cause your body to instantly implode.

You might think expecting such detail from a sci-fi RPG is unrealistic, especially since other sci-fi games such as Mass Effect never simulated such conditions. But Starfield specifically bills itself as an authentic envisioning of the future of space travel, to the point where it has cited the work of companies such as SpaceX as direct inspiration. One of the best ways to make space fiction authentic is to accurately represent the extremely hazardous nature of space as an environment.

First impressions of combat were hardly promising

TV has excelled at this in recent years. Critically acclaimed sci-fi series, such as The Expanse and For All Mankind, go to great effort to show audiences how the human body is affected by phenomena such as air pressure, g-forces, solar radiation and alien atmospheres. When a character draws a weapon on a spaceship in The Expanse, one wayward bullet could potentially kill everyone on board, heightening the tension as a consequence.

It's possible that Starfield will offer a much broader experience than its gameplay reveal suggests, although the studio's games have become increasingly combat-centric since the launch of Oblivion. Either way, bringing these elements into the combat would lend Starfield gunfights greater character, make its portrayal of space more authentic and help to distance it from the one-dimensional mutant-blasting of Fallout 4. CPC

Rick Lane is Custom PC's games editor @Rick_Lane

Teenage Mutant Ninja Turtles: Shredder's Revenge / £22.49 inc VAT

DEVELOPER Tribute Games Inc / **PUBLISHER** Domeru, Gamera Games

Teenage Mutant Ninja Turtles: Shredder's Revenge is a throwback to the beloved Turtles games of the SNES and MegaDrive era, with players smacking colour-coded ninjas and classic villains from the TV show in chaotic, colourful 2D arcade combat.

The game lets up to six players join forces on a pugilistic foot-chase across New York City, as the Turtles' nemesis Shredder attempts to reassemble the robotic body of another villain named Krang. Players can battle through the game's 16 levels as any of the four Ninja Turtles, plus Master Splinter and the Turtle's dogged journalist companion, April O'Neill.

The breezy pixel graphics pop with vibrant colours, while levels and combat animations have detail that would have been impossible 30 years ago. Perhaps the most significant update is the soundtrack, composed by the designer behind the scores of Sonic Mania and Streets of Rage 4, with some delightfully corny rap vocals provided by members of the Wu Tang Clan.

In play, Shredder's Revenge bakes an impressive amount of variety into a handful of combat controls. Every character uses the same combo system of basic attacks, jumps, flips and special attacks, but has unique moves and animations built around those basic combinations. As you batter your way across New York, the game gradually introduces a wide array of enemy types, ranging from variations on Shredder's ninja goons who attack with different weapons, to hulking clay-people and gun-toting anthropomorphic dinosaurs.

From start to finish, it's deliriously fun. The levels pack a huge amount of variety into the New York setting, with missions including a brawl through a TV studio and a riotous trip to the zoo. The game is also filled with fun callbacks to the animated TV shows and the early Turtles games. The animation for reviving other players sees your character hold a slice of pizza to their faces, and pressing the Down key while grappling an enemy will see you toss your foe towards the screen, as seen in Turtles in Time.

However, once you've run through the campaign, which takes three to four hours, there isn't much else to do. The story mode offers side objectives alongside the main missions, but they're all simplistic collection challenges. Arcade mode ditches the story mode's city map for a straight run through the 16 levels, but it's otherwise little different. The main reason to replay Shredder's Revenge is to try out the various characters, but aside from looking different, they all functionally work in the same way.

Nonetheless, Shredder's Revenge is great while it lasts. More than just a Pepperoni-speckled slice of nostalgia, it's capably alongside Streets of Rage 4 as a delightful rejuvenation of a genre lost to time.

RICK LANE

COWABUNGA

+ Radical production values
+ Ace 2D combat
+ Wicked in multiplayer

BUNGA BUNGA

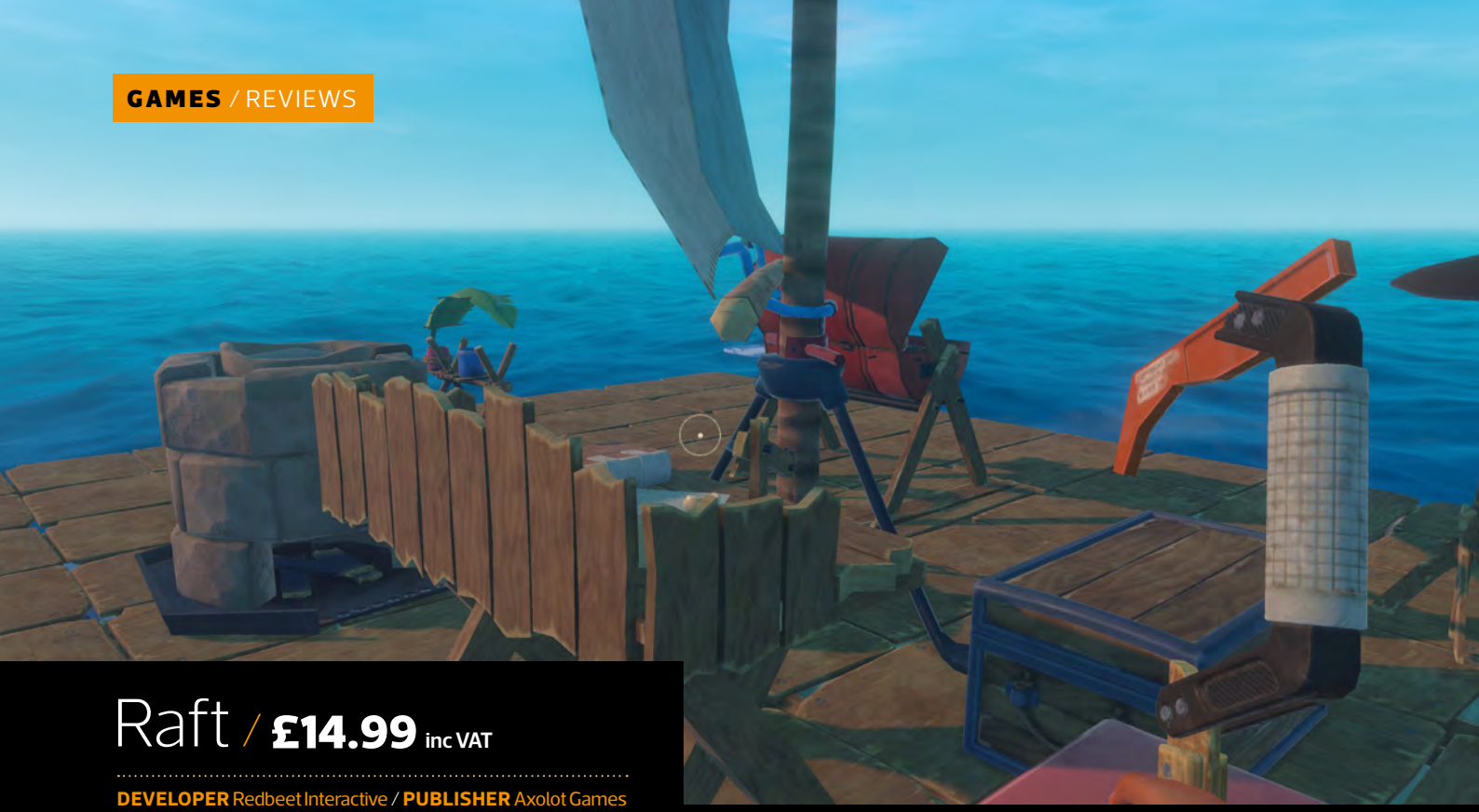
– Not much replay value

/ VERDICT

Like a Saturday morning cartoon, Shredder's revenge is colourful, action-packed and leaves you wanting more.

OVERALL SCORE

80%



Raft / **£14.99** inc VAT

DEVELOPER Redbeet Interactive / **PUBLISHER** Axolot Games

Like an improvised sailing vessel on a stormy ocean, Raft has its ups and downs. It starts out as a typically structured survival game with a novel twist, then morphs into a difficult and at times frustrating battle against its own systems, before finally emerging as a surprisingly compelling ocean-going adventure.

A game of Raft starts out with your character floating in a vast, empty-seeming ocean on a small square of wood. You're apparently a scout searching for other surviving humans on Earth after a climate catastrophe, although you'll only learn this by consulting your character's handbook. Even then, the handbook fails to explain why you've been sent on this journey with nothing but a plastic hook and some rope.

Luckily, a plastic hook is all you ultimately need. As your raft drifts through the ocean, it's passed by an endless stream of floating detritus, ranging from plastic bottles and planks of wood to barrels and crates filled with random assortments of resources.

You can pluck some of these goodies from the ocean by hand, but you can't swim out to more distant objects due to the hungry shark that perpetually harasses your raft. This is where your hook comes in useful. By tossing it into the sea and then dragging back the attached rope, you can collect distant objects without losing limb and life to Jaws.

Using these resources, you can expand and improve your raft to increase your chances of survival, crafting fishing rods to catch food, grills to cook your catch and water evaporators, so you can have a drink that won't poison you with a toxic level of salt. You can also craft a sail and a simple anchor for your raft, both of which are important for getting through the next stage of the game.

This initial bout of building and crafting is thoroughly enjoyable, as you figure out the basics of survival and transform a formless wooden platform into a structure more akin to a floating home. Upon reaching the limits of what you can create with what the sea provides, however, the game suddenly stops being fun for several hours.

The problem stems from a conflict between what you need to do to progress, and what you need to do to survive. Once you've crafted every possible object with flotsam and jetsam, you must venture onto passing islands to get more advanced resources. However, getting to these resources involves some elaborate processes, and it's very easy for the game to interrupt your preparation.

First, you need to find an appropriate island. It needs to have coral shallows where you can dive to collect sand, clay and metal ore in order to build a smelter. However, it also needs to be big enough so you can dive in an area that's sufficiently distant from your raft that the shark will leave you alone. Unfortunately, these large islands are also home to animals such as warthogs, which can be just as dangerous as the shark in this early stage of the game.

RAFT

- \+ Innovative resource gathering
- \+ Interesting adventure
- \+ Building your raft is fun

DAFT

- – Some rough edges
- – Initial survival phase can be a trial

You also need to prepare for an expedition onto land, ensuring that you're sufficiently fed and watered to spend time gathering the resources you need. This is tricky, however, because your initial equipment for food and drink prep only lets you produce a small amount of either at any one time. Combined with constantly needing to gather basic resources to repair shark-induced raft damage, and craft single-use items such as basic anchors, it's easy to become trapped in a loop of subsistence without making any meaningful improvements to your situation.

These frustrations also heighten Raft's other main problem, which is that both visually and interactively, it's surprisingly rough in certain areas. The game looks pretty enough when you're out on the open ocean, but the islands are ugly lumps of grey-green polygons that don't really communicate the lush tropical vibe that's clearly the game's target. Meanwhile, interactions such as chopping down trees and hunting animals is nowhere near as nuanced or satisfying as other survival games such as The Forest, or even the decade-old Don't Starve.

These issues aren't dealbreakers in themselves, but combined, they make for a miserable few hours of grind after that initial flurry of progression. Given that Raft was

in Steam Early Access for many years (and sold extremely well in that time), it's surprising that more time wasn't dedicated to improving the game's overall look, feel and early-game balance.

Luckily, once you've constructed the smelter, alongside a couple of other items, such as the advanced grill and water filter, it's possible to break out from the survivalist loop, whereupon Raft becomes entertaining again. Building a radio transmitter helps you navigate to larger, more interesting islands, where Raft begins layering in its globetrotting story.

The fact your home base is mobile also enables developer Redbeet Interactive to do more with storytelling than many other survival games, and this watery post-apocalypse takes you to some fantastic locations. You'll visit townships constructed out of shipping containers, and a drifting super-yacht that has been mysteriously abandoned. These aren't passive locations either – there are puzzles to be solved and quests to be completed that will lead you on to further new places.

The world of Raft feels expansive and interesting, with audio-logs filling in the details of its eerie, abandoned locales. The whole game can also be played cooperatively, which not only makes it feel less lonely, but also helps to mitigate that tricky intermediate section, helping you to emerge from the survival cycle quicker.

Raft lacks the polish of the best survival games, such as Subnautica and The Forest. However, it has enough ideas of its own to help refresh some of the more familiar mechanics of the genre, and it's worth persevering through its low points to enjoy the story that emerges on the far side. You'll endure some choppy waters to get the best out of Raft, but a fascinating adventure lies beyond them.

RICK LANE

/ VERDICT

Raft can be a patchy survival affair, but stick with it and you'll be rewarded with a neat oceanic adventure.

OVERALL SCORE

77%

STARSHIP TROOPERS: TERRAN COMMAND / £23.97 inc VAT

DEVELOPER The Aristocrats / **PUBLISHER** Slitherine Ltd

BEE

+ Great mission design
+ Interesting tactical systems
+ True to Verhoeven's film

WASP

– Visually staid
– Not much replay value

/ VERDICT

Beyond needing a lick of paint, Starship Troopers: Terran Command is as good an adaptation as you could want.

OVERALL SCORE

83%

A real-time strategy based on Paul Verhoeven's 1997 film, Starship Troopers: Terran Command offers 19 missions through which you battle the film's iconic alien Arachnids for control over the planet Kwalasha, a barren desert world where the hostile surface conceals abundant resources beneath. The game is set almost entirely on this single planet; combined with the generally plain presentation, this makes the game look like a product from ten years ago.

Don't let that put you off. Terran Command demonstrates its aptitude early on, with some clever twists on the usual RTS formula. Although the game's structure is superficially similar to other build-and-rush strategy games, there's very little base building, while rushing your troops into battle will probably get them killed.

This is because most units in Terran Command can't fire through one another's ranks, and so must be arranged in a wide frontline to maximise their damage output and prevent them from being overrun by the Arachnids. In this formation, you must move and deploy your troops carefully to eliminate hives of enemy bugs. These hives spawn Arachnids endlessly until cleared by your troops, which can only be done by exhausting the central hive and any adjoining nests.

The closer your units get to the hive, the more intense the bug assault becomes, so it's important not to rush headlong into the oncoming horde. However, if your troops move too slowly, the hives won't empty fast enough for you to clear them before the next wave of bugs spawn. Hence, it's important to strike a balance between speed and caution.

New bugs threats are also introduced with almost every mission, ranging from hoppers that can harass your units from the air, to hulking tanker bugs that can rip gaping holes in your ranks with their explosive spit. To counter this escalation, you'll also gain new units such as snipers, rocket troopers and even gigantic mechs that can hold off a bug horde single-handed.

Terran Command's couples this drip feed of new toys with intelligent scenario design, which combines thrilling missions with some thematically fitting commentary on fascist jingoism. Nearly every mission sees you short of men and equipment due to high command's poor strategic decisions.

You'll be forced to destroy bug artillery with a handful of isolated units, and defend a fortified internment camp, all so the Federation can watch a political prisoner's execution live on television. Success rewards you not with medals or upgrades, but with even more perilous and foolhardy missions.

There are ways Terran Command could be better. The action could be more spectacular, and there isn't much replay value beyond the main campaign. However, while it lasts, Terran Command is the best single-player RTS since last year's Age of Empires 4.

RICK LANE

THE LOOKER / FREE

DEVELOPER Standing Stone Games LLC / **PUBLISHER** Standing Stone Games LLC

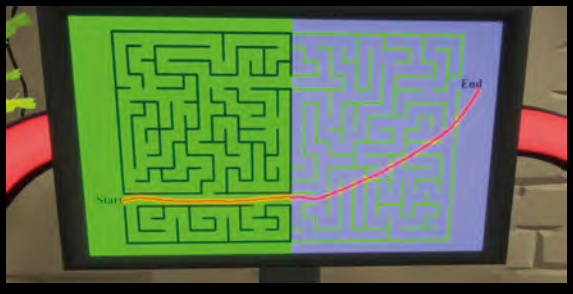
Spoof games are often more fun in theory than in practice. Goat Simulator is an amusing concept, but the game itself is only fun for around five minutes until the novelty wears off. The Looker, however, offers more than a handful of mocking gags. A send-up of Jonathan Blow's brain-scrambling puzzler The Witness, it succeeds both as a parody and as a puzzle game.

As with Blow's game, The Looker begins with the player awakening on a picturesque, abstract island covered in an elaborate sequence of maze. To escape the castle where most of the game takes place, you must complete these sequences to power a device that will raise the castle's portcullis.

Each of these maze puzzles is presented on its own screen. To complete them, you simply draw a line on the screen, just as in The Witness, but there are a couple of key differences. Firstly, in The Looker, the screens are literally scrawled across in bright red pencil. Secondly, all of The Looker's puzzles are jokes. For example, the first puzzle involves drawing a line through a simple maze from the start to the end. The next puzzle in the sequence, however, requires you to draw a line from the end of the maze to the start.

The ways The Looker spins this concept is both amusing and clever. Some puzzles let you skip the maze entirely, while others require you to colour in the wire connecting the screens to activate the next puzzle.

Crucially, the way puzzles are sequenced isn't arbitrary. Like The Witness, each sequence has its own logic that helps you to figure out the solution. The only difference is that the solution is also a punchline.



The Looker couples these playful conundrums with liberally scattered jokes through the game world. It rarely mocks The Witness outright, but it's perhaps most critical in its audio-logs, which directly seek to poke a hole in The Witness' arch, obtuse storytelling. One example spins an elaborate yarn about Marco Polo meeting Kublai Khan, before revealing itself as a play on the famous 'Nigerian Prince' email scam. Alongside these mechanical audio-logs are some great mechanical one-liners, such as the puzzle where you solve a maze by shooting it with a gun.

The way The Looker subverts The Witness' design while also providing a capable facsimile of it is impressive, especially considering the experience is completely free. That said, it's not above criticism either. The game's logic is mostly consistent, but a couple of puzzles make too big a logical leap, while a few others are presented in a way that obscures rather than clarifies the solution.

The Looker is also much shorter than The Witness – it wraps up its comedy act in a couple of hours. Then again, it's free and The Looker is a riot while it lasts.

RICK LANE

WITNESS

+ Funny
+ Surprisingly clever
+ Free

WITLESS

– Logic isn't always consistent
– Short

/ VERDICT

A parody game that walks its talk, the Looker is superbly designed send up of The Witness.

OVERALL SCORE

87%

REALITY CHECK

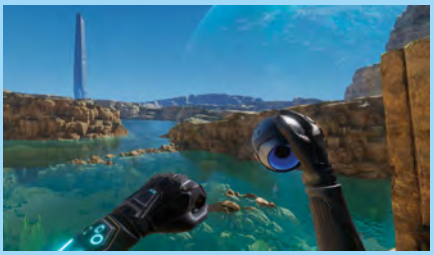
Rick Lane constructs cities out of rocks and prepares for some VR sci-fi in his latest virtual reality roundup

NEWS

HUBRIS

VR first-person shooter Hubris sees you play as an aspiring recruit to an organisation known as the Order of Objectivity (they must be fun at parties), which is dispatched to a system of twin planets in search of a fellow agent who has gone missing.

Hubris' most striking feature is its visuals, looking by far the most graphically ambitious VR game since last year's Lone Echo II. With Meta moving away from PC-reliant VR hardware to Quest-style independent headsets, the impetus to push VR graphics has been diminished recently, but Hubris clearly aims to take that next step towards photorealism, with lush sci-fi environments and incredibly detailed character models.



The game appears to combine traditional first-person gunplay with other familiar VR mechanics, such as climbing, and will let players pilot in-game vehicles such as mechs and hovercraft. There is a question over how well these individual features will function, however. Although Hubris looks great in screenshots, in motion, the combat looks a little flat.

NEWS

ZIGGY'S COSMIC ADVENTURES

VR space simulators aren't a new idea. Space games such as No Man's Sky and Elite Dangerous have let players enjoy the splendour and terror of space in stereoscopic 3D for years, but these games focus mainly on what's happening outside of your cockpit. Ziggy's Space Adventures, by comparison, focuses on what's happening inside your cockpit.

You play an interstellar thief on the run from an oppressive galactic empire after nicking some incredibly valuable alien technology from the aforementioned empire a botched heist.

Evading its imperial clutches will involve more than some nifty piloting skills and a well-honed trigger finger. You'll also have to deftly manage the many systems and components of the ship on the fly.

Ziggy's Cosmic Adventures combines the spacefaring action of Elite Dangerous with the plate-spinning of Job Simulator. Your room-scale cockpit is fully simulated, and you'll need to manually power your shields, balance temperature and pressure, and manage a host of other systems crucial to keeping you alive in space.

You'll be doing all of this while flying through dangerous sectors of the galaxy, avoiding asteroids, battling enemy ships and manually repairing your vessel when struck by laser fire.

The game couples these ideas with a branching story that's intended to be different each time you play. Combined with its winningly cartoonish aesthetic, Ziggy's Cosmic Adventures looks set to breathe some new life into one of VR's more familiar genres.

REVIEW

SHORES OF LOCI / £11.39 inc VAT

DEVELOPER MikeTeeVee / **PUBLISHER** MikeTeeVee

Shores of Loci is a great example of how VR can turn even the most mundane activity into a majestic experience. It's basically a 3D jigsaw-puzzle simulator, only instead of assembling a space shuttle or the Taj Mahal out of foam pieces, you put together living cities out of fat chunks of rock. It's a simple but captivating experience that combines relaxing puzzle solving with an almighty sense of scale.

Each of the game's puzzles sees you stood (or sat) upon a central island surrounded by ocean, where fragments of rock are brought to you via several methods. Sometimes they arrive via longboat; at other times, they're conjured up by the towering stone colossus for whom you appear to be working. Whichever way they arrive, your job is to figure out how to piece them together, using your hands to rotate and manipulate the pieces into place.

Mechanically, Shores of Loci is fairly rudimentary, using only VR's hand tracking and grip controls. The complexity stems from how the puzzles are structured, and the rewards for completing them. The fragments you assemble aren't neatly cut – every piece is a different shape and size, making assembly much trickier than a Peppa Pig jigsaw.

There are clues on the pieces that hint at how they fit together, but the clues differ in each puzzle. One puzzle might have symbols carved into the rock that highlight where pieces match, while another might require you to look at tree root patterns on the undersides of the pieces.

The puzzles aren't static experiences either. The cities you assemble spring to life in your hands. As you connect pieces together, trees will sprout from the undergrowth, while buildings and roads will appear across the surface. Tiny villagers will also start to appear in the burgeoning settlement, milling about the rock face like ants.

But Shores of Loci saves its best trick for when you complete a major puzzle segment. At this point, the rock you've just been handling levitates into the air and grows to life size, planting itself into the scenery in front of you. It's a spellbinding effect, and one that makes piecing together the game's fractured urban spaces incredibly rewarding. Shores of Loci preserves that sense of satisfaction from completing puzzles through variety. There's around a dozen puzzles in all, with settings ranging from quaint Nordic fishing villages to futuristic tropical cityscapes.

There are a few minor problems. It can be difficult to keep track of all the pieces in more complex puzzles, not least because they float freely and react to being bumped by other pieces. What's more, as you assemble the puzzle, it becomes increasingly cumbersome to manipulate. Finally, while there is a story of sorts to Shores of Loci, it's vague and wibbly to say the least.

Ultimately, though, Shores of Loci doesn't really need a story. It works fine as an abstract puzzler, letting you bask in the quiet thrill of construction, and wonder at the nature of all the different civilisations you've helped to build. Smart, relaxing and innovative, Shores of Loci is an excellent game for a quiet night in. CPC

LOCI

+ Simple, elegant concept
+ Well-constructed puzzles
+ Tremendous use of scale

LOKI

– Puzzles can be a little fiddly
– Token story

VERDICT

Like the civilisations at the centre of its puzzling, Shores of Loci builds a memorable experience out of a handful of parts.

OVERALL SCORE

84%

MEMORY REMAINS

HOW MUCH MEMORY DO YOU NEED? WHAT DO MEMORY TIMINGS MEAN? DOES DDR5 MATTER? EDWARD CHESTER EXPLAINS ALL THIS AND MORE IN OUR COMPLETE GUIDE TO MEMORY

Sitting at the heart of every modern PC, memory is as essential a component now as it has ever been. However, its exact role in the PC and in the performance of your PC can sometimes be tricky to nail down. That's where we're here to help as we explain how memory works, what all the jargon associated with it means, how much you need, where speed matters and more.

What is memory?

What we think of as the memory of a PC is specifically a certain layer of data storage between the processing cores of a CPU and the longer-term methods of storing data on a PC, such as SSDs and hard drives. The latter are too slow for a CPU to be constantly accessing them as it goes about performing calculations, so instead a series of faster storage mediums are used to keep the CPU fed quickly with data.

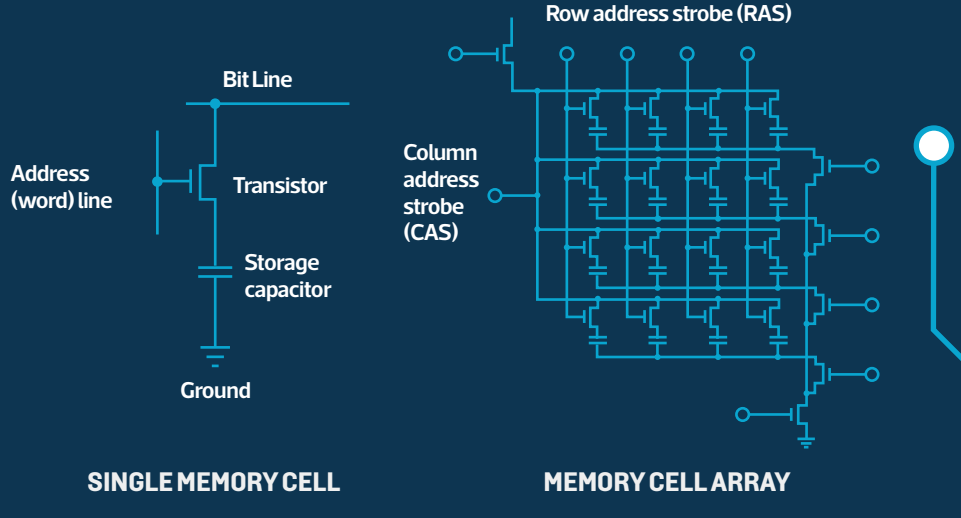
The first layers of data storage for a CPU are the caches that are kept on the CPU die itself. Typically, you get three layers of cache that increase in size and decrease in speed, the further they are from the processing cores. The closest level, called the L1 cache, is typically split into several different types of cache for storing data and the instructions that are to be performed on that data, and is typically in the region of a few tens of kilobytes in total size. Next up is the L2 cache, which is generally a unified pool of data and instructions in the region of 1-4MB in size. Both L1 and L2 cache are generally specific to a single core (or a limited number of cores).

Next up we have L3 cache, which is typically a much larger size than L1 and L2 – in the region of 10-30MB – and is shared across all the cores on a processor.

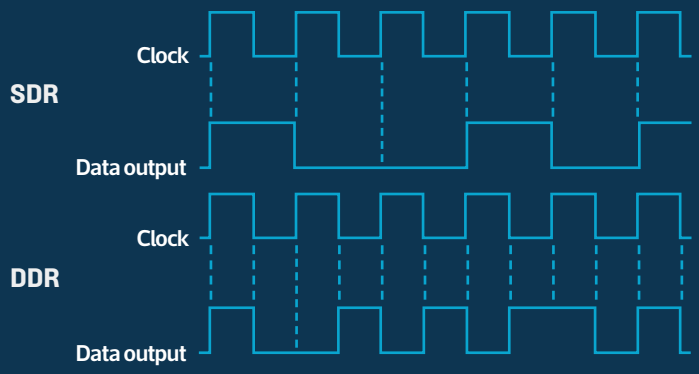
Balancing all these cache sizes and speeds is a key aspect of optimising CPU performance, and because it's so much faster than system memory or long-term storage, increasing the size of these caches can provide big speed boosts. That's why we've seen AMD develop its 3D V-Cache technology for stacking a whole extra layer of L3 cache on top of its CPU core dies. The 3D V-Cache equipped Ryzen 5800X3D triples the L3 cache size of the regular Ryzen 5800X, providing significant performance increases, particularly in gaming.

All of which brings us to regular system memory. While all the caches are to be found crammed on the same dies as the CPU cores,

Memory is arranged in a grid structure where rows must be accessed before a column can then be read



SINGLE MEMORY CELL **MEMORY CELL ARRAY**



DDR memory transfers data on the rise and fall of the memory's clock signal

system memory is physically separated, which comes with one key advantage and one key disadvantage.

The advantage is that all that extra space away from the CPU allows for a huge leap in capacity from the kilobytes and megabytes of L1-L3 cache to the multiple gigabytes of RAM found in a typical PC. This allows whole applications and huge files to be copied from long term storage and held in memory, whereas caches are only large enough to have small portions of any given file or application stored in them.

The disadvantage with this arrangement is that the distance from the CPU, and reliance on PCB traces on a motherboard rather than the microscopic connections inside the silicon of a CPU, mean that system memory must run much slower than CPU caches. Typically, an L1 cache zips along at the equivalent of thousands of gigabytes per second, and L2 and L3 cache run at many hundreds of gigabytes per second, whereas RAM typically runs between 50-100GB/sec – it's still fast, but it's orders of magnitude slower than cache.

How does memory work?

On the surface, memory is quite simple stuff. It's a load of chips stacked on a board (a dual-inline memory module or DIMM) that store data. Each chip has some memory cells in it, each of which stores a 0 or a 1 to represent its bit of data. So far, so simple. However, the actual way in which the memory works is surprisingly complex.

For a start, what we think of as system memory is actually called DRAM or dynamic random access memory. The random access part refers to the ability to access any part of the memory for reading and writing at any time, as opposed to the linear access of a tape, for instance. The dynamic aspect refers to the fact that DRAM cells must have their data constantly refreshed. That's because each cell is a capacitor that gets charged up to store its bit of data, then that charge slowly leaks away. In contrast, on-chip caches use static RAM (SRAM) made up of transistors, which hold their state as long as power is supplied.

The reason capacitors are used is because they're relatively cheap to make compared with SRAM, plus they provide decently fast performance and, unlike flash storage, the cells don't meaningfully degrade over time – they can be charged and discharged effectively infinite times.

Making the situation even more complex is that in order to read the charge level of a cell – to read the memory – the charge is lost, so it has to be immediately written back again. This also makes it clear why DRAM can't store data once your system is turned off – the refresh cycle can't happen while the system is powered down, so the capacitor charge leaks away.

The cells themselves are etched onto a silicon wafer in a grid pattern where the columns are called bitlines and the rows are called wordlines. It's the intersection of these lines that's the final part of the address of a memory cell, and the way the cell is accessed – first by selecting a row, then by selecting a column – is a key aspect of understanding the memory terminology we discuss below.

What does DDR mean?

Double data rate (DDR) DRAM was a term introduced way back in 2002 when the first iteration of the DDR standard arrived. It refers to the ability of DDR memory to transmit data both on the upward and the downward edges of the clock signal, literally doubling the data rate of the memory.

Because of this doubling, when memory is listed as 3200MHz, for instance, it generally means the clock speed is 1600MHz and the effective speed of the memory is 3200MHz. Alternatively, some manufacturers will refer to megatransfers per second (MT/sec) or use a measure of megabits per second (Mbps), as these are both more accurate reflections of what's happening.

In the future, we're also set to see quad data rate (QDR) memory, which uses two clock signals – one each for read and write operations – and transfers data on the rising and falling edges of each signal. It's present in the GDDR5 memory used in graphics cards but didn't make it into the standard for DDR5.

RAM jargon explained

Take a glance at the listings for a memory stick on your favourite shopping site and it can be almightily confusing. Instead of just DDR4 1600MHz or DDR4 3200MT/sec, you'll often see PC4-25600C16, possibly followed by

The listings for memory modules can be decidedly confusing if you don't understand the lingo

Memory timings

Cyberpunk 2077		
	Minimum	Average
42-50-50-80 timings	26fps	38.9fps
32-38-38-80 timings	26.5fps	39fps

RealBench			
	Image editing time	Video encoding time	Heavy multi-tasking time
42-50-50-80 timings	165.8 seconds	46.5 seconds	40 seconds
32-38-38-80 timings	164.4 seconds	46 seconds	38 seconds

Memory timings do have an impact on performance but clock speed and capacity are far more important

a string of hyphenated numbers, such as 16-20-20-49. So, what does that all mean?

Well, the PC4-25600C16 numbering scheme can be broken down into three parts. The first part is simple, as it's just the type of memory. So, PC4 is DDR4, PC5 is DDR5 and so on.

The second long number is the speed in megabytes per second (MB/sec) of the memory, which in the case of DDR4 and DDR5 can be calculated either by taking the effective clock speed and multiplying it by eight, or taking the real clock speed and multiplying it by two to find the Mbps figure, then multiplying that by eight to find the MB/sec figure. So, for a 1600MHz clock speed memory module, its Mbps rating is 2 x 1600MHz = 3200Mbps, its MB/sec rating is 8 x 3200Mbps = 25,600MB/sec, ending up with it being labelled PC4-25600.

To dig into the MB/sec calculation further, this is derived from the fact that DDR4 has a data bus width – the number of simultaneous connections from the memory to the CPU – of 64 bits (DDR5 is effectively 64-bit too so the same 8x calculation works, but under the surface it's a bit more complicated). So, for each bit line of that bus, the memory interface can transfer at the stated Mbps rate of the memory – in our example that would be 3200Mbps. With our 64-bit interface, that gives us a total bitrate of 64 x 3200Mbps, or 204,800Mbps.

However, that number is unwieldy and most computer users are used to working in bytes, not bits, so we divide that bitrate by eight to get the byte rate. That would give us 204,800 divided by eight, which is 25,600MB/sec – you can see why it's easier to just multiply the clock speed by 16 or the DDR effective clock speed by eight.

The final piece of the PC4 puzzle is the C16 number (or equivalent) on the end, which refers to the column address strobe (CAS) latency (CL) of the memory. This is one of the commonly provided measures of the latency in clock cycles that it takes for a memory module to respond to a command. CL is also the first of the four hyphenated numbers you'll see on memory listings, with the other three being row address strobe (RAS) to CAS delay (tRCD), row precharge time (tRP) and row active time (rRAS).

THE REFRESH CYCLE CAN'T HAPPEN WHILE THE SYSTEM IS POWERED DOWN, SO THE CAPACITOR CHARGE LEAKS AWAY

These terms all refer back to the grid structure used to construct the RAM. Because the memory cells are accessed first by a row being activated, then the columns from that row being accessed, there are inherent delays associated with each step of this process. As such, CAS latency is the delay in data starting to arrive back from the memory after a read command has been sent, but only once the row for that set of columns has already been activated.

As for the other timing numbers, tRCD is the time between opening (activating) a row of memory and accessing the columns within it – so the total time to access a column on a non-active row is CL+ tRCD. Next up is tRP, which is the time required to precharge the current row (the process required to deactivate the current row) and open the next row. That gives us a formula for the total time to access data from DRAM when the wrong row is currently open to be CL+tRCD+tRP. Finally, we have tRAS, which is the minimum time needed to keep a row open to allow data to be read or written properly.

The lower these numbers, the lower the overall latency of the memory. However, it's the combination of lower memory timings and faster memory clock speed that ultimately determines performance, as those timings measure clock cycles. The faster the clock speed, the faster those cycles come around.

Infamously, latency timings have steadily increased with each generation of DDR, but their impact has been totally outweighed by the advances in clock speed. For instance, a CL18 3200MHz DDR4 module will have a latency of 18 x 2,000 / 3,200 = 11.3ns, whereas a 6400MHz DDR5 module with CL32 will have an effective latency of 32 x 2,000 / 6,400 = 10ns.

There's a final number you might see on some memory listings and in motherboard BIOS settings as well, which is the command rate. Generally, it will be either 1T or 2T and this refers to the number of clock cycles between a DRAM chip being selected and a command being executed. Using 1T is faster but 2T can be more stable.

Do memory timings matter?

Kicking off our performance tests, we can immediately nip the importance of memory latency settings in the bud, at least for memory coupled with Intel 12th-gen processors. While at times in the past, memory timings have been more important for faster performance, our tests showed a very modest difference in speed.

Using an Intel Core i5-12600K coupled with 32GB of Kingston Fury Renegade 6400MHz (effective) memory and a GTX 1060 graphics card, we recorded just a 0.5fps increase in the minimum frame rate and a 0.1fps rise in average frame rate in the Cyberpunk 2077 benchmark, when going from timings of 32-38-38-80 to 42-50-50-80. Given the large difference in those timings and the microscopic difference in frame rate, it's clear that if your graphics card is your bottleneck for gaming, latency timings don't matter.

For application performance, we saw a slightly more tangible difference in our RealBench tests, with an average 5 per cent performance increase with the tighter timings across the tests. The situation will be slightly different with AMD AM4 processors and upcoming AMD AM5 processors but we kept our testing to Intel processors for this feature for the sake of brevity.

What difference does frequency make?

While memory timings might have a subtle effect on system performance, the impact of memory clock speed is more noticeable. With DDR4 and DDR5 memory clock speeds covering a wide range, one would certainly expect a 6400MHz module to outperform a 2133MHz module, for instance, and sure enough, our tests bore this out.

Using the same setup as before, we underclocked our DDR5 kit to 3200MHz (effective) then 4800MHz and compared this with the performance at the kit's default 6400MHz speed. Across the board we saw notable performance differences, most visible in our heavy multi-tasking workload where we saw the default 6400MHz speed memory knock over ten seconds off the 3200MHz result – a 32 per cent difference.

In single-threaded workloads, the difference wasn't quite so dramatic but even in games we saw our Cyberpunk 2077 average frame rate rise from 38.6fps to 39.2fps while the minimum result rose from 26.7fps to 27.4fps.

Overall, though, both the tiny difference in system performance when varying memory timings, and the more noticeable but still relatively small differences when varying memory clock speed, speak to the particular role of memory in PC performance. When all is said and done, memory doesn't provide the processing speed that makes a PC run fast – it just ensures the processors aren't starved of data on which to work.

DDR5 has a different pinout than DDR4, along with a different notch in the middle, so the two types can't be fitted to the wrong motherboards

As such, memory speed comes down to ensuring it's fast enough not to be holding back performance, but any faster than that is entirely wasted. In games, the bottleneck will nearly always be your graphics card, long before memory speed makes a meaningful impact. Meanwhile, for more CPU-intensive tasks such as video encoding, the CPU is still by far the biggest factor.

There are caveats to these general rules, and the exact difference will depend on your choice of CPU and overall system setup, but that's the broad rule of thumb.

What's the difference between DDR4 and DDR5?

DDR5 is the latest memory standard to arrive, and it brings with it a host of changes over DDR4, including reduced power consumption and increased bandwidth. Currently, it's only

Memory frequency

Cyberpunk 2077		
	Minimum	Average
3200MHz	26.7fps	38.6fps
4800MHz	27.3fps	38.9fps
6400MHz	27.4fps	39.2fps

RealBench			
	Image editing time	Video encoding time	Heavy multi-tasking time
3200MHz	167.9 seconds	46.8 seconds	48.9 seconds
4800MHz	165.5 seconds	46.2 seconds	40.5 seconds
6400MHz	162.5 seconds	45.7 seconds	37 seconds

Too slow a memory clock speed can hold back system performance, but only if your CPU and GPU aren't already the bottleneck

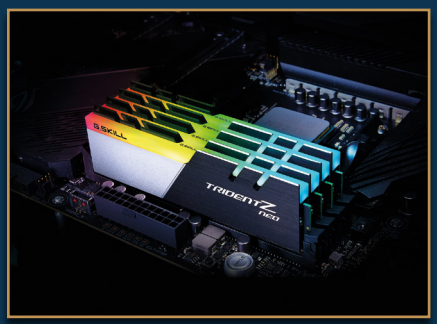
XMP 3 provides one extra vendor-defined XMP profile and two user programmable profiles

supported by Intel 12th-gen platforms, but it's set to be used with AMD's upcoming Zen 4 processors and motherboards that are arriving later this year.

Chief among the advantages of DDR5 is an increase in frequency and overall bandwidth. Where DDR4 runs with a base clock speed of generally 800-2133MHz, DDR5 clocks at 2400-3200MHz. As such, you can regularly find DDR5 memory modules listed as running at 5600MHz or 6400MHz, again due to the megatransfers/MHz DDR confusion.

Also new to DDR5 is a drop in operating voltage from 1.2V to 1.1V. That may not sound like much of a drop but every little counts at this level. Moreover, DDR5 is the first version of DDR memory to introduce an on-board power management IC (PMIC), rather than rely on the motherboard's power delivery. This allows for a wide array of more granular control of power delivery.

Another big change with DDR5 is the overall potential capacity of each DIMM. With DDR4, the upper limit is 64GB per DIMM, but DDR5 stretches this to 512GB. In practical terms, this isn't much of a meaningful

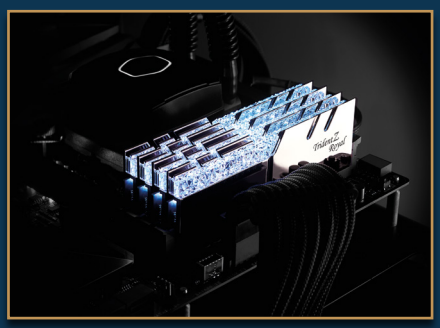


upgrade for the majority of PC users, as 64GB total system memory is well beyond what most people need, let alone 64GB per DIMM. Nonetheless, DDR5 opens up the potential for having systems with vast amounts of memory without the need for dozens of memory slots.

More of a subtle change comes in the form of a new channel architecture. Whereas DDR4 uses a single 72-bit bus consisting of 64 data bits and eight error correction code (ECC) bits, with DDR5 each DIMM has two channels, each of which is 40 bits wide, with 32 bits for data and eight for ECC. This means that while the total data channel width is the same, DDR5 can be accessed more efficiently thanks to the two channels working independently.

The final major change to DDR5 is a doubling of the burst length from eight columns to 16. What does that mean? Well, it again refers back to the grid structure of memory. Essentially, a burst takes advantage of the fact that accessing a row is a process that takes some time (not a lot, but some).

As such, while any given row is activated you might as well read several columns from that row at once, rather than wait for the next full memory address to arrive and tell you to reactivate the same row just to read the very next column. A burst, then, defines how many columns are read in one row access. The



doubling in burst length means that, while the data bus width of DDR5 is effectively halved, it can maintain the same total amount of data to be transferred in a burst on each halved data bus.

What is XMP 3?

A new feature that isn't strictly part of the DDR5 standard, but that is being introduced alongside it, is XMP 3. XMP, or eXtreme Memory Profile, is an Intel-derived technology for specifying the clock speeds and timings of memory. With the existing XMP 2 specification, manufacturers can define up to two configurations for a memory module that can be used to instantly overclock the memory, generally to the speeds and timing specified on the packaging.

THERE WAS ALMOST NO GAIN IN OUR CYBERPUNK 2077 TEST, WHICH IS A TREND WE'VE SEEN IN PREVIOUS DDR4 AND DDR5 COMPARISONS

With XMP 3, Intel is adding a third manufacturer-specified profile, as well as providing the option for users to program and name their own profiles. So, if you find your system doesn't play well with any of the manufacturer XMP profiles (perhaps because those profiles were optimised for an Intel system and you're running an AMD processor), you'll now be able to manually overclock the RAM to find some settings that work, then store those settings ready to be called upon again in case your system resets and loses your settings.

Another advantage of XMP 3 is that it will inherently allow manufacturers to better accommodate a wider range of systems, so that the likelihood of having compatibility issues with AMD or Intel systems will be reduced right out of the box. Because Intel

is still so dominant across the industry, and XMP is its baby, existing profiles tend to favour its platform but XMP 3 will allow more scope for manufacturers to pre-program an AMD-optimised setting.

Is DDR5 faster?

Getting to the really meaty questions when it comes to DDR5, what we all really care about is whether it's actually faster than DDR4, and moreover whether it's worth buying.

To answer the former question, the data is clear: it is faster. Not by much in real-world usage for most standard desktop applications and games, but we're starting to see small bumps, especially as we're now getting legitimately fast DDR5 kits.

When DDR5 first arrived, the only kits available ran at 5600MHz or slower, which although certainly faster than most DDR4, wasn't that much quicker than the fastest DDR4 modules (up to 4266MHz).

However, 6400MHz DDR5 kits are now readily available, and our tests show that the extra bandwidth of such speedy RAM provides a performance uplift across the board. On average, our test system when running DDR4 3200MHz was 5 per cent slower than when combined with 6400MHz DDR5 in our RealBench application tests.

However, there was almost no gain in our Cyberpunk 2077 gaming test, which is a trend we've generally seen borne out in previous comparisons of DDR4 and DDR5. The memory performance is there, but games aren't really tapping into it.

As to the question of whether it's worth buying DDR5 yet, just a few months ago the situation was tipped more in favour of sticking with DDR4, as prices for DDR5 were so high and availability so low, all while performance differences were marginal, so it made very little sense for the average buyer. However, with AMD's Zen 4 arriving just around the corner, faster DDR5 kits becoming available and prices dropping a little, the scales are tipping towards it being worth going for DDR5.

It's imperative that you run two memory sticks rather than one in order to get optimal performance from your memory

However, while DDR5 is the best option for the future, you're still paying a premium right now. The cheapest 16GB (2 x 8GB) DDR5 kit we could find runs at only 4800MHz and costs £80 inc VAT. Meanwhile, you can get 16GB (2 x 8GB) 3200MHz DDR4 kits for £50 inc VAT. Move up to a 5200MHz DDR5 kit and you're hitting £115 inc VAT and that sort of price premium continues as you increase in capacity and rated speed.

Again, DDR5 is generally going to be faster but the real-world advantage is small. All told, it will be well worth totting up the total system cost for a DDR5 motherboard and RAM vs an older DDR4-based system. Just be aware that there will be limited future upgrades going down the DDR4 route.

How many sticks should you use?

Whether you opt for DDR4 or DDR5, one universal consideration is how many sticks of RAM you need to buy. The convention of opting for two memory sticks is well established, but why is that, and is there any disadvantage from having four sticks instead of two?

Well, the reason for generally using two or more sticks of RAM is that most CPUs support two memory channels – one for

DDR4 vs DDR5

Cyberpunk 2077		
	Minimum	Average
DDR4 3200MHz	27.4fps	38.9fps
DDR5 6400MHz	27.5fps	39.2fps

RealBench			
	Image editing time	Video encoding time	Heavy multi-tasking time
DDR4 3200MHz	164.6 seconds	48.9 seconds	39.3 seconds
DDR5 6400MHz	162.9 seconds	45.7 seconds	36.9 seconds

The faster clock speeds of DDR5 do provide a performance boost over DDR4, but it's not a huge uplift

Memory channels

Cyberpunk 2077		
	Minimum	Average
1 x 8GB	24.7fps	37.4fps
2 x 4GB	26.2fps	38.9fps
2 x 8GB	27.5fps	38.9fps

RealBench			
	Image editing time	Video encoding time	Heavy multi-tasking time
1 x 8GB	166 seconds	49.3 seconds	39.7 seconds
2 x 4GB	164.6 seconds	48.9 seconds	39.3 seconds
2 x 8GB	162.3 seconds	48.7 seconds	39.1 seconds

Using just one DIMM impacts performance compared with using two DIMMs, but not by a huge amount unless you're using an integrated GPU

each stick – and some CPUs even support quad-channel memory. The extra channels add a second, third and fourth pathway for data, increasing the theoretical bandwidth. As such, it's imperative that you run two memory sticks rather than one for optimal performance. That said, the difference isn't always that huge.

We saw a drop of just over 2 per cent in our image editing benchmark when comparing a single 8GB stick of 3200MHz DDR4 memory to a pair of 4GB sticks, though our other application tests weren't as conclusive.

In Cyberpunk 2077 we saw a drop of 1.5fps on average, which amounts to a 4 per cent drop. However, the minimum result dropped considerably to 24.7fps, hinting at the bandwidth limitation of running just one DIMM.

Aside from this test, we've also seen dramatic performance differences on AMD's APUs if you only use one stick of memory with the integrated graphics, rather than two. When your GPU is relying on system memory, it needs to have as much bandwidth as possible.

When it comes to running four memory sticks instead of two, the situation is less clear. For a start, true quad-channel memory support is limited to high-end desktop platforms, such as Threadripper, rather than the conventional desktop CPUs most of us buy. As such, aside from RGB aesthetics, buying four memory sticks is entirely pointless for most of us. Moreover, it can actually harm performance as the two extra DIMMs add more noise to the PCB, potentially limiting the peak frequency at which you can run.

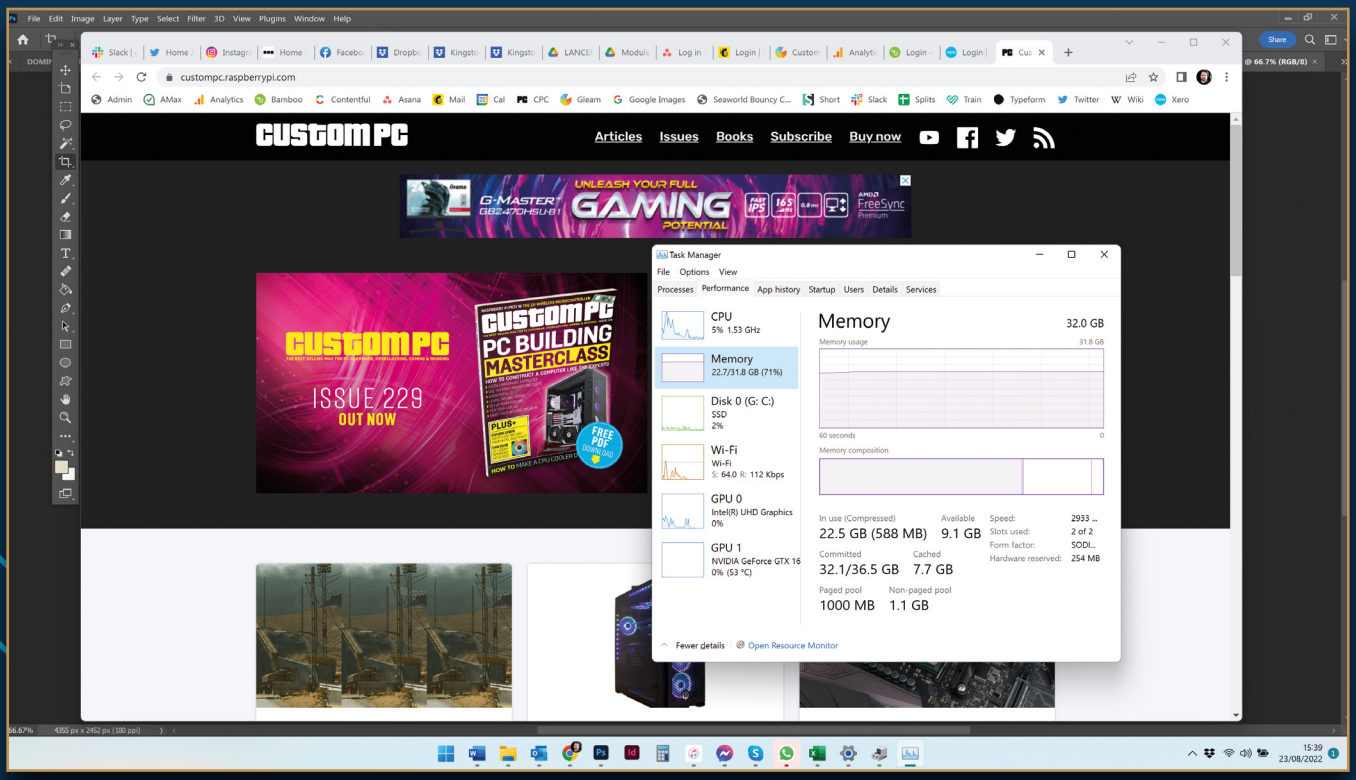
How much memory do you need?

The industry has settled on 16GB being enough memory for most users, with lots of budget systems opting for 8GB – and often it will be a single stick of 8GB, actively harming performance. But is there much to be gained from stepping up to 32GB and beyond?

Well, for a start, when it comes to DDR5, 8GB isn't an option, at least for a dual-channel kit. The minimum-size single DIMM you can buy is 8GB so, while you could run a single DIMM setup, it wouldn't be optimal.

Besides, there's good reason why 16GB has become the norm. With the size of modern games, demand of 4K video and the propensity for many-tabbed web browsers to consume several gigabytes of memory alone, even just a modest workload can fill 8GB of RAM. For example, as I write this sentence, my Firefox browser with its 61 active tabs is taking up 5.5GB all on its own while total system memory usage with Outlook, Skype, Excel and Word opened is 13.7GB.

To further demonstrate the point, we set up a Windows 10 test system with an 8GB memory kit running Chrome with just ten tabs open, along with Cyberpunk 2077 running,



With 17 Chrome tabs open, nine images in Photoshop, and a few other office apps and messengers, our system was already using well over 16GB of memory

and total system memory usage was 7.1GB with some page file use already evident (more on which later). Switching out the 8GB kit for a 16GB kit with the same workload showed the memory usage jumping up to 8.1GB with no page file use, clearly showing that 8GB is already a limitation, even with such a relatively modest workload, with Windows having to divert some memory capacity to virtual memory on your SSD or hard drive.

We used this setup for some test runs, and there was a 1.5fps difference between the 8GB and 16GB setups in Cyberpunk 2077. The need to access virtual memory causes dips in overall system responsiveness, which mean games can be choked for data and end up with dropped frames.

This difference wasn't reflected in our application tests, though, as their much smaller memory footprint means it's much easier for the system to allocate sufficient memory to keep performance ticking over. These benchmarks don't tell you the whole story when it comes to responsiveness and flicking between applications, though, and the 8GB system generally felt much more sluggish in general use than the 16GB setup.

There was no difference between the 16GB and 32GB setups at all in our individual benchmarks, but that's not surprising for the same reasons above. Unless your system is filling that memory, the performance isn't going to change with extra capacity. That said, it certainly doesn't take all that much to start hitting the limitations of 16GB and starting to see drops in performance.

On our test setup, we opened Outlook (with a hefty 10GB OST file), Microsoft Word with a long document, 50 further tabs in Firefox and several other ancillary programs and, once we opened a memory-hungry AAA game, we surpassed that 16GB usage. It's at the upper end of how a general home user would use their PC, but it's not unreasonable.

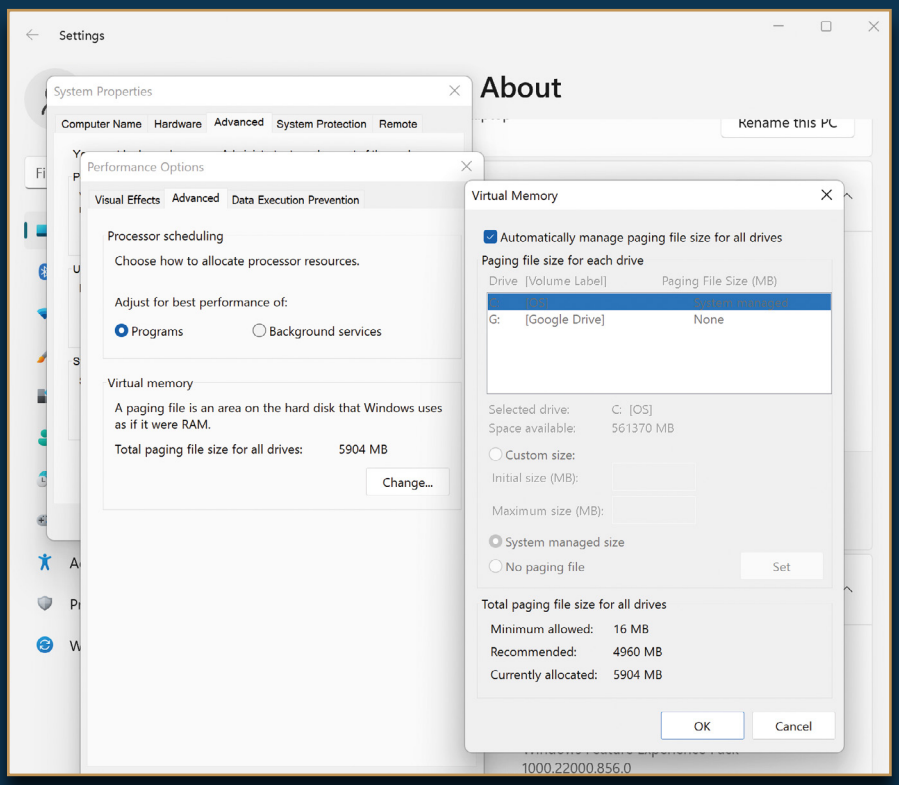
Again, the impact of hitting the 16GB limit is most obvious in Cyberpunk 2077, where occasional stutters and drops to a low frame rate are clear. Switching to 32GB, though, alleviated these issues.

As to going beyond 32GB, that's where most home users would ever struggle to meaningfully push the limits of memory usage. Generally, most AAA games sit at 2-8GB of memory usage, and while browser memory usage can continue to grow with ever more tabs, you have to be actively using them all for them to remain memory hogs, as otherwise they'll go into an idle mode and release some memory.

UNLESS YOUR SYSTEM IS FILLING THAT MEMORY, THE PERFORMANCE ISN'T GOING TO IMPROVE IF YOU ADD EXTRA CAPACITY

One example of a workload that will push memory usage even further is video editing, with even a basic Adobe Premiere pro 4K video project easily using 2-5GB. There are also scientific workloads and CAD operations that will use vast amounts of memory, as well as running lots of complex virtual machines simultaneously.

However, once you're in the area of finding professional workloads being held back by a lack of memory, you're beyond the scope of most home user considerations. If you're



It's possible to remove your page file and just use system memory, if you have enough of it, but these days it's better to just let Windows do its job

a gamer who also uses their PC for web browsing and photo editing, 16GB will cover your needs fine. If you're a heavy multi-tasker who has many active browser tabs open, as well as video editing software and games, perhaps for streaming, then it's worth considering 32GB.

What is virtual memory?

Virtual memory is any storage medium that's used by your system to temporarily store data from real memory. It's used as an overflow buffer for when too many programs are trying to run at once, so there's not enough real system memory. Also called a page file, traditionally this storage location would have been your hard drive, which is why it was so imperative in the old days to have plenty of memory for your needs, as otherwise your system would be relying on the deathly slow access times of a hard drive to deliver data to your CPU.

With the arrival of SSDs, the absolute need to ensure your system isn't relying too much on virtual memory is less severe, as even old SATA SSDs are fast enough for many applications to still feel at least usable when they're being loaded and processed from virtual memory. Meanwhile, with the latest ultra-fast NVMe SSDs, it's even less imperative. Nonetheless, there are two reasons why you'll still want to ensure your system isn't constantly relying on masses of virtual memory.

The first is that having your system regularly write and then delete a load of data to your SSDs will reduce the life of the SSD. Even with the lengthy SSD write endurance ratings of today's SSDs, if gigabytes of data are being written and erased every day, their lifespan will be noticeably impacted. The other factor is overall system speed. While SSDs are fast, they're still nowhere near DRAM speeds, and while for many programs that speed won't be necessary to maintain a snappy-feeling system, for optimal performance you'll want to make sure most tasks are kept on system memory.

For many years, some users have sworn by manually controlling the size of the Windows virtual memory size (go to System Properties / Advanced / Performance to find it) or even disabling it, so as not to have Windows overly rely on using the page file and instead force it to use DRAM at all times – a state that's technically possible with enough system memory.

However, many apps will refuse to work without some sort of page file being set up and outright system crashes can occur if your manually specified page file isn't large enough. As such, it's generally best to leave Windows to manage your page file size – it does a perfectly good job these days.

The only setting you might want to change about your default Windows page file is its location. On some systems you might benefit from specifying a particular drive to use for the page file – perhaps a small but fast spare SSD – rather than using the default same drive as your Windows installation. The logic is the same as using a scratch disk in video editing software – having a dedicated drive frees up access speed to your other drives.

Do RAM heatsinks matter?

The story goes that one of the great cons of modern computing is that the big heatsinks you see slapped on the sides of premium

memory modules aren't doing anything useful at all, as DDR4 memory (and DDR3 before it) runs cool enough that heatsinks don't make the blind bit of difference. And, while the truth is a little more nuanced than that, broadly that is the case.

Removing the heatsinks from typical high-end DDR4 memory modules can cause a degree or two of temperature increase, and temperatures will rise faster when the system is under load. Plus, any form of heatsink – as long as it's actually thermally conductive and not just a bit of metal stick on with non-thermally conductive sticky pads – will help to dissipate any heat from hotspots on some chips.

However, RAM performance isn't affected by temperature in the way that a CPU or GPU is impacted, where the clock speed will be lowered if temperatures get too high, so you don't get any performance loss from a few extra degrees here or there. Instead, RAM is either stable or not.

As long as you're below the threshold where RAM becomes unstable – the DDR4 rated maximum temperature is 80°C, but for overclocked memory, it's generally considered that any temperature over 60°C is likely to cause issues – then your RAM is good to go. In our tests, our G.Skill TridentZ 3200MHz kit hit as high as 33.5°C under load in an open-air test bed with no extra airflow, which is barely above ambient room temperature, and so low that a couple of extra degrees would make no difference.

YOU DON'T GET ANY PERFORMANCE LOSS FROM A FEW EXTRA DEGREES HERE OR THERE – MEMORY IS EITHER STABLE OR NOT

Obviously, heat can build up in a system thanks to other hot components, which can push memory to more problematic temperatures, but most memory heatsinks aren't designed to help a great deal in this instance. Indeed, the bulky nature of many of them can lead to highly restricted airflow around the modules, making the situation worse.

Memory heatsinks come in all sorts of shapes and styles but often they're not doing all that much for cooling

So, when it comes to DDR4, you can happily choose whatever module you like the look of best – or that meets your other performance requirements – and largely ignore any heatsink performance concerns, other than making sure the heatsink isn't so large as to interfere with your other components.

However, with DDR5, the faster clock speeds and addition of the PMIC results in higher overall DIMM temperatures, despite a drop in the RAM operating voltage. Using our open-air test bed again, we measured the temperature readout of the serial presence detect (SPD) hub chip, which sits just above the voltage regulator on our 6400MHz Fury Renegade DDR5 modules, when it was idle and under load.

At idle, it steadily ramped up from 29°C at boot to 34°C on the desktop then, after just a couple of benchmark runs, it hit a maximum of 63.8°C. The SPD hub isn't measuring the actual memory chip temperature, so there's a bit of headroom there, but the whole DIMM was noticeably hotter to the touch than any DDR4 module.

However, again the actual merits of some heatsinks is debatable, particularly if you're running four DIMMs or using a mini-ITX board where the two DIMM slots sit right next to each other. Chunky heatsinks can restrict airflow and simply getting slightly cooler air flowing over the DIMMs is a higher priority than using heatsinks. Adding a fan blowing air across the DIMMs in our test bed saw temperatures drop by 20°C. In short, memory cooling is a concern for DDR5 memory, but better system airflow is likely to net you better results than a chunkier heatsink. CPC

GAME PASS

THE FUTURE OF PC GAMING?

RICK LANE INVESTIGATES THE GROWING PHENOMENON OF MICROSOFT'S GAMING SUBSCRIPTION SERVICE

Microsoft's relationship with PC gaming over the past couple of decades has been turbulent. Windows has been the default base platform for PC gaming since the late 1990s, offering both the broadest support for PC games and the easiest way to access them.

In the late 2000s, though, Microsoft seriously damaged its reputation with PC gamers through Games For Windows Live, an intrusive and obnoxious DRM platform that treated the PC as an offshoot of the Xbox. Since then, Microsoft has struggled to grapple with PC gaming, with its Microsoft Store struggling to compete with the likes of Steam and the Epic Store.

PC Game Pass could change that. A Netflix-style subscription service, it provides access to all of Microsoft's contemporary first-party games, plus a wide range of third-party titles, for £7.99 a month. This includes day-one access to all of Microsoft's new releases, which includes some major titles coming in the next year. At a time when new PC games can cost up to £70, on the face of it, Game Pass seems like an attractive proposition.

But Game Pass is more than just a simple library of games. It represents Microsoft's entire strategy for both the PC and gaming as a whole for the foreseeable future. Hence, it's worth examining what exactly Microsoft is offering potential subscribers, and what its new platform means for the future of games, the players paying for them and the developers creating them.

GAME PASS: THE REVIEW

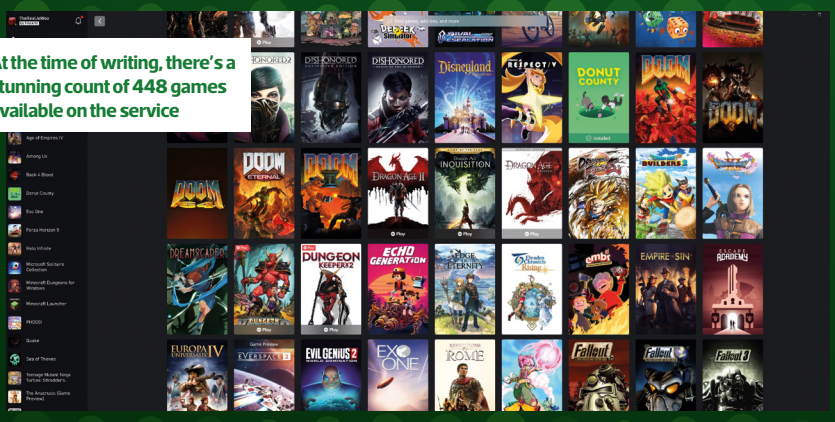
PC Game Pass is only a part of Microsoft's broader Game Pass service, which has numerous features catering to various devices. Microsoft divides this into three subscription types. A standard PC Game Pass subscription costs £7.99 per month, which unlocks access to Game Pass' entire PC game library. At the time of writing, this totals 448 games, including major Microsoft exclusives such as Halo Infinite and Forza Horizon 5.

Game Pass also features many games from Microsoft subsidiaries such as Bethesda, including Doom Eternal, the Fallout series and the Elder Scrolls series. Beyond this, Game Pass offers a wide range of third-party titles from publishers such as Ubisoft and Sega, including titles in the Assassin's Creed and Far Cry line-ups, several Total War games and the entire Yakuza franchise.

Finally, a PC Game Pass subscription also provides access to EA Play, letting you play many titles published by Electronic Arts, including Dead Space, the Mass Effect series, Dragon Age and the most recent FIFA games.

For just shy of eight quid a month, it's an impressive library of games to play, although not all these games will be available on Game Pass permanently. Any games owned directly or indirectly by Microsoft will probably stay on the service in perpetuity, but most third-party Game Pass titles will have a limited shelf life, just as films appear and disappear from services such as Netflix all the time. The upside of this is that Game Pass regularly cycles new games to play into the mix. Indeed, in the time between drafting this feature and editing it, three new games were added to the service.

A major thrust of Microsoft's marketing for Game Pass is 'Day One' access to games,



At the time of writing, there's a stunning count of 448 games available on the service

meaning you can play many brand-new games on Game Pass from the moment they're officially released. All of Microsoft's in-house published games are 'Day One' Game Pass launches (see overleaf for examples), but a surprising number of third-party titles have also seen Day One launches on the service. Examples from this year include Rebellion's Sniper Elite 5, Ubisoft's Rainbow Six: Extraction, and Sega's Total War: Warhammer 3. If purchased individually at launch, these three games alone would cost £150.

The basic subscription nets users access to all of the above, but Game Pass also offers a separate subscription at the same price for access to Xbox Library. On top of that, it also offers a higher-tier subscription called 'Xbox Game Pass Ultimate'. For £10.99 per month, Ultimate gives subscribers access to both the PC and Xbox game libraries, plus access to Microsoft's 'XCloud' cloud gaming service. XCloud enables you to stream games on various devices, such as your PC, Android phones and certain Samsung TVs.

The most important feature of XCloud for PC gamers, however, is that it lets you play some of the more stubborn Xbox console exclusives on PC. These include Fable 2, Gears of War 2 and 3, and Halo 5, none of which was ever graced with an official PC port.

As game streaming services go, XCloud is impressive. Testing Gears of War 2 on PC, the game was highly responsive and, while the picture quality isn't as good as the quality that an official PC port would probably deliver, it looks as sharp and detailed as you can reasonably expect for a 2008 Xbox game. XCloud also works surprisingly well on a years-old Android phone, although controlling games on your phone requires you to choose between connecting a compatible controller, or putting up with the clutter of touch controls on the screen.

Beyond that, the only real problem with XCloud is that it can be a gamble whether the game initially connects. Once it's connected, however, streaming appears stable on a home Wi-Fi connection.

Regarding issues with Game Pass more broadly, most problems revolve around the menu and interface. Like most online entertainment services, the UI is carousel-heavy, frontloading your game options with various categories, starting with featured games, then moving onto recently added games, upcoming games and so on.

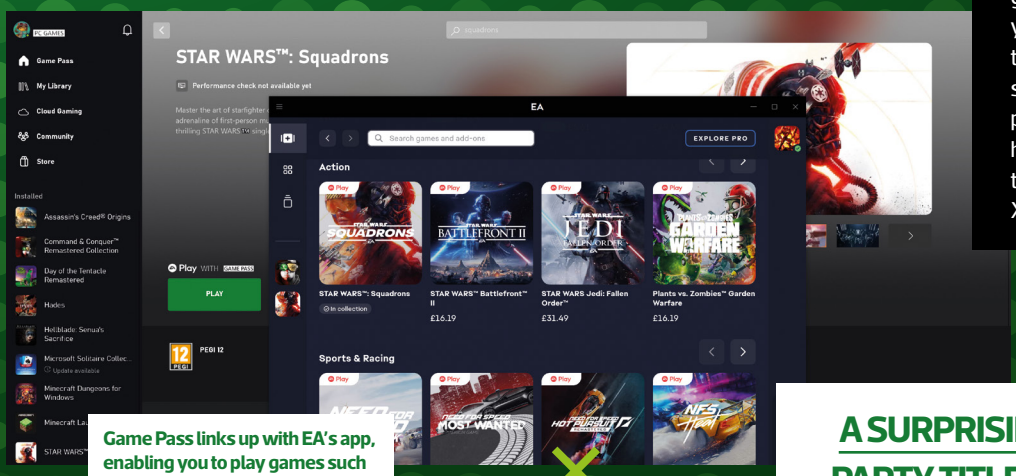
It's structured fairly logically, but it can also be a little overwhelming at first glance. Thankfully, there's a menu option on the front page that takes you to a straightforward list of all available games in alphabetical order, giving you an easy overview of every game on the platform.

A bigger problem than layout is performance. The actual Game Pass software can be clunky to use, especially compared with other services such as Steam. It takes a while to initially load, it's slower to respond to mouse clicks than Valve's platform, and has a tendency to hang if you click through it too quickly.

Another annoyance relates to how Game Pass ties into your overarching Microsoft account. Every time you launch a game, Game Pass interrupts the experience at the start menu, bringing up a separate box to sign into your Xbox Live account. It's an irritatingly intrusive hangover from the days of Games for Windows Live, and demonstrates Microsoft is still grappling with the consequences of its bungled unification of its PC and Xbox services over a decade ago.

There are also many secondary features that Game Pass simply doesn't offer compared to Steam, such as a simple, intuitive screenshot function, community features such as game-specific user discussions and, perhaps most importantly, an equivalent of Steam Workshop. Game Pass does allow for mods to be installed on Game Pass games, but it doesn't have the same integrated, at-a-glance support for additional game content that Steam provides.

As a piece of software built for the PC, Game Pass lacks the features that 18 years of constant support have added to Steam. In terms of basic value, however, Game Pass is undeniably worth the basic subscription of £7.99. Even if you only played the exclusive games made by Microsoft and its subsidiaries, you would probably save money over the course of the year. As for the Ultimate subscription, that's more dependent on your personal circumstances, whether you also have an Xbox Series S or X, or like to game on the go, or if you have a particular fondness for Xbox 360 games.



Game Pass links up with EA's app, enabling you to play games such as Star Wars: Squadrons under the subscription, although there's a lot of faffing with logins required

A SURPRISING NUMBER OF THIRD-PARTY TITLES HAVE ALSO SEEN DAY ONE LAUNCHES ON THE SERVICE

GAME PASS *THE NEXT YEAR*

Game Pass already offers an alluring collection of games, but the service is still far from reaching full maturation. Here's a rundown of the biggest games coming to Microsoft's service in the next year, all of which will be available to play from day one of launch.

A PLAGUE TALE: REQUIEM

DEVELOPER Asobo Studio / **RELEASE** October 2022

A Plague Tale: Innocence was a sleeper hit of 2019. Putting you in the shoes of a 14th-century French noble's daughter named Amicia, the Uncharted style action-adventure saw Amicia and her brother Hugo embark upon a dangerous journey across war-torn Medieval France, hunted by soldiers and stalked by a relentless, hostile swarm of rats.

With stunning visuals and a touching story of companionship in the face of adversity, the original game fell just short of greatness due to some slightly underwhelming stealth mechanics, and a final act that strayed too far into schlock.

The sequel seeks to rectify those mistakes. Requiem transports Amicia and Hugo beyond their native France, as they search for a mysterious island in the Mediterranean. Now older and having learned from her experiences in the first game, Amicia is more capable of dealing with the menacing soldiers that prowl the game world.

She can dispatch them quickly with silent melee takedowns, and use a crossbow to kill enemies from a distance. Meanwhile, Hugo has developed his own unique connection with the rats that prowl the game world, and can use it in a variety of ways, such as helping Amicia to identify enemy locations. If A Plague Tale: Requiem can combine its more elaborate stealth with a story that keeps its feet firmly on the ground, it could be a winner when it launches this October.

IT NEEDS TO COMBINE ITS ELABORATE STEALTH WITH A STORY THAT KEEPS ITS FEET FIRMLY ON THE GROUND

REDFALL

DEVELOPER Arkane Studios / **RELEASE** Q2 2023

The latest game from Arkane Studios, creator of Dishonored and Deathloop, Redfall is a large-scale multiplayer shooter where players team up to liberate their hometown from a clan of powerful vampires. An incident at a mysterious facility in Redfall, Massachusetts has led to an outbreak of vampirism in the town, and those pesky bloodsuckers have blocked out the sun, cut off the town from the rest of the world, and enthralled large portions of the town's populace to do their bidding.

Redfall is a major departure for Arkane Studios, previously known for its dedicated single-player immersive sims. It's the studio's first open-world game, letting players freely explore the abandoned town, moving seamlessly between objectives, and searching inside buildings and other locations for clues to illuminate exactly what happened.

Moreover, Redfall is designed to be a drop-in, drop-out multiplayer experience. Played single-player, it's intended to feel much like Arkane's previous games, using stealth, combat and supernatural abilities to eliminate your foes. But you can also join forces with up to three other players, combining each of the four playable characters' unique abilities for a faster-paced, more knockabout experience.

Nobody has made a cooperative multiplayer immersive sim before, especially not one with an open world. It's a lot for Arkane to pull off, but if the studio can do it, Redfall will be one of the highlights of 2023.

STARFIELD

DEVELOPER Bethesda Softworks / **RELEASE** Q2 2023

The most anticipated game in active development, Starfield is Bethesda's first single-player RPG in eight years, and the first that hasn't been a Fallout or Elder Scrolls game in a quarter of a century. It's a sci-fi adventure that puts you in the role of an interstellar explorer who belongs to a pioneering organisation known as Constellation.

While thematically different from Bethesda's previous games, it follows in the spirit of those earlier RPGs. A highly freeform experience, Starfield will allow players to explore various planetary bodies and interact with different guilds and organisations. You'll be able to fight, talk and sneak your way through quests and objectives, and gradually build the legend of your character.

But there are some key differences. For starters, Starfield plays on a much bigger canvas than previous Bethesda RPG, with over 1,000 explorable planets in its simulated galaxy. The detail of those individual planets is yet to be confirmed, but it's nonetheless a tantalising canvas given the studio's penchant for delivering grand adventures.

Moreover, Starfield features both terrestrial and space exploration, letting you walk around planets on foot, and fly between them with your ship. These spaceships are as customisable as your character, letting you pick different modules and equipment from a variety of manufacturers. You can even choose from different crew members to help run your ship, which has an exciting whiff of Star Trek about it.

There are some concerns. The game's combat looks generic, and Bethesda also confirmed that players can't land seamlessly on planets from space, which is disappointing. However, it would be a mistake to underestimate Bethesda's ability to deliver vast and impressively flexible game worlds.

DIABLO IV

DEVELOPER Blizzard Entertainment / **RELEASE** 2023

It's been over a decade since the last full Diablo game was released, in which time ARPGs such as Path of Exile and Lost Ark have taken the genre into ambitious new directions. It will take a special game for the grizzled king of clicking to reclaim its crown, but Diablo IV certainly looks like it's planning to take its best shot.

The biggest change over previous Diablo games is that Diablo IV will take place in a completely open world. The game's five regions, which range from frost-covered mountains to the infernal fires of Hell itself, can be completed in any order, with a non-linear story that will adapt to the player's chosen path. It's also set to be tonally more in keeping with the first two games, ditching the third game's more cartoonish aesthetic in favour of a grimmer, more realistic style.

In addition, while Diablo IV can be played in single-player mode, it's also designed to accommodate multiplayer parties, and will take place in a persistently online world. This raises some questions about the game's proposed business model, especially considering the predatory free-to-play mechanics at play in the recently released Diablo Immortal. Blizzard claims that microtransactions will be restricted to cosmetic items, and that mechanics such as trading between players will be limited to basic resources. Moreover, one of Diablo III's most controversial features – the auction house – will not appear in Diablo IV.

It sounds promising. The question is whether Diablo IV can do enough to beat the rivals that have appeared in the interceding decade. Path of Exile has one of the best character progression systems of any game, while Lost Ark's combat set a new standard for ARPG spectacle when it launched earlier this year. Make no mistake, Diablo has to do some catching up.

THE BIGGEST CHANGE IS THAT THIS TIME DIABLO IV WILL TAKE PLACE IN A COMPLETELY OPEN WORLD

STALKER 2: HEART OF CHORNOBYL

DEVELOPER GSC Game World / **RELEASE** 2023

The Stalker series of survival shooters always felt slightly ahead of its time, struggling to compact their grand ambitions into the rendering technology of the mid-2000s. The original Stalker games were open-world shooters without a true open world, survival experiences that had to compromise on many of their planned systems.

Stalker 2: Heart of Chornobyl aims to be the game that Ukrainian developer GSC Game World always wanted to make. For the first time, the open world that sees players exploring Chornobyl's Exclusion Zone will be completely seamless. It's also shaping to be utterly stunning, as the sequel is developed in Unreal Engine 5 using cutting-edge photogrammetric scanning technologies.

The game itself is shaping up to be a slicker and more refined version of those previous entries in the series, with players exploring the Zone, avoiding dangerous anomalies and doing battle with mutants and rival Stalkers.

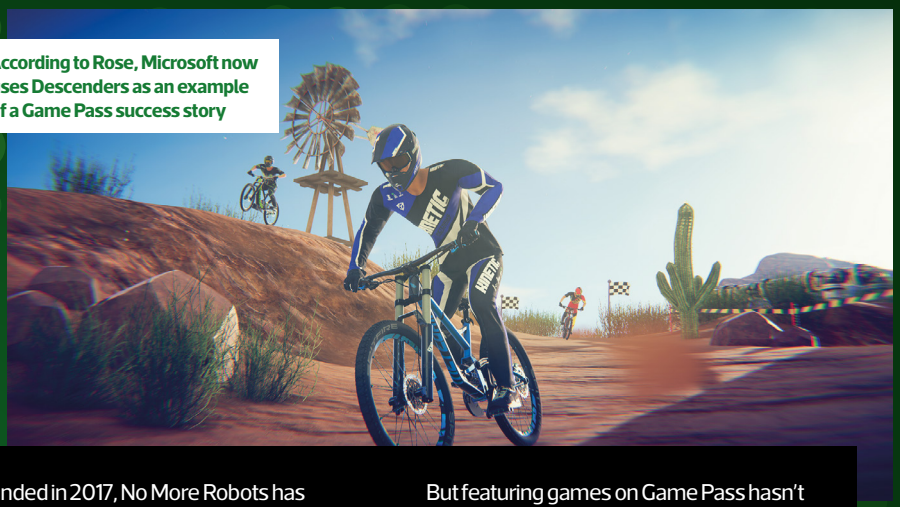
The sequel will feature many of the mechanics that were cut from 2006's Shadow of Chernobyl, such as simulated hunger and fatigue, alongside advanced versions of existing mechanics, including a new iteration of A-life, Stalker's rich simulation of its mutant wildlife behaviours.

Stalker 2 was originally slated for launch this year, but was forcibly delayed due to the Russian invasion of Ukraine. As a consequence, GSC Game World was forced to abandon its offices in Kyiv and transfer its entire operation to the Czech Republic.

The latest reports about Heart of Chornobyl suggest the game is back on track development-wise, and is now slated for a release late next year.

GAME PASS *DEV PERSPECTIVE*

MIKE ROSE OF NO MORE ROBOTS DISCUSSES WHAT GAME PASS MEANS FOR DEVELOPERS AND PUBLISHERS



According to Rose, Microsoft now uses Descenders as an example of a Game Pass success story

In its current form, Game Pass offers a compelling deal for gamers, letting them play a large library of games (many of which are brand-new) for a relatively low monthly fee. But what does this mean for the people who make and sell those games? How do games end up on Game Pass in the first place, and how does a game on the service affect a developer's bottom line? Moreover, as Game Pass grows, what does the shift from game sales to Game Pass subscriptions mean for developers and the industry as a whole?

'The majority of our games have broken even before launch day, because of Game Pass,' says Mike Rose, founder and director of indie game publishing label No More Robots. 'We've got games that, before we even launched, made four or five times as much money as the development costs that were put into them. We've got games that can launch later this year and sell zero copies, but they will be a gigantic success.'

'The majority of our games have broken even before launch day, because of Game Pass,' says Mike Rose, founder and director of No More Robots

Founded in 2017, No More Robots has published several notable indie games, such as the stunt-cycling simulator Descenders, the irreverent Internet detective game Hypnospace Outlaw and the management sim Let's Build a Zoo. No More Robots was also one of the earliest indie publishers to have games on Game Pass, with Descenders becoming one of the first non-mainstream titles to feature on the service.

'Five years ago, I basically said to Xbox, "I want a meeting about this thing you keep talking about recently called Game Pass," and I chatted with them about putting Descenders on it,' Rose explains. They struck a deal whereby NMR and Descenders' developers would receive a fee for the game featuring on the service, a process that Rose states was and remains straightforward. 'A lot of the time they pretty much say a number and I go, "Yeah okay, I like that number,"' he says. 'It's never much more complicated than that.'

Nonetheless, Rose was still sceptical about what putting Descenders on Game Pass might mean for his business. 'I very much thought "I don't know how this is going to go, this might be really bad. Maybe no one's going to buy Descenders ever again."' But the game saw a healthy number of downloads on Game Pass, and helped to establish a strong relationship between Microsoft and NMR. 'Microsoft has used it loads internally,' Rose says, as it enables Microsoft to say 'here's a success story. Here's what can happen with the right settings for a game on Game Pass'.

But featuring games on Game Pass hasn't just helped to guarantee financial security for NMR. Counter-intuitively, putting games on Game Pass often boosts their sales on other platforms. 'We put out Hypnospace Outlaw, this weird game. It did fine when it launched,' Rose says. 'And then we put it on Game Pass, and hundreds of thousands of people played it there. It just became a word-of-mouth thing.' Rose states that, three years after launch, Hypnospace Outlaw is selling better than it ever has. 'The monthly cheques coming in for that game are bats**t,' he says.

From a financial perspective, putting games on Game Pass is a no-brainer for NMR. But featuring games on Microsoft's service isn't entirely free of downsides. Since a subscriber's monthly fee gives them access to every game on the service, players end up trying lots of games they might otherwise not play.

While this is a good aspect of the service on the whole, it can lead to some unpleasant consequences. 'Whenever we are in a service like that, we always find that we get a bunch of horrible reviews,' Rose says. 'Because there are people grabbing it, literally playing it for two minutes, playing the tutorial, then saying "this is garbage," and deleting it.' He points to Descenders as an example. 'Descenders had an average score of 4.6 out of 5 on Xbox, then it went into Game Pass and I stopped looking at the score at some point because it was depressing.'

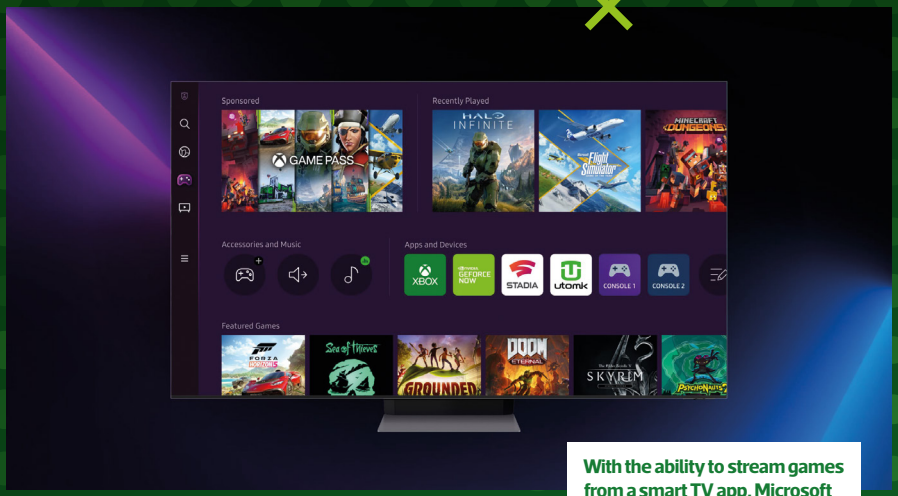
The other downside, so to speak, is that because Game Pass is a curated platform,

there's no guarantee that Microsoft will sign your game. One example from No More Robots is Not Tonight 2, an 'incredibly politically charged' adventure game set in a dystopian America. 'I knew it was never going to go onto Game Pass,' Rose says. 'There was no way Xbox was going to say yes to that.'

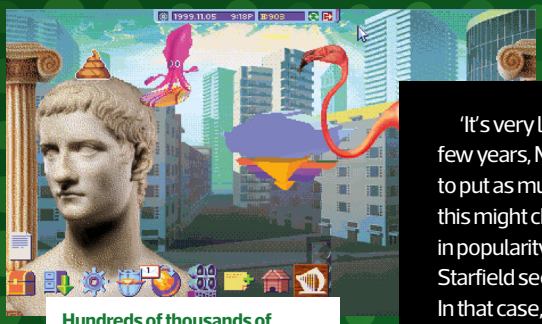
This leads to a broader question – does the curation system make it tempting to develop or publish games specifically to attract the attention of Games Pass? 'We certainly haven't started to sign games that are angled towards Game Pass,' Rose says. 'But clearly other people are, and have been thinking about this kind of thing – you'd be crazy not to. It makes sense if this is the way the model is going.'

On the subject of the business model, Rose explains that, with how Game Pass currently works, the money NMR and its developers earn from Game Pass isn't based on any performance metrics. Developers and publishers are paid up front, with no caveats based on how many people play the game, how many hours are played and so on. 'We would never put our game on a platform like that [based on performance metrics], because it's gross,' he says.

The question is whether or not this will remain the case as Game Pass grows. Rose states that, at present, Game Pass is growing at a rate that best suits third-party developers and publishers. 'It's going middle-of-the-road, and because of that, Microsoft is having to constantly think about the stuff it's signing, the deals it's doing and the way Game Pass looks,' he says.



With the ability to stream games from a smart TV app, Microsoft can circumvent traditional gaming devices entirely



Hundreds of thousands of people played Hypnospace Outlaw when it was put on Game Pass, enabling word of mouth to spread

'It's very likely that, for at least the next few years, Microsoft is going to continue to put as much effort into it as it is now.' But this might change if Game Pass explodes in popularity, if a must-have game such as Starfield sees a massive influx of subscribers. In that case, Microsoft 'wouldn't have to try as hard,' Rose says. 'It would become more of an exclusive club.'

The other potential long-term effect of Game Pass is what it might mean for dedicated gaming platforms, when it comes to both consoles and PCs.

Microsoft 'just wants you to sign up to Game Pass,' says Rose. 'Whether you play it on PC Game Pass, on your phone or on an app on your TV. There will be deals where you maybe buy a Samsung TV and get a year of Game Pass with it.' Indeed, Game Pass might enable Microsoft to circumvent traditional gaming devices entirely.

What such a transition would mean for the PC is harder to glean, but while Microsoft has always held a certain amount of influence over PC gaming, it has never had complete control, and that's unlikely to change even if Game Pass explodes.

For the moment, Game Pass offers as much to developers as it does to players, providing funding and security for a swathe of interesting games, and ensuring that those developers can go on to pursue further projects. Rose himself has just signed a deal for another half-dozen games to feature on Game Pass, with several more titles coming to the service this year. 'We're going to have a busy next 12-18 months,' he says. CPC

THE MONEY NO MORE ROBOTS EARNS FROM GAME PASS ISN'T BASED ON ANY PERFORMANCE METRICS

The team of No More Robots

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Commodo

the

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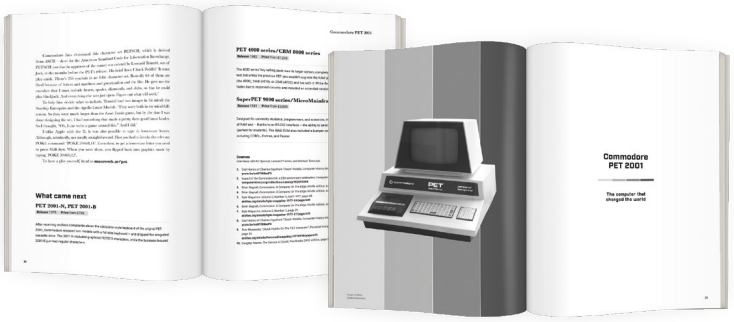

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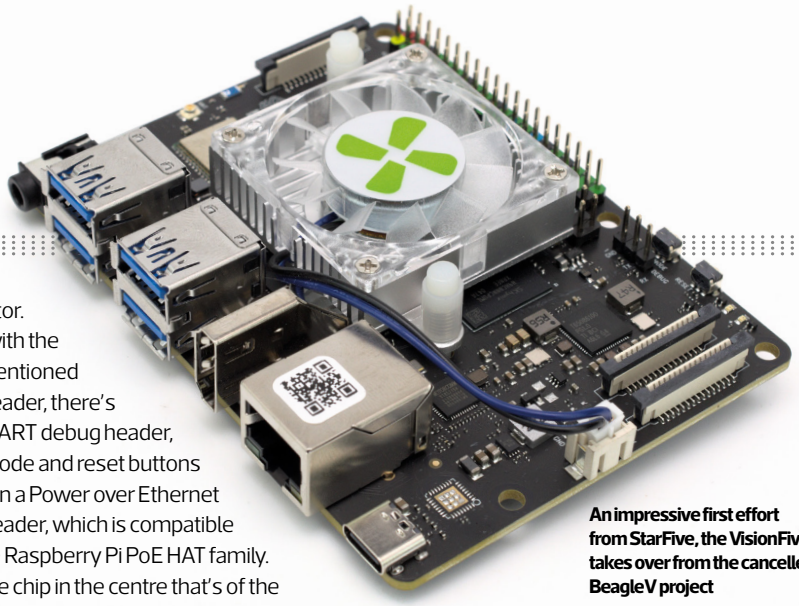
GARETH HALFACREE'S

Hobby tech

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

REVIEW
StarFive VisionFive



An impressive first effort from StarFive, the VisionFive takes over from the cancelled BeagleV project

In the beginning, there was the BeagleV (see Issue 212). Developed in a partnership between **BeagleBoard.org**, Seeed Studio, and StarFive, it was to be an open-hardware single-board computer built around the free and open-source RISC-V architecture. While beta boards were produced, the project was cancelled (see Issue 219) before it could receive a general release. Then came the VisionFive.

Built around the same StarFive JH7100 system-on-chip, it's the BeagleV that never was – for better or worse. Looking like a chunky Raspberry Pi, largely thanks to the familiar (though handily colour-coded) 40-pin general-purpose input/output (GPIO) header to the top-left, the VisionFive ticks all the usual boxes for a single-board computer. There's a set of four USB 3 ports, a USB Type-C port for power, a Gigabit Ethernet port, an HDMI port for video and audio, plus a 3.5mm analogue jack.

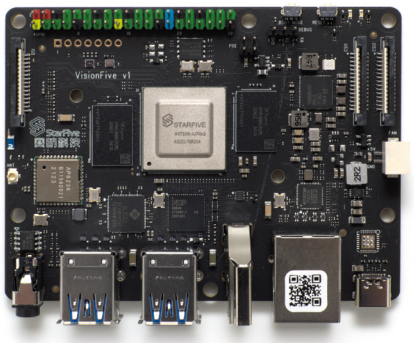
Elsewhere on the board, you'll find a pair of MIPI Camera Serial Interface (CSI) connectors plus a single Display Serial Interface (DSI) connector. Along with the aforementioned GPIO header, there's also a UART debug header, boot-mode and reset buttons and even a Power over Ethernet (PoE) header, which is compatible with the Raspberry Pi PoE HAT family.

It's the chip in the centre that's of the most interest. The JH7100 was originally designed by StarFive for use in computer vision projects. It packs two SiFive U74 64-bit RISC-V cores clocked at 1GHz, along with a Tensilica VP6 vision coprocessor, a neural network accelerator and an Nvidia Deep Learning Accelerator (NVDLA), although there's interestingly no graphics processing unit (GPU).

The lack of a GPU means the video outputs are generated entirely in software. With only two 1GHz RV64GC cores, performance is spotty at best. The official Fedora Linux image boots to an Xfce desktop environment, but even a task as simple as scrolling through a webpage puts obvious strain on the system.

If you're expecting a desktop-class experience, then, you're going to be disappointed. Running the Speedometer 2.0 browser benchmark, the VisionFive managed just 1.32 runs per minute – barely faster than the original Raspberry Pi Zero, at 0.961 runs, and dramatically slower than the newer quad-core Raspberry Pi Zero 2 W at 6.14 runs.

Although it's technically capable of general-purpose desktop computing, the VisionFive

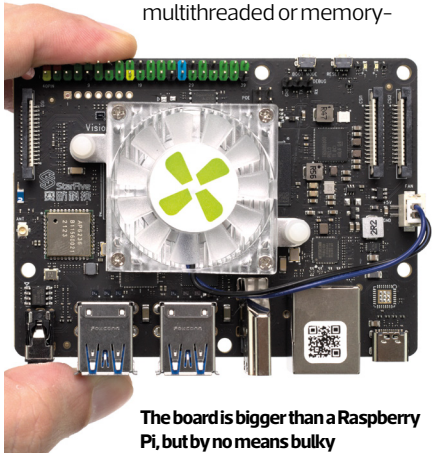


The bundled heatsink and fan isn't really required, as the SoC runs cool

Despite having no GPU, the VisionFive is capable of running a full HD desktop – slowly

is built with other workloads in mind. For those looking to experiment with the RISC-V architecture on real hardware, it has a lot to offer – including, in the version we reviewed, an impressive 8GB of RAM, of which 7GB is available to the user in the stock configuration.

It's also a lot faster than the Sipeed Nezha D1 (see Issue 221), which is built around the single-core Allwinner D1 RISC-V chip. In single-threaded tasks, such as file compression, it benchmarks between 35 and 55 per cent faster. Switch to multithreaded or memory-intensive workloads and that gap jumps to anything from 100 to 246 per cent.



The board is bigger than a Raspberry Pi, but by no means bulky

Sadly, there's a catch – the JH7100 comes with a list of errata covering some critical areas. A design flaw in the L2 cache limits the performance of the USB 3 ports, for instance, with peak throughput testing at 105MB/sec. Another one prevents the board from powering off at shutdown. The 'Gigabit' Ethernet port is limited too, hitting a peak of just 323MB/sec during testing. All these issues will, StarFive promises, be fixed in the JH7110, its next-generation replacement for the JH7100, but this will come as cold comfort to current VisionFive users.

The company's dedication on the software side seems to have wavered too. At the time of writing, the newest official Fedora image was built in December 2021 using the now end-of-life Fedora 33, and was hosted on a server that stopped the download after every 1GB.

The community has stepped up though. An unofficial image provides Ubuntu 22.04 support, albeit with even slower graphics, and the JH7100 is supported in mainline Linux from version 5.17. The board is also supported in Buildroot, for anyone looking to roll their own distribution.

The documentation is also sparse, at best. The getting-started guide is clear enough, but there's little information about making use of the machine learning acceleration hardware, and even getting a process as simple as accelerated video playback running is surprisingly complex. It's not as difficult, however, as upgrading the firmware as and when necessary, which requires a physical USB UART dongle and a system on which you can run a TFTP server.

But these are early days. With community support, and the new JH7110, the VisionFive could be a special device, providing StarFive is also able to optimise the power draw – the VisionFive currently draws a hefty 4.21W when idle, compared to the Nezha D1's 0.74W.

The StarFive VisionFive is available from **shop.allnetchina.cn** now for $179 US (around £150 ex VAT), which gets you the board, heatsink and fan assembly, and a 32GB micro-SD card with Fedora 33 preloaded.

Many of the problems of the JH7100 will be fixed in the JH7110, says StarFive

NEWS IN BRIEF

Vintage CP/M OS opened to all

DRDOS president Bryan Sparks has rewritten a brief paragraph of legalese to confirm the iconic CP/M operating system and its source code are available to everyone to distribute and modify to their heart's content.

Developed by Kildall as the Control Program/Monitor, CP/M was sold by Digital Research and rapidly became the most popular operating system for minicomputers and microcomputers – until a deal with IBM fell through and provided a gap for Microsoft's MS-DOS. 'Let this paragraph represent a right to use, distribute, modify, enhance, and otherwise make available in a nonexclusive manner CP/M and its derivatives,' Sparks' revised licence reads.

REVIEW

Flipper Zero

The Flipper Zero combines the virtual pet experience with hardware tinkering tools

The Flipper Zero, the first product from Flipper Devices, is an unusual beast. At first glance, it's a surprisingly chunky Tamagotchi-style virtual pet, with a monochrome display showing off a series of animations lit in a pleasing orange glow.

That pet, though, is a cyber-dolphin – inspired by Jones from William Gibson's 1986 short story Johnny Mnemonic and the 1995 film of the same name. The dolphin, given a random per-device l33t speak name as a unique identifier, reveals the device's target audience – cyberpunk-style hackers.

Billed as a 'multi-tool device,' the Flipper Zero comes equipped with a range of inputs – not just the four-way direction pad, action button and back button on the front. There's a sub-gigahertz radio, a 125kHz radio frequency identification (RFID) radio, a Near Field Communication (NFC) radio, a Bluetooth radio, an infrared receiver and transmitter, and an iButton contact. Plus, if all that isn't enough, spare general-purpose input/output (GPIO) ports are broken out to the top in a header that's compatible with an optional Wi-Fi adaptor board.

The general concept behind the Flipper Zero is similar to a learning remote, which is one of its modes – activate the infrared receiver, and it can capture signals from your remote controls and recreate them on demand. You can also download other people's captures, or use the integrated universal remote system to brute-force basic TV control signals.

Unlike most universal remotes, though, you're not limited to infrared signals. You can also capture and replay NFC tags, RFID tags, iButtons and a range of radio signals below 1GHz – covering the common industrial, scientific and medical (ISM) bands.

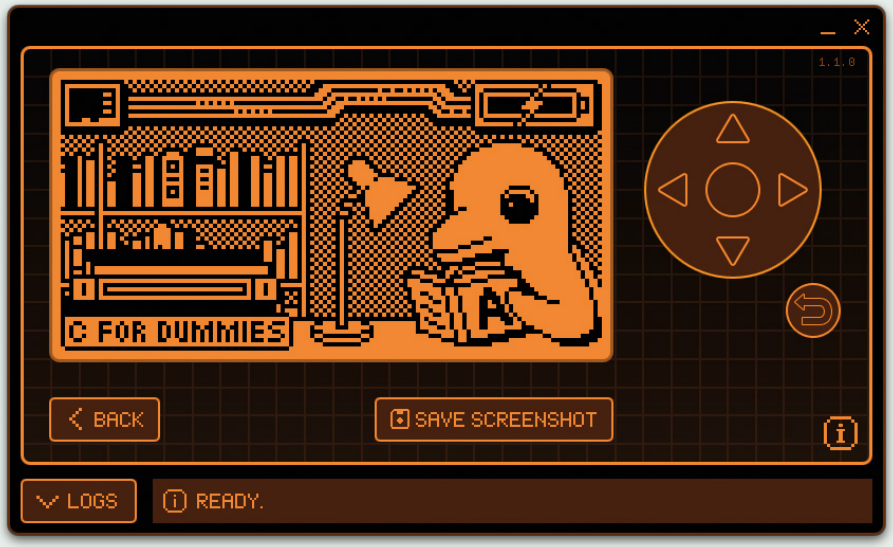
There's a minor catch to the latter feature, however. While Flipper Devices bills the Flipper Zero as a multitool for hackers, it's not looking to get itself or any of its users in legal trouble. Accordingly, the devices are locked at the factory to only operate in the bands cleared for unlicensed use in the country to which the Flipper Zero is shipped.

As a result, many of the signal files you can download from the community are locked, and any attempt to play them back results in a message warning that the chosen frequency is available for receive (RX) only, and can't be transmitted. Third-party firmware downloads that remove this restriction appeared, not surprisingly, very quickly after launch, but their use is illegal.

It's not too onerous a restriction, thankfully. As the bands are blocked based on region, you should never need them, as no devices using the locked-out bands should be present in your country.

As for what you can do with the Flipper Zero, rather than what you can't, it's a lengthy list.

An infrared port provides the ability to duplicate most remote controls



Both the desktop and mobile apps provide remote control features over USB

NEWS IN BRIEF

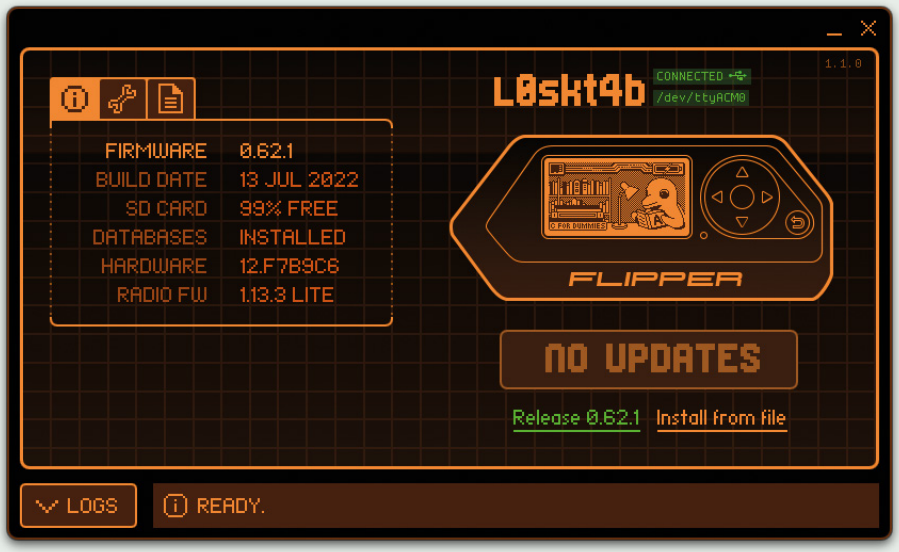
Macintosh Pi offers easy Classic Mac OS emulation

A developer known as 'Jaromaz' has put together a tool to turn a Raspberry Pi into a vintage Apple Macintosh running Classic Mac OS 7, 8 or 9 – complete with functional web browser. To prove the software's capabilities, Jaromaz fitted a new display and a Raspberry Pi 3 Model B+ to an old Macintosh Classic II case. When turned on, it boots straight into the emulator.

In addition to Mac OS emulation, the software bundle provides bare-metal emulation of the Commodore PET, Commodore 64 and Commodore 128 at high speed. Macintosh Pi is available to download from **github.com/jaromaz/MacintoshPi**

In the first few days of playing with L0skt4p, the name granted to the unit on test, it had duplicated every remote in the building, captured the 433MHz radio signal from the office's wireless doorbell, emulated NFC tags and even cloned a vintage Oyster card. It also

It's a neat toy, but the novelty isn't likely to last long enough to justify the price



The desktop software is noticeably more polished than the mobile apps

captured data from contactless bank cards, although thankfully (and not surprisingly), emulation of these won't work for payments.

Carrying out most, but not all, of these tasks keeps the cyber-dolphin happy and earns points towards its evolution through three levels. Other features, including a simple built-in Snake game, don't do this, but are a fun distraction nevertheless.

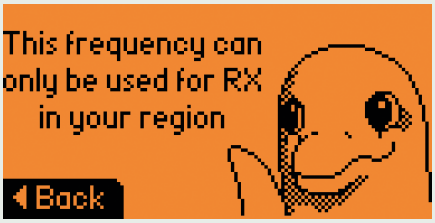
Some features aren't quite ready yet. Support for NFC-F tags is still in the wings, and 'dumb mode' – in which the hacker-friendly features are hidden, so the device looks more convincingly like a simple virtual pet – is present in the menu, but its implementation has been bumped to the very bottom of the road map.

The mobile apps, which use the Flipper Zero's on-board Bluetooth radio, are also buggy and basic. The desktop app, however, is a lot more polished. In addition to enabling you to update the firmware and transfer files to or from a micro-SD card (not included with the Flipper Zero), the app also offers a mirror mode to duplicate the user interface, offering remote control.

There's also a serial console running on the device, accessible via the USB Type-C connector, which also charges the internal battery. Here, some functions are exposed at the command line, including one exclusive feature not accessible on-device: a local radio-based chat system.

It's true the novelty of the device is likely to wear off quickly – there are only so many devices to clone, and taking it on the road to mess with other people's gadgets will likely land you in a world of trouble. Some features, though, are definitely handy to have, including its ability to act as a USB-UART bridge for other hardware.

The Flipper Zero is available to buy from **shop.flipperzero.one** for $169 US (around £141 ex VAT). Meanwhile, the Wi-Fi board costs $29 US (around £24 ex VAT) but requires third-party firmware – such as the Marauder firmware, which needs to be installed in the board's Espressif ESP32-S2 microcontroller – in order to operate.



The sub-gigahertz radio is frequency-locked depending on your country

REVIEW

Zachtronics' Last Call BBS

Zach Barth, founder of games studio Zachtronics, is the designer of some of the most addictive and original games around – to the point they sit in a genre of their own dubbed 'Zachlikes.' Unfortunately, Barth is retiring from the industry and closing down Zachtronics – Last Call BBS is his swansong.

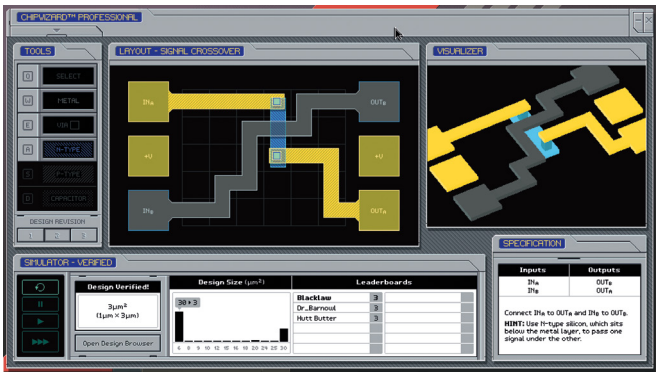
Designed to evoke nostalgia for the late 1980s through to the mid-1990s, Last Call BBS gives the player control of a fictional home computer dubbed the Sawayama Z5 Powerlance. Using its built-in modem, you dial up to the titular bulletin board system – complete with touch-tone dialling and the familiar screech of a modem handshake – to download a selection of small 'pirated' games.

Barth has gone fully immersive here. Each download takes a couple of minutes, although Sawayama's operating system is thankfully multi-tasking, so you can play another game while you're waiting. There's even a quota system – after each game is downloaded, you'll need to wait 15 minutes before you can download the next – a fully artificial restriction, but one inspired by the very real 'ten downloads a day' quotas of actual BBSes of the era.

The games themselves are very Zachlike. The Z5 Powerlance comes with a twist on solitaire preloaded, there's a graphical Sudoku-like puzzler dubbed Dungeons & Diagrams and 20th Century Food Court riffs on the make-and-optimise-a-machine gameplay loop of Spacechem and Opus Magnum.

There are a few surprises too, the biggest of which is Steed Force Hobby Studio. Created, supposedly, by a fan of a fictional Japanese mecha-anime series who was disappointed by the difficulties of importing the tie-in model kits – the game has you walking through the assembly of simulated kits – snipping components from sprues, assembling them according to often vague instructions, painting them and carefully applying decals. There are no real game-loop elements involved, with no timer, no score and no win condition, other than finishing a paint job with which you're happy, but it's a surprising time sink nevertheless.

For fans of cyberpunk hacking puzzler Exapunks (reviewed in Issue 183), there's a variant on the HACK*MATCH game-in-a-game – this time supposedly the 'original' Japanese arcade ROM, rather than the home-console port simulated within Exapunks.



The chip design game is fiendishly addictive

The highlight of the show, though, is ChipWizard Professional – a 'design tool' for building integrated circuits. Clearly a successor to hardware-building title Shenzhen I/O (Issue 161), ChipWizard tasks you with building simple integrated circuits out of the bare essentials of computing – N- and P-type silicon, combined into NPN and PNP transistors, capacitors and metal.

In addition to creating a functional design to solve the given problem – such as signal multiplexing or exclusive OR gating – the player is scored based on the die size of the part, with leaderboards providing an opportunity to chase your friends' 'low' scores.

All this is presented in a convincing retro-futuristic interface, complete with optional CRT curve effect. A faux personal digital assistant app appears to the bottom right during play, providing notes from the person who got the Last Call BBS back up and running long after it had been shut down. As you play, additional notes are revealed, and there are a few secrets to find along the way.

It's a shame to see Barth leave the industry, but nobody could have asked for a better swansong. Last Call BBS is available on Steam for £15.49 inc VAT, while Microsoft Game Pass for PC subscribers can play the Windows port as part of their subscription. CPC

If you miss the days of dial-up modems, BBSes and download quotas, Last Call BBS could be for you

Gareth Halfacree is a keen computer hobbyist, journalist, and author. His work can be found at **freelance.halfacree.co.uk** @ghalfacree

WIN

A 32GB 6400MT/SEC KINGSTON DDR5 MEMORY KIT

Here's an awesome opportunity to gear up for Intel and AMD's forthcoming CPU launches, or to give a boost to an existing Intel 12th-gen system. Kingston is offering one lucky **Custom PC** reader a high-speed Fury Renegade DDR5 RGB memory kit, which picked up an Extreme Ultra award in our Labs test this month.

Game in style with Kingston Fury Renegade DDR5 RGB memory, designed for extreme performance on next-gen DDR5 platforms. Give your system the performance boost and flair needed to stay on top, with ultra-fast memory running at up to 6400MT/sec and, using Fury CTRL, 16 customisable RGB lighting effects on each memory module.

Kingston Fury Renegade DDR5 RGB modules feature a sleek, newly designed black and silver heatspreader, with a dynamic LED light bar, which also uses Kingston's patented Infrared Sync Technology to provide smooth, synchronised RGB lighting effects to complement the looks of the latest PC builds.

Whether you're creating content, multi-tasking or pushing the limits to the extremes for your bleeding-edge game title, Kingston Fury Renegade DDR5 RGB memory is the ideal choice for gamers, enthusiasts, content creators and extreme overclockers. It's 100 per cent factory tested at speed, and backed by a limited lifetime warranty and over 30 years of expertise.

- 32GB (2 x 16GB) capacity
- 6400MT/sec speed
- 32-39-39 latency timings
- 1.4V voltage
- 39.2mm module height
- Dynamic, customisable RGB lighting effects
- Intel XMP 3.0 certified

SUBMIT YOUR ENTRY AT **CUSTOMPC.CO.UK/WIN**

ANTONY LEATHER'S

Customised PC

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

Noctua's NF-A12x25 is still the fan to beat

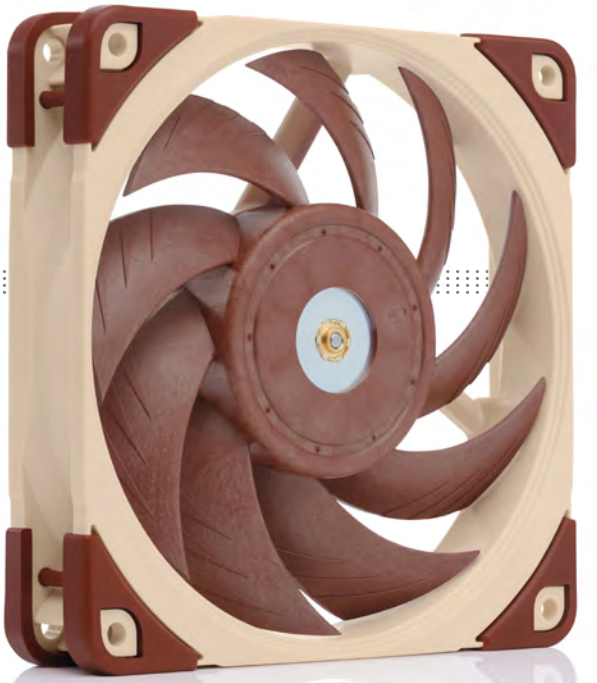
In last month's 120mm fan Labs, we were keen to test as many new fans as possible. For that reason, we weren't able to revisit some models we included last time in order to fit some newcomers into the mix. We did manage to retest one previously well reviewed model, though, which was Noctua's NF-P12 redux, and for a very good reason.

It costs less than £15, making it much more affordable than a lot of premium fans, and it's one of our top picks for radiators, cases and coolers. Thankfully, despite some stiff competition, it still did very well in last month's Labs test. However, as we wanted to stick to a price limit in the group test, we didn't look at Noctua's NF-A12x25 last month. It's still one of our favourite 120mm fans, though, despite its very high price.

As such, I felt compelled to put it through its paces using our new test gear, in order to see how it fared against the likes of the fabulous new be quiet! Silent Wings 4 High Speed fan. If you're potentially interested in purchasing some super-premium, high-performing fans for your PC's case or radiators, then keep reading.

To start, the NF-A12x25's peak airflow was 2.25m/sec and the peak noise level was 56dBA. That's a very low noise level, but the airflow didn't quite beat the be quiet! Silent Wings 4 High Speed, which managed 2.6m/sec at a slightly higher noise level of 61dBA.

Still, it was enough to beat the be quiet! fan and every other in the group test in terms of the airflow-to-noise ratio, with a result of 21.58 compared to 24.89 for the Deepcool FC120, 26.03 for the Thermaltake Toughfan 12 and 26.41 for the be quiet! fan. That said, the latter did have a slightly more pleasant noise quality to the human ear, with the Noctua NF-A12x25 emitting a slight humming tone rather than just pure airflow noise.



The Noctua NF-A12x25 remains an excellent fan at low to medium speeds

Bringing down the RPM to 1,000 saw these figures drop to 0.82m/sec and 41dBA respectively. The noise level here was exceptionally low, beating the be quiet! Silent Wings

4 High Speed by 2dBA and offering slightly more airflow too.

Finally, at a noise-normalised speed where the fan emitted 50dBA, the Noctua managed an airflow speed of 1.49m/sec and hit a massive 1,500rpm, which was the highest speed of any fan at this noise level. This translated into the highest airflow too, beating the second-place be quiet! Silent Wings 4 High Speed, which managed 1.2m/sec.

The Noctua NF-A12x25 is still arguably the best all-round fan available in terms of noise and airflow, which I suspected would be the case. However, it's also hugely expensive and not without competition. The new be quiet! Silent Wings 4 High Speed offers a higher peak airflow, is slightly cheaper with a touch better audio quality too. However, at low-to-medium speeds the NF-A12x25 is unbeatable.

Why the Ssupd Meshlicious is my favourite mini-ITX case

It's not often that I feel compelled to proclaim my love for a product, but after messing around with the Ssupd Meshlicious recently, and critically, reviewing and modding a few other mini-ITX cases, such as the Fractal Design Torrent Nano and Phanteks Evolv XT, the Meshlicious has impressed me a lot.

Now, I know that just a few issues ago, I was complaining that the Meshlicious made it too easy to build an AIO liquid cooler-focused PC, and I haven't changed my mind about that particular fact. There are hundreds of identical rigs doing the rounds on Reddit and social media, and most of them use a liquid cooler in the front and have very similar layouts.

I have nothing against that, as it's clearly a case that's proving popular and getting more people interested in small form factor hardware is always good. However, having so many similar builds detracts from the unique ideas that mini-ITX often brings to the world of PC hardware – apart from the colours, if you've seen one, you've essentially seen them all.

However, over the last week I've been eyeing up the Meshlicious as my next PC case, as it not only has decent water-cooling support, but it's also supremely flexible. Indeed, some of the tweaking now possible inside the Meshlicious involved me making modifications in other cases, involving cutting, sanding and manual work.

With the Ssupd Meshlicious, though, moving the motherboard tray to make more room for the GPU chamber is possible by just moving panels around. You even get replacement panels in the box to cover up the holes made by doing so – a job that I spent hours doing on other cases. The Meshlicious also supports ATX PSUs, but you gain more space by using an SFX PSU, which ties into the ability to move the motherboard tray across the case and reduce CPU cooler clearance.

Clearly, this isn't beneficial to all people. For instance, if you want to use the largest air cooler possible, you'd want to have the case in its standard configuration. However, if you're using an AIO liquid cooler or custom water-cooling system, then you don't need that extra clearance. The fact that Ssupd's designers have thought of this is fantastic, and it effectively enables you to house a high-end water-cooling system inside the case, or make room for triple-slot graphics cards.

You can use an SFX PSU to free up more room elsewhere

You can configure the Meshlicious to accommodate a massive triple-slot graphics card

I absolutely love this kind of forethought and flexibility, and would love to see it in more cases, especially small form factor ones. Picking between standard and sandwich layouts often leads to compromises, but the Meshlicious at least manages to expand the sandwich layout to lean more towards liquid cooling and triple-slot graphics card support, while other tweaks enable you to add multiple hard disks, which is rare in most cases this size.

So, while the Meshlicious might encourage people to build very similar-looking PCs using AIO liquid coolers, if you look past its out-of-the-box configuration, it's hugely flexible and adaptable. What's more, the manufacturer has even included extra touches such as angled cables for your graphics card. I can't wait to see what Ssupd brings us next. CPC

Antony Leather is Custom PC's modding editor @antonyleather

How to Etch your PC's glass panels

Antony Leather shows you how to apply etching cream to mod your case's glass side panels

TOTAL PROJECT TIME / 2 HOURS

You might have heard of engraving, which is using a rotating tool with abrasive tips to grind into surfaces such as metal or plastic, but etching is completely different. Here, you use an etching cream that permanently marks the surface of glass, leaving behind an area that looks frosted or opaque.

It's a great way of customising your glass side panel, as there aren't many ways you can otherwise permanently affect glass, given it generally shatters when you try to drill or cut it. Etching is completely safe, but the tricky part is creating a mask that's accurate and easy to apply. We'll be running through the best way to do this, and how to apply the etching cream, in order to create the perfect pattern.

TOOLS YOU'LL NEED

Silhouette Portrait cutter or scalpel
yolo.co.uk

Adhesive matt vinyl sheet
yolo.co.uk

Transfer/ application tape
yolo.co.uk

Small paintbrush
Most hardware stores

Armour Etch cream
amazon.co.uk

1 / CLEAN THE PANEL

The etching cream needs full access to the glass surface, so any muck or grime can result in disaster. Clean the panel thoroughly using warm soapy water and a sponge, then rinse and wipe it dry with a microfibre cloth, making sure you don't touch the glass again with your bare hands.

2 / CREATE GUIDE LINES

Lining up your design onto the panel can be tricky, but we've used marker pens here, so we can have the text in our design sitting on one line, while the other line marks the centre point. This can be removed later using isopropyl alcohol.

3 / CUTTING BY HAND

If you're creating your masking by hand, printing your design onto the masking sheet is the easiest way to provide a template. You can then use a scalpel to cut around the printed areas, creating holes for the etching cream to access the glass.

4 / USE A CUTTING MACHINE

A cutting machine is fantastic for creating perfect masks in a matter of seconds. You just need to upload your design to the cutter's software, trace the outlines of your desired image and the machine does the rest. We can highly recommend using one if you want the perfect finish, especially with complicated designs.

5 / USE TRANSFER PAPER

Transfer paper is slightly tacky and can be applied over the mask area in order to lift off all the small isolated areas of the mask that would otherwise be left behind. Start by removing areas in the mask you want the etching cream to be able to access, then press the transfer paper on top.

6 / APPLY TO PANEL

Place the masking and transfer paper onto the panel, lining it up with the guidelines you created earlier, then lift the transfer paper off the masking. Lift it from one corner then peel it all off. Use the scalpel to encourage any stray mask pieces to stay stuck to the glass.

7 / PRESS MASKING ONTO PANEL

With the transfer sheet removed, use a credit card or squeegee to press the masking firmly onto the glass panel. This will prevent the etching cream from creeping under the masking edges and also remove any air bubbles.

8 / APPLY ETCHING CREAM

Apply the etching cream liberally over the masking, concentrating on the exposed areas. This is best done with a small or medium paintbrush. Use light strokes, as it's the etching cream that does the work – brushing harder won't provide a better result.

9 / CLEAN AND ALLOW TO DRY

Follow the masking cream's instructions regarding how long to leave it on the panel, which is usually just two or three minutes, then rinse off the cream. Next, peel off the masking and give the panel a final wipe down with a microfibre cloth before leaving it to dry.

How to Install and use a distro plate

Antony Leather shows you how to install a distribution plate to improve the look of your PC and make tubing runs easier

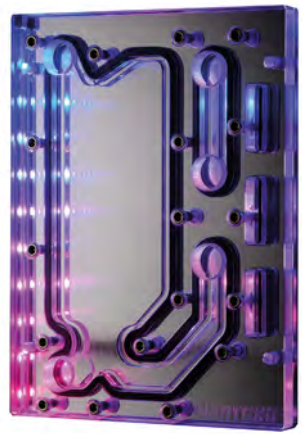
TOTAL PROJECT TIME / 2 HOURS

Water cooling has come a long way in the past few years and one item stands above all others when it comes to making your loop look fabulous. The distribution plate, or distro plate as it's more commonly known, combines numerous inlets and outlets into multiple channels in a single unit, allowing you to direct your tube runs in and out of it to make for a simpler overall tube arrangement, minimising the need for tube bends or angled fittings.

As well as looking amazing, by reducing tubing clutter and allowing for a view of the coolant flowing within them via their often-clear tops, distro plates can also make it easier to construct a water-cooling loop in a multitude of ways.

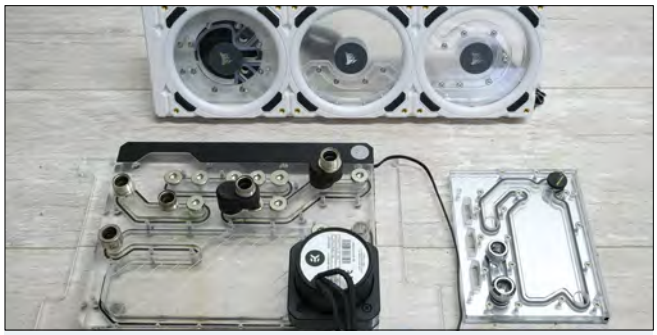
For instance, they can be used to pass coolant from one chamber of your case to another, without any extra tubing work. There are universal distro plates available, and some custom made for specific case models, while some even have integrated pumps. In this guide, we'll be looking at how to install use all three types.

TOOLS YOU'LL NEED



Distro plate
overclockers.co.uk

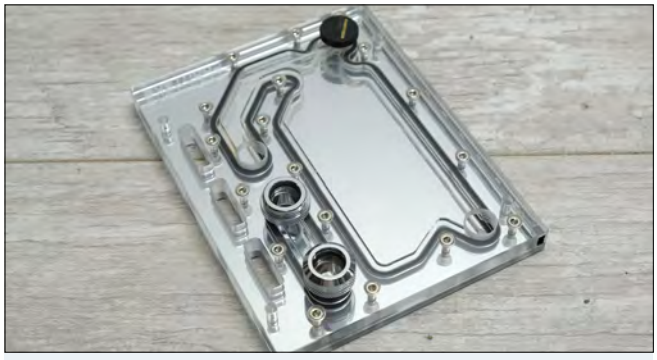
Gorilla mounting tape
Most hardware stores



1 / CHECK YOUR CASE AND LOOP

Make sure that both your case and your water-cooling gear will work well with a distro plate. You'll need a spare fan mount in your case and a large flat area – some popular cases also have specific distro plates available for them. You may need to move components such as reservoirs and radiators to make room too.

UNIVERSAL PUMPLESS DISTRO PLATES



1 / USE A UNIVERSAL DISTRO PLATE

There are several types of distro plate, with the cheapest being universal ones from the likes of Phanteks. These are flat and require 120mm or 140mm fan mounts, or a large enough flat space to mount them. They only act as distro plates, with no pump or fill ports, but can still be useful.

2 / CHECK FOR BEST LOCATION

First, decide what you want to do with your pumpless universal distro plate. You might want to use it to route tubing from one case chamber to another, or simply use it to run straight lines between components such as your CPU and graphics card without having to bend rigid tubing.

3 / INSTALL WITH SCREWS

Most universal models require the use of a fan mount and come with screws to secure them to either 120mm or 140mm fan mounts depending on their size. Place the distro plate into the fan mount and secure it from the rear. If your case includes adjustable fan mounts, these can be useful for fine-tuning the position.

4 / INSTALL WITHOUT SCREWS

You might want to install this distro plate somewhere other than a fan mount, which can be done using a 15mm square section of 3M or Gorilla mounting tape in each corner on the back, instead of using screws. Cut the tape to size, place it on the rear of the plate and fix it into position.

UNIVERSAL PUMP-EQUIPPED DISTRO PLATES

1 / USE A PUMP-EQUIPPED UNIVERSAL DISTRO

Some universal distro plates come with pumps and reservoirs included, removing the need to find separate homes for those components. However, you'll have to factor the extra bulk of the pump into the installation and your tube runs.

2 / FIND BEST LOCATION

There may be aesthetic reasons to consider the location, for example allowing the distro plate to be visible through the front panel, but with a combined pump and reservoir, you'll also need to be able to fill it with coolant. Identify a suitable location that at least allows the latter.

3 / INSTALL THE DISTRO PLATE

Ensure you mount the distro plate the right way up. In the case of the Corsair XD7 we're using here, it fits into a triple 120mm fan mount, but the pump can only be used in one orientation. Use the screws provided to secure it to the fan mounts.

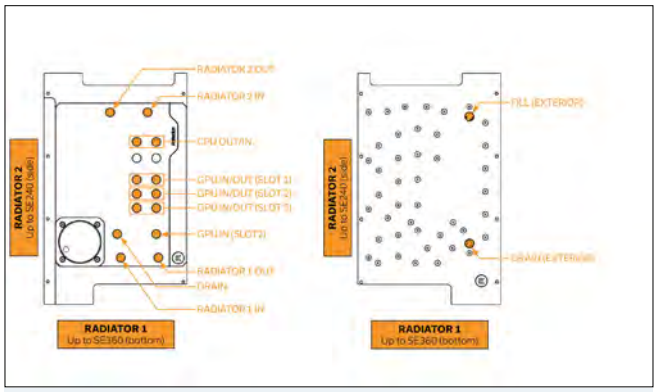
CASE-SPECIFIC DISTRO PLATES

1 / USE A CASE-SPECIFIC DISTRO PLATE

A case-specific distro plate will only fit into a particular model of case. These make best use of the available space to offer a snug fit and often have ports designed to complement the case's design and size. However, check the online manual first, as some distro plates limit the installation of other hardware, including radiators.

2 / INSTALL DISTRO PLATE

Using the screws provided, install the distro plate in position. Use the manual to work out the correct orientation and remove any case panels as required. Here, the EK Reflection PC-O11D Mini distro plate sits in the front of the case and replaces the stock front panel.



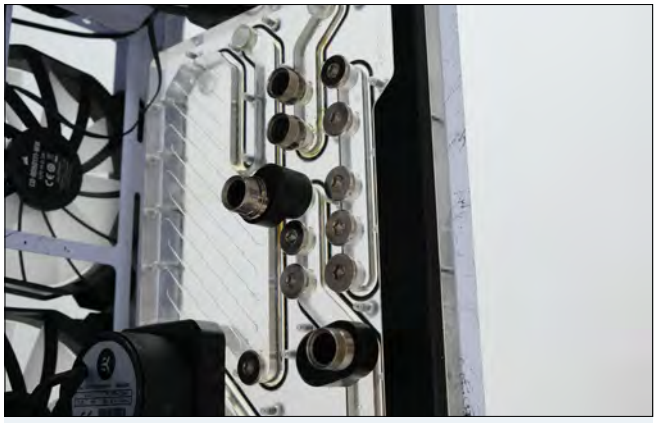
3 / USE MANUFACTURER RECOMMENDATIONS

Some manufacturers recommend using specific ports to run to individual components. This is the case with most case model-specific distro plates such as the EK Reflection PC-O11D Mini. This can be useful for ensuring optimal tube runs.

FINAL STEPS

1 / WORK OUT YOUR TUBING ROUTES

Now it's time to look at your tubing routes. Aim to use as few runs as possible, so you don't overcomplicate your loop, but also aim to remove the need for 90-degree bends in your tubing as much as possible. Be aware of how the coolant flows through the plate too, as this will impact your route options.



4 / INSTALL YOUR FITTINGS

Once the distro plate is installed, go ahead and install your fittings in the correct ports. You'll nearly always have left over ports, into which you'll need to fit blanking plugs. Make sure you use plugs of the same range and colour as the rest of your fittings to keep a clean look.

2 / IDENTIFY FILL OR DRAIN PORTS

Some distro plates include fill or drain ports, or both, so you'll want to identify these first, so you don't accidentally use them to route your coolant.

5 / LEAK-TEST AND FILL

A distro plate is an ideal location for leak-testing your water-cooling loop, as there's nearly always a free port you can open prior to filling, to which you can connect a leak tester without dismantling the rest of your loop. Use a leak tester on a free distro plate port to check for leaks, then go ahead and fill your loop with coolant. CPC

Retro tech

INTEL PENTIUM PRO

Stuart Andrews recalls how Intel built the CPU of the future in the late 1990s

Look at the Pentium Pro as Intel's ugly duckling: the CPU that launched to little serious acclaim and suffered a whole lot of criticism in its early years, but slowly transformed into something incredible. The first CPU based on Intel's P6 architecture, it was arguably the biggest step forward in Intel's architecture since the original 8086, with Intel's engineers making big, risky bets on where mainstream computing was headed, and most of those bets paying off in the long term.

When it appeared in November 1995, many saw it as a failure. Nearly 27 years later, it's still a huge influence on Intel's CPU design today. Pentium Pro was launched at a weird time for Intel. On one level, it dominated the hardware side of personal computing. The 486 had put Intel far ahead of any rival, and the Pentium, launched in 1993, had extended Intel's lead in terms of both sales and performance.

Yet, outside the business and consumer PC market, Intel faced serious competition, with fast, efficient RISC processors surging ahead in the server and workstation markets. Intel might not have had much to fear (yet) from AMD and Cyrix, but it had plenty to worry about from Digital, MIPS and the Power PC alliance comprising IBM, Motorola and Apple. Intel ruled in the PC market, but RISC processors were squeezing the company out of datacentres and high-performance computing sectors.

The obvious move for Intel was an evolution of the Pentium architecture and its powerful superscalar design. Where previous Intel CPUs had worked on one instruction per clock cycle, the Pentium had two data pipelines that could operate on two instructions simultaneously. Admittedly, only one pipeline could handle all instructions, with the second limited to a subset of simple, frequently used instructions, but it was still a speedy chip.

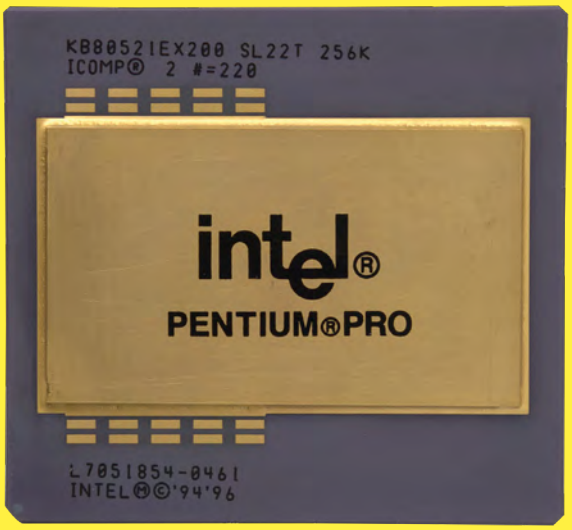
Intel could have optimised these pipelines further, or simply added more, but the P6 team running under Fred Pollack and Bob Cowell had other ideas. It had been working quietly since 1990 on a more revolutionary idea.

RISC MEETS CISC AND GOES OOOE

At the time, RISC vs CISC was the hottest debate in computing. Should you go for a complex instruction set (the CIS in CISC) and have a lot of instructions covering most operations built into your hardware, or a more flexible reduced instruction set (you guessed it) with fewer, more flexible instructions, but the ability to decode and process those instructions at a higher speed?

With the 386, 486 and Pentium, Intel had become the champion of CISC. It was core to Intel's technology, and where the expertise of most of its engineers lay. However, Pollack and Cowell's team was actively researching RISC approaches, and rethinking ways in which you could process instructions more efficiently.

Crucially, the team came up with a type of design that Intel hadn't really done before: it designed P6 as an architecture



Overpriced and underpowered or the future of x86 computing? The Pentium Pro created controversy at launch, but is now seen as a landmark CPU. Photo credit: Rainer Knäpper, Free Art License (artlibre.org/licence/lal/en)

that could evolve over the long term. In a 2009 interview, Cowell talks of how the team built it 'with an eye towards a long-term contribution to the company, as opposed to "let's do a chip and after that let's do another chip."' P6 was an architecture for the future of computing, not just the next component release.

How? Well, firstly, the P6 architecture was designed for out-of-order execution (OoOE). Previous Intel processors were designed to handle instructions in the order that they were received, as defined by the programmer and the compiler program that compiled their finished code. With its dual pipelines and clever instruction caches, the Pentium architecture was pretty smart about how it did this, but the P6 architecture took it to another level.

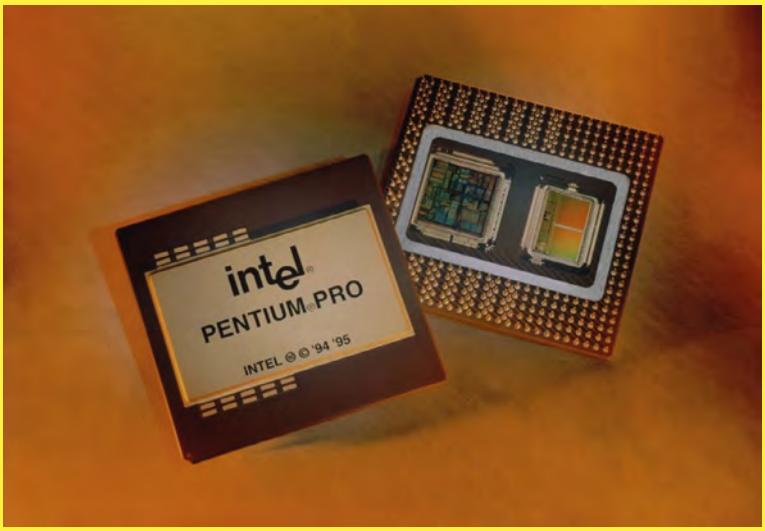
Floating point performance was far ahead of the already improved Pentium design

With OoOE, the CPU itself would look at the instructions coming through the pipeline and make intelligent decisions about the instructions on which to move forward, which instructions required data from other instructions, and which instructions you could advance and deal with during otherwise unused clock cycles.

It could then allocate instructions to the pipeline accordingly. Thanks to out-of-order execution, the P6 architecture wasn't just faster, but smarter, moving instructions from its 8KB instruction cache through its three decoders to the execution units with smooth efficiency.

Secondly, the P6 didn't fight against RISC – it embraced it. The instruction decoders took x86 CISC instructions and broke them down into RISC micro-operations, which could then be processed at higher speeds by the six execution units. This, combined with the out-of-order execution and an optimised 14-stage pipeline, turned the P6 into a number-crunching monster.

The top processors in the line-up, such as this Black Edition, had 1MB of L2 cache. Photo credit: Kyro, licensed under CC BY SA 3.0



The Pentium Pro was a big chip with Intel's most complex architecture to date, yet the CPU core was positively dwarfed by the integrated L2 cache

Floating point performance, in particular, was far ahead of the improved floating point performance of the Pentium design – a critical point when 3D rendering applications and CAD were spicing up the workstation market. Some of us even saw the P6's potential for 3D gaming.

Thirdly, P6 was the first Intel architecture to integrate the Level 2 cache on the CPU itself, rather than on the motherboard. The 486 and Pentium processors had between 8KB and 32KB of L1 cache on-board the die to store the data the CPU was most likely to use next, but the next level of cache, the larger and slower L2 cache, was held separately on the motherboard.

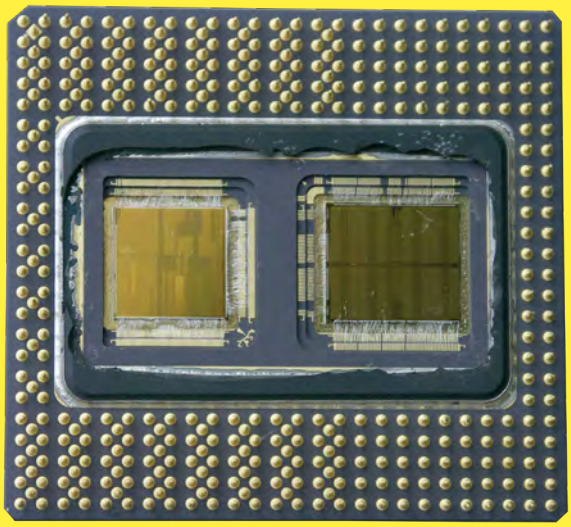
This meant that when the CPU needed data from the cache and couldn't find it in the on-board L1 cache, it had to talk to the motherboard's L2 cache through a 32-bit data bus to find out if it was there. Say a big hello to latency.

The Pentium Pro, however, placed between 256KB and 1MB of L2 cache on a separate die held within the processor module itself, where it connected to the main CPU die through a dedicated, full-speed 64-bit bus. Having more high-speed cache in such close proximity to the CPU dramatically improved performance, to the extent where Intel claimed that 256KB of on-chip L2 cache was as good as having 2MB on the motherboard.

CONFUSION AT LAUNCH

These three factors in combination should have made for a killer CPU, but at first the Pentium Pro came across as a damp squib. Benchmarks put it ahead of the RISC competition by some yardsticks, but not others.

Floating point performance was good, and better than the existing Pentium processors, but it still wasn't quite in the same league as the FPU performance of the fastest Digital and MIPS CPUs. More seriously, the P6's pipelines had difficulty juggling 16-bit and 32-bit code, at a time when



The Pentium Pro's performance owed as much to its built-in cache as to its revolutionary architecture. Even the Pentium II didn't give you full-speed L2 cache. Photo credit: Klaus Eifert, licensed under CC BY SA 2.5

P6 became the basis of the Core microarchitecture Intel still uses today

Windows itself and many applications used a mix of the two. This meant that the Pentium Pro only made sense to people who used Windows NT rather than the tried and tested Windows 3.1 or the new and shiny Windows 95.

It also meant that performance in many mainstream packages wasn't necessarily going to be faster than on a Pentium CPU running at the same clock speed.

When journalists got their hands on the Pentium Pro towards the end of 1995, they found it a curious mixture of amazing performance in some applications and underwhelming speeds in others. Tests by the US magazine PC World concluded that the 200MHz Pentium Pro was just 8 per cent faster than the 200MHz Pentium in benchmarks, despite costing around $200 US more.

To add to the embarrassment, the Pentium Pro had its share of teething troubles. It was slow at writing to video memory, hobbling performance in games. In id Software's Quake, for example, you could expect sub-Pentium frame rates unless you set it to write to system memory instead or installed a third-party utility, FASTVID. Doing so could double your frame rates at higher resolutions.

Despite the Pentium Pro's awesome number-crunching horsepower, it was slower than a Pentium running Quake – until you reconfigured writes to video RAM or installed FASTVID

More seriously, a bug was found in the floating point unit, affecting the results when a large negative floating point number was stored into memory in an integer format.

The bug was tricky to repeat, and of little consequence in most cases. Windows and Microsoft Office were unaffected, while id Software's John Carmack noted that the bug only manifested when storing 80-bit values 'which almost nobody ever uses'. All the same, the bug helped to create the impression that the Pentium Pro had been rushed out before it was ready.

As a desktop CPU, sales were relatively slow. The Pentium Pro was outsold by the standard Pentium throughout its lifespan, particularly as Intel continued to develop the Pentium line through the Pentium MMX, reaching speeds of 233MHz and later even 300MHz in the mobile world. Yet Pentium Pro did meet Intel's long-term aims of building market share in the server and workstation markets. By 1997, 97 per cent of servers under $10,000 had Intel CPUs, and the same applied to 50 per cent of all workstations. Not bad at all!

THE P6 LEGACY

All the same, success in the server market isn't what makes the Pentium Pro a landmark processor. What does is its lasting legacy. In May 1997, Intel combined the P6 architecture of the Pentium Pro with the MMX instructions of the Pentium MMX, creating the Pentium II. In some respects, it was actually a downgrade from the Pentium Pro, running the L2 cache at half the CPU's clock speed, but Intel improved 16-bit performance and doubled the L1 cache to make the Pentium II the fastest x86 CPU of its time.

The Pentium III, which came out two years later, still used the P6 architecture, but added the new Streaming SIMD Extensions to accelerate floating point, 3D and multimedia operations. Pentium III should have been the P6 architecture's swansong, as Intel moved to the NetBurst architecture for 2000's Pentium 4 and 2005's Pentium D.

But then something weird happened. Intel struggled to scale NetBurst's performance, with the promised 10GHz clock speeds wrecked by issues with power and heat. Looking for another way forward, Intel returned to P6 with its Pentium M mobile CPUs, and Pentium M became the basis of the Core microarchitecture Intel still uses today.

That architecture has changed a lot over the years, adding new stages to the pipeline, along with support for more cores, more instructions and more cache. Yet at the centre you'll still find the same ideas and fundamental principles introduced with the Pentium Pro. Instead of joining doomed architectures, such as the 64-bit Itanium or the 32-bit iAPX 432, Pentium Pro became the ultimate survivor, outlasting the 486, the Pentium, NetBurst and, well, just about everything else. CPC

Readers' drives

OpenITX PC

Jerome Kelty designed an open-frame mini-ITX chassis made from laser-cut aluminium, and has kindly made the design files available for anyone else to download and have a go

SEE THE FULL PLANS AT custompc.co.uk/OpenITX

/MEET THY MAKER

Name Jerome Kelty

Age 55

Occupation Jeweller

Location Colorado, USA

Main uses for PC CAD, 3D modelling

Likes Bicycles, building animatronics, cosplay, sci-fi films, animals (I have lots of pets)

Dislikes People who hurt animals

CPC: Let's start at the beginning. What inspired you to build this PC?

Jerome: I've always thought of open-chassis designs as being really interesting. I just love the idea of all the parts being on display and the ease with which you can work on them. Since there aren't any panels to cover anything up, the components play a much larger role in the overall appearance.

CPC: What were your requirements for this custom case?

Jerome: I wanted the build to be really compact and have a very small footprint. I also thought it would be neat if the chassis could be made from individual metal plates that could be bolted together, so it could be packaged flat should it ever be put into production. Making the chassis from individual plates would also allow for greater ease of customisation without having to redesign the entire chassis.

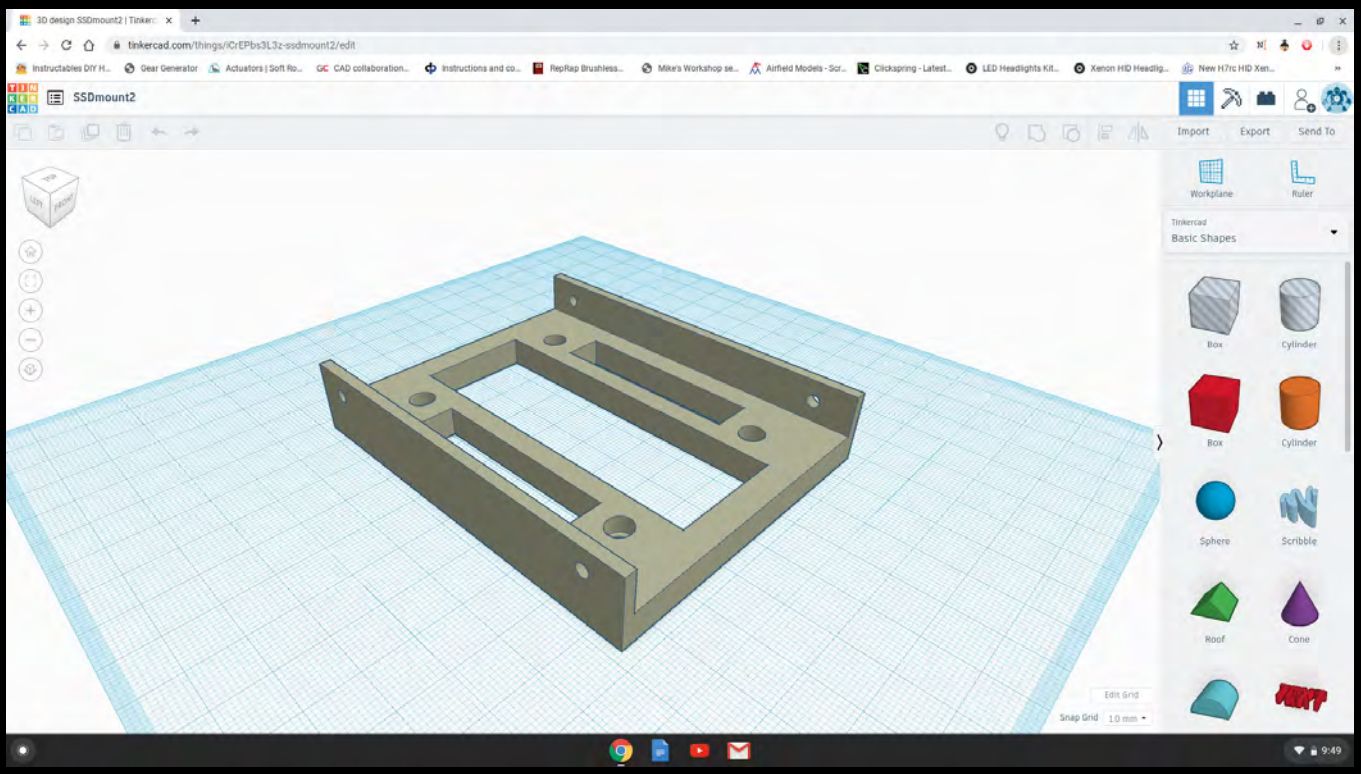
I thought it should be able to accommodate a full-sized ATX power supply and a full-height graphics card with sufficient clearance for airflow. I wanted to be able to use two M.2 drives, along with a 2.5in drive, and have easy access to the M.2 drive on the back of the motherboard. Easy, clean cable routing was also a priority. I wanted the graphics card to fit directly into the PCI-E slot and not have to use a riser cable.

I figured that adding a handle on top would be handy for moving it around, and I also added a bit of space underneath the graphics card, so additional USB ports could be installed later.

CPC: How did you plan and design this build throughout its various stages?

Jerome: I started by laying out the components on sheets of cardboard, in order to get an idea about how I wanted all the parts to sit, and get an idea of the overall form factor. Then I took measurements and did drawings of what would be the individual flat plates in Inkscape. The Inkscape drawings were then imported into Fusion 360 as SVG files so that I could create a 3D model of the chassis.

I downloaded individual component models from GrabCAD, and placed them in the Fusion 360 chassis model to get an idea of the overall look of the design. Once I was



happy with that I was good to go for fabrication.

CPC: How did you get the aluminium pieces cut to shape?
Jerome: The three flat metal plates that make up the chassis are laser-cut from 9.5mm-thick 5052 aluminium by SendCutSend, which is a fantastic laser-cutting service. This was definitely the way to go for both cost and ease of manufacturing, as I don't have a CNC router and cutting metal that thick by hand would have been an enormous amount of work. Laser-cutting thick material does leave a bit of a rough surface, but since I was starting with a sort of test build, I wasn't too concerned with getting pristine edges – I just cleaned up all the sharp edges with a file.

CPC: Were any of the parts 3D-printed?
Jerome: Yes. Printing these parts was the fastest/most economical way for me to do it given the tools I had to work with, so it was really just done that way out of necessity. I designed the parts in Tinkercad and printed them in PLA plastic on my old Printrbot Simple Metal printer.

CPC: How does the frame fit together, and how is your hardware mounted to it?
Jerome: The frame is bolted together at the edges using socket-head cap screws, and the motherboard is held in place using short standoffs, just like a traditional PC build. The 2.5in drive mount is held in place using socket head cap screws. It's all very simple really – it's super-fast to assemble and take apart.

CPC: Is it all made with precision machinery, or did you use any hand tools?
Jerome: With laser cutting, whenever you have shapes or holes to be cut out in metal, they need to be at least 50 per cent of the material thickness. This meant I had to drill and tap all of the threaded holes by hand, so I printed out templates for both the power

SYSTEM SPECS

CPU AMD Ryzen 7 2700

GPU EVGA GeForce GTX 1660 Super

Storage Samsung 960 Evo 250GB, Sabrent Rocket 512GB, ADATA 2.5in SU800 1TB

Memory Originally G.Skill Flare X 16GB CL16 DDR4 3200MHz, but I've now changed it to Crucial Ballistix 32GB CL16 DDR4 3200MHz

Motherboard Gigabyte X570 Aorus Pro WiFi

PSU EVGA B3 450W modular

Cooling Noctua NH-D15

supply and motherboard mounting points. Drilling and tapping all the hole takes a fair bit of work, but it's not too bad if you have access to a drill press.

CPC: How did you plan the cable routing?

Jerome: The cable routing with this design is straightforward. It was just a matter of placing a couple of cut-outs in the chassis plates through which cables cam pass, and leaving a bit of clearance for the cables to fit between the power supply and the motherboard mounting plate.

CPC: You've made the instructions for this chassis available for anyone to download and build themselves. What will they need in order to do this, and what was your motivation for wanting to share your design? How much would it cost?

Jerome: I thought it would be really neat to share it and see how other people could take it and make it their own. It's been really cool to see how other people have modified it to suit their purposes and manufacturing methods. One person has made it even smaller and 3D-printed the chassis, while someone else has made it from thin steel sheet. I think it's great when people can take a design and then modify it to suit their own materials, tools and building techniques.

The beauty of this design is that it lends itself to being built from a wide variety of materials to suit almost any component configuration. Cost is relative to the material used – it cost around $150 US (around £127 ex VAT) for me to have all of the thick aluminium plates laser cut, but it could just as easily be made in acrylic or a suitable wood with just a few small changes. If you don't have access to a laser-cutting or CNC milling service, the design could be modified to be cut using a band saw, scroll saw or jigsaw.

CPC: You currently have an air cooler fitted to the CPU, but could it be adjusted to accommodate a closed-loop liquid cooler?

Jerome: It could easily accommodate a liquid-cooling setup. It would just be a matter of making mounts to attach the radiator to the back side or edge of the motherboard plate.

CPC: What spec did you choose, and why?

Jerome: My hardware requirements were mostly based around doing 3D modelling and CAD work. I wanted a mini-ITX motherboard to keep it as small as possible, and the Gigabyte X570 Aorus Pro WiFi was a solid choice for the cost/features (dual M.2 slots and PCI-E 4 support) – plus, it would give me a bit of room to grow. I found a Ryzen 7 2700 on sale at a fantastic price that was too good to pass up.

Graphics was a bit trickier, as I wanted a good, small (under 200mm in length) 1080p card, and the EVGA GTX 1660 Super really fit the bill in terms of performance for the price. Mini graphics cards were getting a bit hard to find at the time. I knew I wanted to keep my ATX power supply, as SFX power supplies were getting expensive at the time, and I thought the size and weight of the ATX PSU balanced out the design better.

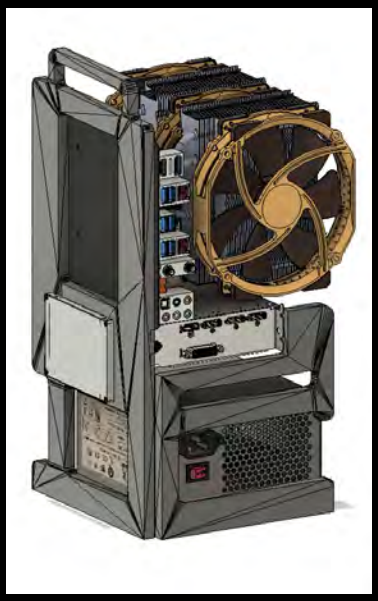
Finally, I just love the Noctua NH-D15 CPU cooler (I mean, what's not to love?) and thought it would look really cool having this large, all-black cooler that's nearly as wide as the complete system. Having all of these similar-width, black components really gave the build a sort of monolithic look that I really liked.

CPC: Do you have any trouble with dust ingress?
Jerome: No trouble at all and it's super-easy to clean. My work area is in my basement and I get very little dust down there.

CPC: Did you come across any difficulties?
Jerome: The most difficult part of the build was drilling some of the holes in the edges of the aluminium plates. I solved this by doing some interesting fixturing with a vice in my drill press.

Drilling the large hole for the power switch was a fair bit of work as well. I've since redesigned the power supply plate to remedy this, as well as make it easier to fit the graphics card.

CPC: How heavy is the final system, and is it easy to carry?
Jerome: The bare chassis weight is around 3.5lbs (around 1.6kg), so the finished build has a similar weight to a traditional case build. It's very solid feeling and super-easy to carry using the handle.



CPC: How long did it take you to complete this build, from start to finish?
Jerome: The total build time from start to finish was under two weeks.

CPC: Is there anything else you want to add about the build process?
Jerome: Just that overall it's a very straightforward build that's easy to modify. A simple vector drawing program, such as Inkscape or Illustrator, is all you need to get parts laser cut.

Also, instead of drilling and tapping holes in the edges of the plates, it would be much easier and faster to cut T-shaped slots to fit traditional threaded nuts – this would allow for construction using a much wider variety of materials as well.

CPC: Are you completely happy with the end result, or do you wish you'd done some of it differently in retrospect?
Jerome: I'm pretty happy with how it all turned out, but there are definitely some parts I'd do differently, such as sanding and smoothing all the edges, and using custom cables to make the wiring look better.

I'd also replace the 3D-printed parts with machined parts. I've already redesigned the power supply plate and changed how the power button is mounted.

I recently gave my GeForce GTX 1660 Super GPU and ATX power supply to my son to use in his system, and I replaced it with a Radeon Pro workstation card and an SFX power supply, so I think I'd like to revisit it and make it even more compact and cleaner. I'd also like to build a water-cooled version that's more gaming orientated. CPC

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CORSAIR

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Corsair Hydro X Series XD3 RGB Pump/Reservoir C

WORTH £151

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Corsair Hydro X Series XC7 RGB CPU Water Block

WORTH £70

The Corsair Hydro X Series XC7 RGB CPU Water Block combines premium construction, vivid RGB lighting and extreme cooling performance to become the centrepiece of your water-cooling loop. It has a nickel-plated copper cold plate and more than 60 high-efficiency micro-cooling fins, which efficiently draw heat away from your CPU, lowering operating temperatures and allowing for maximum overclocks. You can choose a version for Intel or AMD CPU sockets.

Corsair Hydro X Series XR5 240mm Radiator

WORTH £55

The Corsair Hydro X Series XR5 240mm Water Cooling Radiator delivers extreme custom cooling performance, with a 30mm radiator thickness and premium copper core. Its dual 120mm fan mounts on each side are ready for your most ambitious custom cooling build, and its 25 micron-thick cooling fins offer a high thermal transfer rate.

JAMES GORBOLD / HARDWARE ACCELERATED

MEMORY MATTERS

James Gorbold unveils the market dynamics of DDR4 and DDR5 memory

With so much of this issue dedicated to memory and exploring what all the specs mean, I thought it would be interesting to look beyond the tech and see how PC buyers have reacted to the choice between DDR4 and DDR5 memory over the past year. This is particularly interesting to me, having been involved in the design of multiple PC systems, including some that ended up being sent out for review in publications such as **Custom PC**.

Let's start by taking a look at standalone memory sales from retail customers. Before we dive into the numbers, it's worth bearing in mind that the memory sales data I'm going to share will include some people upgrading older systems, which will invariably be based on DDR4 memory, although the majority of sales will be memory going into new builds. So, what do the numbers tell us? Firstly, that for the past few months DDR4 remains by far and away the most popular choice with DIY PC builders, outselling DDR5 by about 550 per cent.

> With DIY PC builders, DDR4 outsells DDR5 by about 550 per cent

Apart from the obviously huge difference in sales, what's interesting about this number is that it's barely different from when Intel launched the industry's first DDR5 platform late last year. In other words, DDR5 has barely gained any advantage over DDR4 in a year. That's not to say that Intel's 12th-gen platform doesn't sell well – in fact, it's extremely popular, but a huge swathe of its sales come from DDR4 systems. For example, in the past few months, DDR4 motherboards have accounted for around 70 per cent of Intel 12th-gen sales.

The sales data for DDR4 vs DDR5 is a bit different when it comes to our professionally built desktop PCs, in which DDR4 outsells DDR5 by 400 per cent. We dive into this data in more depth than we do for standalone memory sales, because we can much more accurately track how the system is going to be used, and it reveals some interesting nuances.

For instance, gamers are voting overwhelmingly with their wallets in favour of DDR4, to the tune of 471 per cent greater sales than DDR5. In contrast, the sales of each type of memory in workstations is much closer, with DDR4 outselling DDR5 by 183 per cent. While this is still a significant lead, it's much closer than the gap between DDR4 and DDR5 sales when it comes to gaming PCs and with DIY builders.

There are a number of possible factors for this. I'm loath to buy into the idea that workstation customers are less price-sensitive than gamers. While workstations are on average considerably more expensive than gaming PCs, that doesn't mean workstation buyers don't care about value for money.

After all, when you can put together a high-end workstation for mechanical and electrical (M&E) services with a Core i9 CPU, 64GB of RAM and an RTX A4500 GPU, which would you choose – the DDR5 version that costs £4,500 or the more or less identically performing DDR4 version that costs £4,200? Instead, I suspect the difference has more to do with that fact that workstation-class motherboards, which typically have more I/O ports, faster networking, and better power and cooling than gaming motherboards, favour DDR5 over DDR4.

Of course, any memory generation transition takes time and the current market dynamic will change when AMD also embraces DDR5. It's also unlikely that DDR5 is an evolutionary dead-end such as Rambus, it's just a slow starter on a single premium priced platform. For now at least, though, the significant price premium and limited performance benefits are relegating DDR5 to second place. CPC

James Gorbold has been building, tweaking and overclocking PCs ever since the 1980s. He now helps Scan Computers to develop new systems.

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