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Welcome

Custom PC Issue 214

/ FROM THE EDITOR

The complexity of modern overclocking

I could draw up a mile-long list of things that are overly complicated. TV model names; bin collection schedules; changing the time on the oven; board games based on the lore of H.P. Lovecraft. You could now reasonably add CPU overclocking to that list, which is why we've dedicated our main cover feature to it in this issue (see p78).

My beard is speckled with enough grey hairs for me to remember when CPU overclocking involved changing the jumpers on your motherboard using a pair of tweezers, with a few limited options for your bus speed and multiplier. You might think that moving all this to the BIOS or EFI would make it easier, and for a while it arguably did.

However, AMD's introduction of huge core counts to mainstream desktop CPUs, along with aggressive boost speeds, has turned the world of overclocking into a complicated cloud of options. Some argue that there's no point in all-core overclocks any more, and you may as well leave your CPU at stock speed. Some want as much multi-threaded power as possible, while others want the fastest gaming performance. What should you do?

To further muddy the situation, there's tech such as AMD's Precision Boost Overdrive on top of the standard boosting algorithms, as well as Intel and AMD's own overclocking tools.

It's all left many people not knowing whether it's worth overclocking their CPU, and if it is, how they should even go about it. In some cases, it's still well worth applying a manual overclock to all cores and whacking up the voltage. In other cases, it's more complicated. All of which leads us to our modern overclocking guide, where we demystify the complexities of overclocking today's CPUs, and whether it's worth your while.

We take you through the basics of all-core overclocking, as well as explaining how Intel and AMD's own overclocking tools and features work, plus how to use them. We've also provided loads of safe settings for you to try on old and new CPUs from both firms, so you can get your hands dirty and overclock your CPU today. CPC

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CUSTOM PC

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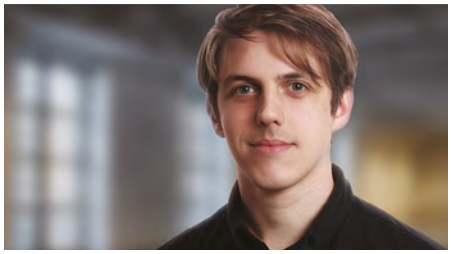

RICHARD SWINBURNE / VIEW FROM TAIWAN

NVIDIA GTC IS LIGHT ON THE 'G'

Nvidia seems to be much more interested in AI and data centres than PC gaming, argues Richard Swinburne

From his now famous kitchen, Jensen Huang recently showed the world what he was cooking up for the future of Nvidia. Despite the name, sadly gaming graphics is no longer what the Graphics Technology Conference (GTC) is about. Instead, there was a lot of focus on AI, data centres, 'accelerated computing' and 'intelligent networking', with graphics served as a side dish.

However, in discussion of Nvidia's next-gen server chips, Jensen detailed a roadmap of CPU, GPU and DPU (essentially network processors) architectures, which showed a two-year cadence of each, with alternating years of CPU and GPUs. Last September, Nvidia's Ampere GPUs launched, and this year, its Arm v9 architecture hits the streets.

That means the next generation of GPUs is likely to land around the third quarter of 2022, which is good, since no one can buy a graphics card this year anyway. It's probable that Nvidia will drop a mid-cycle GPU refresh with speed bumps – as with the RTX 2000 Super series, but if and when that happens will be down to when it can actually make them.

> The next generation of GPUs is likely to land in the third quarter of 2022

My expectation is that Nvidia will jump from using the current 8nm process for its current RTX 3000-series GPUs to a 7nm process for its mid-cycle refresh, then next year's 'RTX 4000-series' GPUs will be built on a 5nm node. The differences between eight, seven and five may not sound like a lot, but they represent huge leaps in transistor density, going from ~45 million per millimetre (8nm) to ~95 million (7nm) and then to ~175 million (5nm).

It's unlikely Nvidia will use this opportunity to lower the enormous power use of its high-end GPUs, but rather use it to pack in more RT, Tensor and shader cores. Alternatively, Nvidia could opt to spend some of its transistor budget on other tech, such as big caches, echoing this design choice at AMD (Infinity Cache) and Intel (Rambo Cache).

We need to watch Nvidia's CPUs too. In a low-key announcement, it stated that it was working in partnership with MediaTek to bring its RTX 3000 graphics to Chromebooks.

MediaTek is currently the largest non-x86 Chromebook chipmaker, and given the current litigation between Nvidia and Qualcomm over the former's potential Arm acquisition, this partnership makes sense. Nvidia shared a slide indicating that its GPUs would work alongside MediaTek's chips in a CPU-GPU paring, as with a traditional laptop, rather than putting RTX tech into a single chip.

This would be a huge gaming boost for Chromebooks, and it could also represent the first steps Nvidia is taking to bring its RTX tech into Android smartphones in future. Chromebooks have been a success in education and office environments, because they're often cheaper and have longer battery life than their Windows counterparts, so unlocking the gaming market will make Microsoft, Intel and AMD feel the heat.

Nvidia has outlined that it will make its own server processors on a two-year cadence, but it could also open the door to its own high-performance PC/laptop CPU based on a common core that competes with Intel Core and AMD Zen. It would be seriously awesome to see a third option on the market, but I doubt it will happen. If GTC reflects Nvidia's ambitions, then AI and data centres are its main focus now, rather than PCs and gaming. 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

TOKENS OF APPRECIATION

Tracy King looks at the current debate raging about non-fungible tokens, and has some ideas for their use in games

Non-fungible tokens are here! But a token for what? An arcade machine? An Overwatch loot crate? The jetwash at the BP garage? Non-fungible tokens, or NFTs, will already be familiar to many of you, but for anyone who hasn't yet wandered into the latest 'under-construction' intersection of art and technology, they're tokens on a blockchain.

Where bitcoin is fungible, like paper money (if I lend you a tenner you don't give me the exact same tenner back), non-fungibles are ... well you get it. They're unique. So in theory, when they're applied to a piece of digital content (let's say, an artwork, or a tweet), they create a way of securing ownership. Digital artists in particular are now selling artwork as NFTs, and lots of people are having Big Opinions about it.

This is good. The art world is comically old-fashioned, elitist and stubborn at times, and anything to shake it up pleases me. I've long worked at the aforementioned intersection of art and technology, and have seen firsthand how the old guard first reject, then oppose, then finally embrace new technologies once they become profitable.

I don't like Banksy's art, but I do love watching hypocritical millionaires sneer at street art while simultaneously hoovering up Banksies. There are questions about NFTs. Is their production devastating for the environment? Is it a scam and no actual money has changed hands? Is it a silly fad that will blow over as soon as it's begun? Will everyone wake up and find all their NFTs deleted like the end of Fight Club? But while the NFT debate rages its cultural impact is here to stay. Once you acknowledge the concept of an 'original' digital item, it sticks, and nowhere is that idea more exciting to me than video games.

But first, I have to add the caveat that if a solution to the enormous environmental impact of NFTs can't be found, all this is moot. There's enough potential profit flying around that lots of people are very motivated to solve it , but also some people are equally motivated to play down the emissions problem with NFTs, so beware of bias.

Anyway, NFTs in video games. The most obvious application is collectibles. NFTs have already been applied to digital basketball 'moments' via NBA Topshot, which has revenues into the hundreds of millions of dollars. They're basically, trading cards, a concept on which many blockbuster video games are based. If rare cards are desirable, imagine unique cards.

NFTs could also be worn as in-game clothing – you maybe couldn't stop another player duplicating the visuals, but you could have a way to indicate that you own the original. Indeed, they're already being applied to real-world, physical fashion. You could one day buy an NFT hat and wear it both in-game and in-chair. Nice.

> You could buy an NFT hat and wear it both in-game and in-chair

Games could offer NFTs as unique prizes or achievements too. These would have to be skill-based rather than random drops though. Any in-game token that could be traded out for regular currency could put the developer into 'this is gambling and therefore must be regulated' territory, as I've covered in previous columns about loot crates.

There are also problems around character and logo design copyright to solve, as major publishers are going to have to figure out what exactly they'll be giving away for somebody else to own.

However, with enough imagination and the potential for motivating profit, and with the assumption that (admittedly large, multiple) problems can be solved, the applications of NFTs in gaming are endless. CPC

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

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Incoming

AOC LAUNCHES NEW GAMING PERIPHERALS

Monitor maker AOC is expanding its gaming product line-up to include keyboards, mice, monitor arms and mouse mats with its new range of accessories. The flagship is the new AGON AGK700 keyboard (pictured), which has a choice of Cherry MX Blue or Red switches, a metal alloy top, per-key RGB lighting and a detachable magnetic wrist rest. The design also sports a column of macro keys on the left, and a large volume control wheel in the middle.

The keyboard line-up is further filled out with the GK200, which the company claims has 'mechanical feeling' membrane switches, and the mechanical GK500 in the middle, which uses Outemu Blue or Red switches.

Meanwhile, the mouse line-up tops out at the AGM700, which has a 16,000dpi Pixart PWM3389 sensor and eight programmable buttons. That's the same number of buttons found on the company's GM500, which has a 5,000dpi Pixart PWM3325 sensor. There's no word on UK pricing or availability yet, but you can see **eu.aoc.com/gaming/accessories** for more information.

AMD LAUNCHES ZEN 3 APUs

AMD has now officially expanded its Zen 3 processor line-up to include a range of APUs with integrated Radeon graphics, codenamed 'Cezanne'. The APU range spans from quad-core to 8-core chips, all of which have SMT enabled, so each core can handle two concurrent threads. However, the integrated GPUs are still based on AMD's Graphics Core Next Vega architecture, rather than the company's latest RDNA architecture.

At the top of the stack is the Ryzen 7 5700G, which has eight cores (16 threads) and a maximum boost clock of 4.6GHz. Meanwhile, the GPU is clocked to 2GHz and has eight Radeon Vega compute units, giving it 512 stream processors. Comparatively, AMD's Ryzen 5 3400G has 11 Vega compute units, giving it 704 stream processors, so this is a step down in terms of GPU shader power.

Six-core Ryzen 5 and quad-core Ryzen 3 variations are also available, with the former chips having seven Radeon Vega compute units, and the latter only having six of them. All the chips have 32KB of L1 instruction cache, and 32KB of L1 data cache, per core, along with 512KB of L2 cache per core. The 6-core and 8-core chips also have 16MB of L3 cache, with just 8MB of L3 cache on the quad-core chips.

Sadly, AMD's Zen 3 APU line-up is currently only being distributed to OEM partners, although we're hoping it will also make it out to retail at a later date.

CORSAIR ONE GETS SPEC UPDATE

Corsair has tweaked the spec of its mini-ITX One systems to support the latest Zen 3 and Rocket Lake-S CPUs from both AMD and Intel. The Corsair One a200 and i200 models come with a GeForce RTX 3080 graphics card as standard, with a choice of an AMD Ryzen 9 5900X, a Core i7-11700K or a Core i9-11900K CPU. You also get 32GB of 3200MHz DDR4 memory as standard, as well as a 1TB NVMe SSD.

The Ryzen 9 5900X-based a200 costs £3,300 inc VAT from **corsair.com/uk**, as does the i200 with a Core i7-11700K, while a Core i9-11900K configuration adds another £100 to the price. When we last reviewed the Corsair One (see Issue 190, p32), it came with a Core i9-9900K and GeForce RTX 2080 Ti, and we were highly impressed by its clever convection-based cooling design and compact dimensions.

Rumour control

OUR ROUNDUP OF THE LATEST UNCONFIRMED TECH GOSSIP. TAKE THESE STORIES WITH THE APPROPRIATE PINCH OF SALT

NVIDIA RTX 3060 REFRESH TO RESTRICT MINING AGAIN

After Nvidia's original GeForce RTX 3060 mining restrictions turned out to be easy to bypass, not least by one of Nvidia's own drivers, the company is reportedly refreshing the RTX 3060 GPU with a new mining-limited model. According to **HKEPC.com**, a new revision of the chip called GA106-302-A1 (the original RTX 3060 is GA106-300-A1) will feature a new PCI-E Device ID, which means it won't run with any existing Nvidia drivers.

There are also reportedly 'further mechanisms' beyond the driver to limit Ethereum mining on the GPUs. In addition, **videocardz.com** reports quotes some tweets from Twitter leaker @kopite7kimi that Nvidia could also be planning mining-limited 302 variants of its GA102 (RTX 3080 and 3090) and GA104 GPUs, which are used in its higher-end GPUs.

MSI GEFORCE RTX 3080 Ti CARDS SPOTTED

Boxes of MSI GeForce RTX 3080 Ti graphics cards have been seemingly photographed in transit between Hong Kong and the USA. The photos were shared by a Facebook user called Lok LOK in Hong Kong, and have since been widely distributed round the Web.

The labels on the boxes say 'GeForce RTX 3080 Ti Ventus 3X 12G OC', implying that the new cards will indeed come with 12GB of memory, as many people have already speculated. Large boxes of MSI GeForce GT 710 and Radeon RX 580 cards were also shown in the photographs, showing there's now demand for old GPUs amid the current stock crisis. The GeForce RTX 3080 Ti is expected to launch later in May 2021.

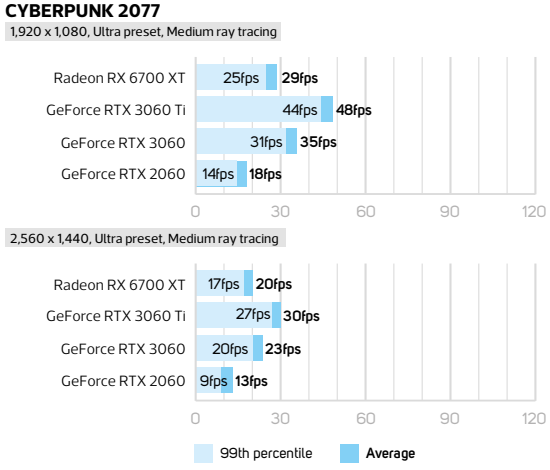
AMD GPUs GET CYBERPUNK 2077 RAY TRACING

CD Projekt Red has now finally enabled ray tracing in Cyberpunk 2077 on AMD GPUs. The update was part of the developer's patch 1.21 for the game, which also includes a colossal number of game fixes (**custompc.co.uk/CyberPatch**).

Only AMD's latest Radeon RX 6000-series GPUs, based on its RDNA2 architecture, feature ray-tracing hardware, so you'll need one of the latest graphics cards if you want to run it.

Ray tracing in Cyberpunk 2077 was already tough for the latest Nvidia hardware, with the RTX 3090 struggling at 4K, even with DLSS enabled in our tests. With no equivalent of DLSS on AMD GPUs at the moment, and with AMD's ray-tracing hardware unable to compete with Nvidia, performance isn't great. We ran the game on a Radeon RX 6700 XT, which struggled even with Medium ray tracing at 1,920 x 1,080, with an average of just 29fps.

Comparatively, Nvidia's nominally cheaper GeForce RTX 3060 Ti maintains an average of 48fps, with a 99th percentile figure of 44fps compared to an unplayable 25fps from the Radeon RX 6700 XT. Even the GeForce RTX 3060 significantly outpaces the Radeon RX 6700 XT in this test. Of course, AMD's other Radeon RX 6000-series GPUs will be quicker, but you'll still be looking at much slower performance than the equivalent Nvidia GPUs.



Letters

Please send us your feedback and correspondence to
custompc@raspberrypi.com

Radeon revival?

While I understand why you're listing eBay prices for GPUs on the Elite list now, I don't understand where you've managed to find prices so low. In Issue 213, you list the GeForce RTX 3080 at a price of £1,200, but where on earth did you find it for that price?! Whenever I search 'RTX 3080' on eBay, they nearly all cost around £1,800, usually more.

If I am going to be reduced to paying scalper prices (and let's face it, that's the situation if I want a new GPU right now), I wonder if I might be better off buying a Radeon RX 6800 XT instead – they seem to be going much cheaper than RTX 3080 cards, even if they're still way overpriced. What do you think?

NICK HOPKINS

Ben: I hate this whole situation. Yes, unless you want to buy a whole new system or wait for several months, you probably are going to be paying scalper prices on eBay. To answer your question about pricing, we search for the products on eBay with a 'buy it now' filter, and discard any obvious scams or offerings from sellers with very little feedback.

Last month, the cheapest genuine RTX 3080 card was going for £1,200, but you're right that prices seem to have escalated ridiculously since then. Having monitored this over a few weeks, it's clear that RTX 3080 cards are generally going for around £500 more than Radeon RX 6800 XT cards, with a bigger gap between RTX 3090 and Radeon RX 6900 XT cards, presumably because Nvidia cards are better for crypto mining.

At normal pricing, the Radeons are highly competitive in terms of raw shader power, but not so much when it comes to ray tracing, and AMD currently has no equivalent of DLSS to help. When there's such a huge price difference though, it's a no-brainer – buy the Radeons – the extra ray-tracing performance isn't worth an extra £500. As a result, we're now listing the Radeon RX 6800 XT and 6900 XT on our Elite list instead. As AMD's Zen 3 Ryzen 9 CPUs are currently nowhere to be found, we've also removed them from out Elite gaming builds.

At eBay scalper prices, the Radeon RX 6800 XT is now a much better buy than a GeForce RTX 3080

When's the next issue out?

CUSTOM PC

Issue 215
On sale on Thursday, 10 June

Some love for homelabbing?

Hi **Custom PC**, I'm a long-time reader of the mag and it's been very useful and enjoyable. Recently, I started branching out into networking and ended up with a 'homelab' in my loft. It's been a lot of techy fun and a great experience.

My lab is a 16U, 300mm deep 19in rack and it has a 16TB Synology NAS, an EdgeRouter X running three VLANs, a Unifi nanoHD access point (on PoE), an old Core i7-3770K with 16GB of RAM running Proxmox with eight containers, a Raspberry Pi 2, Raspberry Pi 3 and Raspberry Pi 4, plus a Rock64. There's also a patch panel and Netgear 24-port PoE managed switch, multiple PoE security cameras and an unmanaged 5-port sub-switch for my living room, and all my phones, tablets, PCs and IoT bits around the home are connected on CAT-6 or Wi-Fi.

I know it's not a 'custom PC', but it's a box of components that I've carefully selected and assembled. My build is a bit messy (I've attached a pic), but there are beautiful builds online with LED lighting, colour schemes, customised cases and lots more. I wondered if it might be a fun extension to the mag as a rotating feature.

STEVEN CAMPBELL

Ben: This is a really interesting idea – I've been following homelabs for a little while online, and there are indeed some really cool setups. I'm not sure enough **Custom PC** readers would be interested enough to make it a regular rotating feature, but I think it could be worth us looking at it as a one-off at some point.

Steven's 'homelab' networking setup in his loft

PHILIPS

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Reviews

LGA1200 PROCESSORS

INTEL ROCKET LAKE REVISITED

Last month we just about managed to squeeze Intel's 11th-gen Rocket Lake CPU coverage into Issue 213, reviewing the Core i9-11900K, Core i7-11700K and Core i5-11600K. The launch wasn't easy for us to navigate under our time constraints, though, with our reviews using very early BIOS and software versions, which may have impacted on boosting, performance and overclocking.

The most significant change, though, was that Intel announced its Adaptive Boost Technology just days before the launch, giving both us and motherboard manufacturers very little time to get to grips with it. We didn't' even have time to implement it in our testing, potentially painting the Core i9-11900K in a less positive light than it might have deserved.

This month, now the dust has settled, Adaptive Boost Technology has been implemented on all Z590 boards and there have been more than a few BIOS updates, we felt it was important to see what, if any, performance improvements have surfaced in the meantime.

We've picked two CPUs for retesting. First up is the Core i5-11600K, which doesn't benefit from the Core i9-11900K-specific Adaptive Boost Technology, but may see improvements from using the latest BIOS versions. We've also retested the Core i9-11900K, as Intel's Adaptive Boost Technology has the potential to increase multi-threaded performance significantly in the right conditions.

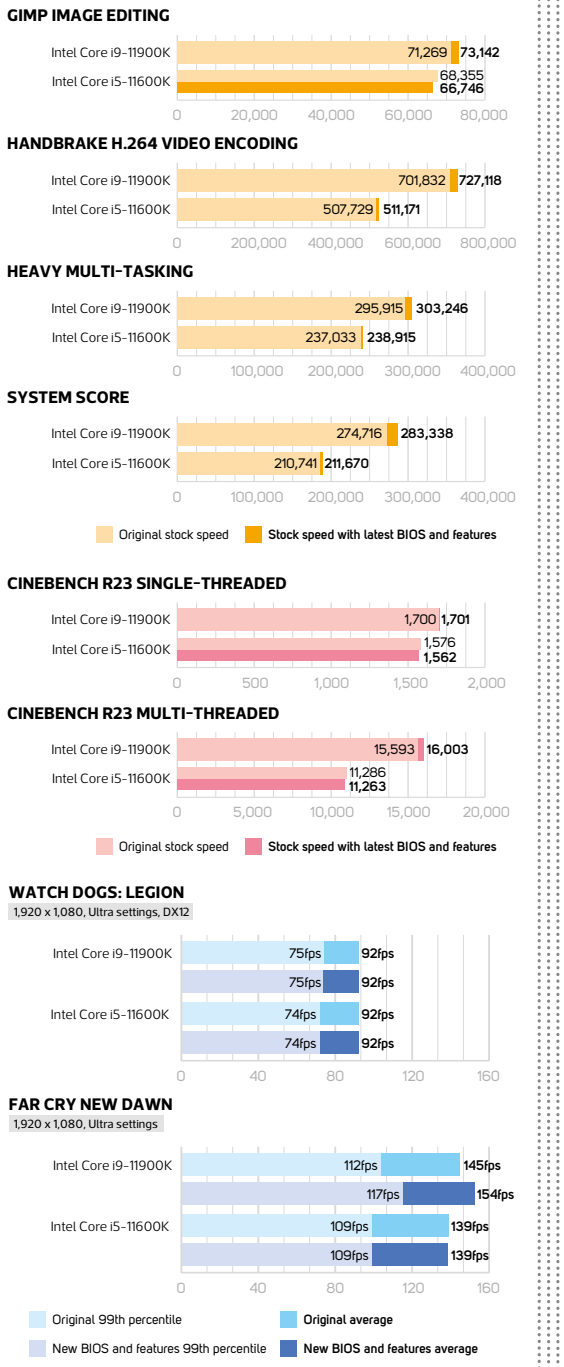
We saw no tangible performance improvement from the Core i5-11600K when using the latest BIOS

For testing, we used exactly the same hardware as we did in our CPU Labs test last month, which includes an Asus ROG Strix Z590-E Gaming WiFi motherboard and an Nvidia GeForce RTX 3070 Founders Edition graphics card.

Initially, we didn't see much improvement with the Core i5-11600K. The score in our image editing test, which benefits from strong single-threaded performance, even fell slightly, but the video encoding and multi-tasking RealBench scores increased by similarly small amounts with an overall system score of 211,670 compared to 210,741. Cinebench scores were within the margin of error too, with next to no difference in the single-threaded and multi-threaded results. Meanwhile, Watch Dogs: Legion saw identical frame rates between our original results and our updated test system, as did Far Cry New Dawn.

The Core i9-11900K was different, though, with Adaptive Boost Technology making a tangible difference by increasing the all-core boost frequency. Starting with Cinebench, while

BENCHMARK RESULTS



there was no significant boost to the single-threaded result, the multi-threaded score rose from 15,593 to 16,003.

That was enough for the Core i9-11900K to extend its lead over the Ryzen 7 5800X, which managed 15,422 at stock speed, and enough to leapfrog the 15,786 scored by Intel's Core i9-10900, which has two more cores.

Moving on to RealBench saw an improvement to the image editing result, which rose 71,269 to 73,142, but the biggest gains were, not surprisingly, in the more multi-threaded portions of the tests. The video encoding score saw a boost from, 701,832 to 727,118 and the multi-tasking score increased from 295,915 to 303,246 with the system score rising from 274,716 to 283,338.

Intel's Adaptive Boost Technology can be enabled in your motherboard's EFI if you have a Core i9-11900K

Finally, Watch Dogs saw no gains, but Far Cry New Dawn, which usually scales well with frequency increases, saw the minimum 99th percentile rise from 112fps to 117fps, while the average frame rate increased by 10fps.

Overclocking hasn't improved, though, and the usual voltages we've used to hit frequencies over 5GHz on previous Intel CPUs don't seem to be enough with Rocket Lake. We did some more investigating as part of this month's overclocking guide (see p78), and found that the Core i5-11600K needed well over 1.4V to hit 5GHz.

That's going to demand some seriously good cooling, which is why we cut this frequency to 4.9GHz for the guide. In short, even with the latest BIOS versions, you'll need to use significantly higher vcores than beforehand if you want to top 5GHz with most Rocket Lake CPUs.

Overall, there doesn't seem to be any significant performance boost to Rocket Lake from using the latest BIOS versions. The only performance increases we saw were thanks to Adaptive Boost Technology, which is only supported on the Core i9-11900K.

Here, with all cores occasionally hitting 5.1GHz at the same time in multi-threaded workloads, the gains were noticeable, but not enough to turn it into a wonder chip – the boost in performance is under 5 per cent. If you do opt for the Core i9-11900K, it's worth turning on Adaptive Boost Technology, which you'll need to do manually in the overclocking section of your EFI.

Thankfully, though, even these results wouldn't change our review conclusions from last month. The Core i5-11600K is a great CPU for the cash, but the Core i9-11900K, while extremely fast and able to match previous-generation Intel CPUs with two more cores, is poor value compared with the Ryzen 7 5800X and Ryzen 9 5900X. The point is also largely moot, as both the Core i9-11900K and Ryzen 9 5900X are out of stock everywhere at the moment anyway.

ANTONY LEATHER

MINI-ITX Z590 MOTHERBOARD

GIGABYTE Z590I VISION D / £284 inc VAT

SUPPLIER scan.co.uk

Gigabyte's Z590I Vision D is the first mini-ITX Z590 motherboard we've seen in the flesh, and it packs a wallop as far as features go. You'd hope so too, given that it costs nearly £300, but it's likely a fair chunk of that price tag is taken up by the Z590I Vision D's key feature, which is Thunderbolt 4 support.

Gigabyte has two Z590 mini-ITX boards, with the other – the Z590I Aorus Ultra – costing less money but lacking Thunderbolt 4, although it does have a few extra power phases than the Vision D, so it may be better for overclocking or even handling the power-hungry Core i9-11900K at stock speed.

Thunderbolt 4 can be really handy though. You can output practically every connection you'd usually hook up to your motherboard's I/O panel over a single cable, including audio, networking and USB cables. The Z590I Vision D also has a DisplayPort input, which allows you to connect your graphics card's output to the motherboard using a short cable, so you can run your main video output over Thunderbolt 4 too. There's an upper limit of 4K at 60Hz here, but it can hit 5,120 x 2,880 at 60Hz if you just use your CPU's integrated graphics.

The only cables you'd then need to connect to your PC are the power and Thunderbolt cable, with support for daisy-chained Thunderbolt 4 hubs, super-fast storage or networking adaptors. It's no surprise, then, that Gigabyte is aiming the board at creators, but there's plenty to like about the board from an enthusiast's point of view too.

It looks stunning for a start, with a white colour scheme and the same triple heatsink design as its Aorus sibling, with a heatpipe connecting them to spread the load. The VRMs failed to top more than 55°C according to our software during a ten-minute prime95 stress test, so VRM temperatures shouldn't be an issue at stock speed or with mild overclocks. The rear panel offers four USB 3 ports, two USB 2 ports, a 2.5 Gigabit Ethernet port and aerial connectors for the 802.11ax Wi-Fi.

Audio outputs for the Realtek ALC4080 codec are limited, though, with just a single line-out plus a mic-in, so you'll be limited to stereo analogue speakers, although to be fair, anyone serious about surround sound could plug their graphics card's HDMI output into a surround receiver. The M.2 doesn't make much sense either, with a large heatsink sitting a centimetre or so above the top M.2 heatsink, but it lacks any thermal paste or pads to offer decent thermal contact, and will likely hinder airflow to your SSD too.

Thankfully, the heatsink that does attach to the SSD kept its peak load temperature below 55°C – without it, our back-to-back runs of CrystalDiskMark saw that temperature top 70°C, so it does still offer a sizeable temperature reduction.

SPEC

Chipset
Intel Z590

CPU socket
Intel LGA1200

Memory support
2 slots: max 64GB DDR4 (up to 4600MHz)

Expansion slots
One 16x PCI-E 4

Sound
8-channel Realtek ALC4080

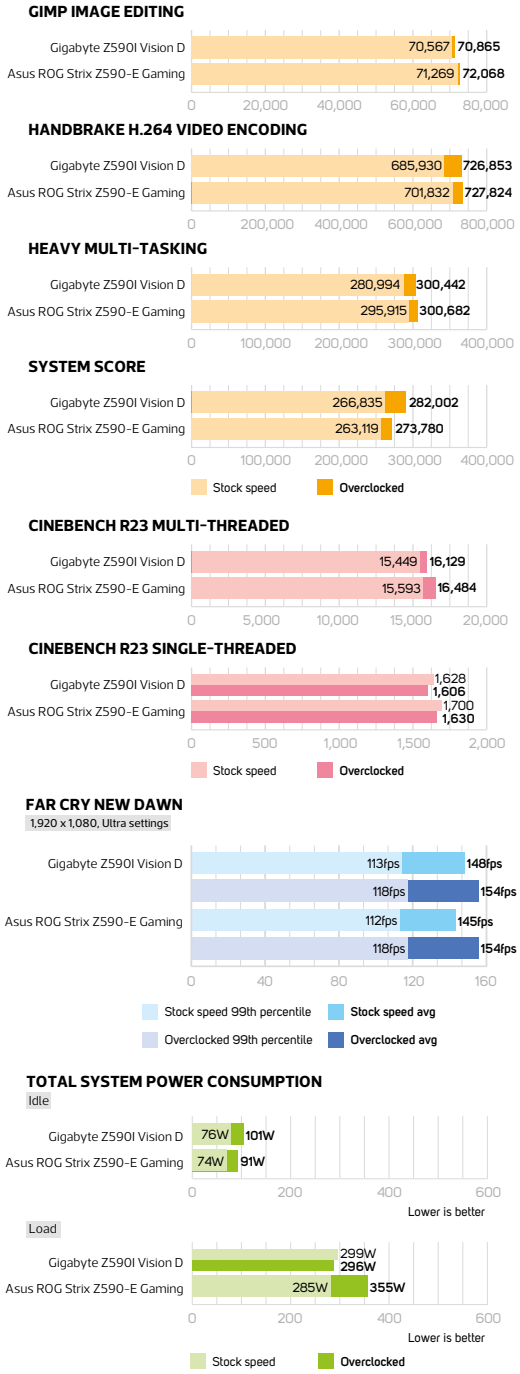
Networking
1x Intel 2.5 Gigabit LAN, 802.11ax Wi-Fi

Cooling
Four 4-pin fan headers, VRM heatsink with heaptipe, M.2 heatsink

Ports
4 x SATA 6Gbps 1 x M.2 PCI-E 4, 1 x M.2 PCI-E 3, 2 x USB 3.1 Type-A, 1 x USB 3.1 Type-C, 1 x USB 3.1 Type-C header, 2 x USB 3, 1 x LAN, 1 x line-out jack, 1 x mic jack

Dimensions (mm)
170 x 170

BENCHMARK RESULTS



It managed a peak read speed of 4,980MB/sec and write speed of 4,274MB/sec, which is in line with what we've seen from other PCI-E 4 boards. As well as the top PCI-E 4 M.2 slot, there's a second M.2 slot that supports PCI-E 3 or SATA M.2 SSDs on the underside of the PCB, and you get SATA 6Gbps ports as well.

The board includes a record number of fan headers for a mini-ITX PCB too, with a total of four thanks to the use of mini

connectors and adaptor cables. This means you can control numerous case fans, a pump and radiator fans for liquid cooling separately. Comparatively, most ATX motherboards often only have one or two more headers.

Meanwhile, Gigabyte's new EFI dons a snazzy white colour scheme with the Z590I Vision D, which is definitely more appealing than the aging EFI design of its older boards. The already excellent fan control suite gets an upgrade too, with Smart Fan 6 offering a much larger fan curve graph for finer tweaking and more temperature points, so you can adjust the curve to a greater degree.

Performance

Despite using the latest F4 BIOS, we couldn't find an option for Adaptive Boost Technology in the EFI, and had to use a beta BIOS still unreleased to the public from Gigabyte in order to enable it. We also had to push all the power and load time limits to the maximum settings to get our CPU to sit at 5.1GHz, but that's standard with other Z590 boards too.

We did this with a vcore of 1.38V – a little higher than some other boards we've tested, but the CPU only hit a peak of 83°C. This overclock saw the multi-threaded Cinebench score rise from 15,449 to 16,129 and system score from 266,835 to 282,002. The audio performance was a tad uninspiring, though, with a dynamic range of 103dBA and a noise level of -102dBA.

Conclusion

The Z590I Vision D is a stunning little motherboard that's loaded with features to please high-end content creators and enthusiasts alike. Its EFI is refreshingly different-looking and sports superb fan control, and it also overclocked our Core i9-11900K to 5.1GHz with relative ease.

However, it's limited in other areas such as audio, and its Thunderbolt 4 support also bumps up the price. While Thunderbolt 4 can be very handy for cabling, it's still a niche feature, so unless you need Thunderbolt 4 or just love the white design, its cheaper sister board will be a better option. If you're happy to jump on the Thunderbolt 4 bandwagon and pay for it, though, this is a highly capable board.

ANTONY LEATHER

VISION

+ Attractive white design
+ Good VRM and M.2 cooling
+ Thunderbolt 4

THANOS

- Expensive
- Only one audio output
- Only worth it for Thunderbolt 4

VERDICT

A great-looking motherboard that brings the Z590 chipset to mini-ITX systems, although it's only really worth the high price if you want Thunderbolt 4.

PERFORMANCE **32/35**

FEATURES **29/35**

VALUE **24/30**

OVERALL SCORE **85%**

ATX B550 MOTHERBOARD

NZXT N7 B550 / £210 inc VAT

SUPPLIER scan.co.uk

It's been a long time since we've reviewed a motherboard from a brand other than the usual four, and while samples of NZXT's previous boards were hard to get, NZXT was keen to send us one of its latest motherboard – the N7 B550. As its name suggests, it's a Socket AM4 motherboard that uses the B550 chipset, so it's compatible with AMD's Ryzen 3000 and 5000-series CPUs.

It's not cheap, though, and that price is probably dictated to some degree by the enormous shroud covering the PCB. Available in white or black, it's the board's key feature and it looks extremely smart indeed. Another unique feature is support for NZXT's CAM software, which you may know from its Kraken AIO liquid coolers, giving you full control over each fan header's response curve with presets or manual control.

There are even more adjustment points than in Gigabyte's new fan control suite in the Z590I Vision D's EFI (see p18), although you can only select the CPU and GPU for the temperature input. The software can also control the board's RGB lighting headers, and overall, it feels much more polished than any other motherboard software we've used.

The downside is that, if you prefer to tweak your cooling from the EFI, there's no snazzy user interface, as you get on other motherboards. That's a little surprising, as NZXT hasn't made the EFI or indeed the motherboard itself, but has partnered with ASRock, which does have an admittedly basic fan utility in its EFIs. The EFI is unmistakably an ASRock design, but that's as far as any familiarity goes.

Meanwhile, the N7's 12+2 power phase design is cooled by two large heatsinks that kept the VRMs below 55°C under load in testing. Sadly, the M.2 SSDs slot covers don't act as heatsinks, though, and our PCI-E 4 SSD actually began to throttle to half its rated speeds during our stress test, so you'll need to leave these caps off to improve M.2 airflow.

The shroud can also foul PCI-E riser cables that are longer than the PCI-E connector on your graphics card, so you'll want to remove it in this area if you want to mount your graphics card vertically.

The rest of the PCB is well laid-out, though, with a generous count of seven fan headers, on-board power and reset buttons, and a Type-C USB header too. NZXT has angled the six SATA 6Gbps ports and dual USB 3 headers, so they sit underneath the edge of the shroud, making for a super-clean look and leaving just the essential large power connectors in full view through their cut-outs in the shroud. It's definitely a very good-looking motherboard, which will appeal to those who prefer a minimalist look.

The rear I/O panel has a decent array of features too. While there's no LED POST code display on the PCB, tweakers and overclockers benefit from a clear-CMOS button and a USB BIOS Flashback button here.

SPEC

Chipset
AMD B550

CPU socket
AMD Socket AM4 (Zen 2, Zen 3)

Memory support
4 slots: max 128GB DDR4 (up to 4666MHz)

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

Sound
8-channel Realtek ALC1220

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

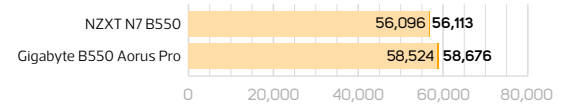
Cooling
Seven 4-pin fan headers, VRM heatsinks

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

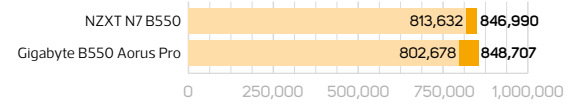
Dimensions (mm)
305 x 244

BENCHMARK RESULTS

GIMP IMAGE EDITING



HANDBRAKE H.264 VIDEO ENCODING



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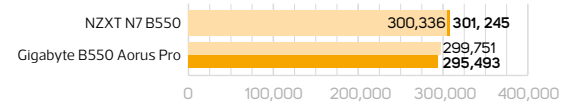

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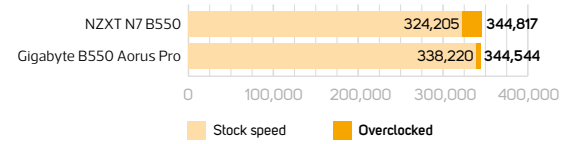
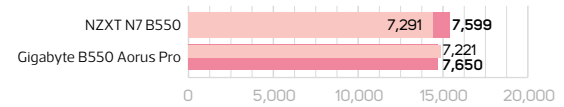
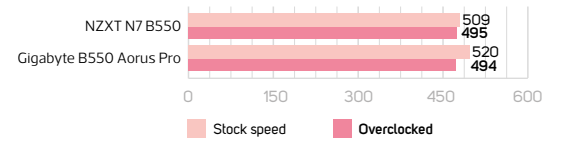


CINEBENCH R20 MULTI-THREADED

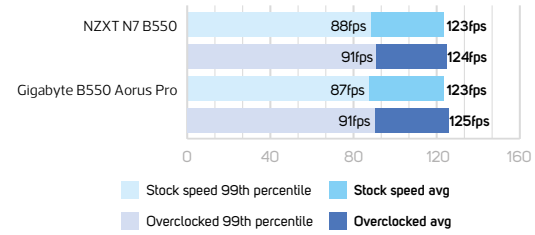


CINEBENCH R20 SINGLE-THREADED



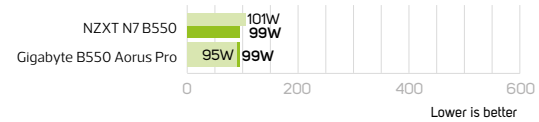
FAR CRY NEW DAWN

1,920 x 1,080, Ultra settings

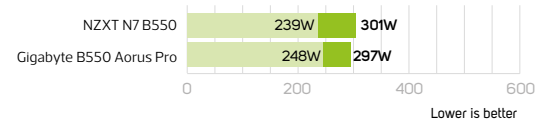


TOTAL SYSTEM POWER CONSUMPTION

Idle



Load



The total of nine Type-A USB ports is great as well, and all but two of them are USB 3 or faster, and get a full-fat USB 3.1 Type-C port. The full complement of audio jacks are hooked up to a Realtek ALC1220 audio codec, and you get an optical output as well. Also on the back you'll find the aerial connectors for the 802.11ax Wi-Fi, a 2.5 Gigabit LAN port and, if you plan on using an APU, an HDMI port.

Performance

It's been a while since we've tested a B550 motherboard, so we've run our usual suite of tests with the Ryzen 9 3900X for comparison, but also tried overclocking the Ryzen 9 5900X as well. We hit the usual 4.3GHz with 1.4V using the former and 4.6GHz with 1.25V with the latter, so the board is easily capable of overclocking both Zen 2 and Zen 3 CPUs.

The overclock saw the multi-threaded score rise from 7,291 to 7,599 in Cinebench R20, although as usual, the single-thread score fell as the overclock disabled boosting. All our RealBench tests saw an increase, though, with the system score rising from 324,205 to 344,817. Audio performance was on par with the competition too, with a dynamic range of 105dBA and noise level of -104dBA, while the M.2 speed with our PCI-E 4 SSD hit 4,997MB/sec read and 4,276MB/sec write with the socket cap removed.

Conclusion

There aren't many white B550 motherboards, and the NZXT N7 undoubtedly looks fantastic, with a choice of black and white models, and its shroud extending over the PCB. It's a great choice if you're planning on picking up a white case, cooler and graphics card.

We'd like to see future iterations of the board work M.2 heatsinks into the design, though, and swap the plastic M.2 caps for metal ones that act as heatsinks to prevent throttling. Removing the caps to use M.2 SSDs also spoils the look. Installing a PCI-E riser cable can also be a problem with the shroud.

However, the extra features, such as CAM software fan and lighting control, power, reset and clear-CMOS buttons, Wi-Fi and an abundance of Type-A USB ports, are all useful. This is a great motherboard, especially if the added aesthetic features appeal to you.

ANTONY LEATHER

MASS EFFECT

- \+ Good VRM cooling
- \+ Attractive design
- \+ CAM software fan and light control

MASS HYSTERIA

- – M.2 caps can't be used with SSDs installed
- – No BIOS fan control suite
- – Quite expensive

PERFORMANCE **32/35**

FEATURES **31/35**

VALUE **22/30**

OVERALL SCORE **85%**

VERDICT

A fantastic-looking B550 motherboard with plenty of features, although the plastic shroud causes a few issues.

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240MM AIO LIQUID CPU COOLER

BE QUIET! SILENT LOOP 2 240 / £120 inc VAT

SUPPLIER cclonline.com

With a price of £120 inc VAT, the be quiet! Silent Loop 2 is an expensive all-in-one liquid cooler, especially when you consider that it lacks the software control you'd find on Corsair and NZXT's equivalents, while the Antec Neptune 240 can be had for £40 less. However, the Silent Loop 2 240 does boast some features that might help to justify that extra outlay.

Firstly, it includes powerful fans, with the included pair of Silent Wings 3 fans able to spin up to a massive 2,200rpm – 600rpm faster than those on the Antec cooler. Despite this, while they're definitely audible at full speed, they weren't that much louder than those on the Neptune 240.

A three-chamber pump has also been strapped to the setup, which be quiet! claims reduces noise. The decibels are further culled by using dampening to reduce vibrations inside the housing. It's certainly not silent, as be quiet! claims, but it's easily one of the quietest pumps we've had the pleasure of not hearing – it was inaudible to our ears once we were more than a couple of feet away from it.

The pump also features an enlarged cold plate, which should be useful for dealing with LGA2066 and Threadripper CPUs, although you'll need to buy an optional mounting kit for the latter.

The fans also have fluid-dynamic bearings and funnel-shaped inlets, which be quiet! claims boosts static pressure. They also have large vibration-killing dampeners in the mounting points. They're devoid of RGB lighting, though, which is fairly typical for be quiet! products, but the company has broken away from its normal light-free strategy with the pump housing, which has a small illuminated logo and LEDs surrounding a neat brushed metal cap.

The digital RGB lighting here can be controlled using a 3-pin RGB motherboard header or using the included controller, which can cycle through lighting modes and colours. There's not much else in the box, though, apart from a two-way 4-pin splitter cable, which enables you to power both fans from a single header, but the pump needs to be connected to a separate one. However, there's no fan hub as we saw with the Antec Neptune 240, or any other cable clutter-reducing features.

There is one very interesting final component in the box, which is a container full of clear coolant. This might seem odd with an AIO liquid cooler, but the coolant in sealed loop coolers can slowly evaporate over time, resulting in air bubbles forming inside. These bubbles can find their way into the pump, causing it to become noisy and even run dry, which can at best impact on performance, and at worse stop it working.

This is also the reason you should aim to position the pump at a lower level than the radiator with AIO liquid coolers, as the radiator acts as a reservoir, trapping this air. By topping up the coolant every year or two using a small port on the radiator, you should stop air forming inside the unit, keeping it quiet and avoiding the need to worry about certain pump and radiator orientations affecting performance with low coolant levels.

Meanwhile, installation involves an above-average number of parts with mounting pins required on most sockets, and a backplate is needed on Socket AM4 and LGA115x/LGA1200. However, installation is straightforward, with just two screws securing the pump to the mounting bracket, so it's easy to fit the cooler with the motherboard already in the case too.

Sadly, if you want to add more fans, there aren't enough screws included in the box, but given the radiator is just 27mm thick, extra fans are unlikely to improve on the included 2,200rpm monsters anyway.

QUIET LIFE

+ Supremely quiet at low and medium speeds
+ Powerful cooling at full speed
+ Refillable loop

QUIET DESPERATION

– No software control
– Fans are loud at full speed
– Competition is cheaper and nearly as cool

SPEC

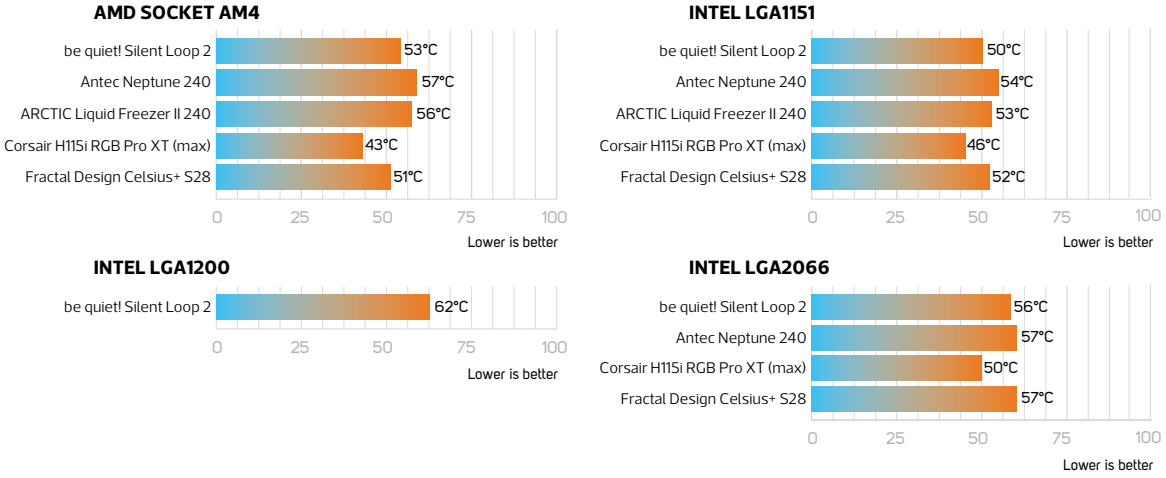
Compatibility
Intel: LGA115x, LGA1200, LGA2066, LGA2011
AMD: Socket AM4, AM3/+, AM2/+, FM2/+, FM1, (TR4/X with optional kit)

Radiator size with fans (mm)
120 x 274 x 52 (W x D x H)

Fans
2 x 120mm

Stated noise
38dBA

TEMPERATURE RESULTS



Performance

In our Socket AM4 system, the be quiet! Silent Loop 2 managed to undercut the Antec Neptune 240 by 4°C and the ARCTIC Liquid Freezer II 240 by 3°C, performing better than the Corsair H115i RGB Pro XT on its lowest fan speed, albeit with more noise.

In our LGA1151 system, dealing with an overclocked Core i5-9600K, there was a similar difference, where the Silent Loop 2 shaved 4°C off the Antec cooler's result and 3°C off the ARCTIC cooler's delta T, and bettering the Corsair H115i RGB Pro XT on its medium fan speed setting.

When pitched against Intel's Core i9-11900K, which was overclocked to 5.1GHz with a vcore of 1.38V, the delta T of 62°C, derived from an ambient temperature of 24°C and CoreTemp-reported temperature of 86°C, was a little toasty. However, it was also well within thermal limits, so the be quiet! Pure Loop 2 can confidently handle Intel's hot-running new 11th-gen flagship.

Finally, dealing with the monstrous Core i9-9980XE, the delta T of 56°C was only 1°C cooler than the Antec Neptune 240, but larger coolers have to run at full speed to beat it. When wound down to lower speeds, the fans quickly became just as quiet as the pump, and trimming both speeds using a 7V adaptor made the noise inaudible unless we put our ears right next to the cooler.

Conclusion

The be quiet! Silent Loop 2 240 is one of the quietest AIO liquid coolers we've tested, and while the fans were never going to be silent at blistering 2,200rpm speeds, they're far from the loudest fans we've reviewed at full pelt. Tuned down to 7V, they're practically inaudible, which bodes well for low to medium loads if you want to keep noise to a minimum.

The pump is equally inspiring here, barely making any noise at full speed, where it lacked the annoying whine of many other coolers, with the low hum likely to be inaudible outside your case. Cutting the speed further made it so quiet that we could only hear it when our ears were right next to it. Cooling is definitely better than cheaper AIO liquid coolers too, although only by a few degrees.

The only issue is that the Silent Loop 2 can't quite justify its price tag, which is significantly higher than the likes of the Antec Neptune 240.

If your budget sits at £100 or less, there are clearly some good alternatives. If low noise is a priority, though, you'll appreciate the Silent Loop 2's ear-pleasing credentials.

ANTONY LEATHER

VERDICT

A simple, smart liquid cooler that's blissfully quiet and can deal with high heat loads, although it's also expensive.

LGA115x / LGA1200

COOLING 32/40
FEATURES 15/20
DESIGN 17/20
VALUE 16/20
FITTING Easy

OVERALL SCORE 80%

AM4

COOLING 33/40
FEATURES 16/20
DESIGN 17/20
VALUE 16/20
FITTING Easy

OVERALL SCORE 82%

LGA2066

COOLING 33/40
FEATURES 16/20
DESIGN 17/20
VALUE 16/20
FITTING Easy

OVERALL SCORE 82%

ATX CASE

ANTEC DF700 FLUX / £70 inc VAT

SUPPLIER scan.co.uk

It's tough to stand out in the highly competitive sub-£100 case market right now. You can use a striking design, unique or premium features or even lavish materials, but all these additions add up and make offering a decent case with good cooling for under £100 a tall order. Imagine our surprise, then, when we opened the box of the Antec DF700 FLUX and found a £70 chassis that ticked a number of these boxes, but went even further and included a highly generous total of five 120mm fans as standard.

As if that wasn't enough, three of these fans in the front section feature digital RGB lighting, and Antec includes a controller with a button on the front panel to cycle through colours and modes, while you can also connect them to any motherboard using a 3-pin or Gigabyte-specific connector, which is included.

With five fans included in the box, our first thought was 'wouldn't it be nice if Antec included a fan hub too?' And sure enough, the far side panel reveals one with six ports and all-but-one of the included fans already hooked up to it. The hub even includes six 3-pin RGB headers for connecting additional fans or light strips.

The fifth fan sits in a box as standard, allowing you to position it where you like. There are five spare locations, with two vacant fan mounts in the roof that support either 120mm or 140mm fans, as well as 360mm and 280mm radiators. In addition, there are two 120mm fan mounts in the PSU cover, which is where Antec suggests you mount the fan, so it can feed your GPU with additional airflow.

However, with our short graphics card being sat over the PSU, there was limited space for air to pass through the vent with the PSU sat immediately below it, so longer cards with the fan in the second forwardmost slot will likely see more benefit from this fan.

Meanwhile, the front section can offer a home to a 280mm or 360mm radiator, or a trio of 140mm fans in place of the three 120mm fans included already, with a final 120mm fan in the rear acting as the only exhaust. The case caters well for air cooling as well, with 175mm of CPU cooler clearance and 405mm of graphics card clearance, although there's no option for a vertical GPU mount.

All inlets are covered with dust filters, including a neat magnetic one in the roof that sits flush with the panel, as does a second inside the far side panel that improves airflow to the PSU cover fan though the lower part of the panel. There's a full tempered glass side panel as well, and both side panels have embedded thumbscrews, and are quick and easy to remove.

The case catches your eye from the outside too, with the three RGB fans putting on a great show, but also because the front mesh panel here has a striking wave pattern bent into it. This really makes it stand out from the crowd. You even get Velcro cable ties, although there are just two of them, and the cable-routing holes lack grommets to help hide the cables. Still, with plenty of holes around the motherboard, routing your cables won't be a problem.

Antec has nailed the storage arrangement too, with space for up to three hard disks and three further dedicated 2.5in SSD mounts. The front panel has two USB 3 ports, audio jacks, the LED control button and power button, only lacking USB Type-C and reset buttons, although a Type-C port is still a rare luxury at this price. Even here, though, Antec has been thoughtful and included rubber port covers to prevent dust ingress.

SPEC

Dimensions (mm)
220 x 467 x 486 (W x D x H)

Material
Steel, plastic, glass

Available colours
Black

Weight
7.4kg

Front panel
Power, 2 x USB 3, LED control, stereo, mic

Drive bays
3 x 2.5/3.5in, 3 x 2.5in

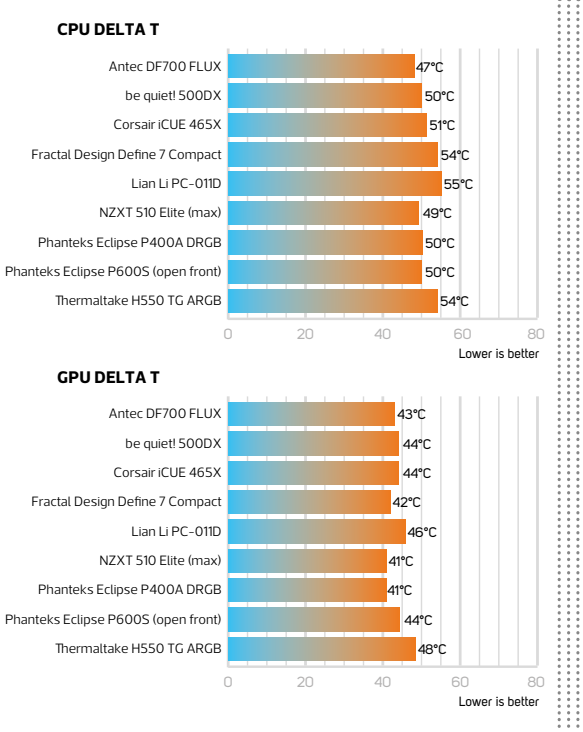
Form factor(s)
ATX, micro-ATX

Cooling
3 x 120/140mm front fan mounts (3 x 120mm fans included), 1 x 120mm rear fan mount (1 x fan included), 3 x 120/140mm roof fan mounts (fans not included), 2 x 120mm PSU cover fan mounts (1 x 120mm fan included)

CPU cooler clearance
175mm

Maximum graphics card length
405mm

TEMPERATURE RESULTS



Performance

Thanks to its army of fans, the Antec's CPU delta T of 47°C was fantastic, being easily the best result we've seen recently. The GPU delta T wasn't quite as stellar, but we suspect the PSU and fan arrangement wasn't ideal for our short graphics card, with the PSU starving the fan of air in this rear mount. However, the second PSU cover mount in front of it was too far forward for our GPU to make use of it.

In the end, though, a GPU delta T of 43°C was still cool enough to beat the be quiet! 500DX, Corsair iCUE 465X and Thermaltake H550 TG ARGB, but the Fractal Design Define 7 Compact was 1°C cooler, with the Phanteks Eclipse P400A DRGB extending that gap to 2°C. The fans were reasonably loud at full speed, but the noise wouldn't be unpleasant with the PC sat under your desk.

Conclusion

We're honestly amazed that the Antec DF700 FLUX costs just £70 inc VAT. The fact that the package includes five fans, three of which have digital RGB lighting and can be operated with an included lighting controller that also doubles as a fan hub is incredible enough. But to have most of the usual conveniences of more expensive cases, such as extensive, easy-to-remove dust filters, additional cooling via the side panel, a tempered glass panel and Velcro cable ties to name a few is the icing on the cake.

Those five fans don't sit idle either, enabling the DF700 FLUX to hit some seriously low temperatures. Were our graphics card a bit longer, we'd likely have seen a lower result here too.

The case is sturdy, well made and sports a striking mesh panel in the front, while it also provides plenty of space for all-in-one liquid coolers and even custom loops.

This would be a great case for £90, but the fact it costs just £70 means it's a bargain. It's ideal if you want an affordable case that has all you need to build a well-cooled PC, while offering plenty of scope for adding large liquid coolers or custom water-cooling gear in the future.

ANTONY LEATHER

FLUX CAPACITOR

+ Excellent CPU and GPU cooling
+ Superb value
+ RGB lighting

BURNT CAPACITOR

− No USB Type-C
− PSU limits effectiveness of rear PSU cover fan
− No vertical GPU mount option

VERDICT

Superb cooling ability, great design and loads of features for a surprisingly low price.

COOLING **29/30**

FEATURES **17/20**

DESIGN **25/30**

VALUE **20/20**

OVERALL SCORE **91%**

32IN GAMING MONITOR

DELL S3220DGF

/ £399 inc VAT

SUPPLIER currys.co.uk

SYNCING

+ Consistently impressive image quality
+ Good balance of size, resolution and curve
+ Sturdy, subtle design

SINKING

– Only middling HDR performance
– Not the best response time
– Some missing features

Gaming monitors from Dell often come with Alienware branding, but the Dell-branded S3220DGF is a subtler affair. You won't find wild design or RGB LEDs on this panel – instead, it concentrates on providing a solid experience. The Dell's panel uses VA technology, which should deliver superb contrast, and it has a 2,560 x 1,440 resolution, a 165Hz refresh rate with AMD FreeSync 2 support and an 1800R curve.

It's a good specification for lots of gaming scenarios – the curve and large diagonal make single-player games look immersive, and the refresh rate is quick enough for mainstream esports. The density level of 92ppi is good enough for esports too, and the relatively low resolution means you won't need an enormously powerful GPU to play games on this panel at native resolution. However, you'll want to move up to a 4K screen if you want crisper imagery.

Decent design joins the solid internals. The plastic exterior is sturdy and discreet, the display doesn't wobble, and it has height, swivel and tilt adjustment – the only missing feature is portrait mode. It has four USB 3 ports and a straightforward, fast on-screen display menu system. Aside from the lack of RGB features, there are also a few notable missing gaming features – it has no USB-C ports or headset hook, and you only get a basic cable-routing hole.

When it comes to image quality, though, the Dell impresses. The VA panel provides a fantastic contrast ratio of 4,616:1 out of the box, and that figure remained at a superb 3,750:1 with the initial brightness of 277cd/m^2 dialled back to 150cd/m^2. The colossal contrast ensures incredible vibrancy and punch, and the sub-0.06cd/m^2 black level means great depth in darker areas.

The delta E of 1.64 and colour temperature of 6,519K are excellent, and the gamma average of 2.26 is good. Colours are supremely accurate, and the Dell delivered a decent sRGB coverage level of 95.5 per cent. For mainstream gaming, it's excellent.

For gaming, the 165Hz refresh rate and 4ms response time provide the smoothness and speed required for mainstream play, but there's still a little blurring in fast-paced situations. The overdrive modes don't cause notable inverse ghosting, but they don't deliver a big performance improvement either. If you're a keen esports fan, we recommend finding a non-VA panel at 240Hz with a faster response time.

For HDR content, the Dell only supports DisplayHDR 400, but in its HDR mode, its peak brightness of 462cd/m^2 pairs with a low black point, so you can see a difference in HDR content on this panel – there's certainly extra punch and depth. Dell's display only uses edge-lit backlighting, though, and it only handles a moderate 85 per cent of the DCI-P3 colour gamut. You'll get a boost to HDR content on this panel, and it's better than most more affordable gaming displays, but it's not a huge upgrade.

SPEC

Screen size
32in

Resolution
2,540 x 1,440

Panel technology
VA

Maximum refresh rate
165Hz

Response time
4ms

Stated contrast ratio
3,000:1

Active sync
AMD FreeSync 2 and Nvidia G-Sync compatible

Display inputs
1 x DisplayPort 1.4, 2 x HDMI 2

Audio
Headphone jack

Stand adjustment
Height, pivot, tilt

Extras
100 x 100mm VESA mount

HDR standard
DisplayHDR 400

Conclusion

The Dell S3220DGF is an unfussy and practical display. It has excellent core image quality and a subtle design, while its size, resolution and curve delivers an immersive gaming experience with modest GPU horsepower. The refresh rate is also fine for mainstream gaming, but you'll want a quicker response time for highly competitive, fast-paced gaming. Those are acceptable compromises at this price, though, and the Dell will sate plenty of gamers. It's a terrific large gaming monitor for a very fair price.

MIKE JENNINGS

IMAGE QUALITY 27/30
GAMING 23/30
FEATURES 16/20
VALUE 18/20

OVERALL SCORE 84%

VERDICT

Great image quality and smart, sensible design make for an ideal mainstream gaming display.

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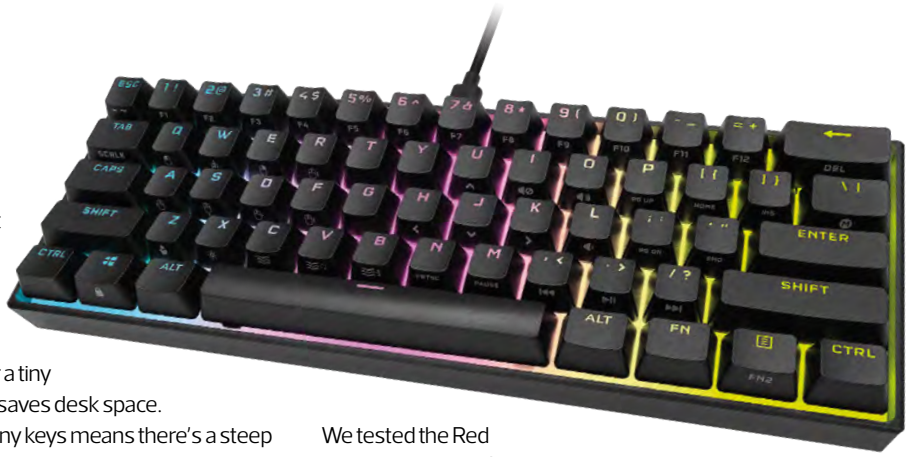
60 PER CENT MECHANICAL KEYBOARD

CORSAIR K65 RGB MINI / £110 inc VAT

SUPPLIER amazon.co.uk



The K65 RGB Mini is Corsair's first foray into the 60 per cent keyboard market. As with all such keyboards, it eschews the numpad, F-keys and even cursor keys of larger-format keyboards, making for a tiny footprint that looks great and saves desk space.

However, the loss of so many keys means there's a steep learning curve if you're not used to these keyboards. All the lost key functions are relegated to secondary functions on other keys, which are activated by pressing the Fn key along with the required key. For instance, Delete is a secondary function of Backspace, and the F-keys are secondary functions of the number keys.

Most of these compromises are manageable but we struggled with the cursor keys being secondary functions of U, H, J and K. It's bad enough that they're secondary functions at all, but we found it too much of a stretch to reach the keys while also holding down the Fn key with our right hand.

Having a second Fn key on the left, or repositioning the cursors keys lower down and to the right, would make them more comfortable to use. Or you could just have them as primary functions, as on the Royal Kludge RK61 (see Issue 208, p61). You can reprogram the keys to work in this way but the key legends won't change.

Otherwise, there's very little to fault with this keyboard. It looks simple and classy with its all-black plastic build and white inner section that enhances the RGB backlighting. It also feels very solidly assembled yet also quite light, making it genuinely portable. The removable (and braided) 1.8m Type-C USB cable helps even further here.

There are no other physical features on the unit itself though – not even flip-down feet on the underside. On the plus side, Corsair includes a keycap removal tool, a spare keycap with a Corsair logo on it and an alternative spacebar with a snazzy triangular pattern on it.

The keycaps are also doubleshot and made from PBT, so the legends won't wear away, go shiny and lose their grippy texture too quickly. The switches themselves are Cherry MX with a choice of linear Red, Silent or Speed variants. We tested the Red versions and they felt as smooth and responsive as ever. Surprisingly, they registered as slightly louder than the ones on the Corsair K70 TKL at 64.7dB, but to our ears sounded less intrusive. They have a lighter, higher-pitched clatter compared with the much hollower, boomy noise of the K70.

Meanwhile, the keyboard's on-board memory can store macros, lighting profiles and key assignments ready for use on any computer. Or, if you install Corsair's iCUE software, you can set up all this as software profiles. The final feather in the cap of this keyboard is its Axon processor, which allows for an 8kHz polling rate, 4kHz keyscan (detects key presses four times faster than normal) and 20-layer on-board lighting effects. Many users will never notice or take advantage of these advanced features, but they're welcome additions for power users.

60 PER CENT

- \+ Stylish 60 per cent layout
- \+ Ultra-compact design
- \+ Removable USB Type-C port
- \+ Doubleshot PBT keycaps

40 PER CENT

- – Steep learning curve
- – Quite expensive
- – Divisive default layout

SPEC

Dimensions (mm)
294 x 105 x 44 (W x D x H)

Weight
580g

Format
60 per cent – 62 keys

Connection
USB Type-C

Switch type
Cherry MX Red, Speed and Silent

Switch life
50 million+ key stroke

Backlighting
RGB

Extras
Removable cable, keycap removal tool, spare spacebar key

Conclusion

The K65 RGB Mini is a fantastic 60 per cent keyboard in terms of looks, build quality, programmability and features, and it has great switches and premium keycaps. However, the default layout of secondary functions slowed us down considerably in everyday keyboard tasks. If you're already familiar with 60 per cent keyboards and know you don't need the extra keys, though, this is a great model.

EDWARD CHESTER

VERDICT

60 per cent keyboards aren't for everyone, but this is a quality option if you can get used to its layout.

DESIGN **22/25**

FEATURES **19/25**

PERFORMANCE **21/25**

VALUE **18/25**

OVERALL SCORE **80%**

TENKEYLESS MECHANICAL KEYBOARD

CORSAIR K70 RGB TKL / £140 inc VAT

SUPPLIER box.co.uk

For several years Corsair's mechanical keyboard line-up stayed relatively steady. After establishing a hit design with its original K70, it iterated on that design in numerous ways without fundamentally changing the formula. Just recently, though, the company overhauled its keyboard line-up, and the tenkeyless K70 RGB TKL is the latest to get an update.

Like the other updated keyboards, the most obvious change is the styling. While the overall shape and feel is familiar, the very thick and coarsely brushed aluminium top plate has gone, replaced by a thinner, more smoothly brushed plate that still looks and feels premium, but lacks a bit of the generous feel of the older design.

The addition of a plastic panel on the top, into which is set an RGB-illuminated Corsair logo and a painted-on K70 logo on the left edge, also takes away a little class from the previous, rather-charming industrial design. Still, it remains a simple, classy-looking keyboard that feels solidly made and has plenty of features.

Most prominent of those new features is a removable cable that plugs into a USB Type-C port on the rear. Next to the USB port is another new feature, which is a switch for putting the keyboard in tournament mode. This disables any backlighting animations, instead setting the keys to a uniform red backlight, and turns off any macros to prevent accidental activation. It's the sort of feature that could be set up with profiles, but it's handy to have an easy, one-touch method.

This keyboard is also fully RGB backlit, with Corsair's software providing umpteen effects and comprehensive custom lighting options. The default lighting pattern looks a bit jarring, with its constantly shifting mix of white, purple, blue, green and yellow (as pictured), but it's easy to change. Corsair is using doubleshot PBT keycaps too, so the legends won't quickly wear off or become shiny.

At the top of the keyboard is an array of multimedia and extra function buttons. On the left are Stop, Back, Play/Pause and Forward media controls, while on the right are controls for profile switching, backlight brightness (with six settings) and Windows key lock, along with a mute button and a knurled metal volume wheel. It's a very useful selection, even if it does add considerably to the size of the keyboard.

Corsair has opted for Cherry MX switches but only the Red, Speed and Silent options, all of which are linear, so fans of tactile and audible feedback miss out. The Red switches we tested offer a smooth, rapid and reliable key response. They also registered as quieter (64.7dB in our test) than those of the Roccat Vulcan TKL Pro, although to our ears, the K70 sounds a little boomier and transfers key strikes into the desk a little more.

You also get Corsair's latest Axon processor as in the K56 RGB Mini, with its 8kHz polling rate and 4kHz keyscan rate, so its performance is up there with the best – not that we noticed any difference in performance compared with standard keyboards with slower specs in these regards.

SPEC

Dimensions (mm)
360 x 164 x 40 (W x D x H)

Weight
930g

Format
TKL – 88 keys

Connection
USB Type-C

Switch type
Cherry MX red, speed and silent

Switch life
50 million+ key stroke

Backlighting
RGB

Extras
Tournament mode switch, volume wheel, removable cable, and buttons for mute, media playback, profile switching, Windows key lock and backlight brightness

Conclusion

Corsair's new TKL keyboard is a mechanical keyboard tour de force. It's stylish, packed with features and has all the performance you could need. It lacks the truly premium feel of higher-end or custom keyboards, and it's a little on the large side for portability, but it's a solid, well-made and feature-rich option if you want a smaller keyboard than standard-sized models.

EDWARD CHESTER

VERDICT

A great combination of compact size, solid build quality and decent capabilities, this is a top-notch TKL keyboard.

TENKEYLESS

+ Stylish design
+ Removable USB Type-C cable
+ Useful tournament mode switch
+ Loads of extra buttons

CLUELESS

– Slightly noisy keys
– Quite large and heavy for a TKL board
– No USB pass-through port

DESIGN 20/25

FEATURES 23/25

PERFORMANCE 23/25

VALUE 20/25

OVERALL SCORE 86%

TENKEYLESS MECHANICAL KEYBOARD

ROCCAT VULCAN TKL PRO / £150 inc VAT

SUPPLIER amazon.co.uk

VULCANOLOGIST

+ Smooth typing experience
+ Premium feel
+ Very prominent RGB lighting
+ Removable Type-C cable

VULCAN DEATH GRIP

– Slightly odd thin keycaps
– Expensive
– Divisive styling

The Vulcan Pro and Vulcan TKL Pro sit at the top of Roccat's keyboard line-up and offer a premium, low-profile mechanical keyboard design based on the company's own Titan switches. We're looking at the tenkeyless (TKL) version here, which drops the numpad to make for a more compact and slightly cheaper option, although at £150 inc VAT, this is still a pricey typing tool.

For all its many other intriguing qualities, the single most striking aspect of this keyboard is its design. While billed as low-profile, this mainly pertains to the keycaps themselves, which measure just 4mm thick at their front edge and 2mm thick at the back. These thin plates then sit on switches that don't appear any more low-profile than more conventional Cherry MX style switches.

The net effect is that the key tops only sit around 5mm lower than resolutely non-low-profile boards, such as the Ducky Shine 7 (See Issue 212). Moreover, the caps have a smaller footprint and don't sit around the switch when pressed, but instead butt up to the switch. With the switch casing being clear and RGB-illuminated, you end up with this rather strange, although not necessarily unappealing, effect of lots of exposed RGB switch mechanisms and these teeny keycap plates floating on top.

Styling aside, the keys feel as good as more conventional ones. The small caps offer a surprising amount of contouring for their size (unlike many low-profile keyboards), and they're very stable with a particularly pleasant linear motion from the switches below. Linear switches aren't everyone's favourite switches for typing due to the lack of tactile feedback, but we got used to these ones very quickly and preferred them to the linear switches on the Corsair K70 RGB TKL, if only marginally. Their optical switching mechanism also makes for a faster response than mechanical keys – not that you'll notice – and a massive 100-million keystroke rating.

The included caps have a pleasantly grippy surface and clear legends, but they're also just made from ABS plastic with printed legends, so they won't last as long as premium PBT doubleshot keys, such as the ones on the Corsair K70 RGB TKL. They're compatible with Cherry MX keycaps, though, so you can just swap them out.

You don't get a huge amount of extra features. There's a precisely notched volume wheel in the top right, along with a mute button, but otherwise, all other extra functions are confined to secondary functions of the standard keys. On the underside there are single-level flip-down feet, while around the back is a Type-C USB port for the included, braided cable.

As befits a compact keyboard with a removable cable, the Vulcan TKL Pro is relatively light, weighing just 660g, yet this keyboard doesn't feel at all flimsy and offers a solid typing experience with no noticeable flex or too much lightweight clatter, unlike some mechanical keyboards. We measured a maximum of 66.8dB from a distance of 20cm while typing, though, which isn't particularly quiet.

The Vulcan TKL Pro is fully customisable via Roccat's software, which lets you reprogram keys, assign macros and control lighting effects.

SPEC

Dimensions (mm)
360 x 133 x 34 (W x D x H)

Weight
660g

Format
TKL – 87 keys

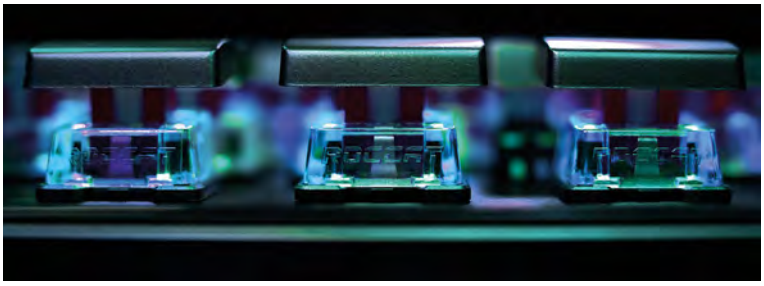
Connection
USB Type-C

Switch type
Roccat Titan (linear)

Switch life
100 million key strokes

Backlighting
RGB

Extras
Volume wheel, mute button, removable cable



Conclusion

The Vulcan TKL Pro is a great-quality compact mechanical keyboard that will appeal to people wanting a little low-lying portable keyboard without compromising on performance. It's a great gaming and typing tool. The main considerations will be whether you like the styling of the slim keycaps and exposed lighting, and whether you can stomach the fairly high price for a non-custom TKL keyboard.

EDWARD CHESTER

VERDICT

A potentially divisive keycap design and high price, but the Vulcan TKL Pro is otherwise a very capable keyboard.

DESIGN 21/25
FEATURES 20/25
PERFORMANCE 21/25
VALUE 18/25

OVERALL SCORE 80%

Wireframe

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INTEL Z590 GAMING PC

CYBERPOWER INFINITY X119 GT / £2,899 inc VAT

SUPPLIER cyberpowersystem.co.uk

CyberPower's Infinity X119 GT rig includes an Intel Core i9-11900K, which is one of the beefiest new Rocket Lake-S chips – it has eight Hyper-Threaded cores, and its base speed of 3.5GHz can ascend to up to 5.2GHz using conventional turbo and 5.3GHz with Intel's Thermal Velocity Boost tech if the thermals allow it.

It's a muscular processor, and it's paired with an MSI GeForce RTX 3080 graphics card. The Suprim X branding means the GPU has three fans and plenty of RGB LEDs, and its stock boost clock of 1710MHz has been significantly overclocked to 1905MHz.

SPEC

CPU
3.5GHz Intel Core i9-11900K

Motherboard
MSI MPG Z590 Gaming Carbon Wi-Fi

Memory
16GB HyperX Fury 3200MHz DDR4

Graphics
MSI GeForce RTX 3080 10GB

Storage
500GB Samsung 980 Pro M.2 SSD; 2TB Seagate Barracuda hard drive

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

Case
CyberPower/Lian Li Lancool PC-008

Cooling
CPU: Cooler Master MasterLiquid Lite 360 with 3 x 120mm fans; GPU: 3 x 90mm fans; side: 2 x 120mm; rear: 1 x 120mm fan

PSU
Corsair TX750M 750W

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

Operating system
Microsoft Windows 10 Home 64-bit

Warranty
Five years labour with two years parts and six months collect and return

Those core components are a great start, and the rest of the CyberPower's specification is reasonably impressive. There's 16GB of 3200MHz memory, a 500GB Samsung 980 Pro PCI-E 4 SSD and a 2TB hard disk. Power comes from a semi-modular Corsair TM750M with 80 Plus Gold certification. We only have minor qualms – at this price, a fully modular PSU and a larger SSD would have been welcome, and afforded this machine a little more versatility.

Meanwhile, the MSI Z590 Gaming Carbon Wi-Fi motherboard provides loads of versatility thanks to a range of high-end features – it has Realtek ALC4080 audio, 2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi and a POST display. It impresses in more conventional departments too, with loads of on-board connectors and ten USB ports at the rear, including a rare and super-fast USB 3.2 Gen 2x2 Type-C connector. There are three M.2 ports, which is a generous allocation, although only one of them supports PCI-E 4. The MSI board looks the part too, with bold dragon designs and plenty of RGB LEDs.

A Lian Li Lancool PC-008 chassis holds all of this hardware, and it's an exclusive model that Lian Li builds for CyberPower. It makes a big first impression, with tempered glass on the side and front panels, plus six RGB LED fans scattered throughout the chassis and glowing with bright, circulating colours.

The radiator for the mighty Cooler Master MasterLiquid 360mm cooler sits in the roof and doesn't block any of the motherboard, cable tidying is solid and build quality is consistently good. There are also pairs of 2.5in and 3.5in drive bays, and a fan controller box around the rear. The only minor issue is that the large graphics card and PSU shroud make it quite challenging to reach the bottom of the motherboard.

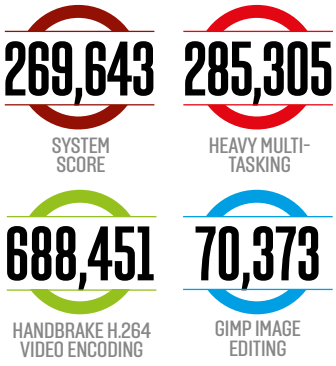
Finally, CyberPower protects this PC with a five year labour warranty including two years of parts coverage, which is more coverage than many companies provide.

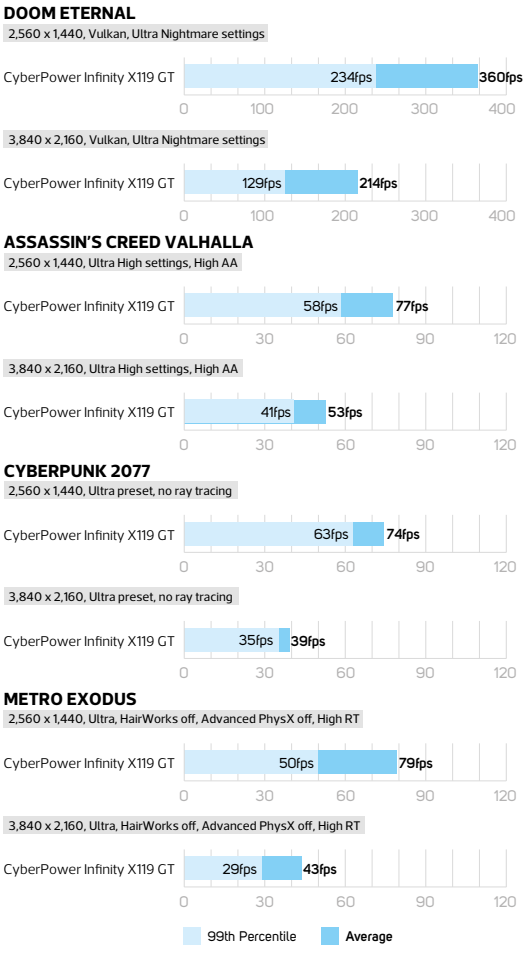
Performance

The overclocked GeForce RTX 3080 will play most games reasonably at 4K, averaging 53fps in Assassin's Creed Valhalla and a massive 214fps in Doom Eternal. If you enable DLSS, it can even cope with ray tracing on High in Metro Exodus, with a 99th percentile result of 41fps. It starts to struggle with the demanding Cyberpunk 2077 at Ultra settings, but even then, it stays above 30fps.

If you're gaming at 2,560 x 1,440 then this machine is superb, staying above 60fps in Cyberpunk 2077 and even averaging 79fps with High ray tracing enabled in Metro Exodus. Meanwhile, its average of 360fps in Doom Eternal shows that this machine can really churn out high frame rates on less demanding titles – great if you have a monitor with a high refresh rate.

BENCHMARK RESULTS





This compares well with the Ultra 9 XT system we reviewed previously, which now costs £2,825 inc VAT and uses a Radeon RX 6800 XT and Ryzen 9 5900X. This Intel and Nvidia-powered machine is faster in three of our games and only fell behind in Assassin's Creed Valhalla.

The situation is different in CPU benchmarks. Make no mistake: the Core i9 chip is very fast, with a slight lead over the AMD Ryzen 9 5900X in our single-threaded image editing test and offering enough speed and cores to run almost any

content-creation task. It's slightly better for gaming than the AMD silicon too. This machine's performance is also bolstered by the SSD's superb read and write speeds of 6,782MB/sec and 3,889MB/sec.

However, the Ryzen 9 5900X-based machine was more than 300,000 points quicker than the Infinity X119 FT in our heavily multi-threaded video encoding test. The Ryzen 9 5900X is undoubtedly a superior choice for demanding workloads, although it's difficult to find at the moment and the Intel chip will get the job done no matter what the task is.

The CPU, its 360mm cooler and the CyberPower's six RGB LED fans also contributed to plenty of fan noise. The noise is consistent from this machine and it's always pretty loud – certainly louder than most PCs at this level. The CPU delta T of 77°C is high too, and the chip's speed peaked at 5.1GHz and 4.8GHz in single and multi-core benchmarks, so it's not quite able to attain its peak turbo speeds.

Conclusion

While Intel's latest Core i9 CPU can't match AMD's Ryzen 9 chips in certain tasks, it's extremely fast and the RTX 3080 is a rapid GPU that can cope with ray tracing much better than AMD's equivalents. Buying a PC such as this one is also one of the only ways you can get hold of this GPU at a non-silly price right now. The motherboard is excellent, the case is well built and the spec list is solid. All told, this PC is ideal if you want a fast, well-balanced unit – it's just a shame about the fan noise.

MIKE JENNINGS

VERDICT

Fast and well built with a superb spec list, although be warned that it also makes a fair bit of noise.

ROCKET-POWERED

+ Excellent gaming performance
+ Great motherboard
+ Bold, sturdy chassis

CRASH LANDING

– AMD's CPUs are faster
– Only semi-modular PSU
– Consistently noisy

PERFORMANCE **23/25**

DESIGN **20/25**

HARDWARE **21/25**

VALUE **20/25**

OVERALL SCORE **84%**

AMD B550 GAMING PC

PC SPECIALIST TORVA ELITE R / £1,349 inc VAT

SUPPLIER pcspecialist.co.uk

PC Specialist's all-AMD system aims to deliver well-balanced mainstream performance in games and content-creation workloads, and it starts with a Radeon RX 6700 XT graphics card. XFX makes the card in this machine, and while there are no overclocks on this Speedster card, it still has base and boost figures of 2321MHz and 2581MHz, and it serves up 2,560 stream processors, plus a large 12GB of memory.

The 6700 XT can also handle ray tracing in games, thanks to 40 AMD Ray Accelerators, but unlike Nvidia's RTX cards, it can't get a helping hand from DLSS, and at the time of writing, AMD's rival Super Resolution tech isn't yet available.

It's paired with an AMD Ryzen 5 5600X CPU, which has six SMT-enabled cores, and here it runs at its conventional base and boost speeds of 3.7GHz and 4.6GHz. It faces new competition from Intel's cheaper Core i5-11600K, but PC Specialist has still priced this machine sensibly at £1,349 inc VAT. Unusually, the CPU is chilled by air rather than liquid, but the PC Specialist FrostFlow 150 air cooler and its two fans don't impede the internals.

Those AMD core components are solid, and the rest of the PC Specialist's hardware is decent. The 16GB of dual-channel RAM runs at 3600MHz, and the 500GB Seagate FireCuda SSD uses the PCI-E 4 interface. There's also a 1TB hard disk, and a Corsair TX650M power supply, which has a semi-modular design and 80 Plus Gold certification. It's all welcome in a PC at this price, and it's all covered by a three year labour warranty with two years of parts coverage.

The motherboard is decent as well. The Asus TUF Gaming B550-Plus has spare memory slots, a free M.2 connector and a solid allocation of empty PCI-E and SATA ports, plus it's equipped with 2.5Gbps Ethernet, dual-band 802.11ax Wi-Fi and decent Realtek ALC S1200A audio.

It has loads of spare fan connectors and a Thunderbolt header, and the rear I/O panel sports eight USB ports split between different speeds. It's a very capable mid-range board, although it's worth bearing in mind that the second M.2 connector doesn't support PCI-E 4, and you don't get any on-board buttons or displays. It looks quite bland too, with no RGB LEDs, but those are minor complaints in a machine at this price.

It's all packaged into a Lian Li Lancool 215 case, which looks decent thanks to its two glowing 200mm intake fans. Elsewhere, it's a conventional mid-tower case, with a PSU shroud, tidy cabling and rubber grommets around the cable-routing holes. At the rear, it offers a fan hub, two 2.5in drive mounts and room for one 3.5in hard drive. The cables are a little untidy at the back, but that's not a big deal.

The PC Specialist lines up against last month's Scan 3XS Gamer RTX. At the time of writing, the latter is still available for £1,299 inc VAT, and it uses an Intel Core i5-11600K and an Nvidia GeForce RTX 3060. It has twice as much storage as the PC Specialist and a year of on site warranty service, but a weaker motherboard.

SPEC

CPU
3.7GHz AMD Ryzen 5 5600X

Motherboard
Asus TUF Gaming B550-Plus (Wi-Fi)

Memory
16GB Corsair Vengeance LPX 3600MHz DDR4

Graphics
XFX Radeon RX 6700 XT 12GB

Storage
500GB Seagate FireCuda 520 M.2 SSD; 1TB Seagate Barracuda hard drive

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

Case
Lian Li Lancool 215

Cooling
CPU: PC Specialist FrostFlow 150 with 2 x 120mm fans; GPU: 3 x 90mm fans; front: 2 x 200mm fans; rear: 1 x 120mm fan

PSU
Corsair TX650M 650W

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

Operating system
Microsoft Windows 10 Home 64-bit

Warranty
Three years labour with two years parts and six months collect and return

Performance

The Radeon RX 6700 XT comfortably handles 1080p gaming. In Assassin's Creed Valhalla and Cyberpunk 2077, it returned 99th percentile minimums beyond 60fps, and it even averaged 53fps in Metro Exodus with ray tracing enabled, and nearly hit a 60fps 99th percentile with that technology disabled. It played most games smoothly at 2,560 x 1,440 too, although it couldn't handle ray tracing in Metro at the higher resolution.

This card will comfortably play single-player games at those resolutions, and its Doom Eternal results show it can churn out high frame rates in less demanding games too – you could happily pair it with a 240Hz 1080p monitor. This GPU is far quicker than the Scan's RTX 3060 and a little faster than the RTX 3060 Ti in some tests as well. Its only weak point compared with the Nvidia competition is ray-tracing performance and the lack of an equivalent of DLSS.

The PC Specialist's AMD processor also has a comfortable lead over the Scan's Intel Core i5-11600K, with better scores in our benchmarks and a significant lead in multi-tasking, helped by the 3600MHz memory. This PC's overall score of 231,815 is more than 31,000 points ahead of the Scan machine. The SSD's read and write speeds of 4,931MB/sec and 2,542MB/sec are also solid, with the former outpacing PCI-E 3 drives.

While this PC is fast and offers good value, though, it does produce noticeable, consistent fan noise – the noise output isn't ruinous, but it's always present. It isn't a problem if you use hefty speakers or a headset, but it's not ideal if you want an environment where you can concentrate in near silence.

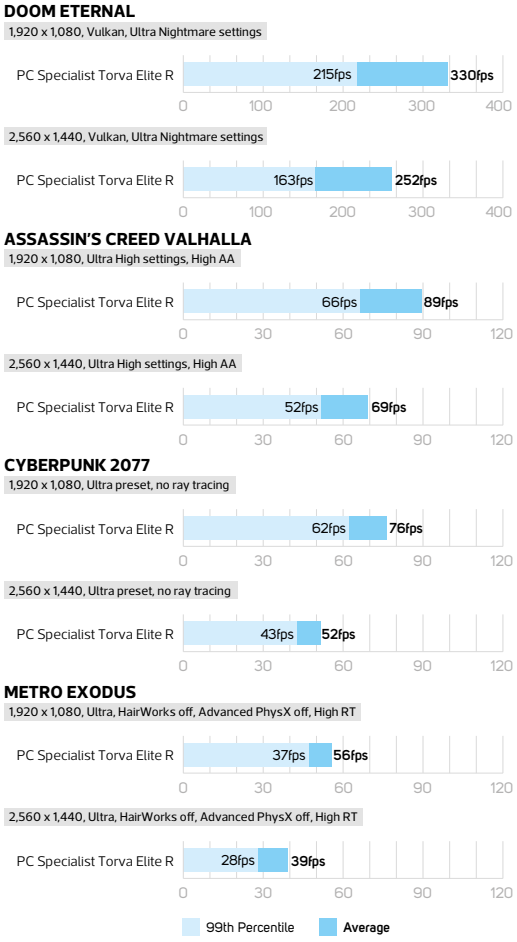
ELITE

- \+ RX 6700 XT impresses
- \+ Ryzen 5 5600X remains superb
- \+ Good motherboard
- \+ PCI-E 4 SSD

DEFEAT

- – Patchy ray-tracing performance compared with Nvidia GPUs
- – Consistent fan noise

BENCHMARK RESULTS



71,336
GIMP IMAGE EDITING

538,786
HANDBRAKE H.264 VIDEO ENCODING

293,852
HEAVY MULTI-TASKING

231,815
SYSTEM SCORE

Happily, the ever-present fans work well in terms of cooling; internal temperatures were acceptable, and the CPU easily attained its 4.6GHz turbo speed.

Conclusion

The Torva's AMD GPU and processor outpace the Nvidia and Intel gear we've seen in other similarly priced machines, and elsewhere, this machine offers a fast SSD, a feature-packed motherboard and a solid warranty. Conversely, the Torva's fan noise is pretty loud and the Radeon graphics card has patchy ray-tracing support. Many people won't be affected by those negatives, though, and this PC provides ample mainstream gaming and work power for £1,349 inc VAT, which is excellent in the current climate.

MIKE JENNINGS

PERFORMANCE 21/25
DESIGN 19/25
HARDWARE 21/25
VALUE 24/25
OVERALL SCORE 85%

VERDICT

Great gaming performance for a very reasonable price in this current climate, although it's also noisy and the GPU's ray-tracing performance isn't brilliant.

Custom kit

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

G-LAB K-PAD THORIUM / £16.68 inc VAT

SUPPLIER amazon.co.uk

The K-Pad Thorium is a PlayStation-pattern game controller that can hook up to your PC. It uses a wired connection with no vibration capability, which means there are no batteries or motor, so it's strikingly lightweight. It's comfortable to use and the simple design makes it easy on the eye, without any over-the-top frills.

The more unusual design decisions made with the K-Pad instead lie in the trigger buttons, which have a long travel distance and an unusually strong spring. At first they feel odd, and they don't feel ideal for games where you're not really making careful use of the triggers.

However, they're great for games where you're trying to get precise control via the trigger buttons.

Beyond the triggers, the main button group doesn't do anything clever. The same can be said for the analogue sticks that, gamepad layout preference aside, are fine. It feels like this pad was aiming to offer something different, but those ambitions only made it as far as the trigger buttons. It's not a bad pad for the money, but it's also nothing to write home about.

Trigger's broom ●●●○○ **Trigger button**

LIFESAVER POWER BANK / £16.99 inc VAT

SUPPLIER lifesaverpower.com

The Lifesaver is a 5,000mAh power bank that opts for comfortable carrying and convenience over capacity. The Lifesaver has built-in micro-USB and Lightning connectors, with a micro-USB to USB-C adaptor tucked into the casing underneath the cable. Recharging the battery is achieved with a micro-USB cable, which is supplied but isn't part of the device.

The size of the Lifesaver, coupled with its relatively low capacity for a bank of this size, means it avoids being too brick-like, and it's also not small and lumpy like lipstick-style battery packs. Instead, it's comfortably pocket-sized, with rounded corners and a grippy matt surface. It's the size of a smartphone, but surprisingly light at 123g.

This makes it ideal for use on the move, or if you need to recharge your phone while it's in use and don't want some hefty chunk of metal dangling off it. A simple line of lights tells you how much charge is left in increments of 25 per cent, which is about as detailed as you need for a bank that will need charging soon after any serious usage.

Dangle ●●●●○ **Spangle**

ASUS ROG WRIST REST / £24.95 inc VAT

SUPPLIER amazon.co.uk

Asus' ROG Wrist Rest is a luxurious beast. Generally, wrist rests are subject to the ergonomic whims of the keyboard with which they're supplied, or they're understated in order to avoid crowding your desk space. The ROG, while shorter than a full-length keyboard, mounts a big soft cushion and enough tenacious rubber feet to hold it in place, regardless of whether you push it up against the edge of your keyboard or just plonk it down a comfortable distance away. A big squashy cushion for your wrists is a great idea for extended gaming sessions, or those lazy times when you just can't be bothered to lift up your arm even a little bit. It's expensive but lovely.

Pushy ●●●●○ **Cushy**

UGEARS FOLDABLE PHONE HOLDER / £8.99 inc VAT

SUPPLIER ugearsmodels.com

This Ugears phone holder kit is a deceptively tricky wooden building project. Comprising 73 components, mostly pieces of flat wood, the build is described as easy and supposed to take two hours. Coming from somebody whose capacity for model kits topped out at Land Raiders and Wellington bombers, it definitely presents some challenges, but we mean that in a good way.

The Ugears kit comes at you with two clever little complications on the puzzle formula. The first is that the parts come from sheets of flat wood, and many of them look extremely similar, so you need to follow the instructions more closely than you expect. The second is that the construction uses no glue and only one tool, a tiny wooden arm on one of the component sheets that's good for prodding and pressing.

As there are no tools, the bits are attached via pegs, which require some force, but you're using them to attach quite delicate parts. This means you need a deft touch and an appreciation for the fact that a chance to try again after a misplacement isn't guaranteed. The end result is a perfectly serviceable mobile phone holder, but getting it there is remarkably fun, especially if you're not familiar with this sort of construction.

Destruction ●●●●○ **Construction**

ADATA SE900G USB SSD / £156.71 inc VAT

SUPPLIER amazon.co.uk

There are jokes to be made about the needlessly convoluted naming conventions of the recent USB variants, and there's a justifiable scepticism towards the need for masses of extra storage in these days of cloud computing and streaming services. However, when you cut through all the nonsense, it turns out that a USB 3.2 Gen 2x2 SSD connected to a PC with a corresponding USB 3.2 Gen 2x2 port is incredibly fast. Our sample tested with a read speed of 1,751MB/sec and a write speed of 1,572MB/sec, which is pushing three times the best speed you could get from a SATA 3 connection.

At this speed, the ADATA SE900G isn't just a great backup option, but it could also be a perfectly serviceable drive for games or any other files that need to move with speed. All this rapid data handling comes in a relatively small package, with a fetching RGB illuminated pattern on the casing. The only thing to be wary of with the SE900G compared with an ordinary USB drive is the cables; the supplied cables are short and also thick, necessarily so, and if you want to use your own cables, make sure they're rated for 20Gbps because running an SE900G on an insufficient cable will severely compromise performance.

The SE900G is backwards compatible with USB 2, and its performance is still respectable on a USB 3 connection, reading at 460MB/sec and writing at 451MB/sec. If there's a catch, it's that you can't control the RGB lighting pattern, but that's an incredibly small catch on an otherwise extremely good device.

USB 3.2 Gen 2x2 ●●●●● **Sensibly named standard**

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

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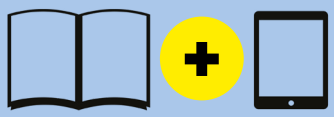

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LABS TEST

Budget gaming monitors

Edward Chester puts eight of the most affordable gaming monitors available to the test

How we test

Not so long ago, buying a cheap gaming monitor meant a host of compromises, including basic LCD panels with poor viewing angles and bad colours, as well as a total lack of extra features. These days, though, you can get some very capable displays for well under £200.

The main change has been the filtering down of better-quality LCD panels with faster refresh rates. The cheapest TN panels have largely now been replaced with IPS and VA panels that boast much better viewing angles, more accurate colour reproduction and better contrast. They respond quickly too, with 1ms response times and refresh rates of at least 144Hz.

To test the panels, we first measure their image quality using a colorimeter. This checks for the contrast, colour accuracy and colour range of the displays, as well as the uniformity of the image across the panel. We test at a brightness of 150 nits with the display otherwise in its out-of-the-box configuration, to see how it performs in the state in which buyers will receive it. We also crank up the brightness to 100 per cent to check for maximum brightness.

Next, we calibrate the display, finding the best-performing modes the panel offers and seeing just how much configuration is required to get it looking its best. These days, most panels take only a little bit of tweaking to get looking exactly right, but some panels can take considerably more effort, so this is reflected in our image quality scores.

Modern displays also often have extended colour gamuts, which allows them to produce the brighter colours of HDR standards – although none of these displays supports proper HDR. As such, we've included testing of both the default high gamut modes and low gamut (sRGB) modes where available.

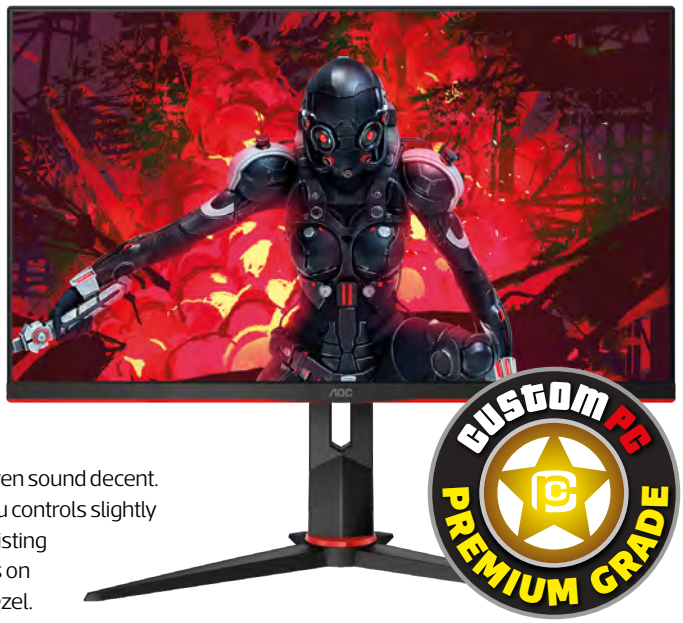
We next check the viewing angles of the panel along with its responsiveness. For the latter, we use the blurbusters.com UFO ghosting test to check for how quickly the panel's pixels respond to image changes. We also play games on the screen to subjectively test for how responsive it feels. Finally, we assess the overall styling, build quality, features (such as USB hubs and stand adjustment options) and ease of use of the display.

Contents

- AOC 24G2U / p43
- AOC C24G2U / p44
- Asus TUF Gaming VG24VQ / p45
- BenQ Mobiuz EX2710 / p46
- iiyama G-Master GB2466HSU / p47
- iiyama G-Master GB2470HSU / p48
- LG UltraGear 24GN600 / p49
- MSI Optix G241 / p50
- Results graphs / p51

AOC 24G2U / £179 inc VAT

SUPPLIER ebuyer.com



Showing just what an impressive number of features and great value modern budget screens can offer, AOC kicks off this labs test with a bang. This £180 inc VAT screen includes a fully adjustable stand, speakers, a 4-port USB 3 hub and even has a VGA input. All this and it has a 1,920 x 1,080 (1080p) IPS panel that tops out at 165Hz and has a stated 1ms response time. Like all the other displays on test, it includes both a backlight-strobing blur reduction mode and adaptive sync support (FreeSync/G-Sync) that works with AMD and Nvidia GPUs.

The 24G2U doesn't disappoint when it comes to build quality and styling either. It's not the best-looking bit of industrial design in this Labs, but it's no ugly duckling either. The stand is also stable, with smooth adjustments and, again like all the other displays on test, it can be removed to reveal a VESA mount for use with alternative monitor arms.

The ports all face downwards on the back, making for a quite crowded array, given that you have four USB ports and the extra VGA port, along with a DisplayPort input and two HDMI sockets, plus a headphone jack, line-in and power socket. However, it's fantastic to get such a broad selection, and the power supply is internal too, so there's no annoying power brick. The speakers and headphone jack even sound decent.

The on-screen menu controls slightly let the side down, consisting of a row of four buttons on the underside of the bezel. The labelling on the front makes it easier than the blind poking around that's required with the iiyama GB2470HSU, but the buttons aren't particularly easy to press. Thankfully, the menus are logically laid out and offer all the settings you need to get the image looking as you like.

Speaking of which, image quality is very good. Out of the box, the colour balance isn't technically perfect, but it's good enough for most uses while contrast is decent for an IPS panel. The gamma curve is near perfect, though, and delta E colour accuracy is very good. Meanwhile, the viewing angles are excellent and IPS glow wasn't particularly egregious either.

What's more, you get an extended colour gamut to make for brighter, bolder colours, as well as a proper sRGB mode that pulls in the colour gamut and also offers a near-perfect image in every other regard. Unfortunately, this mode fixes the brightness at 236 nits, which is a bit brighter than we normally use, but it's fine for occasional colour critical work.

Gaming performance is also top-notch. The IPS panel responds quickly, making for a minimum of smearing in fast motion, while the adaptive sync takes care of tearing and stutter. Switch on the blur reduction (which requires turning off adaptive sync, as on all the other displays) and it's even nippier, offering an experience that's ample for competitive online first-person shooters. Only the LG panel offers a snappier response in this class of display.

SPEC

Screen size 23.8in

Resolution 1,920 x 1,080

Panel technology IPS

Maximum refresh rate 144Hz

Stated response time 1ms

Stated contrast 1,000:1

Adaptive sync FreeSync and G-Sync compatible

Display inputs 1 x DisplayPort 1.2, 2 x HDMI 1.4, 1 x VGA

Audio 2 x 2W speakers, headphone out, line in

Stand adjustment Height, pivot, rotation, tilt

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

BANG FOR BUCK

+ Excellent image quality
+ Loads of features
+ Fantastic gaming performance

BUCKING BRONCO

– Slightly underwhelming design
– Clunky OSD controls
– sRGB mode has fixed brightness

Conclusion

The AOC 24G2U is an astonishingly accomplished monitor for a great price. It's packed with features, offers great image quality and its gaming performance is right up there too. The LG UltraGear 24GN600 offers a slightly snappier response, but also has relatively low contrast and few extra features.

VERDICT

A truly fantastic bargain of a gaming monitor.

IMAGE QUALITY	GAMING	OVERALL SCORE
26/30	26/30	92%
FEATURES	VALUE	
20/20	20/20	

AOC C24G2U / £180 inc VAT

SUPPLIER ebuyer.com

The main feature distinguishing the various different monitors in this Labs test is the choice of either an IPS or a VA panel. The former gives better viewing angles, generally smoother, more natural-looking colours and a faster response time for gaming, but has relatively low contrast and can suffer from IPS glow, where a distracting lightness can appear across the screen when viewed from an angle.

Meanwhile, VA panels have high contrast and don't suffer from IPS glow, but aren't generally as good for accurate colour reproduction and have a very noticeably slower response time for gaming. We recommend IPS for image and video editing, and fast-paced gaming, while VA is great for watching videos and playing slightly slower-paced games – especially dark and moody ones that take advantage of the higher contrast.

The C24G2U, then, is the VA cousin to the IPS-equipped 24G2U with both displays sporting nearly identical features and price. Where the two models differ, though, is that the C24G2U has a curved screen. This is common with VA panels, and it helps to make up for the slightly worse viewing angle of this panel type. Sitting in the centre of the curve gives an almost perfectly uniform image.

Otherwise, you get the same stand, the same selection of ports around the back, the same speakers and the same less-than-stellar menu controls. The 24G2U was feature packed and well built, and the same is true for the C24G2U.

Jumping straight into our tests of the panel, the advantages of VA are immediately obvious. The C24G2U registered a contrast ratio of 3,703:1 – nearly quadruple the result of the 24G2U. Fire up a film such as Alien and the inky blacks of this screen – just 0.04 nits compared to 0.14 for the 24G2U with the backlight brightness set to 150 nits – really enhance the darkness of space.

Every other aspect of image quality impressed too, with very accurate out-of-the-box colour balance, a good gamma curve and solid colour accuracy. You also get an extended colour gamut of 126 per cent sRGB that gives colours an extra bit of zip. However, unlike the 24G2U, the sRGB mode doesn't reduce the colour gamut. We'd recommend the 24G2U instead for image and video editing anyway, but this cements the judgement.

As for the disadvantages of VA, they're in strong evidence when it comes to gaming. The very long, discoloured trails in the Blur Busters ghosting test betray the slow real-world response time of the panel. Fire up a game and, although it feels quick, there's a distinct smudginess in the most rapid movements.

Rather surprisingly, the blur reduction mode didn't seem to make as much of a difference here as on the other VA panels in this Labs. It still tightened up the blurriness considerably, but it nonetheless felt relatively sluggish, and well behind the IPS panels on test. It's still fine, even for competitive online play, but faster panels will give you an advantage in terms of fast-paced clarity.

Conclusion

The C24G2U is a fantastic example of a VA LCD gaming screen. Its high contrast and low black level make films, and dark and moody games pop. Meanwhile, the mass of extra features and excellent out-of-the-box image quality all belie its very modest asking price. For fast-paced gaming, though, the slow response time holds it back compared with its IPS-based sibling.

SPEC

Screen size 23.6in

Resolution 1,920 x 1,080

Panel technology VA

Maximum refresh rate 165Hz

Stated response time 1ms MPRT

Stated contrast 3,000:1

Adaptive sync FreeSync and G-Sync compatible

Display inputs 1 x DisplayPort 1.2, 2 x HDMI 1.4, 1 x VGA

Audio 2 x 2W speakers, headphone out, line in

Stand adjustment Height, pivot, rotation, tilt

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

THE DARKNESS

+ High contrast panel
+ Loads of features
+ Excellent overall image quality

DARK TIDINGS

– VA panel slow compared with IPS
– sRGB mode doesn't reduce gamut
– Fiddly OSD controls

VERDICT

A solid option for those who like the high contrast of VA panels.

IMAGE QUALITY	GAMING	OVERALL SCORE
28/30	20/30	83%
FEATURES	VALUE	
17/20	18/20	

ASUS TUF GAMING VG24VQ / £199 inc VAT

SUPPLIER overclockers.co.uk

There was a time when Asus wasn't hugely competitive at the lower end of the gaming monitor market, as it concentrated more on its high-end Republic of Gamers (ROG) products. Its recent line of TUF monitors, though, have brought it right back into the game, offering competitive performance and value. The VG24VQ is just such a display.

While it's on the expensive side in this Labs test, it still costs under £200. Plus, for that price, you get a fully adjustable stand, which is one of the key premium additions in this price range. Beyond the stand there isn't too much in the way of physical extra features though. There's no USB hub and while you do get speakers and a headphone jack, audio quality is basic, with a thin, weedy sound from both.

HARD AS NAILS

- \+ High contrast panel
- \+ ELMB mode is good for gaming
- \+ Easy-to-use OSD controls

NAIL CLIPPINGS

- – Poor default colour balance
- – VA panel slow compared with IPS
- – ELMB doesn't work with adaptive sync

SPEC

Screen size 23.6in

Resolution 1,920 x 1,080

Panel technology VA

Maximum refresh rate 144Hz

Stated response time 1ms MPRT

Stated contrast 3,000:1

Adaptive sync FreeSync and G-Sync compatible

Display inputs 1 x DisplayPort 1.2, 2 x HDMI 1.4

Audio 2 x 2W speakers, headphone out

Stand adjustment Height, pivot, rotation, tilt

Extras 100 x 100mm VESA mount

Video connections are the standard single DisplayPort and two HDMI inputs, while the power supply is kept in an external power brick. It's a notably tiny power brick though. One plus point for the Asus is its menu system, which is controlled by a four-way joystick and three other shortcut buttons on the right rear of the panel. The menus are nice and snappy and mostly intuitively laid out.

Meanwhile, the monitor's panel uses a VA type of LCD, which is slightly curved with a 1500mm radius. It's rated to a maximum refresh rate of 144Hz and has a 1ms motion picture response time (MPRT) rating. Asus' included adaptive sync system also works with AMD and Nvidia graphics cards, and the VG24VQ even includes the company's Extreme Low Motion Blur (ELMB) backlight-strobing blur reduction technology.

Sadly, it's not the ELMB-Sync technology used on more expensive Asus screens, as this allows for backlight strobing with adaptive sync. Here, though, you'll have to choose to have either the no tearing and stuttering, or the faster response of blur reduction.

A high contrast ratio is the key selling point of VA displays and sure enough, the VG24VQ hit up to 3,511:1 in our tests. That's not quite at the level of the AOC 24G2U or iiyama GB2466HSU, but it's still three times the figure that the IPS displays on test deliver.

In other areas this display's image quality is only okay. Out-of-the-box colour balance is among the worst on test, and the display's sRGB mode (which ideally should have the best colour balance) is way off, with a colour temperature of 7,523K. However, in most other areas it's accurate, and tweaking the RGB settings (100 x 95 x 93 in our case) can sort out the colour balance.

When it comes to gaming, the main problem with VA of a slow response time is in strong evidence, making for a lot of smearing in fast motion, although it's not as bad as on the iiyama GB2466HSU. The blur reduction mode comes to the rescue, though, sharpening up the movement. IPS and TN panels remain better in this regard, but this screen is still viable for all but the most competitive of gaming.

Conclusion

We've generally been impressed with Asus' recent TUF Gaming monitors, and the VG24VQ is a good effort too. It's offers a perfectly decent feature set and performance for its price. However, its iffy default colour balance and the slow response of the VA panel let it down slightly, and it can't compete with the C24G2U for sheer value.

VERDICT

A solid option for those that covet the high contrast of VA panels.

IMAGE QUALITY	GAMING	OVERALL SCORE
22/30	20/30	75%
FEATURES	VALUE	
16/20	17/20	

BENQ MOBIUZ EX2710 / £250 inc VAT

SUPPLIER overclockers.co.uk

We've snuck something a little different into this group test with the BenQ EX2710. We set out to do a budget 24in monitor test, but BenQ wasn't able to supply that size of model, so we let the company send over a bargain 27in panel instead. The big compromise with opting for a bigger panel is that you pay more, with this display costing £250 inc VAT. You also get a lower pixel density than the 24in screens on test, as the BenQ still has a 1,920 x 1,080 resolution.

In terms of overall features, the EX2710 is largely in line with the other panels on test, with its IPS panel sporting a 1080p resolution and a 144Hz maximum refresh rate. However, there is one feature that sets it apart. On the bottom right of the screen's bezel is a dedicated HDRi button for selecting one of the screen's three HDR modes.

These modes all extend the colour range of the display in line with the wider gamuts used in HDR standards. However, it's a minimal increase, stretching from the screen's default 115 per cent sRGB coverage to 120 per cent. Beyond that, these modes essentially try to emulate HDR by dynamically adjusting the colour response of the panel. It's largely for nought, though, as all the HDRi modes look decidedly underwhelming.

Otherwise, image quality is generally good. The out-of-the-box colour balance is close to perfect, while maximum brightness is adequate and contrast is decent too. However, you can't reduce the extended colour gamut, so if you're into image and video editing, you may want a display that sticks more strictly to 100 per cent sRGB. The panel's uniformity lets the side down a bit, though, with brightness varying by as much as 20 per cent down the left edge. It's not a major concern for gaming but again, it's worth bearing in mind for image editing.

Meanwhile, the design of the display is smart enough, with its very slim bezel around the top and sides, and the sturdy silver base providing attractive contrast. The only eyebrow raiser is the strip of thick orange rubber in the stand's base. For features, you miss out on a USB hub, but get the standard one DisplayPort and two HDMI video inputs, while the stand offers height, tilt and rotation adjustment. The speakers in this display sound better than most too, offering more clarity and depth. The headphone output also sounds clear and fulsome.

Around the back of the panel are the display's controls, consisting of an input button, mini joystick and power button. The joystick does a great job for navigating the comprehensive menus, making it a breeze to set up and tweak the display.

When it comes to gaming, the EX2710's IPS panel held its own against all but the LG UltraGear 24GN600, and comfortably outpaced the VA panels on test. Its blur reduction mode tightened up its gaming performance even further too, although as with other monitors on test, enabling this feature requires you to turn off adaptive sync.

Conclusion

If you're happy to spend a little more money on a bigger screen, the BenQ EX2710 is a good value option. It offers decent image quality, a reasonable set of features and solid gaming performance. It's a shame you miss out on a USB hub, and its HDRi feature is rather pointless, but it's still a solid gaming monitor.

SPEC

Screen size 27in

Resolution 1,920 x 1,080

Panel technology IPS

Maximum refresh rate 144Hz

Stated response time 1ms

Stated contrast 1,000:1

Adaptive sync FreeSync and G-Sync compatible

Display inputs 1 x DisplayPort 1.2, 2 x HDMI 1.4

Audio 2 x 2.5W speakers, headphone out

Stand adjustment Height, pivot, rotation, tilt

Extras 100 x 100mm VESA mount, pointless HDR button

MOBIUS STRIP

+ Good overall image quality
+ Easy-to-use menus
+ Capable gaming performance

TIME LOOP

− HDRi feature is rather pointless
− Bigger screen adds to cost
− No USB hub

VERDICT

A bigger screen costs more, but this is still a good value panel.

IMAGE QUALITY	GAMING	OVERALL SCORE
22/30	24/30	78%
FEATURES	VALUE	
16/20	16/20	

IIYAMA G-MASTER GB2466HSU / £190 inc VAT

SUPPLIER box.co.uk

The iiyama G-Master GB2466HSU is, along with its sibling, the GB2470HSU, an impressively fully featured monitor for its low price. Despite costing under £200 inc VAT, it sports a USB hub, a height-adjustable stand and speakers. They're not the sort of extras that might excite you on more expensive screens but at this price range, every little counts.

This monitor uses a VA-type LCD panel, and like the other VA panels on test, it's slightly curved, sporting a 1,500mm radius. Aside from this curvy addition, this is a fairly plain monitor as far as styling goes, but not in a bad way. All the surfaces are finished in a muted mottled black plastic that's simple but smart, while the V-shaped stand and slim bezels around the top and sides finish off the clean look.

In stark contrast to the likes of the MSI Optix G241, the iiyama is quite heavy, weighing in at 4.8kg, but that weight includes a sturdy stand that's adjustable in terms of height, rotation and tilt, plus the monitor includes an internal power supply, so there's no external power brick. Around the back are several downward-facing connection options, consisting of one DisplayPort and two HDMI video inputs, a USB upstream port, two USB 2 downstream ports and a headphone jack.

Unfortunately, the sound quality from the headphone jack is terrible. It's tinny and shrill, and the same can be said of the speakers. It's a shame they're this bad when you considering that iiyama has bothered to include them. The menu system is also less than stellar. It uses a four-way mini joystick to navigate, but the menu itself isn't particularly speedy or intuitive, although it at least contains all the options you'll need.

In terms of features, this panel offers the same 1080p resolution, adaptive sync support and blur reduction mode functions as the others on test but it can also refresh at up to 165Hz. The extra advantage over 144Hz is all but imperceptible in real-world use, but technically that microscopic advantage is there.

In our game testing, the slow real-world response time of the VA panel resulted in a lot of smearing in fast motion. In this regard, the iiyama was about as sluggish as the AOC C24G2U and slightly worse than the Asus VG24VQ. However, engaging the MBR blur reduction mode worked wonders. Image quality drops when it's enabled due to aggressive overdrive causing inverse ghosting, but the sharpness in motion is there.

As for image quality, the big advantage of VA panels is in particularly strong evidence here. With a measured contrast ratio of 3,905:1, this panel easily tops the contrast chart in this Labs. This brings an extra depth and lifelike quality to the image that's particularly beneficial for dark and moody films and games. In other areas it's decent if not outstanding, with a reasonably accurate colour balance, good gamma rating and fine colour accuracy. Its maximum brightness is bit low though.

SPEC

Screen size 23.6in

Resolution 1,920 x 1,080

Panel technology VA

Maximum refresh rate 165Hz

Stated response time 1ms

Stated contrast 3,000:1

Adaptive sync FreeSync and G-Sync compatible

Display inputs 1 x DisplayPort 1.2, 2 x HDMI 1.4

Audio 2 x 2W speakers, headphone out

Stand adjustment Height, pivot, tilt

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

MASTER AND COMMANDER

+ Very high contrast
+ Lots of features
+ Good overall image quality

STEAMBOAT WILLIE

- Sluggish response time
- Only USB 2 hub
- Terrible speakers

Conclusion

You get a lot of features for your money with the iiyama G-Master GB2466HSU, but the USB hub is only USB 2, and the speakers and headphone jack sound poor. Otherwise, the high contrast, and decent overall image quality make this a great screen for watching video and playing games in the dark. Its gaming performance is a little sluggish, though, unless you enable the blur reduction mode.

VERDICT

High contrast and plenty of features, but there are a few compromises here too.

IMAGE QUALITY	GAMING	OVERALL SCORE
22/30	18/30	74%
FEATURES	VALUE	
17/20	17/20	

IIYAMA G-MASTER GB2470HSU / £170 inc VAT

SUPPLIER box.co.uk

Like its VA panel-touting sibling on p47, the iiyama G-Master GB2470HSU offers a lot for its modest price. Despite being one of the cheapest displays on test, it still includes a height-adjustable stand, a USB hub and speakers, plus its IPS panel is rated to a 0.8ms response time and it has a 165Hz refresh rate.

Crucially, this checklist of features is not hugely let down in practice. The only major black mark is the menu system. It uses a series of buttons that run down the right rear of the screen, and there's a steep learning curve to remembering which button is which and how they correspond to navigating the on-screen display. It's really infuriating to use at first, and while we did get used to it eventually, it was never effortless.

Otherwise, the GB2470HSU generally impressed, starting with its simple understated design. It's all black, with a plain mottled plastic finish, but it looks classy and you get a very slim, low-profile bezel around the top and sides. For physical features, you get a 2-port USB 2 hub, with an upstream port on the rear and the downstream ports conveniently located on the left edge. The power supply is internal and you get a headphone jack that, unlike the GB2466HSU, sounds okay. The same can't really be said of the tinny 2W speakers though.

Oddly, iiyama has only fitted this display with one HDMI port, rather than the two of the other displays on test, and it's joined by a single DisplayPort input. The stand is fixed to the display out the box, but it can be removed to reveal a 100 x 100mm VESA mount, while the base of the stand is attached without the need for a screwdriver. It offers height, tilt and two-way pivot movement but strangely omits side-to-side rotation.

By most measures this is a decent display when it comes to image quality as well. Its out-of-the-box colour balance isn't too far off ideal, while the gamma curve and colour accuracy are all good too. Contrast, meanwhile, is excellent for an IPS panel. All this and the uniformity is good, there's no obvious backlight bleed and the IPS glow isn't as noticeable as on the LG panel. You also don't have to worry about any unnecessary extended gamut.

Gaming performance is decent too. This panel easily outperforms the VA panels on test for responsiveness, although there's a noticeable step down from the LG IPS panel in particular. In the Blur Busters ghosting test, there are noticeably longer trails that show the relatively slow pixel response time.

Nonetheless, it's still a decent enough panel for competitive gaming, and to get even more responsiveness and sharpness in fast motion, there's a backlight-strobing blur reduction mode. Image quality suffers a little when these modes are enabled, as they clearly crank up the overdrive, creating inverse ghosting. For competitive gaming, though, this isn't a great worry and performance is excellent.

SPEC

Screen size 23.8in

Resolution 1,920 x 1,080

Panel technology IPS

Maximum refresh rate 165Hz

Stated response time 0.8ms

Stated contrast 1,100:1

Adaptive sync FreeSync and G-Sync compatible

Display inputs 1 x DisplayPort 1.2, 1 x HDMI 1.4

Audio 2 x 2W speakers, headphone out

Stand adjustment Height, pivot, tilt

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

GRANDMASTER

+ Good overall image quality
+ Solid gaming performance
+ Great value

APPRENTICE

– Speakers are terrible
– Awkward menu system
– Only one HDMI input

Conclusion

While the GB2470HSU can't quite keep up with the LG 24GN600 in terms of native responsiveness, it still has solid gaming performance, especially with its blur reduction mode engaged. Its main problem is the stiff competition from the AOC 24G2U in this crowded market, which only costs an extra £9. If the AOC is out of stock, though, the GB2470HSU's impressive feature set, good all-round image quality and low price make it a great runner-up.

VERDICT

A great gaming screen for a fair price, but it can't quite compete with the AOC in this cramped market.

IMAGE QUALITY	GAMING	OVERALL SCORE
24/30	24/30	83%
FEATURES	VALUE	
17/20	18/20	

LG ULTRAGEAR 24GN600 / £180 inc VAT

SUPPLIER overclockers.co.uk

LG has carved out a unique position in the gaming monitor market thanks to having the very latest and fastest-responding IPS panel technology, with the company manufacturing the panels itself. This same advantage is evident even in this cut-price model, but the same compromises seen on some other LG gaming displays apply here.

Specifically, this monitor has a contrast ratio of just 700:1 according to LG and 778:1 according our measurements. That's 30 per cent lower than the typical contrast for IPS panels, and although its not always dreadfully noticeable in brightly coloured games and the Windows desktop, you notice that lack of depth in darker games and movies.

Further denting its appeal in these scenarios is the IPS glow that casts a subtle shimmering spread of light from the corners of the screen, depending on the viewing angle. This affects all IPS panels to a degree, but we noticed it more on this panel than others on test.

Still, for the majority of tasks and games, we didn't find either of the above issues too distracting. Your mileage may vary though – some users can't stand IPS glow while others can't abide the poorer viewing angles and slower response times of VA – this is really a case of your priorities.

Every other measure of image quality, though, is good. Oddly, the display showed perfect colour balance at max brightness, but it worsened at our test setting of 150 nits. Still, this is largely a display you can use straight out of the box, with no need to tinker with calibration.

As for this monitor's features, it's a very basic display, with a stand that only offers tilt adjustment and needs a screwdriver to assemble. There's no USB hub or even speakers, and the power supply is external, though you get the requisite single DisplayPort and two HDMI video inputs. There's a headphone jack too, but sound quality from it is poor. There's distortion to it, almost like it's constantly being overdriven. It's usable, but only just.

Meanwhile, the screen's menus are controlled by a single four-way joystick on the underside of the bezel, and it's a particularly responsive and intuitive setup with all the image quality and gaming tweaking features you'll need.

When it comes to gaming performance, the screen offers the same 1080p resolution, 144Hz refresh rate and 1ms response time specs as most of the other IPS panels on test. Plus, you get FreeSync and G-Sync compatible adaptive sync support, and a blur reduction mode. As with other monitors on test, though, the blur reduction can't work with adaptive sync.

Unlike several of the other display on test, however, there's certainly no need for the blur reduction for this to be a competitive gaming screen, as the native response time is excellent. There's minimal trailing evident in the Blur Busters ghosting test, and games remain sharp and clear during fast motion. Turning on the blur reduction simply cranks the responsiveness up a notch, making this easily the best panel on test for fast-paced gaming.

Conclusion

Low contrast and IPS glow dent this screen's appeal for movie watching and playing dark, atmospheric games, but it's a beast when it comes to competitive gaming. The inherently fast response time of the panel, along with a capable blur reduction mode, put it at the head of the pack in this regard. If you want the best budget screen for fast-paced competitive gaming, this is the display for you, although the lack of features dents it value.

BLUR BUSTERS

- \+ Great gaming performance
- \+ Good out-of-the-box colour balance
- \+ Decent value

BLOCKBUSTERS

- – Low contrast
- – Noticeable IPS glow
- – Basic feature set

SPEC

Screen size 23.8in
Resolution 1,920 x 1,080
Panel technology IPS
Maximum refresh rate 144Hz
Stated response time 1ms
Stated contrast 700:1
Adaptive sync FreeSync and G-Sync compatible
Display inputs 1 x DisplayPort 1.2, 2 x HDMI 1.4
Audio Headphone out
Stand adjustment tilt
Extras 100 x 100mm VESA mount

VERDICT

The ideal competitive gaming screen on a budget, but it's not one for movie buffs.

IMAGE QUALITY	GAMING	OVERALL SCORE
22/30	30/30	82%
FEATURES	VALUE	
14/20	16/20	

MSI OPTIX G241 / £189 inc VAT

SUPPLIER overclockers.co.uk

The MSI Optix G241's big standout feature is its extended colour gamut, which stretches to 130 per cent of the sRGB colour space. What does that mean? Well, colours noticeably look more vivid, with bright reds and greens really standing out.

In theory, this is ideal for HDR content, as HDR standards are designed to properly address a wider range of colours. However, this screen doesn't support HDR.

Instead, it just stretches the standard sRGB colour range to the wider gamut that it supports. That's fine if you just want a generally bright and bold image, but it's not so good if you also want a display that's good for accurate image and video editing – if you alter colours in your work so they look accurate on a display such as this one, they'll look dull on normal displays.

Aside from its extended colour gamut, though, the G241 holds its own. It's a particularly smart-looking monitor and it's also remarkably light (3.3kg), which makes it easy to just pick up the whole unit with one hand in order to access the ports at the back.

A key reason for it being so light is that it isn't exactly overflowing with physical features. The stand only offers tilt adjustment and requires a screwdriver to assemble, and there's no USB hub or even any built-in speakers. You get a headphone jack that sounds okay, but otherwise it's just the DisplayPort connector and two HDMI video inputs, a menu button and the screen itself. Even the power supply is external.

The menus are controlled by a single mini joystick on the rear right of the screen, and the combination works well. The menus also provide all the options we'd expect, other than the ability to reduce that extended colour gamut.

This display uses IPS LCD technology, and it has the same 1080p resolution, 144Hz maximum refresh rate and 1ms response time as most of the other panels on test, along with adaptive sync support and a backlight strobing blur reduction mode.

Overall image quality is decent, depending on your views on the extended colour gamut.

The maximum brightness of 342 nits is plentiful, while the contrast ratio of 1,375:1 is impressive for an IPS panel. However, you can improve the image by switching to the user colour mode; in its default state, this boasts a contrast ratio of 1,493:1. Tweak the RGB colour balance from 50 x 50 x 50 to 49 x 46 x 50 and the image is all but perfect.

When it comes to gaming performance, the native response time of this panel is a little slow. There's a smeary quality to the image with very noticeable coloured fringing around the edges of moving text, for instance – that's an issue we'd normally associate with a slower panel that has the overdrive setting turned up too high.

Sure enough, without the blur reduction mode activated, this isn't the sharpest-looking of the IPS monitors on test. However, the blur reduction goes a long way to making up for these shortcomings, tightening up the response in fast motion.

Conclusion

If you're a fan of bold, bright colours, the extended colour gamut of this display will be right up your street. Its relatively high contrast for an IPS panel, sharp design and easy-to-use menus are all plus points too. However, there are better-rounded and better-equipped options if you're after a panel that delivers slightly more accurate colours and the best in gaming performance. CPC

SPEC

Screen size 23.8in

Resolution 1,920 x 1,080

Panel technology IPS

Maximum refresh rate 144Hz

Stated response time 1ms

Stated contrast 1,000:1

Adaptive sync FreeSync and G-Sync compatible

Display inputs 1 x DisplayPort 1.2, 2 x HDMI 1.4

Audio Headphone out

Stand adjustment Tilt

Extras 100 x 100mm VESA mount, 95 per cent DCI-P3 colour gamut

SHARP AS A PIN

+ Extended colour gamut looks vivid
+ Smart design
+ Easy-to-use menus

DULL AS DISHWATER

− Overly bright colours
− Slightly smeary in fast motion
− Lacking features

VERDICT

A decent all-round display with HDR pretensions, but its extended colour gamut isn't for everyone.

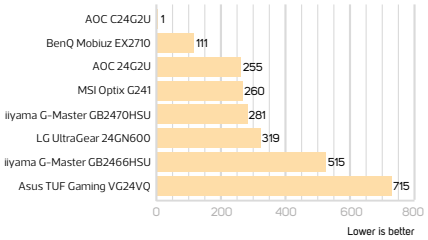
IMAGE QUALITY	GAMING	OVERALL SCORE
22/30	24/30	73%
FEATURES	VALUE	
12/20	15/20	

BUDGET GAMING MONITOR LABS RESULTS

DEFAULT SETTINGS

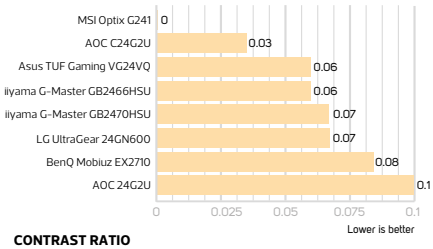
COLOUR TEMPERATURE (KELVIN)

Deviation from ideal result (6,500K)



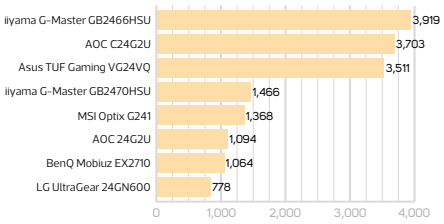
AVERAGE GAMMA

Deviation from ideal result (2.2)



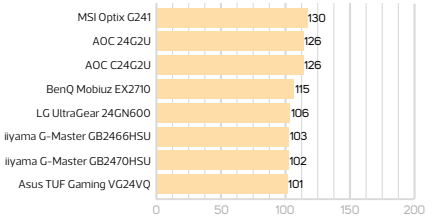
CONTRAST RATIO

Ratio of white-to-black luminance



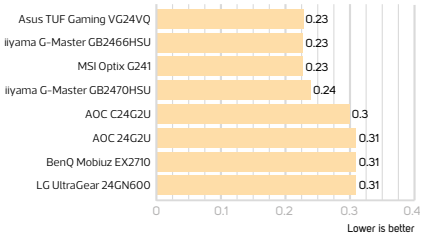
SRGB COLOUR SPACE*

Percentage of sRGB colour space covered



COLOUR ACCURACY

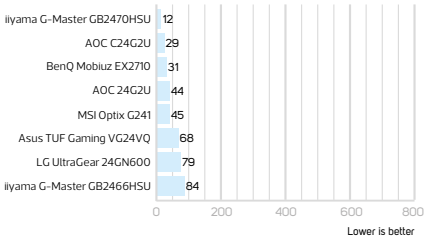
Average delta-E 2000



CALIBRATED

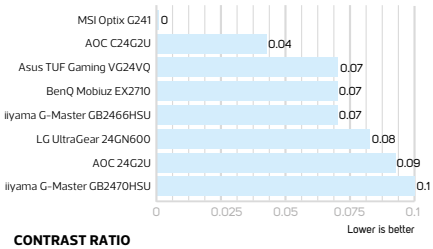
COLOUR TEMPERATURE (KELVIN)

Deviation from ideal result (6,500K)



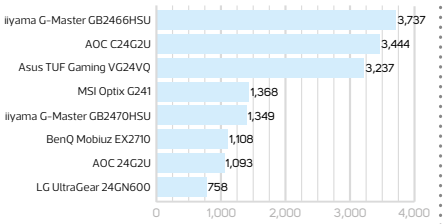
AVERAGE GAMMA

Deviation from ideal result (2.2)



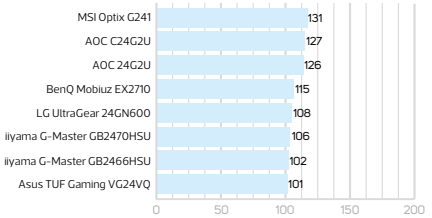
CONTRAST RATIO

Ratio of white-to-black luminance



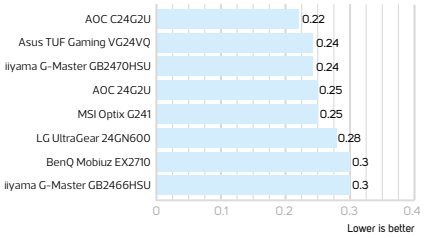
SRGB COLOUR SPACE*

Percentage of sRGB colour space covered



COLOUR ACCURACY

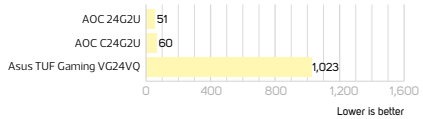
Average delta-E 2000



SRGB MODE

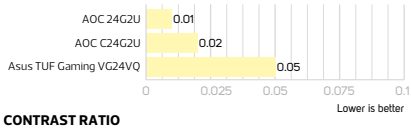
COLOUR TEMPERATURE (KELVIN)

Deviation from ideal result (6,500K)



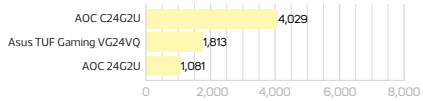
AVERAGE GAMMA

Deviation from ideal result (2.2)



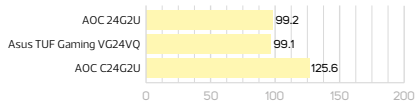
CONTRAST RATIO

Ratio of white-to-black luminance



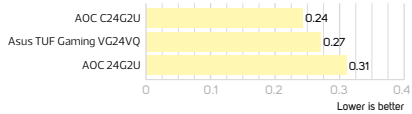
SRGB COLOUR SPACE*

Percentage of sRGB colour space covered



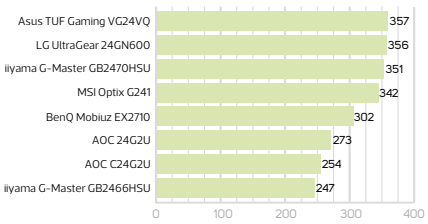
COLOUR ACCURACY

Average delta-E 2000



MAXIMUM BRIGHTNESS

Brightness in cd/m² (nits)



** A higher colour space percentage is generally better for gaming, but as close to 100 per cent as possible is better for sRGB work*

LABS TEST

Pint-sized PC cases

Antony Leather reviews eight of the latest mini-ITX cases to see which ones are best for building a tiny powerhouse

How we test

We had a dilemma about testing this month, as half of the cases in this Labs test lacked any fans out of the box. This is clearly not the configuration in which they'd be used, and we absolutely wouldn't recommend using any case without fans, never mind an already stuffy small form factor case.

With this is mind, we decided to compromise. Cases that lacked any fans were equipped with two 1,500rpm Noiseblocker fans in order to assess how they would perform with some good-quality airflow, and make an accurate assessment against the rest of the field.

Cases that had one fan also received a boost, gaining a single additional fan, while we left cases that already sported two fans at their stock configuration. That way, every case had two fans, albeit at slightly differing speeds.

We awarded more feature points to cases that came with fans, but can appreciate that some manufacturers prefer to provide a clean slate for owners to install their own premium fans, and adding stock fans in these scenarios just needlessly inflates the price.

Our trusty test gear includes an Intel Core i5-2500K overclocked to 4.4GHz using a vcore of 1.3V and an Nvidia GeForce GTX 1660 6GB graphics card with a cooler that exhausts into the case. The card's fan speed is set at 75 per cent to prevent automatic fan control from interfering with the results. This is installed in an Asus P8Z77-I Deluxe mini-ITX motherboard with 4GB of Kingston DDR3 memory, a Crucial MX500 SDD and a Corsair SF-750 SFX PSU.

The CPU cooler is a low-profile Zalman CNPS 8900, which can fit into nearly all mini-ITX cases to obtain comparable numbers. We leave each case for 15 minutes, running Prime95's smallest FFT test (**mersenneforum.org**) to load the CPU and Unigine's Valley benchmark (**unigine.com**) to load the GPU.

CPU temperatures were taken from CoreTemp (**alcpu.com/CoreTemp**), and GPU temperatures were recorded from GPU-Z (**techpowerup.com/gpuz**). We then subtracted the ambient temperatures from the results to give delta T readings, allowing us to test in normal conditions across several days and varying temperatures. We score each case using weighted calculations for their cooling, design, features and value to give an overall score, with mini-ITX cases scoring additional points for clever use of space and overall size.

Contents

- Cooler Master MasterBox NR200P / p53
- Jonsbo A4 / p54
- Kolink Rocket Heavy / p55
- Lian Li O11 Dynamic Mini / p56
- Phanteks Shift 2 / p57
- SilverStone LD03-AF / p58
- SilverStone Sugo 15 / p60
- Streacom DA2 V2 / p61

COOLER MASTER MASTERBOX NR200P / £100 inc VAT

SUPPLIER scan.co.uk

We didn't think it was possible for a mini-ITX case to land that improved upon traditional designs in a radical way, but Cooler Master's MasterBox NR200P managed just that when we first reviewed it back in Issue 206. It's reasonably compact, although is far from the smallest case we're reviewing this month, but Cooler Master has done a good job of making it flexible and designing it to make the best use of its interior.

This flexibility is both the case's greatest strength and its weakness, as the fact it can support SFX-L PSUs means it's also a little larger than strictly necessary. The ability to use horizontal and vertical GPU orientations also means some added extras have to be included, such as a PCI-E 3 riser cable, and side panels with mesh as well as glass, adding to the price, making it less specialised and, again, adding to its volume. However, if you can afford the asking price, the ability to fine-tune the case to your own needs means you nearly always have a win-win situation when it comes to thermals.

There are some notable omissions for these times, including a Type-C USB port, RGB lighting, an aluminium chassis or a particularly outstanding appearance for that matter. The NR200P is well built, although it does have far more plastic than the likes of the SilverStone LD03-AF and Jonsbo A4. It's ultimately not as attractive as the similarly sized Kolink Rocket Heavy either, but while it ditches a Type-C port, it more than makes up for this with the extensive number of accessories included in the box.

These include the aforementioned tempered glass and mesh side panels, allowing you to boost airflow for a vertically mounted graphics card, or install a glass panel with a standard graphics card orientation for a better view of the interior. The fact it includes these panels, as well as PCI-E riser cable and two powerful 120mm fans for just £100 is remarkable.

There's room for a 240mm radiator in the base and a 280mm model in the side, plus there's even a pump mount, so a custom water-cooling loop is a definite possibility. On the downside, the 155mm CPU cooler clearance means that most tower-shaped air coolers will be too large. Meanwhile, storage options include bays for up to two hard disks and two SSDs, making it one of the most well-rounded cases here.

Its CPU delta T of 50°C was excellent, and there's plenty of scope for improving on this by adding more fans or liquid cooling. Only the SilverStone LD03-AF was equipped with better thermal performance out of the box, with the rest of the cases this month requiring our additional test fans to match or better the Cooler Master. The GPU delta T of 38°C was unbeatable, though, being a clear 3°C cooler than the competition, although the fans were quite noisy at full speed.

SPEC

Dimensions (mm) 185 x 376 x 292 (W x D x H)

Material Steel, plastic, glass

Available colours Black, white

Weight 5.1kg

Front panel Power, 2 x USB 3, 1 x audio headphone/mic

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

Form factor(s) Mini-ITX, mini-DTX

Cooling 2 x 120mm roof fan mounts (fans included), 1 x 92mm rear fan mounts (fan not included), 2 x 120mm base fan mount (fan not included), 2 x 120/140mm side fan mounts (fan not included)

CPU cooler clearance 155mm (vented side panel), 153mm (glass side panel), 76mm (vertical GPU)

Maximum graphics card length 330mm

MASTER OF COIN

+ Good cooling
+ Flexible interior
+ Mesh and glass panels included

MASTER OF NONE

– No USB Type-C port
– Many tower air coolers won't fit
– Could be smaller and better-looking

Conclusion

The Cooler Master MasterBox NR200P is still the best mini-ITX case in terms of flexibility and value, and it performs excellently out of the box too, which is rare. It's not the best-looking or smallest case, but it's otherwise a fantastic choice.

VERDICT

Still a great, compact case with good cooling and excellent flexibility.

COOLING	FEATURES	OVERALL SCORE
25/30	18/20	86%
DESIGN	VALUE	
25/30	18/20	

JONSBO A4 / £130 inc VAT

SUPPLIER overclockers.co.uk

By volume the Jonsbo A4 is one of the smallest cases on test this month. It's a great example of a mini-ITX case that focuses on one specific layout while leaning more towards aesthetics than cooling. It's beautiful, but the fact it has glass side panels, while mounting the GPU on its side, means cooling is unlikely to be stellar. However, at least Jonsbo has provided two fan mounts in the base of the case to feed the CPU and GPU with cool air, plus two further mounts in the roof that can also house a 240mm radiator.

All of the fan mounts are 120mm, so the A4 lacks the beefier 140mm mounts of the Cooler Master, Streacom and Lian Li cases this month, and sadly, the lower fans aren't quite offset enough to allow air to flow in front of a two-slot graphics card's fans. In addition, blowing air upwards may even work against the exhaust vents with some fans, so you'll need to check if your own graphics card's cooler suits the case's airflow configuration.

The construction is top-notch, except for a few rough edges on the panels, and a slide-off roof reveals two tool-free panels, which are much easier to remove than the screw-on panels of the Kolink Rocket Heavy. The case is limited to an SFX or SFX-L PSU, which is sandwiched inside a removable cage next to the motherboard. Cable routing is reasonable, and the cage offers a place to stow cable slack, with a couple of routing holes also included in this location. One handy feature is a small Perspex plaque on the side, which has all the case's screws pre-screwed into it.

However, the narrow nature of the case means it doesn't have much room for a CPU air cooler, with clearance of just 71mm, so it's best to use an all-in-one liquid cooler on the CPU. Custom water cooling will require a very compact pump and reservoir as, unlike the Streacom DA2 V2 and Cooler Master MasterBox NR200P, there's very little room for extra custom loop components.

Thankfully, you do get a hard disk mount, albeit at the expense of a lower 120mm fan, plus two SSD mounts and there's also a USB Type-C header. However, the A4 lacks audio ports on the front panel and, unlike the Kolink Rocket Heavy, it's limited to dual-slot graphics cards as well.

No fans are included in the box, so we had to add our pair of 120mm fans with one in the base and one in the roof. This resulted in a CPU delta T similar to that of the Cooler Master MasterBox NR200P and SilverStone Sugo 15, while being better than the Kolink Rocket Heavy and Streacom DA2 V2. The GPU delta T was reasonable, but the MasterBox NR200P and Streacom DA2 V2 were noticeably cooler.

SPEC

Dimensions (mm) 169 x 340 x 273 (W x D x H)

Material Steel, plastic, glass

Available colours Black, silver

Weight 5.6kg

Front panel Power, 1 x USB 3, 1 x USB Type-C

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

Form factor(s) Mini-ITX, mini-DTX

Cooling 2 x 120mm roof fan mounts (fans not included), 2 x 120 base fan mounts (fan not included

CPU cooler clearance 71mm

Maximum graphics card length 325mm

JON BON JOVI

+ Four 120mm fan mounts
+ Space for a 240mm radiator
+ Compact

JON BON JELA

– Average GPU cooling
– No space for a radiator in lower fan mounts
– Lacking in features

Conclusion

Adding a couple more fans and an AIO liquid cooler would bolster the Jonsbo A4's cooling, but overall, it's more the lack of features and high price that hurt the case's score. That said, it's easy to work with the A4, and if you really want a simple, small, good-looking case with space for high-end hardware, and you can afford it, the A4 is still a solid case, on the proviso that you buy some fans for it.

VERDICT

A pretty case with half-decent cooling – only a high price and a comparatively average set of features let it down.

COOLING	FEATURES	OVERALL SCORE
24/30	10/20	76%
DESIGN	VALUE	
29/30	13/20	

KOLINK ROCKET HEAVY / £110 inc VAT

SUPPLIER overclockers.co.uk

We've reviewed both of the Rocket Heavy's predecessors from Kolink, and it looks as though the company is finally getting a handle on what it takes build a decent modern mini-ITX case. The Rocket Heavy maintains the good looks of its forebears, with a gunmetal grey chassis that sports hexagonal perforations, with the colour extending to the interior as well.

This time, though, Kolink has sensibly made the move to 120mm fan support (the original Rocket only had 80mm fan support), with a pair of mounts in the roof and an internal mount next to the motherboard mounts. However, unlike the Jonsbo A4 and Cooler Master MasterBox NR200P, the base of the case lacks fan mounts despite having large vents in this location.

The front panel's vents are also quite minimal, with less than half the available area actually open to airflow, but at least you get one 120mm fan installed as standard. That said, Kolink told us there would be optional vented panels available for this case in the near future, as well as a version of the case that includes these panels as standard.

Sadly, it's time consuming to deal with the tempered glass panels that are included with the current model, as they secure with a total of eight screws – as a point of comparison, the Jonsbo A4's tool-free construction offers a much quicker method of removing the panels.

If you like your window to give you a view of your motherboard then you're also out of luck, as the Rocket Heavy stacks the graphics card on top of it instead of in a separate chamber. Thankfully, as it's a wider case than the A4, so you get a little extra CPU cooler clearance at 85mm, but the Rocket Heavy is clearly designed to be used with all-in-one liquid coolers.

On the plus side, you get a full-fat USB Type-C port on the front panel, plus a generous quartet of USB ports, two of which are USB 3. Storage isn't great, though, with one hard disk mount and two SSD mounts, but it's no worse than most of the other cases on test.

The Rocket Heavy also supports triple-slot graphics card with a length limit of 340mm, although we'd definitely consider one of the new vented panels if you'll be using a monster graphics card. You're also forced to use a PCI-E riser cable in this case, and for now it only supports PCI-E 3 bandwidth, plus you'll need to invest in an SFX or SFX-L PSU.

We added a second 120mm fan to the equation for testing, and the Rocket Heavy's thermal performance then got within spitting distance of the Cooler Master MasterBox NR200P, but was outdone by the Jonsbo A4, SilverStone LD03-AF and SilverStone Sugo 15 on the CPU delta T. Meanwhile, the GPU delta T of 65°C matched the Jonsbo A4 and bettered both SilverStone cases.

Conclusion

Adding a vented panel or two will definitely make the Kolink Rocket Heavy a much better mini-ITX case, although we'd also like to see a few more features in future designs, such as easier panel removal, plus lower fan and radiator mounts. It's otherwise an attractive, compact and well-assembled case, though, and it's great to see Kolink improving cooling with its latest mini-ITX chassis.

HEAVY METAL

+ Attractive design
+ Space for a 240mm radiator
+ Compact size

HEAVY BREATHING

- Average cooling
- No lower fan mounts
- Fiddly side panels

SPEC

Dimensions (mm) 180 x 350 x 265 (W x D x H)

Material Steel, glass

Available colours Grey

Weight 4.75kg

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

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

Form factor(s) Mini-ITX, mini-DTX

Cooling 2 x 120mm roof fan mounts (one 120mm fan included), 1 x internal 120mm fan mount (fan not included)

CPU cooler clearance 85mm

Maximum graphics card length 340mm

VERDICT

Far better than either of Kolink's previous dinky case efforts, although its side panels are fiddly to remove and there are no lower fan mounts.

COOLING	FEATURES	OVERALL SCORE
24/30	12/20	77%
DESIGN	VALUE	
26/30	15/20	

LIAN LI O11 DYNAMIC MINI / £92 inc VAT

SUPPLIER overclockers.co.uk

We debated whether to include Lian Li's O11 Dynamic Mini in this month's group test, for the simple reason that it's rather large and can actually house micro-ATX and ATX motherboards, albeit with reduced cooling capacity, so it's not strictly a mini-ITX case. However, the case is configured out of the box to work with mini-ITX motherboards, with an adaptor included that needs to be installed for larger boards, plus it's also limited to SFX and SFX-L PSUs to save space. Given these credentials, we felt we were justified in including it.

There's no denying its size, though ,and every other case in this month's group test could fit inside it one at a time with room to spare. However, unlike some of Thermaltake's past efforts at creating large mini-ITX cases, the O11 Dynamic Mini does actually make excellent use of its internal space. You can fit a total of three 280mm radiators in the roof, side and base of the case, with alternative room for 360mm radiators in the base and roof.

There's oodles of clearance available too, with 100mm in the roof and 85mm in the side. It supports triple-slot graphics cards, and with an optional kit, your card can be mounted vertically. Plus, even then, there's enough room for a slim radiator and fans in the base. It includes a pump mount as well, so there's all the space and mounts you need to make a monstrous water-cooled mini-ITX PC.

Despite the price tag of just £92 inc VAT, you also get tool-free tempered glass side panels and USB 3.1 Type-C support, which you don't always find in some of the more expensive cases on test this month. The view of the interior from the glass panels is also great. Storage isn't as lavishly bestowed as you might expect, though, with space for just two 2.5in SSDs and two 3.5in hard disks. There are also no fans included as standard either, so we had to add our own fans to see how it would perform with a little airflow.

With such a massive volume of well-ventilated space, cooling wasn't going to be much of an issue once we'd added some fans. We saw the best CPU delta T on test of 37°C, and the third best GPU delta T of 41°C. What's more, with a CPU cooler clearance of 172mm, there's clearly scope for building a high-end air-cooled PC inside the case too.

SPEC

Dimensions (mm) 270 x 420 x 380 (W x D x H)

Material Steel, glass

Available colours Black, white, grey/white

Weight 8.52kg

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

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

Form factor(s) Mini-ITX, mini-DTX, micro-ATX, ATX

Cooling 3 x 120mm/2 x 140mm roof fan mounts (fans not included), 3 x 120mm/2 x 140mm base fan mounts (fans not included), 2 x 120/140mm side fan mounts (fans not included)

CPU cooler clearance 172mm

Maximum graphics card length 395mm

DYNAMITE

+ Huge water-cooling potential
+ Great view of interior
+ Good for air and water-cooled systems

DUST MITE

- Enormous
- Vertical GPU support is optional
- No fans included

Conclusion

There's clearly a big issue with the Lian Li O11 Dynamic Mini, however, and that's its size. It's almost obscenely large for a mini-ITX case, and you'd need to pair the likes of AMD's Ryzen 9 5950X or Intel's Core i9-10980XE, along with a GeForce RTX 3090 or Radeon RX 6900 XT, to even come close to warranting the kind of water-cooling hardware you can cram inside this chassis.

Compact it is not, although it's certainly smaller both in footprint and volume than most ATX cases. On the plus side, the case is extremely well made, has plenty of features, exceptional water-cooling support and it costs just £92. Plus, if you ever need to upsize your motherboard in future, you might not need to a new case either. The only thing you will need are some fans.

VERDICT

With the exception of its colossal size, this is a fantastic case for the cash.

COOLING	FEATURES	OVERALL SCORE
29/30	18/20	85%
DESIGN	VALUE	
20/30	18/20	

PHANTEKS EVOLV SHIFT 2 / £108 inc VAT

SUPPLIER overclockers.co.uk

With the NZXT H1 now out of action due to fire safety issues, if you want a tall, elegant mini-ITX tower with tempered glass and room for large graphics cards, your options haven't been particularly numerous. One exception is Phanteks' Evolv Shift case, with the Shift 2 building on the original design with some tweaks to boost various parts of it.

Let's start with the most obvious change, which is the large grille design on the rear panel, which should improve airflow compared with the piddly side vents of the old model. The USB ports are now also located at the base and not on the side, providing a wider area of the side mesh that's clear for airflow. Above this area, vents have also been cut into the inner panel of the chassis, allowing more air to reach these mesh areas.

Meanwhile, the SFX PSU mount has been flipped on its side, which makes installing SFX-L PSUs far easier, although this change does mean that installing a radiator is no longer possible in this location. However, you can fit up to a 140mm fan in the base, as well as in the second side mount. You also get better control over the digital RGB lighting, with dual mode buttons on the top of the chassis. A single 140mm fan is included, so we added a 120mm fan to make it up to two fans for our testing, so we could get a more balanced look at cooling ability.

There's still no USB Type-C port, though, and also no audio jack sockets, although the glass side panels are at least easier to remove than the ones on the likes of the Kolink Rocket Heavy. There are also optional mesh panels available, should you wish to boost airflow further.

Despite being such a narrow chassis, the clever design means there's room for decent-sized components. There's 85mm of CPU cooler clearance, for example, as well as room for 2.9-slot graphics card that measures up to 335mm long. You'll need to use the included PCI-E 3 riser cable, though, so remember to switch to PCI-E 3 mode in your motherboard's BIOS if you're using a PCI-E 4 motherboard, CPU and GPU.

On the downside, storage options are basic, with space for a single 3.5in hard disk and two 2.5in SSDs, with two more of the latter using an optional bracket. The cooling still isn't great either. The CPU delta T of 59°C is a big improvement with our second fan vs just one, but it was still the warmest result on test by a couple of degrees. The GPU delta T of 52°C was again the warmest result on test, although it was still far from throttling territory.

Conclusion

Cooling still isn't the Phanteks Evolv Shift 2's strong point, despite some improvements in this area, and we'd definitely recommend filling all three fan mounts and using an AIO liquid cooler for the CPU. As tower cases go, the SilverStone LD03-AF is far more capable in terms of cooling, although it doesn't quite have the swagger of the Shift 2. This is a seriously attractive mini case, and using the optional mesh panels and adding more fans will undoubtedly improve the cooling score. If you're sold on the looks, or keen to keep your case's footprint to a minimum, The Shift 2 is definitely worth considering.

SPEC

Dimensions (mm) 170 x 274 x 490 (W x D x H)

Material Aluminium, steel, glass

Available colours Black, grey

Weight 6.8kg

Front panel Power, 2 x USB 3

Drive bays 1 x 3.5in, 2 x 2.5 (additional 2 x 2.5in with adaptor)

Form factor(s) Mini-ITX

Cooling 2 x 120/140mm side fan mounts (1 x 140mm fan included), 1 x 120/140 base fan mount (fan not included)

CPU cooler clearance 85mm

Maximum graphics card length 335mm

SHIFT

+ Attractive design
+ Small footprint
+ Space for large graphics cards

SHIFTY

− No USB Type-C support
− Mediocre cooling
− Limited CPU cooler clearance

VERDICT

A fantastic-looking tower with a super-small footprint, but you'll need to boost its cooling.

COOLING	FEATURES	OVERALL SCORE
19/30	14/20	74%
DESIGN	VALUE	
27/30	14/20	

SILVERSTONE LD03-AF / £95 inc VAT

SUPPLIER quietpc.com

SilverStone has a grand history of mini-ITX case support, and we've included two of its latest offerings this month as they're so different. The first one to appear in this Labs test is the LD03-AF, which is the company's answer to the Phanteks Evolv Shift 2, with a small footprint and skyscraper tower design.

It's shorter and stockier than the Shift 2 but, like the Phanteks case, it also sports some design tweaks over the original LD03. The most prominent addition is a large vent cut into the glass side panel sitting over the graphics card. With the AF suffix at the end of its name standing for 'airflow', the LD03-AF is clearly trying to improve on the mediocre cooling of its predecessor. You also get two powerful 120mm Air Penetrator fans blasting air in a vertical stacked arrangement. Plus, unlike the previous model, it includes a Type-C USB port.

SILVERSTONE

- \+ Excellent CPU cooling
- \+ Small footprint
- \+ Quick and easy side panel removal

M25

- − Average GPU cooling
- − GPUs limited to dual-slot
- − Limited water-cooling potential

SPEC

Dimensions (mm) 265 x 230 x 414 (W x D x H)

Material Steel, glass

Available colours Black

Weight 5.34kg

Front panel Power, reset, 2 x USB 3, 1 x USB Type-C, audio jacks

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

Form factor(s) Mini-ITX, mini-DTX

Cooling 1 x 120mm roof fan mounts (fan included), 1 x 120mm base fan mount (fan included)

CPU cooler clearance 190mm

Maximum graphics card length 309mm

The rest of the case is largely identical to the original LD03 design, with pop-off side panels giving clear access to the interior around three sides. You'll need an SFX or SFX-L power supply, as ATX units aren't supported. However, thanks to the square dimensions, even though you can fit a 120mm liquid cooler's radiator in the lower 120mm fan mount, there's a generous 190mm of clearance for a CPU air cooler – that's far more than the Phanteks Evolv Shift 2 as well as all the other cases on test this month.

The downside is that there's little scope for building a custom water-cooling loop with large radiators in this case. You're also limited to a dual-slot graphics card, which will need to be shorter than 309mm and measure under 167mm wide too. On the plus side, there's no need to use a riser cable, meaning you can enjoy all the extra bandwidth that PCI-E 4 has to offer without problems.

Meanwhile, storage options are rather limited. You're able to install a single hard disk or SSD in one mount, with a second mount dedicated to 2.5in SSDs, but we do feel SilverStone could have added another hard disk mount here given the cavernous interior.

In terms of cooling performance, the GPU delta T was well away from throttling territory, but far from the best result on test at 47°C – only the Shift 2 was warmer. That said, most other cases lay within just 5°C of this result, while the Cooler Master MasterBox NR200P and Streacom DA2 V2 offered more significant benefits for GPU cooling. The CPU delta T was far more potent at 38°C – only the Lian Li O11 Dynamic Mini was cooler and even then, only once we'd added fans to its fanless chassis. You may not want to run this case's Air Penetrator fans at full speed all the time, though, as they were a tad noisy.

Conclusion

There are clearly more attractive mini cases available than the odd-looking LD03-AF. The Phanteks Evolv Shift 2 certainly looks sleeker, as tower designs go. The SilverStone doesn't offer exceptional GPU cooling either, although it's more than up to the task of handling a high-end PC and is particularly well suited to air cooling, thanks to a roomy interior and decent CPU cooler clearance. There's not much room for storage or cooling expansion, and it's also limited to dual-slot graphics cards, but with change from £100 and excellent CPU cooling, this is a great case if you plan to air-cool your PC.

VERDICT

Excellent CPU air cooling and a very reasonable price, although its GPU cooling could be better.

COOLING	FEATURES	OVERALL SCORE
26/30	11/20	80%
DESIGN	VALUE	
26/30	17/20	

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SILVERSTONE SUGO 15 / £160 inc VAT

SUPPLIER scan.co.uk

With SilverStone's other entry this month retailing for under £100 inc VAT, we had to double-check the price of the Sugo 15, as it will set you back more than £60 more. That's an awful lot considering they've both limited to mini-ITX systems of a similar size. However, the reason why this cube case costs so much more was immediately clear when we got our hands on it.

It's clad in thick aluminium panels, which feature shiny silver sprung thumbscrews, and every inch of the case is epically well made. The panels feature striking triangular vents, although they're likely not that efficient in terms of letting airflow into the chassis, so we were interested to see if they hinder airflow. It's also reasonably large in terms of footprint, with a shoebox size of 247 x 366mm, although it only measures 211mm tall.

We were a bit disappointed to see an ATX PSU mount inside the case, given SilverStone's huge array of powerful SFX PSUs – interestingly, this mount is also positioned vertically in the centre-front of the case. Limiting this mount to an SFX PSU would have enabled SilverStone to shed some volume and, unlike Jonsbo's similar PSU mount, the Sugo 15 lacks a direct way to route the PSU's cables through the PSU cage to your components, instead having to spread out to the sides.

This keeps the CPU area clear, though, and you get a massive 182mm of CPU cooler clearance, which is enough even for the largest fan-equipped coolers. What's more, there's space for triple-slot graphics cards measuring up to 330mm long, which connect directly to the motherboard for easy PCI-E 4 support. Meanwhile, the front panel sits at the very front of the case and offers USB 3 ports, plus a Type-C USB port, an audio jack, and both power and reset buttons.

In terms of airflow, the case has a single fan out of the box, but it can also house a single 120mm fan in the roof, plus either two 120mm or 140mm fans on a bracket on the side, where you could alternatively mount a 240mm radiator. If you ditch the latter mounts, there's space for two hard disks or one hard disk and a 120mm radiator, all of which are mounted in the side bracket.

However, the rear fan mount can play host to a 120mm radiator too. SilverStone also deserves praise for its use of magnetic, easily removable dust filters. SilverStone has added magnetic strips to the case, so they stick to the otherwise nonmagnetic aluminium.

In terms of cooling, the SilverStone's CPU delta T of 48°C was a mid-table result for this Labs test, with our extra fan pointing at the CPU cooler from the roof for best effect. The GPU delta T of 44°C was much better, and even had the measure of its sibling – the LD03-AF, although the latter posted a far lower CPU delta T.

Conclusion

Sadly, the Sugo 15's price puts it on the back foot compared with the other cases this month. It also doesn't look particularly small, and cable tidying will be a challenge. However, we can't argue with the fantastic build quality and flexible interior, which could easily house a high-end mini-ITX PC with a decent graphics card and large air cooler.

SPEC

Dimensions (mm) 247 x 366 x 211 (W x D x H)

Material Steel, aluminium

Available colours Black, white

Weight 4.25kg

Front panel Power, reset, 2 x USB 3, 1 x USB Type-C, audio jack

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

Form factor(s) Mini-ITX, mini-DTX

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

CPU cooler clearance 182mm

Maximum graphics card length 330mm

SUGO DI POMODORO

+ Excellent CPU and GPU cooler support
+ Fantastic build quality
+ Easy side panel removal

CHEAP KETCHUP

– Average CPU cooling
– Cable routing could be improved
– ATX PSU support adds to volume

VERDICT

A really well-made case, although its price is high and cable tidying is a challenge.

COOLING	FEATURES	OVERALL SCORE
23/30	14/20	76%
DESIGN	VALUE	
28/30	11/20	

STREACOM DA2 V2 / £190 inc VAT

SUPPLIER quietpc.com

With some stiff and affordable competition this month, the previously reviewed Streacom DA2 V2 (see Issue 210) faces a tough ask to justify its huge price tag in the face of some excellent, flexible and high-performing mini-ITX cases. It picked up our Extreme Ultra award last time, thanks to a fantastic rail system that enables it to be highly flexible when it comes to mounting components.

In fact, nearly every component in the Streacom DA2 V2 can be moved around to some extent, including the power supply. While this case supports ATX PSUs, it's possible to reconfigure the PSU mount with an SFX PSU to make way for more storage if you want it.

Despite having a similar size to the Kolink Rocket Heavy, Jonsbo A4 and SilverStone Sugo SG15, the DA2 V2 beats all three of these cases in numerous areas. It can house up to three hard disks, for example, while they can only accommodate up to two. It can also house a 280mm radiator in its side panel, while those cases are limited to 240mm models. What's more, it can be configured with a horizontal or vertical GPU mount, albeit with optional components.

This DA2 V2 has room for a dizzying amount of fans too, including 180mm models. The all-aluminium construction makes for a striking appearance as well, especially with its outer curved panels hiding the air vents beneath them for a cleaner look. Meanwhile, the side panels are tool-free and simply slip off the case if you apply pressure from one end.

There are lots of clever ideas packed into this case. The only issues with it are firstly the lack of a USB 3.1 Type-C port, as it's limited to just USB 3 out of the box, although an optional Type-C adaptor is available. There's also just 145mm of CPU cooler clearance, and you're also limited to dual-slot graphics cards. On the plus side, though, there's enough room to install radiators that could water-cool your CPU and graphics card anyway.

No fans are included in the box, but with our two fans installed, the Streacom achieved a CPU delta T of 57°C. That's much cooler than our original fanless test, but it's still the second warmest result on test, being well behind the Cooler Master MasterBox NR200P, Kolink Rocket Heavy and Jonsbo A4. Only the Phanteks Evolv Shift 2 was warmer. The GPU delta T of 40°C was much better, though, being second only to the Cooler Master MasterBox NR200P – if you plan to only water-cool one component in this case, it should be your CPU.

Conclusion

The high price puts the Streacom DA2 V2 at a major disadvantage from the outset, and the likes of the Cooler Master MasterBox NR200P and Jonsbo A4 make for viable alternatives that are far cheaper. The Lian Li O11 Dynamic Mini is significantly larger, but is a similar blank slate, costs half the price and sports even better water-cooling support.

However, when it comes to offering an extensive amount of internal flexibility, good water-cooling support and room for storage in a small space, the DA2 V2 can't be faulted. If you're up for spending a weekend planning and tweaking your way to the mini PC of your dreams, this is the case for you. CPC

SPEC

Dimensions (mm) 180 x 340 x 286 (W x D x H)

Material Aluminium, steel

Available colours Black, silver

Weight 3.9kg

Front panel Power, 1 x USB 3 Type-C

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

Form factor(s) Mini-ITX, mini-DTX

Cooling 2 x 120/140mm roof fan mounts (fans not included), 1 x 92mm rear fan mounts (fan not included), 2 x 120mm/140mm base fan mounts (fans not included), 2 x 120/140mm or 1 x 180mm side fan mounts (fans not included)

CPU cooler clearance 145mm

Maximum graphics card length 330mm

CHECKMATE

+ Highly flexible layout
+ Good water-cooling support
+ Great build quality

CHECK OUT

– USB 3.1 Type-C is optional extra
– Expensive
– Limited CPU cooler height support

VERDICT

It might be expensive, but the DA2 V2 is also beautiful and a tinkerer's dream.

COOLING	FEATURES	OVERALL SCORE
21/30	16/20	78%
DESIGN	VALUE	
30/30	11/20	

How we test

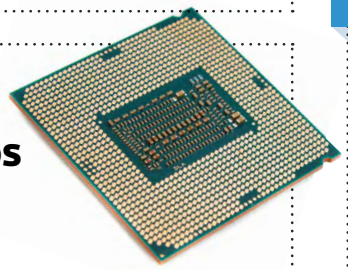
MOTHERBOARDS

TEST PROCESSORS

› **Intel LGA1200** Intel Core i9-11900K
› **AMD AM4** AMD Ryzen 9 5900X, and AMD Ryzen 9 3900X for standalone reviews that require comparisons with older results.

Common test hardware between our CPU test rigs includes 16GB (2 x 8GB) of Corsair Vengeance RGB Pro 3466MHz DDR4 memory, a 2TB Samsung 970 Evo SSD, a 1TB PCI-E 4 Corsair MP600 SSD and an Nvidia GeForce RTX 3070 Founders Edition graphics card.

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 New Dawn on Windows 10 Home 64-bit. We also test the board's M.2 ports, and record the noise level and dynamic range of integrated audio using RightMark Audio Analyzer.



PROCESSORS

TEST MOTHERBOARDS

› **Intel LGA1200 Rocket Lake**
MSI MEG Z490 Ace
› **Intel LGA1200 Comet Lake**
Asus ROG Strix Z590-E Gaming WiFi
› **AMD AM4** MSI MPG Gaming B550 Carbon WiFi

Common gear between our CPU test rigs includes 16GB (2 x 8GB) of Corsair Vengeance RGB Pro 3466MHz DDR4 RAM, a 2TB Samsung 970 Evo SSD and an Nvidia GeForce RTX 3070 GPU. Cooling comes from 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 10 with security updates, as well as the latest BIOS versions and drivers. We record results at stock speed and overclocked, and our tests include the **CPC** RealBench suite for image editing, video encoding and multi-tasking, Cinebench's single and multi-threaded tests, Far Cry New Dawn and Watch Dogs: Legion.

For our game tests, we record the 99th percentile minimum and average frame rates either using the game's built-in benchmark or Nvidia FrameView. Finally, we measure the idle and load power consumption of the whole system, using Prime95's smallfft test with AVX disabled to stress the CPU.

MONITORS

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

CPU COOLERS

We measure the CPU temperature with CoreTemp, and subtract the ambient air temperature to give a delta T result, enabling us to test in a lab that isn't temperature controlled. We load the CPU with Prime95's smallfft test and take the reading after ten minutes.

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

INTEL LGA1200
Intel Core i9-11900K overclocked to 5.1GHz with 1.38V vcore.

INTEL LGA1151
Intel Core i5-9600K overclocked to 4.8GHz with 1.2V vcore.

INTEL LGA2066
Intel Core i9-9980XE overclocked to 4.2GHz with 1.08V vcore.

AMD AM4
AMD Ryzen 9 5900X overclocked to 4.5GHz with 1.25V vcore, or AMD Ryzen 7 1700 overclocked to 3.9GHz with 1.425V vcore for standalone reviews that require comparisons with older results.

AMD TRX4
AMD Threadripper 3960X overclocked to 4.2GHz with 1.265V vcore, 32GB of 3466MHz Corsair Vengeance RGB memory, Samsung 960 Pro SSD, Corsair RM850i PSU.

GRAPHICS CARDS

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

TEST KIT

AMD Ryzen 9 5900X, 16GB (2 x 8GB) of Corsair Vengeance RGB Pro SL 3600MHz DDR4 memory, Asus ROG Strix B550-E Gaming motherboard, Thermaltake Floe Riing 240 CPU cooler, Corsair HX750 PSU, Cooler Master MasterCase H500M case, Windows 10 Professional 64-bit.

GAME TESTS

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

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

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

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

POWER CONSUMPTION

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

CUSTOM PC AWARDS

EXTREME ULTRA

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

PREMIUM GRADE

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

PROFESSIONAL

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

APPROVED

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

CUSTOM KIT

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

CUSTOM PC REALBENCH

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

GIMP IMAGE EDITING

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

HANDBRAKE H.264 VIDEO ENCODING

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

LUXMARK OPENCL

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

HEAVY MULTI-TASKING

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

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.

Budget system with integrated graphics

Quad-core CPU, basic gaming

Needs a micro-ATX or ATX case.
We recommend a 350W 80 Plus power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 5 3400G	currys.co.uk	**#194** p20	£170
CPU COOLER	AMD Wraith air cooler included with CPU	N/A	**#194** p20	£0
GRAPHICS CARD	AMD Radeon RX Vega 11 integrated into CPU	N/A	**#194** p20	£0
MEMORY	16GB (2 x8 GB) Corsair Vengeance LPX Pro 3200MHz (CMK16GX4M2 Z3200C16)	scan.co.uk	**#204** p74	£91
MOTHERBOARD	Asus TUF B450M-Plus Gaming (micro-ATX)	scan.co.uk	**#204** p74	£85
STORAGE	500GB WD Blue SN550 (M.2 NVMe)	scan.co.uk	**#204** p24	£53
		Total £399		

Entry-level RTX gaming

6-core CPU, 1080p gaming

Needs a micro-ATX or ATX case.
We recommend a 500W 80 Plus power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 5 3600	scan.co.uk	**#213** p41	£179
CPU COOLER	ARCTIC Freezer 7 X	scan.co.uk	**#202** p20	£18
GRAPHICS CARD	Nvidia GeForce RTX 3060	ebay.co.uk	**#213** p16	£660
MEMORY	16GB (2 x8GB) Corsair Vengeance LPX Pro 3200MHz (CMK16GX4M2Z 3200C16)	scan.co.uk	**#204** p74	£91
MOTHERBOARD	Asus TUF B450M-Plus Gaming (micro-ATX)	scan.co.uk	**#204** p74	£85
STORAGE	500GB WD Blue SN550 (M.2 NVMe)	scan.co.uk	**#204** p24	£53
		Total £1,086		
UPGRADES				
SWAP GRAPHICS CARD	AMD Radeon RX 6700 XT (1080p gaming with ray tracing and 2,560 x 1,440 gaming)	ebay.co.uk	**#213** p19	£720
SWAP STORAGE	1TB WD Blue SN550 (M.2 NVMe)	scan.co.uk	**#204** p24	£91

2,560 x 1,440 gaming system

6-core CPU, 2,560 x 1,440 gaming with real-time 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 i5-11600K	scan.co.uk	**#213** p49	£250
CPU COOLER	Antec Neptune 240	scan.co.uk	**#204** p16	£80
GRAPHICS CARD	AMD Radeon RX 6700 XT	ebay.co.uk	**#213** p19	£720
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz (CMW16GX4M 2Z3600C20)	scan.co.uk	**#210** p74	£107
MOTHERBOARD	ASRock Z590 PG Velocita	scan.co.uk	**#213** p58	£276
STORAGE	1TB Gigabyte Aorus NVMe Gen4 M.2 SSD (M.2 NVMe)	scan.co.uk	**#210** p74	£150
		Total £1,583		
UPGRADES				
ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	**#166** p54	£80

Mid-range gaming system

8-core CPU, 2,560 x 1,440 and some 4K gaming with real-time ray tracing

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

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 5800X	scan.co.uk	**#213** p44	£408
CPU COOLER	Antec Neptune 240	scan.co.uk	**#204** p16	£80
GRAPHICS CARD	AMD Radeon RX 6800 XT	ebay.co.uk	**#211** p42	£1,200
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz (CMW16GX4M 2Z3600C20)	scan.co.uk	**#210** p74	£107
MOTHERBOARD	Asus ROG Strix X570-E Gaming (ATX)*	overclockers.co.uk	**#193** p44	£290
STORAGE	1TB Gigabyte Aorus NVMe Gen4 M.2 SSD (M.2 NVMe)	scan.co.uk	**#210** p74	£150
		Total £2,235		
UPGRADES				
ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	**#166** p54	£80
SWAP CPU COOLER	Corsair H100i RGB Platinum (240mm AIO liquid cooler)	amazon.co.uk	**#185** p82	£104

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

Core component bundles cont ...

4K gaming system

8-core CPU, 4K gaming

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

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 5800X	scan.co.uk	**#213** p44	£408
CPU COOLER	Corsair H100i RGB Platinum (240mm AIO liquid cooler)	amazon.co.uk	**#175** p20	£104
GRAPHICS CARD	AMD Radeon RX 6900 XT	ebay.co.uk	**#211** p44	£1,550
MEMORY	16GB (2 x 8GB) Corsair Vengeance RGB Pro 3600MHz (CMW16GX4M 2Z3600C20)	scan.co.uk	**#210** p74	£107
MOTHERBOARD	MSI Prestige X570 Creation (E-ATX)*	overclockers.co.uk	**#193** p48	£440
STORAGE	1TB Samsung 980 Pro	ebay.co.uk	**#208** p52	£185
	Total £2,794			
UPGRADES				
ADD SECONDARY STORAGE	4TB Western Digital Blue	overclockers.co.uk	**#166** p54	£80

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

Heavy multi-threading workstation

Serious multi-threaded power, 1080p gaming

Needs an E-ATX case with room for a 280mm all-in-one liquid cooler. We recommend a 750W 80 Plus Gold power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Threadripper 3960X	scan.co.uk	**#197** p18	£1,310
CPU COOLER	NZXT Kraken X63 (280mm AIO liquid cooler)	scan.co.uk	**#207** p47	£115
GRAPHICS CARD	Nvidia GeForce GTX 1660 Super	ebay.co.uk	**#199** p44	£400
MEMORY	32GB (4 x 8GB) Corsair Dominator Platinum RGB 3600MHz	scan.co.uk	**#197** p20	£291
MOTHERBOARD	ASRock TRX40 Taichi (E-ATX)	overclockers.co.uk	**#198** p44	£470
STORAGE	1TB Samsung 980 Pro	ebuyer.com	**#208** p52	£185
	Total £2,771			
UPGRADES				
SWAP GRAPHICS CARD	AMD Radeon RX 6700 XT (2,560 x 1,440 gaming with real-time ray tracing)	ebay.co.uk	**#213** p19	£720
SWAP CPU	AMD Threadripper 3970X (32 cores - massive multi-threaded power)	scan.co.uk	**#197** p19	£1,830
ADD SECONDARY STORAGE	4TB Western Digital Blue	cclonline.com	**#166** p50	£80

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. We've also recommended a small PSU and a low-profile CPU cooler, if your chosen case requires them.

Mini-ITX

Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Intel Z590 (LGA1200)	Gigabyte Z590I Vision D	scan.co.uk	**#214** p18	£284
Intel Z490 (LGA1200)	Asus ROG Strix Z490-I Gaming	scan.co.uk	**#206** p40	£275
AMD B550 (AM4 budget)	Asus ROG Strix B550-I Gaming	scan.co.uk	**#206** p44	£197
AMD X570 (AM4 mid-range)	Asus ROG Strix X570-I Gaming	amazon.co.uk	**#198** p20	£272

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ALL-PURPOSE	Cooler Master MasterBox NR200P	scan.co.uk	**#206** p18	£100
TOWER	SilverStone LD03-AF	quietpc.com	**#214** p58	£95
PREMIUM	Streacom DA2 V2	quietpc.com	**#214** p51	£190

ATX cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Phanteks Eclipse P300 Glass	overclockers.co.uk	**#176** p28	£48
BUDGET RGB	Antec DF700 FLUX	scan.co.uk	**#214** p26	£70
SUB-£100	be quiet! Pure Base 500DX	scan.co.uk	**#202** p39	£99
COMPACT	Fractal Design Define 7 Compact	overclockers.co.uk	**#203** p32	£100
HIGH AIRFLOW	Fractal Design Meshify 2	scan.co.uk	**#212** p45	£125
MID-RANGE	Phanteks Eclipse P600S	overclockers.co.uk	**#202** p44	£139
SUB-£150	Fractal Design Define 7	overclockers.co.uk	**#204** p18	£140
PREMIUM	Phanteks Enthoo Evolv X	overclockers.co.uk	**#187** p24	£215

Micro-ATX

Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Budget AMD B450 (AM4)	Asus TUF B450M-Plus Gaming	scan.co.uk	**#204** p74	85
AMD B550 (AM4)	MSI MAG B550M Mortar	ebuyer.com	**#204** p42	£120

Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Fractal Design Focus G Mini	scan.co.uk	**#180** p46	£50
MID-RANGE	Fractal Design Define Mini C	scan.co.uk	**#161** p26	£75

Networking

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ROUTER (WI-FI 6)	TP-Link Archer AX6000	overclockers.co.uk	**#196** p57	£250
MESH ROUTER (WI-FI 6)	Asus AiMesh AX6100	amazon.co.uk	**#196** p54	£350
WI-FI ADAPTOR	TP-Link Archer TX3000E	overclockers.co.uk	**#196** p58	£60
DUAL-BAY NAS BOX	Synology DS220j	box.co.uk	**#200** p22	£149
DUAL-BAY MEDIA NAS BOX	Synology DS218play	box.co.uk	**#174** p34	£206
2.5 GIGABIT DUAL-BAY NAS BOX	QNAP TS-231P3	ebuyer.com	**#212** p25	£275

Monitors

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

Up to 25in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN, 144HZ, IPS, 1,920 X 1,080, F, G	AOC 24G2U	ebuyer.com	#214 p28	£179
25IN, 240Hz, IPS, 1,920 X 1,080, F, G	Acer Predator XB253Q	amazon.co.uk	#209 p57	£326
25IN, 360Hz, IPS, 1,920 X 1,080, F, G	Asus ROG Swift PG259QN	overclockers.co.uk	#212 p20	£699

Over 28in

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
31.5IN, 60Hz, VA, 4K, F	iiyama ProLite XB3288UHSU	scan.co.uk	#205 p43	£370
32IN, 165HZ, VA, 2,560 X 1,440, F, G	Dell S3220DGF	currys.co.uk	#214 p28	£399
34IN, 144Hz, IPS, 3,440 x 1,440, W, F	iiyama G-Master GB3461WQSU	cclonline.com	#206 p53	£430
34IN, 144Hz, IPS, 3,440 x 1,440, W, F, G	LG UltraGear 34GN850	currys.co.uk	#206 p55	£949
38IN, 144Hz, IPS, 3,840 X 1,600, W, F, G, HDR	LG UltraGear 38GN950	currys.co.uk	#208 p30	£1,500
35IN, 200Hz, VA, 3,440 x 1,440, W, G, HDR	Asus ROG Swift PG35VQ	scan.co.uk	#198 p58	£2,389

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	£220
27IN, 240Hz, IPS, 1,920 X 1,080, F, G	Asus TUF Gaming VG279QM	scan.co.uk	#209 p60	£349
27IN, 144Hz, IPS, 2,560 x 1,440, F, G	Asus TUF Gaming VG27AQ	overclockers.co.uk	#201 p54	£429
27IN, 240Hz, TN, 2,560 x 1,440, F, G	AOC AG273QZ	overclockers.co.uk	#202 p27	£480
27IN, 240Hz, IPS, 2,560 X 1,440, F, G	Alienware AW2721D	dell.com	#212 p21	£700

Non-gaming

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

Peripherals and audio

Gaming keyboards

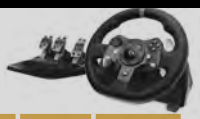
CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
MEMBRANE	Corsair K55 RGB	amazon.co.uk	#201 p45	£50
BUDGET TKL MECHANICAL	HyperX Alloy FPS Pro	amazon.co.uk	#201 p46	£70
MECHANICAL	Corsair K68 RGB	amazon.co.uk	#181 p53	£114
OPTICAL ESPORTS	Asus ROG Strix Scope RX	overclockers.co.uk	#209 p43	£125
MECHANICAL MMO	Corsair K95 RGB Platinum	scan.co.uk	#164 p26	£185
PREMIUM MECHANICAL	Corsair K70 Mk.2 Low Profile	scan.co.uk	#193 p56	£150
PREMIUM TKL MECHANICAL	Corsair K70 RGB TKL	scan.co.uk	#214 p31	£140
LUXURY MECHANICAL	Ducky Shine 7 RGB	overclockers.co.uk	#212 p53	£180
LUXURY WIRELESS MECHANICAL	Razer BlackWidow V3 Pro	scan.co.uk	#208 p60	£221

Gaming mice

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET GAMING	Corsair M55 RGB Pro	amazon.co.uk	#200 p24	£30
FIRST-PERSON SHOOTER	SteelSeries Rival 600	scan.co.uk	#184 p59	£65
MMO	Razer Naga Trinity	amazon.co.uk	#186 p52	£83
AMBIDEXTROUS	Razer Viper 8K	currys.co.uk	#213 p23	£80
WIRELESS	Corsair Dark Core RGB Pro	amazon.co.uk	#202 p25	£90
PREMIUM WIRELESS	Razer Deathadder V2 Pro	scan.co.uk	#210 p28	£116
ULTRA LIGHTWEIGHT	Roccat Burst Pro	currys.co.uk	#211 p28	£50
PREMIUM LIGHTWEIGHT	Logitech G Pro X Superlight	logitech.com	#213 p22	£130

Peripherals and audio cont ...

Game controllers



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
RACING WHEEL	Logitech G29 Driving Force	currys.co.uk	**#202** p50	£230
GAMEPAD	Microsoft Xbox One Wireless Controller	currys.co.uk	**#191** p56	£50
BUDGET FLIGHT STICK	Logitech Extreme 3D Pro Joystick	currys.co.uk	**#207** p52	£40
FLIGHT STICK	Thrustmaster T.16000M FCS HOTAS	scan.co.uk	**#207** p56	£150

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	£83
WIRELESS	Corsair Virtuoso RGB Wireless	ebuyer.com	**#204** p50	£162
PREMIUM WIRELESS	Razer BlackShark V2 Pro	overclockers.co.uk	**#211** p26	£180

Speakers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
STEREO	Edifier R1280DB	amazon.co.uk	**#192** p57	£120

Non-gaming keyboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
WIRELESS MULTI-DEVICE	Logitech K780	currys.co.uk	**#203** p58	£80
WIRELESS TKL MECHANICAL	Keychron K2 Version 2	keyboardco.com	**#208** p57	£84
TKL MECHANICAL	Filco Majestouch Convertible 2 Tenkeyless	keyboardco.com	**#203** p55	£140

PCs and laptops

Pre-built PC systems

CATEGORY	NAME	CPU	GPU	SUPPLIER	ISSUE	PRICE (inc VAT)
6-CORE GAMING	PC Specialist Torva Elite R	AMD Ryzen 5 5600X	AMD Radeon RX 6700 XT	pcspecialist.co.uk	**#214** p36	£1,349
8-CORE GAMING	Chillblast Fusion Commando 3060Ti	AMD Ryzen 7 5800X	Nvidia GeForce 3060 Ti	chillblast.com	**#210** p34	£1,860
8-CORE RTX 3080 GAMING	PC Specialist Obsidian I	Intel Core i7-10700KF	Nvidia GeForce RTX 3080	pcspecialist.co.uk	**#209** p40	£2,119
WATER-COOLED 16-CORE GAMING	Scan 3XS Absorbere	AMD Ryzen 9 5950X	Nvidia GeForce RTX 3090	scan.co.uk	**#209** p46	£5,462
DREAM PC	Scan 3XS Barracuda	Intel Core i9-10980XE OC to 4.3GHz	Nvidia GeForce RTX 3090	scan.co.uk	**#145** p58	£14,084

Laptops

CATEGORY	NAME	CPU	GPU	SCREEN	SUPPLIER	ISSUE	PRICE (inc VAT)
RTX GAMING	Gigabyte Aorus 15G XC	Intel Core i7-10870H stock speed	Nvidia GeForce RTX 3070	15.6in 1,920 x 1,080 IPS 240Hz	overclockers.co.uk	**#213** p30	£1,899

RICK LANE / INVERSE LOOK

MILITARY MORALS

The return of Six Days in Fallujah raises questions about the gaming industry's relationship with modern military conflict, argues Rick Lane

Remember Six Days in Fallujah, the cancelled tactical military shooter based on a large, infamous battle of the Iraq War? Well, it's back. Peter Tamte, former CEO of Atomic Games (the defunct studio behind the cancelled original), has created a new publisher named Victura with the intent of resurrecting the project.

The original game was cancelled due to Konami's loss of confidence in the project after the reaction to its announcement. Concerns were raised about its ability to portray a battle in which the US military's aggressive assault resulted in numerous civilian casualties, as well as America's purported use of white phosphorous against non-combatants.

It would be tricky for any game to do justice to this event, let alone an FPS, where the genre's modus operandi of slaughtering enemies by the dozen makes nuanced discussion of morality rather difficult. But within days of its announcement, the people behind this new Six Days in Fallujah had already made several worrisome blunders.

> Slaughtering enemies by the dozen makes nuanced discussion of morality rather difficult

In an interview close to the announcement, Tamte stated that the developer was 'not trying to make a political commentary' about one of the most hotly political events of an already politically incendiary war. Publisher Victura quickly issued some emergency PR, stating that the events the game depicts were 'inseparable from politics' and that the game would tackle 'many tough topics'.

The game's battlefields are also procedurally generated, which flies in the face of the team's stated desire to recreate 'the true stories of marines, soldiers and Iraqi civilians who fought Al Qaeda'. How can the developers claim to recreate those stories if the game doesn't attempt to recreate the layout, architecture and culture of Fallujah itself?

Tamte has personal links with the US military, having previously worked on building training systems for the marines. Victura has denied official US military involvement in the project, and there's no evidence to suggest the US military has directly helped to fund it. Then again, Six Days in Fallujah would hardly be the first game to uncritically portray the US military as heroes in a controversial scenario. The Call of Duty series has been doing it as far back as Call of Duty's 4's fictionalised invasion of a Middle Eastern dictatorship.

The 'Highway of Death' level in 2019's Call of Duty: Modern Warfare was also based on an event in the first Gulf war, where a US-led coalition trapped and then bombarded hundreds of retreating Iraqi troops along Highway 80, after a ceasefire had been agreed. In Modern Warfare, it's the Russians who bomb the game's fictionalised version of the highway, essentially rewriting the history of a real event.

Likewise, Rainbow Six, Ghost Recon and Medal of Honor provide distinctly westernised takes on modern conflicts, pitting players against facelessly evil Russian or Arabian people. Until recently, this passed without much interrogation, which is why it's important that Six Days in Fallujah has been picked up on it, and why it's important that the portrayal of war in games continues to be treated with scepticism. CPC

Rick Lane is Custom PC's games editor @Rick_Lane

Doom Eternal: The Ancient Gods Part Two / £15.99 inc VAT

DEVELOPER id Software / **PUBLISHER** Bethesda

Custom PC APPROVED

Having brought the celestial realm of Urdak to heel in id Software's first Doom Eternal expansion, The Ancient Gods Part One, the second part sees the Slayer embark on a roundabout journey to hell for one final confrontation with the Dark Lord, manifested as an evil version of the Slayer himself. The expansion's three levels – The World Spear, Reclaimed Earth, and Immora, are the most colourful and varied of the game so far.

Immora in particular offers a spectacular backdrop to the endpoint of the Slayer's journey. An army of Sentinels joins the Slayer to fight the demonic hordes, while huge mechs do battle with gigantic beasts in the far distance. That said, Part Two's levels are smaller than those in Part One, reducing the number of secrets and encounter types compared with both the first expansion and the original game.

This is the only area where Part Two sees a reduction over Part One. Indeed, its primary contribution is a brace of new, extra-challenging variants of Doom Eternal's demons. These include the Armoured Baron, who requires precision shooting or deft use of the plasma rifle to strip him of his metal shell, and the Stone Imp, which is invulnerable to all but one of the player's conventional attacks. Most fearsome, however, is the Cursed Prowler, who can obliterate the player's movement abilities with a single swipe of its claws.

These new enemies make Eternal's furious test of your muscle memory even more frantic, as you constantly juggle weapons to fit the current picosecond of the ongoing encounter. Yet unlike in Part One, the demons don't have things all their own way. Part Two introduces a new weapon, the sledgehammer, which stuns enemies for an extended duration, while also boosting the number of resources they drop. This can be exploited for massive health, armour and ammo boosts. It also obliterates any smaller demons nearby, making it tremendously satisfying to use.

For the most part, Part Two is as good as the expansion that preceded it, and is arguably a better balanced experienced than the relentless assault of Part One. Sadly, it's let down by an underwhelming final encounter. The Dark Lord is basically an evil version of the Slayer, but not a mirror image of himself. Instead, id Software has placed the Dark Lord in a giant suit of armour, and given him the same counter-based weakness as Doom Eternal's Maurauder.

The destination may not be quite the ultimate showdown for which we hoped, but the journey on which TAG: Part 2 takes you more than makes up for that. Combined, The Ancient Gods is one of the best expansions in years, and an essential companion to Doom Eternal.

RICK LANE

ANCIENT GODS

+ Excellent trio of new levels
+ Cleverly redesigned enemies
+ Massive flipping hammer

ANCIENT DEMONS

– Levels slightly reduced in size
– Underwhelming final boss

/ VERDICT

Another fantastic add-on to Doom Eternal, even if it ends with less of a bang than we'd hoped.

OVERALL SCORE

88%

Evil Genius 2 / £34.99 inc VAT

DEVELOPER Rebellion / **PUBLISHER** Rebellion

Glance at any screenshot of Evil Genius 2, and you'll be forgiven for thinking the game is just a big laugh. The cartoon style, the comedy traps, the fact that Rebellion has roped in Brian Blessed to play one of the Geniuses – it all makes it appear like silly knockabout fun. To an extent, that's true. However, behind Evil Genius 2's pantomime presentation lies a cold and calculating criminal brain, one that simultaneously gives Evil Genius 2 much-needed depth, but also burdens its simple villainous pleasures with grind and bloat.

A straight sequel to the 2004 management sim, Evil Genius 2 sees you once again trying to take over the world as a crackpot Machiavellian mastermind. You must build a base on your secret island lair, recruit different types of minions to run your odious operation, embark upon moneymaking schemes across the globe, and ultimately construct a Doomsday device to crush your enemies and become undisputed master of the world.

However, only from little lasers do giant death rays grow. Before you can take over the world, first you must establish your base. This means hollowing out your island idyll, designing rooms such as a Vault for your gold, a barracks and a dining hall to satisfy your minions' needs, training rooms to train different minion types, research labs for unlocking new traps and devices, comms depots to expand your operation globally and various other options.

Unlike most management sims, which spread out the different types of room you can build across their running time, Evil Genius 2 lets you construct most of the available rooms from the outset. This makes the early game a frenzy of activity, made doubly exciting by the fantastically stylish appearance of Evil Genius 2.

Make no mistake, Rebellion's sequel is comfortably one of the best-looking management games around. Its cartoon take on 1960s spy fiction is perfectly judged, from the ACME-style traps, such as a boxing glove on a spring, to the jazzy, Avengers-style soundtrack.

What truly makes Evil Genius 2 such a joy to watch, however, is the animation. Not only does every minion have specific animations for interacting with every room object in the game – whether that's a dining table or an interrogation chair – but so much effort has been put into expressing the personality of different minions.

Guards, for example, lumber around corridors, hunched slightly forwards and swinging their arms like Popeye. Scientists, meanwhile, strut about your lair with their arms clasped behind their back, all haughty and superior like the world's strictest chemistry teachers.

The combination of this aesthetic with your frantic building makes Evil Genius 2's opening few hours utterly captivating. If Evil Genius 2 sustained this momentum across the whole game, it would undoubtedly be the best management sim around. Sadly, though, after this initial building phase, the game slows down dramatically.

This gear change is partly a good idea, as it's where the real strategy of Evil Genius 2 begins. With your basic lair established, you move on to conquering the globe on the World Domination map. You do this by establishing Criminal Network Nodes in each of the world's many regions. This unlocks schemes that earn you money in exchange for minions, who bravely sacrifice themselves to see through each scheme. However, schemes also generate 'Heat', reflecting the world's awareness of your dastardly designs, eventually triggering the arrival of snooping agents into your lair.

The more you grow your Network, the more minions you need to train, and the more Agents come a-knocking. In this way the game escalates, and so the strategy emerges. The need for more minions means expanding your base, which requires more money, which means embarking on more schemes.

At the same time, you need to defend yourself against more powerful agents, which means investing in more 'Muscle' minions, such as guards and mercenaries, while also researching and upgrading new traps, such as the Shark Tank and the Laser Disco. Alternatively, you could spend that money on your Cover Operation, a luxurious Casino front designed to attract clueless tourists and distract enemy spies with booze, gambling and stage shows.

From a mechanical perspective, this all works well. Managing your minions and solving problems in your lair is always entertaining, while defending your base from agents can be genuinely challenging, especially when a Super Agent such as Agent X or Wrecking Bola shows up. The problem is that the simulation is accompanied by a series of campaign missions that are far too long for the systems Rebellion has built.

Every mission has multiple objectives, which often require you to repeat the same process three times, and sometimes necessitate the completion of another mission that *also* has multiple objectives. Most of these objectives are completed by doing a scheme, which simply means sending a bunch of minions to the World Map and waiting for a timer to complete.

The result is that Evil Genius 2's midgame becomes beleaguered by grind, where you're repeating the same basic processes, then waiting for missions to resolve. Part of the problem is that you have no real input into the missions themselves. The game tries to flesh them out with kooky cutscenes, where the Genius either berates a minion or trades insults with a rival Crime Lord, but aside from showing the weaker side of Evil Genius 2's presentation – the voice acting – it isn't enough to detract from the fact that you're doing the same task over and over again.

It isn't always like this. The moment you need to expand your base, unlock a new trap from research, or get a new room object from completing objectives, the game suddenly lights up again. But there's simply too much emphasis placed on the World Domination map, which doesn't have enough interactivity or nuance to make your time spent with it feel rewarding. Ultimately, Evil Genius 2 doesn't quite live up to its malevolent masterpiece potential, but it's still a fun and stylish reprisal of one of the most distinctive management sims around.

RICK LANE

EVIL GENIUS

+ Fantastic style
+ Great base building
+ Good management systems

COMMON CRIMINAL

– World Domination map too shallow
– Too much grind and downtime

/ VERDICT

Evil Genius doesn't quite reach Doctor Evil levels of criminal capering, but it would make a competent number two.

OVERALL SCORE

75%

MUNDAUN / £15.49 inc VAT

DEVELOPER Hidden Fields / **PUBLISHER** MWM Interactive

MUNDAUN

+ Fantastic art style
+ Engaging, well-balanced mix of systems.
+ Fantastic surrealist horror

MUNDANE

− Script can lack subtlety
− A couple of fiddly puzzles

Taking place on the slopes of an Alpine mountain with distinctive twin black peaks, Mundaun sees you play as Curdin, a young man who returns to his childhood home after learning that his grandfather has died, despite pleas from the local chaplain to stay away from the region. Upon arrival, Curdin discovers that his grandfather's death is shrouded in mystery, tied to events in his past and a mysterious force lurking beneath the mountain.

Mundaun immediately distinguishes itself through its art style. Every texture has been painstakingly hand-drawn in pencil, resulting in a distinctive greyscale effect that lends the game a thick and oppressive atmosphere. Coupled with an eerie ambient score reminiscent of Hildur Guðnadóttir's recent work on the Chernobyl miniseries, Mundaun uses its aesthetic to build breathtaking mountain landscapes, from quaint sloping pastures dotted with ramshackle chalets, to bleak plateaus threaded with narrow, precipitous passes.

However, what makes the game work is the way it deftly balances a surprisingly wide range of mechanics, while melding its earthy pastoral setting with surrealist folk horror.

Split across three large, openly explorable areas, Mundaun mixes environmental puzzling with driving, stealth, a sprinkling of combat and even some side activities, such as gathering hay and brewing coffee.

All these aspects are weighted evenly within the game's structure, rarely forcing you into a particular mode. For example, you can fight the game's enemies if you wish, but you can also choose to evade them for a nonviolent approach.

Meanwhile, Mundaun's approach to horror is less about raw scares, and more about creating a general atmosphere of dread. There are long stretches of low-key, almost pleasant downtime in Mundaun, where you chat with locals, solve puzzles, and explore the mountain's passes and pastures.

Then you'll realise the tunnel through which you're driving is oddly long, or a figure appears to be *floating* across the terrain ahead. Suddenly, you've shifted from relative normality into a totally surreal scenario. This game has an incredible knack for the uncanny. As a small example, one of your main companions is the severed head of a goat.

Mundaun is exceptional throughout, with some excellent twists and a satisfying ending (which can go one of two ways). There are a couple of issues, however. The script has a tendency to over explain plot points, when it would be better served leaving room for the player's own deductive skills.

Also, while most of the puzzles are well balanced, one that involves retrieving honey from a house infested with bees is more frustrating than frightening. Finally, and this isn't really a problem, but it should nonetheless be noted that game dialogue is voiced in Swiss with English subtitles.

These handful of niggles do little to detract from Mundaun being arguably the finest first-person horror since Frictional's SOMA. Engaging, thought-provoking and utterly strange, Mundaun's Alpine folk tale is truly a game to savour.

RICK LANE

/ VERDICT

Fascinating and unsettling in equal measure, Mundaun is a triumphant example of first-person horror.

OVERALL SCORE

90%

BREATHEDGE / £19.99 inc VAT

DEVELOPER Redruins Softworks / **PUBLISHER** Hypetrain Digital, Redruins Softworks

Imagine Subnautica set in space, but then fire Subnautica's meticulously crafted survival mechanics and compellingly told story out of the airlock. Replace them with irritating humour, rudimentary crafting and confused design. Congratulations, you've just made Breathedge.

The premise sees your character escorting his grandfather's corpse on an interstellar journey in what's basically a giant space hearse. However, the rocket takes a wrong turn and smashes into an asteroid field, killing everyone but you and your friendly pet chicken. Saved by your habitation pod's built-in airlock, you must explore the wreckage, gathering together resources to escape.

It does at least look fantastic. The wreckage-strewn asteroid field is a visually stunning and distinctive environment, while the vast chunks of spaceship drifting in all directions tug at your innate desire to explore. The environments also feature lots of in-built visual gags, which make exploration rewarding.

Sadly, little else in Breathedge is so engaging. Problems commence with the core survival and crafting systems.

Breathedge's resource gathering and item assembly is at best basic and at worst boring. Crafting amounts to collecting the appropriate resources and pressing a button to watch a timer fill out, while actual resource gathering involves bashing open crates or hoovering them up out of deposits.

The early game, meanwhile, is hobbled by your ludicrously tiny oxygen supply and a general lack of direction, which means you spend the first few hours constantly backtracking to your pod to refill your tanks. The game improves slightly once you've built a network of oxygen stations, letting you explore more freely, while the introduction of base building and pilotable vehicles in the game's second area further improves the experience.

Unfortunately, the constant needling of the game's irritating humour never changes. It isn't the script that's the problem, but the delivery. Most of the jokes are cracked by your AI companion, who speaks in a neutral tone that's also ridiculously fast, sounding like a satnav reading a best man's speech while desperate for a pee. It obliterates the rhythm required to make the jokes land, and the constant babbling becomes infuriating.

Breathedge's structure also completely changes after Act 2, switching from open-world space survival to a linear-narrative game, which compounds the humour problem and removes the one feature the game actually gets right. It's as if the Doom Slayer suddenly gave up demon slaughtering to grow crops in Stardew Valley, a bizarre switcheroo that doesn't work at all.

It's a shame, because Breathedge's world deserves to be explored. However, no pretty environments can make it worth grappling with the tedious survival systems and the obnoxious humour. In space, nobody can hear you scream, which is good because they also can't hear us yawn.

RICK LANE

BREATHE

+ Impressive 3D environments
+ Exploration can be fun

SUFFOCATE

- Tedious survival and crafting systems
- Annoying humour
- Becomes a different game in final act

/ VERDICT

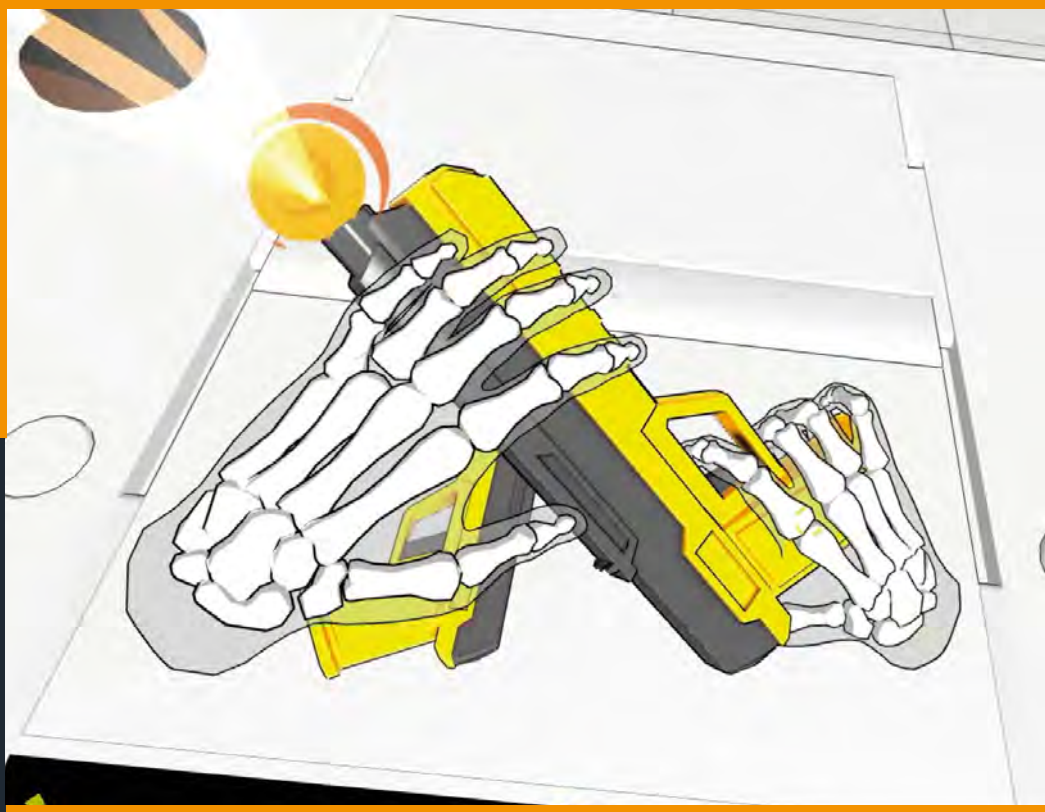
Breathedge's space survival is brought crashing to earth by underwhelming systems and a misjudged attempt at comedy.

OVERALL SCORE

50%

REALITY CHECK

Rick Lane gets to grips with VR hand tracking in his roundup of the latest VR happenings



REVIEW

HAND PHYSICS LAB / £7.49 incVAT

DEVELOPER Dennys Kuhnert / Holonautic / **PUBLISHER** Holonautic

Hand Physics Lab is the first game to properly grapple with one of the Oculus Quest's most interesting features – hand tracking. Letting you dispense with VR controllers, hand tracking lets you use your own paws to control VR apps and games. Using the Quest's built-in cameras, the system tracks and then replicates your hand movements in VR space, down to the individual movement of your fingers and thumbs.

Recalling the early days of VR gaming, when most games were essentially showcases for the tech, Hand Physics Lab is a collection of 80 different activities designed to demonstrate your manual manipulation ability. They range from painting and drawing with handheld pens, through solving classic puzzles such as marble runs, and activities such as throwing balls at tin cans, all the way up to more complex interactions such as weapon handling and controlling RC cars.

These activities are split between two different game modes. There's a linear sequence of 250 puzzles that commence with simple button pressing and become gradually more complex. There's also a sandbox mode that lets you interact with a set range of activities however you like. That said, most of the sandbox activities are locked until you earn a sufficient number of 'stars' by completing puzzles in puzzle mode. It's a rather arbitrary limitation, although it's not too much of a problem, as the puzzles are well designed and engaging with them is fun.

At first, Hand Physics Lab feels like magic, easily offering the biggest 'wow' moment since VR originally landed on the scene. Being able to interact directly with objects without any controllers, to freely use your fingers and thumbs to pluck a ball off a table or literally flick a switch, is truly liberating.

Unfortunately, it isn't long before this sense of freedom is accompanied by frequent frustration. The hand tracking is amazing when it works, but it's also highly inconsistent. Effective tracking requires both a moderate light level (not too bright, not too dark), and sufficient contrast between your hands and your surroundings to work. Meanwhile, Hand Physics Lab's take on hand tracking is, as the title suggests, heavily physics-based. This makes it slower and more cumbersome than the Quest's vanilla hand tracking, with slight but noticeable latency between your hand movements and the corresponding movements in the game.

The result is that your virtual hands aren't always that easy to control, lashing out at random angles or failing to grip and drop objects appropriately. Hand Physics Lab plays up to this clumsiness to a degree. At times it feels more like Surgeon Simulator or Octodad, deliberately giving you 'floppy fingers' or requiring you to reach into an absurdly long pipe to retrieve objects. While amusing, this undermines the game's intent as a showcase for hand physics, deliberately making the control scheme harder to use rather than easier.

Ultimately, Hand Physics Lab is unlikely to see you throwing your touch controllers out of the window. However, it's nonetheless a fascinating demonstration of the potential for hand tracking, and a glimpse into the likely future of VR controls.

HANDHELD

- \+ Wide range of activities
- \+ Well-constructed manual puzzles
- \+ Hand tracking feels potentially revolutionary ...

HANDFUL

- – ... but isn't there yet
- – Physics-emphasis compounds unwieldiness
- – Humour undermines showcase

VERDICT

A flawed showcase for VR hand tracking, but a fascinating one nonetheless.

OVERALL SCORE

60%

NEWS

WARHAMMER AGE OF SIGMAR: TEMPESTFALL

We've seen a bunch of fictional universes make forays into VR over the past few years, from Star Wars and Jurassic Park to superhero simulators such as Iron Man VR. Now it's Warhammer's turn to get in on the VR action.

Developed by Carbon Studio, Warhammer Age of Sigmar: Tempestfall sees players assume the role of Castor Stormscryer, Lord Arcanum of the Stormcast Eternals, Sigmar's personal army. You're sent to investigate an event called the Necroquake, which has triggered creatures known as the Nightgaunt to rise up across the Mortal Realms.

To people less well-versed in Warhammer lore, this basically means you'll be battling your way through a linear action-adventure based on the Warhammer: Age of Sigmar miniatures game, using a combination of powerful melee weapons and magic. Carbon Studio has stated that both these elements will be 'motion-based'.

For combat, this means blocks and counters will be directional, requiring you to line up your weapon accurately to defend enemy strikes. It's not entirely clear what it means for magic yet, although it could well involve using hand gestures to cast spells against your foes.

Only a snippet of the game has been revealed, although the screenshots suggest Tempestfall will be one of the more technically ambitious VR games around. The game is due for release later this summer, so expect a review in the next few months.

NEWS

SAM & MAX: THIS TIME IT'S VIRTUAL

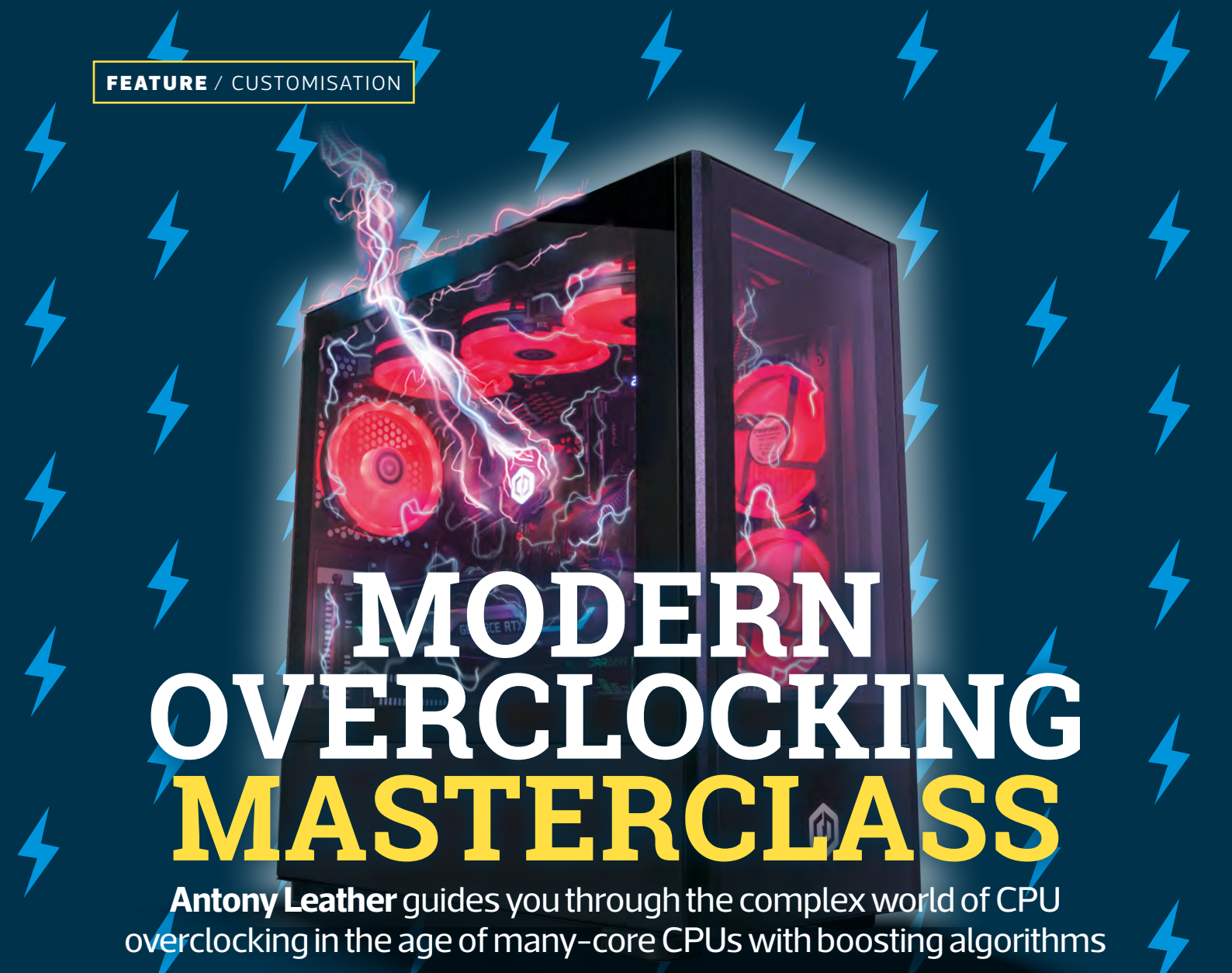
After hitting the road with LucasArts and going episodic with Telltale, freelance police and adventure gaming icons Sam & Max are making the transition into VR later this year. Developed by HappyGiant Games, Sam & Max: This Time It's Virtual sees the dynamic duo take on a new recruit – you.

To test whether you have what it takes to join their team, Sam & Max will guide you through the Freelance Police Academy of Remedial Crimebusting and Planetary Protection, which is definitely not situated in an abandoned amusement park.

Far from being a cheap spin-off, This Time It's Virtual comes with some serious pedigree. HappyGiant Games was founded by Mike Levine, formerly an effects artist at LucasArts, while the lead designer on the project is Mike Stemmle, who co-directed Sam & Max: Hit the Road and designed The Devil's Playhouse, the best of Telltale's trilogy of Sam & Max games. To cap off the project, Sam & Max's creator Steve Purcell is serving as a consultant.

Going by the game footage, This Time It's Virtual certainly appears to have nailed the colourful style and chaotic humour of previous Sam & Max games. One big question remains over how it plays, however. The game appears to take players through a series of 'challenges' within Sam & Max's academy designed to test your law enforcement skills. Another word for these challenges would appear to be 'minigames'. In short, the game's depth is unclear, as is how well it will fit together as a coherent experience.

Still, the return of Sam & Max is reason enough to be intrigued. The game has been announced as releasing in June, so we'll find out soon enough whether HappyGiant's VR gambit pays off. CPC



MODERN OVERCLOCKING MASTERCLASS

Antony Leather guides you through the complex world of CPU overclocking in the age of many-core CPUs with boosting algorithms

In the old days, overclocking meant a free and straightforward performance boost for anyone with the right knowledge and a decent CPU cooler. You upped the voltage and multiplier, and your CPU went like the clappers. You can still do that, of course, but the introduction of single-core boosts at stock speed, and CPUs with many cores, have made overclocking a bit of a muddy swamp to navigate.

However, overclocking definitely remains a valuable, performance-boosting tool for unlocked processors that is fun, free and relatively easy. A traditional manual overclock, where you set a specific multiplier or frequency and then input a CPU voltage – isn't the only way to do it though. In fact, in many situations a manual overclock can now result in lower performance than stock speed.

Thankfully, the likes of AMD and Intel have come up with ways to take advantage of ever higher boost frequencies over one or several cores, but still give you a boost to multi-threaded performance when most or all of your CPU cores are under load.

In this guide, we'll discuss how to understand your CPU's boosting capabilities in depth, to see if a manual overclock is worth it in the first place, or whether one of the new automatic or semi-automatic overclocking methods is better to get more performance.

We'll look at the differences between these methods, and advise you about which one is right for your particular needs, as well as offering tips on how to apply a quick overclock to any given CPU to get you started.

The rise of boosting

Overclocking is possible thanks to the way CPUs are manufactured. Not all processors are equal, even given the extraordinary microscopic precision with which they're made. Some cores will be able to hit higher frequencies than others, and some will reach similar frequencies but with lower voltages. AMD and Intel use this situation to their advantage, selling the lesser-able parts as lower-end CPUs and 'binning' the more capable ones as more expensive CPUs that can hit higher frequencies.

Given that all these CPUs may have more headroom than their advertised frequencies, this raises the possibility of lower-end models being able to overclock to similar speeds as their more expensive siblings, albeit with higher voltages. Meanwhile, those flagship products representing the cream of the crop could also have extra headroom. However, as the CPU war between AMD and Intel has heated up, both companies have strived to hit higher and higher peak frequencies out of the box, also known as boost frequencies.

This approach has really muddied the waters when it comes to overclocking, many modern

Common overclocking terms

Vcore	The CPU voltage
Multiplier	The figure multiplied by the CPU base clock that gives the CPU its final frequency
Base clock	The internal bus speed of the motherboard platform
Peak boost speed	The maximum frequency a CPU's cores can reach at stock speed – usually just on one or two cores
Base frequency	The lowest guaranteed CPU core frequency, although it's largely irrelevant
All-core boost	The highest frequency all a CPU's cores can reach at the same time
Vdroop	A fall in CPU voltage when under load, which can potentially result in instability
Loadline calibration	Increases the CPU overclock voltage when the CPU is under load, in order to counteract vdroop
Manual overclock	Applying a voltage and frequency multiplier to a CPU's cores manually, usually with all the cores running. However, it's also possible to apply different speeds to different cores on some Intel platforms
EFI	Extensible firmware interface. The brain behind your motherboard, which provides a graphical interface for overclocking and other settings, such as fan speed and boot options. This is sometimes called a BIOS (basic input output system), which is what PC motherboards used to have instead of an EFI several years ago

CPUs' boosting algorithms are intelligent enough to make the most of one or two best-performing cores, which can reach higher frequencies than the other cores. AMD has been so aggressive here that many of its latest CPUs can hit far higher frequencies on one or two cores than you can ever hope to achieve with a manual overclock across all cores.

The issue here is that the boosting technology – in AMD's case, called Precision Boost – is disabled when you apply a manual overclock. As a result, while a manual overclock might achieve a higher speed across all cores than some CPUs achieve at stock speed, it may not be as fast as the peak boost frequency across smaller numbers of cores, which the CPU can manage on its own at its default settings.

Whether or not you should use a manual overclock depends on your specific CPU, even within the same range of CPU models

The end result is that if your overclock reaches higher frequencies than the CPU can manage out of the box across all cores at the same time but not higher than its single-core peak, you'll see more performance in multi-threaded workloads, but in lightly threaded loads, your CPU may actually perform worse.

It's a tricky situation and there's no right or wrong answer. The best overclock for you largely depends on what workloads you'll be throwing at your PC, as well as your specific CPU's capabilities. Sometimes it's best to leave your CPU at stock speed, others should be overclocked if you're main goal is improving multi-threaded performance. Meanwhile, some processors can still hit higher frequencies when all their cores are overclocked, going even higher than their peak boost frequency.

Peak stock boost frequencies often happen across just one or two cores, so the frequency will drop as soon as the CPU is loaded across more cores. Your manual overclock might actually be matching what your CPU can only reach across half the number of cores at stock speed, so while performance might suffer in very lightly threaded or single-threaded workloads, your manually overclocked CPU will be faster in other workloads.

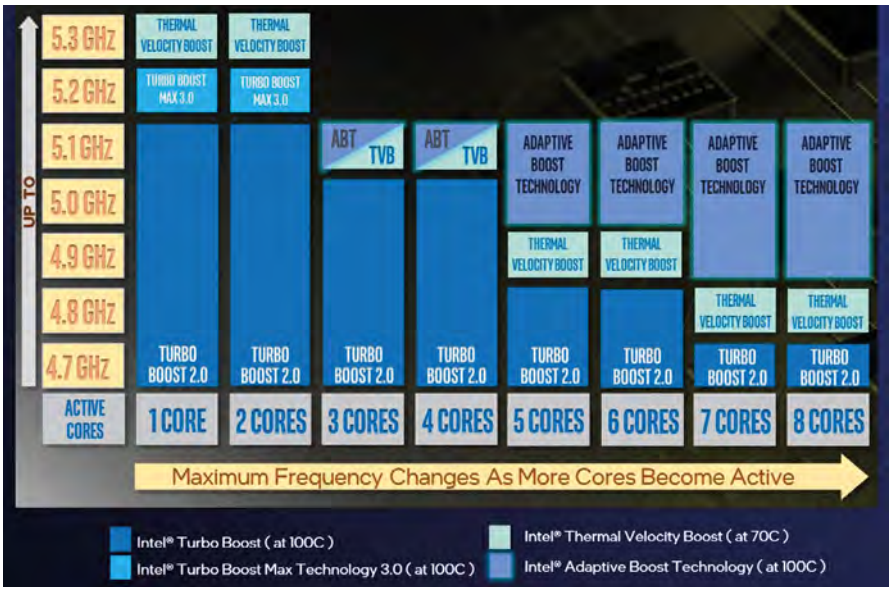
While many CPUs are already pushed close to their limits in terms of all-core clock speeds, some of them can still be overclocked across all cores to the same level or even further than even their peak boost frequencies. There are some more complicated manual overclocks too, which allow you to still reach those high frequencies on one or two best-performing cores. Intel, for example, allows you to manually adjust each individual core yourself to a specific frequency, and even identifies the best-performing cores to get you started.

A MANUAL ALL-CORE OVERCLOCK MAY NOT BE AS FAST AS THE PEAK BOOST ACROSS A SMALLER NUMBERS OF CORES

Is manual overclocking dead?

Manual overclocking is far from pointless, and if you're just getting into overclocking, or if you don't have the many hours it takes to read up on all the dark arts and fine tuning, a simple set-and-forget manual overclock is absolutely where you should start. Even if your overclock sits a couple of hundred megahertz below the peak boost frequency your CPU can achieve, your overclock is still unlikely to result in much lower performance.

Meanwhile, AMD has various forms of its Precision Boost Overdrive feature, which you can tweak to provide higher all-core boosts as you would with a manual overclock. Unlike the latter, however, your CPU will still boost to its maximum boost frequencies in order to keep lightly threaded performance at peak levels.



Intel's Core i9-11900K has no fewer than four boosting algorithms at work at any one time, including Intel's new Adaptive Boost Technology

The latest version goes even further, enabling you to lower the voltage as much as possible too. We'll be taking a look at all these methods later in this guide.

Different boosting methods

Before you start overclocking, you need to have an idea about the frequencies your CPU reaches in different scenarios. This is important, because you firstly need to work out which overclocking method is right for you and your CPU. In some cases, leaving your CPU at stock speed or tweaking its boosting algorithms might be the best option.

To start, there's the all-core boost frequency – where a CPU will hit a certain frequency across all cores at the same time when you're running a multi-threaded workload that uses all of them. The peak boost frequency is usually higher than the all-core boost frequency and will likely be limited to just one or two cores. This limits power consumption when all cores are loaded, keeping the CPU within a specific limit or thermal design power (TDP) wattage.

Intel's K-series CPUs have unlocked multipliers

For example, AMD's Ryzen 9 5950X has 16 cores, and when all of them are loaded, it often draws slightly less power than the Ryzen 7 5800X with all of its eight cores under load. That's because the 5800X will boost to much higher frequencies, while the Ryzen 9 5950X has to rein in the clock speeds when all its cores are loaded, in order to stay within certain power and thermal limits.

For this reason, the Ryzen 9 5950X usually responds well to manual overclocks – if you remove those limits and have good enough cooling, the rest of its cores are usually able to hit frequencies that go well beyond their usual limit.

The way the CPU gets to the all-core boost frequency, though, can differ wildly, even between models in the same range. Both AMD and Intel add certain boosting features to flagship products, so they can hit higher boost frequencies if your cooling and motherboard's power delivery are sufficient.

For example, Intel's basic boosting technology is called Turbo Boost 2, and it's present on most of its CPUs, even at the extreme low end. It defines how fast a CPU's cores can run whether just one is loaded, all the way to up to situations where all of them are loaded at the same time. For many CPUs, this figure will represent the limit of their frequencies.

Premium models now also include features such as Thermal Velocity Boost and Turbo Boost Max Technology 3, which add extra boosting headroom. The latter will allow one or two cores to hit higher frequencies than Turbo Boost 2, and these cores are the best-performing ones in a CPU. As we mentioned earlier, you can usually see these cores identified in the EFI with stars next to them, allowing you to manually tweak them too.

Thermal Velocity Boost works differently in that it can apply to all cores and is primarily dependent on CPU temperature, in this case around 70°C. If the CPU is below this temperature, 100MHz will be added to the Turbo Boost 2 frequency, increasing it across the core boosting spectrum.

As if that wasn't enough, the Core i9-11900K introduced yet another feature called Adaptive Boost Technology. This allows all eight of its cores to hit the same 5.1GHz frequency that just two of its cores can reach in Turbo Boost 2, but only in certain conditions.

THERMAL VELOCITY BOOST CAN APPLY TO ALL CORES AND IS PRIMARILY DEPENDENT ON CPU TEMPERATURE

Without Adaptive Boost Technology, our Core i9-11900K sample would only reach 4.8GHz with seven and eight cores loaded, so this tech can result in a significant boost to performance of up to 5.1GHz. The fact it can hit 5.1GHz out of the box does mean a manual overclock is likely a waste of time on this CPU, though, unless you're able to hit several hundred megahertz higher.

AMD has a similar offering with Precision Boost 2, which has been working away under the hood of Zen-based CPUs since the launch of the Ryzen 2000-series. However, unlike Intel's advanced boosting technologies, Precision Boost 2 is available with all of AMD's CPUs – not just its expensive flagships. AMD's CPUs will clock higher if they're cooler, and they can be further tweaked using its Overdrive tools, which we'll examine later.

If you're struggling to get to grips with all of the above, there's also an easier way to work out where your CPU sits on the boosting scale. MSI's Afterburner software can graph the frequency

of all your CPU's cores individually, allowing you to fire up your most-used games and software to see what frequencies they reach and across how many cores.

That way, you can see if your manual overclocking exploits will offer any gains. For example, if you find that your favourite game rarely uses more than two or three cores, and those cores are boosting at or close to your CPU's peak boost frequency, you'll need a manual overclock to hit close to this figure or you'll potentially lose performance.

If your software is typically using five or more cores, then its frequency will likely be much lower than the one it reaches on one or two cores, providing a lower target for your manual overclock. Just remember that if you do decide to apply a manual overclock, the boosting features we've discussed from Intel and AMD above will be disabled, and your CPU will be limited to the frequencies and voltages you set.

Which Intel CPUs can you overclock?

The key to modern manual overclocking is your CPU's multiplier. This multiplies a frequency called the base clock in order to achieve the desired CPU frequency. For example, a system bus of 100MHz and a multiplier of 50x will give a CPU frequency of 5000MHz or 5GHz. This is also how boosting works – by raising or lowering the multiplier, but with manual overclocking you're taking control. However, not all CPUs allow you to adjust the multiplier manually, and others require specific motherboards to unlock the feature too.

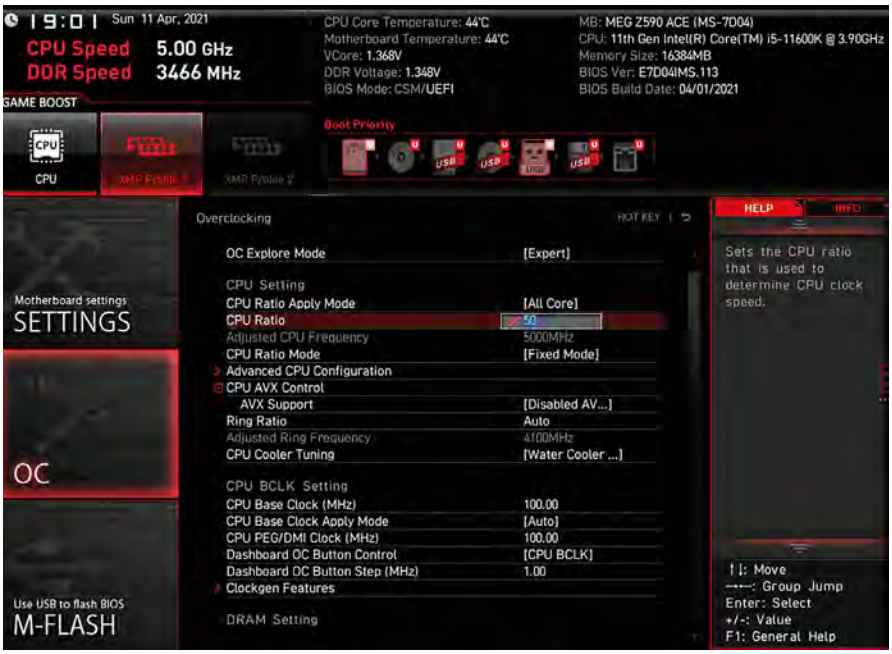
For example, Intel limits overclocking to K-series and KF-series CPUs on its mainstream desktop platform, but all of its high-end desktop X-series models are overclockable. As long as the model number is followed by either of these suffixes, such as Core i5-11600K or Core i7-11700KF, then you can adjust the multiplier manually.

If there's no K or KF (or X) then that CPU has a locked multiplier and it will only raise and lower the multiplier automatically according to its boosting technologies. This includes CPUs such as the Core i5-10400F.

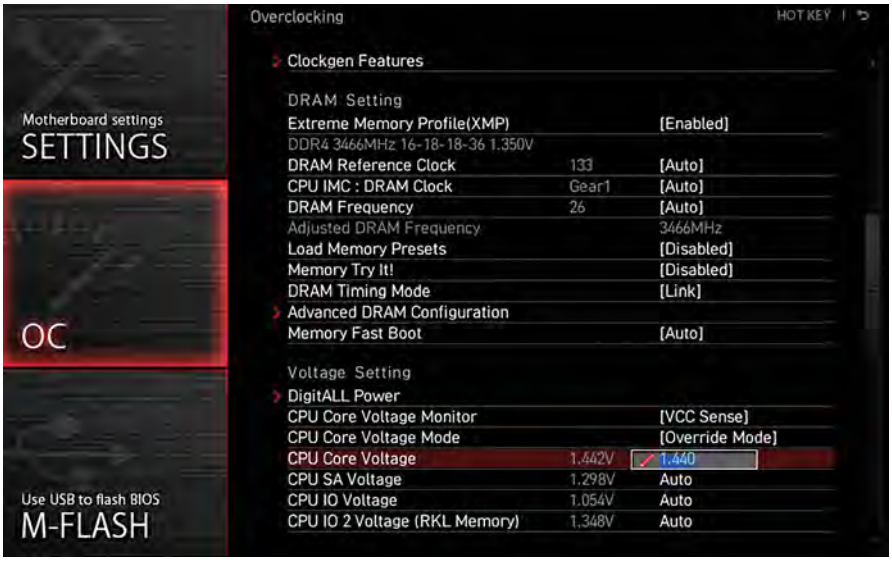
The 'F' here simply means that the CPU lacks integrated graphics and costs a bit less than the standard model as a result. You'd need a 'K' for it to be overclockable.

Intel also limits overclocking to specific motherboard chipsets. You'll need a motherboard based on a Z-series or X-series chipset, such as Z390, Z590 or X299, for CPU multiplier overclocking.

Prior to Intel's latest 500-series chipsets, any motherboards that didn't have the flagship Z-series chipsets would also limit the memory speed to whatever is natively supported by the CPU. For example, the Core i9-9900K will support memory frequencies up to 2666MHz in a motherboard without a Z-series chipset – even if you drop in a 3200MHz kit, you won't be able to run it at that frequency unless you opt for a Z-series motherboard too. This has changed with the new 500-series chipsets, with B560 and H560 supporting memory overclocking and allowing you to boost memory speeds higher than those natively supported by the CPU.



Overclocking involves increasing the CPU's multiplier, which is easily done in the EFI



You can easily adjust the CPU voltage from within the EFI

Which AMD CPUs can you overclock?

AMD considers itself overclocking-friendly, and rightly so, seeing as all of its Ryzen CPUs support overclocking and have unlocked multipliers. The only issue is that not all of them respond that well to manual overclocking, and many are already sailing quite close to the wind when it comes to their maximum frequencies.

As AMD has shrunk its manufacturing process from 14nm with the first Ryzen chips, to 12nm with 2nd-gen Ryzen and then to 7nm with 3rd-gen Ryzen, the voltages considered safe for overclocking have also lowered – we'll go into more detail about this later.

AMD, like Intel, limits overclocking to specific chipsets. Its B-series and X-series chipsets such as X470 or B550 support overclocking, but its A-series chipsets don't, at least officially, although some manufacturers have found ways around this limitation. However, as overclocking can put more pressure on the surrounding power circuitry and its cooling, even if you find an A-series chipset motherboard that allows overclocking, you'd be well advised to opt for a more capable board based on an X or B-series chipset.

How to overclock your CPU

There are several ways to change the multiplier of your CPU. You can even do it from within Windows using your motherboard's software, or with AMD and Intel's own overclocking programs – Ryzen Master for AMD and XTU for Intel. However, Ryzen Master won't save your settings between reboots and XTU can be hit or miss, depending on which settings you tweak.

While they're useful tools for testing and tweaking from the comfort of the desktop, you'll want to use your motherboard's software or preferably the EFI. Using the EFI will mean your overclock is always applied the instant you fire up your PC; motherboard software can lack certain options, while also taking a minute or more to load and apply your overclock.

Adjusting the vcore

Pushing your CPU to the limit usually means increasing the CPU voltage (often called the vcore), as a higher CPU frequency means the transistors inside your CPU are switching faster. As they switch faster, the voltage needed for them to work properly increases, as the reduced switching time requires the voltage to hit a certain level in less time.

A higher voltage means the transistor will work properly at higher frequencies. If the voltage is too low, it won't work properly, and your PC can crash or exhibit overclocking-related stability issues. If your PC does crash here, though, it's unlikely to be irreparable. This is just your CPU's way of saying it needs a higher vcore – it's a bit like running out of fuel in a car.

However, you don't always need to increase the voltage and you should always try to lower it as much as possible. You may find that you can add a small overclock without adding any extra voltage, and you may even be able to reduce the voltage compared with stock speed too, lowering heat and power consumption. The vcore, like the multiplier, is a key element of overclocking and you can adjust it using AMD and Intel's software mentioned above, your motherboard's own overclocking utility or preferably in your motherboard's EFI.

Find the multiplier or core ratio field in your EFI's overclocking section – we've entered '50' to get a clock speed of 5GHz on our Core i5-11600K

A vcore of 1.44V should enable you to hit 5GHz across all cores on a Core i5-11600K, as long as your cooling is powerful enough

Will I need a better cooler?

Whether you need to upgrade your cooler depends on so many factors that there's no easy answer. In general, though, the stock cooler that comes in the box with some CPUs isn't usually sufficient to handle a decent overclock.

In most situations, though, having a basic £30 aftermarket air cooler is a good starting point, and it should be able to cope with moderate overclocks on 6-core CPUs and even AMD's 7nm 8-core CPUs at a stretch too. Your overclocking headroom will also depend on your case's cooling abilities, as well as the ambient room temperature.

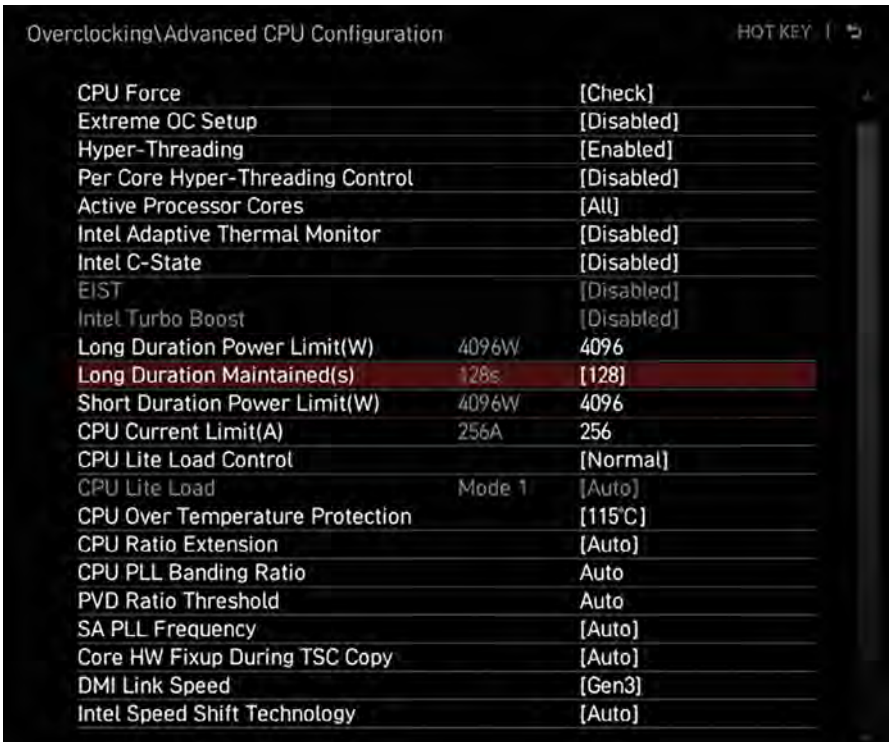
Before you start

We've highlighted various safe settings you can use to get started with overclocking later in this guide, but first you'll need to see how your current cooling copes with your CPU. To do this, grab CoreTemp (**alcpu.com**) for Intel CPUs and AMD Ryzen Master (**amd.com**) for AMD CPUs. These apps will tell you the temperature of your CPU. Now download Prime95 (**mersenne.org**) and run the smallest FFT test, making sure that AVX instructions are disabled.

Check the CPU temperature in the software after five minutes. You'll need it to be below 80°C for AMD CPUs and 85°C for Intel CPUs, as the latter often run a little warmer anyway – an overclock resulting in load temperatures in the 90s is acceptable.

This is a worst-case scenario, as games and most software won't put this much load on your CPU.

If your results are close to these limits, even at stock speed, there are a few experiments



You can improve stability by increasing the power, current and duration limits to their maximums

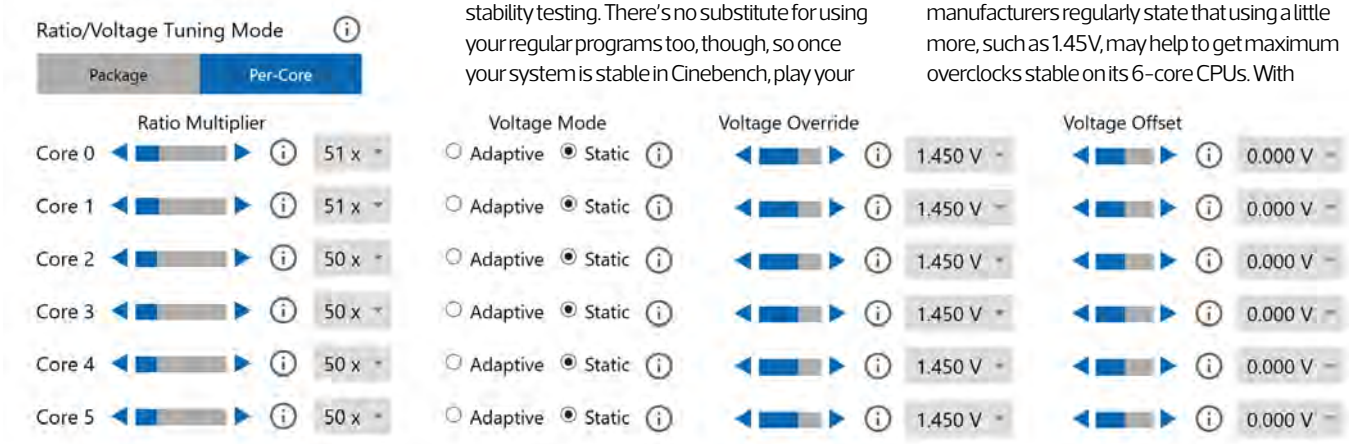
you can try. Firstly, removing old thermal paste from the cooler and reapplying fresh high-performance paste can knock 5°C off these temperatures. You can also check your cooler's fan speeds are set to ramp up properly and if you're using a liquid cooler, try increasing its pump speed.

Finally, remember that no two CPUs are the same when overclocking. Some will require more voltage to hit a certain frequency. If you try our settings and they still don't work, kick the frequency back 100MHz and try again. Eventually you'll find a stable frequency for that voltage.

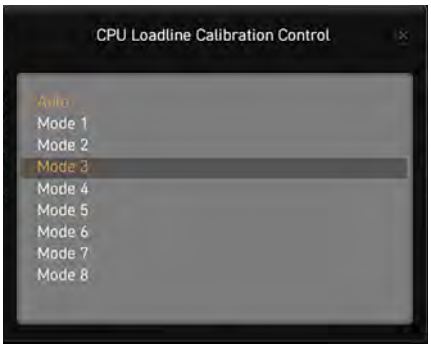
Test your overclock

Testing your overclock is vital, or you risk having a flaky, unstable PC. We've found Cinebench's R23 multi-threaded test (**maxon.net/Cinebench**) to be a great stability test – it will often crash even when Prime95 remains stable. The new R23 version even allows you to extend the usual benchmark to 30 minutes for stability testing. There's no substitute for using your regular programs too, though, so once your system is stable in Cinebench, play your favourite games or use your content creation programs to ensure your PC is rock solid.

NO TWO CPUs ARE THE SAME – SOME WILL NEED MORE VOLTAGE TO HIT A CERTAIN FREQUENCY THAN OTHERS



Intel's Extreme Tuning Utility enables you to adjust the frequency and voltage of individual cores



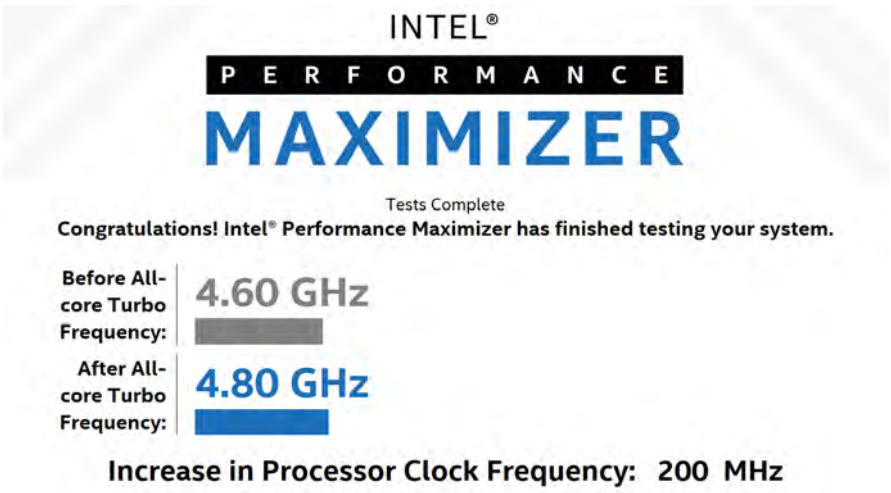
Loadline calibration will add a certain amount of extra voltage when a CPU is under load, counteracting vdroop. Start with the third highest setting

Overclocking Intel CPUs

Intel has used a 14nm manufacturing process for several years and CPU generations now, and these processors are generally happy to receive higher voltages than their 7nm AMD counterparts. In addition, Intel's CPUs overclock to similar levels with similar voltages across generations, so whether you have 8th, 9th, 10th or 11th-generation CPUs, you should be able to use similar settings to the ones in this example guide using a Core i5-11600K. However, you can also refer to the table on p87 for specific settings for old and new Intel CPUs.

A vcore of 1.4V is generally considered to be the upper limit for overclocking Intel's 8-core and 10-core CPUs, but motherboard manufacturers regularly state that using a little more, such as 1.45V, may help to get maximum overclocks stable on its 6-core CPUs. With

Intel's Performance Maximizer will restart your PC and start a series of stability tests with different voltages and frequencies



After 30 minutes of testing, Intel's Performance Maximizer added 200MHz to our CPU's all-core turbo frequency

fewer cores, heat is less of an issue. However, you'll still need a large air cooler or liquid cooler to cope with this voltage, so don't be surprised if your CPU gets too toasty at these voltages and you're forced to lower them. Using higher voltages can potentially shorten the lifespan of your CPU as well.

Start by locating the overclocking section in your motherboard's EFI, which you usually access by pressing Del when your PC starts up. The overclocking options are usually found in a section labelled 'advanced' or 'overclocking'. You're looking for a setting called multiplier or CPU ratio. Here you can enter your chosen multiplier – in the case of our example, we're inputting 50, which multiplies the 100MHz base clock and gives us an end CPU frequency of 5000MHz, or 5GHz.

Next you need to input a vcore. We've opted for 1.44V, which should be enough to get to 5GHz across all cores with our liquid-cooling setup. If you have a less powerful cooling setup, a Core i5-11600K should be able to hit 4.9GHz with a 49x multiplier and a 1.375V vcore.

Additional Intel steps

If your settings don't result in a stable system, or if your CPU clock speed doesn't stick at your settings, there are some additional tweaks you can try. In the advanced CPU settings in your motherboard's EFI, you can increase the power, current and duration limits to their maximums. This should allow the CPU to stretch its legs and maintain an overclock under high loads where it might otherwise drop back.

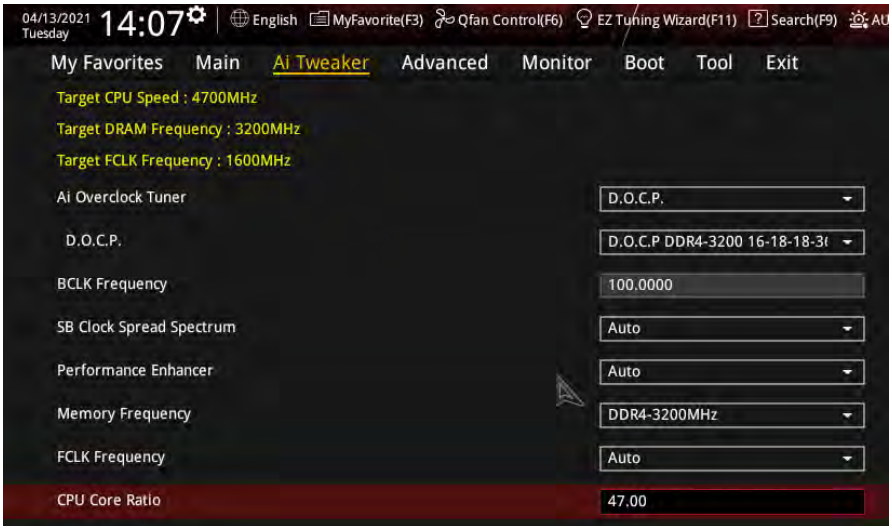
Next there's a setting called loadline calibration, often found in the CPU power settings. When a CPU is under load, the vcore can fall – a phenomenon known as vdroop. This can cause an otherwise stable overclock to crash. Loadline calibration will add a certain amount of extra voltage in these situations to counteract vdroop. The lower the number, the larger the extra voltage applied. Start with the third highest, which is usually what motherboard manufacturers recommend for overclocking if a simple vcore and multiplier tweak doesn't work.

Another setting you can try to tweak is the CPU cache or ring ratio. This adjusts the frequency of certain parts of the CPU, such as the cache and memory controller. A higher ratio means more performance, so you should try to increase this setting once you know the rest of your overclock is stable.

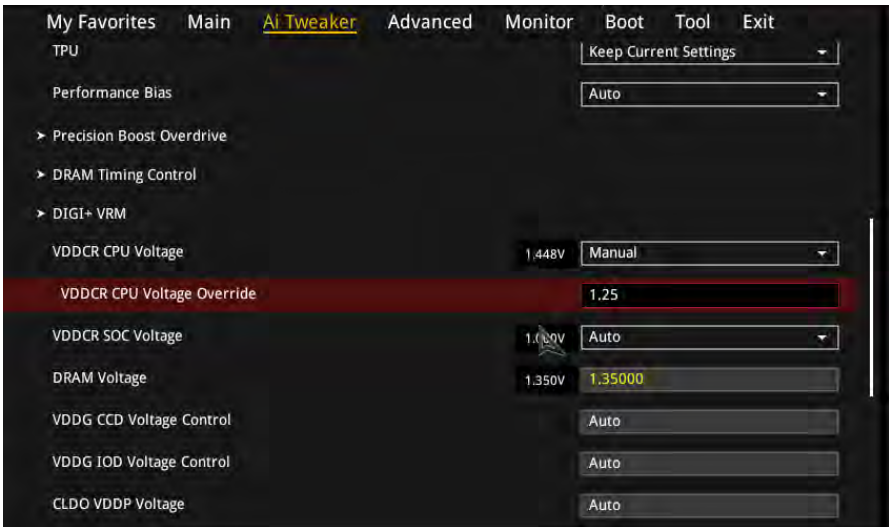
Tweaking individual Intel cores

If you want to delve deeper into overclocking your Intel CPU, there are plenty of other tweaks you can try. For starters, you can change a lot of settings on a per-core basis. You can disable Hyper-Threading on specific cores, which can improve performance in some games, so you could disable it on the first four cores, but enable it on the remaining cores to give a boost in multi-threaded workloads.

You can also change the multiplier on individual cores. The benefit of this is that not all cores on a CPU might be able to hit a certain frequency in an all-core manual overclock. For example, we could only reach a maximum 5GHz all-core overclock with our Core i5-11600K, but by bumping the first two cores of our Core i5-11600K to 5.1GHz, we saw the single-threaded score in Cinebench R23 rise from 1,559 to 1,577.



Find the multiplier or core ratio field in your motherboard's EFI – we've inputted '47' to get our Ryzen 5 5600X running at 4.7GHz



In our Asus EFI, we had to set the CPU voltage section to manual, and then input our chosen vcore into the override field

A handy tool here is Intel's Extreme Tuning Utility (**custompc.co.uk/IntelETU**), which enables you to tweak your CPU's frequency on a per-core basis from within Windows for quicker stress testing. Start by finding your CPU's maximum stable all-core overclock, then increase the first core's multiplier by one and continue increasing it until you hit stability issues. Once that happens, roll the frequency back 100MHz and move on to the next core.

There's an added benefit to tuning your CPU in this way, which is that you can also adjust the voltage for each core. A blanket 1.45V for all cores will likely be just enough for some, but more than enough for others, which means your CPU's power consumption and heat output will be higher than necessary. Once you've finished boosting the frequencies, try reducing the voltage of each core in turn.

When you're done, you can then apply the settings you've used in Intel's software to your BIOS. This is highly dependent on your CPU and motherboard's specific abilities, and extremely granular, so unfortunately we can't suggest exact settings here for your CPU. However, while this tweak is time-consuming, it's relatively easy to do and can enable you to squeeze extra performance out of your CPU, as well as reducing and heat and power consumption compared with an all-core manual overclock.

Intel Performance Maximizer

We're all in favour of automatic overclocking software, so long as it actually works. Intel's freely downloadable Performance Maximizer (**custompc.co.uk/IntelPM**) actually does a reasonable job, so we've included it here if you're not quite ready for manual overclocking, or if you just want an easy fix. The software will restart your PC and start a series of stability tests with different voltages and frequencies.

We ran it on our Core i5-11600K, and it took around 30 minutes of testing time, resulting in the all-core boost frequency rising from 4.6GHz to 4.8GHz. However, the software also appears to be very liberal with the voltage and not particularly aggressive with the frequency.

Our own manual overclock sees 4.9GHz as an easy target with 1.375V, but the software plumbed in 4.8GHz with a hefty 1.4V vcore. It was stable, but not particularly refined, although unlike AMD's Ryzen Master software, it did make the overclock stick between reboots. It's a good starting point for getting the figures for a manual overclock, though, and it seems to be trustworthy in terms of getting a stable overclocked system.

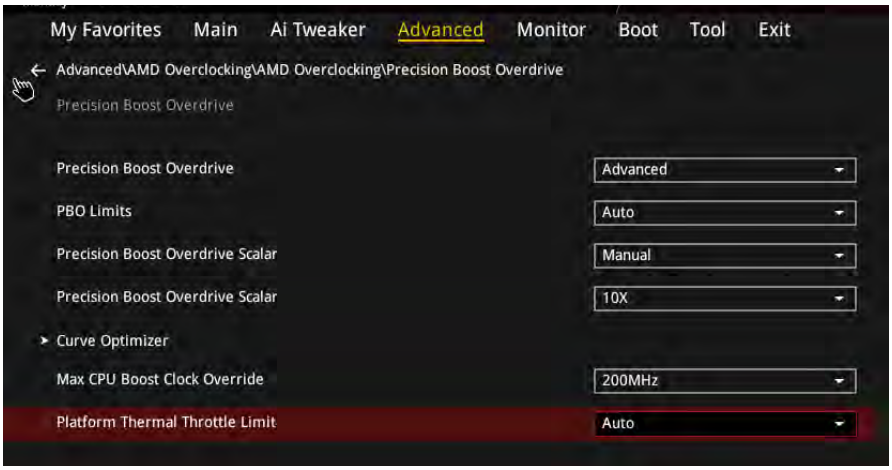
Overclocking AMD CPUs

As we've mentioned previously, overclocking your CPU is all about considering the gains you'll see, as you don't always get a lot of headroom, thanks to manufacturers sailing close to the wind with their boost frequencies. We've been talking about this a lot in our reviews of AMD CPUs, as they're especially tight in terms of overclocking headroom.

The Ryzen 7 5800X, for example, could only hit an all-core overclock of 4.6GHz, which is 100MHz lower than the peak boost frequency of 4.7GHz and just 100MHz higher than the all-core boost we observed of 4.5GHz.

However, AMD's 6-core CPUs have often been more suitable for all-core overclocks, as they have comparatively low all-core and peak boosts, but have similar headroom to more expensive models. If in doubt, a manual overclock is a good test, and if multi-threaded speed is your goal, then it can be worth losing a couple of hundred megahertz of peak boost across one or two cores if you gain the same amount over the stock speed all-core boost.

A good tool for testing an AMD overclock is Ryzen Master – AMD's monitoring and overclocking software. It allows you to apply overclocks within Windows to speed up testing, so it's well worth using. For Ryzen 5000-series CPUs, you don't want to use a vcore of more than 1.3V for an everyday overclock, and ideally you want a vcore closer to 1.25V, as AMD's latest 7nm CPUs can degrade in a relatively short time frame if they're seriously overvolted.



AMD's Precision Boost Overdrive can increase power limits, so your CPU can hit higher frequencies, but it can also result in higher temperatures

Intel CPU overclocking settings

	Multiplier	Resulting frequency	Gain over stock all-core boost	Gain/loss over stock peak boost	Vcore	Advanced steps
Core i9-11900K	51	5.1GHz	0MHz	-200MHz	1.33V	See section A of key
Core i7-11700K	49	4.9GHz	+300MHz	-100MHz	1.38V	See section A of key
Core i5-11600K	49	4.9GHz	+300MHz	0MHz	1.375V	See section A of key
Core i9-10900K	51	5.1GHz	+200MHz	-200MHz	1.325V	See section A of key
Core i9-10850K	51	5.1GHz	+300MHz	-100MHz	1.35V	See section A of key
Core i7-10700K	51	5.1GHz	+400MHz	0MHz	1.34V	See section A of key
Core i5-10600K	51	5.1GHz	+600MHz	+300MHz	1.33V	See section A of key
Core i9-9900K	49	4.9GHz	+200MHz	-100MHz	1.36V	See section A of key
Core i7-9700K	51	5.1GHz	+500MHz	+200MHz	1.32V	See section A of key
Core i5-9600K	51	5.1GHz	+800MHz	+500MHz	1.32V	See section A of key
Core i7-8700K	50	5GHz	+700MHz	+300MHz	1.3V	See section A of key
Core i5-8600K	50	5GHz	+900MHz	+700MHz	1.35V	See section A of key

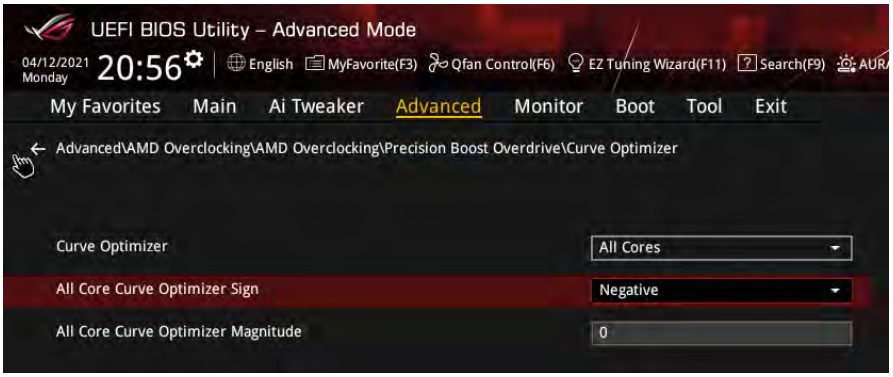
Start by applying a CPU frequency and voltage in Ryzen Master's manual section – here we're aiming to get our Ryzen 5 5600X up to 4.7GHz with a 1.25V vcore. Now go ahead and test your overclock using Cinebench and Prime95. With AMD CPUs, it's especially important to reduce the vcore as much as possible. From here, once you find a stable overclock in Ryzen Master, you'll need to then transfer the settings into your motherboard's EFI, as Ryzen Master won't make your overclock stick if you reboot your PC.

Locate the advanced or overclocking section of your EFI, then find the CPU ratio or multiplier field. In our case, we've inputted '47' in order to hit a CPU frequency of 4.7GHz. After that, locate the vcore or CPU voltage option and input your required voltage – in our case, that involved setting the CPU voltage section to manual, and then inputting 1.25 into the override field.

Precision Boost Overdrive

Precision Boost (PB) is AMD's boosting tech, but the company also has a secondary layer of boosting called Overdrive (PBO). This is manually controlled by you, but it isn't a manual overclock. Instead, you can increase certain limits in the hope that the algorithm will see cooling and power headroom, and apply higher frequencies, or maintain stock boosts for longer.

This is where good cooling and a decent motherboard are helpful, although with the original PBO, the gains are still often modest. The advantage, though, is that any gains will be paired with the fact that the CPU will continue using its boosting algorithms, which isn't the case with a manual overclock.



Precision Boost Overdrive 2 can be applied to increase or decrease voltages, but it didn't have a huge impact on performance in our tests

PBO allows you to increase the voltage applied to the CPU by using a 'scalar' setting. This increases the power and thermal limits of the CPU to enable it to hit higher frequencies. A scale from one up to ten is available, with ten increasing these limits the most, but high settings can increase temperatures and power draw significantly, so you'll need to test them on your own PC to see how it copes.

There's also the Boost Override feature. This allows you to set a boost frequency limit over and above stock boost speeds. The maximum is 200MHz, but in addition to cooling and power delivery, the way this is applied to each Ryzen CPU can vary. Some CPUs get a higher peak boost on a single core, while others benefit more in terms of multiple-core or all-core frequencies.

Our Ryzen 7 5800X saw no benefit from PBO in the all-core boost, hitting the same figure of 4.523GHz under load. This isn't surprising, given that our own experience with the CPU and manual overclocking showed it was already running close to its limits. We did see the peak single-core boost hit 4.95GHz on occasions compared to 4.875GHz at stock speed, though,

AMD CPU overclocking settings

	Multiplier	Resulting frequency	Gain over stock all-core boost	Gain/loss over stock peak boost	Vcore	Advanced steps
Ryzen 9 5950X	46	4.6GHz	+700MHz	-300MHz	1.25V	See section B of key
Ryzen 9 5900X	46	4.6GHz	+500MHz	-200MHz	1.25V	See section B of key
Ryzen 7 5800X	46	4.6GHz	+100MHz	-100MHz	1.25V	See section B of key
Ryzen 5 5600X	47	4.7GHz	+300MHz	+100MHz	1.25V	See section B of key
Ryzen 9 3900X	43	4.3GHz	+300MHz	-300MHz	1.325V	See section C of key
Ryzen 7 3800XT	43	4.3GHz	+100MHz	-400MHz	1.325V	See section C of key
Ryzen 7 3800X	43	4.3GHz	+100MHz	-200MHz	1.325V	See section C of key
Ryzen 7 3700X	43	4.3GHz	+300MHz	-100MHz	1.325V	See section C of key
Ryzen 5 3600X	43	4.3GHz	+200MHz	-100MHz	1.325V	See section C of key
Ryzen 5 3600	42.5	4.25GHz	+250MHz	+50MHz	1.325V	See section C of key
Ryzen 7 2700X	42.5	4.25GHz	+350MHz	-50MHz	1.375V	See section C of key
Ryzen 5 2600	42	4.2GHz	+500MHz	+300MHz	1.375V	PBO and PBO2 not supported

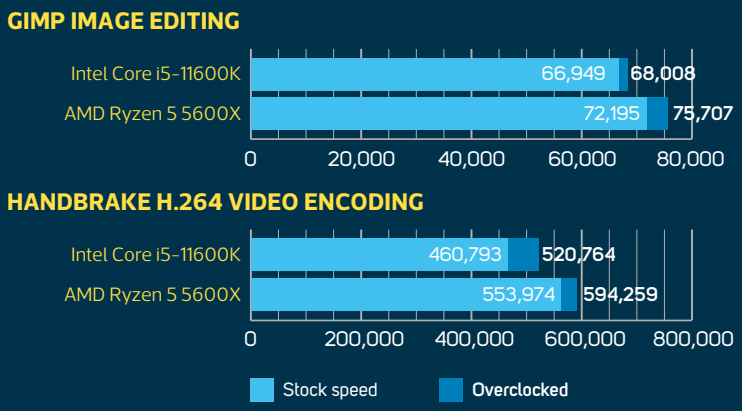
Key

A Attempt for higher frequency/lower voltage. Increase Ring/Cache ratio as high as possible. Try per-core frequency and voltage adjustment.

B Apply 200MHz PBO frequency and adjust scalar up to x10. Investigate PBO2 all-core and per-core adjustments in both negative and positive offset.

C Apply 200MHz PBO frequency and adjust scalar up to x10. PBO2 not supported.

Before and after performance comparison



which saw the single-core test in Cinebench rise from 1,579 to 1,586.

AMD has also recently introduced Precision Boost Overdrive 2 (PBO2), which takes the tech much further and is rather complicated. Instead of plumbing scalars into the EFI, PBO2 gives you much finer control, with up to 30 'counts', each of which is the equivalent of 3mV-5mV. In other words, you can adjust the voltage by 90-150mV in both a positive or negative way. PBO2 will actively look to boost the frequency along the whole curve, and with the extra thermal headroom provided by using the negative option, it may boost higher.

However, we found that it did little to increase performance in either negative or positive options, with its emphasis being more on reducing voltages at specific frequencies, which in turn enable your CPU to run cooler.

Our AMD Ryzen 7 5800X got an all-core boost of 4.7GHz with PBO2 enabled, which is 200MHz higher than at stock speed, when using a positive count of 20. However, even then it still turned out to be slower in a multi-threaded run of Cinebench, and in the single-threaded Cinebench test for that matter. We tried the same approach with the Ryzen 9 5900X, but got similar results, even with a custom water-cooling system – the CPU was ultimately faster at stock speed or with standard PBO enabled.

Overclocking settings to try

We've created some starting points for you in the tables above, which should result in stable overclocks on these CPUs with a reasonable cooling setup. However, as each CPU is different and motherboards also differ in terms of their power delivery, you may find you can reach these speeds with lower voltages, or that you're able to increase the frequency further too. These are starting points and you should always try to lower the voltage as much as possible. CPC

HOW MANY CORES DO YOU NEED FOR GAMING?

AS CPU CORE COUNTS HAVE EXPLODED, THE BURNING QUESTION ON MANY ENTHUSIASTS' LIPS IS WHETHER WE ACTUALLY NEED ALL THOSE CORES FOR GAMING. EDWARD CHESTER AND BEN HARDWIDGE CRUNCH THE NUMBERS

Ever since AMD shook up the CPU market with its first Ryzen CPUs, the debate has raged over just how many cores most users – and particularly gamers – need. In one fell swoop, AMD had doubled the core count for competitive mainstream processors (AMD previously had 8-core chips, but they weren't good). Suddenly, the market had gone from the endless quad-core CPUs that Intel deemed sufficient for its top-end mainstream line to the eight cores provided by the Ryzen 7 1800X.

However, despite a massive leap in this one area, AMD still couldn't compete with Intel chips when it came to clock speed and instructions per clock, which was what really mattered for gaming then. Multi-core performance was clearly useful for some tasks but gaming apparently wasn't one of them.

However, with its most recent Zen 3 Ryzen processors, AMD has finally brought its instructions per clock into line with Intel – even surpassing it in some areas – which finally means we have close to parity between the two CPU brands when it comes to gaming performance. What's more, core counts have continued to rise, with AMD's mainstream CPUs now topping out at a whopping 16 cores, while Intel's latest 11th-gen Core processors max out at eight cores.

All of which begs the question of how many cores you need. Clearly, CPUs with many cores are great for heavily multi-threaded software, but are all those cores ever useful for games? Not so long ago, a dual-core chip with Hyper-Threading was adequate for gaming, while quad-core CPUs were an unnecessary luxury. But do modern games take advantage of more cores now? That's what we're here to find out. First, though, let's explore the theory of why an ever-increasing core count doesn't necessarily improve the performance of games.

The multi-core revolution

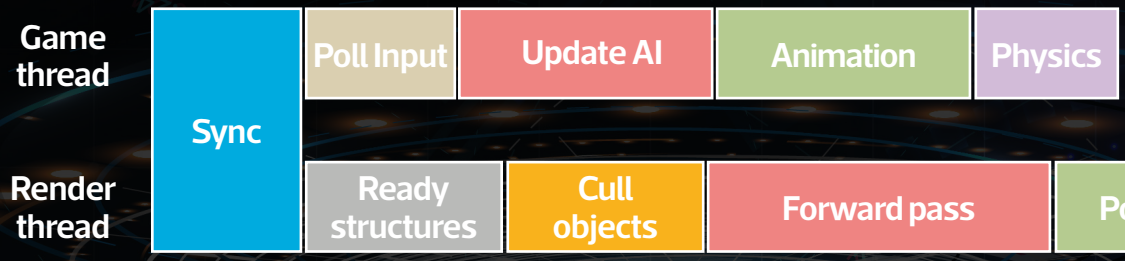
Cast your minds back to 2005, when AMD had just released the world's first consumer dual-core processors. In one fell swoop, the usability of PCs was revolutionised, as programs didn't have to completely give up control of the CPU in order for another program to perform a function. Now, one program could merrily carry on uninterrupted while a whole other core could deal with whatever else the system had to worry about.

Very quickly, it was clear that a second core was useful for gaming – if games have to give up CPU clock cycles to perform other tasks, you end up with dropped frames and generally poor performance.

However, beyond this basic advantage of an extra core taking care of background tasks, games themselves didn't really take advantage of any extra CPU cores for a long time. As such, the step up to dual core was entirely sufficient for a long time. Unless you had a lot of tasks in the background, that single extra core was enough to ensure an interruption-free time.

However, as the years have rolled on, we've become used to having many more apps and tasks running in the background while gaming. Web browsers with multiple tabs open, an email client, Skype, Discord and much more: all these might be sat there occasionally pinging your system for resources.

Moreover, games themselves have slowly started to take advantage of extra cores. From



The traditional approach to adding multi-thread support to games is to have a main thread and dedicate some tasks to other threads

offsetting audio calculations to performing AI and much more, there are ancillary tasks that game developers can now pass on to a second, third or fourth core, while the main game thread takes care of the most critical tasks that affect the player's experience, such as user input. All of which brings us on to the biggest hurdle in eking out ever-greater gaming performance from today's CPUs: humans.

The human factor

Games are, by and large, synchronous applications, which means that only one task can be performed at a time, or more specifically, that one task is nearly always dependent on a result from the task before. There are a few factors here, but the main one is that games involve waiting for unpredictable human interaction.

By nature, games rely on input from players before they can perform the calculations necessary to show what happens next, whether that's updating the image on screen, calculating the trajectory of an in-game bullet or triggering an animation.

You can't predict or pre-calculate that user input (within reason), so in turn you can't perform any of the operations that result from that input until it occurs.

Games do, of course, perform lots of background tasks, such as pre-fetching the assets required for the next area of the game, performing enemy AI and animating weather effects, but there's only so much that can be done in advance or simultaneously.

This reliance on unpredictable user input is the Achilles heel of extracting gaming performance from many CPU cores. If a game could predict, or outright knew, your inputs, it could merrily spread the resultant workload in all manner of ways, in much the same way as a 3D animation studio such as Pixar can completely offset the highly complex rendering of the final frames of a film until months or years after an animation of a character has been finalised.

However, the moment a user gets involved and isn't happy to wait months for a game to respond, all that parallel work could be undone. It's for this reason that many games are still very limited in how much they can take advantage of multiple cores. However, there are some workarounds.

Ways of multi-threading games

The first and most obvious area in which games can and do take advantage of multi-core processing is in performing all the ancillary tasks that don't require user input.

Tasks such as complex character animations, AI, in-game world physics and real-time weather changes can all to some extent be pushed off onto other threads that can be processed on other cores. With the rise of open-world games and the general complexity of modern AAA titles, there's significant scope for these extra functions to take advantage of more CPU cores.

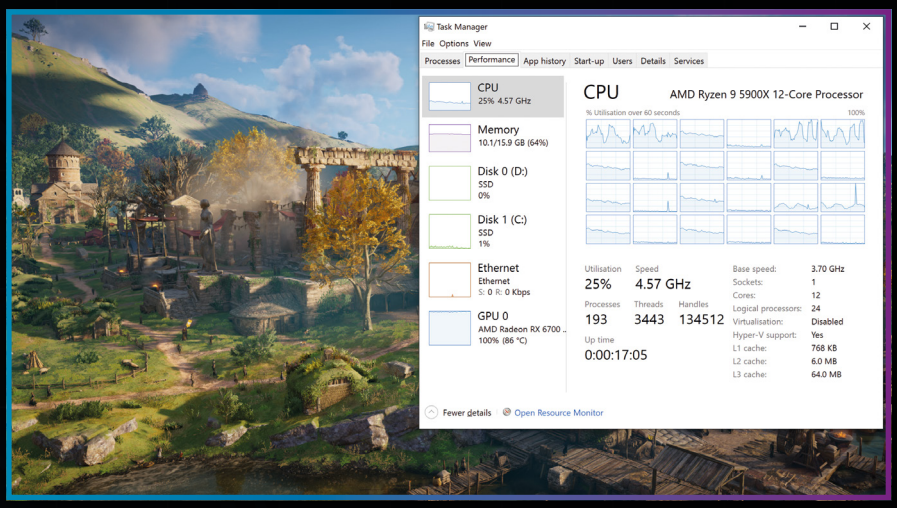
For instance, the real-time strategy game Ashes of the Singularity is famously one of the few games that really takes advantage of multi-core CPUs thanks to the massive number of AI units on-screen at once. Calculating all the unit movement paths, collisions, physics, projectile paths and more, all across hundreds of units, lends itself well to multi-core processing. It only takes one user input (select some units and get them to attack some other units) to fire off a vast chain of events.

This is also why we have graphics cards, as rendering any given frame requires a huge number of independent calculations to be performed, all from a fixed moment in time – for that snapshot, there's no need to worry about user input or anything else – so it's easy to spread those tasks across hundreds of dedicated GPU shader cores.

Conversely, for many FPS games where you may only have a handful of enemies on screen at once, and any given input by the user only tends to affect a small portion of the game world's assets – and of course, where split-

FROM AUDIO CALCULATIONS TO AI, THERE ARE ANCILLARY TASKS THAT GAME DEVELOPERS CAN PASS TO A SECOND, THIRD OR FOURTH CORE

Shadow of the Tomb Raider took advantage of all 24 of our Ryzen 9 5900X's threads, but that still didn't translate into faster performance beyond four cores



Assassin's Creed Valhalla takes advantage of several CPU threads, and performance drops off on a dual-core setup

second response to user input is so important – there's an inherent limitation on what can be offset to other cores.

The most basic way in which this splitting off of tasks is managed is to have a main game thread take care of areas such as user input, updating the AI, and performing animation and physics calculations. Then, you might have a dedicated render thread for taking care of the graphics pipeline and other dedicated threads for audio processing or asset loading. This is the sort of setup found in game engines such as Unreal Engine 2, 3 and 4.

This splitting up of tasks is relatively easy for a programmer to implement. However, we're still very much reliant on the main game thread running as quickly as possible and not causing any hang-ups. Moreover, it doesn't scale very well. With ancillary tasks being pre-allocated to certain threads, and many processes still undertaken by the main game thread, the game developer is largely having to bake in a degree of maximum core support. So, if more cores are available, the game engine won't have a means of taking advantage of those cores.

Task-based programming

To get around the problems inherent to having a main game thread and a handful of dedicated ancillary threads, we can instead use a task-based thread system. Here, instead of the main thread running some tasks itself and just relying on extra cores to perform a handful of other pre-defined functions, the main thread does almost nothing itself other than split up the workload into tasks made as small as possible, and then pass those tasks on to other threads/cores for processing. The results of all the smaller tasks are then merged and synchronised by the main thread when they're completed.

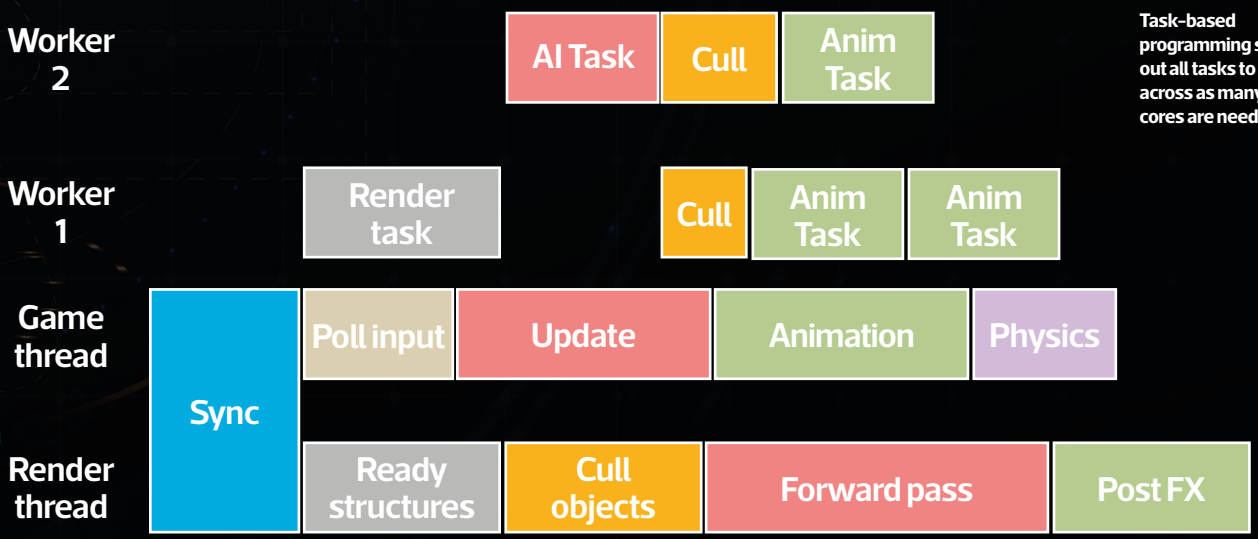
This ability to simply throw any task at any core makes it a much more scalable approach. However, it's not without limitations. For a start, we're stuck with the problem of ensuring all the data syncs up. There are only so many tasks that can be running in parallel before one will need an update from another – an AI task might affect an animation task, which will affect a physics task and so on – before it's able to move on.

That's why we still seldom see much more than a handful of cores under significant load, even in games that are optimised for multi-threading. The system might be able to allocate many tasks to many cores, but the constant waiting for the results of them means some cores are often sat idle.

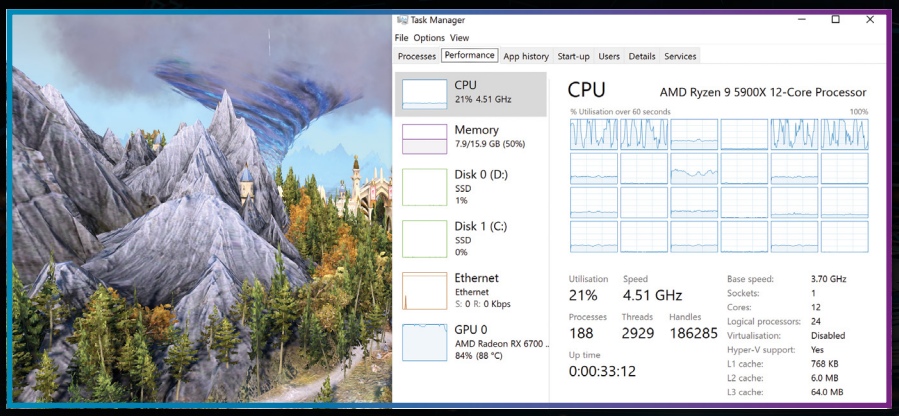
We see this in games such as Shadow of the Tomb Raider and Doom Eternal. They utilise just about as many cores as you can throw at them, but we don't see an uptick in performance much above six cores. For the game to run faster, each individual task would need to be completed quicker, which again simply comes back to each core getting its work done as quickly as possible.

Performance analysis

The other limitation with this task-based method is that it's inherently complicated due to the need to manage so many disparate threads. Whichever method is chosen, there's



Task-based programming separates out all tasks to be run across as many CPU cores are needed



Warhammer: Total War II mainly stresses four threads, but also utilises others in a way that results in stronger performance with six cores than four cores

A FEW YEARS AGO, A CORE i3 WITH TWO CORES AND FOUR THREADS WOULD BE FINE FOR BUDGET GAMING, BUT THAT'S NO LONGER THE CASE

only so far that multiple cores on your CPU can help to improve your frame rate. To test just how many cores you do need, then, we fired up our test rig.

Our new graphics test rig, based on a 12-core Ryzen 9 5900X CPU, gave us an ideal opportunity to test multiple games with different numbers of cores enabled. You're able to disable one of the chiplets on this CPU in the motherboard EFI, and also disable individual cores inside each chiplet, meaning we could set up this CPU as a dual-core, quad-core, 6-core, 8-core and 12-core chip.

Testing was conducted with an AMD Radeon RX 6700 XT graphics card with any ray-tracing features disabled, and SMT is always enabled, so each CPU core can handle two threads. We've tested at both 1,920 x 1,080 and 2,560 x 1,440, using a mix of old and new games across a variety of genres.

Two is no longer company

We started with a dual-core (four threads) setup. Just a few years ago, a Core i3 chip with two cores and four threads (or an overclocked unlocked Pentium chip) would be fine for a budget gaming rig, but that's no longer the case. All of our games showed a performance deficit between having two and four cores enabled, and they all consistently took a surprisingly long time to load as well. During our game tests, the CPU was regularly running at over 90 per cent load here.

In some games, such as Metro Exodus, the difference is slight, as it's more dependent on GPU performance. In other games, however, the performance difference was substantial. Shadow of the Tomb Raider, for example, dropped from an average of 217fps at 1,920 x 1,080 to just 122fps, and the 99th percentile result halved when going from four to two cores. This game really suffered with just two cores enabled, with the machine visibly drawing untextured triangles at the beginning of the benchmark before it could properly get started.

Assassin's Creed Valhalla also dropped from an average of 90fps to 57fps at the same resolution, and the 99th percentile result in Doom Eternal dropped from 238fps to 163fps. It's the 99th percentile results that are particularly revealing here, as they show what happens when the game is interrupted by background Windows tasks and the frame rate suddenly drops.

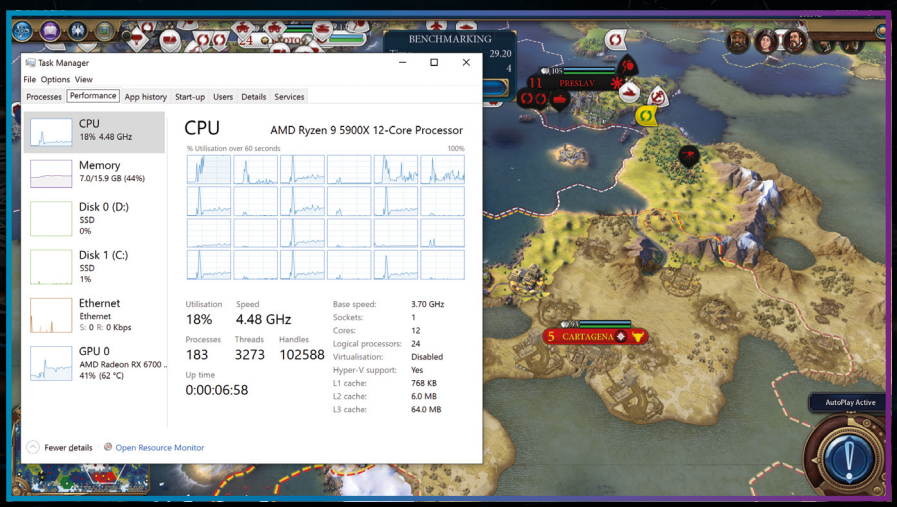
We found this happened a lot when testing with just two cores enabled – the first benchmark run would always have to be discarded, and it would then get smoother, but the results were still often highly variable. As with single-threaded games benefiting from a dual-core CPU to handle background tasks in the past, this now appears to have moved to games themselves requiring at least two CPU cores, with another two cores needed to prevent background tasks from interfering with your frame rate.

Four and six cores

Stepping up to four cores (eight threads) largely solves the problems with stuttering, dropped frames and general interference from background tasks, including our machine slowly drawing out the scene when it first starts Shadow of the Tomb Raider.

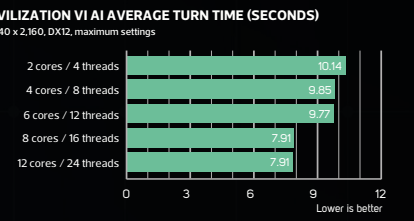
The result is a much smoother experience that isn't just shown in frame rates, but is also keenly felt while you're playing – with four cores enabled, it feels like your PC can breathe a little and isn't constantly scrabbling to keep up with the demands of Windows background tasks.

In some games, including Cyberpunk 2077, Doom Eternal, Assassin's Creed Valhalla and Metro Exodus, our tests showed no notable performance benefit from having more than four cores. In other games, though, there's a benefit from having six cores. Again, this is most noticeable in the 99th percentile results.



Civilization VI heavily stresses just one thread for the most part, but the way it uses the other threads available still results in a quicker turn time with eight cores compared to six

PERFORMANCE RESULTS



For example, there's a 9fps difference in the 99th percentile results in Shadow of the Tomb Raider when you go from four to six cores.

You also see a benefit in Warhammer: Total War II when you ruin the Campaign benchmark, particularly at 1,920 x 1,080. At this resolution, there's an 8fps difference in the 99th percentile result when you step up from four to six cores. The differences are much smaller than moving from two cores to four cores though. With a 6-core CPU, you're buying yourself a little more headroom in strategy games, and a bit of futureproofing for games that might use more threads, but four cores are still clearly enough for a lot of games.

Beyond six

In most of our test games, there's little benefit from moving up to eight or 12 cores, even in a strategy game such as Warhammer: Total War II. In some games, such as Doom Eternal, having more than six cores even puts you at a disadvantage, as the CPU can't boost as far.

One surprising exception is Civilization VI, which showed an improvement of nearly two seconds in its average turn time – a figure that barely changes when you go from two to six cores. We ran this test several times on all configurations to be sure of this, but the results were consistent.

This situation was particularly surprising, as our monitoring showed that the game was mainly single-threaded – to a much greater degree than the other games we tested.

While most of the work is handled by one thread, though, the game does show activity on 12 other threads – they're not being maxed out, but being able to spread the load across eight cores does seem to free up the system enough to boost Civilization VI's AI performance. There's no further benefit if you step up to 12 cores here though.

So how many cores do I need for a gaming rig?

The age of budget gaming systems based on sub-£100 dual-core CPUs has clearly now passed, but a quad-core (eight-thread) CPU will be fine for most of today's games in terms of core count. If you can afford it, stepping up to a 6-core CPU is the sweet spot, giving your PC plenty of room to breathe in strategy games, while giving you some headroom for future games that may take better advantage of more cores.

Beyond that point, though, there's very little point in opting for more cores for gaming purposes, at least at the moment. That's not to say that having many CPU cores is pointless – having loads of CPU cores is great for highly parallel workloads, from video encoding to 3D rendering. Unlike older many-core CPUs, the latest Zen 3 Ryzen 9 chips enable you to do this with little negative impact on gaming performance, which is great.

If gaming is your main performance priority, though, we'd recommend buying a 6-core CPU and overclocking it (see p78), rather than spending extra money on a CPU with more cores – getting a faster GPU will be a much better use of your budget here. CPC

GARETH HALFACREE'S

Hobby tech

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

REVIEW
Solo V2

Seen here in its silicon sheath, the Solo V2 aims to be the ultimate open-source security dongle

Conor Patrick's Solo launched in October 2018 with a simple promise: an affordable security key, following the FIDO2 Universal 2nd Factor (U2F) standard. It would also have the added bonus of smartcard-emulating FIPS 201 PIV support, based on a fully open-source firmware – a far cry from the black-box proprietary nature of its competition.

The redesigned hardware is compact and robust, with waterproof resin over the core hardware

Originally designed as the 'something you have' to go along with the 'something you know' password in a two-factor authentication system, FIDO and FIDO2 aim to replace the old-fashioned, time-based one-time password (TOTP) systems, where a numerical code is read from a physical dongle or smartphone app, with a simpler idea. You insert a small USB key into a free port, tap a single button and you're authenticated – if someone steals your password, they'll get nowhere without the dongle, and vice versa.

After the success of the Solo and its wireless Near-Field Communication (NFC) stablemate, the Solo Tap, Patrick went back to the drawing board with a view to improving the design. The result is the Solo V2, which replaces both devices and boasts a range of upgrades.

The first change is that there's no USB-only variant this time, with all Solo V2 keys including NFC capabilities with boosted range. There are still two variants though – the first variant uses a USB Type-C connector, while the second opts for a smart double-sided USB Type-A connector – meaning it, like the USB Type-C variant, can be put into a USB port either way up. It's no gimmick either – the key includes a status LED on one side of the board, and by being able to insert the key either way up, you can make sure the LED is always facing you.

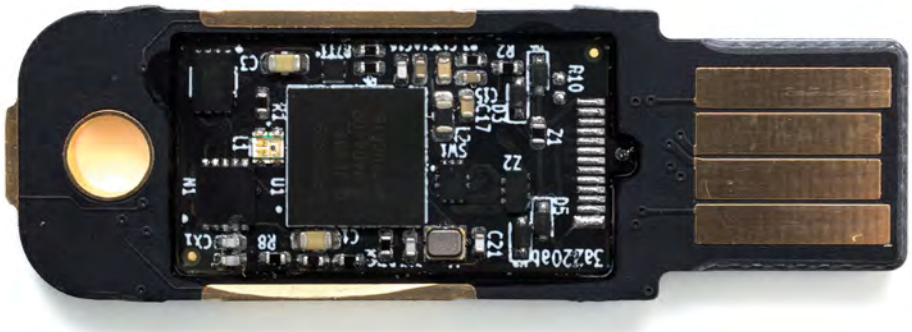
The second change is that the hardware is considerably more robust this time – as it should be, given that the dongle is designed to live on your keyring and rattle around in your pocket. The main PCB is placed into a carrier board before being sealed with transparent resin, making it both tamper and waterproof.

NEWS IN BRIEF

RetroArch announces open hardware project

Emulation platform RetroArch has announced that it's branching into the hardware realm, starting with a USB-connected cartridge reader for Nintendo 64 games. 'Playing the game should be as easy as just loading the ROM from this device,' developer Daniel De Matteis explains. 'But our hope is that with the RetroArch integration, we finally get the promise of a true cross-platform game console where you can take your games library with you, whether it's digital or physical, and just use it across the devices that you already have RetroArch on.' See **libretro.com** for more information.

The USB Type-A variant is double-sided, allowing it to be inserted either way up in a USB port



The resin protects the electronics from dust, water and shock while also being tamper-evident

The third change is that the Solo's physical buttons, which are used to confirm authentication, have been removed in favour of more reliable touch-sensitive areas. There are pads to the left and right of the board, plus one on the very end – and the bundled silicon cover, designed to protect the key when attached to your keyring, keeps these bare for quick use.

The Solo V2 works over NFC or USB, with a choice of Type-A or Type-C connectors

The biggest shift, though, is in the open-source firmware that runs atop the key's secure processor. The Solo V2 makes the move to Rust, a programming language that aims to address many of the pitfalls that introduce security problems, such as buffer overflows, in software.

Unlike most security keys, the open-source Rust-based firmware on the Solo V2 can be upgraded at any time as new features are added. One such feature, the ability to act as a TOTP dongle as well as FIDO2, is already in development.

Anyone interested in adding their own can work on the firmware directly or develop apps that run atop it on a framework dubbed Trussed, which is designed to offer the same functions as Java Card, only in Rust.

In use, the Solo V2 is as simple as any of its competitors, thanks to WebAuthn support. Go to a site or service that supports the standard, add the key by inserting it into a free USB port and tapping one of the touch surfaces, then next time you log in, you'll be prompted to insert and tap the key again to authenticate. The keys are also supported by Microsoft for its Microsoft Accounts and Windows logon as part of an Active Directory setup, where they are – rather controversially – used as a single-factor for password-free logon.

Mobile support, via USB or NFC, is rather more limited. You're entirely able to use FIDO2 security keys in both Android and iOS, but only if you're using the stock Chrome or Safari browser respectively. If you're running a third-party browser, you're out of luck.

The list of services supporting FIDO2 is also surprisingly short. While more tech-savvy platforms such as GitHub, Twitter, Google, Facebook and Dropbox all support FIDO2 via WebAuthn, it's rarer to see support on other 'mainstream' services, even where the additional security would be highly welcome, such as those with internet banking.

That's not the Solo V2's fault, though, and providing the services you're looking to protect include WebAuthn support, there's no reason to buy a rival device over the Solo V2 – and every reason to do the opposite.

At $39 US (around £34 inc VAT) from **custompc.co.uk/SoloV2**, the Solo V2 is cheaper than the rival YubiKey 5 NFC. However, there's also international shipping from the USA to consider – bumping up the cost of a single key considerably and making joining together with friends for a multi-device bulk order a tempting proposition, at least until the gadget develops an international reseller network.

REVIEW

FunKey S

A surprisingly polished open-hardware device, the FunKey S is a lot more than a shrunken Game Boy Advance SP

Handheld gaming isn't the big business it once was. Of the three main console companies still in the hardware business – Microsoft, Sony and Nintendo – only Nintendo still has a handheld offering at all, and it launched the Switch on the promise that it could easily convert to big-screen gaming at a moment's notice.

What if the problem is size though? What if rather than having a device you had to carry in your backpack, or that bulges awkwardly from your straining pocket, you could game on a gadget hanging from your keyring? That's the vision behind the FunKey S, an open-hardware project to bring back handheld gaming in as small a size as possible.

With a design clearly inspired by Nintendo's classic Game Boy Advance SP, the FunKey S is tiny. Ridiculously so, in fact. The device measures just 42.5 x 44.5 x 13.8mm, folding open to reveal a full-colour 1.54in IPS display. The controls comprise a 4-way D-pad, four primary buttons, two secondary buttons and a power button, with a pair of shoulder buttons added for good measure.

The console is powered by an Allwinner V3s system-in-package (SiP), which offers a single-core ARM Cortex-A7 CPU running at 1.2GHz and 64MB of DDR2 memory. That doesn't sound like much these days, but the FunKey S isn't targeting 'these days' – it's built with vintage gaming in mind. As such, it ships with a selection of emulators, taking the user from the days of the Nintendo Entertainment System, Game Boy and Sega Master System through to the SNES, Mega Drive, 32X, PC Engine, Atari Lynx and even Sony's original PlayStation.

All these emulators run atop a customised Linux-based operating system designed for speed – and it delivers. From a cold boot, you can be ready to play in under ten seconds – when you get bored, just close the lid and a magnetic switch puts the console into a low-power sleep mode from which your game

The buttons are small but satisfying to press, and they can be swapped out for different colours

The folding design protects the screen while the FunKey S dangles from your keyring

It would be hard to make the FunKey S any smaller without making it entirely unusable

can be restored within five seconds of opening it again – wholly automatically.

The software also includes the majority of features you'd expect from a modern emulator, including save states and the ability to choose between stretching the graphics to fill the display or having them appear in their original aspect ratio. The latter is entirely necessary too – the compact display uses a 1:1 aspect ratio at a 240 x 240 resolution, meaning most games are stretched vertically to make the most of the available space.

So far, so good, but there are disadvantages to the compact design too. The display is bright and clear, but it only offers a 50Hz refresh rate – not the 60Hz classic NTSC rate the games were designed to use. There are no bumpers to keep the buttons from touching the glass front protecting the screen either, leaving it with visible – though cleanable – marks. The magnet used to detect when the screen is closed is also surprisingly strong, and will happily pick up magnetic dirt and even small metal objects. Battery life is limited too, at around an hour and a half – and it takes 60 minutes to charge from empty.

A USB port provides a data connection and charges the internal battery in around an hour

A bigger issue is sound reproduction. There's no headphone jack and you only get one speaker, although the design of the housing reveals that two speakers were originally planned. At present, the speaker is set to play only the left audio channel – meaning you miss half of the sound in stereo games. The team behind the FunKey S has pledged to fix this problem in a software update, however – and has already released a post-launch patch to improve compatibility with certain game ROM formats.

For those willing to tinker, it's possible to unlock additional features. The 32GB micro-SD card comes pre-loaded with the software image, and can be set to appear as a removable drive via the same micro-USB port that charges the FunKey S, so you can install additional emulators – or modify existing ones. The Mega Drive emulator can be tweaked to play Mega CD games, for instance – although the save-state feature isn't implemented for these games, so you'll lose your progress when you close the lid or quit the current game.

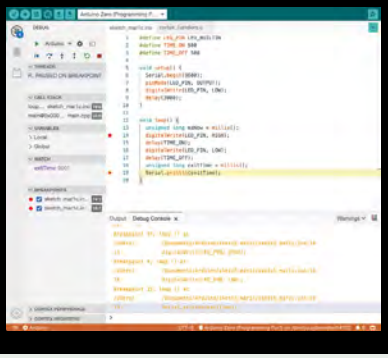
Performance of all the emulators is nothing short of incredible, given the device's size. Being able to pull out your keyring and play Ridge Racer – from a CD image captured from your physical copy, of course – on a device that fits on the tips of your fingers, is an amazing experience.

Every aspect of the project is open, too, from the software to the hardware design. You can 3D-print replacement casings, tinker with the software or even produce your own PCBs. For the customisation fans, the hardware is even bundled with replacement buttons in a selection of colours, although taking the unit apart and reassembling it afterwards is a fiddly process. The FunKey S is available to order from **funkey-s.backerkit.com** now, priced at €65 (around £67 inc VAT).

NEWS IN BRIEF

Arduino IDE 2.0 brings modern features

The classic, Java-based Arduino IDE is dead; long live the Arduino IDE 2.0, which comes a lot closer to the experience you might expect from a modern integrated development environment. 'It carries a modern editor and provides a better overall user experience thanks to a responsive interface and faster compilation time,' the Arduino team promises of the update, which was available in beta form at the time of writing. 'Don't be afraid of trying it today: the upgrade will be frictionless and the interface will look very familiar.' The latest release is available for free download at **arduino.cc** now.



REVIEW

Retro Computer Colouring Book

Colouring books have entertained kids for decades, but it wasn't until around 2015 that colouring books for adults became big business. Like their child-targeting equivalents, adult colouring books offer a relatively mindless pastime with a certain zen quality – and allow those, like the author of this piece, who lack natural artistic talent, to nevertheless produce a vaguely aesthetically pleasing result. The adult books – comedy versions with legitimately 'adult' themes aside – are typically composed of more complex imagery, mandala-style patterns and other more detailed shapes.

The Retro Computer Colouring Book: Version 1 takes a different approach. As the name implies, the book focuses on vintage computing devices – 15 in total, though they're spread across more than twice as many pages in a thin print-on-demand paperback tome.

The brainchild of the pseudonymous 'Old Bald Guy' of development service Quick Web Ltd, the book took reference photographs of classic computers and – with an iPad featuring a drawing stylus Guy suggests may have 'more [processing] power ... than all of the computers in this book combined' – traced them to produce clean line art illustrations printed on white paper, ready for colouring.

This is, of course, where the situation gets a little tricky. With a few notable exceptions, such as the Sol Terminal and the Ferrari-red Sony HIT-BIT HB-101, neither of which are represented in the book, the home computers of the 1970s and 1980s were produced primarily in shades of black, beige and the same white as the underlying paper behind each image.

Guy is well aware, of course. 'Most of them were beige,' he admits in the book's bumph. 'You probably won't need many other colours. Except silver, maybe – there's a couple of [Tandy RadioShack] TRS-80s within. You'll need silver for those.

'Not sure how you can colour the [Sinclair] ZX80, however. It's white. So is the paper. Be creative!'

It's clear that the book's premise is tongue in cheek. That said, creativity is still an option. Sure, the Sinclair ZX Spectrum, its rainbow decal aside, may have been primarily black, but the Retro Computer Colouring Book gives you a chance to wonder what life might have been like if Sir Clive had been a little more permissive with the colour palette that made up the Sinclair brand. Or perhaps you're up for the challenge of creating the world's first tie-dye IMSAI 8080 illustration?

Having the label refer to the previous page's illustration is a little distracting

If you've ever wondered what an Apple II might look like in orange, now's your chance to find out

It's also refreshing to see a print-on-demand colouring book that has a little effort behind it, after years of buying children-themed titles that turn out to collect stolen – and often low-quality – imagery from around the web, and then publish it for as long as possible before the underlying rightsholders notice and get it removed with a swift cease-and-desist order.

If you go into the purchase understanding that there are only 15 images to colour, and you're willing to overlook the annoyance of having the name of each machine printed on the rear of the corresponding page, meaning that the label you see while colouring is the label of the machine you've just finished rather than the one you're working on now, there's entertainment here – and a little shot of nostalgia to boot.

The Retro Computer Colouring Book: Version 1 is available from **amazon.co.uk** for £4.50 (VAT exempt); as a print-on-demand title, it's unlikely to appear elsewhere, although you can also search for it under ISBN 978-1659101850. CPC

Gareth Halfacree is a keen computer hobbyist, journalist, and author. His work can be found at **freelance.halfacree.co.uk** @ghalfacree

WIN

A MASSIVE 49IN AOC GAMING MONITOR

WORTH **£900**

SPEC

- 49in curved VA panel
- FreeSync Premium Pro
- 5,120 x 1,440 resolution
- 120Hz refresh rate
- 1ms response time (MPRT)
- Remote control included
- 2 x HDMI 2 and 2 x DisplayPort 1.4 inputs, plus USB Type-C with DisplayPort

We've got an absolutely awesome prize up for grabs this month, as our exceptionally generous pals at AOC are offering to send this enormous 49in AG493UCX monitor to one lucky **Custom PC** reader.

This curved ultra-wide VA display provides double the screen space of regular monitors, making for more efficient use of space and an unprecedented 32:9 ratio. Meanwhile, its Dual QHD (DQHD) resolution of 5,120 x 1,440 ensures crisp imagery, and you practically get two 27in QHD monitors in one.

Indeed, you can also use this monitor's Picture by Picture (PbP) feature to use multiple input sources (such as from your laptop and desktop PC) simultaneously and display them on the same screen.

DQHD also grants you a commanding view over your game and makes for sharp and brilliant images. As if that wasn't enough, there's FreeSync Premium Pro support to sync the panel's refresh rate with your GPU's frame rate, providing a fluid, tear-free gaming experience at peak performance.

There's even an integrated KVM switch, so you can share one keyboard and mouse between two computers using the same monitor.

SUBMIT YOUR ENTRY AT **CUSTOMPC.CO.UK/WIN**

Competition closes on Friday, 11 June. Prize is offered to participants in the UK aged 13 or over, except employees of the Raspberry Pi Foundation and Raspberry Pi Trading, the prize supplier, their families or friends. Winners will be notified by email no more than 30 days after the competition closes. By entering the competition, the winner consents to any publicity generated from the competition, in print and online. Participants agree to receive occasional newsletters from Custom PC magazine. We don't like spam: participants' details will remain strictly confidential and won't be shared with third parties. Prizes are non-negotiable and no cash alternative will be offered. Winners will be contacted by email to arrange delivery. Any winners who have not responded 60 days after the initial email is sent will have their prize revoked.

ANTONY LEATHER'S

Customised PC

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

How important is power efficiency?

I have a love-hate relationship with power efficiency. That might seem strange – after all, who would want a product that's less efficient than or more power-hungry than a competing product? Most of my time as a PC enthusiast has been about beating the heat as well, which is why I love water cooling, enjoy testing cases that boost air cooling and got into PC modding in the first place.

However, there seems to be an unhealthy obsession with power efficiency among PC enthusiasts right now. Intel has had some bad press over the past few years because its CPUs are still made on a 14nm process. AMD got the same gibes when its CPUs drew too much power in the pre-Ryzen days.

Both AMD and Nvidia have also been subject to criticism for hot-running products that drew huge amounts of power from the wall. Nvidia's Pascal cards – the likes of the GTX 1060 – were very power-efficient and so much so that they were some of the coolest-running, quietest modern graphics cards we'd ever seen.

Nvidia's Pascal GPUs, such as the GeForce GTX 1060, were extremely power-efficient

You could cram them into cramped, tiny cases and they'd still be cool, yet they offered excellent gaming performance and board partners could afford to make tiny, short-PCB models due to low cooling requirements too. For these reasons, the GTX 1060 has topped the Steam Hardware Survey charts for years, and its power efficiency made it desirable for cryptocurrency mining too. AMD's comparably hot and power-inefficient Radeon RX 500-series GPUs struggled to compete here.

However, AMD's Ryzen CPUs have performed a similar feat to Nvidia's Pascal GPUs. Some of AMD's 6-core and 8-core CPUs have been easily cooled, even with the reference coolers AMD provided, and water-cooling them was mostly pointless, especially at stock speed. Moving to a 7nm manufacturing process has seen this trend continue, and you only have to look at AMD's 12-core and 16-core Ryzen CPUs to appreciate the benefits of high power efficiency and resulting lower heat loads.

They're leaps ahead of Intel's equivalents here, which draw huge amounts more power and practically demand liquid cooling to get the most out of them. Of course, not having to worry too much about heat or power

is good. It means fewer stability issues, worry-free summer heatwaves, less money spent on cooling and a slightly lower electricity bill.

While I'm an advocate of using less electricity to reduce emissions as well, a lot of the bad press over hot-running components and above-average power consumption does seem a little short-sighted. Some of the best components over the years haven't been particularly power-frugal or cool-running.

Dealing with overclocked CPUs and hot summers was the reason I got into water cooling in the first place, and back then I didn't give two hoots about whether my hardware was power-efficient, as long as it was fast and not impossible to cool with reasonable noise levels. There's a reason why we have such excellent cases and cooling hardware today as well – they've been honed over the past couple of decades to become better at dealing with heat and keeping our hardware cool.

However, if you look at any online social media thread, you'll see people criticising products for being hot-running or drawing a lot of power. People will actively seek out alternatives, even if they're more expensive or slower. For me, PC hardware has always been about speed – I want my PC to be as fast as possible in games and content creation, and all other factors are secondary, subject to my bank balance of course. This attitude seems to be quite rare these days, especially in the face of rabid fanboyism.

The problem with the AMD vs Intel argument is that a lot of people will have been put off Intel CPUs when, at various times over the past few years, they've actually been just as good, if not better, than those of AMD. Admittedly, this has mostly been in games, but dismissing a CPU because it uses a 14nm manufacturing process is just silly. Dropping to 7nm won't improve your frame rates at all. A lower TDP won't cut those Adobe Premiere export times.

As always, it's important to find a balance. If a product fits your needs and is available for a fair price, plus reviews point at it simply needing a bit more grunt in the cooling department or a higher than average wattage on a PSU, that's a small price to pay for a setup that will likely keep you entertained for years.

If you have a potent cooling system, why does a little extra heat matter anyway? For me, performance should always come first with power efficiency and thermals second, unless you're on a mission to keep heat and noise to an absolute minimum.

Intel's Rocket Lake-S CPUs may have a comparatively high power draw, but they're still potent in games

Even then, underclocking hardware, which is very popular right now and we've studied in this month's overclocking guide (see p78), can really help to reduce power and heat loads. At the moment, our concerns also include actually being able to buy the hardware you want, and if gaming is your main concern, Intel's 10th and 11th-gen CPUs could well be better options than AMD's Ryzen 9 CPUs in terms of availability and reasonable pricing.

If I were building a PC right now and needed a degree of multi-threaded grunt in addition to great gaming performance, I would of course opt for the Ryzen 9 5900X. But you can't buy it and there will be plenty of people out there that would suggest opting for a lesser CPU such as the 6-core Ryzen 5 5600X instead. I would argue that the Core i9-10850K – which has ten cores – is a worthy alternative.

It offers significantly more multi-threaded grunt, it's still fast in games and it's surprisingly affordable. In fact, the Core i9-10850K costs just £375, while the Ryzen 5 5600X, if you can find it in stock right now, will set you back around £350. If you want to save some money, Intel's new Core i5-11600K offers a great deal for £259 inc VAT, and still has six cores and decent gaming performance. In short, get what's best for you and your needs, not what the power numbers or fanboys say. CPC

The Core i9-10850K shouldn't be discounted just because it's made on a 14nm process

Antony Leather is Custom PC's modding editor @antonyleather

How to Etch glass side panels

Antony Leather shows you how to etch designs into your case's tempered glass panels

TOTAL PROJECT TIME / 2 HOURS

When it comes to customising glass portions of your PC, etching is the easiest and safest way to do it. Tempered glass will shatter if you mess around with it too much, and it does so by design, leaving you with few options when it comes to customising glass side panels. Etching, though, is easy, perfectly safe, generates next to no mess and you can do it practically anywhere.

However, it's important that you get it right the first time. Masking off areas is easy enough, especially if you use a cutting machine. However, etching is permanent and can't be reversed, even with copious amounts of polishing, so you need to be very sure before you apply the etching cream. The end result can look fantastic, though, and it's a great way to add a professional-looking design to your case.

TOOLS YOU'LL NEED

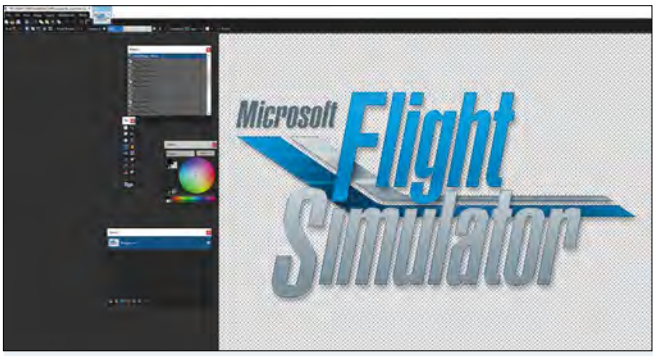
Clear transfer / application tape
yolo.co.uk

Adhesive vinyl sheet
yolo.co.uk

Paint brush
Most hardware stores

Cutting machine or scalpel
yolo.co.uk

Armour Etch cream
fredaldous.co.uk



1 / DECIDE ON YOUR DESIGN

Creating an etching mask is tricky if you're doing it by hand, in which case we recommend stocking to a simple design – otherwise it could take you days to cut out the masking.

2 / WASH THE PANEL

To ensure the etching cream can work on the glass properly, it's important to wash the panel first. This ensures there's no grease or grime on the surface that could prevent the cream from making proper contact.

3 / CUT OUT MASKING

We've used a Silhouette Cameo Portrait cutting machine to cut out our masking on adhesive vinyl film sheet, but you can also use carbon copy paper to trace a design onto adhesive film by hand, and then use a scalpel to cut out your design more accurately.

4 / TRANSFER TO PANEL

Once you've cut out your design, transfer the adhesive film to the chosen area on your PC, taking care not to damage it. If you have a particularly intricate design, you may want to use transfer paper to lift the masking off the backing sheet in order to transfer it.

5 / INSERT THE DETAILS

Some designs will have sections that end up being separated from the main part as they've been cut out, such as holes in the middle of letters. Lift these using a scalpel or plastic pick, then place them into position within your mask. Again, transfer paper could help here, enabling you to lift the whole design in one go.

6 / REMOVE AIR BUBBLES

Occasionally, placing the masking can result in visible air bubbles being trapped underneath it, especially in larger areas. You can use a bank card or a similar piece of flat, flexible plastic to work out the bubbles, lifting the film if necessary.

7 / APPLY ETCHING CREAM

Once your masking is complete, apply the etching cream (we've used Armour Etch) using a brush. Apply it liberally, but don't press too hard, as there's no need to work it into the surface. Wipe off any drips and remove any cream that's been accidentally applied outside the masking area immediately.

8 / CLEAN PANEL

Follow the instructions for your cream regarding the length of time it needs to stay on the glass. This is usually only a minute or two at most. Once that time is up, put on some protective gloves and rinse the panel under warm water to remove the cream.

9 / ALLOW TO DRY

You can now remove the masking. Clean the area to remove any sticky residue from the masking. The etching is quite durable, but avoid getting any coloured water-cooling coolants near it, as it can stain in the right conditions.

How to Engrave your case

Antony Leather shows you how to use a Dremel to engrave designs on your case's side panels

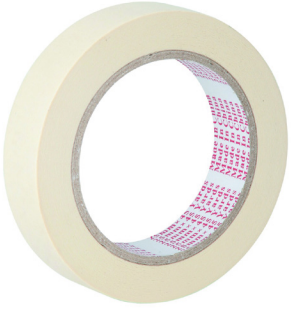
TOTAL PROJECT TIME / 3 HOURS

Engraving requires a steady hand, patience and a good grasp of the design you want to create, but it also offers a relatively easy, cheap and mess-free way to customise your PC case. You don't have to deal with any paint fumes, and it's generally a fairly quiet activity too, so it's unlikely to annoy any fellow housemates, especially if you can allocate a room to yourself for a few hours.

You can engrave several materials found in PC cases, including steel, aluminium and acrylic. However, we suggest using our etching guide this month (see p102) if you want to deal with glass. To get started, you'll need a rotary engraving tool with engraving attachments. A Dremel is ideal, especially if you have the extension shaft tool, but there are cheaper engraving-specific tools out there too. You can trace and engrave nearly any design you want, and in this guide we'll talk you through the best ways to do it.

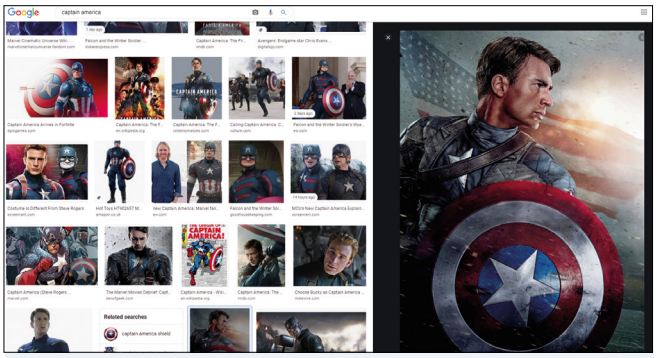
TOOLS YOU'LL NEED

Dremel or other rotary tool and engraving tips
amazon.co.uk



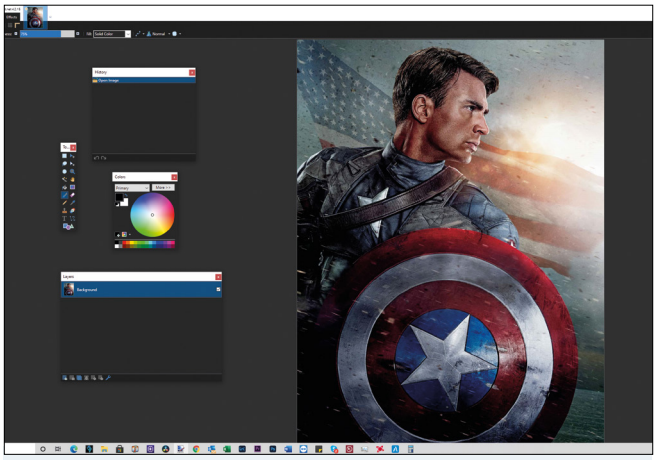
Masking tape or Frog tape
Most hardware stores

Carbon copy paper
ebay.co.uk



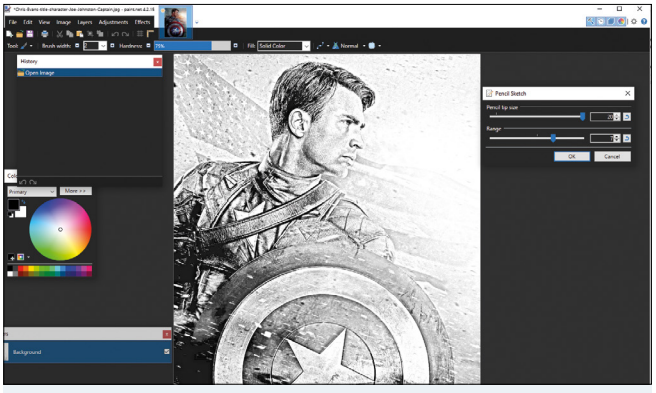
1 / DECIDE ON YOUR DESIGN

Nearly any design can be engraved, but it's best to make your work as easy as possible, so avoid highly intricate patterns, as they can dramatically increase the time and complexity of the engraving process.



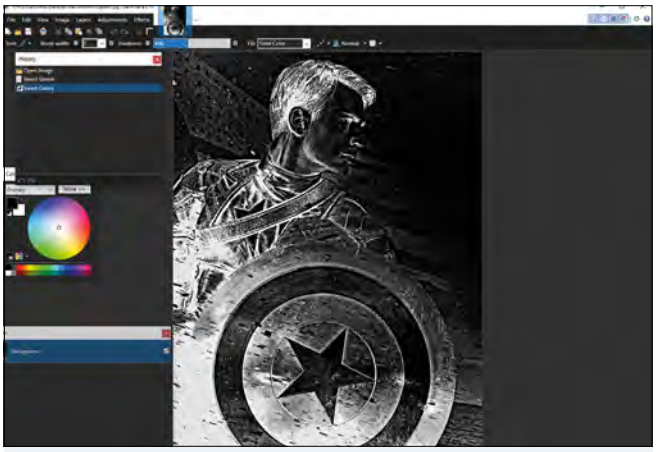
2 / DOWNLOAD PAINT.NET

We'll be sketching over the design using a print-out as a template, and you may find it easier to convert the image to a basic sketch so that the key elements are easier to trace. Start by downloading Paint.net (**getpaint.net**), which is a free image-editing program.



3 / USE PENCIL SKETCH

Once you've selected the design you want to engrave, import the image file into Paint.net, head to Effects, then Artistic and select Pencil Sketch. This will highlight the main details of the image, giving you better contrast on the parts you want to engrave.

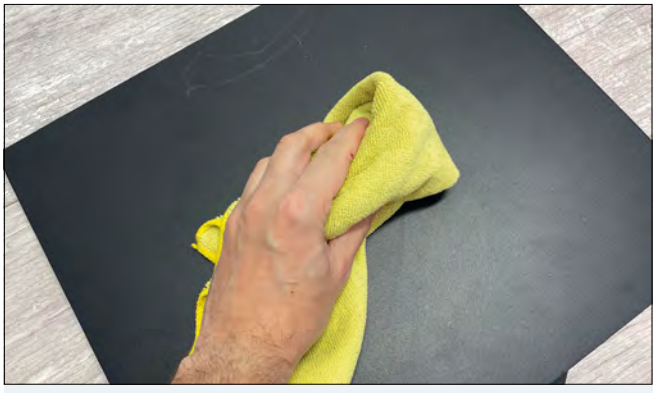


4 / INVERT THE COLOURS

A handy trick to get an idea of which parts of your design will look better engraved is to invert the colours under the Adjustments menu. This will turn the outlines white, which will make your design look similar to an engraved black case panel.

5 / USE CARBON COPY PAPER

Once you've printed out your design, tape it to a sheet of carbon copy paper with the transfer side facing down.

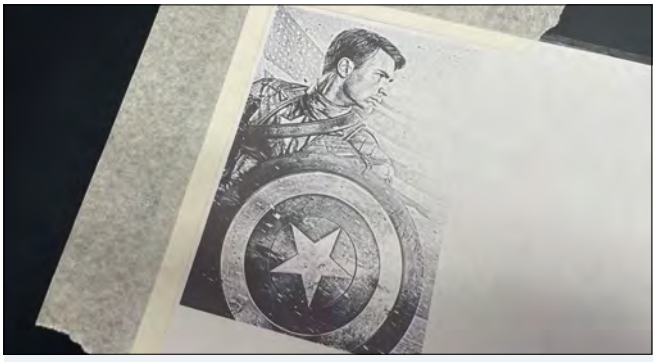


6 / CLEAN THE SURFACE

It's important to clean the side panel that you want to engrave, so the carbon paper residue can adhere to it, allowing you to see all your tracing lines. Use warm soapy water to remove any grime and a clean cloth to dry it.

7 / PRACTISE FIRST

Using the right pressure and writing instruments is key to transferring the design with the carbon copy paper – we suggest using a ballpoint pen or a semi-blunt pencil with a large nib. Use a small section of the carbon copy paper along with your printer paper to test your technique and find out how much pressure you need to use.

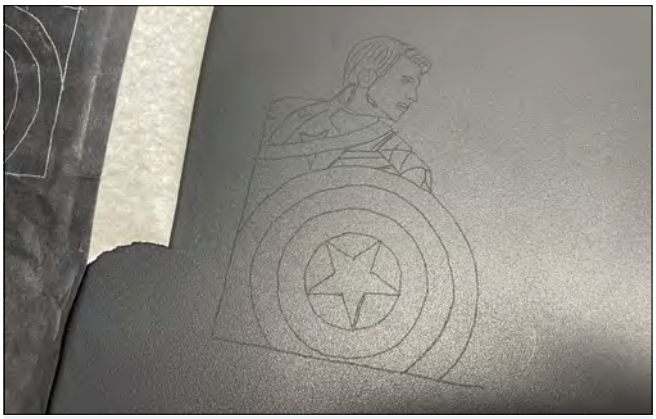


8 / SECURE TO ENGRAVING SURFACE

Use masking tape or Frog tape to secure the carbon copy paper and design print-out onto your chosen surface. Don't use Sellotape or duct tape, as they can leave behind sticky residues that you'll need to clean off afterwards.

9 / DRAW ON DESIGN

Start by drawing over your design with your instrument, pressing as firmly as necessary from the practice session. For larger areas, simply roughly shade in the space to mark them as places that require a full-area engrave.



10 / REMOVE PAPER

Carefully lift away the papers once you're done with the design. The carbon transfer is quite delicate, so be careful not to rub it with your hands. If necessary, you can go over the design with a marker pen, drawing only on areas you'll engrave.

11 / KNOW YOUR BITS

Selections of engraving tips for rotary tools are inexpensive and often available in sets. Point-tip bits should be used for outlines and shading small areas, while round-tip ones should be used for shading larger areas. You may need to alternate tips, depending on the paint thickness on your case's panels.

12 / PRACTISE ON HIDDEN SECTION

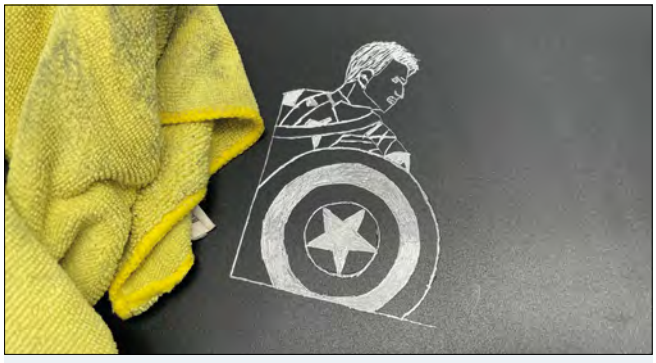
Wear a mask and goggles when engraving, and test each tip. Do this on a hidden part of your case, such as the inside of a side panel or a spare drive bay that has the same coating as your target panel. You can then identify the bits that work best with your material and get used to the rotary tool.

13 / ENGRAVE OUTLINES

Using a medium speed setting, trace the outlines of the design, first using sweeping motions and holding the tip at an angle, so it's not pointing straight down. Go over the areas a second time if necessary.

14 / FILL IN AREAS

Switch to a rounded tip for larger areas, and take care not to press too hard. It's better to go over each area two or three times with lighter pressures, as this will result in a more even surface than pressing too hard at the start.



15 / CLEAN PANEL

The engraving will create dust, but it should settle locally and it's easy to clean away. Use a damp cloth to clean your engraving area. Removing the dust may reveal parts that need finishing, so don't be afraid to fire up your rotary tool again. CPC

Folding@home

Join our folding team and help medical research

ACTIVE USER MILESTONES

USERNAME	POINTS MILESTONE
Desertbaker	4,000,000,000
car1_Garforth	200,000,000
Little_Willie	500,000,000
SP1	400,000,000
Simlec	400,000,000
C2TBD	200,000,000
Count_Stex	100,000,000
filreed	100,000,000
Jon_Simmo	90,000,000
YCDCN22	80,000,000
Haphestus	50,000,000
CheeZee73	40,000,000
AlSomething	40,000,000
crazystuntman	20,000,000
knobtasticus	20,000,000
Daniel_Selley	20,000,000
JasperofBelper	7,000,000
Bluehubble	6,000,000
PendragonOrion_ALL_1Gpy...	5,000,000

USERNAME	POINTS MILESTONE
StoneColdJay	4,000,000
Bazil	3,000,000
Wickermonkey	3,000,000
yonedafolding	2,000,000
mhfz48	1,000,000
Andy__k	1,000,000
JackDK	1,000,000
PatWI	500,000
iamannie	500,000
dhhowells	400,000
Mister_M	300,000
hamki	200,000
AspIT	100,000
souper82	100,000
capt_carl	80,000
giobusca	40,000

WHAT IS FOLDING?

Folding@home uses the spare CPU and GPU cycles for medical research, with a current focus on COVID-19. You can get the client from **foldingathome.org/start-folding** and our team's ID is 35947. Once you pass a significant milestone, you'll get your name in the mag – we'll print all the milestones we can fit on the page. You can discuss folding with us and other readers online at the bit-tech forums (**custompc.co.uk/FoldingForum**).

TOP 20 PRODUCERS

RANK	USERNAME	DAILY POINTS AVERAGE	OVERALL SCORE
1	DocJonz	15,487,688	15,618,801,467
2	Desertbaker	8,542,192	4,244,175,102
3	Lordsoth	6,309,755	5,687,277,294
4	C2TBD	5,344,698	222,911,861
5	Slavcho	4,466,889	4,204,646,479
6	PC_Rich	3,467,350	6,780,154,090
7	madmatt1980	1,690,017	1,042,301,763
8	KevinWright	1,580,182	1,488,992,618
9	kcanti	1,525,208	1,130,162,727
10	Little_Willie	1,436,680	535,129,364
11	1car1_Garforth	1,312,531	210,097,250
12	peete	1,289,116	186,024,795
13	gKitchen	1,243,364	280,556,871
14	coolamasta	855,103	1,092,386,937
15	Dickie	836,916	1,271,873,313
16	filreed	797,459	112,081,852
17	dis80786	688,203	154,395,832
18	Simlec	655,925	401,389,860
19	mort6dav3	613,074	181,719,252
20	Count_Stex	577,168	110,238,191

TOP 15 OVERALL

RANK	USERNAME	POINTS	WORK UNITS
1	DocJonz	15,618,801,467	347,951
2	PC_Rich	6,780,154,090	166,221
3	Lordsoth	5,687,277,294	183,075
4	Shirty	5,266,143,058	39,848
5	Nelio	4,638,586,520	523,610
6	Desertbaker	4,244,175,102	72,572
7	Slavcho	4,204,646,479	75,008
8	HHComputers	3,544,050,839	85,007
9	Dave_Goodchild	3,099,093,357	160,891
10	piers_newbold	2,703,256,197	107,638
11	Scorpuk	2,565,487,007	57,788
12	clanseven	2,223,720,446	33,156
13	tarka_dahl	1,844,501,445	26,278
14	Unicorn	1,753,462,654	57,079
15	daxchaos	1,637,104,710	41,302

Retro tech

EGA

Stuart Andrews recalls how 16 colours changed the PC world

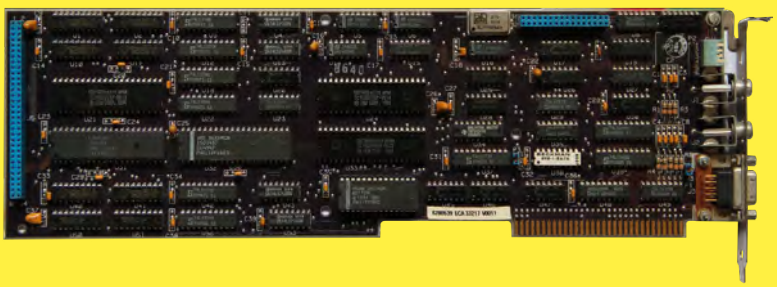
Pity the poor PC of 1983-1984. It wasn't the graphics powerhouse we know today. IBM's machines and their clones might have been the talk of the business world, but they were stuck with text-only displays or low-definition bitmap graphics. The maximum colour graphics resolution was 320 x 200, with colours limited to four from a hard-wired palette of 16. Worse, three of those colours were cyan, brown and magenta, and half of them were just lighter variations of the other half.

By this point, IBM's Color Graphics Adaptor (CGA) standard was looking embarrassing. Even home computers such as the Commodore 64 could display 16-colour graphics, and Apple was about to launch the Apple IIc, which could hit 560 x 192 with 16 colours. IBM had introduced the Monochrome Display Adaptor (MDA) standard, but this couldn't dish out more pixels, only higher-resolution mono text.

Meanwhile, add-in-cards, such as the Hercules or Plantronics Colorplus, introduced higher resolutions, but did nothing for colour depth. The PC needed more, which IBM delivered with its updated 286 PC/AT system and the Enhanced Graphics Adaptor (EGA).

THE NEW STATE OF THE ART

The original Enhanced Graphics Adaptor was a hefty optional add-in-card for the IBM PC/AT, using the standard 8-bit ISA bus and with support built into the new model's motherboard. Previous IBM PCs required a ROM upgrade in order to support it.



The original IBM EGA card was a whopper, even without the additional daughtercard and memory module kit. Credit: Vlask, CC BY-SA 3.0

Using Chips and Technologies' EGA chipset, early graphics card manufacturers such as ATi could produce smaller, cheaper boards. Credit: Vlask, CC BY-SA 3.0

It was massive, measuring over 13in long and containing dozens of specialist large scale integration (LSI chips), memory controllers, memory chips and crystal timers to keep it all running in sync. It came with 64KB of RAM on-board but could be upgraded through a Graphics Memory Expansion Card and an additional Memory Module Kit to up to 192KB. Crucially, these first EGA cards were designed to work with IBM's 5154 Enhanced Color Display Monitor, while still being compatible with existing CGA and MDA displays. IBM managed this by using the same 9-pin D-Sub connector, and by fitting four DIP switches to the back of the card to select your monitor type.

EGA was a significant upgrade from low-res, four-colour CGA. With EGA, you could go up to 640 x 200 or even (gasp) 640 x 350. You could have 16 colours on the screen at once from a palette of 64. Where once even owners of 8-bit home computers would have laughed at the PC's graphics capabilities, EGA and the 286 processor put the PC/AT back in the game.

BIRTH OF AN INDUSTRY

However, EGA had one big problem; it was prohibitively expensive, even in an era when PCs were already astronomically expensive. The basic card cost over $500 US, and the Memory Expansion Card a further $199. Go for the full 192KB of RAM and you were looking at a total of nearly $1,000 (approximately £2,600 inc VAT in today's money), making the EGA card the RTX 3090 of its day, and only slightly more readily available. What's more, the monitor you needed to make the most of it cost a further $850 US. EGA was a rich enthusiast's toy.

However, while the initial card was big and hideously complex, the basic design and all the tricky I/O stuff were relatively easy to work out. Within a year, a smaller company, Chips and Technologies of Milpitas, California, had designed an EGA-compatible graphics chipset. It consolidated and shrunk IBM's extensive line-up of chips into a smaller number, which could fit on a smaller, cheaper board. The first C&T chipset launched in September 1985, and within a further two months, half a dozen companies had introduced EGA-compatible cards.

Other chip manufacturers developed their own clone chipsets and add-in-cards too, and by 1986, over two dozen manufacturers were selling EGA clone cards, claiming over 40 per cent of the early graphics add-in-card market. One, Array Technology Inc, would become better known as ATI, and later swallowed up by AMD. If you're on the red team in the ongoing GPU war, that story starts here.

CHANGING GAMES

EGA also had a profound impact on PC gaming. Of course, there were PC games before EGA, but many were text-based or built to work around the severe limitations of CGA. With EGA, there was scope to create striking and even beautiful PC games.

This didn't happen overnight. The cost of 286 PCs, EGA cards and monitors meant that it was 1987 before EGA support became common, and 1990 before it hit its stride. Yet EGA helped to spur on the rise and development of the PC RPG, including the legendary SSI 'Gold Box' series of Advanced Dungeons and Dragons titles, Wizardry VI: Bane of the Cosmic Forge, Might and Magic II and Ultima II to Ultima V.

It also powered a new wave of better-looking graphical adventures, such as Roberta Williams' Kings Quest II and III, plus The Colonel's Bequest. EGA helped LucasArts to bring us pioneering point-and-click classics such as Maniac Mansion and Loom in 16 colours. And while most games stuck to a 320 x 200 resolution, some, such as SimCity, would make the most of the higher 640 x 350 option.

With EGA, there was scope to create striking and even beautiful PC games

What's more, EGA made real action games on the PC a realistic proposition. The likes of the Commander Keen games proved the PC could run scrolling 2D platformers properly. You could port over Apple II games such as Prince of Persia, and they wouldn't be a hideous, four-colour mess.

And when the coder behind Commander Keen – a certain John Carmack – started work on a new 3D sequel to the Catacomb series of dungeon crawlers, he created something genuinely transformative. Catacomb 3-D and Catacomb: Abyss gave Carmack his first crack at a texture-mapped 3D engine, and arguably started the FPS genre.

Sure, EGA had its limitations – looking back, there's an awful lot of green and purple – but with care and creativity, an artist could do a lot with 16 colours and begin creating more immersive game worlds.

A SLOW DECLINE

EGA's time at the top of the graphics tech tree was short. Home computers kept evolving, and in 1985, Commodore launched the Amiga, supporting 64 colours in games and up to 4,096 in its special HAM mode. Even as it launched EGA, IBM was talking about a new, high-end board, the Professional Graphics Controller (PGC), which could run screens at 640 x 480 with 256 colours from a total of 4,096.

PGC was priced high and aimed at the professional CAD market, but it helped to pave the way for the later VGA standard, introduced with the IBM PS/2 in 1987. VGA supported the same maximum resolution and up to 256 colours at 320 x 200. This turned out to be exactly what was needed for a new generation of operating systems, applications and PC games.

What extended EGA's lifespan was the fact that VGA remained expensive until the early 1990s, while EGA had developed a reasonable install base. Even once VGA hit the mainstream, many games remained playable in slightly gruesome 16-colour EGA. Much like the 286 processor and the Ad-Lib sound card, EGA came before the golden age of PC gaming, but this standard paved the way for the good stuff that came next. CPC

Forgive the blocky pixels and 16-colour palette. In Catacombs 3-D and Catacombs: Abyss lay the seeds of Wolfenstein and Doom

Readers' drives

Oazis ROG Monitor PC

Blasphemy or brilliance? János Kerekes takes a Dremel to an old grey Sony Trinitron CRT monitor in order to create this unique water-cooled PC

/MEET THY MAKER

Name János Kerekes

Age 55

Occupation Construction company site manager

Location Hungary

Main uses for PC Due to the design it's on display in an exhibition room

Likes Watching movies with the family and the popcorn of course

Dislikes If something happens differently from the original plan

CPC: How did this project start? What inspired you to build a PC inside a CRT monitor shell, and where did the name come from?
János: One of my best friends asked for it. His company sells monitors and he wanted a special computer. The name was the company's idea.

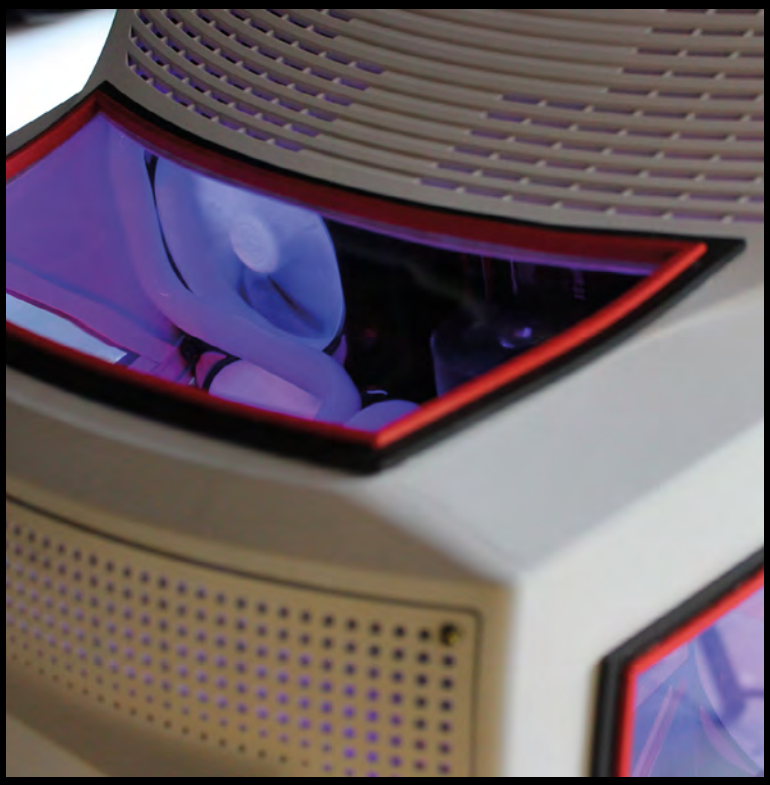
CPC: Why did you pick that particular Sony Trinitron monitor for this project, and why has it been rebranded Asus?
János: The CRT monitor was provided by the customer, just like the hardware that was built into it. All the hardware was made by Asus, so that's the reason why it has been rebranded.

CPC: How hard was it to gut the insides out of the monitor, and how did you go about dismantling it?
János: At first it gave me a huge headache, as this monitor weighs approximately 50kg. In addition, Sony has taken care to assemble this monitor as precisely as possible, using all the available space. A lot of care and a little bit of brute force were required.

CPC: We love the neat and tidy front I/O panel with the USB ports, power button and so on. How did you go about doing this?
János: The monitor already had USB ports, but because I was building a PC inside the monitor, I had to construct a completely new I/O panel. For this, I used a 5.25in-wide I/O panel from a previous PC. It was almost the same size as the gap, so I just had to make a few small changes.

CPC: How did you make the rotating bit on the stand glow like that?
János: My idea was to make the structure of the monitor look better, so I cut a plexiglass sheet to the same size and shape as the bottom of the monitor. Then I placed LEDs in it and connected it to the original power button. Because the monitor stand can rotate, it was particularly tricky to manage the routing of all the cables through the case.

CPC: Take us through the process of modifying the Sony Trinitron monitor shell in order to mount a PC inside it.
János: It took days to find the appropriate layout, as I had to consider the features of the monitor shell and the fixing points that I had available. I didn't want to create visible fixings, so I had to make custom mounts for all



The glass of the ray tube makes it heavy at the front, and when the tube is removed, it hugely alters the balance

the hardware and water-cooling components. On the monitor, there was a part covered with plastic sheet, which I've used to hide the necessary screw connections.

CPC: How did you make the custom metal frame parts, such as the radiator and PSU mounts?
János: For the motherboard, radiators and PSU I used aluminium sheets, which I cut and filed to the right shape, then I fixed them to the case. I had to think a lot about the design of the original CRT monitor and its weight distribution.

The glass of the ray tube makes it heavy at the front, and when the tube is removed, it hugely alters the balance of the screen's chassis. I couldn't just install all the components towards the back of the monitor shell, as this would end up tipping the screen.

CPC: Those are some really tidy blowholes – how did you make them so neat?
János: To make the blowholes, I marked the openings for the 120mm fan on the top of the monitor shell, and then I cut them with a rotary multitool. The fans were then cut from their surrounds and fixed in place with silicon glue.

CPC: Why did you paint the monitor white, and how did you go about painting it?
János: I painted it white at the customer's request – he wanted to make the PC white instead of the factory grey of the original Sony Trinitron monitor.

To achieve a smooth finish, I had to sand the whole shell and I then painted it with several layers of special plastic paint, using an airbrush.

SYSTEM SPECS

CPU Intel Core i7-6700K

Case Sony GDM-FW900

Graphics card Asus R9 Nano

Storage 240GB Samsung SSD

Memory 32GB G.Skill Trident Z Neo

Memory Kingston 16GB (2 x 8GB) HyperX Predator DDR4 2666MHz

Motherboard Asus Maximus VIII Impact

PSU BitFenix Fury Gold 750W

Cooling EK-FB Asus M8i monoblock, EK-FC R9 Nano , EK-XRES 100 DDC 3.2 pump res combo, EK-CoolStream PE 240, EK hard tubing, EK hard tubing fittings

CPC: How did you create the windows and the red/black accents?

János: The original case didn't have any clear sections or openings that allowed you to see the insides, so I made a few openings that I filled with clear plexiglass, so you could get a better view.

The two side windows weren't that hard to make because they were simple, flat shapes. However, the top part was curved from the front to the back, and from left to right, so I had to use a heat gun to gently bend it into shape. It took three hours to get it right. To finish off the look and introduce the Asus ROG colour scheme, I cut some black and red foam PVC sheeting into strips and used them to line the edges of the windows.

CPC: Mounting a new LCD panel inside the monitor must have been hard work – what monitor did you use and how did you go about fitting it into the CRT shell?

János: All the hardware came from Asus, including the monitor, so we chose to use the PB248Q, which is a 24in display with an IPS LCD panel. The original frame for the LCD monitor had to be removed so that the panel would sit flush with the CRT monitor's frame. The hole in the CRT frame also had to be enlarged. The panel was then secured in place by tapping some of the plastic parts of the original frame and using bolts with large flat heads to hold the back of the panel. I also cut away the on-screen menu controls and mounted them on the little cylindrical section on the Sony monitor that held its on-screen controls.

CPC: What components did you choose for this build, and why? Did you make the lettering on the water-cooled Radeon Nano waterblock yourself?

János: Because of the small amount of space inside the monitor, I had to use only mini-ITX parts, so that what was part of the reason I chose the Nano card. Another consideration here was that the appropriate water-cooling blocks for the motherboard and graphics card were available from EKWB. I made the backplate and lettering for the graphics card, with the letters being made from the same foam PVC material as the window surrounds.

CPC: There are a lot of tight bends in the hard tubing – what's your process for measuring, cutting and bending your tubing?

János: I care a lot about design, which is why I chose to use hard tubing. My plan was to create a harmonious arrangement between the tubes and the hardware, rather than just adding the tubing as an afterthought. This added work but I had a lot of experience from my previous builds and the right tools for the job, including a homemade bending template.

The original rotary switch on the Sony monitor's control panel turns on power to both the PC and the Asus monitor

CPC: How is the monitor wired up so that it powers on with the display, and where does it get its display input?
János: It was important to include two different power supplies inside the case, neither of which is visible from the outside. I had to build an external disconnect switch into the PC to introduce the mains power, then split that to the PC and monitor. I utilised the original rotary switch on the Sony monitor's control panel to turn on power to both the PC and the Asus monitor. The monitor connects to the video card through the DisplayPort input, which is reachable via a hole in the back of the CRT monitor.

CPC: Did you come across any difficulties, and how did you solve them?
János: Maybe the biggest challenge was integrating the Asus monitor's control panel within the Sony monitor's cylindrical control panel. It was a very tight fit and I wanted to retain the original power switch function of the Sony monitor, so it was very fiddly.

CPC: How long did it take you to complete this build, from start to finish?
János: I was working on this project for a month with no days off.

CPC: Are you completely happy with the end result, or do you wish you'd done some of it differently in retrospect?
János: I can never say I'm completely satisfied with any work that I've done. I always find there's a detail that I could have made in a different way, and that's true of some parts of this build. However, it's all part of the fun of modding, and mistakes lead us to improve our knowledge and experience for the next time. CPC

WIN CORSAIR HYDRO X WATER-COOLING GEAR

To enter your rig for possible inclusion in Readers' Drives, your build needs to be fully working and, ideally, based in the UK. Simply send us a couple of photos on Twitter (@**CustomPCMag**) or Facebook (**CPCMagazine**), or email low-res ones to **ben.hardwidge@raspberrypi.com**. Fame isn't the only prize; you'll also get your hands on some fabulous prizes, courtesy of Corsair.

Corsair Hydro X Series XD3 RGB Pump/Reservoir C

WORTH £151

The Corsair Hydro X Series XD3 RGB Pump/Reservoir Combo features a high-performance DDC PWM pump, integrated RGB lighting and in-loop temperature sensor to drive even the most compact custom cooling systems. It has a high-performance Xylem DDC PWM pump controlled via PWM to deliver the perfect flow balance for your loop. There are also 16 individually addressable RGB LEDs, which light up the pump head to produce stunning, customisable lighting effects to match your build.

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 the AM4/LGA1151 or LGA2066 version.

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

CAN INTEL REMAIN RELEVANT?

James Gorbold dissects Intel's recent strategic announcements, including a commitment to increasing manufacturing capacity

While there's not a huge amount happening in terms of consumer technology at the moment, there's an awful lot happening behind the scenes in boardrooms and in the enterprise space, which is likely to have major ramifications for the PC industry as a whole.

One significant change is the start of the reign of new Intel CEO Pat Gelsinger. Hosting his first online keynote, he laid out his vision for Intel over the coming years. There were no were no product announcements, as it takes years not months to develop new integrated circuits (ICs). What was announced, however, showed real ambition to take Intel forwards after the short-term stewardship of Intel's previous CEO Bob Swan.

The most significant announcement is a renewed focus on manufacturing, previously one of Intel's crown jewels, but an area that has recently suffered from process development and yield issues, especially the transition to 10nm, which is multiple years behind schedule. Intel's new strategy is to sink money into manufacturing, with two new fabrication plants, costed at a cool $20 billion US, with construction in Arizona planned for later this year.

> The transition to 10nm is multiple years behind schedule

While it will be several years before these few fabs start producing wafers, when they do come online, the increased capacity will be highly beneficial. No doubt the recently announced financial incentives being handed out by the Biden administration to encourage manufacturing investment in the USA also had a role to play here.

What's more, if Intel is truly serious about entering the graphics market, it will need more manufacturing capacity than ever before. Just look at the current GPU shortage to see the trouble created when you under-forecast demand.

Speaking of GPUs, Intel says it's going to increase the number of products built by third-party fabs as well. Intel already outsources the manufacturing of a lot of tier two ICs, such as chipsets and networking products, but the new strategy expands this third-party manufacturing approach to core products from both the client and data centre divisions.

Intel isn't operating in a vacuum, however, with many challenges and challengers still to be overcome. Just a few days after Gelsinger's keynote, Intel launched its latest generation of 3rd-gen Xeon Scalable processors. Aimed squarely at the server market, these aren't the sort of CPUs that normally get more than a passing mention in **Custom PC**, but as Intel's first 10nm processors outside of a handful of Ultrabooks, they represent a significant milestone.

The headline specs, such as an increased core count from 28 to 40, support for PCI-E 4 and a new 8-channel memory controller, would have made this CPU range a real game changer if these processors had launched last summer as planned. However, in spring 2021, they struggle to keep up with AMD's 3rd-gen EPYC processors.

What's worse, with the need for a new socket, the new 3rd-gen Xeon Scalable CPUs aren't backwards compatible with existing 1st and 2nd-gen Xeon Scalable servers. And while Intel has struggled to get any new CPUs out on schedule in recent years, these new Xeons probably won't be around for long either, with Intel's Sapphire Rapids CPUs due to launch later this year with far more on-paper appeal in the form of PCI-E 5 and DDR5. What's more, Nvidia has also announced that it will soon have a new tool, its Grace CPUs, to go after Intel in the lucrative data centre market. 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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