

RGB MEMORY WE TEST 9 OF THE LATEST RAM KITS

# CUSTOM PC

THE BEST-SELLING MAG FOR PC HARDWARE, OVERCLOCKING, GAMING & MODDING / ISSUE 199

## GRAPHICS CARDS

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**11**  
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# Welcome

Custom PC Issue 199

/ FROM THE EDITOR

## Graphic content

**M**aking sense of the current sub-£350 graphics card market is a bit like trying to unravel an intricate logic puzzle. It's only been nine months since we last took a snapshot of this part of the market, and since then we've seen seven new GPUs introduced, as well as several older models disappearing from the shelves.

Add in a veritable Alphabet spaghetti of different suffixes and model numbers, and it becomes hard to make a buying decision. What's the difference between a GeForce GTX 1660 and a 1660 Super or 1660 Ti? Can you really run ray tracing on a £250 graphics card? Does a last-gen Radeon RX 590 with a price drop offer better value than a current-gen GPU at the same price?

In order to make sense of it all and answer these questions, we've dived headfirst into the sub-£350 graphics card pool, and tested 11 GPUs in the £150-£350 price bracket (see p40). It goes all the way from the GeForce GTX 1650 Super to the Radeon RX 5700 XT, and pretty much every GPU we could find in between.

What's more, we've also updated our test suite, adding a new Red Dead Redemption 2 benchmark, and changing the way we calculate the minimum frame rate to make it more realistic. In addition, we've tested ray tracing across every GPU that supports it, with and without DLSS, so you can see if there's any real benefit to buying an RTX GPU.

There are some surprises along the way, including new GPUs that struggle, and previous award winners that have already been beaten by newer models, but we've pulled it all apart and made recommendations for several budgets, depending on your priorities. If you're considering a graphics upgrade, but don't know where to start, then this is the issue for you.

It's not all about graphics cards this month, of course. Other highlights include our in-depth guide to airflow on p82. If you're into water cooling, I also recommend reading through Customised PC (see p112), where Antony Leather explains why it's better to set your fans and pump to respond to coolant temperature, rather than your CPU temperature. He also shows you how to do it on p106. **GPS**



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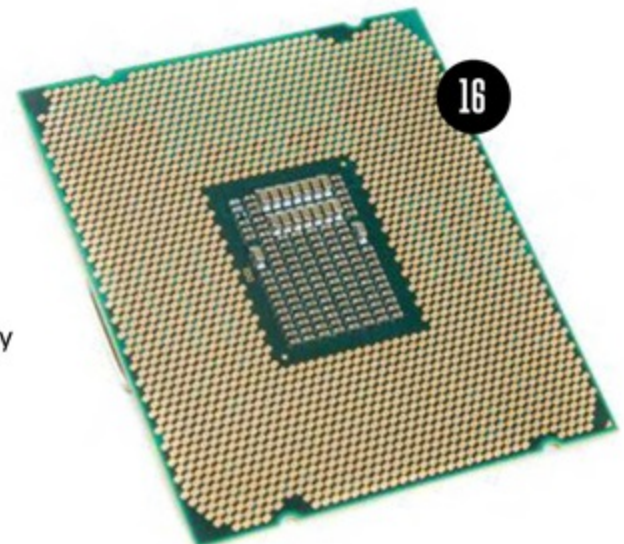
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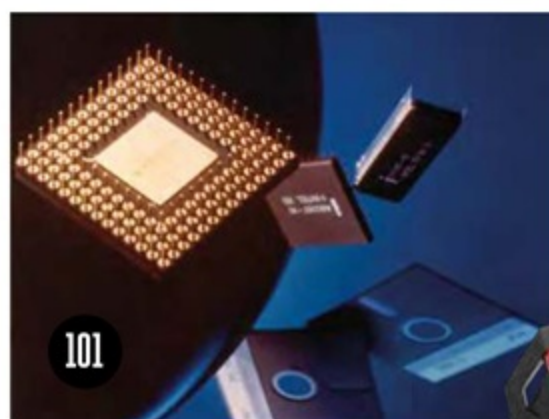
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2TB Seagate SATA-III HDD  
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Cooler Master Master Liquid Lite 120 Cooling System  
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HD 7.1



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RICHARD SWINBURNE / VIEW FROM TAIWAN

# POWERFUL CHANGES

Say goodbye to 3.3V and 5V on your PSU. Richard Swinburne explores the new ATX12VO specification

I've made some calls and I can exclusively confirm for Custom PC that the biggest change to PC power supply design since 1995 – Intel's new 'ATX12VO' platform – will launch this year. However, it will only be exclusive to commercial system builders at the beginning. The new ATX12VO (the 'O' stands for 'only') platform completely redesigns PC power as we know it. Intel has removed the 3.3V and 5V rails, so the PSU will only provide 12V power to the motherboard, graphics cards, storage or other internal peripherals.

Meanwhile, the 24-pin ATX socket is being replaced by a new 10-pin connector, and the EPS connector that goes near the CPU socket will only be optional. Even the 5VSB (standby) rail, used by devices such as USB peripherals in order to remain powered, will be replaced with 12VSB (although the USB output will remain at 5V). Instead, the motherboard will handle all voltage conversions from 12V down to lower voltages. For SATA-powered kit, such as SSDs, hard drives and optical drives, which need a 5V input, the power will now be drawn from the motherboard, which will have a side-mounted SATA power connector near the SATA data ports.

The reason why this new platform is currently only for commercial system builders is because the changes require new PCs to commit to either ATX or ATX12VO with multiple components. Instead of trying to manage multiple parallel products for ATX or ATX12VO, it's easier for motherboard companies to commit to big orders for one product, rather than the dozens of models needed for the DIY retail channel. No doubt Intel remembers the BTX debacle, and it won't be keen to make that same mistake.

Intel has removed the 3.3V and 5V rails, so the PSU will only provide 12V power

We saw two big changes to PC PSUs in the mid-to-late 2000s. Firstly, the 80 Plus initiative was extremely successful at improving efficiency. Secondly, PSUs started to mainly focus on only AC-to-12VDC conversion, then converting 12V to 5V and 3.3V, as the latter are minor rails. ATX12VO basically removes this latter stage from the PSU completely, letting the motherboard handle voltage conversion (which it can already do anyway). The end result is an improvement in overall platform efficiency, while reducing the net cost. This cost advantage is likely minimal for a DIY PC builder, but it will soon add up for system builders shipping thousands of PCs.

Of course, this shift to a new PSU standard won't be entirely smooth for DIY builders such as ourselves. While some modular PSUs could simply be upgraded with a new 10-pin cable, it's likely that not all models will have such cables available, and PSU companies won't want to be lumbered with the cost of validating these cables. There's also plenty of old SATA drives still in use that need 3.3V, but it won't be clear which ones. It's possible to overcome these problems with adaptors or new cables, but these add more layers of complexity, cost and confusion to upgraders, with only a small savings advantage.

The main advantage for me will be saying goodbye to the incredibly ugly 24-pin ATX cable. With the huge sheets of glass surrounding PC cases now, it will be good to be able to make PCs with cleaner internal cabling. But let's not stop there! The edge-mounted power connectors on graphics cards are also hideous and need to go. Who is with me? For more information, you can study the new ATX12VO specification for yourself at [custompc.co.uk/ATX12VO](http://custompc.co.uk/ATX12VO) **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](https://twitter.com/ricswi)





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TRACY KING / SCEPTICAL ANALYSIS

# AN APPLE GAMES MACHINE?

Rumours about a \$5,000 Apple games machine may not be as far-fetched as you think, reasons Tracy King

**A**pples feature in several fairy tales, from Greek myths to Snow White. They're even called 'forbidden fruit' following the Garden of Eden story and a Latin translation error (the word 'malum' means both apple and evil). The most modern apple-based fairy tale, though, doesn't involve any princesses or dwarves.

There's a rumour, allegedly a leak from Apple's China manufacturers, that the computing behemoth is about to launch a \$5,000 US gaming machine. The industry press has responded with scepticism, not least because this rumour crops up fairly frequently but never bears fruit. But this time, I'm not entirely sure it's seedless.

Apple's origins are via custom PCs and gaming. The two Steves, Jobs and Wozniak, first collaborated on the Atari classic Breakout, after meeting as hobbyists at the Homebrew Computer Club. The Apple I was as far removed from a contemporary Mac as it gets (the Steves even shared the schematics with fellow club members, so they could build and customise their own ones, imagine that). Gaming was built in from the start, with the Apple II incorporating a (crappy) gaming paddle/early joystick.

There are 567 known games for the Apple II, and countless more homemade affairs lost to the bin of floppy disks. That's more than Atari. But over time, the market split between 'work' computers and gaming beasts (hello Commodore, with your 29,000 games), and Apple became Macintosh and then Mac. Today, a Mac is the opposite of a custom PC. A locked-in, out-of-the-box, off-the-shelf computer for those who don't want to tinker. I have no problem with Macs (I use one in my office in my other guise as an animation producer), but I don't play games on it.

Jobs and Wozniak first collaborated on the Atari classic Breakout, after meeting as hobbyists at the Homebrew Computer Club

Some people do though. There are around 7,000 games available for macOS on Steam (more than Linux, but only around a third of Windows). But the cost of a high-end Mac vs a comparable gaming PC means the former isn't good value for money, and I doubt anyone is buying a Mac as first and foremost a gaming machine. It's a bonus that you can game on a Mac but it's not its main value.

Value of any sort isn't Apple's selling point. Everything it makes is sleek, convenient, 'intuitive' and works out of the box with zero tinkering, from the iPhone to the Mac Pro. This is often cited as an argument against Apple entering the gaming machine market, but I see it as a parallel to consoles. With the launch of Apple Arcade, a subscription gaming store that's attracted major developers, Apple has shown it's not afraid to be seen as a gaming company.

To release a high-spec gaming machine, Apple would need the support of major game developers – that's trivial for a big company with Apple's resources.

Developers are already lining up for Apple money – it would only take a couple of decent Apple-exclusive games. With iPhone sales slowing, Apple will be looking for new hardware markets. It's just possible that there are now enough gamers who don't care as much about customisation as they care about the Apple experience. People who own every console and smart gadget, and would consider a gaming Mac a prestigious acquisition.

Gaming is now as mainstream and popular as any other form of entertainment, and it's only going to grow. Maybe it won't be this year, as rumoured, and it might not have a happy ending, but I don't think a gaming Mac is a fairy tale. **GPG**

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

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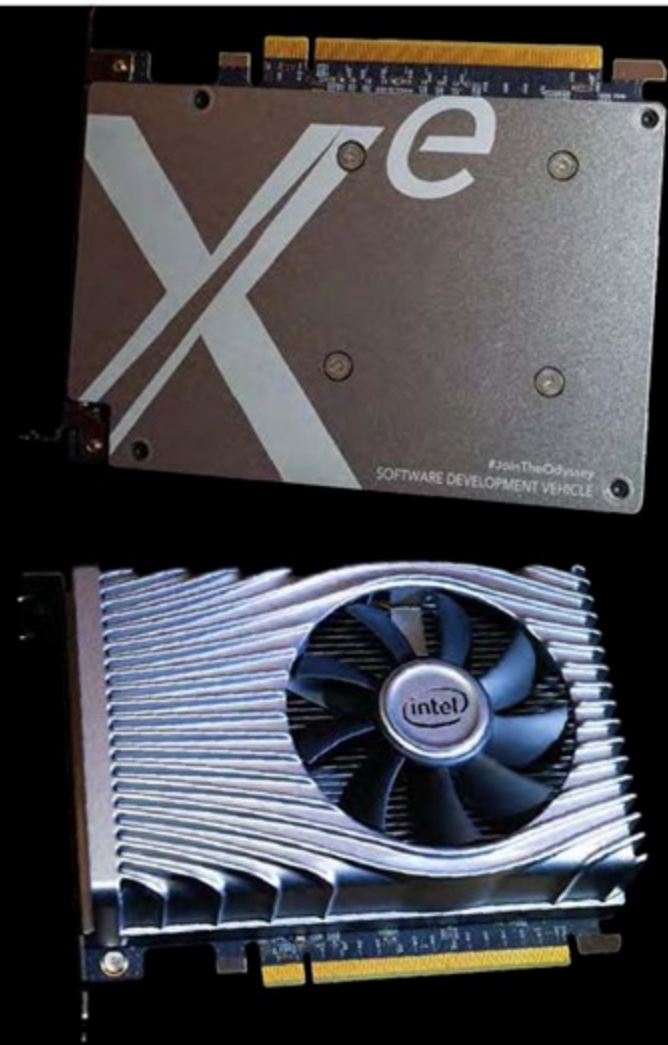


## INTEL UNVEILS GRAPHICS CARD

Intel has finally taken the wraps off its new graphics card, or at least some of the wraps anyway. The Intel Xe DG1 absolutely exists, and it's definitely able to do graphics, but further details are thin on the ground. The prototype card was demonstrated running *Destiny 2* in a live demo at CES 2020, but is currently only intended to be used by software vendors. Intel says it's not necessarily representative of the final product.

Externally, the Intel Xe DG1 is a small card, equipped with RGB lighting, and its cooler has a simple aluminium casing with a single fan, suggesting that it's aimed at the budget end of the graphics card market. Intel hasn't given any solid indication of pricing or release dates either, but the company confirmed that it will be doing a deep dive into its new graphics card architecture at GDC in March this year.

PHIL HARTUP



## 'Big Navi' arriving this year, says AMD CEO

AMD CEO Dr Lisa Su has confirmed that AMD has plans to release a high-end GPU based on its new RDNA architecture this year. Su described the product as 'Big Navi' in an AMD video log at the CES trade show in January.

The first Navi products have been steadily released over the past few months, manufactured on a 7nm process node and competing with Nvidia's budget and mid-

range GPUs. The Navi10 GPU (pictured) has already been used in all the Radeon RX 5700-series GPUs, as well as the Radeon RX 5600 XT.

However, AMD currently doesn't have a competitive product that can go up against Nvidia's top-end GeForce RTX 2080-series GPUs. Perhaps 'Big Navi' will be that product, but if there's no hardware ray-tracing support, it will struggle to compete

with Nvidia's high-end GPUs unless it significantly undercuts them on price.

AMD has already stated that hardware ray-tracing support will be coming in its next generation of RDNA GPUs, but it remains to be seen if that feature will make it into 'Big Navi'. In the meantime, we've tested most of the current line-up of AMD Navi GPUs, from the Radeon RX 5500 XT to the Radeon RX 5700 XT, in our graphics cards Labs on p40.



# Rumour control

PHIL HARTUP'S ROUNDUP OF THE LATEST UNCONFIRMED TECH GOSSIP. TAKE THESE STORIES WITH THE APPROPRIATE PINCH OF SALT

## GEFORCE RTX 3080 SPECS LEAKED?

Leaks and rumours have started to appear about the possible spec for Nvidia's next generation of GPUs, currently codenamed Ampere. The first leak comes from a new Twitter account called **@CorgiKitty**. There's no particular reason to think it's a legitimate leak except that it's relatively consistent with another apparent leak from **news.mydrivers.com**

The two GPUs described by the leaks have the working names of GA104 and GA103; in the context of previous Nvidia GPUs, we assume these will form the basis of the GeForce RTX 3070 and GeForce RTX 3080 respectively. If the rumour is true, the top-end chip would have 3,480 stream processors, a huge 320-bit wide memory interface and 10/20GB of GDDR6 video memory. This would be a significant step up, especially in terms of the amount of memory.

The spec for the other chip would involve 3,072 stream processors, a 256-bit wide memory interface and 8/16GB GDDR6 RAM. The MyDrivers rumour also states that the new GPUs will be manufactured on a 7nm process, and that the cards might arrive in a standard version with a Super upgrade soon after, like the current generation of RTX GPUs.

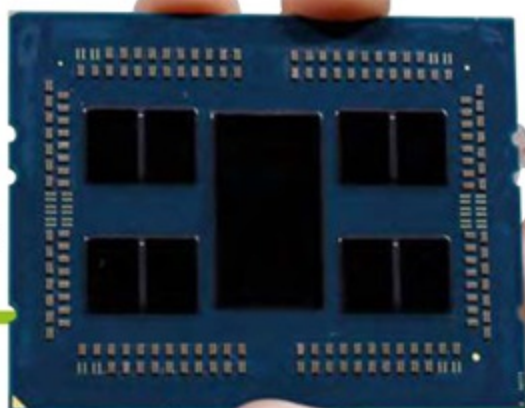
## MORE INTEL CPU PRICE CUTS COMING

Taiwanese tech site Digitimes cites 'unnamed PC makers' as suggesting that Intel might once again be looking to make price cuts in the second half of this year. There are no specifics about which CPUs are in line for price cuts this time, although we can probably rule out the HEDT chips getting discounted again, as they've had a recent price drop already.

## 64-CORE THREADRIPPER ON THE WAY

AMD CEO Dr Lisa Su has said that the company's 64-core Threadripper 3990X CPU will be launching worldwide on 7 February, so it will likely be in the shops by the time you read this. Equipped with AMD's Simultaneous Multithreading Technology (SMT), the chip is able to execute up to 128 threads concurrently, and has a 2.9GHz base clock with a 4.3GHz stated maximum turbo clock.

Meanwhile, there's 4MB of L1 cache, 32MB of L2 cache and a huge 256MB total of L3 cache. It will need plenty of cooling power, though, with a default TDP of 280W. What's more, AMD will even be unlocking this 64-core monster chip for overclocking. Not surprisingly, it won't be cheap. The recommended retail price for the Threadripper 3990X is a cool \$3,990 US (around £3,678 inc VAT at the current exchange rate), so you'll have to seriously need all those cores if you're going to buy one.



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## What's that?

Our pals at be quiet! are offering a Dark Base Pro 900 Rev. 2 Silver case to one Custom PC reader. The image above is a distorted close-up of a piece of hardware featured in this issue. If you identify it, email the name and page number of the product to [competition@custompcmag.org.uk](mailto:competition@custompcmag.org.uk), with 'What's that? 199' in the Subject field, as well as your postal address.

## Previous winners

The winner from our Issue 197 competition was Ian Nourse, who correctly identified the Speedlink Orios LED XL mousepad from p47. Congratulations Ian, we'll be in touch shortly to get your prize sorted out.

**Terms & conditions**  
Competition closes on Friday 6 March, 2020. Please see p31 for our competition terms and conditions.



# ALIENWARE UNVEILS PORTABLE GAMING PC CONCEPT

Alienware has unveiled a portable PC gaming device at the CES show in January, and it looks very much like the Nintendo Switch. Unveiled as a proof of concept, rather than a finished product, Alienware's Concept UFO is built around an 8in screen with a 1200p resolution, compared with the Switch's 6.2in 720p screen.

Meanwhile, a 10th-gen Intel CPU does the heavy lifting with its integrated graphics, although not much is known about performance and battery life right now. Comparatively, the Nintendo Switch uses an ARM-based Nvidia Tegra SoC.

The Concept UFO is a fully fledged Windows 10 PC, with all the compatibility this brings with it, so you would be able to keep up with your desktop games when you're out and about. There are USB-C ports, and it can accommodate a keyboard and mouse if desired. It also has Wi-Fi, Bluetooth and Thunderbolt connections. The side-mounted gamepads

can also come off and lock together to make a full-sized pad, although they lack the Switch's ability to use each pad on its own for two players.

PHIL HARTUP



# NEW CORSAIR CPU COOLERS

Corsair has just expanded its range of CPU coolers, adding the A500 and the iCUE RGB Pro XT range to its line-up. Unlike the company's usual all-in-one liquid coolers, the A500 sees Corsair making a traditional air cooler with a heatsink and fan.

It's equipped with four copper heatpipes that make direct contact with the CPU heatspreader, and is rated to handle CPUs with a TDP of up to 250W. The twin Corsair ML120 fans are PWM-controlled at speeds between 400 and 2,400rpm. There are no illumination features, but that's a hefty amount of cooling power.

Meanwhile, there are three variations of the iCUE RGB Pro XT, the H100i, H115i and H150i (pictured), with 240mm, 280mm and 360mm radiators respectively. These radiators are equipped with Corsair ML-series PWM fans, with the 120mm versions having a top speed of 2,400rpm and the 140mm fans spinning at up to 2,000rpm. The iCUE software allows for users to control not only the pump speeds but also the 16 RGB LEDs in the CPU waterblock, although the fans themselves don't have RGB lighting. Notably, the fans are not RGB-equipped.

All the coolers are available from [corsair.com/uk](https://corsair.com/uk) now, with the iCUE RGB Pro XT range costing £160 for the H150i, £140 for the H115i and £120 for the H100i. The A500 comes in at £90 (all prices inc VAT).

PHIL HARTUP







Make It Yours.



## GOING DARK

### MASTERBOX SL600M BLACK EDITION

The MasterCase SL600M Black Edition ATX chassis features award-winning, vertical airflow technology and a black powder-coat applied to aluminum panels. Two 200mm fans mounted to the bottom assist the natural rise of hot air up and out of the system.





# Reviews

## Intel Cascade Lake-X

### LGA2066 PROCESSORS

INTEL CORE i9-10900X, 10920X  
AND 10940X / **£612 (10900X);**

**£707 (10920X); £823 (10940X)** all inc VAT

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

**I**ntel has taken a good battering from AMD recently. The latter's Zen 2 architecture has seen the company draw level in areas where it previously lagged behind, exceed Intel in other areas and close gaps where Zen+ was noticeably slower. Meanwhile, AMD's 3rd-gen Threadripper CPUs have given AMD a

commanding lead at the top of the stack too.

It's forced Intel into the highly unusual move of slashing prices of its HEDT CPUs, so its latest 10-core, 12-core and 14-core Cascade Lake-X CPUs are much more affordable than their predecessors. Stock seems to be thin at the moment, and some retailers appear to be charging exorbitant prices, but we're going with Novatech's pricing for this review, which was the cheapest we could find for bona fide, checkout-capable pre-orders.

For instance, the Core i9-10940X, with 14 cores and 28 threads is on pre-order for £823 inc VAT. That's still not cheap, but its predecessor cost close to £700 more. The Core i9-10920X, which has 12 cores and 24 threads, can be had for £700, which is over £300 less than the previous Core i9-7900X, with just ten cores and 20 threads, cost at launch. Finally, the Core



Intel Core i9-10900X

### SPEC

**Base frequency** 3.7GHz (10900X); 3.5GHz (10920X); 3.3GHz (10940X)

**Max boost frequency** 4.7GHz (10900X); 4.8GHz (10920X and 10940X) Core Cascade Lake-X

**Core** Cascade Lake-X

**Manufacturing process** 14nm

**Number of cores** 10 (10900X); 12 (10920X); 14 (10940X)

**Number of threads** 20 (10900X); 24 (10920X); 28 (10940X)

**Hyper-Threading** Yes

**L3 cache** 19.25MB

**L2 cache** 10 x 1MB (10900X); 12 x 1MB (10920X); 14 x 1MB (10940X)

**Memory controller** Quad-channel DDR4, up to 2933MHz

**Packaging** LGA2066

**Thermal design power (TDP)** 165W

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

i9-10900X, which has 10 cores and 20 threads too, costs just £612. Again, it's not cheap, but it dips well below the Ryzen 9 3950X in terms of price. That may be a moot point, given the latter has six more cores and 12 more threads though.

Otherwise, the specifications on paper appear to be nearly identical between the three CPUs. They're all made using a 14nm manufacturing process, which hasn't changed since the introduction of Broadwell-E several years ago. They're also architecturally very similar to the original Skylake-X CPUs, with few tweaks other than hardware-enabled security mitigations. There's 1MB L2 cache per core, the L3 cache is the same for all three CPUs and all the chips have a TDP of 165W as well.

Some of the CPUs differ under the hood though. For starters, the Core i9-10900X is the odd CPU out, as it uses Intel's Low Core Count (LCC) die as opposed to the High Core Count (HCC) die used with any Intel CPU above ten cores, including the other two CPUs on test.





## LAKE

- + Big all-core overlocks
- + More PCI-E lanes than mainstream platforms
- + Affordable motherboards

## POND

- High power consumption
- AMD Ryzen 9 chips offer much better value
- High power consumption

Meanwhile, the Core i9-10920X uses the same HCC die as the Core i9-10980XE, but with six cores disabled.

The LCC die is a remnant of Intel's 6-core and 8-core HEDT CPUs, which have become rather pointless in the wake of the Ryzen and Threadripper onslaught, as well as their comparatively poor multi-GPU support. These chips are nearly identical to their equivalent predecessors though – they just cost a lot less money.

That helps though. The Core i9-10980XE costs barely half the price of its predecessor and is still a monster CPU, especially once it's overclocked. In fact, it's faster than the Ryzen 9 3950X in many benchmarks before we even consider its quad-channel memory support and extra PCI-E lanes. After all, performance and value are the most important considerations when buying PC hardware, not whether Intel has been caught napping.

Frequencies are important too, and the Core i9-10900X can reach an all-core boost clock of 4.3GHz and peak boost clock of 4.7GHz. The other two CPUs max out at 4.8GHz peak boost and have 4.3GHz and 4.1GHz all-core boost frequencies respectively. The 12-core and 14-core CPUs have peak boost frequencies that are 300MHz higher than their Basin Falls predecessors, and the Core i9-10900X's peak boost frequency is 200MHz higher than that of the Core i9-9900X.

You also need to account for the price of the whole supporting platform. AMD's 3rd-gen Threadripper CPUs are already significantly more expensive than these CPUs, and TRX40 motherboard pricing compounds that issue. Comparatively, X299 motherboards have been around for several years and can readily be found for under £200 – half that of the cheapest TRX40 boards out there.

In terms of features, AMD's current offerings certainly offer more core for your cash, but HEDT processing isn't just down to the number of cores. Part of the reason why Intel's HEDT CPUs cost more than AMD's AM4 Ryzen CPUs is because the Intel chips offer quad-channel memory support, as well as more PCI-E lanes than mainstream CPUs such as AMD's Ryzen 9 3950X.

The number of PCI-E 3 lanes has increased from 44 to 48 with Cascade Lake-X CPUs too, and while AMD's 3rd-gen Ryzen CPUs support PCI-E 4, that won't allow you to use more devices. The main current benefit of PCI-E 4 at the moment is full bandwidth for the latest NVMe SSDs. However, if you want to be able to run several M.2 NVMe SSDs flat out at the same time, neither Intel's Z390 nor AMD's X570 motherboards can do it without sharing bandwidth. Your only option is to go with an HEDT-focused platform, such as TRX40 or X299.

On the flip side, raw CPU performance is still important in many areas. With the huge increases in mainstream CPU performance, largely instigated by AMD, you can now easily own a PC that's capable of handling casual 4K video editing – an area that doesn't need nor benefit massively from extra PCI-E lanes or memory channels.

## Performance

There's no doubt that, at stock speed, none of Intel's new HEDT Cascade Lake-X CPUs stacks up particularly well against the AMD competition in most tests. The Ryzen 9 3900X and Ryzen 9 3950X were faster in our single-threaded image editing test, previously an Intel stronghold, and they also won out in our video encoding and heavy multi-tasking tests. The Core i9-10900X's system score





Intel Core i9-10920X

of 220,297 did at least give the Threadripper 2950X a run for its money, but the Ryzen 9 3900X was much faster and costs a couple of hundred pounds less too.

Despite having two more cores than the 10900X, the Core i9-10920X only added another 25,000 points to that system score. At £800, it's definitely a better option than the Threadripper 2950X in our RealBench suite, given that the latter costs the same price and requires more expensive motherboards. However, it still failed to better the AMD 12-core CPU, despite having the same core count. Even the Core i9-10940X failed to beat AMD's 12-core Ryzen, only offering similar performance in the video encoding test.

Meanwhile, Blender saw the stock speed Core i9-10900X languish in last place, with AMD's mainstream and HEDT CPUs doing particularly well here. The Core i9-10920X saw the render time fall from 56 seconds to 49, while that figure fell to just 42 seconds with the Core i9-10940X, matching the Ryzen 9 3900X.

Ever the darling of AMD's benchmarks, Cinebench R20, painted a similar story, with the Core i9-10940X just about keeping up with the cheaper Ryzen 9 3900X, but failing to compete with the Ryzen 9 3950X in the multi-threaded test, but beating the Threadripper 2950X. Even Far Cry 5 saw the AMD chips winning out. The Intel trio sat between minimums of 85fps and 88fps, while the Ryzen 9 3900X and Ryzen 9 3950X managed 91fps and 92fps respectively.

The smaller manufacturing process and architectural efficiency of AMD's latest CPUs also mean they have a lower power draw than these Intel chips. Intel's architecture is now showing its age, with these chips drawing roughly 100W more than the 12-core and 16-core AMD mainstream CPUs, peaking at 378W under load with the Core i9-10940X.

Overclocking, though, proved very fruitful on these Intel CPUs, and you should be able to reach all-core overclocks of at least 4.8GHz with a vcore of around 1.3V or less. We managed to hit 4.8GHz with the Core i9-10900X using a vcore of 1.325V, but achieved a massive 4.9GHz across all cores using just 1.3V with the Core i9-10940X and Core i9-10920X.

Heat was certainly an issue though. Temperatures were hitting the low 90s (°C) under sustained loads, even with a 240mm EKWB Phoenix liquid cooler, but the overclocks resulted in some sizeable benchmark gains.

The Core i9-10920X and Core i9-10940X were then able to leapfrog the Ryzen 9 3900X in our Handbrake video encoding test, with the 14-core CPU coming within spitting distance of the Ryzen 9 3950X.

However, the system scores were still behind overall. The overclocked single-threaded scores in Cinebench went from an AMD whitewash to mostly matching the two mainstream Ryzen CPUs. The latter also fell back once overclocked, as they lost their stock speed boost frequencies.

The overclocked multi-threaded Cinebench scores were certainly a vast improvement for the Intel CPUs, with the Core i9-10900X's score rising from 5,486 to 6,159, the Core i9-10920X's score going from 6,504 to 7,498 and the Core i9-10940X's score increasing from 7,222 to 8,628. The overclocks allowed the middle of the three Intel CPUs to match the Ryzen 9 3900X, and the Core i9-10940X also came within a few hundred points of the Ryzen 9 3950X, but ultimately failed to topple it.

Once overclocked, the Intel CPUs also excelled in games, with the average frame rate hovering around 130fps, and minimums sitting between 92fps and 96fps. These are slightly higher frame rates than the Ryzen 9 3950X, which was using fairly speedy 3466MHz memory too. However, it's extremely close here. Far Cry 5 is one game that saw AMD make big gains in with Zen 2, but Intel does still have a lead in a number of other games once the CPUs are overclocked.







Intel Core i9-10940X

Blender saw the biggest improvements from overclocking, with the all-core boost frequencies receiving big lifts. The Core i9-10900X's time fell from 56 to 47 seconds, the Core i9-10920X's time dropped from 49 seconds to 37 seconds, and the Core i9-10940X's time went from 42 seconds to 35 seconds. The latter was enough to come within a second of the Ryzen 9 3950X, but the Core i9-10920X was still a couple of seconds adrift. The Core i9-10900X, meanwhile, was nowhere near close enough to matching the Ryzen 9 3950X, being a long way from worrying AMD's mainstream Ryzen flagship.

Unfortunately, power consumption was already not one of Intel's strong points, and while overclocking the CPUs offered sizeable gains, it also upped the power draw considerably. Our test systems sat at load draws of between 345W and 378W at stock speed, but this increased to between 465W and 576W once the chips overclocked. In comparison, AMD's Ryzen 9 3950X peaked at 340W when overclocked.

## Conclusion

There's quite a bit to discuss here, so let's start with the Core i9-10900X. Intel's new 10-core CPU is now the cheapest current option for entry to its HEDT platform at just over £600 inc VAT, but there are two big issues here. While the Ryzen 9 3950X isn't strictly a fair comparison, given that it costs £100 more, the 10900X is also completely outperformed by the £150-cheaper Ryzen 9 3900X in most tests, and it only starts to become competitive once it's overclocked.

You should only consider this CPU if you really need more PCI-E lanes and quad-channel memory support, as the Ryzen 9 3900X offers far better value. Secondly, while it's a better option than the Threadripper 2950X, Intel's own Core i9-9900X is still readily available and offers a cheaper 10-core entry option to the X299 platform.

The Core i9-10920X is slightly more interesting. At £700 inc VAT, it has the same price as the Ryzen 9 3950X. However, even when overclocked, it failed to match the AMD CPU in most tests, only gaining an advantage in Far Cry 5. Our benchmarks aren't exhaustive, though, and the Intel CPU could offer more of an advantage in other game titles, and in software such as Adobe Premiere Pro.

However, in our benchmarks the AMD CPU is undoubtedly the speed king. It's important to consider the mainstream vs HEDT platform argument here though. If you really need those extra PCI-E lanes or quad-channel memory support, it's a better option than 2nd-gen Threadripper, especially as the Threadripper 2920X now appears to be off sale, and our 10920X sample managed a massive overclock too.

Finally, there's the Core i9-10940X with its 14 cores and 28 threads. Had this CPU been released a year ago at this price, Intel would be in a whole lot less bother, and it wouldn't have had to contend with the Ryzen 9 3950X either. Running 14 cores at close to 5GHz is still an impressive feat, but it's only this chip that can square up to the Ryzen 9 3950X.

Thankfully, the price difference between the two CPUs when we went to press was only a little more than £100. If you want a PC that hits those maximum frame rates in all games with the grunt to deal with multi-threaded workloads occasionally too, it's a beast, and it will save you close to £200 compared with the Core i9-10980XE.

Again, though, unless you need the extra PCI-E lanes and memory channels, the AMD CPU is still a better buy. You also need to overclock the 10940X to make it worthwhile, and it's worth remembering that Intel's LGA2066 socket may not have much of an upgrade path beyond Cascade Lake-X.

ANTONY LEATHER

## VERDICT - INTEL CORE i9-10900X

Not fast or powerful enough to compete with AMD's latest mainstream CPUs.

## VERDICT - INTEL CORE i9-10920X

A reasonable CPU for the cash, especially if you want quad-channel memory, but it's still lacking compared with AMD's Ryzen 9 3950X.

## VERDICT - INTEL CORE i9-10940X

It's no Core i9-10980XE, but it nearly matches AMD's 3950X in content creation and is faster in games.

Intel Core  
i9-10900X

PERFORMANCE

36/50

FEATURES

15/15

VALUE

22/35

OVERALL SCORE

73%

Intel Core  
i9-10920X

PERFORMANCE

39/50

FEATURES

15/15

VALUE

26/35

OVERALL SCORE

80%



Intel Core  
i9-10940X

PERFORMANCE

41/50

FEATURES

15/15

VALUE

27/35

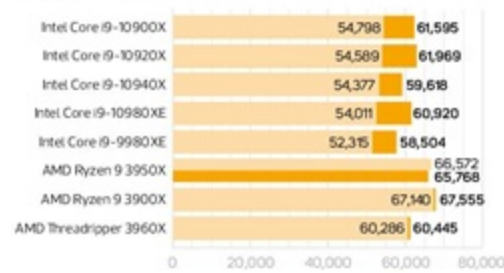
OVERALL SCORE

83%

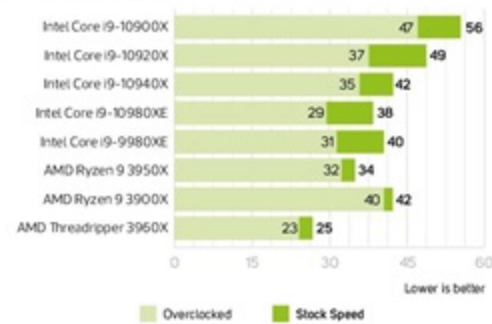


# INTEL CASCADE LAKE-X RESULTS

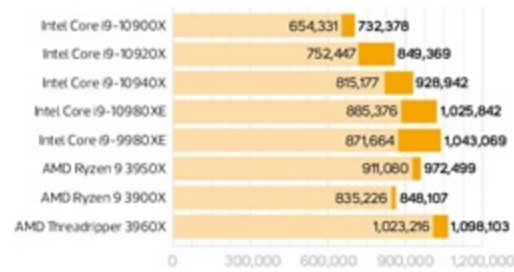
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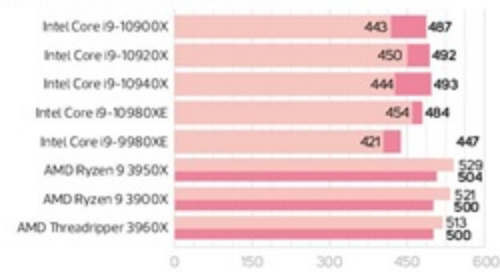
## BLENDER (SECONDS)



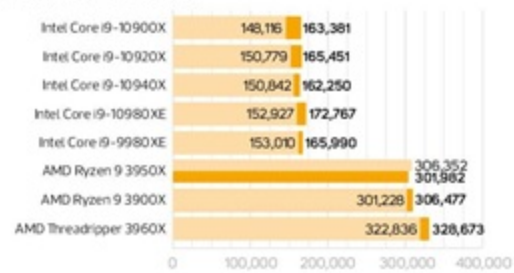
## HANDBRAKE H.264 VIDEO ENCODING



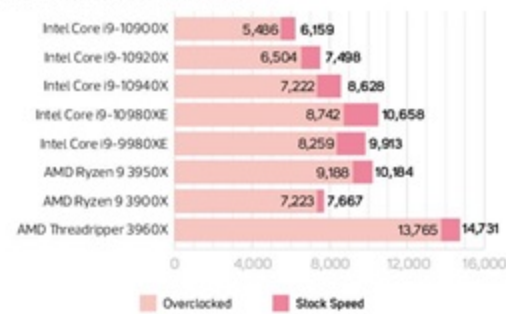
## CINEBENCH R20 SINGLE-THREADED



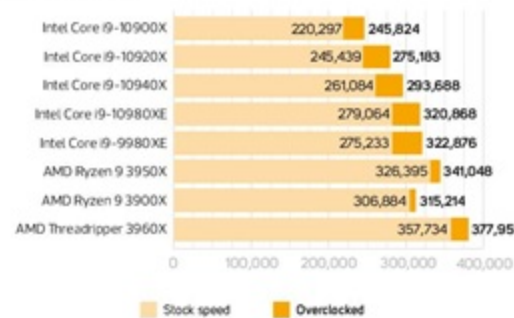
## HEAVY MULTI-TASKING



## CINEBENCH R20 MULTI-THREADED

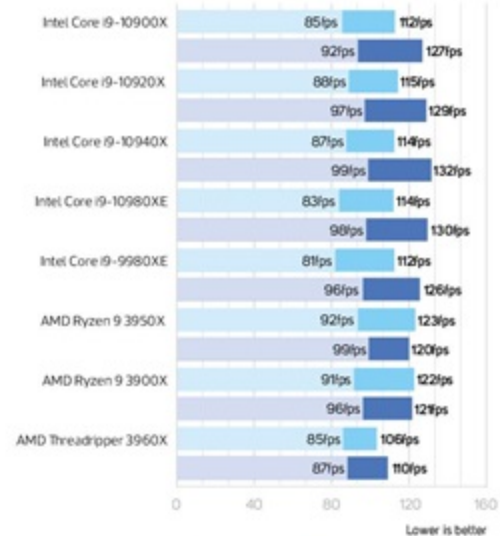


## SYSTEM SCORE



## FAR CRY 5

1,920 x 1,080, Ultra settings

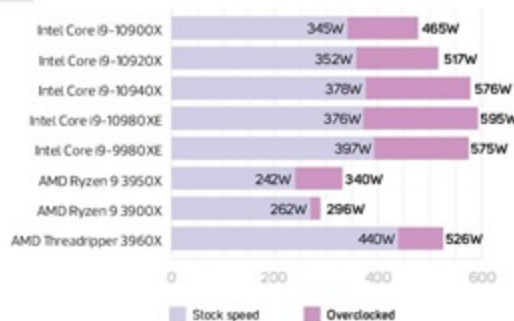


## TOTAL SYSTEM POWER CONSUMPTION

Idle



Load

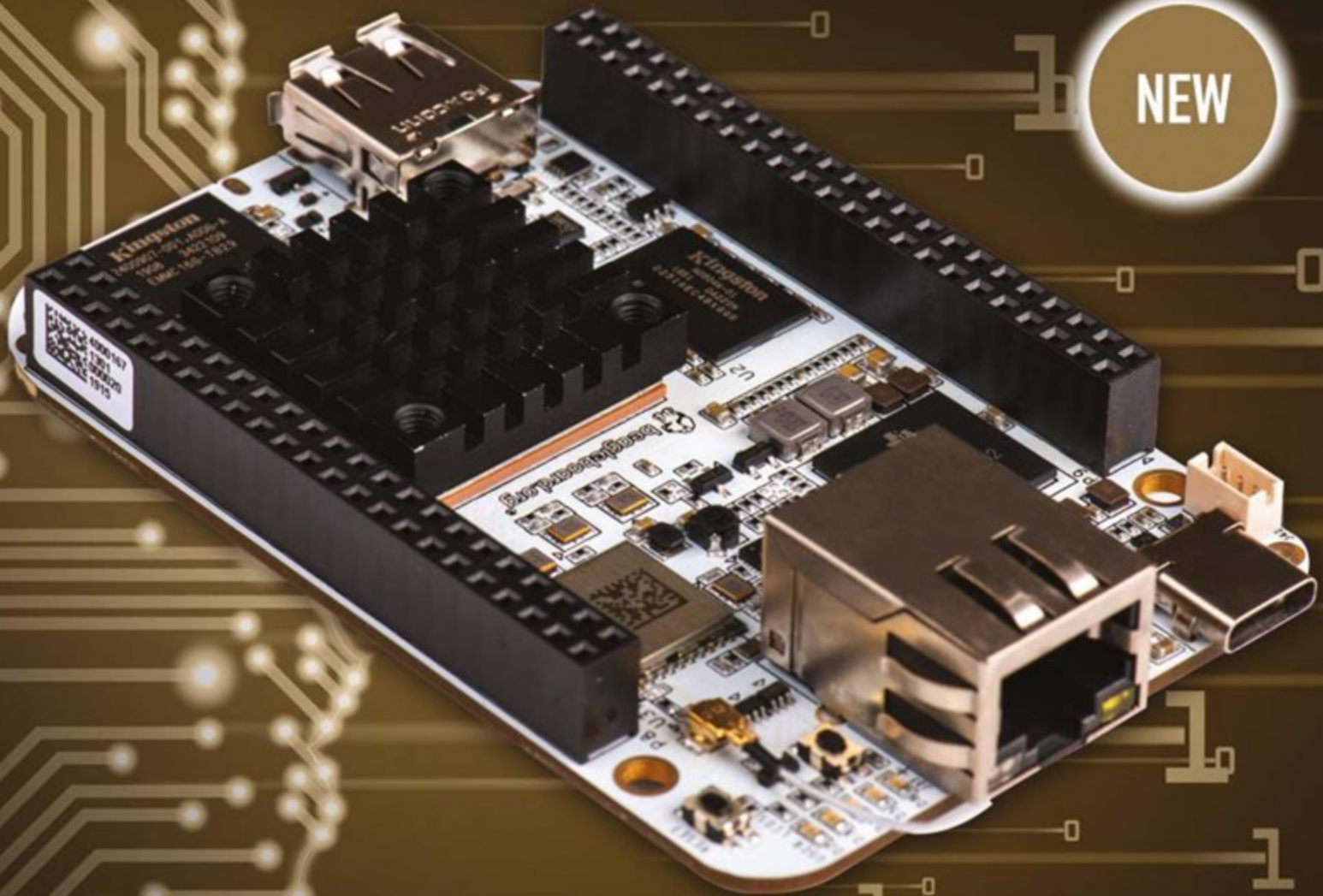




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# TRX40 MOTHERBOARD

## MSI TRX40 PRO WIFI / £430 inc VAT

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



### WIFI

- + M.2 expansion card
- + Well-rounded premium feature set
- + Cheaper than competition
- + Great audio

### DEADZONE

- Fewer M.2 ports than competition
- Some slow performance numbers
- Passive VRM cooling

### SPEC

**Chipset**  
AMD TRX40

**CPU socket**  
AMD Socket TR4X

**Memory support**  
8 slots: max 256GB DDR4  
(up to 4666MHz)

**Expansion slots**  
Four 16x PCI-E 4, One 1x PCI-E 4

**Sound**  
8-channel Realtek ALC1220

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

**Overclocking**  
Base clock 80-200MHz, CPU  
multiplier 10-63x; max voltages:  
CPU 2.1V, RAM 2.1V

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

**Dimensions (mm)**  
305 x 244

While AMD's 3rd-gen Threadripper CPUs are fantastically fast and powerful, they're also hugely expensive, and the same generally goes for their accompanying TRX40 motherboards. However, at £430 inc VAT, MSI's TRX40 Pro WiFi is the cheapest TRX40 motherboard we've tested, even undercutting the ASRock TRX40 Taichi (see Issue 198, p44).

Of course, MSI has had to trim some features to get to this price, but the TRX40 Pro WiFi still has enough clout to build a monster system. For starters, while there are only two PCI-E 4 M.2 ports on the PCB, MSI has managed to include a PCI-E 4 expansion card to add two more ports, both of which are cooled with a massive heatsink and fan.

While using the on-board M.2 ports saw our PCI-E 4 SSD's temperature hit 63°C, using the expansion card saw that figure drop to 35°C, so it's well worth using the card if you'll be putting your SSDs under sustained heavy loads. The ASRock, meanwhile, includes an expansion card that has four ports, so it's worth considering if you have a monster NVMe storage array planned. The TRX40 Pro WiFi also has eight SATA ports, so there's definitely scope for housing a gargantuan amount of storage.

MSI has included a decent array of overclocking and testing tools too, with power, reset, clear-CMOS and USB BIOS FlashBack buttons, plus an LED POST code display. However, there's not much RGB lighting, with just a smattering of 3-pin and 4-pin RGB headers, and no on-board lighting, nor flashy digital displays.

MSI's VRM cooling is fairly basic too, with just two large heatsinks linked by a heatpipe, but no active

cooling and no heatpipe linking the heatsinks to the chipset fan either. There's a 12+3 phase power design underneath, and under load, the VRMs hit a peak of 68°C, which is reasonable, but boards with active cooling have been a little cooler, including MSI's monster Creator TRX40, which topped out at 62°C. Still, for a fanless design, the board does a good job.

On the plus side, as the chipset fan only deals with the chipset, you're unlikely to see it rotating much – it only spun up when booting in our tests. Even if it does prove noisy, you can control its fan response curve in the EFI.

We'd like to see another fan header or two, though, with six being the minimum we'd expect from a board of this calibre. There are also no 2-pin thermal probe headers, although MSI's EFI does at least allow you to pick from temperature sources other than the CPU temperature to control your fans. The EFI is generally excellent too, with a slightly more modern-looking and concise layout compared with Gigabyte's boards, although Gigabyte's EFIs offer more control over your fans.

MSI's software for the TRX40 Pro WiFi is slightly clunky too, with Dragon Center providing the overclocking, fan control and Mystic Light RGB suite in one package. However, it feels quite fragmented compared with others we've tried.

The rear I/O panel isn't what we'd call lavishly populated either, which might be smart given the price, but there are seven Type-A USB ports, USB Type-C, as well as ports for the 802.11ax Wi-Fi aerials and audio ports for the Realtek ALC1220 audio. There's no more here than you'd expect to see on a premium AM4 board, which shows the hefty premium you pay for TRX40.

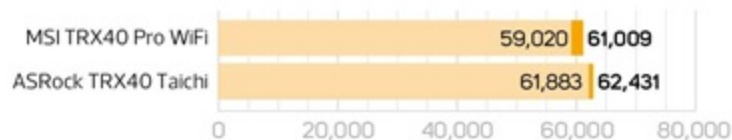
### Performance

There were one or two anomalies in our results, such as score of 59,020 in the image editing test compared to the minimum of 61,000 we've seen with other boards.

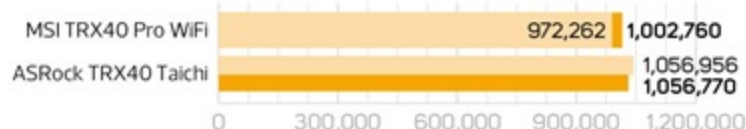


## BENCHMARK RESULTS

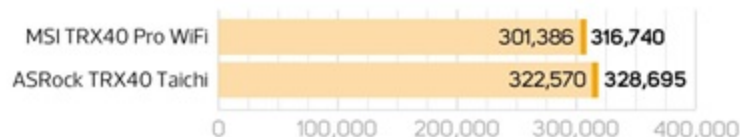
### GIMP IMAGE EDITING



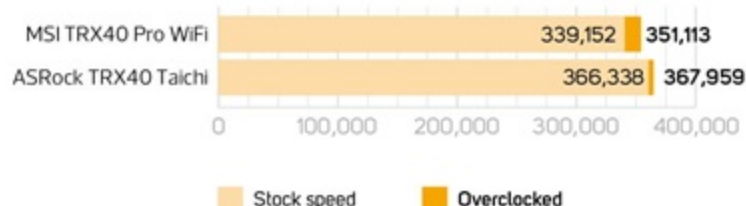
### HANDBRAKE H.264 VIDEO ENCODING



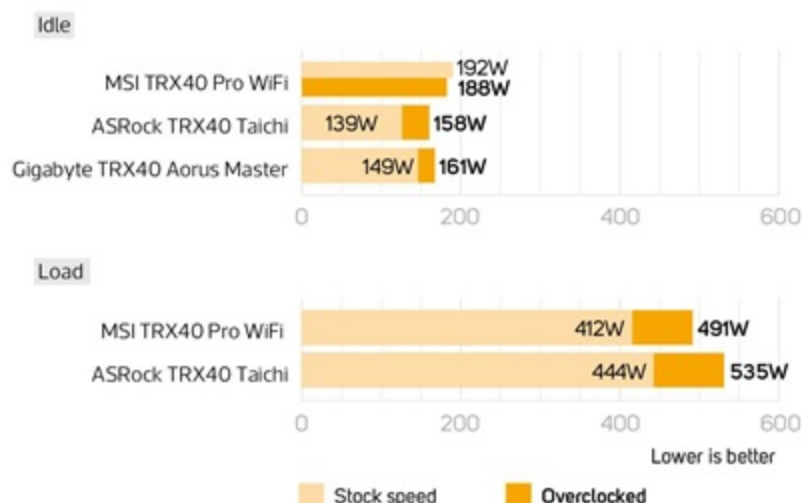
### HEAVY MULTI-TASKING



### SYSTEM SCORE

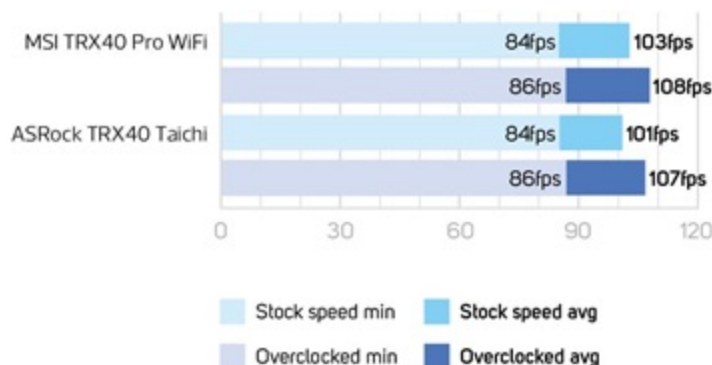


### TOTAL SYSTEM POWER CONSUMPTION



### FAR CRY 5

1,920 x 1,080, High settings



The video encoding score wasn't the lowest we've seen, but was again lower than average at stock speed, as was the multi-tasking score. Overall, though, it wasn't the slowest TRX40 board we've tested, with the system score just beating the Asus ROG Strix TRX40-E Gaming.

We managed to overclock our CPU to 4.35GHz across all 24 cores by pumping 1.325V through our Threadripper 3960X, but to get it stable, we also needed to apply level 3 loadline calibration in the EFI. This saw the system score rise from 339,152 to 351,113 and the minimum frame rate in Far Cry 5 increase from 84fps to 86fps. Idle power consumption was rather high at stock speed, though, with the draw of 192W being much higher than other boards. However, the load and overclocked numbers were more competitive.

Audio performance was excellent; the MSI traded blows with the best TRX40 boards, such as Asus' ROG Zenith II Extreme and MSI' Creator TRX40, with a dynamic range of 115dBA. M.2 speeds were on the money too, with read and write speeds of 4,978MB/sec and 4,243MB/sec respectively, adding a couple of hundred megabytes a second to the oddly slow speeds we saw with the Gigabyte boards last month.

### Conclusion

MSI's TRX40 Pro WiFi ditches some unnecessary features in an attempt to make an affordable, yet still decent, TRX40 platform, and it largely succeeds. It has a solid set of features, but still includes some fancy features such as its M.2 expansion card.

Apart from some slightly low numbers in a couple of benchmarks, and the rather clunky software, it's otherwise a great effort for the cash. However, it's not quite as good as the ASRock TRX40 Taichi, which costs just £25 more and includes more M.2 ports, actively cooled VRM heatsinks and an integrated I/O shield. If those features aren't important to you, though, the MSI TRX40 Pro WiFi is an excellent low-cost alternative.

ANTONY LEATHER

### VERDICT

A decent TRX40 board for the price – there aren't many reasons to spend more money.



### PERFORMANCE

31/35

### FEATURES

25/35

### VALUE

29/30

### OVERALL SCORE

85%





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# GAMING MOUSE

# RAZER DEATHADDER V2

/ **£70** inc VAT

SUPPLIER [razer.com](http://razer.com)

## SNAKEBITE

- + Stylish and well built
- + Great sensor and switches
- + New lightweight design and cable

## SQUASH

- A touch pricey
- Large size won't suit everyone
- Shape only fits palm-grip users

**T**he Razer DeathAdder is one of the legends of the industry, having been around in various forms since 2006 and selling over 10 million units, according to Razer's own claims. Now there's another update to the classic design, with this latest iteration sporting the company's newest 20,000dpi sensor, optical main switches and a new cable.

It shouldn't come as a surprise, considering the age of this mouse's design, but there is a strange old-school feeling to it. So many mice these days sport ambidextrous, lightweight designs, or at the very least they have universal shapes that lend themselves to a variety of grip styles. The DeathAdder V2, though, is resolutely a big, bulky mouse that really only suits palm-grip use, unless you have really big hands.

For fingertip grip, the really grippy rubber sides provide a secure purchase, but the sheer bulk of the mouse under your palm leaves too little room for the range of motion required. Meanwhile, for claw grip, the back of the mouse is too sloped and slippery, with this section of the mouse sporting a slightly textured plastic finish, rather than grippy rubber.

These shape considerations aside, though, the DeathAdder V2 is a top-notch mouse. For a start, it looks great. The subtle, sharp lines of the RGB lighting around the scroll wheel and on the rear logo, just look so much classier than most mice. Meanwhile, the otherwise all-black look and quality feel of the materials gives off a premium vibe.

For buttons, you get the standard arrangement, but with two DPI buttons on the top rather than just one. In use, though, these buttons sit too low to be easily activated mid-game, rendering them rather pointless. You either have a DPI button accessible, so it can be used mid-game, as on the previous DeathAdder Elite, or you keep them well out of the way to completely prevent accidental hits, as with the modern trend for having them on the underside of the mouse. Instead, you get a profile-switching button on the DeathAdder V2's underside.

Meanwhile, the two main buttons use Razer's new optical switches, the chief benefit of which is the ability to eliminate the debounce delay required for electronic switches. This can be upwards of 4ms, which may not sound like much, but such delays add up. These optical

switches have a response time of just 0.2ms. We couldn't feel the difference in testing, but potentially, you'll gain that fractional advantage once in a while.

Perhaps the most tangible improvements with this version of the DeathAdder over the previous Elite model, though, are the substantial drop in weight from 105g to 82g and the addition of Razer's new ultra-flexible Speedflex cable. The latter helps to reduce the annoyance of your cable pushing back against the mouse, disrupting your aim.

As ever, Razer also offers both on-board memory and software profile support, via its comprehensive, if slightly obtrusive, Synapse software.

## Conclusion

The Razer DeathAdder V2 isn't the most universally shaped mouse, with its size and shape making it suited mainly to gamers with large hands who like to use a palm grip. However, in every other way, it's a solid update to the venerable mouse design. The new 20,000dpi sensor offers little tangible improvement over previous versions, but the weight loss, new cable and optical switches are all welcome changes.

EDWARD CHESTER

## VERDICT

A very capable mouse, although its shape won't suit everyone.



DESIGN  
**16/20**

FEATURES  
**18/20**

PERFORMANCE  
**20/30**

VALUE  
**22/30**

OVERALL SCORE

**76%**

## SPEC

Weight 82g

Dimensions (mm) 127 x 62 x 43

Sensor 20,000dpi Focus+ optical

Buttons 7 (left, right, scroll wheel, back, forward, 2 x top DPI)

Cable 2.1m Speedflex

Extras On-board and cloud profile storage, optical switches



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# GAMING KEYBOARD

## Corsair K95 RGB Platinum XT / £210 inc VAT

SUPPLIER scan.co.uk

### PLATINUM

- + New padded wrist rest
- + Excellent build quality
- + Snazzy lighting and software

### PLATITUDE

- Expensive
- Limited new features
- USB port is only USB 2

If you think Corsair's high-end K95 keyboards are mostly identical, we wouldn't argue with you for the most part, although the brand-new K95 RGB Platinum XT has just enough new features to warrant the extra letters after its name. The detachable wrist rest, for instance, no longer offers a harsh, solid, rubber-coated plastic surface – its plush, padded faux leather feels so much more comfortable. The wrist rest stretches the entire length of the keyboard and will make any third-party soft wrist rest redundant.

There's a slightly different selection of switches from which to choose too, including CherryMX Speed Silver RGB Silver and the super-clicky CherryMX RGB Blue, as well as the usual linear-feeling CherryMX RGB Brown. The Speed Silver switch is much like a Red switch, with the same actuating force of 45cN, but less pre-travel and total travel. In short, it activates much higher up, which was noticeable on our Speed Silver-equipped sample.

Corsair has also tweaked its keycap design, with the new PBT double-shot keycaps replacing older ABS models, which Corsair claims should improve stability and reduce wear on the keycap symbols during use. Corsair's signature side-mounted macro keys also now offer the ability to work cross-functionally with Elgato's Stream Deck software.

The rest of the keyboard is a typical K95, though, with two USB cables to power the keyboard, lighting and USB pass-through port. The latter remains stuck at USB 2, so it's only

good for hooking up mice and headsets rather than USB 3 hubs and high-speed storage. You also get the usual dedicated media keys, including a great-feeling, handy volume wheel, as well as a brushed aluminium fascia.



Internally, you also get 8MB of on-board storage, which can house up to five profiles independently of any Windows software. There's also complete anti-ghosting coverage and N-key rollover, as you'd expect from a modern gaming keyboard, and you get textured replacement keycaps for the popular left-hand gaming key areas too.

Meanwhile, Corsair's iCUE software worked without a hitch. It also offers more than just lighting control, with full adjustment options for the USB polling rate, layout and key switch debounce time – the latter is used to prevent double registrations when keys are pressed too rapidly. Creating macros and profiles was easy too, and the per-key lighting control can be synchronised across all iCUE-enabled devices. Corsair also told us at CES that Asus motherboards will soon offer iCUE compatibility.

### Conclusion

The K95 RGB Platinum XT is a joy to use, and comfort is much improved thanks to the new padded wrist rest. Whether you just want an RGB mechanical keyboard with macro switches and media keys, or if you want to delve into the depths of the iCUE and Elgato streaming software, you won't be disappointed. There is one issue with the Corsair K95 RGB Platinum XT, though, and that's the price. At £210 inc VAT, it costs £40 more than (already expensive) existing models. Had it offered USB 3 support, it would have grabbed our top award, but the added comfort, extensive features and great build quality mean it's still a fantastic keyboard if you can afford it.

ANTONY LEATHER

### VERDICT

Supremely comfortable and awash with features, but its high price puts it out of reach for many people.

### SPEC

Connection  
Wired, USB

Cable  
1.8m, braided

Material  
Plastic, aluminium

Switch type  
CherryMX RGB Brown,  
CherryMX Speed RGB Silver  
or CherryMX RGB Blue

Backlighting  
RGB

Extras  
USB pass-through, wrist  
rest, additional textured  
keys, volume wheel,  
macro keys, key puller

DESIGN  
37/40

FEATURES  
32/35

VALUE  
18/25

OVERALL SCORE

87%



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# GAMING MOUSE

## SPEEDLINK VADES

/ £15 inc VAT

SUPPLIER coolshop.co.uk

### VADER

- + Very cheap
- + Plenty of buttons
- + Good software

### SNOKE

- Basic sensor
- A little heavy
- Limited lighting control

**S**peedlink is a name associated with budget PC peripherals, with the company's products often sitting among the cheapest options when it comes to gamepads, joysticks and steering wheels. It also turns its hand to gaming mice, though, and the Vades is its latest creation, costing a mere £15 inc VAT. We review a lot of expensive mice at **Custom PC**, but we wondered if a budget mouse could also possibly deliver where it counts.

On the surface, the Vades does indeed seem to offer plenty for its price. You get several LED lighting zones and a total of seven buttons that are software-programmable. The latter is far from a given even for far more expensive mice.

Starting with that LED lighting, Speedlink has managed to pack quite a lot into the design. The lighting covers four zones, with the scroll wheel, rear logo and two strips on either side giving off a pleasant glow. These zones aren't individually controllable, but it's still an impressive array for the money. Crucially, though, the colour can only be set to one of four colours: blue, magenta, red or purple. The mouse will either cycle through these four colours, or you can choose a static colour that's determined by the DPI setting (blue is DPI 1, magenta is DPI 2 and so on).

Back to the more positive elements, though, and it's surprising to find that a large part of the surface of the mouse is given over to a soft-touch metallic red finish that looks reasonably smart, feels good in the hand and provides a little extra grip. Otherwise, the overall look is a bit fussy – we generally prefer a cleaner style of mouse, but that's largely down to personal taste.

As for ergonomics, this mouse seems to only be targeting one main demographic of user, in terms of grip style and

hand size. The steeply sloped left-to-right angle and overall size of the mouse suits a palm grip, where the mouse nestles right in the meat of your palm. However, the buttons only then fall into place if you have quite small hands. For fingertip use, the whole unit is too tall and bulky, while the back doesn't provide enough purchase for claw grip. It's a touch heavy too, weighing in at 108g.

Speedlink makes no grand claims about the quality of the two main buttons of this mouse – there's no mention of Omron here, but they still

feel precise and responsive. The other buttons aren't bad either, especially for the price. We were also reasonably impressed by the tracking, considering its lowly 2,400dpi sensor (expandable to 4,800dpi with software interpolation). The tracking isn't flawless in games, but it's adequate, and the easily accessible DPI button made it easy to switch between different games and between gaming and desktop use.

However, the bright red glow that shines forwards from the sensor on the bottom of the mouse is surprisingly distracting, especially if it catches on a shiny object in front of it, such as the glass panel of a PC case. The software also messes around with Windows settings when you're changing DPI settings, which is a pain.

### Conclusion

The Speedlink Vades is far from the perfect gaming mouse, with its tracking performance being only just about adequate and lacking some of the finesse of more expensive options. However, the extra buttons and software programmability means it ticks the essential boxes for general gaming use. If you're on a very tight budget, it's a passable upgrade over the very most basic mice.

EDWARD CHESTER

### VERDICT

A surprisingly capable gaming mouse for its price, although it's not without compromise.

### SPEC

Weight 108g

Dimensions (mm) 127 x 81 x 43

Sensor 2,400dpi, expandable to 4,800dpi with software

Buttons 7 (left, right, scroll wheel, back, forward, top DPI, double-click)

Cable 1.8m, rubber

Extras LED lighting



DESIGN  
14/20

FEATURES  
14/20

PERFORMANCE  
18/30

VALUE  
20/30

OVERALL SCORE

66%



# WIN

## A 27in AOC 144Hz GAMING MONITOR

Fancy starting off the year by getting your hands on a brand-new gaming monitor? For free?! That's what the lucky winner of our competition will be doing, courtesy of the fine folks at AOC.



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**[CUSTOMPC.CO.UK/WIN](https://CUSTOMPC.CO.UK/WIN)**

Competitive gamers will love the AOC 27G2U, with its colour-accurate 27in IPS display, smooth 144Hz refresh rate, 1 ms MPRT response time and FreeSync support. It also has an attractive frameless design with red accents.

Competition closes on Friday, 6 March, 2020. Prize is offered to participants in the UK aged 13 or over, except employees of the Raspberry Pi Foundation, 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.



## GAMING PC

# CHILLBLAST FUSION CONQUEROR

£5,999 inc VAT

SUPPLIER chillblast.com

**T**he Chillblast Fusion Conqueror is a monster, inside and out. The Cougar Conquer 2 chassis is mind-blowing, looking like a Transformer, with dramatic angles, a litany of metal panels and four slabs of tempered glass alongside front-mounted RGB LEDs. It's one of the most outrageous PC enclosures around, and it pairs the exorbitant design with huge dimensions: it measures 744mm deep

and 631mm tall. This case will occupy a lot of space and demand loads of attention. The key feature is its detachable sub-chassis. It's a large metal frame that holds the components – effectively, a case inside the case. It allows the bulk of this machine to slide out, in order to make upgrading and swapping parts easier.

It's a good idea, especially with so many components blocked by glass and metal. In practice, though, it's not so practical. You need to remove loads of screws first, so it's not as easy as just popping off a side panel. The sheer size of this case doesn't grant you many practical features either; you get support for 240mm radiators at the front, 360mm radiators in the roof and six case fans alongside pairs of 2.5in and 3.5in drive bays – the same sort of compatibility offered by conventional enclosures. Those cases will look neater too; while Chillblast has done a great job with the cables here, the gaps between the panels mean wires remain visible.

There's a monster spec too. The AMD Ryzen Threadripper 3970X has 32 cores, and can execute 64 concurrent threads. Chillblast has

left it at its stock clock speed of 3.7GHz, with a turbo peak of 4.5GHz. Understandably, it needs hefty cooling, and Chillblast has obliged with a 360mm Enermax unit. The 3970X is geared towards hardcore content creators – people who need loads of cores for video production, 3D artistry, software development and CAD design.

This machine also has 64GB of quad-channel memory, a 2TB Seagate FireCuda 520 M.2 SSD and a 4TB Samsung 860 QVO SATA SSD. Meanwhile, the king of consumer GPUs handles gaming duties, with an Asus-made RTX 2080 Ti card, which overclocks the GPU's boost clock from 1545MHz to 1650MHz.

It's all plugged into a Gigabyte TRX40 Aorus Pro WiFi motherboard, which offers practical features but few extras. It has four spare memory slots, two vacant M.2 connectors and loads of free SATA ports and on-board headers. At the rear, there are five USB 3.2 ports and a Type-C connection – and, as the name suggests, dual-band 802.11ax wireless. There are steel-reinforced slots throughout the design, and audio is also good, thanks to a Realtek ALC4050H and ALC1220-VB codecs.

However, there's only a single 1x PCI-E slot, and just a sole Gigabit Ethernet port. There are no on-board buttons or displays either. The specification is rounded out by a Corsair AX1200i PSU, which impresses with its 80 Plus Platinum certification and modular design.

Finally, this PC is protected by Chillblast's five year labour warranty, with two years of collect and return parts coverage. It's a solid deal, although we'd like to see more parts cover on a machine at this price.



## SPEC

### CPU

3.7GHz AMD Ryzen Threadripper 3970X

### Motherboard

Gigabyte TRX40 Aorus Pro WiFi

### Memory

64GB G.Skill Trident Z RGB  
3600MHz DDR4

### Graphics

Asus GeForce RTX 2080 Ti 11GB

### Storage

2TB Seagate FireCuda 520 M.2 SSD,  
4TB Samsung 860 QVO SSD

### Networking

Dual-band 802.11ax Wi-Fi,  
Gigabit Ethernet

### Case

Cougar Conquer 2

### Cooling

CPU: Enermax LiqTech II RTX 360  
RGB with 3 x 120mm fans; GPU: 3 x  
90mm fans; front: 1 x 120mm fan

### PSU

Corsair AX1200i 1,200W

### Ports

Front: 2 x USB 3, 1 x USB 3.1 Type-C,  
2 x audio; rear: 5 x USB 3.2 Gen 2,  
1 x USB 3.2 Gen 2 Type-C, 4 x USB  
2, 1 x optical S/PDIF, 5 x audio

### Operating system

Microsoft Windows 10 Home 64-bit

### Warranty

Two years collect and return  
parts and labour, plus three years  
labour only return to base



## BENCHMARK RESULTS



### SHADOW OF THE TOMB RAIDER

2,560 x 1,440, Highest Detail, TAA



3,840 x 2,160, Highest Detail, TAA



### TOTAL WAR: WARHAMMER II

2,560 x 1,440, Ultra Detail, FXAA, DX11



3,840 x 2,160, Ultra Detail, FXAA, DX11



### BATTLEFIELD V

2,560 x 1,440, Ultra settings, High DXR, TAA, DX12



3,840 x 2,160, Ultra settings, High DXR, TAA, DX12



99th percentile Average

## Performance

Not surprisingly, the 32-core 3970X is a beast. Its Handbrake video encoding result of 1,119,641 is huge – nearly 500,000 points faster than last year's Threadripper chips. It's around 150,000 points beyond the 16-core Ryzen 9 3950X too, and it squeaks ahead of Intel's 18-core i9-10980XE.

The Chillblast returned an overall application score of 382,767. That's around 40,000 points beyond the Ryzen 9 3950X and about 60,000 points ahead of Intel. It's a huge amount of power – easily enough to motor through any multi-threaded productivity task with more speed than anything else. However, cheaper Zen 2 CPUs will deliver

most of this performance for lower prices – at this end of the market, CPUs suffer from diminishing returns. You only need a 32-core Threadripper CPU if you're using very heavily multi-threaded software,

Meanwhile, the Seagate FireCuda 520 uses PCI-E 4 and offers sensational read and write speeds of 5,004MB/sec and 4,254MB/sec respectively. It's backed up by a SATA 4TB Samsung 860 QVO data drive, which runs at 547MB/sec and 486MB/sec – slower than the latest NVMe drives, but much quicker than a mechanical hard disk.

This PC's gaming pace is great too. Even though it's not a gaming system, the RTX 2080 Ti stomped through our benchmarks at 2,560 x 1,440, and while it struggled with Battlefield V at 4K with DXR on high settings, its 99th percentile frame rate improved to 51fps with DLSS enabled.

The hefty Enermax CPU cooler does a good job with temperatures too – the CPU's delta T of 50°C is fine. The GPU remained cool throughout as well. What's more, the Chillblast's fan noise is no louder than conventional gaming rigs when idle, and the noise is easy to mask. The noise modulates during games, but a headset or speakers will render the system inaudible. This PC makes more noise when the CPU is stressed, which is no surprise, but it's acceptable given the power on offer if you really need it.

## Conclusion

That price, though, is a stumbling block. It includes system building costs and warranty, but you could save hundreds by opting for a more conventional case or a cheaper AMD CPU. That said, the Conqueror isn't built for cost saving. The Chillblast provides the absolute pinnacle of CPU performance – and, for people who need to motor through multi-threaded work tasks, that's vital. The Chillblast pairs this incredible speed with great components elsewhere alongside sensational aesthetics. It's an awesomely powerful PC if you can afford it.

MIKE JENNINGS

## VERDICT

Incredible CPU power and design, albeit for an eye-watering price.



### WILLIAM

- + Lashings of CPU power
- + Great component choices
- + Eye-catching, bold chassis

### HAROLD

- Extremely expensive
- Chassis design won't suit everyone
- Noisy when CPU is loaded

### PERFORMANCE

25/25

### DESIGN

23/25

### HARDWARE

24/25

### VALUE

17/25

### OVERALL SCORE

89%





## GAMING PC

CYBERPOWER  
ULTRA 7 RTX/ **£1,899** incVATSUPPLIER [cyberpowersystem.co.uk](http://cyberpowersystem.co.uk)

## SPEC

## CPU

3.9GHz AMD Ryzen 7 3800X

## Motherboard

MSI MPG X570 Gaming Edge WiFi

## Memory

16GB Corsair Vengeance Pro RGB 3200MHz DDR4

## Graphics

MSI GeForce RTX 2080 Super 8GB

## Storage

500GB Seagate FireCuda 520 M.2 SSD, 2TB Seagate Barracuda hard drive

## Networking

Dual-band 802.11ac Wi-Fi, Gigabit Ethernet

## Case

Corsair iCUE 465X RGB

## Cooling

CPU: Corsair Hydro H100i RGB Platinum with 2 x 120mm fans; GPU: 2 x 90mm fans; front: 3 x 120mm fans; rear: 1 x 120mm fan

## PSU

Corsair RM750x 750W

## Ports

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

## Operating system

Microsoft Windows 10 Home 64-bit

## Warranty

Two years parts and labour with six months collect and return, followed by one year labour only return to base

**C**yberPower's new Ultra 7 RTX is a no-nonsense build that offers a good specification at a lesser price than rivals. Despite costing under £1,900, it deploys an MSI GeForce RTX 2080 Super GPU graphics card, with 3,072 stream processors, and 8GB of 15.5GHz (effective) GDDR6 memory.

Meanwhile, the CPU is an 8-core Ryzen 7 3800X at stock speed, so it runs at 3.9GHz with a 4.5GHz turbo peak. Comparatively, the Stormforce Crystal RTX 2080 Super used the same GPU alongside a slower Ryzen 7 3700X CPU, but with a higher price of £1,999. Similarly, last month, CyberPower's own Infinity X99 Super (see Issue 198, p38) arrived at £1,999, using the same MSI RTX 2080 Super card alongside an 8-core Intel Core i9-9900KS.

The Ultra 7 RTX also has an X570 motherboard, so you get PCI-E 4 support, with the 500GB Seagate FireCuda 520 SSD promising great speeds. There's also 16GB of 3200MHz memory, and a 2TB hard disk. It's all powered by a fully modular Corsair RM750x, which has 80 Plus Gold certification, putting it ahead of both the aforementioned competing PCs.

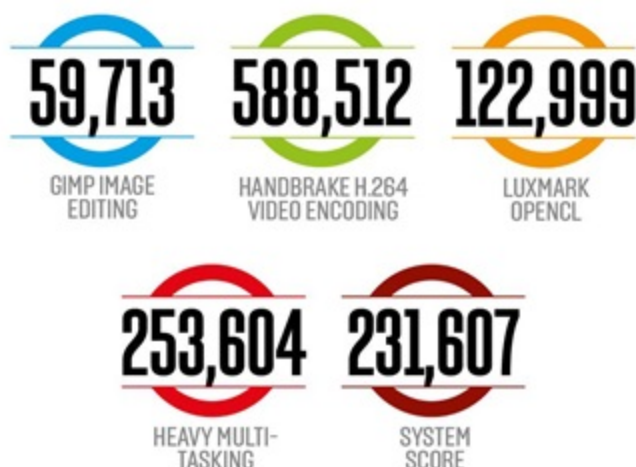
The MSI motherboard is otherwise basic, though, with a couple of spare memory slots, a vacant M.2 port and three empty 1x PCI-E slots alongside several spare SATA ports. However, there's no provision for a second GPU in SLI. There are no on-board buttons either, and the heatsinks are small and plain. The board has Gigabit Ethernet, dual-band 802.11ac wireless and Bluetooth 4.2, but no Wi-Fi 6 or Bluetooth 5. At the rear, there are several USB 3.2 ports, a Type-C connection and a BIOS Flashback button, but little else.

The components slot inside a decent Corsair iCUE 465X mid-tower chassis. Its tempered glass front and side panels look great, the RGB intake fans look bold and build quality is solid. CyberPower has kept cables tidy at the front with the help of rubber grommets and a PSU shroud, while the illuminated fans are joined by DDR4 lighting, and a smart ring of RGB LEDs on the Corsair Hydro cooler's waterblock.

The radiator is also stowed in the front of the chassis, so it doesn't intrude on other components. The rear serves up four 2.5in drive mounts and a sole tool-free 3.5in bay, alongside



## BENCHMARK RESULTS



### SHADOW OF THE TOMB RAIDER

2,560 x 1,440, Highest Detail, TAA



3,840 x 2,160, Highest Detail, TAA



### TOTAL WAR: WARHAMMER II

2,560 x 1,440, Ultra Detail, DX11, FXAA



3,840 x 2,160, Ultra Detail, DX11, FXAA



### BATTLEFIELD V

2,560 x 1,440, DX12, Ultra settings, High DXR, TAA



3,840 x 2,160, DX12, Ultra settings, High DXR, TAA



Minimum Average

a fan controller with three vacant spots. It's untidy here, though, with wires blocking some upgrade routes, including some wires lashed to a 2.5in caddy with cable ties.

Finally, CyberPower's warranty has three years of labour coverage and two years of parts protection. That's a good deal, although it's a shame you only get collect and return cover for the first six months.

## Performance

The RTX 2080 Super will handle any game at 1080p and it's very quick at 2,560 x 1,440 as well. It returned 99th percentile frame rates of 63fps and 76fps in Warhammer and Shadow of

the Tomb Raider at this resolution. The RTX 2080 Super just about handles 4K gaming too – in those two titles, its 99th percentile minimums of 36fps and 41fps are playable, and toning down a few settings will enable you to get smoother frame rates too.

Ray tracing is a big challenge for this GPU at 4K though. In Battlefield V at 2,560 x 1,440 with High DXR and RAA, the 99th percentile result of 46fps is playable, but it dropped right down to 16fps at 4K. To get ray tracing running smoothly, you'll need to turn to DLSS, which saw the 2,560 x 1,440 99th percentile result jump to 59fps. At 1080p and 2,560 x 1,440, this machine offers decent gaming performance, getting beyond 60fps in most games, and it will also play most games at 4K if you're willing to tweak settings.

The CPU is quick too, with an overall score of 231,607 that outpaces the weaker AMD chip in the Stormforce machine. The SSD is very impressive as well, with read and write speeds of 4,538MB/sec and 2,446MB/sec. The CyberPower can handle everyday computing, gaming and work tasks, including video and photo editing, fine. That said, the Core i9-9900KS in last month's CyberPower was faster, so it's a better option if you need the best performance possible.

This machine is a good thermal performer as well. Its peak CPU and GPU delta Ts of 64°C and 53°C are fine. It's quiet when idle, only a little louder during games and modest during a full-system test. It isn't silent, but it's not intrusive and the noise is easy to mask.

## Conclusion

CyberPower's Ultra 7 RTX offers great performance for the money, with enough pace for 2,560 x 1,440 gaming at top settings, plus decent CPU speed. The SSD is fast, the chassis is reasonable and it remains quiet, especially when compared with last month's CyberPower Infinity X99 Super. It's also £100 cheaper than its rivals. The only downers are the basic motherboard and the slower gaming performance compared with the Core i9-9900KS-equipped Infinity X99 Super. The Ultra 7 RTX has a better balance, though, with quieter operation, a faster SSD, a better PSU and a cheaper price.

MIKE JENNINGS

## VERDICT

A well-balanced build with good all-round performance and a fair price, although it struggles with ray tracing beyond 2,560 x 1,440.



### ULTRA

- + Superb performance
- + Smart, sturdy and quiet
- + PCI-E 4 SSD

### ULTRON

- Can't handle ray tracing at 4K
- Some Intel chips are faster in games
- Basic motherboard

### PERFORMANCE

21/25

### DESIGN

21/25

### HARDWARE

21/25

### VALUE

22/25

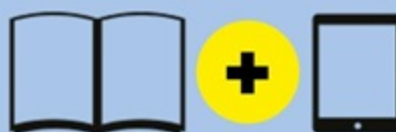
### OVERALL SCORE

85%



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# Custom kit

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

## ADATA SE800 / £149.99 inc VAT

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

If the ADATA SE800 represents what we can expect from USB drives in the future, then PC storage could be changing radically. It's a 1TB SSD with a USB 3.2 Gen 2 interface and a USB Type-C connector. What first strikes you is that there's so little to it – the SE800 is tiny, lightweight and also certified for IP-68-grade dust and water resistance, thanks to the rubbery cover for the connectors.

Secondly, it's reasonably inexpensive, particularly when you consider its speed. We didn't have a USB 3.2 controller with which to test the drive, but it's still fast when it's plugged into a standard USB 3 port – when tested with CrystalDiskMark, we clocked a read speed of 463MB/sec and a write speed of 454MB/sec.



That's considerably slower than the latest NVMe PCI-E SSDs, but close to a SATA SSD. For comparison, a USB 3 hard drive on the same test bed could only produce 37MB/sec read and 38MB/sec write speeds.

Of course, this drive is great for quick backups and portability, but you could also install games on it and it would be fine. Speeds are expected to be higher when connected to a USB 3.2 port, but these are still rare. Even without one, the SE800 nails the landing with a neat, robust and reasonably priced drive.

Terrible ●●●●● Terabyte

## MAYOGA TABLET HOLDER /

£18.49 inc VAT

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



The Mayoga is a tablet or phone holder based around a metal arm and a series of springs, clamps and pivots. The result feels a lot like the arm of a desk lamp, with the same sort of range of movement. This would be fine if the Mayoga was only seeking to be the arm of a desk lamp, but it needs to do more as a tablet or phone holder. Let's start with the grip for the phone or tablet – there are interchangeable parts to hold onto the device and neither works particularly well, relying on a plastic slide – it really needs a more solid gripping system.

Also, the lamp-light angles and postures that the arm achieves are better suited to a light hanging down than a device that might want to face in any number of directions for use. Any adjustment to the pivots needs to be followed by a tightening of the bolts to lock it back into place, but even then it's not entirely solid when using a device with a touch-screen. It does look quite smart when it's set up in place, in a monitor-arm sort of way, but there are better ways to do this job.

Ghost ●●●●● Tablet



## BRISKYTO CABLE CLIPS

/ £5.95 inc VAT

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

The Briskyto Cable Clips are designed to hold your cables neatly together, while being stuck to a flat surface. You get three different-sized, rubbery black cable clips with a strip of double-sided tape on the bottom – the biggest holds seven cables, then five, then three.

The grips are best sized for USB cables, power cables or those of a similar size. The cable clips don't look bad, and they would fit right in with a mostly black desktop setup. They're very useful if you've found yourself with an unkempt USB hub, or if you have USB cables trying to form some sort of electronic king rat and you need to restore order.

Rat nest ●●●●● Mouse pad



## ROCKETBOOK SMART NOTEBOOK

/ **£32.99** inc VAT

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

The Rocketbook Smart notebook is a reusable lined notebook. You write on the pages with the supplied Pilot Frixion pen, or a marker or highlighter, and then you erase it with the eraser on the end of the pen, or a damp cloth. The cloth is also supplied but you're going to need your own damp.

Writing on the pad feels good. It's slimmer than a normal paper pad, which is fine because it's reusable, but there's enough there to give it a comfy writing surface. The idea of the reusable pad has been done elsewhere, and significantly cheaper, but the Rocketbook's ace in the hole is its app, which allows you to take pictures of your pages of notes on a phone

or tablet and upload them seamlessly into cloud-based storage. There's a line of icons at the bottom – you cross out the icon you want, then your phone camera uploads the picture based on that icon to the corresponding account.

The app is very easy to set up, and you can choose up to seven different storage options to correspond to each icon and connect through the app. For example, if you log in with a Google account, the notes are sent to your mail. The Rocketbook is a great bridge for getting your random notes and cobweb doodles into cloud storage.

Rocket salad ●●●●○ Rocket boots



## LUMINOODLE USB BIAS LIGHTING / **£24.99** inc VAT

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

This set of USB-powered lights is designed to sit on the back of your monitor, providing white light that eases eye-strain from watching in the dark and improve contrast. The effect is quite striking visually, although the Luminoodle LEDs lack the versatility of many other similar systems that offer different-coloured lights.

The LEDs are tiny, mounted on a narrow strip that sticks firmly. Prior experience with such devices has shown that their worst enemy is often their own mass, and the unwillingness of the strips to stay stuck once shaped to fit, so Luminoodle has got this right.

The lights switch on when plugged in, and there's no means to control them beyond this without buying an additional controller. This is available as an extra remote control with a dimmer switch, although it should be a part of the pack anyway. The Luminoodle is a neat, though slightly incomplete, bias lighting setup.

Ramen ●●●●○ Lumi

Seen something worthy of appearing in Custom Kit? Send your suggestions to [phil.hartup@gmail.com](mailto:phil.hartup@gmail.com)



## LABS TEST

# Graphic equaliser

**Ben Hardwidge and Edward Chester** delve into the tangled web of the £150–£350 graphics market, in order to find the sweet spots

## How we test

**A**ll our graphics card tests are performed on our graphics test rig, incorporating a Core i7-8700K CPU overclocked to 4.7GHz on all cores, 16GB of 3000MHz Corsair Vengeance LED DDR4 memory and a Gigabyte Z370 Aorus Gaming 5 motherboard.

### Minimum gauge

For a long time, we've said that the minimum frame rate is a more important metric than the average. While the average may be a fair representation of what you're likely to experience for the most part, it's the minimum that you'll really notice when you're playing a game, so you want to know the worst-case scenario.

However, we're now taking a more nuanced approach to the way we calculate the minimum. Until now, we've reported the very lowest frame rate recorded in each benchmark as the minimum, but this might only come down to the occasional rogue dropped frame, and it can also make it difficult to get reliably repeatable results in some benchmarks.

When you're playing a game, an occasional rogue dropped frame might be a bit annoying, but it's only a split second before you can get on with playing again. If you experience prolonged periods of slowdown for a few seconds then that's a bigger problem. For this reason, we've adopted a new way of reporting frame rates.

Using Nvidia's FrameView app ([custompc.co.uk/FrameView](http://custompc.co.uk/FrameView)), we record the frame rate, and the software also organises them into

Custom PC's graphics test rig has a Core i7-8700K overclocked to 4.7GHz on all cores







We now use Nvidia's FrameView software to measure the 99th percentile frame rates

percentiles, so you can see what frame rate you're likely to maintain most of the time. Instead of the very minimum, we're now reporting the 99th percentile frame rate for each benchmark.

This means that 99 per cent of the frame rates recorded in each benchmark are at this figure or above. Occasional dropped frames are discarded as part of the 1 per cent (unless there's an awful lot of them), but noticeable, prolonged drops in the frame rate are recorded.

There are other benefits to using FrameView over FRAPS. The latter doesn't work in all DirectX 12 titles, for example, and FrameView also allows us to benchmark with Vulkan. As before, we run every test at least three times at each resolution, discarding spurious results, and then reporting the average.

## Red Dead Redemption 2

We wanted to replace our aging Deus Ex: Mankind Divided test with a new game that used a different API, and Red Dead Redemption 2 fits the bill perfectly. When you fire up the game, it automatically detects your hardware and applies the settings it thinks will work best.

That's good for gamers, as it means you can get the game working on a variety of different levels of hardware. As benchmarkers, however,

it causes a few problems, because it also changes the definition of the blanket presets – the High preset on one card will enable different graphics settings than the same preset on another card.

For this reason, we have to use our own custom settings and apply them again from scratch each time we install a new card. We couldn't just set every setting to Ultra, either, as it would then take up too much graphics memory (there's a handy chart in the game to show you how much memory your chosen settings need).

As a compromise, we turn on nearly every advanced graphics feature, set the individual settings to High and set the sliders around three quarters of the way across. This enables us to compare GPUs on a like-for-like basis in a demanding test. We run the game's built-in benchmark, and set FrameView to record the end portion, which is based on real gameplay.

## Ray tracing and DLSS

Due to teething problems when Battlefield V was first released, we used to run it in both DirectX 11 and 12, but we now just test in the latter mode. We record a custom play-through in the Under No Flag War Story with FrameView. If a card supports ray tracing, we also test it in two modes. One with High DXR and TAA enabled, which shows us how the GPU copes with ray tracing at the 'true' resolution, while also enabling us to compare cards that don't support DLSS, such as Nvidia's GeForce GTX 1660 series.

On Nvidia's RTX cards, we also test with DLSS. This method of super-sample anti-aliasing effectively renders at a lower resolution than the one selected, and scales it up using Nvidia's Tensor cores. It enables you to switch on ray tracing while getting smoother frame rates. It generally looks fine at 2,560 x 1,440 and above, but it can look overly blurry at 1080p, as the resolution from which it's scaling is so much lower.

We're also now incorporating ray tracing into our scores. It has a low weighting (10 per cent), as only a few games support it and not everyone is fussed about it. However, the list of supporting games is growing, and CyberPunk 2077 will also support it when it's released this year.

Our other tests are Total War: Warhammer II, using DirectX 11, as the DirectX 12 beta has stuttering issues with Nvidia's current drivers – we record the built-in Battle benchmark with FrameView. We also record the built-in benchmark in Shadow of the Tomb Raider with FrameView, running it at the Highest graphics preset with TAA. Finally, we run Unigine's Superposition benchmark to load the GPU, and record the power draw at the mains using a Watts Up? Pro meter.

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# ZOTAC GEFORCE GTX 1650 SUPER / £150 inc VAT

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



**T**he Nvidia GeForce GTX 1650 Super provides a notable upgrade over the original GTX 1650 thanks largely to a big increase in its stream processor count. Where the older card had just 896, the new version packs in 1,280. Elsewhere, though, this card is as modest as its price suggests.

The card itself is tiny, measuring just 159mm in length, which is barely longer than the PCI-E slot. Despite this modest size, Zotac has equipped the card with two fans, but they produce quite an irritating high-pitched whirr when the card is under load. A 6-pin PCI-E power cable is also required.

The TU117 chip that powers this card ticks over at 1530MHz with a 1725MHz boost clock. There are variants with slightly quicker boost clock speeds but only up to around 1800MHz, so there's very little in it. You also get 4GB of

GDDR6 memory running at 12GHz (effective), which interfaces with the GPU over a modest 128-bit interface, making for a total bandwidth of 192GB/sec. Attached to this is the render back end that incorporates 32 ROPs. For video outputs, you get one each of DisplayPort 1.4, HDMI 2b and DVI-D DL.

The GTX 1650 Super is based on Nvidia's latest Turing architecture but it has one crucial omission – hardware ray-tracing support. Unlike the GTX 1660-series GPUs, the 1650 Super doesn't even support ray tracing via its CUDA cores. As such, ray tracing is a non-option although, given its overall lack of horsepower, it's not like enabling ray tracing in games would result in playable frame rates anyway.

We noticed a couple of issues when we put this card to the test too. Firstly, the boost clock quickly slows down after a few minutes, as first runs of our tests were consistently faster than subsequent runs, resulting in 4-5fps drops in performance in some instances. The worst-case results are those that we've used in our graphs. The card also struggled to run Red Dead Redemption 2 at 2,560 x 1,440, with it crashing several times, though we did eventually record some results.

Otherwise, the performance picture is clear. The GTX 1650 Super offers a solid improvement in performance across the board compared with the GTX 1650. Whereas the older card offered nearly half the speed of the 1660 in previous testing, the 1650 Super significantly closes the gap.

Nonetheless, by and large, we're looking at 1080p gaming only here. In all our tests, the 1650 Super delivered over 30fps at this resolution but couldn't do the same at 2,560 x 1,440. In older, less graphically rich titles, you'll be able to play at higher resolutions but we certainly wouldn't recommend this card for higher-resolution gaming overall.

## Conclusion

The Zotac GeForce GTX 1650 Super is a decent option for entry-level gaming. It offers reliable 1080p gaming performance, it has a low power draw and it can be had for under £150 (just). However, AMD's Radeon RX 590 is significantly faster for only an extra £15, and if there's room in your budget, it's also worth another £50 to get the much faster GTX 1660 Super.

## VERDICT

A decent 1080p entry-level option, but you don't have to spend much more money to get much quicker performance.

## SUPERMAN

- + Low price
- + Much faster than GTX 1650
- + Low power draw

## SUPERGRAN

- Variable boost performance
- Slightly whiny fans

## SPEC

**Graphics processor** Nvidia GeForce GTX 1650 Super, 1530MHz base clock, 1725MHz boost clock

**Pipeline** 1,280 stream processors, 32 ROPs

**Interface** PCI-E 3

**RT Cores** 0

**Tensor Cores** 0

**Memory** 4GB GDDR6, 1500MHz (12GHz effective)

**Memory interface** 128-bit

**Bandwidth** 192GB/sec

**Outputs/inputs** 1x DisplayPort 1.4, 1x HDMI 2b, 1DVI-D DL

**Power connections** 1x 6-pin

PERFORMANCE

33/50

EFFICIENCY

9/10

RAY TRACING

0/10

VALUE

24/30

OVERALL SCORE

66%





# AMD RADEON RX590 / **£165** inc VAT

SUPPLIER scan.co.uk

## SPEC

**Graphics processor** AMD Radeon RX 590, 1469MHz base clock, 1580MHz boost clock

**Pipeline** 2,304 stream processors, 32 ROPs

**Interface** PCI-E 3

**RT Cores** 0

**Tensor Cores** 0

**Memory** 8GB GDDR5, 8GHz effective

**Memory interface** 128-bit

**Bandwidth** 256GB/sec

**Outputs/inputs** 3 x DisplayPort 1.4, 1 x HDMI 2b, 1 x DVI-D

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

## RADAR

- + Good 1080p performance
- + Low price
- + 8GB of memory

## SEMAPHORE

- No ray tracing
- Very high power consumption
- Needs lots of cooling power

**T**he Radeon RX 590 was something of a last gasp for the company's Graphics Core Next architecture. Designed as a drop-in upgrade for OEMs, the GPU could be used on existing RX 580 board designs. Indeed, the GPU is basically just an RX 580 with a die shrink and clock speed boost. Over a year since launch – and many years since the GCN architecture debuted – and this card is seriously showing its age, but hefty price drops mean it still has some merit.

The major downside to this older architecture, though, is woefully bad power efficiency. This card tops the power usage charts in this group test by some margin, despite it being far from the fastest. That's why our sample XFX card also required two large fans and a hefty heatsink equipped with four heatpipes to keep it cool. You'll also need plenty of additional power, with both a 6-pin and an 8-pin PCI-E power socket sitting on the top edge of this card.

When it comes to gaming performance, though, the surprisingly low price means this card can defy its age, consistently delivering performance that beats the GeForce GTX 1650 Super, GTX 1660 and RX 5500 XT. In this regard, it's a standout bargain for cards

of its class. However, we really can't ignore that power consumption, plus this clocked-up GPU also gets very hot, requiring substantial cooling. On our sample XFX Fatboy card, the large cooler also stretches beyond the width of two PCI-E slots, so you'll need to give

over three slots to accommodate it. The cooler isn't too noisy, but it's massive. XFX has at least made good use of the extra bulk of this card, though, by equipping it with three DisplayPort sockets as well as an HDMI and DVI. The addition of a DVI port reduces the ventilation through the backplate though.

What's more, opting for this older GPU (or indeed any AMD GPU at the moment) means you miss out on the buzz feature of the moment, in the form of hardware ray-tracing support. While some of Nvidia's cheaper cards also omit this feature – or only have it in a compromised form – AMD's cards simply don't support it at all at the moment. In coming years, the already aging architecture of this GPU will also see it becoming less futureproof.

## Conclusion

At first glance, everything about the AMD Radeon RX 590 suggests it shouldn't be much of a contender. It's an old card based on an old architecture that's infamously power-hungry and lacks the allure of hardware ray-tracing support. However, sheer gaming performance and a very low price mean it's surprisingly competitive, even now. What's more, unlike most sub-£200 graphics cards, it also comes with 8GB of memory. If you can afford to stretch your budget, you'll be much better off overall saving up for a GTX 1660 Super, but if there's no slack, the Radeon RX 590 is currently a cracking 1080p gaming card for a surprisingly reasonable price.

## VERDICT

**A surprise price/performance champion, but spending just a little more money will get you more features and far lower power consumption.**

PERFORMANCE

37/50

EFFICIENCY

4/10

RAY TRACING

0/10

VALUE

29/30

OVERALL SCORE

**70%**





# NVIDIA GEFORCE GTX 1660 / £180 inc VAT

SUPPLIER scan.co.uk

**A**t a glance, the GTX 1660 seems to be a sensible next step up over the GTX 1650 Super, with more stream processors and ROPs for just £30 more. However, its use of GDDR5 RAM holds it back. This older RAM standard uses more power and, despite this card having a wider 192-bit memory interface than the 128-bit interface of the GTX 1650 Super, its slower speed means you only get the same overall memory bandwidth as the cheaper card.

All that said, its performance is still decent, thanks to the sheer horsepower of the TU116 GPU at its heart, despite it having had two streaming multiprocessors disabled. In our tests, it managed to stay above 60fps in Battlefield V at 1080p, which is decent for this price of card. It fared less well in our other

## THE FORCE

- + Reliable 1080p gaming performance
- + Hardware ray-tracing support
- + 6GB of memory

## THE SCHWARTZ

- No dedicated RT cores
- Slow GDDR5 memory
- Only £19 more for much better performance

## SPEC

**Graphics processor** Nvidia GeForce GTX 1660, 1530MHz base clock, 1785MHz boost clock

**Pipeline** 1,408 stream processors, 48 ROPs

**Interface** PCI-E 3

**RT Cores** 0

**Tensor Cores** 0

**Memory** 6GB GDDR5, 2GHz (8GHz effective)

**Memory interface** 192-bit

**Bandwidth** 192GB/sec

**Outputs/inputs** Usually 3 x DisplayPort 1.4, 1 x HDMI 2b

**Power connections** 1 x 8-pin



more demanding tests, but still delivered around 40fps in most games at 1080p. Crank down the detail settings in these games and you'll comfortably be looking at over 60fps.

The GTX 1660 also fairly consistently beats the AMD Radeon RX 5500 XT 8GB, although notably, it loses out to the cheaper AMD Radeon RX 590. As such, for pure gaming performance, the older AMD card is the better bet, even if it does draw a ridiculous amount of power.

Another reason some may be tempted by this Nvidia card, though, is that it's the cheapest way of getting hardware ray tracing support. You don't actually get dedicated RT cores in the GPU, but Nvidia has enabled ray-tracing support via the standard CUDA cores. Unfortunately, the combination of an already modest card combined with the extra demands of ray tracing means you won't exactly be pushing the limits of even a 60Hz monitor. In Battlefield V with ray tracing, this card hit 27fps (99th percentile) and a 34fps average, dropping to 15fps and 21fps respectively at 2,560 x 1,440.

What really hurts the appeal of the GTX 1660, though, is the proximity in price of the much more capable GTX 1660 Super. For just £19 more, you get a big uplift in performance thanks to its faster GDDR6 memory.

Meanwhile, a single 8-pin PCI-E power socket is required to get the card going, so

those with only the very cheapest power supplies may require an upgrade – the cheapest PSU on [overclockers.co.uk](https://www.overclockers.co.uk), for instance, has only a single 6-pin PCI-E cable. However, the GTX 1660 is pretty power-efficient, especially compared with the Radeon RX 590, and it doesn't require an enormous amount of cooling power.

## Conclusion

The addition of hardware ray-tracing support broadens the appeal of the Nvidia GeForce GTX 1660 over other cheaper graphics cards. However, you likely won't be playing many games with this feature for long, as performance is woeful. General rasterisation performance is decent for the money, but the GTX 1660 Super makes far more sense for just an extra £20, and the cheaper Radeon RX 590 is also faster if you want to save some cash.

## VERDICT

A versatile, affordable graphics card, but its reliance on GDDR 5 memory means it's not a standout bargain.

PERFORMANCE

36/50

EFFICIENCY

9/10

RAY TRACING

1/10

VALUE

24/30

OVERALL SCORE

70%





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## ZOTAC GEFORCE GTX 1660 SUPER / £199 inc VAT

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

**W**e've alluded to it several times on previous pages and here it finally is: the current sub-£200 champion graphics card, the GTX 1660 Super. Built on the same Nvidia TU116 GPU as the GTX 1660, the Super version houses the same number of stream processors and runs at the same base and boost clock speeds as its cheaper sibling, but crucially, it uses GDDR6 memory. This one change makes all the difference, as memory bandwidth leaps from 192GB/sec to 336GB/sec, unlocking a huge amount of extra performance.

Our sample Zotac GTX 1660 Super card has two fans that, intriguingly, are different sizes. This card isn't an exotic delight for the sight, and there are no fancy frills such as RGB lighting, but the Zotac GeForce GTX 1660 Super still has a smart look. More

### SPEC

**Graphics processor** Nvidia GeForce GTX 1660 Super, 1530MHz base clock, 1785MHz boost clock

**Pipeline** 1,408 stream processors, 48 ROPs

**Interface** PCI-E 3

**RT Cores** 0

**Tensor Cores** 0

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

**Memory interface** 192-bit

**Bandwidth** 336GB/sec

**Outputs/inputs** 3 x DisplayPort 1.4, 1 x HDMI 2b

**Power connections** 1 x 8-pin

importantly, this card does a good job when it comes to cooling and noise control. Those two fans do an excellent job of keeping on top of heat transfer, remaining surprisingly quiet even long into gaming sessions. This will depend on the airflow configuration of your case, though, as this isn't a blower-style cooler (along with most of the cards on test), so little hot air is exhausted out the back of the card.

Zotac has helped where possible with heat exhaustion by opening up one whole side of the rear I/O bracket. This means you miss out on a fifth video output, but the three DisplayPort sockets and single HDMI port will be enough for most. Like the GTX 1660, a single 8-pin PCI-E power adaptor is required to get enough juice to this card.

When it comes to gaming performance, this card really shows the importance of memory bandwidth. In Battlefield V at 2,560 x 1,440, for instance, performance leaps up by 22 per cent, from 48fps to 59fps, compared to the GTX 1660. The gains aren't always so striking elsewhere, but in Total War: Warhammer II at 2,560 x 1,440, we also see a leap from 25fps to 34fps.

The extra memory bandwidth can't perform miracles, though, and this card still struggles with ray tracing due to its lack of dedicated RT cores. A frame rate of 31fps at 1080p is the best it could manage in our testing – it's technically borderline playable, but you really need a much higher frame rate for a game such as Battlefield V.

### SUPERB

- + Reliable 1080p performance
- + Can stretch to some 2,560 x 1,440 gaming
- + Ray-tracing support
- + GDDR6 memory

### SOUP HERB

- No RT cores
- Poor ray-tracing performance

Crucially, what the GTX 1660 Super delivers is a perfect sweet spot of price and performance. It comfortably outperforms the GTX 1660 while costing just £19 more, and it only trails the GTX 1660 Ti by a handful of FPS, despite costing £45 less. It also comfortably outpaces the AMD Radeon RX 590 while consuming far less power.

### Conclusion

The Nvidia GTX 1660 Super is the undisputed king of the sub-£200 graphics card market right now. It offers an excellent balance of performance and price while including support for the latest ray-tracing features. Several cards get close to it in some areas, but the GTX 1660 Super comfortably tops the charts when it comes to bang for your buck.

### VERDICT

At current pricing, the GTX 1660 Super is the card to get if your budget can't stretch beyond £200.

PERFORMANCE

39/50

EFFICIENCY

9/10

RAY TRACING

2/10

VALUE

26/30

OVERALL SCORE

76%



# ASUS ROG STRIX RADEON RX 5500 XT 8GB / £229 inc VAT

SUPPLIER ebuyer.com

**T**he Radeon RX 5500 XT is built on AMD's latest RDNA architecture, which not only brings improved performance but also vastly improved power efficiency over the company's previous GCN architecture. As such, despite delivering performance that's in the same ballpark as the Radeon RX 590, the 5500 XT has a substantially lower TDP.

This improvement comes both from the architecture itself but also the move

from a 12nm manufacturing process to a 7nm process. In our tests, our system drew 135W less power under load with this card, compared with the RX 590. It's based on AMD's Navi 14 GPU, and houses 1,408 stream processors and 32 ROPs.

Our Asus test sample also runs at similar clock speeds to those competitors around it, with a base clock of 1737MHz and boost clock of 1845MHz. GDDR6 memory is also in use, with 8GB of it running at a hefty 14GHz effective speed. The card even uses the new PCI-E 4 interface. However, the RX 5500 XT just a 128-bit memory interface, which is considerably narrower than several cards in its class. That said, the use of GDDR6 memory means it still boasts a 224GB/sec memory bandwidth, which at least outpaces the GTX 1660.

All of the above would suggest that the price of this card would sit someone between the GTX 1660 and GTX 1660 Super, but that's not the case with this particular Asus card. This Asus ROG Strix variant is up to £31 pricier than some other 8GB versions of this card, plus there are 4GB versions that start at just £160, which is much closer to the pricing we'd expect for a card of this calibre. As such, while this card may not leap out as great value for money, other versions fare better.

You do get some RGB lighting on the edge for your money, as well as a reasonably

smart design. There are two good-quality fans and a switch that lets you swap between quiet and performance modes, with the latter enabling a 1865MHz clock speed boost (we tested at this setting). The fans ramp up and down noticeably in performance mode but the quiet mode is true to its name. It's a good premium design overall, but it does feel like overkill for a relatively low-budget GPU.

As expected from its spec sheet, the performance of this card puts it in direct competition with the GTX 1660, with the two cards trading blows throughout our testing. As such, as we've already recommended the GTX 1660 Super over the GTX 1660, and with AMD cards lacking ray tracing, the RX 5500 XT (and particularly this pricier Asus model) isn't the obvious choice at this price range. Even if the 4GB cards perform similarly, you'd still be better off buying AMD's Radeon RX 590 and getting twice as much memory.

## Conclusion

The AMD Radeon RX 5500 XT is a decent GPU overall, and a huge improvement over previous power-hungry AMD budget GPU designs. However, this Asus version is just too expensive for the performance it delivers. With a drop in price, AMD's Radeon RX 5500 XT would be worth considering, but at this price, we recommend opting for the GTX 1660 Super instead.

## SPEC

**Graphics processor** AMD Radeon RX 5500 XT, 1737MHz base clock, 1845MHz boost clock

**Pipeline** 1,408 stream processors, 32 ROPs

**Interface** PCI-E 4

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

**Memory interface** 128-bit

**Bandwidth** 224GB/sec

**Outputs/inputs** 3 x DisplayPort 1.4, 1 x HDMI 2b

**Power connections** 1 x 8-pin

## PEGASUS

- + Solid 1080p performance
- + Improved power efficiency
- + 8GB of memory

## PONY

- Lacks ray-tracing support
- Too expensive
- Premium cooler is overkill



## VERDICT

Decent performance, but the wrong price, and this Asus ROG Strix design is overkill for the spec.

### PERFORMANCE

36/50

EFFICIENCY  
8/10

### RAY TRACING

0/10

VALUE  
21/30

### OVERALL SCORE

65%





## NVIDIA GEFORCE GTX 1660 Ti / £245 inc VAT

SUPPLIER scan.co.uk

**O**n paper, Nvidia's GeForce GTX 1660 Ti looks as though it would provide a comfortable upgrade in performance over the GeForce GTX 1660 and its Super variant, thanks to it using a fully enabled TU116 GPU.

Both the GeForce GTX 1660 and GTX 1660 Super have two of their streaming multiprocessors disabled, resulting in them having 128 fewer stream processors than the Ti model.

However, with the GTX 1660 Super clocked slightly higher and being otherwise identical to the GTX 1660 Ti, the performance gap between the two cards is much narrower than you might expect, particularly when the GTX 1660 Ti costs so much more money.

Physically, there's very little to tell the difference between a GTX 1660 Super and

GTX 1660 Ti, partner card tweaks aside. Most variants are around 230mm in length, come with two fans and require an 8-pin PCI-E power connector.

Diving into our testing, you can see that the GeForce GTX 1660 Ti does indeed sit just above the GTX 1660 Super but below the RTX 2060, as we'd expect.

However, the step up from the GTX 1660 Super is minimal, and not representative of the extra cost involved. At 1080p, we're looking at gains of 2-3fps in most tests, with a maximum gain of 5fps in one test.

Meanwhile, at 2,560 x 1,440, the performance difference comes down to just 1-2fps gains in most tests. This would be fine if the GTX 1660 Ti was only a handful of pounds more expensive than the Super, but in fact it costs considerably more. While the GTX 1660 Super can currently be bought for as little as £200 inc VAT, the GTX 1660 Ti costs closer to £250.

As a result, the GeForce GTX 1660 Ti, just doesn't have the bang for buck to stand out – the GTX 1660 Super is the better buy for gamers on tighter budgets, while the RTX 2060 (or indeed AMD's Radeon RX 5600 XT) is better for people with a little extra money to spend.

Otherwise, there's still plenty to like about this mid-range GPU, if you can pick one up for a discount price. While you don't get dedicated ray-tracing cores, the card does support DXR via its stream processors. It's barely playable in Battlefield V with DXR at

### NVIDIA

- + Fully enabled TU116 GPU
- + Low power draw
- + Entry-level ray tracing

### VIDEO NASTY

- Too expensive
- Barely faster than GTX 1660 Super

High settings, but it allows you some room to experiment at lower resolutions.

Power efficiency is decent too, with our test system drawing just 1W more under load with the GeForce GTX 1660 Ti installed than with the GTX 1660 Super.

### Conclusion

The GeForce GTX 1660 Ti was a decent choice before the GTX 1660 Super came along, but that's now changed. While it still has a slight performance advantage over its cheaper sibling, the lead is tiny and it costs quite a bit more money. It's worth picking up if you find a bargain but it's not great value for money at its current price of around £250 inc VAT.

### VERDICT

Stiff competition around it means the GTX 1660 Ti is no longer a top-tier mid-range graphics card.

#### PERFORMANCE

40/50

EFFICIENCY  
9/10

#### RAY TRACING

2/10

VALUE  
21/30

#### OVERALL SCORE

72%

### SPEC

**Graphics processor** Nvidia GeForce GTX 1660 Ti, 1500MHz base clock, 1770MHz boost clock

**Pipeline** 1,536 stream processors, 48 ROPs

**Interface** PCI-E 3

**RT Cores** 0

**Tensor Cores** 0

**Memory** 6GB GDDR6, 1.5GHz (12GHz effective)

**Memory interface** 192-bit

**Bandwidth** 288GB/sec

**Outputs/inputs** 3 x DisplayPort 1.4, 1 x HDMI 2b

**Power connections** 1 x 8-pin



# SAPPHIRE PULSE RADEON RX 5600 XT / £255 inc VAT

SUPPLIER overclockers.co.uk

**T**he Radeon RX 5600 XT is the latest addition to AMD's GPU range. Sitting between the pricier Radeon RX 5700 and cheaper 5500 XT, it's based on the same Navi 10 GPU as the Radeon RX 5700 and even has the same number of compute units and stream processors. However, it runs at lower clock speeds, has a narrower memory interface and less memory.

With a highly competitive price of £255 inc VAT for the Sapphire Pulse card we tested, it's in direct competition with the

Nvidia GeForce GTX 1660 Ti, and that means the RX 5600XT stacks up well. With 2,304 stream processors, it has buckets of parallel processing power. Both the GeForce GTX 1660 Ti and the Radeon RX 5600 XT also use a 192-bit memory interface, talking to 6GB of RAM, although this Sapphire card clocks the memory up to 1750MHz (14GHz effective), so it has more bandwidth than the Nvidia card.

This particular Sapphire Pulse card is a well-built, premium affair, although its extreme height may be a concern for those with smaller cases: it's 135mm tall, whereas as a standard expansion bracket is 120mm. Taking full advantage of that extra real estate, you get two large fans that not only stay still and silent when the card is idle, but remain impressively quiet when the card is under load too.

Output options consist of three DisplayPort sockets and one HDMI output, with the whole second expansion slot open for ventilation. A metal plate also sits on the back of the card, helping to protect the precious circuitry below.

A notch in the backplate allows access to a BIOS switch that lets you flip the card between a performance and a quiet mode. The 'silent' mode has a 1460MHz game clock, 1620MHz max boost clock and 12GHz (effective) memory clock. In this mode, the card comfortably outpaces the GTX 1660 Ti but still sits some way back from the RTX 2060 in our gaming tests.

Performance mode ups the clock speeds significantly, to a 1615MHz game clock and 1750MHz boost clock, along with a 14GHz (effective) memory clock. Sure enough, in this mode, this card seriously impressed, far outstripping the GTX 1660 Ti in all our tests and even beating the RTX 2060 in most tests too. The performance mode makes the fans slightly louder, but the noise isn't overly irritating – especially if you're wearing headphones – so we'd be inclined to leave the card on this setting.

Overall, the performance in this mode is plenty for 1080p gaming and adequate for 2,560 x 1,440 gaming. What's quite astonishing to find is that the card delivers all of this performance while consuming relatively little power. Our system drew 222W from the mains with the RX 5600 XT installed, compared to 241W with the RTX 2060. As with all of AMD's current GPUs, though, you miss out on ray-tracing support here, so it depends where your priorities lie.

## Conclusion

The Sapphire Pulse Radeon RX 5600 XT offers excellent bang per buck. At £255 inc VAT, this well-built card easily beats equivalent GeForce GTX 1660 Ti cards, but its lack of ray-tracing support hurts it compared with the GeForce RTX 2060. If getting the fastest performance for around £250 is your top priority then this card is the best in its class. However, if you want the best eye candy, it's still worth paying the extra cash for the RTX 2060's hardware ray-tracing support.

## SPEC

**Graphics processor** AMD Radeon RX 5600 XT, 1355MHz base clock, 1615MHz game clock, 1750MHz boost clock

**Pipeline** 2,304 stream processors, 64 ROPs

**Interface** PCI-E 4

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

**Memory interface** 192-bit

**Bandwidth** 336GB/sec

**Outputs/inputs** 3 x DisplayPort 1.4, 1 x HDMI 2b

**Power connections** 1 x 8-pin

## HEARTBEAT

- + Faster than RTX 2060
- + Low power draw
- + Great cooler

## CARDIAC ARREST

- No ray-tracing hardware
- Only 6GB of memory



## VERDICT

Excellent performance and power efficiency but no hardware ray-tracing support.

PERFORMANCE	43/50	RAY TRACING	0/10	OVERALL SCORE
EFFICIENCY	9/10	VALUE	28/30	
				80%



# NVIDIA GEFORCE RTX 2060 / £273 inc VAT

SUPPLIER Ebuyer.com



**T**he GeForce RTX 2060 is the cheapest entry point to the world of proper hardware-accelerated ray tracing. As the switch from GTX to RTX naming implies, this card provides you with dedicated RT cores for completely offsetting those calculations from the CUDA cores, providing a massive leap in ray-tracing performance. Originally launching at £329 inc VAT, recent price drops have brought it under £275, making it appear a very tempting option, if your budget allows.

Based on the TU106 GPU that also powers the RTX 2060 Super and RTX 2070, the RTX 2060 uses a considerably stripped-down version, with six SMs disabled, resulting in noticeable drops in capability across the board. The total number of CUDA cores drops from 2,304 to 1,920, the number of ROPs from 64 to 48, TMUs go from 144 down to 120 and RT cores drop from 36 to 30. The memory

interface also drops from 256-bit to 192-bit and total memory maxes out at 6GB.

The back-end limitations mean that while this card can cope with the extra graphical richness of more complex scenes – both with and without ray tracing – it isn't quite as capable as faster cards when it comes to higher resolutions and frame rates, at least in theory.

One big advantage of this reduction in processing capacity, though, is that you don't need any extra power over the other cheaper cards we've looked at. Just a single 8-pin power connector is required to keep this card ticking over, while RTX 2060 Super and other more powerful cards require another 6-pin cable or more.

This card really is all about its ray tracing, though, and sure enough in our testing, it proved just how much extra oomph those RT cores provide. In Battlefield V with DXR, it hit a genuinely playable frame rate average of 55fps, with a 99th percentile drop of just 46fps. Those represent big leaps over the 40fps and 32fps scores of the GTX 1660 Ti. Even at 1440p you get 33fps average while the GTX 1660 Ti struggles to 26fps. That may not be truly playable but could be fun to explore.

What's more, we can really see how much of a difference those RT cores make when we compare games without ray tracing. In our other tests, we see an average rise in frame rate of 17 per cent, whereas in Battlefield V with DXR we see a 38 per cent difference.

As such, while this card does generally impress across the board, its appeal in many ways comes down to how important ray tracing is to you. If you just want to be able to

## RTX

- + Good gaming performance up to 1440p
- + Playable ray-tracing performance
- + Competitive pricing

## ARTEX

- Limited to 1080p or lower resolution for ray tracing
- Not a huge upgrade for non-ray-tracing games

play around with it and see what it looks like, you can do that on the much cheaper GTX line-up. If, however, you genuinely want to play games with it enabled, you're going to need at least an RTX 2060. Perhaps crucially, though, you may need an even faster card, as otherwise you'll be stuck having to play resolutions often lower than 1080p.

## Conclusion

The RTX 2060 is the ideal mid-range card for most buyers – it offers excellent all-round 1080p gaming performance and generally reliable 1440p gaming too. Add in genuinely playable ray-tracing performance, Tensor cores, DLSS support and a competitive price and you have a winner.

## VERDICT

**An ideal all-rounder for those seeking a mid-range graphics card.**

### PERFORMANCE

43/50

### EFFICIENCY

8/10

### RAY TRACING

6/10

### VALUE

26/30

### OVERALL SCORE

**83%**

## SPEC

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

**Pipeline** 1,920 stream processors, 48 ROPs

**Interface** PCI-E 3

**RT Cores** 30

**Tensor Cores** 240

**Memory** 6GB GDDR6, 14GHz effective

**Memory interface** 192-bit

**Bandwidth** 336GB/sec

**Outputs/inputs** 2 x DisplayPort 1.4, 1 x HDMI 2b, 1 x DVI-DL

**Power connections** 1 x 8-pin



# AMD RADEON RX 5700 / £299 inc VAT

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

**T**he Radeon RX 5700 uses the same configuration of the Navi 10 GPU as the 5600 XT, with its four disabled compute units. However, it ups the clock speeds and uses a much wider 256-bit memory interface for a whopping 448GB/sec memory bandwidth. The result is an impressively powerful card.

One of only two cards in this group test to sport a blower-style cooler, the reference RX 5700 is a very smart-looking card. The smooth, clean lines of its cooler shroud and illuminated Radeon logo is a vast improvement over any of the other cards we've seen in this group test – other than the near identical RX 5700 XT. You do miss out on a backplate, so it looks far less appealing from that angle, which seems like a missed opportunity.

The blower does a decent job of keeping heat and noise in check, but the fan is noisier than coaxial fan-based cooler designs. The cooler also appears to contribute to the overall length of the design, with much shorter, multi-fan cooler designs available. As such, despite its good looks, we recommend a card with a third-party cooler.

## SPEC

**Graphics processor** AMD Radeon RX 5700, 1465MHz base clock, 1625MHz game clock, 1725MHz max boost clock

**Pipeline** 36 compute units, 2,304 stream processors, 64 ROPs

**Interface** PCI-E 4

**RT Cores** 0

**Tensor Cores** 0

**Memory** 8GB GDDR6, 14GHz effective

**Memory interface** 256-bit

**Bandwidth** 448GB/sec

**Outputs/inputs** 3 x DisplayPort 1.4, 1 x HDMI 2b

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



Another crucial physical feature to note is the requirement for both a 6-pin and an 8-pin PCI-E power cable. Most cards that are cheaper and slower than this one require only a single cable.

When it comes to internal features, the big omission here is again the lack of ray-tracing support. We can't speak for how important you may feel this feature is, but even if it's just for playing around with older or more simple games, such as Minecraft and Quake, there's fun to be had with the new feature. The fact that AMD cards simply don't support it at all puts them at a disadvantage.

Instead, the RX 5700 makes its bid for your wallet based on pure gaming performance. We've already seen how AMD's new RDNA architecture and 7nm manufacturing process has vastly improved the performance and power consumption of AMD's latest graphics cards, and the RX 5700 continues that trend.

The RX 5700 trades blows with the RTX 2060 Super across our testing, more often than not coming out on top, even if the margin is small. However, with the RX 5700

costing £50 less than the RTX 2060 Super, there's a clear ray-tracing premium involved here. If you're not that fussed about it, the RX 5700 is clearly the better buy.

Not even power consumption holds back the appeal of the RX 5700, with this card actually using less power than the RTX 2060 Super when under load. Considering how much AMD has struggled with this side of things in recent years, it's quite astonishing to be able to say that.

## Conclusion

There's no two ways about it, the RX 5700 is the best pure bang for buck graphics card at around the £300 price point right now, and by some margin too. It's as fast as the RTX 2060 Super while using a fraction less power and costing £50 less. However, you miss out on ray tracing, so it really comes down to how much you value you place on having that feature.

## VERDICT

The pure performance champ at its price point, but it lacks ray tracing.

### T-REX

- + Good for 1080p and 1440p gaming
- + Best bang for buck at its price
- + Surprisingly power-frugal

### VELOCIRAPTOR

- Noisy stock blower fan
- Lacks ray tracing

PERFORMANCE

45/50

EFFICIENCY

8/10

RAY TRACING

0/10

VALUE

28/30

OVERALL SCORE

81%



# AMD RADEON RX 5700 XT / £349 inc VAT

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

**T**he Radeon RX 5700 XT represents the current pinnacle of AMD's graphics card line-up, so it seems a natural place to wrap up our comparison of the more affordable end of the graphics card spectrum. If you want greater performance than this you'll have to splash out considerably more and your choices are limited to just three Nvidia cards. Step up to an RTX 2070 Super and it will set you back an extra £100 or so, while the rest of Nvidia's top-tier cards add several hundred pounds on top of that.

The one caveat to that opening statement is the remaining stock of the vanilla RTX 2070. You can pick those cards up for as little as £350 while stocks last, at least at the time of writing, and they offer similar performance to the RX 5700 XT but with ray-tracing support. We can't guarantee stock will be around for long but if they are available, they're a great buy at that price.

But back to the RX 5700 XT and it uses the fully enabled Navi 10 GPU, with its 40 compute

units, 2,560 stream processors and 64 ROPs. It's also clocked higher than the RX 5700, with a 1605MHz base clock, 1755MHz game clock and 1905MHz max boost. In comparison, the RX 5700 ticks along at 1465MHz base clock, 1625MHz game clock and 1725MHz max boost clock, so the XT is roughly 10 per cent faster at each level. The game clock is the speed that AMD proposes the card can realistically sustain during gaming, as compared with the boost clock, which may only be achievable in very short bursts.

Based on AMD's new RDNA architecture, the RX 5700 XT again shows just how much progress AMD has made on its latest graphics cards, even if much of it is down to its leadership in 7nm manufacturing, while Nvidia still uses a 12nm process. Regardless, the RX 5700 XT delivers seriously impressive performance, topping our charts by a comfortable margin. On average, it's 11 per cent faster than the second-placed card, which is either the RX 5700 or RTX 2060 Super, depending on the test. Considering the RX 5700 XT costs around the same as the RTX 2060 Super, that's a decent lead.

However, the issue of ray-tracing support, or lack thereof, has bubbled up throughout this group test, and perhaps where it's felt most acutely is at this higher end of the performance

## SPEC

**Graphics processor** AMD Radeon RX 5700 XT, 1605MHz base clock, 1755MHz game clock, 1905MHz max boost clock

**Pipeline** 40 compute units, 2,560 stream processors, 64 ROPs

**Interface** PCI-E 4

**RT Cores** 0

**Tensor Cores** 0

**Memory** 8GB GDDR6, 14GHz effective

**Memory interface** 256-bit

**Bandwidth** 448GB/sec

**Outputs/inputs** 3 x DisplayPort 1.4, 1 x HDMI 2b

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

charts. The likes of the RTX 2060 Super and RX 5700 XT have the horsepower to run games that support ray tracing at playable frame rates, so the lack of this feature hurts all the more. Again, though, this is still something of a niche feature and a personal preference, so it's not a clear-cut choice, even if the most anticipated game of the year – Cyberpunk 2077 – is set to support it.

Also, one final black mark against this particular reference version of the RX 5700 XT is that its blower cooler is horrendously noisy when gaming, so we'd recommend a card with a different style of cooler instead.

## Conclusion

Other than dwindling discounted stock of the RTX 2070, the RX 5700 XT is the clear pure gaming performance champion for its price. It comfortably outpaces the RTX 2060 Super while costing the same. However, the lack of ray tracing is a problem. How big a problem will depend on the sort of games you want to play and just how much future support we get for the feature.

## VERDICT

Powerful, power-frugal and competitively priced. This is a top-tier graphics card, if ray tracing isn't a concern.

PERFORMANCE 49/50	RAY TRACING 0/10	OVERALL SCORE <b>83%</b>
EFFICIENCY 7/10	VALUE 27/30	

### IBM XT

- + Excellent gaming performance
- + Surprisingly power-efficient
- + Competitively priced

### SINCLAIR ZX80

- Lacks ray tracing support
- Very noisy fan on AMD cooler







# ZOTAC GEFORCE RTX 2060 SUPER MINI / £350 inc VAT

SUPPLIER Ebuyer.com

## SPEC

**Graphics processor** Nvidia GeForce RTX 2060 Super, 1470MHz base clock, 1650MHz boost clock

**Pipeline** 2,176 stream processors, 64 ROPs

**Interface** PCI-E 3

**RT Cores** 37

**Tensor Cores** 272

**Memory** 8GB GDDR6, 14GHz effective

**Memory interface** 256-bit

**Bandwidth** 448GB/sec

**Outputs/inputs** 3 x DisplayPort 1.4, 1 x HDMI 2b

**Power connections** 1 x 8-pin

## ANT MAN

- + Decent 1080p performance
- + Low price
- + 4GB of memory

## THE WASP

- Thermal throttling
- Slightly whiny fans

**S**uper by name and super by nature, the RTX 2060 Super expands upon the RTX 2060 in just about every way, offering more processing power and a much improved memory interface for a substantial uptick in performance that really allows those ray-tracing cores to breathe.

Delving a little deeper into those upgrades, the RTX 2060 Super uses the same TU106 GPU as the RTX 2060 but here, the whole chip is enabled. This means the stream processor count moves from 1,920 to 2,176, the RT core count increases from 30 to 36 and the ROPs jump from 48 to 64. Along with this, the memory interface has broadened from 192-bit to 256-bit, removing this potential bandwidth bottleneck.

The result of all these extras is an average of 10 per cent performance improvement over the RTX 2060, with an even larger 20 per cent average uptick in our ray-tracing benchmarks.

What's more, those performance figures translate to much more playable frame rates. The RTX 2060 delivers just 33fps in Battlefield V at 1440p but the RTX 2060 Super can manage 42fps. Still not enough for competitive play but it's getting much closer to a satisfactory smooth feel, especially if you have a monitor with adaptive sync (G-Sync).

Looking at our ray-tracing DLSS results, the RTX 2060 was already delivering just about playable frame rates at 1080p but struggled at 1440p. The RTX 2060 Super pushes the average at 1080p up to 72fps while hitting 53fps at 1440p. Crucially, DLSS looks so much better at 1440p than 1080p,

so this card represents a genuine upgrade in functionality, not just a faster number.

However, ray tracing aside, when it comes to raw gaming performance, the RTX 2060 Super is handily beaten by the RX 5700 XT, despite the latter generally being a little cheaper. If you're not too concerned about ray tracing then the RX 5700 XT is clearly the better buy. However, ray tracing is pretty cool, so we'd be inclined to go the Nvidia route, especially if you've already invested in a G-Sync monitor.

As for the particular Zotac card we reviewed, it's a basic affair with no lighting or other extras to speak of. Its two-fan cooler is quiet and effective, though, and it is indeed small, as its name suggests, measuring just 210mm in length. You do also get a protective backplate, which should help prevent any damage from knocks or static when handling the card.

## Conclusion

The RTX 2060 Super doesn't quite offer the best bang for your buck but thanks to its support for ray tracing, it's a great choice for those with around £350 to spend on a graphics card. Ray tracing looks amazing and is seeing growing support, so it's a feature we'd certainly like to have if spending this sort of money on a PC. **GPU**

## VERDICT

Ray-tracing support tips the balance in the favour of this excellent mid-range graphics card.

PERFORMANCE

45/50

EFFICIENCY

8/10

RAY TRACING

7/10

VALUE

24/30

OVERALL SCORE

84%

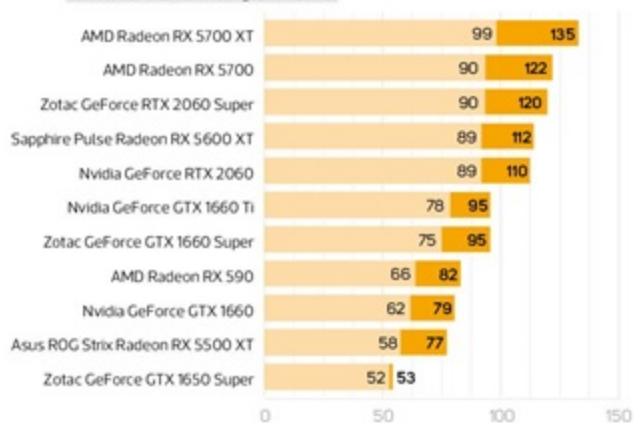




# GRAPHICS CARDS LABS RESULTS

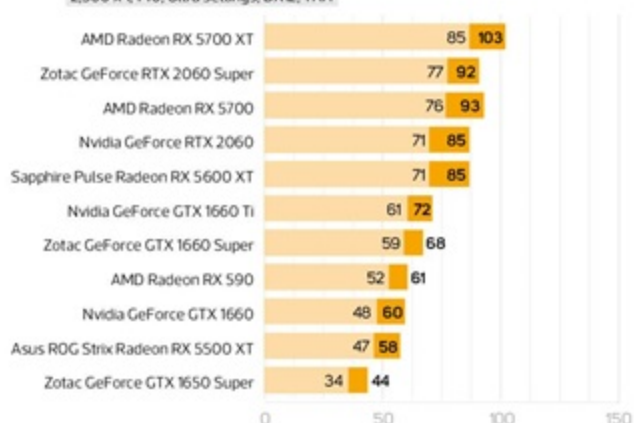
## BATTLEFIELD V (FPS)

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



## BATTLEFIELD V (FPS)

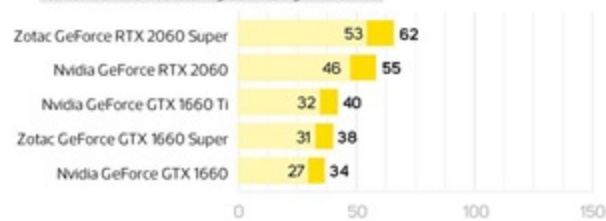
2,560 x 1,440, Ultra settings, DX12, TAA



99th percentile Average

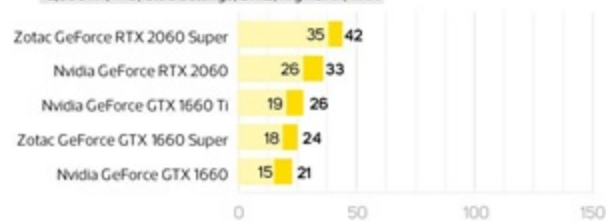
## BATTLEFIELD V RAY TRACING (FPS)

1,920 x 1,080, Ultra settings, DX12, High DXR, TAA



## BATTLEFIELD V RAY TRACING (FPS)

2,560 x 1,440, Ultra settings, DX12, High DXR, TAA



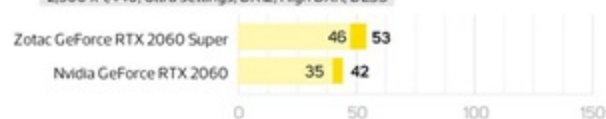
## BATTLEFIELD V RAY TRACING DLSS (FPS)

1,920 x 1,080, Ultra settings, DX12, High DXR, DLSS



## BATTLEFIELD V RAY TRACING DLSS (FPS)

2,560 x 1,440, Ultra settings, DX12, High DXR, DLSS



99th percentile Average

## SHADOW OF THE TOMB RAIDER (FPS)

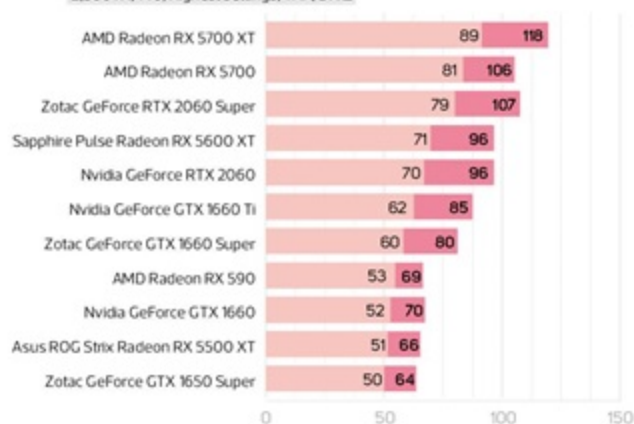
1,920 x 1,080, Highest settings, TAA, DX12



99th percentile Average

## SHADOW OF THE TOMB RAIDER (FPS)

2,560 x 1,440, Highest settings, TAA, DX12



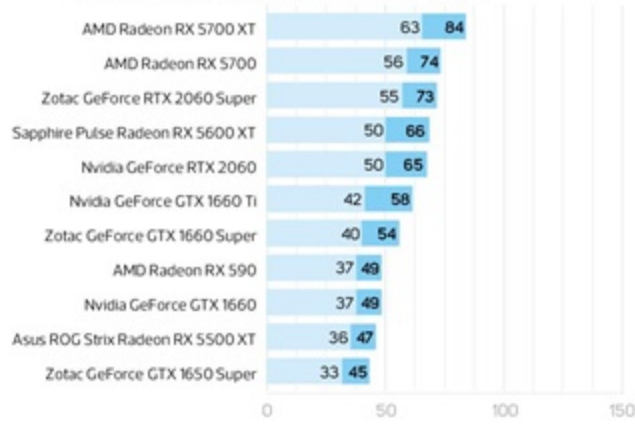
99th percentile Average



## GRAPHICS CARDS LABS RESULTS

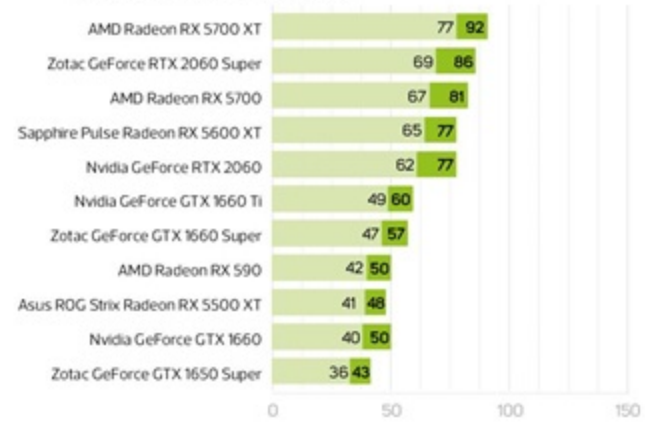
### RED DEAD REDEMPTION 2 (FPS)

1,920 x 1,080, custom high settings, High TAA, 4x AF, Vulkan



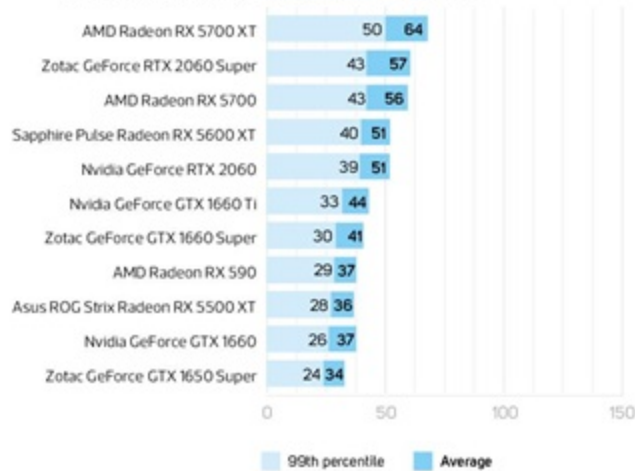
### TOTAL WAR: WARHAMMER II (FPS)

1,920 x 1,080, Ultra settings, FXAA, DX11



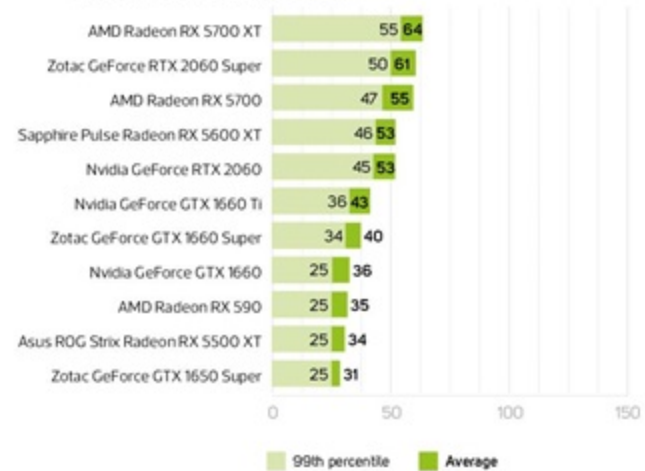
### RED DEAD REDEMPTION 2 (FPS)

2,560 x 1,440, custom high settings, High TAA, 4x AF, Vulkan



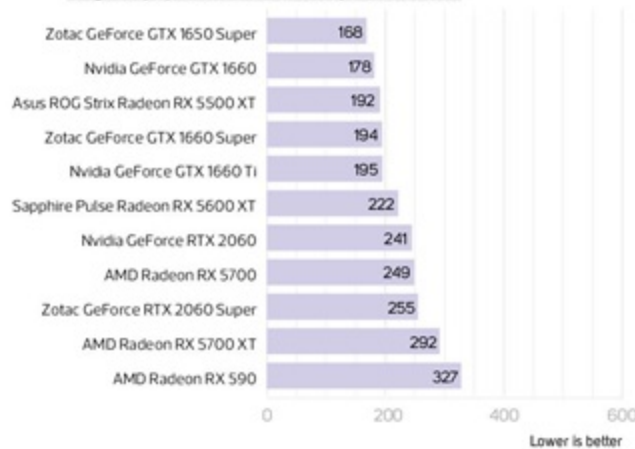
### TOTAL WAR: WARHAMMER II (FPS)

2,560 x 1,440, Ultra settings, FXAA, DX11



### TOTAL SYSTEM LOAD POWER CONSUMPTION (WATTS)

Unigine Superposition Benchmark, 4K Optimized, DirectX





LABS TEST

# Light entertainment

Antony Leather tests nine of the latest RGB memory kits, gauging their overclocking headroom and lighting abilities

## How we test

**F**or all but the very cheapest memory modules, RGB lighting-equipped kits are now the norm and they now don't cost much more money than non-illuminated kits, meaning you can easily add some serious flair to your PC. Of course, if you're not interested in rainbow effects and millions of colours, you can also fine-tune a static colour to precisely match your case's colour theme, all without the need for cables.

There's a decent array of kits available now too, and in a range of speeds. This month, we've sifted through nine kits to see where you should put your cash. We haven't opted for a specific speed this time around, for the simple reason that even some newer kits are only available in speeds below 3000MHz, while some use the latest tech to reach much higher frequencies. In short, there was

no single speed that allowed everyone to join the party, so we've selected kits between 3000MHz and 3600MHz, but with a focus on value, lighting and overclocking.

We've tested each kit using an MSI MEG X299 Creation motherboard, an Intel Core i9-10900X CPU and an Nvidia RTX 2070 Super graphics card, and benchmarked each kit in our usual suite of Custom PC RealBench tests, as well as Far Cry 5. We also tested how far each kit could be overclocked, identified the manufacturer and type of dies used in each kit, as well as testing the lighting software.

We use weighted scoring based on the memory's stock speed performance, overclocking headroom, lighting and features, before giving a value rating based on a combination of these results in relation to the price.

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- Corsair Dominator Platinum RGB / p59
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- Results graphs / p65



# ADATA SPECTRIX D60G / £91 inc VAT

SUPPLIER cclonline.com



**A** DATA has had a rather mixed run of reviews in the past, with its XPG Spectrix D40 kit performing reasonably well, but its M.2 heatsink being one of the worst products we've reviewed.

However, its new RGB memory – the Spectrix D60G – caught our eye with its full-height RGB lighting, which stretches from top to bottom on the sides of each module.

It looks fantastic when the lights are on, and it easily matches Corsair's legendary Vengeance RGB Pro memory in terms of wow factor. The LEDs sit under a diffusing plastic plate, but the lights still remain vivid, offering vibrant colours without tell-tale pinpoints of light showing through.

The modules' dark details and angular light strips make the Spectrix D60G one of the best-looking kits on test this month, despite having a very reasonable price tag that will leave you with plenty of change from £100. Despite scoring highly on the RGB wow factor scale, the Spectrix D60G modules aren't

particularly tall, sitting at just 46mm. If you're lucky, you may still be able to use them if you have a large CPU cooler that overhangs the DIMM slots. However, the Spectrix D60G modules are still significantly taller than Antec's super-short 5 Series DIMMs.

The modules will work with your motherboard's RGB software, with support from all the major players – ASRock, Asus, Gigabyte and MSI – so there's no need for guesswork or extra software here. The speeds are wide-ranging too, stretching from 3000MHz to 4133MHz. The fastest kit we could find in the UK when we began testing was 3200MHz, but some higher-frequency options have recently become available, which will delight AMD 3rd-gen Ryzen users wanting to get the best performance from their new platform.

However, the step up to 3600MHz requires an extra £40, which seems excessive for just a few hundred megahertz, so we were keen to see just how far we could push our kit when it came to overclocking. Our 3200MHz sample came with latency timings of 16-18-18-38, which are rather slack for a 3200MHz kit, but it does at least sport Samsung B-die chips, which are known to overclock well, plus they offer good compatibility with AMD systems, particularly with 1st-gen Zen and Zen+ CPUs and older AM4 motherboards.

Overclocking proved to be exceptionally fruitful for a 3200MHz kit, with a DDR voltage of 1.4V allowing us to push the Spectrix D60G kit to a massive 3800MHz. Only kits with

higher stock speeds on test managed to get further than this figure, and the 3200MHz G.Skill Trident Z RGB kit only managed to overclock to 3466MHz. Clearly, this means the ADATA Spectrix D60G offers exceptional value, and while we can't guarantee that each kit will have the same overclocking capabilities, it's certainly worth entering the lottery given the low price compared with other kits in the first place, as well as the spectacular lighting and appearance.

## Conclusion

With stunning looks, superb overclocking headroom, a very reasonable price and universal lighting software support, the ADATA Spectrix D60G is by far our favourite RGB memory kit this month. It doesn't offer the fastest stock speed, but some very safe and simple BIOS tweaking will unleash it. The lighting is spectacular too and you'll get change from £100 inc VAT, making the Spectrix D60G a no-brainer if you're looking for an affordable RGB memory kit that will turn heads.

## VERDICT

Fantastic RGB lighting, loads of overclocking headroom and a very reasonable price make for our top memory pick.

PERFORMANCE

29/30

DESIGN

29/35

VALUE

31/35

OVERALL SCORE

89%

## DATA

- + Fantastic lighting
- + Universal motherboard software compatibility
- + Massive overclocking headroom

## WESLEY CRUSHER

- Faster kits are much more expensive
- DIMMs could be shorter
- Corsair's LEDs are slightly more vibrant

## SPEC

Memory chip Samsung B-die

Timings 16-18-18-38

Voltage 1.35V

Height (from base) 46mm

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



# ANTEC 5 SERIES / £109 inc VAT

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

**L**ike many PC part manufacturers, Antec has recently branched out from cases and power supplies and gotten into the memory game, although it has a fairly limited range of modules compared with the likes of Corsair. Its 5 Series modules don't really appear to stand out from the crowd either, with a fairly unremarkable design.

To make matters worse, these kits are only available in speeds up to 3000MHz, which might be okay for a typical Intel PC, but they won't enable you to get the most out of the latest AMD 3rd-gen Ryzen systems, which benefit from faster memory. Despite these shortcomings, though, the 3000MHz kit still costs the same amount of money as most other kits with higher speeds.

Under the hood you'll find Micron B-die chips, which are rated at latency timings of 16-18-18-36 at 1.35V and 3000MHz; these are quite loose given the lowly frequency. Still, if you need RGB lighting, but only have room under your CPU cooler for short memory modules, the Antec 5 Series may well be what you're looking for.



With a height of just 38mm, the Series 5 modules are among the shortest RGB DIMMs we've tested. This means the DIMMs will clear many large, overhanging CPU air coolers, which won't be true for most of the kits on test this month, especially the gargantuan Team Group Night Hawk RGB and Corsair Dominator Platinum RGB. Meanwhile, the sides offer large heatsinks, but overall there are certainly better-looking modules on test this month.

Looking at the RGB Lighting, the 5 Series' LEDs sit in diffusing plastic strips, and look relatively vivid in terms of colour. There's also an offset metal strip, which splits the lighting into two sections. It looks attractive, but the asymmetry might be jarring for some people.

However, Antec's web page only states that the 5 Series' lighting is compatible with Asus' Aura Sync software to control the lighting patterns and colours, and no other motherboard makers' software, which would make them very restrictive given there's no universal software from Antec as an alternative either. However, the kit we tested worked fine with our MSI motherboard's Mystic Light software, so we think Antec probably needs to update its product page so that owners of non-Asus motherboards aren't put off.

In terms of performance, the Antec's lower memory speed, compared with other kits on test, wasn't an issue with our MSI Z390 test motherboard, but you'll likely see some performance improvements if you opt for faster memory on an AMD 3rd-gen Ryzen system, thanks to some of the inner workings of the CPU being tied to memory speed.

Unfortunately, though, the Micron B-die chips didn't take too kindly to overclocking, hitting just 200MHz above their rated frequency of 3000MHz, even once we'd upped the DDR voltage to 1.4V. This was in stark contrast to the Adata XPG Spectrix D60G 3200MHz kit, which costs less money and managed to hit 3800MHz with its Samsung B-die modules.

## Conclusion

The Antec 5 Series' supremely low module height will definitely offer greater compatibility with large heatsinks that overhang your DIMM slots, but it otherwise doesn't do particularly well against the competition. It's too expensive for the speeds on offer and overclocks poorly, so you're rather stuck in terms of frequency. It isn't available in particularly high speeds either, making it especially unappealing to owners of the latest AMD systems. The price doesn't reflect these limitations either, with cheaper kits offering faster speeds, far more overclocking potential and better RGB lighting.

## VERDICT

**These short modules are good if you have a large CPU cooler that overhangs your DIMM slots, but they overclock poorly and need to offer more at this price.**

### SNOWBALL FIGHT

- + Attractive RGB lighting
- + Very low profile

### BLACK ICE

- Better lighting available elsewhere
- Competing kits are faster and cheaper
- Unremarkable design

## SPEC

**Memory chip** Micron B-die

**Timings** 16-18-18-36

**Voltage** 1.35V

**Height (from base)** 38mm

**Stated software compatibility** Asus Aura

PERFORMANCE

25/30

DESIGN

24/35

VALUE

23/35

OVERALL SCORE

72%



# CORSAIR DOMINATOR PLATINUM RGB / £143 inc VAT

SUPPLIER scan.co.uk

**A**vailable in a huge range of speeds and in dual-channel and quad-channel kits, Corsair's Dominator Platinum RGB uses the familiar oversized Dominator heatsink design that's been a popular sight in PC hardware circles for over a decade. This time, though, you get full RGB lighting.

Rather than opt for a diffusing strip to spread out the colours of the lighting and allow them to intermix, the LEDs are instead left as bright pinpoints of light, like a single strip of LED pixels. They're not any old LEDs either, but Corsair's new Capellix LEDs, which are tiny but brighter and more power-efficient than usual RGB LEDs. As a result, they're supremely vivid, making for an impressive

display. However, we're undecided if they ultimately look better than the more diffuse lighting style of the Vengeance RGB Pro kit, for instance. This may come down to how funky a design you manage to program into the lighting – zebra-striped memory, anyone?

Another advantage of the lower power draw of these Capellix LEDs is potentially improved memory performance. There's limited power coming from memory slots as standard, so any extra power consumed by LEDs leaves less power to drive faster memory frequencies. That's why, when RGB LED memory kits were first introduced, they were severely limited when it came to memory speed. Capellix LEDs and their ilk help to close up the gap to non-illuminated modules.

Our sample kit sits at 3466MHz, but there's plenty of options above and below this from 3000MHz to 4800MHz, but at nearly £150 for our sample, it's significantly more costly than Corsair's own Vengeance RGB Pro, which will set you back just £125. You'll also need to use Corsair's iCUE software to have full control over the LEDs, but Corsair is currently working with motherboard manufacturers to bring support for their hardware in iCUE to allow you to synchronise your hardware's lighting.

The software offers a good amount of control too, with countless lighting effects as

well as the ability to control the brightness of the LEDs. Sadly, while Corsair offers dummy modules for its Vengeance RGB Pro modules, there are no dummy modules for the Dominator Pro RGB to fill those DIMM slots with lighting and eliminate gaps between modules. You'll need to buy the full four DIMMs for 4-slot boards and probably spend a fortune populating all eight slots on quad-channel boards.

Overclocking was surprisingly fruitful. Setting the limit at 1.4V DDR voltage, the Samsung B-die chips hit 4000MHz, equating to a 534MHz boost, so if you want to overclock your memory, there's plenty of headroom here, at least with our sample kit. There's one major drawback to the Dominator Pro RGB, which is its height. At 55mm, it will hamper efforts to install large CPU coolers so be sure to check your cooler's documentation first.

## Conclusion

We've always loved the elegance and excellent build quality of Corsair's Dominator memory modules and the Dominator Pro RGB is no different. The lighting will appeal to those that prefer to see individual LEDs and there's plenty of overclocking headroom thanks to the use of Samsung B-die chips.

The heatsinks look fantastic too, although achieving a continuous lighting show by filling all your DIMM slots will be expensive. If Corsair can galvanise support for motherboards in its software to synchronise lighting, it will be even more impressive. It's a little pricey and there's stiff competition in this group test, but this is still one of our favourite RGB memory kits.

## SPEC

**Memory chip** Samsung B-die

**Timings** 16-18-18-36

**Voltage** 1.35V

**Height (from base)** 55mm

**Stated software compatibility** Corsair iCUE

## PLATINUM

- + Excellent lighting
- + Great software
- + Decent overclocking headroom

## FOOL'S GOLD

- Expensive
- Lighting not diffused
- No dummy modules



## VERDICT

A well-made and attractive RGB memory kit with cutting-edge LEDs.

PERFORMANCE

28/30

DESIGN

34/35

VALUE

24/35

OVERALL SCORE

86%



# CORSAIR VENGEANCE RGB PRO / £124 inc VAT

SUPPLIER scan.co.uk



**M**emory pricing got so ridiculous not so long ago that Corsair and other manufacturers such as Aorus, who is sadly absent this month thanks to it changing memory dies, went as far as offering dummy modules to allow you to fill all the DIMM slots on your motherboard even when only using a small number of real memory sticks. This allowed you to provide a full, unbroken stretch of RGB lighting atop your memory, without breaking the bank.

It sounded bonkers at first, but Corsair's Vengeance RGB Pro modules really do look best stacked side by side without the gaps between them that are caused by correctly spacing the memory modules for proper dual or quad-channel configurations. If, in particular, you're running a quad-channel motherboard with eight DIMM slots then the cost savings of filling half the slots with £20-a-piece dummy modules is significant.

While memory is cheaper now, you're still looking at over £120 for a dual-channel kit of 3466MHz modules such as those we're testing here. Having the option of adding in cheaper dummy modules means the

Vengeance RGB Pro has a distinct advantage over other kits, if you particularly care about the internal aesthetics of your PC.

What's more, the lighting on this kit is among the best we've seen in terms of brightness and boldness of colour, and Corsair has done an excellent job of diffusing the LEDs using a strip of opaque plastic. There's no hint of individual LEDs beneath, so you get a nice ethereal organic glow, and the lighting effects configured using Corsair's iCUE software look fantastic. It's personal preference – and a stylistic choice – as to whether you prefer the pixelated style of the Corsair Dominator Platinum RGB or the smoother style here. It's certainly easier to create a mesmerising and fun effect with this kit, though. However, the heatsinks are rather plain by comparison, with just two thin sheets of metal either side, although they do at least come in black or white.

While Corsair's preferred method of controlling the LEDs is its own iCUE software, they work with most motherboard manufacturer's software, albeit with fewer effects. However, Corsair is working on getting this to act the other way around, allowing iCUE to control your motherboard's LEDs instead, which will allow it to also hook up Corsair's fans and coolers.

The modules are quite tall, at a little over 50mm, so this may cause issues with large CPU heatsinks, and there are several shorter kits in this month's Labs test if you run into that problem. Under the hood are Samsung B-die memory chips, which should offer great compatibility with AMD Ryzen and

Threadripper CPUs. The range of dual and quad-channel kit frequencies is impressive too, stretching from 2666MHz up to 4600MHz. Heading into our EFI saw the kit reach the same 4000MHz as the Dominator Pro RGB and G.Skill Trident Z Royal, with more than 500MHz added to the stock frequency in a very easy overclock.

## Conclusion

Corsair's Vengeance RGB Pro is a great example of RGB memory and the future looks bright in terms of lighting control thanks to Corsair working to integrate motherboard lighting control into its own iCUE software.

Despite it being one of the older kits to offer high frequencies, it still looks great, although there are some cheaper alternatives this month, such as the ADATA Spectrix D60G, as well as some shorter ones too. With cheap dummy modules available to fill vacant DIMM slots and a good range of speeds in both dual and quad-channel versions, though, it remains very high on our shortlist.

## VERDICT

The Corsair Vengeance RGB Pro still has what it takes and is one of the best-looking kits out there.

## NUCLEAR FUSION

- + Fantastic lighting
- + Great software
- + Good overclocking headroom

## COAL

- Tall
- More expensive than the competition
- Aging design

## SPEC

Memory chip Samsung B-die

Timings 16-18-18-36

Voltage 1.35V

Height (from base) 51mm

Stated software compatibility Corsair iCUE

PERFORMANCE

28/30

DESIGN

32/35

VALUE

26/35

OVERALL SCORE

86%



# G.SKILL TRIDENT Z RGB

£95 inc VAT

SUPPLIER [ebuyer.com](http://ebuyer.com)

**I**t was lucky that G.Skill was using Samsung B-die memory in its Trident Z modules when Ryzen hit the shelves back in 2017. That first generation of Ryzen CPUs and AM4 motherboards were a bit finicky when it came to memory, and they worked best with those Samsung chips. As such, G.Skill became one of the go-to choices. It was also one of the first to offer cableless RGB lighting and at decent speeds too.

The memory compatibility issues of 2017 and 2018 have long since died away, but Trident Z remains highly popular and continues to be one of our favourite kits. What's perhaps surprising, though, is that the original Trident Z RGB kits are still readily available, so we felt it necessary to fully reassess their capabilities. The question is, how well have they aged?

G.Skill is still using the same basic design that's largely carried into its outrageous Royal modules that we also looked at this month. A key benefit is that their height is kept to 44mm, which is significantly shorter than either of Corsair's modules in this test. Even so, this is still potentially too tall for some CPU coolers, so it's still best to check compatibility before you buy. The modules are attractive

with or without lighting too, thanks to the striking brushed aluminium side plates, but like Corsair's Vengeance RGB Pro, they look best stacked together. Sadly, G.Skill doesn't offer dummy modules so you'll need to delve a little deeper into your wallet to achieve that look here, especially with a quad-channel motherboard.

Whether you opt for dual or quad-channel, there are plenty of speeds available, ranging from 2400MHz up to 4000MHz, although some can be tricky to track down in the UK. As usual, under the hood are Samsung B-die chips and these have timings of 16-18-18-38 at our kit's rated 3200MHz frequency. We upped the DDR voltage to 1.4V to see how far we could push them and managed a respectable but not amazing 3466MHz – far short of the ADATA XPG Spectrix D60G, which despite also sporting 3200MHz Samsung B-die chips, managed 3800MHz.

To control the RGB lighting, you'll need to use either ASRock, Asus, Gigabyte or MSI's RGB software, where you'll get varying levels of control over the modules. There's the option to use a vast array of static colour options as well as half a dozen or more lighting effects. The overall look is excellent, making for some of the best-looking RGB DIMMs out there, which is more than we can say for the garish Trident Z Royals.

## SPEC

**Memory chip** Samsung B-die

**Timings** 16-18-18-38

**Voltage** 1.35V

**Height (from base)** 44mm

**Stated software compatibility** Asus Aura Sync, Gigabyte RGB Fusion, MSI Mystic Light, ASRock RGB LED

## ZORRO

- + Great lighting
- + Flexible software control
- + Low price

## ZZZZZ

- Average overclocking
- Aging design
- The competition's lighting is slightly better

## Conclusion

The G.Skill Trident Z RGB modules still have a lot going for them and now that memory prices have calmed, you'll have change from £100 for the 3200MHz kit we tested.

The lighting looks fantastic in the wake of fresh competition, and you can use your motherboard's RGB software to control the modules and synchronise it to your motherboard lighting. While they're not as low-profile as the Antec 5 Series, they're still compact and would be our first port of call if compatibility was a priority for a large heatsink. Available in a range of speeds, we prefer them to G.Skill's Trident Z Royal, although Corsair and ADATA pip G.Skill to the post with cheaper, faster, better-looking options.

## VERDICT

Still a fantastic memory kit, but our 3200MHz sample had limited overclocking headroom.

PERFORMANCE

25/30

DESIGN

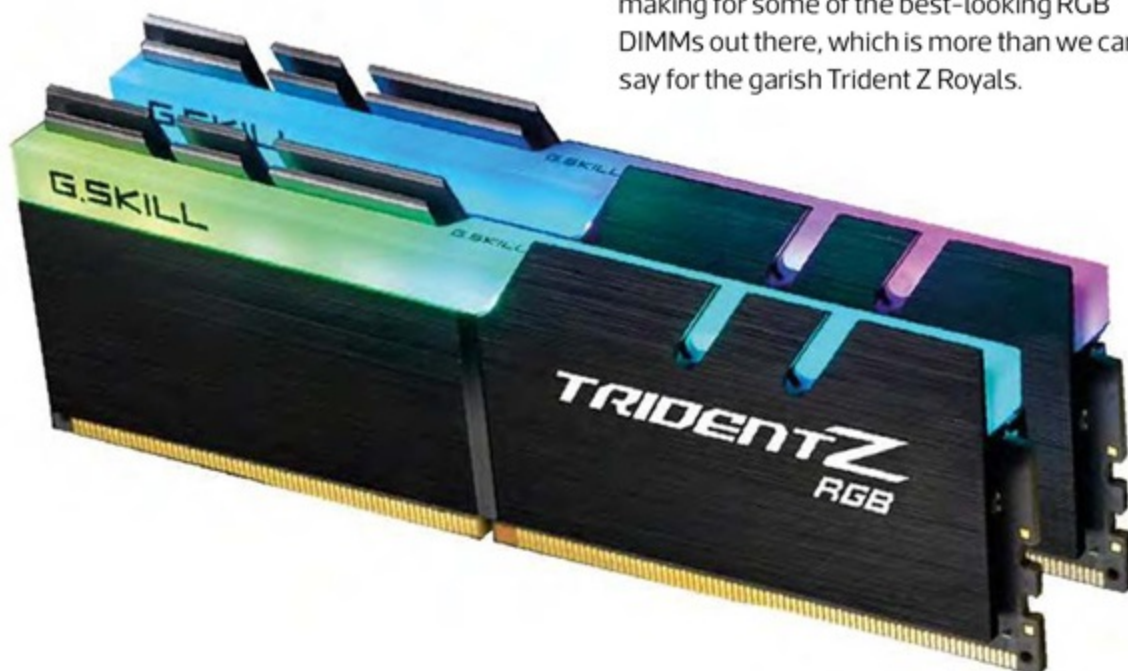
29/35

VALUE

28/35

OVERALL SCORE

82%





## PATRIOT VIPER RGB / £97 inc VAT

SUPPLIER amazon.co.uk

**A**s one of the more affordable kits on test, the Patriot Viper RGB has stiff competition from the superb ADATA XPG Spectrix D60G and G.Skill Trident Z RGB, which give you change from £100 for dual-channel 3200MHz kits. The Patriot's heatsinks are aggressive-looking, with viper-like logos on the side. They're available in black or white, although the former has more speed options, ranging from 2666MHz to 4133MHz, while the white kits only reach 3200MHz. However, there

## SPEC

Memory chip Hynix C-die

Timings 16-18-18-36

Voltage 1.35V

Height (from base) 46mm

**Stated software compatibility** Viper RGB Software, Asus Aura Sync, Gigabyte RGB Fusion, MSI Mystic Light, ASRock RGB LED

don't appear to be any quad-channel kit options.

A diffusing strip covers the LEDs running the length of each module, with raised sections at each end that unfortunately see the height rise to 46mm. This does add some pizzazz to the lighting, although the light isn't as well diffused as the Corsair Vengeance RGB Pro modules, as you can see the individual



LEDs underneath. You can use most motherboard software to control the LEDs and synchronise them with your hardware, plus Patriot also offers its own software.

The modules use Hynix C-die chips with 16-18-18-36 timings, and unfortunately they didn't take very well to overclocking, refusing to even budge up to 3466MHz despite us raising the DDR voltage to 1.4V. This was the worst result on test, especially given that the ADATA XPG Spectrix D60G is cheaper, rated at the same speed and was happy to hit 3800MHz.

## VIPER

- + Wide software support
- + Affordable

## SLOW WORM

- No overclocking headroom
- Not as good-looking as the competition
- Limited kit options



## TEAM GROUP NIGHT HAWK RGB / £74 inc VAT

SUPPLIER overclockers.co.uk

**I**f you're looking for RGB memory for as little money as possible, then Team Group's Night Hawk RGB will leave you with change from £80, making it one of the cheapest 16GB dual-channel

3200MHz kits currently available. However, these kits are only available at 3200MHz in the UK, even though Team Group's website lists faster versions. With a height of 53mm, these modules aren't short either. The clearance on any large CPU air cooler is likely to be lower than 53mm, so if you're using a large cooler, make sure it doesn't overhang the DIMM slots before purchasing.

The heatsinks themselves certainly look good, with a towering wing design and

plenty of intricate details. Large diffusing strips allow the RGB LEDs beneath them to splash their light along the heatsinks, and there are openings on the sides too, enhancing the light show. However, the colour isn't as vivid as the lighting on the Corsair or G.Skill modules on test this month, and ADATA's XPG Spectrix D60G ultimately looked much better too.

Thankfully, the modules now support a huge range of software, which is just as well as, when we first reviewed them, Team Group's own software had gremlins. Now, though, these modules support RGB software from ASRock, Asus, Gigabyte, MSI, Thermaltake and Razer. Our 3200MHz kit used Samsung B-die chips with 16-18-18-38 timings, but our sample only managed to hit 3333MHz before stability issues surfaced, which is disappointing.

## SPEC

Memory chip Samsung B-die

Timings 16-18-18-38

Voltage 1.35V

Height (from base) 53mm

**Stated software compatibility** Asus Aura Sync, Gigabyte RGB Fusion, MSI Mystic Light, ASRock RGB LED, Thermaltake RGB Plus, Razer Chroma RGB



## Conclusion

Unfortunately, while they're reasonably priced, attractive and have flexible lighting support, the Patriot Viper RGB failed to overclock at all, putting it at a sizeable disadvantage. Cheaper and better-looking kits fare better here, and the Patriot's module height of 46mm isn't exactly low-profile either. The ADATA XPG Spectrix D60G is a far better bet at this price.

## VERDICT

An affordable price, but the Patriot kit is held back by poor overclocking and average lighting.

PERFORMANCE  
23/30

DESIGN  
27/35

VALUE  
25/35

OVERALL SCORE  
75%

## NIGHT HAWK

- + Very cheap price
- + Wide software support
- + Good-looking heatsinks

## NIGHTMARE

- Tall modules
- Only available at 3200MHz in UK
- Lighting isn't that vivid

## Conclusion

At £74 inc VAT, the Team Group Night Hawk RGB is still a reasonable offering if you need an affordable way to colour-match your memory to the rest of your PC. As long as you have room for the towering modules and you're happy with limited frequencies and overclocking potential, it's well worth considering if you're on a tight budget.

## VERDICT

Great value for money, if a little tall, but not a great overclocker.

PERFORMANCE  
24/30

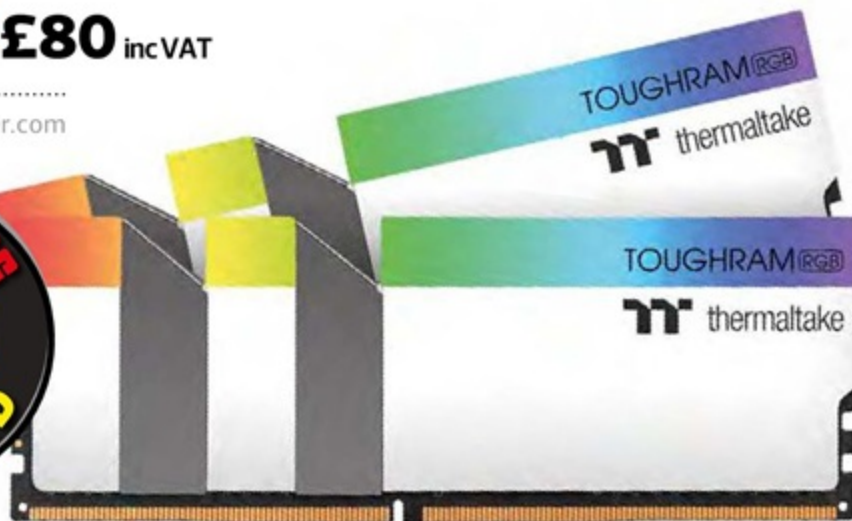
DESIGN  
26/35

VALUE  
30/35

OVERALL SCORE  
80%

# THERMALTAKE TOUGHRAM RGB / £80 inc VAT

SUPPLIER ebuyer.com



**A**nother supremely affordable RGB memory kit this month is Thermaltake's ToughRAM RGB, which not only costs just £80, but also runs at 3600MHz out of the box. Thermaltake is certainly aggressive on pricing, but less so with its module design; while distinctive, it doesn't leap out from the crowd like kits such as the ADATA XPG Spectrix D60G. At this price and this speed, though, we can forgive middling aesthetics.

A large block of diffusing, opaque plastic sits on top of RGB LEDs, giving the ToughRAM a large illuminated surface area compared with other kits on test. However, it doesn't do as good a job at hiding the LEDs beneath, which are slightly visible in some sections, meaning the light isn't as even and linear as on Corsair's Vengeance RGB Pro modules, for example. The design also uses wedge-shaped cut-outs to jazz up the appearance, with mirrored metal strips on the sides.

## TOUGH

- + Low price
- + Solid lighting and aesthetics
- + High speed for the price

## ROUGH

- Poor overclocking
- Not as good-looking as other kits
- Limited software support

## SPEC

Memory chip Hynix C-die

Timings 18-19-19-39

Voltage 1.35V

Height (from base) 48mm

Stated software compatibility  
Thermaltake ToughRAM Software,  
Razer Chroma RGB, Amazon Alexa

Thermaltake has also gone for unique software support, with its own reasonably capable ToughRAM Software, as well as support for Razer Chroma RGB and Amazon Alexa, control the lighting colours and effects. Sadly, you can't use your motherboard's software to control and synchronise it, and our MSI motherboard's Mystic Light software certainly didn't work with it.

Heading into the EFI and supplying a bit more voltage to see how far we could push the ToughRAM, we hit a 3800MHz wall; while fast, this is only 200MHz higher than the stock speed of 3600MHz, perhaps due to Thermaltake using Hynix C-die chips, also used by the poor-overclocking Patriot Viper RGB. These are rated at very loose 18-19-19-39 timings too.

## Conclusion

While there are better-overclocking and more attractive kits, we can't argue with Thermaltake's superb value for money. The modules aren't particularly short at 48mm, but it's hard to beat 16GB of 3600MHz RGB memory for £80. If you're happy to sacrifice motherboard lighting control, this is a fast memory kit if you're on a tight budget.

## VERDICT

A high-speed RGB memory kit for not much cash, although software support is poor.

PERFORMANCE  
25/30

DESIGN  
29/35

VALUE  
32/35

OVERALL SCORE  
86%



# G.SKILL TRIDENT Z ROYAL / £154 inc VAT

SUPPLIER amazon.co.uk



**A**s the most expensive memory on test, you'd hope that G.Skill's Trident Z Royal memory was pretty special, and it's undeniably the most lavishly bestowed memory we've ever seen. Living up to its name, the modules are essentially the DIMM equivalents of crowns, with a large sparkling 'jewel' sitting atop a golden or silver rim.

In this case, the jewel is a clear piece of angular, clear plastic that's shaped like an elongated diamond, with flat edges that catch the light. It looks fit for royalty (albeit ostentatious) before you turn on the RGB lighting, but when you switch on the lighting, the appearance goes from eyebrow-raising to questionable.

The lighting reflects to such a degree that the rest of your case will undoubtedly look like it arrived at a black-tie party with joggers and

running shoes, although it could easily be the other way around. Whether you like the look of these modules is largely down to your own personal taste, but the gold-coloured heatsinks of our samples, as well as over-the-top jewel design at the top, plus the lack of any sort of light diffusion, means they won't be for everyone.

If you like your PC case to be full of bling then you'll love them, but we'd rather see the luscious heatsinks, which thankfully also come in silver, paired with a less flashy lighting system. The lighting is slightly less easy on the eyes without the LEDs being set under a diffusing strip, but you can at least use motherboard RGB lighting software from ASRock, Asus, Gigabyte and MSI to control it, with static or pulsing colours often looking best.

The speeds of these kits reach 4000MHz at stock speed in quad-channel form, and a massive 4800MHz in dual-channel flavour. However, for some reason, G.Skill has missed out the sweet spot at 3466MHz, with these kits instead landing either side at 3200MHz or 3600MHz.

The latter is usually the highest frequency you can run at a one-to-one ratio with AMD's Infinity Fabric on Ryzen and Threadripper CPUs, but there's often diminishing returns and higher prices involved in getting there. Our sample kit sat at 3600MHz with reasonably tight timings of 16-16-16-36 and, as you'd expect, Samsung B-die chips sit under the heatspreader too.

Pushing the DDR voltage to 1.4V enabled us to push the memory past its stock speed, and we managed to overclock our 3600MHz kit to 4000MHz before stability

issues kicked in. That's a 400MHz boost over the stock speed, although this lofty speed can also be reached using 3466MHz Samsung B-die modules, as proved by both the Corsair kits on test this month.

## Conclusion

With their crystal-inspired, angular clear tops and gold-coloured shiny heatsinks, the G.Skill Trident Z Royal modules would be welcome in a dragon's hoard. They're an interesting addition to the Trident Z line-up, and they offer a range of speeds (albeit without a 3466MHz option) and decent overclocking, at least with our 3600MHz sample.

It's available in silver too, which would go well with clean, bright builds. At this price, though, and given that ADATA's XPG Spectrix D60G looks arguably better (at least to our tastes) and costs £60 less, while also reaching 3800MHz once overclocked, it's a tad too pricey to be highly recommended. If you're building a blinged-up PC that goes all out on flashiness, and you have the money, then the Royal modules do the job fine, but you can get much better value elsewhere. **CPG**

## ROYAL JEWELS

- + Enough bling to sink a luxury yacht
- + Decent overclocking headroom
- + Universal software control

## ROYAL MESS

- Garish design
- Expensive
- No light diffuser

## SPEC

Memory chip Samsung B-die

Timings 16-16-16-36

Voltage 1.35V

Height (from base) 44mm

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

## VERDICT

The ultimate bling RAM, but with a price to match.

PERFORMANCE

27/30

DESIGN

34/35

VALUE

22/35

OVERALL SCORE

83%

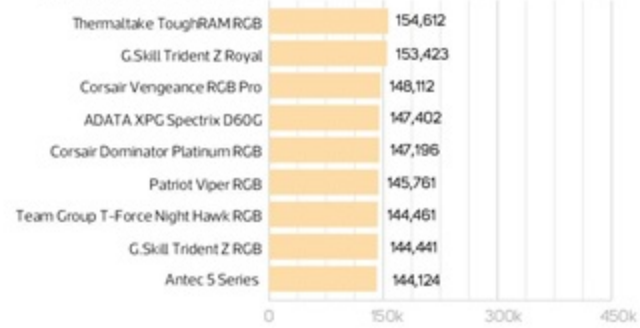


## RGB MEMORY LABS RESULTS

### GIMP IMAGE EDITING



### HEAVY MULTI-TASKING



### HANDBRAKE H.264 VIDEO ENCODING



### SYSTEM SCORE



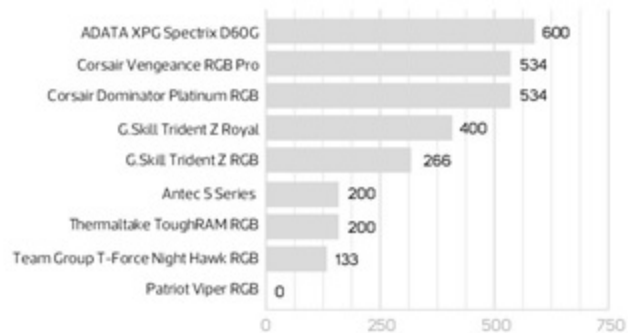
Stock Speed Overclocked

### FAR CRY 5 (FPS)

1920 x 1080, Ultra settings



### OVERCLOCK ABOVE DEFAULT SPEED (MHz)





# How we test

## MOTHERBOARDS

### TEST PROCESSORS

- **Intel LGA1151** Intel Core i9-9900K
- **Intel LGA2066** Intel Core i9-7900X
- **AMD AM4** AMD Ryzen 9 3900X
- **AMD TRX4** AMD Threadripper 3970X



Our test gear comprises a GeForce RTX 2070 Super Founders Edition and a 2TB Samsung 970 Pro SSD (or a PCI-E 4 1TB Corsair MP600 SSD on X570 and TRX40 boards). We also use Corsair Vengeance RGB 3466MHz DDR4 RAM – a 16GB dual-channel kit for mainstream systems, and a 32GB quad-channel kit for HEDT systems.

We use Custom PC's own RealBench suite, and Far Cry 5 installed on Windows 10 Home 64-bit to test basic performance. We also test the board's SATA and M.2 ports, and record the noise level and dynamic range of the integrated audio using RightMark Audio Analyzer. We try to overclock our test CPU to its maximum air-cooled level on each motherboard, and record the performance results.

## PROCESSORS

### TEST MOTHERBOARDS

- **Intel LGA1151** MSI MEG Z90 ACE
- **Intel LGA2066** MSI MEG X299 Creation
- **AMD AM4** Gigabyte X570 Aorus Master
- **AMD AM4 (APU)** MSI X470 Gaming Pro Carbon
- **AMD TRX4** Asus ROG Zenith II Extreme



We otherwise use the same core spec to test each CPU. Our test gear comprises an Nvidia GeForce RTX 2070 Super Founders Edition (or an APU's integrated GPU for gaming tests) and a 2TB Samsung 970 Pro SSD. We also use Corsair Vengeance RGB 3466MHz DDR4 memory – a 16GB dual-channel kit for mainstream desktop systems, and a 32GB quad-channel kit for HEDT systems.

We use Custom PC's own RealBench suite, Cinebench and Far Cry 5, installed on Windows 10 Home 64-bit, and record the power draw of the test PC. These tests cover a broad range of performance characteristics, including image editing, gaming, video encoding and 3D rendering. We run all tests at stock speed and at the CPU's highest overclocked frequency.

## MONITORS

We test image quality with an Xrite 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. We also run games on them to assess their responsiveness, and to see how well any adaptive sync tech works, and to gauge their performance at high refresh rates.



## 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, 3000MHz Corsair Vengeance LPX memory, 256GB Crucial MX100 SSD, be quiet! System Power 9 500W PSU, Windows 10 64-bit.

### INTEL LGA1151

Intel Core i5-9600K CPU overclocked to 4.6GHz with 1.2V vcore, MSI Z370 PC Pro motherboard.

### INTEL LGA2066

Intel Core i9-7900X overclocked to 4.2GHz with 1.15V vcore, MSI X299M Gaming Pro Carbon AC motherboard.

### AMD AM4

AMD Ryzen 7 1700 overclocked to 3.9GHz with 1.425V vcore, Asus ROG Strix B350-F Gaming motherboard.

### AMD TR4

AMD Threadripper 2950X overclocked to 4.1GHz with 1.425V vcore, AMD Threadripper 2990WX overclocked to 4GHz with 1.3375V vcore, ASRock X399M motherboard.



## GRAPHICS CARDS



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

We test graphics cards at 1,920 x 1,080, 2,560 x 1,440 and 3,840 x 2,160, although we omit the latter resolution on cheaper cards that can't produce playable frame rates at this setting.

### TEST KIT

Intel Core i7-8700K overclocked to 4.7GHz on all cores, 16GB Corsair Vengeance LED 3000MHz DDR4 memory, Gigabyte Z370 Aorus motherboard, Cooler Master MasterLiquid 240 CPU cooler, Corsair HX750 PSU, Cooler Master MasterCase H500M case, Windows 10 Home 64-bit.

### GAME TESTS

**Red Dead Redemption 2** Tested at custom high settings. We run the game's built-in benchmark, and use FrameView to record the end portion, which is based on real gameplay. We report the 99th percentile and average frame rates.

**Battlefield V** Tested in DirectX 12 at Ultra settings on every card. If a GPU also supports real-time ray tracing, we then test it with DXR enabled on High settings with TAA, and also with DLSS if it's supported. We run through a one-minute custom benchmark in the 'Under No Flag' War Story, recording the 99th percentile and average frame rates with FrameView.

**Shadow of the Tomb Raider** Tested at the Highest settings preset with TAA. We run the built-in benchmark and record the 99th percentile and average frame rates with FrameView.

**Total War: Warhammer II** Tested in DirectX 11, as the DirectX 12 beta currently causes stuttering issues on some GPUs. We test at Ultra settings with FXAA, and run the built-in 'Battle' benchmark. We record the 99th percentile and average frame rates with FrameView.



### POWER CONSUMPTION

We run Unigine Superposition at 4K Optimized DirectX settings. We measure the power consumption of our whole graphics test rig at the mains during the test, and record the peak power draw. This result is for the whole system, not the graphics card alone.

## CUSTOM PC AWARDS



### EXTREME ULTRA

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



### PREMIUM GRADE

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



### PROFESSIONAL

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



### APPROVED

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



### CUSTOM KIT

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

## CUSTOM PC REALBENCH

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

### GIMP IMAGE EDITING

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

### HANDBRAKE H.264 VIDEO ENCODING

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

### LUXMARK OPENCL

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

### HEAVY MULTI-TASKING

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



## Core component bundles

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

### 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	overclockers.co.uk	#194, p20	£129
CPU COOLER	AMD Wraith air cooler included with CPU	N/A	#176 p80	£0
GRAPHICS CARD	AMD Radeon RX Vega 11 integrated into CPU	N/A	#194 p20	£0
MEMORY	8GB (2 x 4GB) Corsair Vengeance LPX 3000MHz (CMK8GX4M2A3000C16)	scan.co.uk	#176 p80	£45
MOTHERBOARD	MSIB450M Mortar (micro-ATX)*	overclockers.co.uk	#182 p50	£85
STORAGE	500GB WD Blue SN500 (M.2 NVMe)	ebuyer.com	#191 p78	£65

**Total £324**

\*This motherboard may require a BIOS update in order to recognise the new CPU, which can be performed without needing an old CPU, downloading the latest BIOS to a USB flash drive and pressing the Flash BIOS button

### Budget gaming system

#### Quad-core CPU, 1080p gaming

Needs a micro-ATX case. We recommend a 450W 80 Plus power supply. See Issue 191, p78, for an example build guide.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	Intel Core i3-8100	cclonline.com	#191 p78	£105
CPU COOLER	Rajjintek Juno Pro RBW	overclockers.co.uk	#191 p78	£12
GRAPHICS CARD	Zotac Gaming GeForce GTX 1660 Super	overclockers.co.uk	#199 p46	£199
MEMORY	16GB (2 x 8 GB) Corsair Vengeance LPX 3000MHz (CMK16GX4 M2A2666C16)	scan.co.uk	#191 p78	£65
MOTHERBOARD	Gigabyte B360M DS3H (micro-ATX)	scan.co.uk	#191 p78	£75
STORAGE	500GB WD Blue SN500 (M.2 NVMe)	ebuyer.com	#191 p78	£65

**Total £521**

#### UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 2060 (1080p gaming with ray tracing and some 2,560 x 1,440 gaming)	ebuyer.com	#199 p50	£273
SWAP STORAGE	Kingston A2000 1TB	box.co.uk	#196 p30	£130



## Mid-range all-purpose system

### 6-core CPU, 2,560 x 1,440 gaming, real-time ray tracing at 1080p

Needs an ATX case. We recommend using a 550W power supply with 80 Plus Bronze certification. See Issue 193, p76, for a similar example build guide.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 5 3600	scan.co.uk	#195 p16	£171
CPU COOLER	Deepcool Gammaxx GT	scan.co.uk	#192 p52	£30
GRAPHICS CARD	Zotac GeForce RTX 2060 Super Mini	ebuyer.com	#199 p53	£350
MEMORY	16GB (2 x 8GB) ADATA XPG Spectrix D60G 3200MHz (AX4U320038G16-DT60)	cclonline.com	#199 p57	£91
MOTHERBOARD	MSI X570-A Pro (ATX)	cclonline.com	#193 p48	£154
STORAGE	1TB Corsair MP600	amazon.co.uk	#193 p26	£190

**Total £986**

#### UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 2070 Super (2,560 x 1,440 gaming with real-time ray tracing)	scan.co.uk	#193 p16	£450
ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	#166 p54	£90
SWAP CPU COOLER	ARCTIC Liquid Freezer II 240	scan.co.uk	#196 p26	£65

## Mid-range gaming system

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

Needs an ATX case with room for a 240mm all-in-one liquid cooler. We recommend a 600W 80 Plus Bronze power supply.



COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 7 3700X	overclockers.co.uk	#192 p14	£290
CPU COOLER	ARCTIC Liquid Freezer II 240	scan.co.uk	#196 p26	£65
GRAPHICS CARD	Nvidia GeForce RTX 2070 Super	scan.co.uk	#193 p16	£450
MEMORY	16GB (2 x 8GB) ADATA XPG Spectrix D60G 3600MHz (AX4U3600 38G17-DT60)	cclonline.com	#199 p57	£132
MOTHERBOARD	Asus ROG Strix X570-E Gaming (ATX)	overclockers.co.uk	#193 p44	£300
STORAGE	1TB Corsair MP600	amazon.co.uk	#193 p26	£190

**Total £1,427**

#### UPGRADES

ADD SECONDARY STORAGE	Western Digital Blue 4TB	overclockers.co.uk	#166 p54	£90
SWAP CPU COOLER	Corsair H100i RGB Platinum (240mm AIO liquid cooler)	scan.co.uk	#185 p82	£120



# Core component bundles cont ...

## 4K gaming system

**12-core CPU,  
4K gaming with real-time  
ray-tracing abilities**



Needs an E-ATX case with room for a 240mm all-in-one liquid cooler. We recommend a 650W 80 Plus Gold power supply.

COMPONENT	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
CPU	AMD Ryzen 9 3900X	overclockers.co.uk	#192 p14	£440
CPU COOLER	Corsair H100i RGB Platinum (240mm AIO liquid cooler)	scan.co.uk	#175 p20	£120
GRAPHICS CARD	Nvidia GeForce RTX 2080 Ti	scan.co.uk	#189 p20	£950
MEMORY	16GB (2 x 8GB) ADATA XPG Spectrix D60G 3600MHz (AX4U3600 38G17-DT60)	cclonline.com	#199 p57	£132
MOTHERBOARD	MSI Prestige X570 Creation (E-ATX)	overclockers.co.uk	#193 p48	£430
STORAGE	1TB Corsair MP600	amazon.co.uk	#193 p26	£190

**Total £2,262**

### UPGRADES

ADD SECONDARY STORAGE	4TB Western Digital Blue	overclockers.co.uk	#166 p54	£90
SWAP CPU	AMD Ryzen 9 3950X (16 cores)	overclockers.co.uk	#197 p24	£699

## Heavy multi-threading workstation

**Serious multi-threaded power,  
1080p gaming**



Needs an E-ATX case with room for a 240mm 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	overclockers.co.uk	#197 p18	£1,250
CPU COOLER	Enermax Liqtech II TR4 240 (240mm AIO liquid cooler)	overclockers.co.uk	#186 p44	£130
GRAPHICS CARD	Zotac Gaming GeForce GTX 1660 Super	overclockers.co.uk	#199 p46	£199
MEMORY	32GB Corsair Dominator Platinum RGB 3466MHz (CMT32GX4 M4C3466C16)	scan.co.uk	#197 p20	£286
MOTHERBOARD	ASRock TRX40 Taichi (E-ATX)	overclockers.co.uk	#198 p44	£455
STORAGE	1TB Corsair MP600	amazon.co.uk	#193 p26	£190

**Total £2,510**

### UPGRADES

SWAP GRAPHICS CARD	Nvidia GeForce RTX 2070 Super (2,560 x 1,440 gaming with ray tracing, and some 4K gaming)	scan.co.uk	#193 p16	£450
SWAP CPU	AMD Threadripper 3970X (32 cores - massive multi-threaded power)	overclockers.co.uk	#197 p19	£1,770
ADD SECONDARY STORAGE	6TB Seagate BarraCuda Pro	cpc.farnell.com	#166 p50	£222



# 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 Z390 (LGA1151)	ASRock Z390 Phantom Gaming-ITX/ac	scan.co.uk	#185 p50	£177
AMD X570 (AM4 budget)	Gigabyte X570-I Aorus Pro WiFi	overclockers.co.uk	#195 p24	£227
AMD X570 (AM4 mid-range)	Asus ROG Strix X570-I Gaming	overclockers.co.uk	#198 p20	£270

### Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Metallic Gear Neo Mini	amazon.co.uk	#195 p48	£60
MID-RANGE	Phanteks Enthoo Evolv Shift Air	overclockers.co.uk	#195 p49	£95
PREMIUM	Lian Li PC-Q37WX	overclockers.co.uk	#195 p47	£200

### CPU coolers

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
LOW-PROFILE	Noctua NH-D9L	amazon.co.uk	#143 p17	£42

### Power supplies

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
800W SFX	SilverStone StriderSX800-LTI	scan.co.uk	#185 p82	£156



## ATX Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Phanteks Eclipse P300 Glass	overclockers.co.uk	#176 p28	£55
BUDGET QUIET	be quiet! Pure Base 500	aquatuning.co.uk	#196 p24	£68
BUDGET RGB	Phanteks Eclipse P400A	novatech.co.uk	#194 p24	£84
SUB-£100	Lian Li Lancool One Digital	overclockers.co.uk	#184 p32	£95
MID-RANGE	Phanteks Eclipse P600S	overclockers.co.uk	#187 p24	£135
HIGH-END	NZXT H700i	overclockers.co.uk	#196 p51	£170
PREMIUM	Phanteks Enthoo Evolv X	overclockers.co.uk	#187 p24	£200
LUXURY	Cooler Master Cosmos C700M	awd-it.co.uk	#183 p28	£410

## Micro-ATX



### Motherboards

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
Intel Z390 (LGA1151)	Asus ROG Maximus XI Gene	overclockers.co.uk	#189 p28	£285
AMD X399 (TR4)	ASRock X399M Taichi	scan.co.uk	#179 p28	£318
AMD B450 (AM4)	MSI B450M Mortar	overclockers.co.uk	#182 p50	£85

### Cases

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
BUDGET	Fractal Design Focus G Mini	overclockers.co.uk	#180 p46	£47
MID-RANGE	Fractal Design Define Mini C	scan.co.uk	#161 p26	£80

## Networking



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
ROUTER (WI-FI 6)	TP-Link Archer AX6000	amazon.co.uk	#196 p57	£250
MESH ROUTER (WI-FI 5)	Netgear Orbi 2-Pack (RBK50)	amazon.co.uk	#172 p57	£260
PREMIUM MESH ROUTER (WI-FI 6)	Asus AiMesh AX6100	overclockers.co.uk	#196 p54	£350
WI-FI ADAPTOR	TP-Link Archer TX3000E	overclockers.co.uk	#196 p58	£60
SINGLE-BAY NAS BOX	Synology DS118	box.co.uk	#174 p34	£146
DUAL-BAY MEDIA NAS BOX	Synology DS218play	box.co.uk	#174 p34	£180



# Monitors



## AMD FreeSync

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN BUDGET 1,920 X 1,080	AOC G2460VQ6	amazon.co.uk	#174 p52	£120
24IN MID-RANGE 1,920 X 1,080	AOC C24G1	cclonline.com	#191 p28	£175
24IN 240Hz ESPORTS 1,920 X 1,080	AOC AGON AG251FZ	overclockers.co.uk	#187 p48	£290
27IN 2,560 X 1,440	Samsung C27HG70	ebuyer.com	#171 p28	£446

## Nvidia G-Sync

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN 2,560 X 1,440	AOC AGON AG241QG	amazon.co.uk	#169 p55	£400
27IN 2,560 X 1,440	Asus ROG Swift PG279Q	ebuyer.com	#155 p48	£680
35IN ULTRA-WIDE 3,440 X 1,440	AOC AGON AG352UCG6	overclockers.co.uk	#180 p52	£670
27IN 4K PREMIUM	Asus ROG Swift PG27UQ	scan.co.uk	#181 p31	£1,956
35IN ULTRA- WIDE HDR 3,440 X 1,440	Asus ROG Swift PG35VQ	scan.co.uk	#198 p58	£2,700

## AMD FreeSync and Nvidia G-Sync

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
24IN BUDGET 1,920 X 1,080	AOC G2590FX	overclockers.co.uk	#190 p53	£175
25IN MID-RANGE 1,920 X 1,080	Asus VG258QR	currys.co.uk	#190 p54	£269

## Non-gaming

CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
27IN 4K	AOC U2790PQU	lamda-tek.com	#194 p30	£280
27IN 5,120 X 2,880	Iiyama ProLite XB2779QQS	scan.co.uk	#179 p34	£695

# Peripherals and audio

## Gaming keyboards



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
MEMBRANE	Corsair K55 RGB	overclockers.co.uk	#176 p52	£45
MECHANICAL	Corsair K68 RGB	ebuyer.com	#181 p53	£120
MECHANICAL MMO	Corsair K95 RGB Platinum	scan.co.uk	#164 p26	£140
PREMIUM MECHANICAL	Corsair K70 Mk.2 Low Profile	scan.co.uk	#193 p56	£130
LUXURY MECHANICAL	Razer Huntsman Elite	scan.co.uk	#193 p59	£189

## Gaming mice



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
FIRST-PERSON SHOOTER	SteelSeries Rival 600	scan.co.uk	#184 p59	£74
MMO	Razer Naga Trinity	scan.co.uk	#186 p52	£65
AMBIDEXTROUS	Razer Lancehead Tournament Edition	currys.co.uk	#177 p53	£60
ULTRA LIGHTWEIGHT	Glorious PC Gaming Race Model O	overclockers.co.uk	#195 p58	£45



# Peripherals and audio cont ...

## Game controllers



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>STEERING WHEEL &amp; PEDALS</b>	Logitech G920 Driving Force	currys.co.uk	#159 p55	£200
<b>GAMEPAD</b>	Microsoft Xbox One Wireless Controller	argos.co.uk	#191 p56	£45

## Speakers

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

## Gaming headsets



CATEGORY	NAME	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>STEREO</b>	Sennheiser GSP 300	amazon.co.uk	#194 p56	£65
<b>SURROUND</b>	Asus ROG Centurion	cclonline.com	#163 p49	£216
<b>WIRELESS</b>	SteelSeries Arctis 7	currys.co.uk	#178 p58	£130
<b>PREMIUM WIRELESS</b>	Corsair Virtuoso RGB Wireless SE	scan.co.uk	#195 p30	£180

# PCs and laptops



## Pre-built PC systems

CATEGORY	NAME	CPU	GPU	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>BUDGET PC WITH INTEGRATED GRAPHICS</b>	Falcon Raptor RX	AMD Ryzen 5 3400G stock speed	AMD Radeon RX Vega 11	falconcomputers.co.uk	#176 p52	£499
<b>SUB-£1,000 GAMING</b>	AlphaBeta i5 RTX	Intel Core i5-9600KF stock speed	Nvidia GeForce RTX 2070 Super	alphabetaapc.com	#197 p40	£999
<b>8-CORE GAMING</b>	Wired2Fire Predator	AMD Ryzen 7 3700X stock speed	Nvidia GeForce RTX 2060 Super	wired2fire.co.uk	#196 p40	£1,280
<b>GEFORCE RTX 2080 SUPER GAMING</b>	CyberPower Ultra 7 RTX	AMD Ryzen 7 3800X stock speed	Nvidia GeForce RTX 2080 Super	cyberpowersystem.co.uk	#199 p34	£1,899
<b>PREMIUM MINI-ITX</b>	Corsair One i160	Intel Core i9-9900K stock speed	Nvidia GeForce RTX 2080 Ti	corsair.com	#190 p32	£3,250
<b>WATER-COOLED 16-CORE GAMING</b>	Scan 3XS Vengeance RTX Ti Fluid	AMD Ryzen 9 3950X OC to 4.3GHz	Nvidia GeForce RTX 2080 Ti	scan.co.uk	#197 p42	£4,499
<b>THEADRIPPER PC</b>	Chillblast Fusion Conqueror	AMD Ryzen Threadripper 3970X stock speed	Nvidia GeForce RTX 2080 Ti	chillblast.com	#199 p32	£5,999
<b>DREAM PC</b>	Scan 3XS Barracuda	Intel Core i9-9900X OC to 4.4GHz	2 x Nvidia GeForce RTX 2080 Ti	scan.co.uk	#145 p58	£9,791

## Laptops



CATEGORY	NAME	CPU	GPU	SCREEN	SUPPLIER	ISSUE	PRICE (inc VAT)
<b>GEFORCE RTX GAMING</b>	Chillblast Phantom 17	Intel Core i7-9750H stock speed	Nvidia GeForce RTX 2070	17.3in 1,920 x 1,080 IPS 144Hz	chillblast.com	#197 p53	£1,949
<b>PREMIUM GAMING</b>	Asus ROG Zephyrus S GX701GX	Intel Core i7-9750H stock speed	Nvidia GeForce RTX 2080 Max-Q	17.3in 1,920 x 1,080 IPS 144Hz G-Sync	amazon.co.uk	#190 p28	£3,300



# Games



RICK LANE / INVERSE LOOK

## CYBERPUNK 2020

With Cyberpunk 2077's launch coming later this year, Rick Lane explores the definition of Cyberpunk in current times

**C**yberpunk 2077 is probably the most anticipated game on the planet. As such, CD Projekt's massive RPG has been the subject of a lot of speculation. Almost every aspect of it, from its representation of race to gender, sexuality and violence are all being examined under the microscope before the game has even launched.

Much of this speculation is bound up in assumptions of what is, or what should be, the definition of Cyberpunk, and whether or not CD Projekt's work is in line with that. Like all science fiction, Cyberpunk originated as speculative fiction. When *Blade Runner* and particularly *Neuromancer* were released in the early 1980s, they were created as visions of the future intended to inform the now. However, Cyberpunk was also hotly counter-cultural – an angry and anxious projection of where neoliberal capitalism might take us.

Since then, these two works have come to define the aesthetics of Cyberpunk – rain-slicked pavements, walls of neon and slums in the shadows of skyscrapers. It's this aesthetic that 2077 adopts, yet there's a difference between embracing the style of Cyberpunk and embracing the spirit of it. You can have the neon, rain, glass and cynicism, but all that gives you is a veneer – a retro-futurist cartoon that's now almost 40 years old.

That said, you could argue that it's difficult to be speculative at all today. In 2020, *Neuromancer* reads less like sci-fi and more like travel literature – Bill Bryson's adventures in the Sprawl. Where does Cyberpunk go when we already have drones, hyper-fast internet, VR headsets and fridges that eavesdrop on your conversations? How do you create near-future sci-fi

when technology moves so fast that the future has zoomed past before your work has been published, like a cultural generation-ship left in the wake of technology's FTL cruiser?

It's a question that William Gibson himself attempted to answer in 2014's *The Peripheral*, which has to reach for pocket universes in order to feel futuristic. To create new Cyberpunk fiction, you need to find a new baseline. Some games have tried a similar strategy too – *Deus Ex: Human Revolution* offered a very different image of Cyberpunk by zooming in on a specific element of the genre, namely cybernetic augmentations.

*Human Revolution* dives deep into this theme, considering the political and social implications of a world where people's bodies can exceed the limits of evolution, which has a dramatic influence on the game world that Square Enix created. Instead of looking towards older visions of Cyberpunk for aesthetic inspiration, *Human Revolution* looks at styles that fit it thematically, settling on the fashions of the Italian Renaissance for its clothing and interior designs. Narratively, meanwhile, it considers the social implications of human enhancement in specific detail, such as exploring what happens when people can't afford the drugs that prevent their bodies from rejecting the augmentations that keep them alive.

This focus is what makes *Human Revolution* stand out among other Cyberpunk games. It gives itself a point in space to explore, rather than a style to mimic. We've yet to see whether Cyberpunk 2077 can do the same, but that's what will make the difference between it being a fun RPG, or a work that makes a meaningful contribution to Cyberpunk as a genre. **8/10**

You can have the neon, rain, glass and cynicism, but all that gives you is a veneer

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



# Halo Reach / £6.99 inc VAT

## (£29.99 inc VAT for Master Chief Collection)

DEVELOPER Bungie / 343 Studios / PUBLISHER Microsoft

**A**t the time of its release, Halo: Reach was arguably the best Halo game since Combat Evolved. A decade on, however, Reach is showing its age, and on PC, it's eclipsed by a large number of superior shooters.

What mainly separated Reach from other Halo games was its storytelling, which put players in a battle they were destined to lose from the start. As the conglomerate alien force known as the Covenant invaded the planet Reach, the six Spartans of Noble Team traversed the planet from battle to battle, gradually being whittled down until only one remained.

It was stirring in its day, and some of the game's key moments remain thrilling and dramatic, such as the space assault on a Covenant Supercarrier, the evacuation of Reach's capital New Alexandria and Noble Six's final, fatal showdown. Unfortunately, the writing, acting and animation has aged less well. Noble Team is stoic to the point of being wooden, and the script fails to communicate the emotion of the situation well.

Mechanically, Halo's strongest asset was always its highly dynamic firefights, and those remain intact in the transition to PC. The Covenant forces make for tricky opponents, and you regularly need to use fire and manoeuvre tactics to outflank them. Much of the visual spectacle is generated by the combat, with the alien weapons and vehicles producing a dazzling and deadly laser show that has lost little of its appeal.

However, Reach lacks the speed and impact of games such as Doom or even Bulletstorm, which launched just a year later. Meanwhile, the audio for weapons sounds very subdued, undermining the whole experience. The addition of mouse-look on the PC is also a mixed blessing. In multiplayer, it makes Reach a far more reactive shooter, but it also makes the single-player game very easy, so you'll want to crank up the difficulty level.

The PC version of Reach offers some advantages over the console version too, with support for 4K and ultrawide monitors, as well as the ability to tailor your field of view to your liking. That said, it's not a remaster, so don't expect up-to-date visuals. It also lacks detailed graphics options for tweaking anti-aliasing, anisotropic filtering and so on.

Halo Reach remains a decent FPS, but time and competition has worn away much its original appeal. That said, the PC launch is only the first part of the Master Chief Collection, which will also see Halo 1-4 released throughout 2020. Perhaps those other games will better stand the test of time.

RICK LANE



### REACHING FOR GLORY

- + Combat still spectacular and dynamic
- + Key campaign moments still work

### GRASPING AT STRAWS

- Underwhelming audio
- Story and narrative have aged badly

### / VERDICT

Halo Reach can just about still blast with the best of them, but it's showing its age in many areas.

### OVERALL SCORE

# 63%





# Star Wars Jedi: Fallen Order / £49.99 inc VAT

DEVELOPER Respawn Entertainment / PUBLISHER EA

**T**he past few years have left the distinct impression that Disney isn't entirely sure what to do with the world's biggest sci-fi franchise when it comes to games. Disney's publishing partnership with Electronic Arts has resulted in two mediocre games over a period of six years.

We wish we could say that Jedi: Fallen Order bucks this trend. A single-player, Jedi-focused action game sounds like just the ticket after two multiplayer-focused fiascos. Unfortunately, Fallen Order only epitomises the problems the franchise has been facing. It's a bizarre accumulation of ideas from the past ten years of big-budget game development, strung together in a way that just about works but leaves cracks the size of Beggar's Canyon running right through the experience.

Fallen Order puts players in the role of Cal Kestis, a Jedi on the run from the death squads of Order 66 during the gap between Revenge of the Sith and A New Hope. Hiding out as a shipbreaker on a distant junkyard planet, Kestis' secret identity is compromised quicker than a stormtrooper's chest armour, and he narrowly escapes death via the intervention of an ex-Jedi named Cere (pronounced 'Seer'). The

pair then join forces to find a Jedi Holocron that contains a list of hundreds of Force-sensitive people across the galaxy, and prevent it from falling into the hands of the Empire.

It's an enjoyable enough MacGuffin chase. Cal is a relatively likeable chap, if a little on the stiff side, while the crew of your ship eventually evolve a pleasing camaraderie. That said, it has the distinct whiff of being unfinished. There are seemingly major characters (including one played by Forest Whitaker) who are given major prominence in the early story, but are never seen again. Meanwhile, other major characters appear very late in the game, and everyone suddenly treats them as if they've been buddies for years. The way your ship is designed for you to move around also implies a Mass Effect-style approach to storytelling, but Fallen Order has nothing like Mass Effect's narrative depth.

The same goes for the visual and structural side of Fallen Order. The game's key set pieces look fantastic, with the big-budget spectacle you'd expect from a proper Star Wars game. Then you end up on planets such as Bogano, whose boxy cliff faces and low-res vegetation seems to be plainly rushed out of the door. Some planets, such as Kashyyyk and Zeffo, look great in some areas but dreadful in others.

It's highly inconsistent.

## JEDI

- + Good combat
- + Some spectacular sequences

## FALLEN ORDER

- Inconsistent visual quality
- Half-baked story
- Sloppy level design





Level design is bizarrely thought out too. Structurally, *Fallen Order* takes inspiration from both *Dark Souls* and *Uncharted*, blending action-centric platforming with mazy levels that unveil themselves as you explore. Some areas are blocked off until you acquire the right Force power or equipment upgrade, which may be on another planet entirely. The problem is that *Fallen Order* doesn't provide much of a reason to explore beyond the main story.

All the important upgrades are acquired on the main path, meaning the best you can expect from poking further around is a new poncho or a slight health boost. Some areas, such as the wrecked Star Destroyer *Venator*, merit exploration in their own right, but many areas are built from highly artificial-looking platforming objects, such as slides that are very thinly disguised as glaciers or muddy slopes.

There's little question that *Fallen Order* is a mess of ideas, but it isn't all bad. The majority of the game's focus is on lightsaber combat, and that's where *Fallen Order* shines brightest. Again, it owes a big debt to *Dark Souls*, with a heavy emphasis on blocking and dodging enemy attacks, and getting your hits where possible. Death will catapult you back to the nearest checkpoint and respawn all the enemies, while you get a limited supply of health boosts, more of which can be discovered by exploring.



It's a light and snappy system that expands to offer an impressive array of abilities. Not only do you gain access to multiple Force powers, such as push and pull, but you also get several lightsaber arrangements, including a double-bladed saber that's very useful for fighting multiple opponents at once. You can combine Force powers with saber combat too. Pulling a stormtrooper into your grasp and executing them with a quick stab through the gut never ceases to satisfy.

*Fallen Order*'s saber combat is easily its best feature, although there are still some problems. While *Respawn* has mimicked the structure of *Dark Souls*' combat, *Fallen Order* lacks the same sense of rhythm, meaning it's very hard to learn the timings of enemy attacks and counter them effectively. Also, the game's representation of a lightsaber's cutting power is strange. The game won't let you cut off the arms of Stormtroopers, but it's quite happy to let you slice alien animals in half, which seems far crueller and unnecessary.

The final issue is that *Fallen Order* is far too sparing with the Jedi duels. When they occur, they're highlights of the game, but there are only about five of them across *Fallen Order*'s length of 16-20 hours, and two of them are only abridged fights. Indeed, *Fallen Order* is generally at its best during the more bespoke sequences. The opening mission on *Kashyyyk*, which sees you sneak aboard an AT-AT lumbering through a swamp, is breathtaking.

It's a shame that *Fallen Order* doesn't focus on these types of moments, giving every level a specific goal and building the action around it. If you're a *Star Wars* fan, *Fallen Order* is still worth playing, but it may well test your patience at points. Otherwise, you're better off sticking to the games that *Fallen Order* imitates less well.

RICK LANE

## / VERDICT

*Fallen Order* is strong in the Force, but it lacks the discipline and focus required to be a Jedi.

OVERALL SCORE

58%





# Phoenix Point / £35.99 inc VAT

DEVELOPER Snapshot Games / PUBLISHER Snapshot Games

**P**hoenix Point has a bizarre knot of influences. It's a spiritual successor to X-COM (Or UFO: Enemy Unknown in the UK) created by X-COM's original designer, Julian Gollop. However, it's equally inspired by the recent reboot of X-COM spearheaded by Firaxis. It's like Shakespeare writing a play based on a film of Macbeth. It sees players attempting to save the world from an alien virus that turns people into terrifying, hostile monsters.

On the Geoscape – a holographic representation of Earth – you need to explore the virus-ravaged world to scavenge resources, locate and upgrade underground bases, and acquire alien technology. You can then research the latter to produce advanced weapons and equipment. Those nasty mutants won't give away their tech without a fight, however, so you regularly need to battle them in tough, uncompromising tactical combat.

Phoenix Point's main divergence from X-COM is an increased level of granularity to its strategy. Not only must you concern yourself with the alien threat, but there are also three human factions vying for resources and territory across the Geoscape. You can interact with these factions in a variety of ways.

Helping them in diplomatic disputes with other factions, and defending their havens from alien attacks, will improve your reputation with them, eventually providing access to their unique weapons and equipment.

Alternatively, you can raid their havens, stealing their food, vehicles and technology. What you do with one faction will affect your relationship with others, resulting in a satisfying sub-game of political intrigue.

The tactical combat, meanwhile, adds multiple layers of complexity. Your soldiers can aim at individual enemy body parts for different effects, while each level's destructible buildings can radically change battlefield topography over the course of a fight. One of the most interesting mechanics is the ability to combine soldier classes, letting you give your sniper the sprinting speed of an assault soldier, or your heavy weapons guy the accuracy of a sniper.

In the early game, it's fun to dive into Phoenix Point's many layers, but that complexity shifts from intriguing to tedious as you spread across the globe. Needing to manage tiny areas, such as the ammo-count of individual soldiers, slows progression to a crawl. Moreover, while Phoenix Point borrows X-COM's aesthetics, it lacks its sense of style and drama, presenting its end-of-the-world scenario with all the flair of a geography teacher talking about soil erosion. Battles start and end with little sense of occasion, and the music is underwhelming.

Nonetheless, if you're happy to sacrifice some of X-COM's style and pacing, Phoenix Point does provide a more organic, if slower, world-saving strategy experience.

RICK LANE

## RISEN

- + Nuanced combat
- + Fun political scheming
- + Complexity enjoyable at first

## ASHES

- Lacks style
- Too much micromanagement later

## / VERDICT

Emphasising substance over style, Phoenix Point is a tweedier, more bookish X-COM that is undeniably complex, but not always thrilling.

## OVERALL SCORE

74%



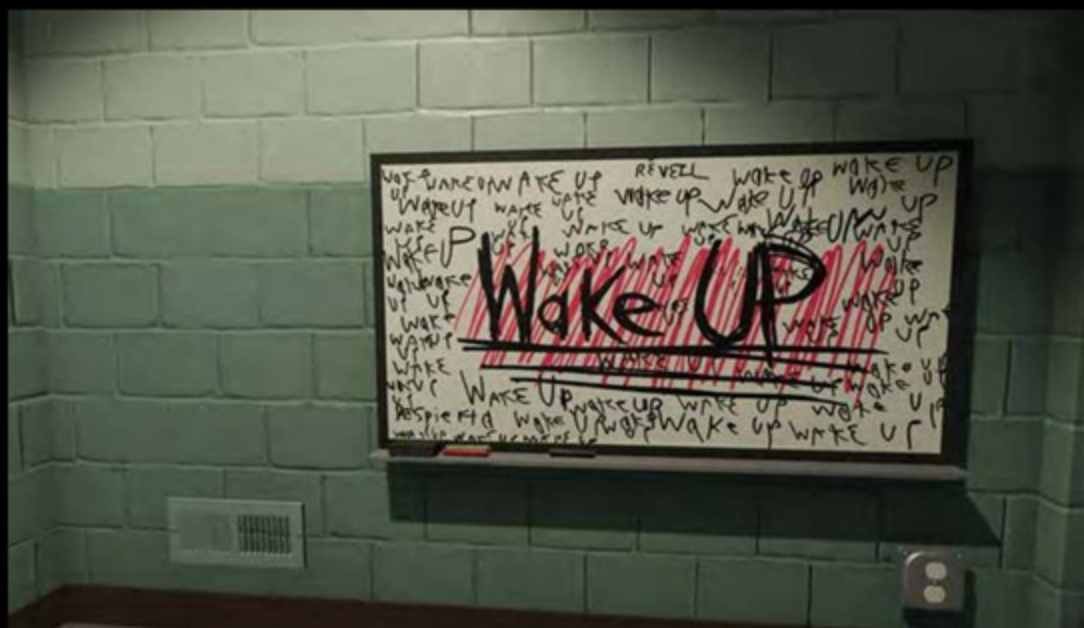
# Superliminal / £15.99 inc VAT

DEVELOPER Pillow Castle / PUBLISHER Pillow Castle

**P**ortal with perspectives. That's the simplest way to describe Superliminal, a first-person puzzle game with a mind-bending central mechanic, a brain full of kooky jokes and a female AI character who may or may not want to kill you. It's difficult to avoid comparing Pillow Castle's puzzler with Valve's mini-masterpiece, and equally difficult for Superliminal to come off as anything other than inferior.

That said, it still has a lot going for it. You play a patient at a cutting-edge research centre specialising in sleeping problems. You're undergoing some new-fangled dream therapy to help you overcome your difficulties with insomnia. The dream theme is primarily a way to contextualise Superliminal's core mechanic, in which you can adjust the size of objects simply by picking them up and moving them around the room. Let's say you pick up a chess piece off a table, then turn around to face the opposite wall. When you put down the chess piece, it will assume the size it appears to be, relative to the wall in front of your eyes.

It's an impressive gimmick. Making a wedge of Swiss cheese the size of a staircase without the cheese ever seeming to actually grow in size is a clever optical illusion.



Messing around with objects in this manner is entertaining in its own right. That's just as well, because Superliminal doesn't always know how to turn its gimmick into compelling puzzles.

After half an hour of solving conundrums by making objects bigger and smaller, the game seems to run out of ideas, switching to a series of less interesting puzzle concepts for a couple of levels. Fortunately, the object resizing returns in much more dramatic fashion in the second half, with you resizing entire houses and exploring a chessboard the size of a small village.

Beyond its gimmick, Superliminal would be unremarkable if it weren't for its fascinating surrealism. It's evident throughout the experience, but comes to the fore during the final third, seeing you explore increasingly strange and dizzying spaces where conventional geometry is deliberately broken down. The light, daft humour also conceals a more sincere and positive message about facing up to problems rather than shying away from them, which it delivers to surprising effect as the game reaches its end.

As a result, while Superliminal may not be the most brain-tickling puzzle game around, it's undeniably fun and has more soul for a game of this ilk than you might expect. If you're disappointed that Valve only made two Portal games, Superliminal fills that gap in a surprisingly competent fashion.

RICK LANE

## SUPERLIMINAL

- + Neat puzzling gimmick
- + Enjoyable surreal environments
- + Fun, upbeat story

## SUBLIMINAL

- Struggles to make the most of its central concept
- Secondary puzzles less engaging

## / VERDICT

Superliminal doesn't always make the best of its perspective-altering mechanic, but the visuals and the humour are enough to carry it to success.

## OVERALL SCORE

70%



# REALITY CHECK

Kayaks, Christmas and counterintelligence, it's **Rick Lane's** monthly VR roundup

## REVIEW

### ESPIRE 1: VR OPERATIVE / £22.99 inc VAT

DEVELOPER Digital Lode / PUBLISHER Tripwire Interactive

Espire 1 is essentially a James Bond simulator, if James Bond were an asexual robot who frequently threw his gun at people by mistake. It's a first-person stealth game that's as intriguing as it is frustrating. It contains every feature you could want from virtual stealth, but it lacks the refinement needed to make its sneaking satisfying.

The game puts you in the role of a drone operator working for an Australian counterintelligence organisation. You're tasked with investigating an incursion into one of the organisation's black sites developing remote-controlled robots. Taking control of one such android, you need to infiltrate the facility and slip past the enemy patrols to figure out their dastardly plan (and how to stop it).

Espire 1 is built upon a familiar stealth game format, but Digital Lode's VR translation quickly communicates its potential. The ability to physically lean around corners, for example, is very satisfying, as is climbing walls and other objects, hand-over-hand, to slip past guards from higher vantage points. It also takes different tolerances for VR into consideration. If you don't fancy spending six hours crouch-walking through

vents, there's a specialised crouching button to take the strain off your thighs.

Similarly, the game features an optional anti-nausea setting that washes out the peripheries of the screen when you move around, which succeeds in combating motion sickness.

Your robot's stealthy gadgets are equally tweaked to make the best of VR. You can activate a thermal imaging display by raising your touch controller to the side of your head and clicking the appropriate button, while you need to physically pull back the bolt on your single-shot tranquiliser pistol to cock it. One of its most nifty features is the ability to sneak behind a guard and shout 'freeze!' to make them surrender.

All of Espire 1's tools make for enjoyable tinkering, particularly in the game's Challenge mode, which comprises individual levels themed around a specific aspect of the game, such as climbing or shooting. In the campaign, however, deploying your abilities practically isn't very easy. Weapons and equipment are all attached to a bandolier you wear across your torso. This seems like a good idea, but it makes it far too easy to grab the wrong tool for the job,

hence why you often end up accidentally throwing your weapons at enemies.

Speaking of enemies, the AI of the guards is haphazard at best. Sometimes you'll stand right beside them and they won't see you; at other times, they'll spot you climbing across a gantry on the far side of a warehouse. When you're spotted, combat is tricky and underwhelming. The guns are difficult to aim accurately, while the game's physics engine seems to be stuck on Moon mode, with both weapons and enemies lacking any sense of weight. Ultimately, Espire 1 has all the right tools for the job, but it's too roughshod to slip past our critical defences.

#### GHOST

- + VR stealth has potential
- + Lots of fun gadgets
- + Challenge mode is enjoyable

#### BANSHEE

- Shoddy AI
- Clumsy inventory system
- Disappointing combat

#### VERDICT

Espire 1 wants to be *Splinter Cell* in VR Goggles, but ends up stumbling right into the alarm sensors.

#### OVERALL SCORE

71%





NEWS

## PHANTOM: COVERT OPS

Of all the ways VR games attempt to circumvent the limitations of current VR headsets, *Phantom: Covert Ops* must have one of the weirdest solutions. It's a VR stealth shooter in which you have a single night to silently infiltrate a military base somewhere near the Black Sea. The twist? You spend the entire game sat in a kayak.

Rather than taking a standard stealth structure and transplanting it wholesale into VR – like *Espire 1* (see opposite) – *Phantom* instead aims to build a stealth game with VR specifically in mind. The kayak's slower, more deliberate movement is designed to be easy to control with your hands, while you'll be able to hide from enemy boat patrols in reed banks and underneath jetties.

When not paddling around the wetlands surrounding your target, you'll be using night-vision goggles to scout out patrols, wielding guns to disable lights and take out guards, and

planting sticky explosives to disable key infrastructure around the base. Intriguingly, the game features open-ended levels, letting you approach objectives in different ways and use the tools at your disposal in a more creative fashion. In other words, it's a proper stealth experience, not *Canoe of Duty*.

*Phantom* was originally scheduled to launch in 2019, but has been pushed back several months to an unspecified release date early in 2020. When it does arrive, the game will be available for both Oculus Rift and Oculus Quest, with versions designed specifically to cater towards the relative power of each headset.



OPINION

## VR'S HOLIDAY BLOWOUT

Since John Carmack went viral with a plastic box duct-taped to his face, VR's future has been constantly questioned. Every aspect of it, from its physical limitations to the cost of the equipment, has triggered claims that VR gaming is some obscure niche destined to die out.

It's true that VR still represents a mere fraction of the larger gaming industry, but as 2019's Christmas and New Year period shows, it's one that's growing rather than shrinking. Christmas 2019 saw unprecedented sales of VR headsets. Oculus Quest back orders were pushed back to mid-February, while the Valve Index has been sold out since late November.

Some of this is a consequence of the festive season itself – the Oculus Quest is an ideal Christmas day gizmo, after all. However, the announcement of *Half-Life: Alyx* has also been a key influence, giving VR a big, unique franchised game that it previously lacked.

What's more, the recently released VR shooter *Boneworks* broke *Beat Saber*'s record to become the biggest-selling VR game yet, shifting 100,000 copies in its first month and grossing an estimate \$3 million US in revenue. Meanwhile, our long-time favourite *Superhot VR* sold \$2 million US worth of copies over the Christmas week alone, no doubt because of all those new VR headsets being unwrapped after Santa's annual visit. VR may never become the default way people play games, but it also isn't going to disappear anytime soon. **CPC**





# The **ULTIMATE** air-cooling guide

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**ANTONY LEATHER** INVESTIGATES WHAT REALLY MATTERS  
WHEN IT COMES TO FANS, AIRFLOW AND COOLING





Many fans in the front of a case produces a positive pressure environment. Many fans exhausting air out the back creates a negative pressure environment

**W**hile most PC cases are equipped with at least one case fan, case manufacturers often don't offer advice on how to set up your PC with the best airflow and cooling in mind. If you add more fans, for example, where should you place them? Are fewer higher-power fans better than numerous low-speed ones? Are closed-front panel cases really worse for cooling than mesh panel cases? Should you avoid mounting your graphics card vertically? We'll be investigating what really makes a difference when it comes to setting up your PC's cooling.

## Air pressure

Perhaps the most debated topic in air cooling is that of whether you should have positive or negative air pressure in your case. As soon as you add a fan to an external opening, it affects the overall pressure inside the case. An intake fan will blow extra air into a case and an exhaust fan will suck it out. Blowing air into a PC case will add to the existing pressure level inside your case (positive) while sucking out air will result in the internal pressure being lower than the ambient pressure in the room (negative).

Clearly, having both exhausts and intakes is important. Getting cool air into your PC will aid cooling and can be particularly useful to your graphics card, for instance. Meanwhile, exhaust fans allow hot air to be expelled, so it can be replaced by cooler air again. Both serve to keep the inner air temperature in check, and in an ideal world you'd have a perfectly balanced pressure system. However, once you've built your PC and added any fans, it's likely your system won't

Adding a second fan to the CPU cooler does more than most other fan configuration changes



have a completely neutral air pressure and will reside in negative or positive pressure territory.

Which pressure setup your case is working with can be worked out by adding together the total intake and exhaust airflow ratings of any fans, or just with a small piece of tissue paper held against a panel gap. If the paper gets sucked towards the case, it's operating with a negative pressure (air is being sucked in through all the gaps and pushed out by the fans) and if it gets blown outwards, the case is under positive air pressure (the higher pressure air is looking to escape through the panel gaps).

As an example, if you have a single exhaust fan and three intake fans of similar sizes and speeds – a popular out-of-the-box configuration – it's fairly obvious your PC will sit in the positive airflow category; there's more air going in than coming out. The question is, of course, which setup is best?

## Negative air pressure

Negative air pressure can often lead to a quieter PC for the simple reason that exhaust fan positions are usually not at the front of the case, and are therefore further from your ears and concealed in your case. Getting heat out of a PC is usually the most effective way of keeping your PC cool too, which is why many cases that include a single fan mount it in the

rear as an exhaust. Those that install it as an intake fan often end up with warmer results in our tests, especially when it comes to CPU cooling performance. Negative air pressure can also be useful in small form factor PCs, where the tight confines mean that getting heat out of a case quickly is even more important and something we'll talk about in more detail later.

There are downsides to negative air pressure though. The most troubling of these is dust. Negative air pressure will mean that air is drawn in through all the recesses in your case – not just the front fan mounts that are protected with dust filters. These gaps allow dust to get into your case unchecked, where it can build up on internal components, covering heatsinks, blocking airflow and even clogging up the very motors of your fans. Dust is a factor for positive airflow setups too, but the accumulation can be far quicker in negative pressure scenarios. Although not strictly a result of negative pressure, often cases that are configured with negative pressure have the fans mounted in such a way that airflow just doesn't get where it needs to. For instance, you may only have fans at the rear or roof of your case, or a single fan at the front paired with one or two exhaust fans at the top and back. In these scenarios, your CPU cooler and particularly your GPU may simply be starved of cool enough air.





Many cases only come with one front intake fan, but packing the front of the case with intake fans can have major benefits

## THESE GAPS ALLOW DUST TO GET INTO YOUR CASE, WHERE IT CAN BUILD UP ON INTERNAL COMPONENTS, COVERING HEATSINKS AND BLOCKING AIRFLOW

They probably won't overheat, as the air is still being circulated and getting out of the case, but with more direct access to colder air directly from outside the case, they could operate at much lower temperatures.

### Positive air pressure

It's becoming far more common for out-of-the-box case setups to use positive air pressure, usually with a trio of RGB fans in the front of a case and very often the rear fan mount being vacant. However, there are good and bad points here just like with negative air pressure. For starters, the above setup can lead to poorer CPU cooling thanks to the lack of an exhaust fan sitting next to the heatsink.

Also, at the extreme, only having intake fans can see the internal case temperature rise more than a negative air pressure system. You can try to push all the cool

air you want into a case, but positive air pressure will only be a fraction as effective at expelling warm air than an actual exhaust fan. The negative impacts of positive air pressure can be magnified in small cases too, where there are fewer vents to allow air to escape as well as a smaller volume of air absorbing that heat in the first place.

Otherwise, the big issue that positive air pressure fixes is dust ingress. The higher internal air pressure will mean air is forced out of the gaps in the case instead of being drawn in. Your graphics card and CPU can also be fed directly with cool air, aiding cooling. Realistically, the only way positive air pressure can hinder cooling is if you're not matching your system's heat output with suitable exhaust fans. You can have high positive air pressure to reduce dust and still have several exhaust fans to actively remove warm air.

### So what should I use?

For the most part, a slight positive air pressure offers the best balance of dust prevention and heat management. As long as you have at least one exhaust fan, you should be good to go. Running your PC without any exhaust fans is a bad idea and adding further intake fans will not drastically improve cooling. However, there's no substitute for proper testing, so we've carried out some exhaustive benchmarks covering a range of fan setups to see not just whether negative or positive air pressure is best for noise and cooling, but also where's best to position the fans.

We used a Ryzen 7 2700X overclocked to 4GHz, using a vcore of 1.4V, along with a Deepcool Gammaxx GT air cooler and Palit GeForce GTX 1660 Ti, all housed in a Fractal Design Meshify C case to represent a typical gaming PC. We also used Corsair LL120 RGB fans locked to running at 7V and locked the graphics card's fan to 70 per cent too, to prevent any fan control from interfering with our testing.

We ditched the CPU's fan to include another LL120 fan and paired this with a second fan for the dual-fan CPU cooler results. We used a digital thermometer to record the temperature inside the case while we used AMD Ryzen Master for the CPU temperature and GPU-Z for the GPU temperature, recording the peak temperature after ten minutes and allowing ten minutes for the temperatures to subside before we started another test.

We used Prime95's smallfft test with AVX disabled to load the CPU and Unigine's Valley Benchmark to load the GPU. We usually calculate the delta T (recorded temperature minus the ambient room temperature) to get around temperature variations on different days. However, all our testing was carried out on the same day, where ambient temperatures were within one degree of each other throughout testing, so our results are identical to those shown in the software.

Our stock test system has one intake fan and one exhaust fan, with the former sitting midway between our graphics card and CPU. We should highlight the fact that the Fractal Design Meshify C is only one case, and a relatively high-airflow one at that, so our results can't be taken as representative of all cases, particularly those with different volumes and form factors. However, it's a very popular case and typical of the affordable mid-range options currently available.



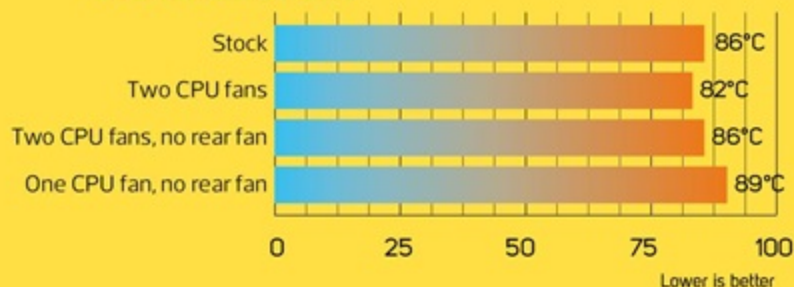
### CPU cooling: rear fans and additional heatsink fans

In its stock configuration, we saw a peak CPU temperature of 86°C and our first test was to see what happened if we added a second fan to the heatsink. Most heatsinks include a second set of clips and even a splitter cable to power an additional fan, so this can be very easy to do. When doing so, our CPU temperature fell by 4°C, turning an already decent cooler into an excellent one. However, remove the rear fan from the case and the temperature climbed all the way back up, and with just one heatsink fan, it rose a further 3°C, so it's clear that a rear fan is important not just for improving CPU cooling, but also to reap the benefits of adding a second heatsink fan.

**Question: Should you always have a rear fan aiding your CPU cooler?**

**Answer:** Yes, it can boost CPU cooling even when your CPU cooler has two fans.

#### CPU TEMPERATURE



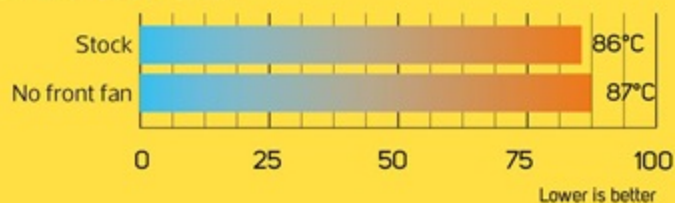
### CPU cooling: front fans

Switching to the front fans and instead of having this case's front fan sitting between the CPU and GPU, we aligned it with the CPU heatsink for theoretical maximum benefit. However, this had no measurable impact on CPU temperature, with the CPU temperature remaining at 86°C. Removing the front fan entirely only saw the CPU temperature rise by 1°C. However, while our CPU cooler may not have been able to take much of an advantage of the extra airflow, the case temperature rose 3°C when we removed the front fan, despite it being a long way from our thermal sensor located in the bottom half of the case.

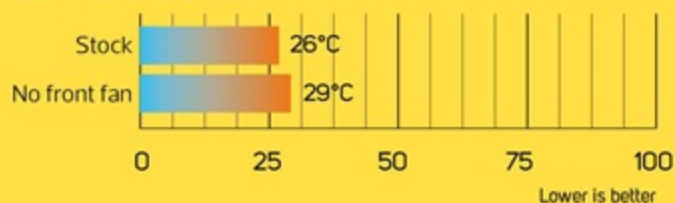
**Question: Do you need your front fan to be pointing at your CPU cooler?**

**Answer:** No, it has minimal impact compared with having it sat between your CPU and GPU, but having at least one intake fan is important for lowering internal temperatures.

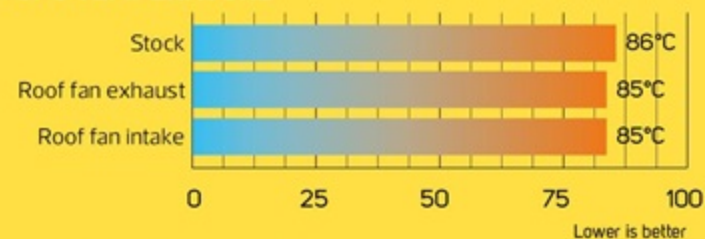
#### CPU TEMPERATURE



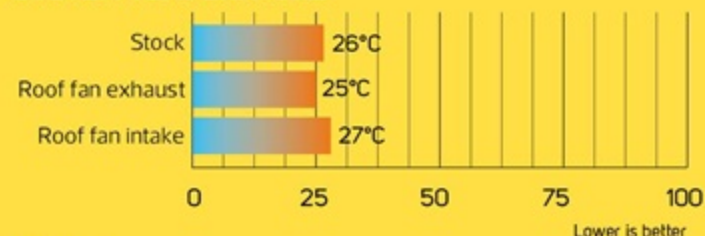
#### SYSTEM TEMPERATURE



#### CPU TEMPERATURE



#### SYSTEM TEMPERATURE



### Roof fans

Most cases have a couple of fan mounts in the roof, but when and how is it best to use these? To find out we added one of our LL120 fans to the roof above the CPU cooler as both an intake and exhaust, with our case already donning our stock setup of single intake and exhaust fans. The CPU temperature fell just one degree in both instances – again within the margin of error, but while the system temperature fell one degree with the fan as an exhaust, it was one degree warmer than the stock configuration with the fan acting as an intake, with the warm heatsink exhaust being blown down towards the GPU and our thermometer. As a result, adding a roof fan can improve your system's temperature a little acting as an exhaust, but it might cause issues with the standard airflow arrangement if you have it as an intake and working at right angles to your CPU cooler.

**Question: Are roof fans worth it?**

**Answer:** Having them as exhausts can help to lower case temperatures to a small degree, but adding a fan to your heatsink, rear or front of your case first is best.





## Exhausts vs intakes

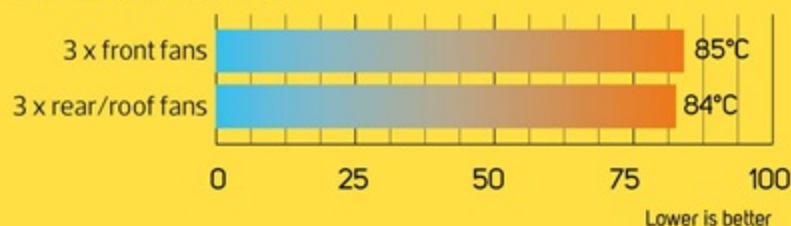
Adding a few more fans to the mix gives you the option of fully occupying all those front fan mounts or rear and roof mounts. The next test involves seeing which of these scenarios is best in probably the most extreme form of positive vs negative air pressure. To start with, we removed the rear fan and had just three front fans installed as intakes. Then we removed all of these and placed them in the two roof mounts and rear mount as exhausts. This time, we also measured the noise level, GPU temperature and system temperature as well as the CPU temperature.

The noise level sat at 58dBA with the three front fan mounts occupied, however, as we predicted, this dropped to just 53dBA with the fans in negative airflow mode placed at the rear of the case. The system temperature, though, was two degrees cooler with all three fans at the front and the GPU sat at a temperature of 66°C compared to 69°C with all fans acting as exhausts. Interestingly, with so much positive air pressure, the CPU was only one degree warmer lacking the rear exhaust fan, while doing this with just one front fan had a much bigger impact.

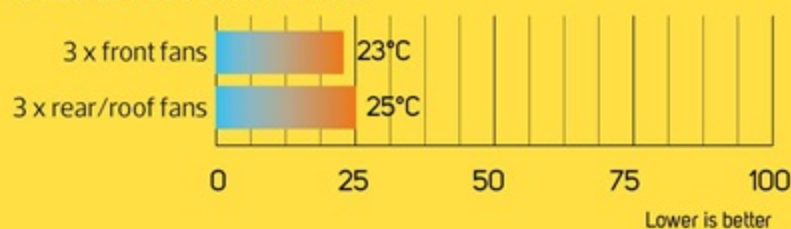
**Question: Are three front fans or three rear fans the best configuration?**

**Answer:** While having lots of exhaust fans can offer lower noise levels, they'll result in negative air pressure and potential dust ingress, as well as higher system and GPU temperatures in a typical high-airflow ATX case.

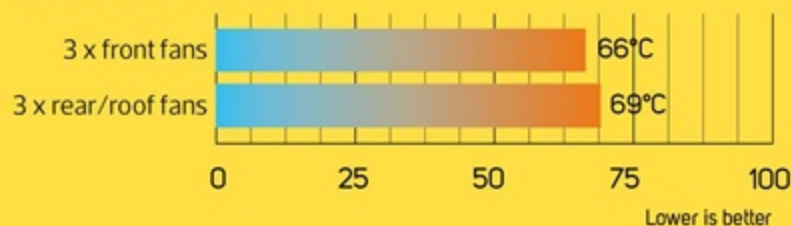
### CPU TEMPERATURE



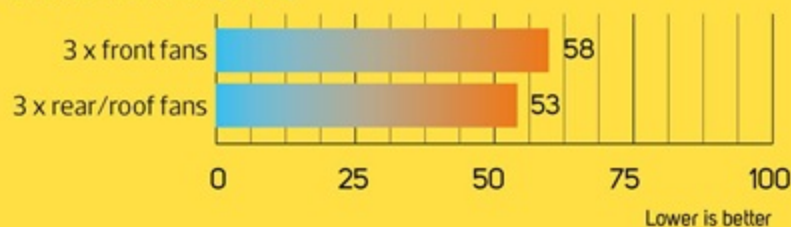
### SYSTEM TEMPERATURE



### GPU TEMPERATURE



### NOISE LEVEL (DBA)



## ADDING A ROOF FAN CAN IMPROVE YOUR SYSTEM'S TEMPERATURE A LITTLE ACTING AS AN EXHAUST, BUT IT MIGHT CAUSE ISSUES WITH THE STANDARD AIRFLOW ARRANGEMENT



### Keeping your GPU cool

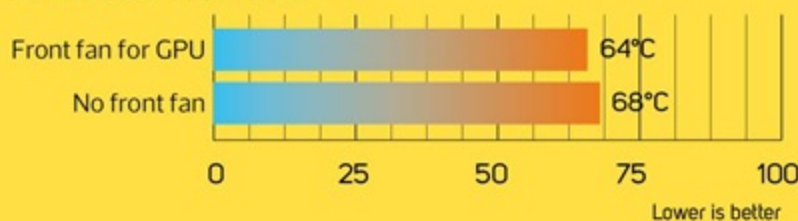
We've already established that your CPU's tower heatsink is often more concerned about having more fans itself as well as a rear fan than having a front fan directly in line with it. This means that if you're looking to add a single front fan to your case or you already have one and don't know where's best to mount it in the front of your case, there are only two more reasons to be possibly tweaking its position.

Firstly, there's the overall case temperature, where we've already established that having at least one front fan can have a sizeable impact. However, should you bother to align the fan with your GPU's cooler? To test this, we placed a single 120mm fan in such a position that its fan sat squarely in line with our graphics card's cooler, feeding it with cool air. To start with, though, we got results for our system with no front fan, which saw a GPU temperature of 68°C. However, this fell to just 64°C with the 120mm fan installed and the system temperature fell by 2°C too.

**Question: Should you have a front fan in line with your GPU?**

**Answer:** Definitely. If you have just one intake fan, you should point it at your graphics card, as our setup's GPU benefited far more from the airflow than the CPU, even with its fan at a fairly potent 70% speed.

### GPU TEMPERATURE





## Fan speed

So now we've established that a rear fan and a front fan pointing at your GPU is the bare minimum setup you should be aiming for, do you need to have those case fans at maximum speed all the time to reap the benefits? Altering fan speed is incredibly easy to do and your motherboard will likely do it automatically for your system fans. However, some fans can be quite noisy at full speed and slowing them down can have a huge impact on reducing this.

The trouble is, opting for slow-spinning fans can render your PC vulnerable on hot summer days, so it's often sensible to have reasonably powerful fans that can be tuned to only spin up when needed. Our Corsair LL120 RGB fans top out at an ear-splitting 2,200rpm but we fixed them at 7V for our testing. This equated to a 1,500rpm spin speed and a loudness that was on the limit of what we'd be happy to sit next to. We ran our main suite of tests at these settings and also with the fans reduced to just 900rpm, where they were far more pleasant to sit next to.

At full speed, the system measured 54dBA with all fans at 1,500rpm. At 900rpm on the case fans but with the CPU fan sat at 1,500rpm still, the system measured just 50dBA from one metre away. This was not only a substantial reduction on paper, but the whine and high-pitch airflow noise at 7V and 1,500rpm completely disappeared too. While noise levels were much improved, what did this mean for cooling? Well, we were pleasantly surprised. The CPU temperature increased by just one degree and the GPU temperature by two degrees. The biggest jump was the case temperature, which rose three degrees, but we'd gladly take this insignificant hit in cooling for the massive noise reduction the lower fan speeds offered.

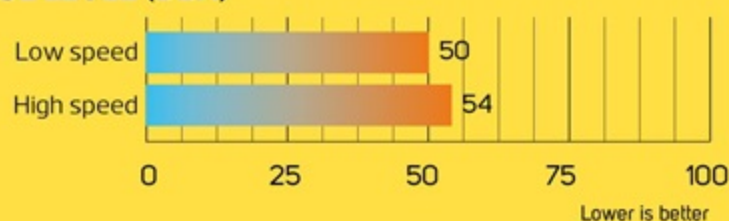
### Question: Should you reduce your case fan speed to cut noise?

**Answer:** Definitely. Our testing showed that, with our system at least, cutting system fan speed by 20-30 per cent resulted in tiny increases in CPU, GPU and system temperatures, but had a huge impact on noise levels. However, you'll need to fine-tune your own PC to get the right balance and to allow it to respond to warmer summer temperatures too.

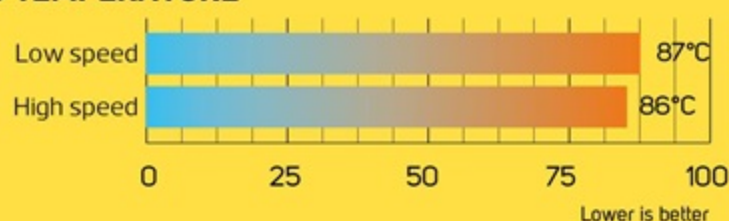


4-pin PWM fans provide more refined control of fan speed than 3-pin DC fans

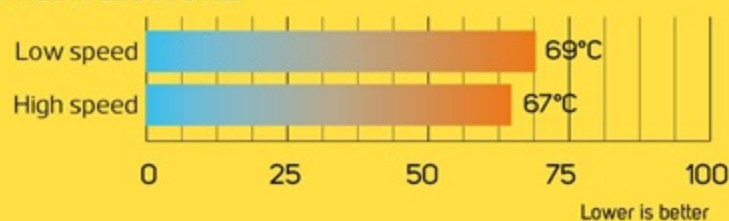
## NOISE LEVEL (DBA)



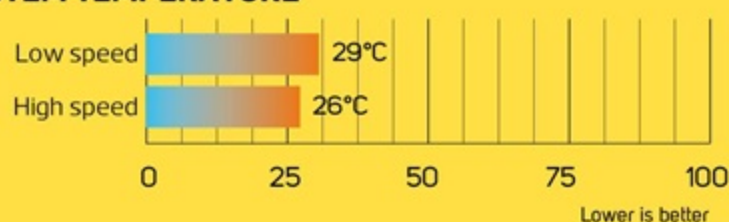
## CPU TEMPERATURE



## GPU TEMPERATURE



## SYSTEM TEMPERATURE



## What's the difference between 4-pin PWM and 3-pin fans?

Most of us are aware that 4-pin PWM (Pulse Width Modulation) fans usually offer a more universally supported way of controlling fan speeds, but PWM signals are also very clever at cutting noise and allowing your fan to spin at speeds it otherwise can't. A 3-pin fan cable traditionally offers power, ground and a tachometric signal for monitoring fan speed. Here, the only way to alter the speed of a fan is to alter the voltage. This isn't something all motherboards can do, although most modern boards do have a DC or direct current mode for fan headers to be able to alter the speed of 3-pin fans.

The problem here is that fans have a minimum start-up voltage. The maximum is 12V for full speed, but many fans will fail to start spinning below 5V or in some cases even more. The result is that they can have a narrow operating range close to their maximum speed and if the voltage dips close to the minimum, the fan can make unpleasant noises or whine too. The answer to increasing a fan's operation speeds, lowering noise levels and avoiding the clicking or whining noise of fans on the edge, is PWM. Here an additional cable allows for the relaying of telemetry as well as the ability to apply 12V to the fan, but only in regular pulses rather than constantly. The frequency of these pulses is called the duty cycle, where a 100 per cent duty cycle means the fan is spinning at full speed, while a 10% duty cycle will result in a much lower speed.

The benefit here is that as the fan is receiving 12V and not 2V or 4V, it will always start to spin. So even if it only receives occasional 12V pulses on a low 10 per cent duty cycle, it will get going but just at a slower speed. To hit similar speeds with direct voltage, the voltage would be





High-airflow fans have narrower blades with larger gaps between whereas high static pressure fans have large, more angled and closely spaced blades

so low the fan wouldn't start in the first place. Thankfully, most aftermarket fans support PWM these days, but we still occasionally come across 3-pin fans in cases. Modern motherboards should still be able to control them to some degree using DC mode, but if you're buying new fans, it's worth opting for 4-pin PWM models.

### What's the difference between high static pressure and high airflow?

Fans can be rated by two main metrics called static pressure and airflow. The meaning of the latter should be fairly obvious: it's simply the maximum amount of air that the fan can move over a period of time, often measured in cubic feet per minute (cfm). A high airflow fan will fill a bag (or case) with air faster than a low airflow fan. Crucially, though, this is a measurement taken where there's little to no resistance on the fan, such as something blocking the flow of air.

Static pressure, meanwhile, is the measure of the maximum pressure a fan can produce when met with a great deal of resistance. Specifically, if you had a box with just one hole in it and you placed a fan over that hole, the static pressure is the maximum pressure the fan could exert on the air inside.



Phanteks' P600S can be run in high-airflow or closed front section modes

In some ways, the two measurements are analogous to power and torque in cars, where airflow is analogous to power and static pressure is analogous to torque. Crucially, though, unlike with car engines, high airflow and static pressure are often contrary to one another. This has to do with the fin design of fans, where fins optimised to ensure air is forced through with a great deal of pressure are less optimised to spinning fast and pushing through lots of air: it's the same reason aeroplanes have adjustable pitch propellers.

What matters when it comes to case fans is that high-static pressure fans are in theory better for spinning slowly, and thus quietly, while pushing air through relatively high resistance areas such as heatsinks, radiators or dust filters. Meanwhile, high-airflow fans are in theory better for quickly getting as much air as possible into or, particularly, out of a case with as little resistance as possible.

In reality, though, there are relatively few applications in normal PC usage where high-airflow fans are desirable. Their inherently higher spin speeds, and therefore noise levels, mean they're undesirable from a noise point of view and for those applications for which they'd theoretically be best –

pushing large volumes of air into or out of the whole case – the presence of dust filters and fan grilles limits their effectiveness.

### Are high-airflow mesh cases always better for airflow?

In short, with everything else being equal, yes. Closed front panel cases, whether they're donning tempered glass or acrylic panels, may look nice and allow RGB fans to shine through for some impressive aesthetics, but they usually force air to be drawn in through narrow side vents and this adds restriction, which in turn hinders airflow.

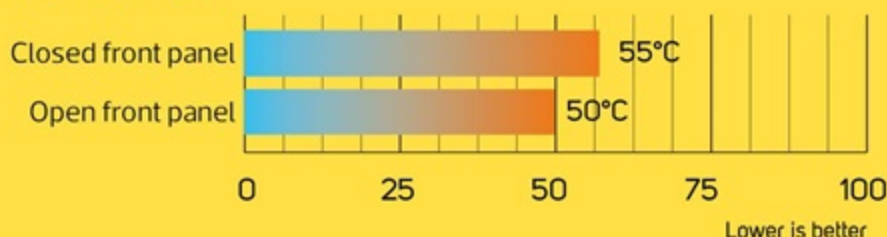
However, it's not all bad news. By covering the fans, noise levels are reduced. It's also easier to add in a dust filter without ruining the look of the front of the case. Plus, of course, it can look much more attractive. In many cases, the loss in cooling is minor too.

For example, in our testing with Phanteks Eclipse P600S last year, which is equipped with a front mesh as well as a closed panel for the option to use either setup, the CPU temperature fell from a delta T of 55°C to 50°C switching from using the panel to the mesh beneath. Meanwhile, the GPU delta T fell from 51°C to 48°C. They're not totally insignificant changes

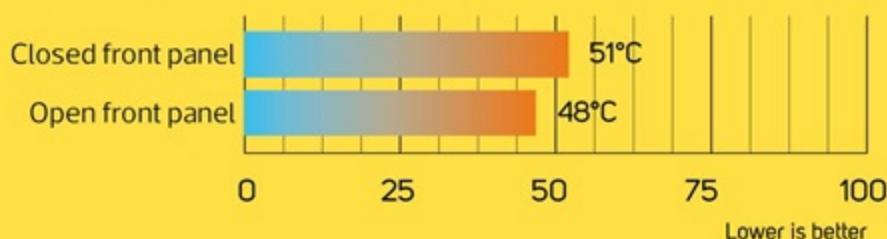


## PHANTEKS ECLIPSE P600S, CLOSED FRONT/MESH FRONT

### CPU DELTA T



### GPU DELTA T



but certainly small enough that other factors could outweigh them. Not all cases have this ability, of course, but it proves that just because a case has a closed front section doesn't always mean it will have poor cooling.

### Is using your case's vertical GPU mount a bad idea?

Rotating your GPU so its cooling fans or water block are visible through the side panel is increasingly popular. Not only does it generally help the overall aesthetics of the build by covering the otherwise often quite bare expanse of the bottom section of the motherboard, but it also allows you to show off the most expensive and best-looking item in most of your PC.

However, there's a downside to having it sit vertically in your case, which is that many cases with vertical GPU mounts have the GPU sitting close to the side panel. This can restrict airflow and in turn, mean your graphics card can run hotter, leading to lower peak frequencies, higher and noisier fan speeds, and even outright overheating.

In the end, we didn't run a definitive test of this, as there proved to be too many factors at play for a meaningful result. For a start, some graphics cards cope better than others. The exact position of the vertical mount in the case is a huge variable too. Just a few extra millimetres can make all the difference, and the space you get can vary far more than this. Not to mention, some cases offer multiple positions. In short, you'll need to investigate whether the compromise is worth it with your particular graphics card and case. Just try it out and see what

happens. Or, if you're looking to buy a case with such a mount, be sure to double-check the space the case provides, the size of your graphics card's cooler, the type of cooler and the ventilation setup of the case.

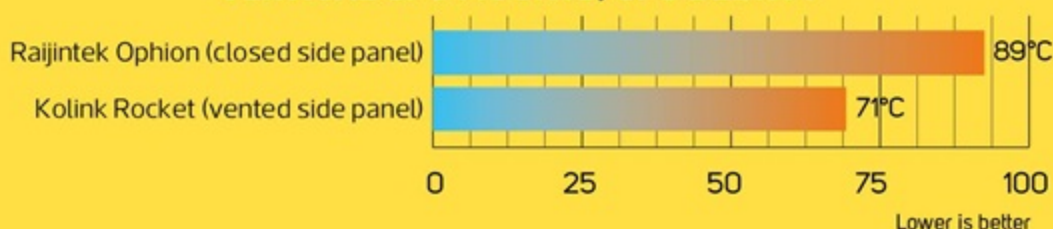
With smaller cases, this variability can be particularly significant, given the often closer proximities to the side panel with the graphics card. A classic demonstration of this was in our last but one mini-ITX group test where two

similar cases, both with vertical GPU mounts, were tested against each other with the same hardware. The only difference was that one had a vented side panel allowing the graphics card to breathe and the other didn't. The latter was Raijintek's Ophion Evo, which delivered a GPU delta T nearly 20°C higher than that of the Kolink Rocket, which had the vented side panel.

We followed this up in a subsequent Customised PC column, where we used a modified panel on the Ophion Evo, adding its own ventilation. We dropped the GPU delta T by a huge 17°C. So, if GPU cooling is important, you'll want to carefully test your own hardware in tower cases, while smaller cases such as the Kolink Rocket and Raijintek Ophion Evo benefit massively from well-vented side panels. Without them, vertically mounted air-cooled graphics cards can be a very bad idea.

**There's much more testing we could have done here and this feature could have taken up half the magazine, but nearly all of it you can do easily at home with your own hardware, a few extra fans and some temperature monitoring programs to help you keep track of changes. It takes patience and time but it's worth testing a few setups to find the best cooling configuration for your PC. [GPG](#)**

### VERTICAL GPU MOUNTS, GPU DELTA T









# VIRTUAL REALITY

FROM DISPLAYS AND LENSES TO CONTROLLERS AND HEAD TRACKING,  
RICK LANE EXAMINES THE TECHNOLOGY BEHIND VR HEADSETS

**V**R technology is evolving fast. It was only four years ago that the Oculus Rift and HTC Vive opened up a new way of interacting with virtual worlds. Since then, we've seen a flurry of new headsets that have added many new features to those original designs. Touch-controllers, internal headtracking, wireless VR, even prototypical hand-tracking have all become realities in the space of half a decade.

But how exactly does all this work, what do these changes mean for the VR experience, and if you want to experience VR for yourself, which headset should you buy? In this article, we dive deep into the technology behind VR headsets, and how that technology is changing with every passing day.

## The basics

Virtual Reality headsets, also known as head-mounted-displays or 'HMDs', are essentially designed to mimic how our own eyes work, taking advantage of our innate ability to visualise depth in the world. They use the exact same graphics rendering technology as any other computer (indeed, most headsets will use your PC to do that job) but instead of projecting a single image onto a single display, HMDs instead render two images.

Crucially, these images aren't identical. They portray the rendered image from a slightly different angle, mimicking the way our eyes individually interpret the world from similar, but unique viewpoints, creating a sense of depth. Most headsets project two feeds onto a single screen, although some (such as the original Oculus Rift CV1) have two individual screens built into the headset.

This is the foundation of the stereoscopic 3D effect, but if that was all a VR headset

contained, then all you'd get out of using one is a headache, because you'd just be staring at one or two image displays situated roughly 2in from your face. Imagine standing directly in front of two TVs and trying to watch both at the same time. Ouch.

That's where the lenses come in. While the angled images are what generate the 3D effect, it's the lenses that convince your eyes they're looking into 3D space.

Situated between your eyes and the screen(s), VR lenses adjust the angle of the light from the screen so that it's entering your eye at a parallel angle. This creates the illusion of not just depth but distance, letting your eye focus on individual objects in the image as if you were inside a room, on a mountainside, or in space. It's the difference between looking at a pop-up-book and feeling like you're actually somewhere else.

All of this tech only gets you as far as looking at a stationary image in stereoscopic 3D. For VR games to work, the player needs to be able to look and move around. This is where head-tracking comes in. Head-tracking simulates your ability to look around your environment by shifting the image on the screen in response to the movements of your head.

Head-tracking systems use multiple tools, such as gyroscopes to measure changes in the head's angle, and accelerometers to measure shifts in movement (such as craning your head from side to side). Some tracking systems also use LED lights placed around the headset. These are monitored by an external camera to judge the headset's current angle and position, a little like how pilots judge where a runway is at night.

Successful head-tracking systems also need extremely low latency – 50 milliseconds or less – to prevent the lag between turning your head and the shift in VR environment to be noticeable. This is partly why high-end VR headsets still require you to be tethered to your PC, rather than using a wireless system.

This is the basic construction of any given VR headset. But the various headsets on the market differ considerably in terms of screen types, lenses, frame rates, fields of view, and many other considerations.

## Screens

Most VR headsets use one of two different screen types. These are known as OLED (Organic Light-Emitting Diode) or LCD (Liquid Crystal Display). The specifics of how these screens work would require an article in and of itself, but the key difference between the two is that LCD screens require a backlight, so the image produced by the liquid crystals is visible. OLEDs contain an organic compound that emits its own light when an electrical current is passed through. Hence, an OLED screen does not require a backlight to illuminate the image.

In the early days of VR, OLED displays were considered the preferred screen type for HMDs. Because OLED displays emit their own light, they provide better colour contrast in low-light situations, such as strapping a VR headset to your face. LCDs are brighter due to the backlight, but this can also 'wash out' deeper colours such as dark blues and blacks.

The lack of a backlight also means OLED displays can be lighter and slimmer than their LCD equivalents. Both the Rift CV1 and





Our depth perception is derived from stereoscopic vision

## THE SIGNIFICANCE OF THE FIELD OF VIEW IS DRASTICALLY INCREASED, BECAUSE YOUR EYES ARE SO CLOSE TO THE IMAGE BEING DISPLAYED

the HTC Vive used OLED panels, with the Rift having two separate OLED panels, allowing users to adjust the positions of those panels to match the space between their eyes (known as interpupillary distance).

Intriguingly, however, all the most recent high-end headsets, like the Rift S, the Vive Cosmos, and the Valve Index, have switched to using LCD screens. This is because new, VR-specific LCD screens have been developed with less blinding backlights and a higher pixel-per-inch display, among other important considerations.

This latter feature helps to reduce the infamous 'screen-dooring' effect that early headsets struggled with, whereby the individual pixels on the display were clearly visible as tiny, mesh-like squares, making users feel like they were looking at their game through a screen door. Eliminating screen-dooring has been one of the main focuses of VR development since the launch of the first Rift and Vive, with many of the innovations in more recent HMD designs being geared towards minimising the effect.

### Field of view

Screen type isn't the only aspect of a VR headset that can affect the quality of the experience. Much like a conventional screen, having a wide field of view (FOV) can improve the immersive qualities of a game. In VR, the significance of FOV is drastically increased, because your eyes are so close to the image being displayed.

The ultimate goal of VR display is to replicate how our eyes see in real life. Humans have a peripheral field of view of approximately 120 degrees, so ideally, you want your headset to at least match that. Otherwise, your VR experience will feel like looking through a letterbox. A higher field of view also compounds the 3D effect of VR, producing a greater sense of contrast between the objects viewed in your peripheral vision and those within your macula (the centre of the retina which provides the greatest level of focus).

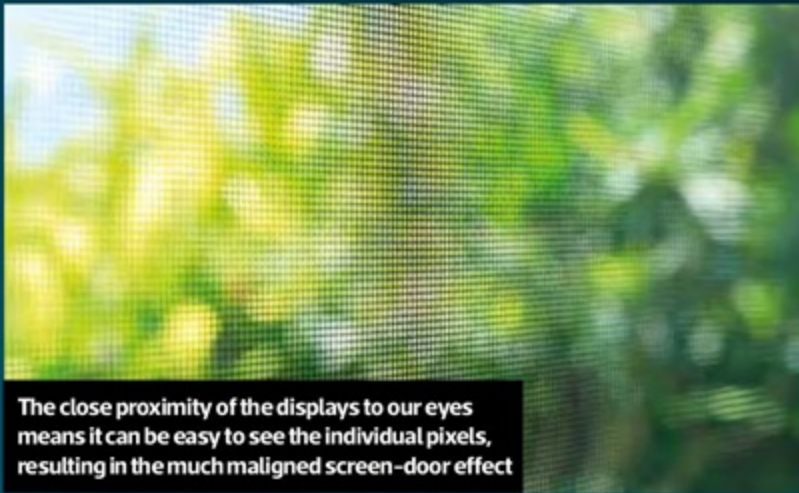
Most VR headset have fallen short of this. The Rift CV1 had an FOV of roughly 90

degrees, while the HTC Vive was higher at 110 degrees. The more recent Rift S has an FOV of 80 degrees, which is less than the CV1, an issue for which Oculus came under fire. The Oculus Quest manages to improve on the Rift's FOV, however, letting you see 100 degrees of vision. The best headsets for panoramic viewing, however, are the Valve Index, which offers 130 degrees of vision, and the Pimax 5k Plus, which offers a maximum FOV of 170 degrees.

### Refresh rates

As with gaming on a standard monitor, a good refresh rate is crucial to enjoying a smooth experience. But VR headsets have a considerably higher refresh rate than what is advised for conventional gaming. Ideally, conventional PC games will run at a standard of 60fps, matching the standard refresh rate of most monitors. But since the launch of the original Vive and Rift, VR headsets have settled on a standard refresh rate of 90Hz.





The close proximity of the displays to our eyes means it can be easy to see the individual pixels, resulting in the much maligned screen-door effect



Fresnel lenses first saw widespread use in lighthouses

The reason for this is again due to that added level of immersion. VR essentially convinces your brain into perceiving the virtual world in the same way as the real world, so it expects to be able to process the images it sees in the same way. If it's not able to do this, the resulting disconnect can cause disorientation and nausea.

Until recently, it was generally accepted that a refresh rate lower than 90Hz increased the chance of negative effects. Yet some more recent headsets, such as the Rift S, have shipped with a maximum refresh rate of 80Hz. Isn't this just a one-way ticket to barf-town? As it turns out, refresh rates are only half the story. Equally important to maintaining a pleasant experience is ensuring low pixel persistence.

This can be roughly translated as 'removing motion blur'. High pixel persistence means that pixels stay on the screen for a longer portion of each individual frame. Normally this is a good thing, because nobody wants to look at a black screen, right? But because you naturally move about so much in VR (even when sitting down), this can result in a smearing effect very similar to motion blur.

Lowering the pixel persistence effectively enables developers to solve this problem without supercharging the refresh rate of the headset. This is why the Rift S is able to get away with that lower refresh rate.

## Lenses

Did you know that you have lighthouses to thank for how current VR headsets work? In 1819, the French scientist Augustin-Jean Fresnel was selected by the French Commission of Lighthouses to review ways to improve illumination. Fresnel noticed that the large, bulky lenses used by lighthouses to focus the light's beam were highly inefficient. So he came up with the idea of cutting the lens down to be



VR headsets use a single lens per eye, rather than the multiple-element lenses of lighthouses

much smaller and thinner, then setting several such lenses up together producing a better-focused beam at a smaller overall cost.

Such lenses became known as 'Fresnel lenses' and this is the type of lens that nearly all VR headsets use. Putting conventional lenses in a VR headset results in several problems. Firstly, all that extra material increases the weight of the headset, which need to be kept light so you don't end up with chronic neck pain. Secondly, the bulbous nature of convex lenses increases the distance between the screen and your eyes. That extra distance means you need even bigger lenses, which means a further size increase, and so the problem keeps spiralling until you end up with a headset the size of a car.

Fresnel lenses solve this problem, allowing the screen to sit close enough to the eye that the size of the headset can be kept relatively compact. Fresnel lenses also help to combat screen-dooring, because the lenses can be designed specifically to maximise the number of pixels in a user's field of view, squashing those mesh lines down, so they're less visible.

Unfortunately, as Fresnel lenses helped to solve one problem, they also caused another. To achieve their clever space-saving effect, they rely on having angled step changes in the

surface of the lens. These steps degrade image quality, making for a slightly less sharp image and introducing an effect known as 'God Rays'. This is where, when light from the screen hits one of these angles, it causes a noticeable line of light similar to the crepuscular rays seen when sunlight filters through cloud, only this effect seemed to be emitting from random objects rather than the sky. This particularly affected the Rift CV1 but can also be noticed to a lesser extent on the likes of the Vive.

More recent headsets such as the Quest, Rift S and Vive Pro have all utilised more specifically tailored Fresnel lenses to combat this effect, without compromising on the overall weight of the headset or the reduction in screen-dooring. Meanwhile, the Gear VR is one of the few mainstream headsets to not utilise Fresnel lenses, but it was limited to being used with Samsung mobile phones.

## Resolution

Of all the areas in which VR Headsets moved forwards, resolution has probably seen the hardest push. Because of how the VR display is magnified through the headset's lenses, VR requires a much higher resolution to match the sharpness of conventional computer displays





As well as the headset and controllers, the Vive Pro's outside-in tracking requires two wall-mounted room sensors

and eliminate screen-dooring. At the same time, headset designers also have to consider that the device (or the PC it's attached to) has to render that image twice, which is why VR gaming can be so technically demanding.

First-generation headsets fell well short of an ideal resolution. Both the Rift CV1 and the HTC Vive had a resolution of 1,080 x 1,200 per eye. The result of this was highly noticeable screen-dooring, while objects rendered at a distance lost a large amount of detail.

More recent headsets have seen significant increases in resolution. The Rift S, for example, operates at 1,280 x 1,440 per eye, while the portable Oculus Quest is higher still, operating at 1,440 x 1,600 per eye. This is actually the same resolution as the Valve Index. At this resolution, screen-dooring is markedly reduced, although still noticeable if you actively go looking for it. The Vive Cosmos has a higher resolution still at 1,440 x 1,700. But the current champion of headset resolution is the Pimax 8k, offering a whopping 2,560 x 1,440 per eye.

A higher resolution definitely improves the overall VR experience. Not only does it improve image quality, it also makes aspects such as in-game text easier to read, as well as small displays and readouts. This is particularly useful if you're playing a flight simulator or a space game such as *Elite Dangerous*.

### Positional tracking

While nearly all of our focus has been on the HMDs themselves, they're only half the story of how VR works. There are two other key components in a current VR setup. The first is positional tracking. Used primarily for 'room-scale' VR experiences, this is how VR tracks your location in real life, and reflects those movements in the game space.

Originally, all VR devices used an 'outside-in' setup. This required the user to physically place external sensors around the play space as part of the setup. These 'base-stations' worked differently in both form and function depending on the headset. The Rift CV1 used free-standing base stations designed to be placed on a tabletop, which tracked movement via Oculus' Constellation System. This used infrared LEDs embedded beneath the headset's faceplate which blinked in a certain pattern, allowing the sensors to precisely track the headset.

The Vive, meanwhile, used a different system called Lighthouse. Designed by Valve, Lighthouse works almost in opposition to Constellation, with the base station emitting an infrared pulse at a frequency that's picked up by the headset and the controllers. The Vive's base stations had the drawback of requiring to be physically mounted on walls or attached to camera stands to get a clear view of the room. But they offered consistent 360-degree tracking out of the box, whereas the Rift's tracking was limited to 180 degrees unless you purchased a supplementary base station.

Last year, however, Oculus released two new headsets – the Rift S and the Oculus

Quest – both used a new, inside-out tracking system that eliminates the need for base stations. Known as Oculus Insight, the system is centred around five cameras built into the headset, two on the front, one on each side, and one on the crown. This is combined with accelerometers and an AI algorithm designed to predict how the headset will move.

The results are indistinguishable from having a properly set-up outside-in system, but removes the need to set that up or ever adjust it. Even if you don't play room-scale games, and only use VR sitting down, having the tracking built into the headset makes more sense than having base stations cluttering up your desk and/or walls.

Outside-in tracking hasn't completely gone away, however. The Vive Pro uses the same Lighthouse system as the Vive, although the recently released Vive Cosmos uses an inside-out system like the Rift and the Quest. The Valve Index uses an updated version of Lighthouse that uses free-standing base stations, similar to those of the Rift CV1. Frankly though, it's likely only a matter of time before Valve adopts an inside-out system as well.

### Tracking

In the primordial days of VR, the focus was all on the headset, and games were controlled using conventional peripherals such as a gamepad, or keyboard and mouse. But as developers strove to make VR a full-body immersive experience, they had to develop new ways to interact inside virtual worlds. This led to the design of new controllers, commonly referred to as 'touch' controllers (although only Oculus' controllers are officially called that).

Touch controllers essentially function like regular game controllers, but with two additional features. Firstly, they enable the



The Valve Index's controllers have individual finger tracking and a strap that allows you to let go of virtual objects without dropping the controller





**The Oculus Rift controllers have pressure-sensitive thumbsticks, and thumb and index finger buttons**

VR headset (or external sensors if you're using an outside-in system), to track the location of the user's hands relative to the VR space. Typically, the sensors are encased in a ring-shaped chunk of plastic usually located at the top of the controller, which is why they have such a distinctive look. Secondly, alongside the buttons and triggers you'll normally see on a gamepad, touch controllers include an additional button that, when pressed, allows the user to 'grip' objects in the game world.

Combined, these two features form the foundation of VR's more distinctive experiences, allowing users to pick up and throw objects, press buttons, punch enemies, and wield weapons in a natural way.

In the few years of their existence, touch controllers have evolved quickly, with each new iteration aiming to more precisely replicate the natural movements of the hand. The Vive was the first on the scene with separate hand-held controllers that included a specialised grip function. But they were designed as controllers first, as is evident by their TV remote-like shape.

The Rift CV1's touch controllers iterated upon this design, offering a more ergonomic shape that fitted more comfortably into the hand, as well as pressure-sensitive thumbsticks and trigger buttons that enabled individual control of your virtual thumb and index finger. The more recent versions for the Quest and Rift S reduced the overall weight and moved the sensor ring to the top of the controller, but they have a slightly less natural fit in the hand than the CV1 version.

The most advanced controllers on the market are those of the Valve Index. Through specialised, pressure-sensitive hand grips, they enable full virtual articulation of all five fingers on the hand. They're also designed to let you realistically 'grip' and 'drop'

objects. Rather than pressing a button, as with Oculus' controllers, with the Index you physically squeeze the grip to pick up objects. Meanwhile, the controller is strapped around the back of your hand, so you can let go of it completely without dropping it. This allows you to let go of objects naturally without dropping the controller, and also lets you relax your grip when you're not actively engaged in the game.

In a few years, VR may not need controllers at all. Oculus is already beta-testing a hand-tracking system that does away with physical controllers entirely, letting you control games directly with your hands. It's difficult to see how a lot of games would work with this, considering many VR experience utilise buttons present on the controllers as well as the tracking capability. But given how fast VR tech is changing, don't count it out.

### Which headset should you buy?

This really depends on what kind of experience you're after. Currently, the Valve Index represents the top-of-the-line VR experience. It may not have the highest resolution compared with the Pimax and the Cosmos, but its controllers are easily the best designed of any VR device currently available. The Index does have one big downside, however, and that's its outside-in tracking, requiring you to mess around with external base stations.

If ease of use and versatility are important considerations, then the Oculus Quest is without doubt the headset for you. It's ridiculously easy to set up, and it can be played pretty much anywhere with minimal recalibration. Also, with the recent launch of Oculus Link, the Quest can now be plugged into your PC and used like a Rift S, taking advantage of your PC's power to play any Rift-compatible

game (including the upcoming Half-Life: Alyx). Oh, and retailing at £400, it's also the cheapest high-end headset on the market.

HTC is lagging behind. The Vive Pro and the Vive Cosmos are both decent headsets, but they offer neither the flexibility of the Quest, nor the interactive fidelity of the Index. That said, if you want a higher-end experience than the Quest offers, but can't quite stretch to dropping a grand on an Index, then an HTC headset would provide a perfectly acceptable VR experience.

### And the future?

We already mentioned, hand-tracking, which is clearly possible as Oculus is already doing it, although whether it's practical for general gaming is yet to be demonstrated. Beyond that, there are two areas on which VR developers are likely to be concentrating. The first is resolution. While the latest VR headsets are a big improvement over the original Rift and Vive, there's still some way to go before they offer the kind of clarity equivalent to even a conventional 1080p monitor, let alone 4K displays.

The other major innovation that we hope happens soon is uncoupling VR headsets from the PC. Even for a sitting-down experience, having wires dangling from your head and trailing around your feet isn't ideal. Of course, wireless headsets such as the Oculus Quest already exist. But while the Quest is an excellent device, it's considerably less powerful than a headset directly tethered to a PC. The ideal solution is either more powerful mobile headsets, or wireless streaming from headset to PC. The problem with the latter, other than battery life and weight, is getting the latency low enough so that there isn't noticeable lag between your inputs and the output inside the goggles. **SPC**

**The Oculus Quest is the best all-round VR headset right now**







GARETH HALFACREE'S

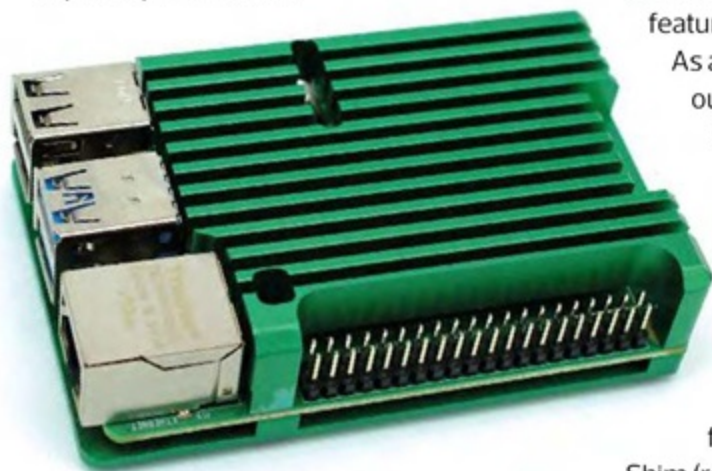
# Hobby tech

The latest tips, tricks and news in the world of computer hobbyism, from Raspberry Pi, Arduino and Android to retro computing

## REVIEW

### Pimoroni Heatsink Case for Raspberry Pi 4

**T**he launch of the Raspberry Pi 4 Model B (reviewed in Issue 193) brought a range of welcome improvements over its predecessors, not least of which were a significantly more powerful processor, increased maximum memory up to 4GB, and USB 3 ports for high-speed peripherals. It also drew criticism, as it was power-hungry and capable of hitting its 80°C thermal throttle point with ease, especially when cased.



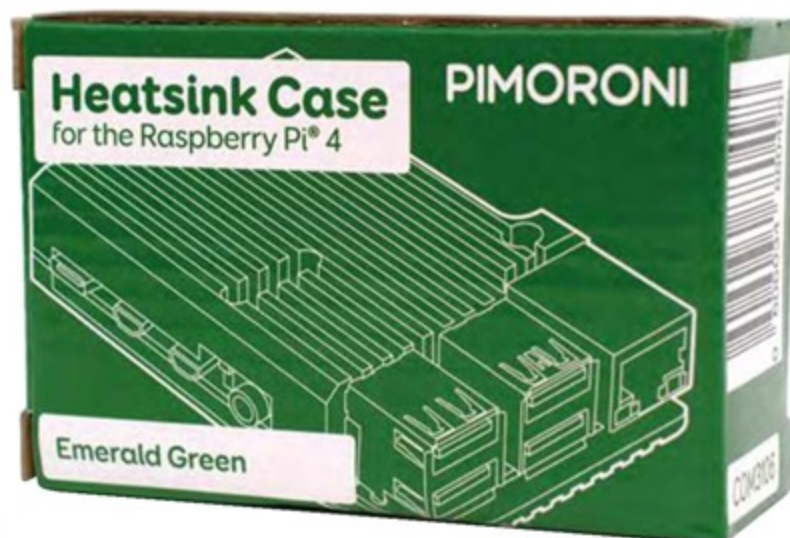
The two-part design does a good job of protecting and cooling a Raspberry Pi 4

Since then, the Raspberry Pi Foundation has been working to improve the situation through a series of firmware updates. These updates have added tweaks such as more dynamic clock control, a new virtual machine for handling the HDMI ports, and enabling some of the USB 3's power-saving features that were previously ignored.

As a result, the power draw and heat output have been pushed down to the point where it's now unlikely that an uncased Raspberry Pi 4 will throttle under most real-world workloads.

Aftermarket cooling accessories, though, continue to prove popular, and Pimoroni has a new entry to share,

following the success of its Fan Shim (reviewed in Issue 194). It's a wholly passive, two-part heatsink case designed specifically for the Raspberry Pi 4 Model B.



**Despite the branding, the case isn't a Pimoroni design**

A clarification is required here, however: while the packaging suggests otherwise, the case isn't a Pimoroni original design. You'll find the same design on sale from a variety of retailers – and even a variant design not offered by Pimoroni, which includes two GPIO-powered cooling fans in a cut-out on the top.

There's a reason Pimoroni hasn't opted to stock the active-cooling variant though – it's entirely unnecessary. We set the stress-ng utility to perform small fast Fourier transform operations repeatedly on all four CPU cores, alongside the glxgears tool with V-blank disabled to load the GPU. It's an extremely power-hungry, synthetic workload that represents a worst-case





Assembly is simple enough, bar the easy-to-tear 3M thermal pads

scenario, and the case-cooled Raspberry Pi 4 coped fine with it, staying below 60°C for the ten-minute benchmark run.

This is perhaps surprising, because the design of the case isn't fantastic. The underside of the upper heatsink includes pillars designed to contact the system-on-chip (SoC), the RAM chip and the USB 3 controller. While three 3M thermal transfer pads are included – and extremely fiddly to install, being near-impossible to remove from the tissue backing without tearing – Pimoroni's custom installation instructions advise to only use the one on the SoC.

Leaving out the RAM chip makes sense, as it doesn't get hot even under load – connecting it to the heatsink will likely only increase, not decrease, its operating temperature. The USB 3 controller, though, was a significant source of heat prior to the firmware updates, so why does Pimoroni advise to leave off the thermal pad?

It's because the heatsink's contact pillar is not only the wrong size but in the wrong place – it only contacts the very bottom corner of the controller chip, covering around a quarter of its surface area. It's

a design flaw, to be sure, but not a serious one.

Since the release of the power-saving firmware update last year, the controller chip has been a lot

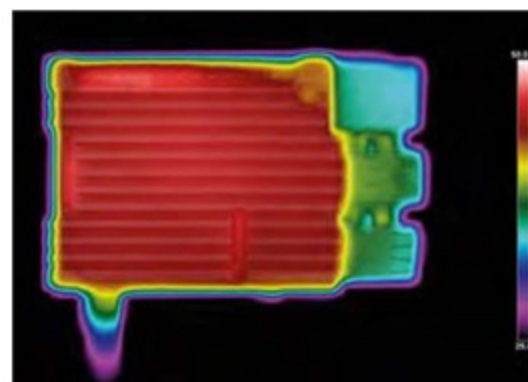
better behaved and less in need of cooling.

There are other issues, however. There's no cooling whatsoever for the power management circuitry at the bottom-left of the board, which is likely to limit the peak overclock available to power users. The bottom heatsink plate is also largely for show, making no contact with the board whatsoever.

The cases are available anodised in a variety of eye-catching colours, although both review samples supplied showed patches that had been missed. The cases also use Torx-style screws, rather than the more common Phillips type – but at least a small key is provided for people who don't have a Torx bit to hand.

Thankfully, the case performs well. For the overwhelming majority of users, the passive variant will be more than enough to both cool and protect a Raspberry Pi 4 under all but the most extreme environmental conditions. The case also doesn't block any of the ports; the GPIO header and power-over-Ethernet (PoE) header are both easily accessible, and cut-outs are provided for the display and camera serial interface (DSI and CSI) ports, although the ribbon cables should be attached at the Raspberry Pi 4 end before assembly, or you'll have to take the case apart again.

At £12 inc VAT from [pimoroni.com](http://pimoroni.com) in black, gold, grey, red, purple, blue or green – the case is more expensive than the better-performing Fan Shim (£9.60 inc VAT), but operates entirely silently while also providing protection for the Raspberry Pi 4 itself. If your heart is set on adding cooling to the board, this heatsink case is a great option.



The case does a good job of spreading the heat across its whole surface area

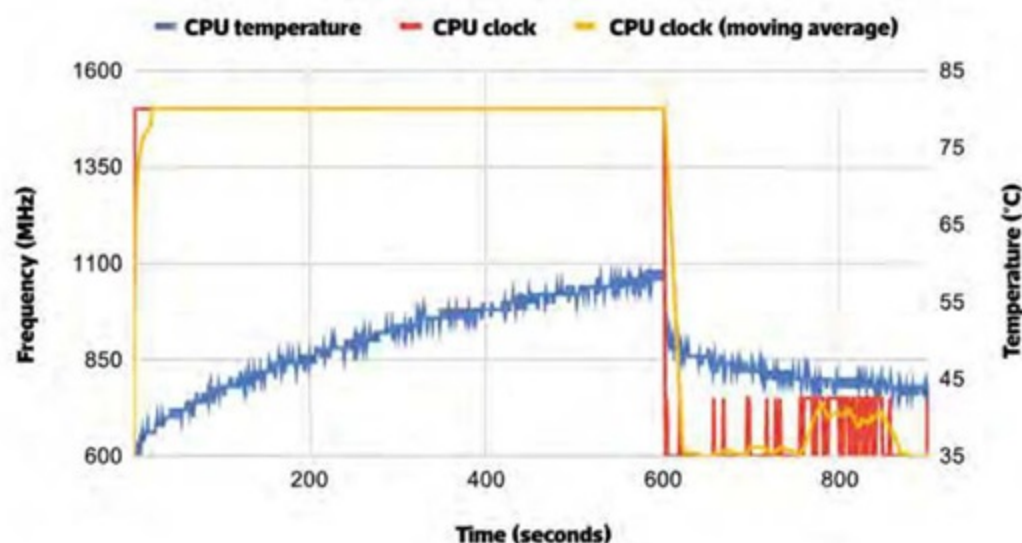
## NEWS IN BRIEF

### ZX Spectrum Next nears completion

The ZX Spectrum Next, previewed back in Issue 176, is finally approaching completion – some two years after Kickstarter backers were originally scheduled to receive their models. The board-only form has already shipped (and been reviewed here), but the completed and cased ZX Spectrum Next has been hit by a series of delays, many revolving around the keyboard, which is to be paired with housing from since-departed Sinclair designer Rick Dickinson (interviewed in Issue 137). The keyboards and housing are now complete, the project's creators claim, with the first assembled units expected to ship in early 2020.

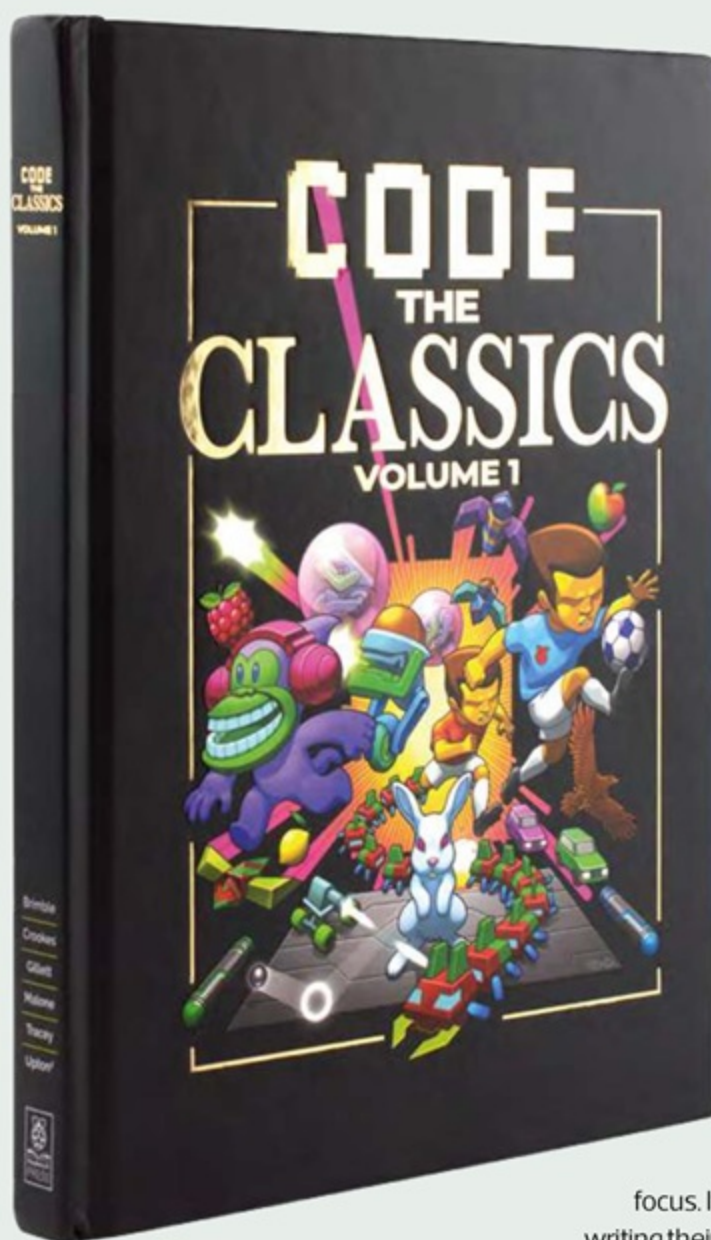


### THERMAL THROTTLING - PI 4 IN PIMORONI HEATSINK CASE



The case has no trouble keeping the Raspberry Pi 4 below the 80°C throttle point





Code the Classics wears its Usborne inspiration on its sleeve

## INTERVIEW

# Eben Upton on Code the Classics

**T**oday, it's difficult to throw a stone and not hit half a dozen coffee-table tomes designed to evoke nostalgia for a bygone era of gaming. There's a huge range, from more general publications, such as Commodore 64: A Visual Compendium (see Issue 136) and The Art of Point and Click Adventure Games (see p100), to more niche books, such as Toshi Omagari's Arcade Game Typography (see Issue 197).

Code the Classics, though, is different. While it's filled with colour imagery of classic games of the 8-bit and 16-bit era, with expository text and interviews, it has a decidedly more hands-on

focus. It walks the reader through literally writing their own clones of five classic games, courtesy of programmer and Raspberry Pi Foundation co-founder Eben Upton.

'I learned to program a computer so I could write games,' Upton explains. 'I write retro games for fun – you might have seen a few of the things that I've done and put out over the last few years. I write a lot of platform games, so I didn't want to write too many platform games. I restricted myself to one platform game here. I've never written a football game – to be honest, I've not really played many football games, so there's an element of this being my idea of what a football game might be like. I wrote it, then I put it in front of some friends who do play football games and they criticised it mercilessly. Then I changed it until they liked it.'

The platformer, a Bubble Bobble clone dubbed Cavern, and the football game, the Sensible Soccer-inspired Substitute Soccer, are joined by three other games: Myriapod, a Centipede clone; Infinite Bunner, a Frogger clone; and Boing!, a Pong clone that serves as the reader's introduction to the process of game making.

'In the Pong game, we focus on what the overall scaffold is like, how the menu system works,' Upton explains. 'It's used in the other games, so it builds up nicely.'



I learned to program a computer so I could write games, says Eben Upton

## NEWS IN BRIEF

# Dangerous Prototypes unveils Bus Pirate Ultra

Dangerous Prototypes' Ian Lesnet has published details of an upcoming board design dubbed the Bus Pirate Ultra, taking the original Bus Pirate universal communications tool and placing a field-programmable gate array (FPGA) at its heart to

considerably increase its power and flexibility. 'Previous Bus Pirates relied on the hardware peripherals available in a microcontroller, which vary in features and have the occasional bug. With an FPGA, we can implement practically any peripheral with all the fixes and hacks we want,' Lesnet explains. More information is available on [dangerousprototypes.com/blog](http://dangerousprototypes.com/blog); no release date is yet available.





The print edition is in full colour throughout, and the print quality is excellent



All the code is presented in the form of type-in listings, which will be familiar to readers of a certain vintage. 'This is kind of an ultra-shiny version of the sort of thing Usborne used to do,' says Upton, referring to the educational paperbacks published in the 1980s and 1990s, which

contained typically BASIC-based type-in programs designed to introduce kids to programming, with games as the hook.

'There are ways to build more modern games, 3D games in particular, which are quicker and just as valid from the point of view of learning about programming, but this is one angle of attack on that kind of 2D gaming. Obviously, we've made an effort to make them look as good as a modern casual game, because I think that's important.'

This focus on looks meant Upton was going to need help. 'Programmer art is the devil's work, right? Even back on 8-bit computers, where it was a more constrained design space,' he explains. 'As time has gone on, a kind of gulf opened up between what a completely unartistic person like me can draw, and what a real artist can draw, and it gets wider and wider. I worked with Sean Tracey [author of Make Games with Python] on this and when we saw the first cut of the game, which had programmer art, we decided we wanted better art. We then decided we wanted better music, and then we decided we wanted better text in the book ...'

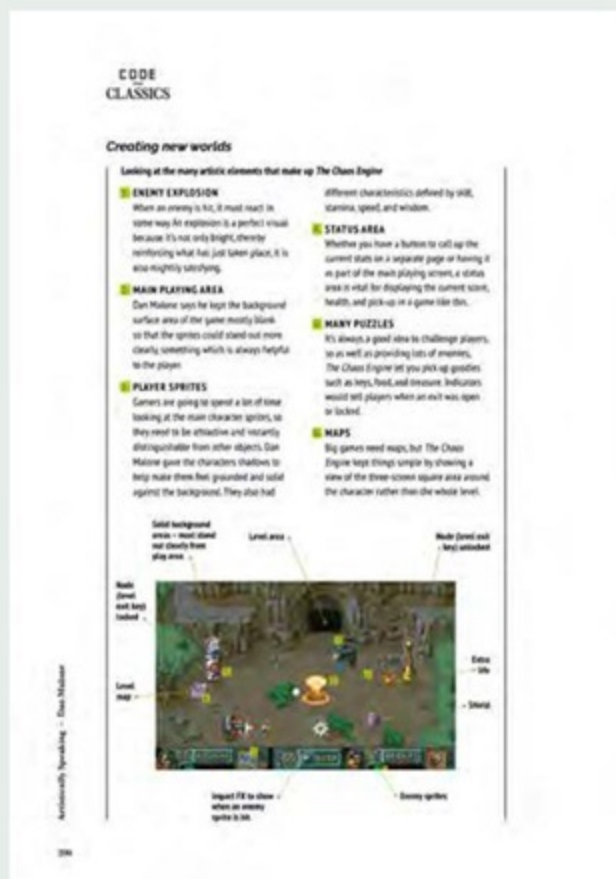
Upton called upon some friends old and new to fill in the gaps. 'Dan

[Malone, artist] I've worked with for a long time. He worked for my first startup, which was a games company,' he recalls. 'Alastair [Brimble, composer] I've never worked with before, but obviously I grew up playing Team 17 games on my Amiga, and Alastair created a lot of the classic original soundtracks for those games. So it just seemed natural: I went to his website, I was like, 'I've always wanted to work with Alastair,' so when we needed music, I just called him up and fortunately he was available.'

Tracey, Malone and Brimble weren't the only people providing assistance to polish the book: David Crookes, Andrew Gillett and Liz Upton all contributed to the text, which includes interviews with programmers of the original titles, as well as analyses of all sorts of aspects, from game mechanics to individual graphics, to the guides to creating the games themselves.

The result, published in hardback, is undeniably polished and reaches further than most contenders in what's becoming a crowded space.

The book, which is Volume 1 of a planned series, is available now from [wireframe.raspberrypi.org](http://wireframe.raspberrypi.org) priced at £12 (VAT exempt) in hardback, or as a free PDF download under a Creative Commons licence.



The book includes analyses of how classic games worked



## REVIEW

## The Art of Point and Click Adventure Games

**B**itmap Books' *The Art of Point and Click Adventure Games* is a massive tome that focuses on the graphics of classic point and click adventures. Released initially in a limited collectors' edition, packaged like a big-box 'IBMPC' game, and including an electronic copy of the book on a USB flash drive shaped like a 3.5in floppy diskette, *The Art of Point and Click Adventure Games*' first production run quickly sold out. After considerable demand, Bitmap Books has arranged a second printing, which may well be in stock by the time this issue of *Custom PC* hits the shelves.

There's a good reason for the demand: *The Art of Point and Click Adventure Games* is an impressive creation. While, yes, the bulk of the book's 240-odd pages are taken up by full-colour screenshots – captured from emulators for the older titles – like many rival nostalgia-grabs, there's plenty of written meat on the pictorial bones.

A particular highlight is the interview material. Readers will find multi-page interviews with industry giants including, but not limited to, Ron Gilbert, Jim Walls, Paul Cuisset, Gary Winnick, Al Lowe, Éric Chahi and Tim Schafer, along with a few

newcomers, such as *The Lion's Song* creator Stefan Srb and Paradigm's Jacob Janerka.

Gary Whitta provides a foreword, while the introduction provides a ten-page history of the point and click genre itself, starting with text-based interactive fiction and working its way up through 2D, 3D, and full-motion video titles, before heading into modern crowdfunded throwbacks and narrative-driven adventures, such as *Life is Strange*, which have largely replaced traditional point-and-click adventures in the public eye.

There's even a four-page glossary, though with the occasional blooper – while Amstrad fans would have loved 3in floppy disks to have been the standard software distribution medium, as claimed, it was the 3.5in variant that proved more popular until it was supplanted by cheaper and more capacious optical discs.

These minor errors aside, *The Art of Point and Click Adventure Games* is a fantastic read – and the design and production qualities are up to the usual high level of Bitmap Books' previous publications. While the now out-of-print collectors' edition came with a smart box and a handful of extras – including



**A now out-of-print collectors' edition bundled the book with some extras in a big-box-inspired cardboard house**

a replica of the 'Ask Me About LOOM' badge that fans of *Monkey Island* will recognise – the book itself is identical in either variant.

There are books that go into more depth about particular companies or platforms – Rob Smith's *Rogue Leaders: The Story of LucasArts* would be an easy recommendation, if it weren't sadly long out of print and now available second-hand for over £150. However, few books about this genre flow as well and have the high production quality of *The Art of Point and Click Adventure Games*.

It also makes a great companion piece for *The CRPG Book* (see Issue 192, p98); while there's some overlap, the two books take very different approaches. *The CRPG Book* focuses on reviews, which consider mechanics and playability, while *The Art of Point and Click Adventure Games* is more concerned with (although not solely focused on) the visual aspect – as the name makes clear.

*The Art of Point and Click Adventure Games* will either be available to pre-order or to buy, depending on how long the second print run takes to complete and ship, at [bitmapbooks.co.uk](http://bitmapbooks.co.uk) priced at £29.99 (VAT exempt). It can also be ordered at your favourite bookseller under ISBN 978-0-9956586-6-0. **CPC**

**As with all of Bitmap Books' output, the production quality is fantastic**



Gareth Halfacree is a keen computer hobbyist, journalist and author. His work can be found at [freelance.halfacree.co.uk](http://freelance.halfacree.co.uk) [@ghalfacree](https://twitter.com/ghalfacree)



# Intel 386

Ben Hardwidge looks back at the PC's first 32-bit CPU

**W**e often complain about the over-inflated price of graphics cards these days, but the prices of today's PC components are extraordinarily generous in comparison with the early days. If you want the latest top-end Threadripper CPU, the fastest gaming GPU and an enormous amount of storage, a machine such as Chillblast's Fusion Conqueror (see p32) will deliver all of it in a well-built machine for £5,999 inc VAT.

Now, I'm not going to pretend that's a small amount of money – it's unaffordable for most of us. But, to get some perspective, let's take the TARDIS back to September 1986, when Compaq released the Deskpro 386, marketed as the first 'true' 32-bit computer. This was a good 11 months after Intel first launched the first 12MHz 386 CPUs, but seven months before IBM's first 386 machine got out of the doors, marking a new era where 'clone' PCs were becoming dominant.

## ADJUST THAT FIGURE FOR 34 YEARS OF INFLATION, AND THE PRICE IS £19,890

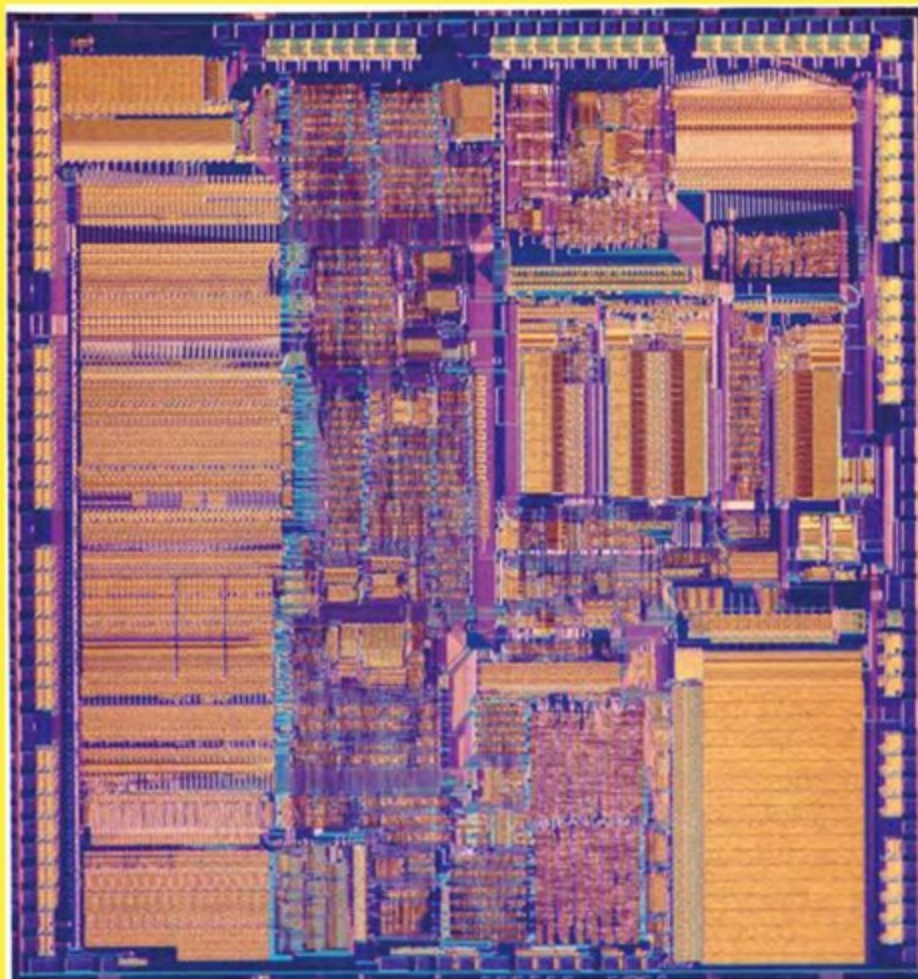
The top-end launch model of the Deskpro came with a 16MHz Intel 80386 CPU, 1MB of RAM, a 130MB hard drive and a 1.2MB 5.25in floppy drive. It cost \$8,799 US, which works out at around £6,737 (the exchange rate in 1986 was very similar to now). Adjust that figure for 34 years of inflation, and the price is £19,890, and that doesn't even include VAT.

If you couldn't afford superfluous luxuries such as a 130MB hard drive, you could alternatively plump for the cheaper model with a 40MB drive – a bargain at \$6,499 US (£14,694 ex VAT, adjusted for inflation). This is why most PC users at this time used machines with much older CPUs, often with no hard drive and small amounts of memory, for many years – I was still using an 8MHz 8086 a good 12 years after 1978 when that CPU was first launched.

Just like the prices, the numbers involved with the manufacturing process of the 386 are staggering compared with today's CPUs. The first 386 chips contained 275,000 transistors, which made them a marvel of miniaturisation at the time, but that's a piddly number compared with over 9 billion transistors, which you'll find in the Ryzen 9 3950X across all its dies. In terms of raw transistor numbers, a Ryzen 9 3950X is like 35,000 386 CPUs.

Those transistors were massively bigger as well, produced on a 1,000-1,500nm node, compared to 7nm in AMD's latest CPU dies. The very first CPUs off the production

Inside a 386 die, with 275,000 transistors



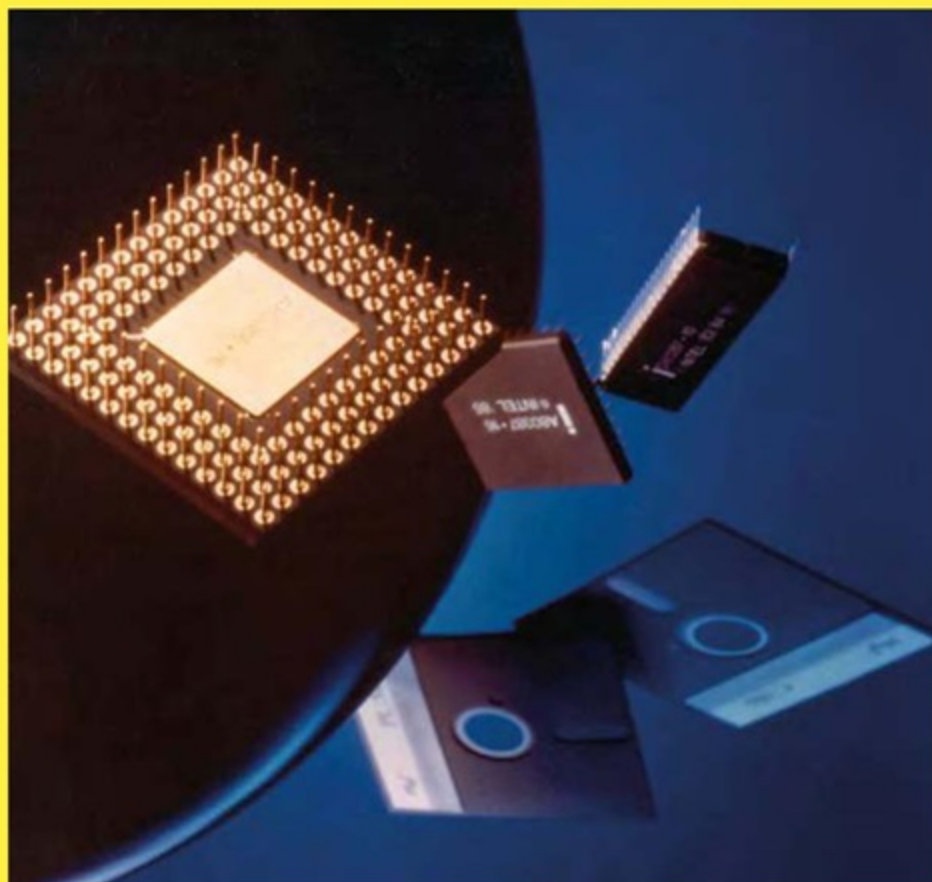


line were clocked at 12MHz, then 16MHz, with 20MHz, 25MHz and 33MHz flavours launching later – even the latter is around 1 per cent of the clock speed we see on today's CPUs. Pin-compatible CPUs were also made by AMD, as well as other manufacturers, including Cyrix.

### Memory management

The first 32-bit x86 CPU was big news in the computing world though. While Motorola's 68000 (used in the Atari ST and Commodore Amiga, among others) had introduced us to an internal 32-bit CISC CPU architecture back in 1979, it also used a 16-bit external data bus and a 24-bit address bus. Intel's first 80386 CPUs were 32-bit internally and across external buses, offering a huge advance over the previous 16-bit 8088, 8086 and 80286 processors.

An Intel marketing shot for the 386 shows a 16MHz 386 CPU, as well as an 80387 CPU and some 1.2MB 5.25in floppy disks



In theory, this meant a PC could now address 4GB of RAM (a limit that would only become seriously challenged 20 years later), although realistically the limits of technology at the time meant that most 386 PCs could only address up to 32MB, and even that was considered overkill. For reference, my 386 PC in the 1990s came with 4MB of RAM, but I upgraded it to 8MB using 30-pin SIMMS and it felt decadent.

More importantly for the time, the 386's memory system was designed to be easily extended well beyond the 640KB base memory limit of MS-DOS. The ins and outs of archaic memory systems are well beyond the scope of a two-page nostalgia piece, but the basic gist is that a 16-bit x86 CPU could only address 64KB of memory, so any memory on top of this figure had to be divided into 'segments' that it could address separately.

In order to maintain backwards compatibility, the 386 still retained this segmenting approach in 'real mode', but it also offered a new form of 'protected mode'. This mode was first introduced with the 286 to allow the use of virtual memory (effectively paging to a hard drive). However, the 386 added an on-board paging translation unit to mediate between the segments and the physical address bus, which effectively enabled the computer to present all these segments as one big sea of memory, even though it was technically still segmented.

It made for a much friendlier memory system for software developers, particularly for memory-hungry graphical user interfaces, and it paved the way for PCs with ever larger memory allocations.

### The joy of SX

The ability to address so much memory was overkill for the home market, though, and the prices of original 386 machines put them well out of the reach of this market anyway. To get the 386 into home machines, Intel introduced a cut-down version called the 386SX, with the original design now getting the 'DX' suffix.

This isn't to be confused with the 'SX' and 'DX' suffixes used on the later 486 chips though. When it came to 486 CPUs, the DX versions had a built-in floating-point unit, called a math coprocessor at the time, while the SX chips only had an integer unit, although you could add an 80487 math coprocessor to most 486SX machines separately.

Conversely, neither the 386SX or DX had a built-in floating point unit – you needed a separate 80387 coprocessor if you wanted that. The difference between the 386SX and DX was that the former had a 16-bit data bus, although it kept the CPU's internal 32-bit architecture. The idea was that having a 16-bit data bus would cut down on the need for highly intricate PCBs with loads of traces, reducing the cost of manufacturing. The other knock-on effect of fewer connections was that a 386SX could only address up to 16MB of RAM. However, as we've already covered, this was still way more than enough for the home market at the time.

### Software

The big problem for the 386 for most of its useful lifespan was mainstream software support. An executable file called

**A special 386 version of Links gave you gorgeous SVGA graphics for the time**







Technically, you could play Doom on a 386, but only on a tiny screen surrounded by a big frame

EMM386 was made a part of several variations of DOS to allow these primitive operating systems to access a 386's extended memory, but Microsoft's Windows operating system was still stuck in the 16-bit era at this time. There were nods to the 386's capabilities in Windows 3, including a 386 Enhanced Mode (if you had 2MB of RAM) that let you run DOS and Windows software at the same time, but there was no mainstream 32-bit operating system.

It wasn't until Microsoft introduced Windows NT 3.1 in 1993 that 32-bit Windows became a reality, but even then there was little supporting 32-bit software, and it also ran slowly on most machines at the time. It wasn't until Windows 95 came out, ten years after Intel made the first 386 CPUs, that the 386's internal 32-bit architecture was properly used in everyday software. It introduced the Win32 API, giving you proper 32-bit computing abilities, and it enabled filenames longer than eight characters.

I was thrilled at the time. I was still using a 20MHz 386SX with 8MB of RAM as my main PC, which just satisfied Windows 95's system requirements. It was dog-slow, of course. As a reference point, in the morning I would switch on the PC. Then I would go downstairs, eat a bowl of Weetabix, then make and drink a cup of tea. By the time I got back to my PC, Windows 95 would have just about finished loading. Windows 95 was really designed for 486 and Pentium machines, but you could still run it on a 386, finally fulfilling its 32-bit promise.

That doesn't mean the 386 was useless for all this time though. It still had loads of power when acting as a 16-bit processor – upgrading from a 16MHz 286 to a 33MHz 386 made a huge difference to the performance of Windows 3.1, and for gamers, the 386 was the holy grail. This was before the days of GPUs and 3D accelerators, so every aspect of number crunching for games was performed on the CPU, which meant you needed all the CPU power you could get.

By the early 1990s, PC gaming had started to progress from basic EGA graphical adventures and platform games, and were starting to see games that really took advantage of processing power. If you wanted to play Wing Commander II or Strike Commander, you really needed to have a 386, and preferably a 486. Meanwhile, X-Wing, TIE-Fighter, Doom, The 7th Guest, Dungeon

Master II, Myst The Elder Scrolls: Arena, Sim City 2000 and UFO: Enemy Unknown (otherwise known as XCOM) all required a 386 CPU as the bare minimum. There was also a special 386 version of the Golf game Links, giving you superior graphics at 800 x 600.

That said, I ran many of these games on my 20MHz 386SX in the early 1990s, and while they technically worked, I usually had to run them at extremely low detail, and even then the frame rate would have been unacceptable by today's standards. Running Doom required me to have big bars around a tiny screen in order to make the game playable.

### The 386's legacy

There was clearly room for improvement where gaming was concerned, but the 386 laid the foundation for what was to come, being the binary blueprint for many of its successors. It introduced us to the IA-32 (sometimes called i386 or x86) standard that's still used by some software today – any Windows software in the 'Program Files (x86)' folder on your C drive will be fundamentally based on this instruction set, and Intel continued to develop new IA-32-only CPUs well into the Pentium 4 era. It was only when AMD launched its first 64-bit AMD64 CPUs in 2003, and PCs started bumping up against that 4GB memory limit, that mainstream CPUs started to push into the 64-bit era.

## IT WAS THE 386SX THAT GOT THESE POWERFUL PCS INTO OUR HOMES FOR GAMING

In many ways, my old HP Vectra 386 is the PC for which I hold the most affection from the past. I was still using my 20MHz 386SX up until 1997, a good 12 years after the first 386 chips came off the production line, and I'd pushed my machine as far as it could go. Every 30-pin SIMM slot was filled; all the IDE channels were occupied by hard drives and a quad-speed CD-ROM drive; most of the 16-bit ISA slots were taken up by a 1MB SVGA card, a 14.4K modem and a 16-bit sound card (with a wavetable daughterboard).

It's so different to my PC now, which only has one of its expansion slots filled. My 386 might have struggled with Windows 95 and Doom, but it ran Windows 3.1 well, and it made for an awesome setup for playing Dune, Civilization and the LucasArts adventures.

Plus, while the 386SX was considered to be limited in comparison with the 386DX at the time, it was the 386SX that got these powerful PCs into our homes where we could use them for gaming. Once the 386 started getting into homes, the PC started to take off as the leading games machine that we know today. It was the 386SX that that first properly put the PC in front of the Amiga and Atari ST when it came to gaming power, leading to PC exclusives such as X-Wing and Myst, and the PC has never looked back since. **CPG**



# How to Dustproof your case

**Antony Leather** shows you how to use an old pair of tights to protect your case from dust

**TOTAL PROJECT TIME / 2 HOURS**

**M**ost cases offer a degree of dust protection these days but, depending on your budget or the age of your case, you may find that it lacks decent dustproofing. Dust can clog fans and heatsinks, as well as radiators. It can also stick to your PC's innards, hampering cooling, looking horrible and, at worst, shortening your hardware's lifespan.

If your PC lacks suitable protection, there are some cheap and easy ways to modify your case to equip it to battle against dust ingress. In this guide, we'll show you how to use a pair of tights to catch dust while still allowing airflow into your case. We touched on this with a couple of steps in our dust filters guide in Issue 189, but with our big airflow feature this month (see p82), we thought we'd revisit it in more depth.

## TOOLS YOU'LL NEED



**Thin tights or stockings**  
Family member or new from most clothing stores



**Glue gun**  
Most hardware stores



**Leather hole punch**  
[amazon.co.uk](http://amazon.co.uk)



**Scissors**  
Most hardware stores



**Washers**  
[amazon.co.uk](http://amazon.co.uk)



### 1 / CHECK FOR OPEN CASE VENTS

Dust can enter through small vents, as well as large openings, so it's important to identify all of them. Common filter-less locations are the base of the case, as well as side vents, such as the one pictured, which feeds the front fans.



### 2 / USE READY-MADE FILTERS

If your PC lacks dust filters, but has standard fan mounts or mesh-covered openings in the case panels, then you may be able to buy off-the-shelf dust filters for it. Kits are available for specific cases, while universal filter sets can be applied to most cases for a more natural, factory-applied look.



### 3 / MAKE YOUR OWN FAN FILTERS

If you want a cheap and effective way to battle dust, you can create your own filters using common household materials. You'll need thin tights or stockings, washers and some glue. We'll be making filters for fans, but you can secure filter material to anywhere in your case using a glue gun.





#### 4 / CUT TIGHTS TO SIZE

You'll want the material to be large enough to stretch taut over the fan intake, and to be glued at the sides. The mesh size is already small enough to catch dust, so stretching it will serve to boost airflow.



#### 5 / APPLIE GLUE TO FAN FRAME

Glue one edge of the material to the rear of the fan frame, using a thin bead to secure the material. Press the material in place and allow the glue a few moments to dry.



#### 6 / STRETCH MATERIAL OVER FAN FRAME

With one edge secured, stretch the material over the opposite edge. You need to pull with reasonable force, but not so much that the glue can't hold. After that, go ahead and do the same for the remaining two edges.



#### 7 / PUNCH FAN HOLES

The material can fray if you screw into it haphazardly, so we recommend punching some clean mounting holes into it with a leather hole punch. This will cut neatly and ensure your filters are durable.



#### 8 / ADD WASHERS

To prevent the fan screws from twisting the mesh, use washers over the material to separate them. This will allow you to tighten the screws without damaging the filter. Glue the washers in place to make mounting the fan easier.



#### 9 / SCREW FANS TO CASE

Finally, mount the fan into the case or radiator using washers and fan screws. The fan will now have complete dust protection, shielding your PC's innards. To clean it, just go over it with a vacuum cleaner when necessary.



# How to

## Use coolant to control fans and pumps

**Antony Leather** shows you how to use coolant probes to set your water-cooling parts to respond to the temperature of your coolant

**TOTAL PROJECT TIME / 2 HOURS**

**I**t seems logical to set your fans to spin up when your CPU is put under load, but with a water-cooled system, there's a few reasons why the coolant temperature is the most important factor. For starters, your coolant temperature doesn't fluctuate nearly as much as the CPU temperature. What's more, as water can absorb a lot of heat for each degree it warms, setting your fans to spin up as soon as your CPU gets warm will often have little to no effect on CPU temperature, at least in the first few minutes.

In addition, if your graphics card is under more load than the CPU, the coolant temperature may rise significantly, yet your CPU may remain at a low temperature, meaning your graphics card could end up suffering. In this guide, we'll show you how to rig your water-cooling system's fans to respond to coolant temperature, so your water-cooled system will perform optimally.

### TOOLS YOU'LL NEED



Coolant probe  
overclockers.co.uk



Fan controller with  
temperature probe support  
overclockers.co.uk



4-pin Molex to  
3-pin adaptor  
aquatuning.co.uk



PWM fan hub  
overclockers.co.uk



### 1 / CHOOSE PROBE TYPE

There are two types of thermal probe. Pass-through probes screw into G1/4in ports and have female threads on top, meaning you can screw fittings into them and don't need an unused port. Others use long, hidden physical probes to delve deeper into components, but require more clearance.



### 2 / IDENTIFY SPARE G1/4IN PORT

In order to insert the longer probes, you'll need to check the clearance behind the port thread first. The required clearance can be up to 2cm, so it's a much better idea to use a port on a reservoir than one on a waterblock.



### 3 / INSTALL THERMAL PROBE

Once you've identified a suitable location for your probe, screw it into the thread and make sure its rubber O-ring makes good contact. Place the probe in a position where it will make contact with moving coolant, rather than a recessed area of a reservoir.





#### 4 / FIND MOTHERBOARD PROBE HEADER

Thermal probe headers are small 2-pin features on motherboards. Your board may have several of them, while some examples are included on daughterboards too. Use your motherboard's manual to identify them, or check the specifications of the board you intend to buy.



#### 5 / CHECK EFI FOR PROBE INPUT

Not all motherboards offer thermal probes and, of those that do, not all of them allow the fan speed to be linked to thermal probe input. Dive into your motherboard's EFI to see if you can link the control of fan speeds with thermal probe inputs.



#### 6 / USE THIRD-PARTY CONTROLLER

If your board lacks thermal probe headers, or the ability to link probes with fan speeds, all is not lost, as third-party fan controllers can offer a good alternative. Most of them need a 5.25in bay, but many of them can be mounted anywhere in your case, such as the Aquacomputer Aquaero.



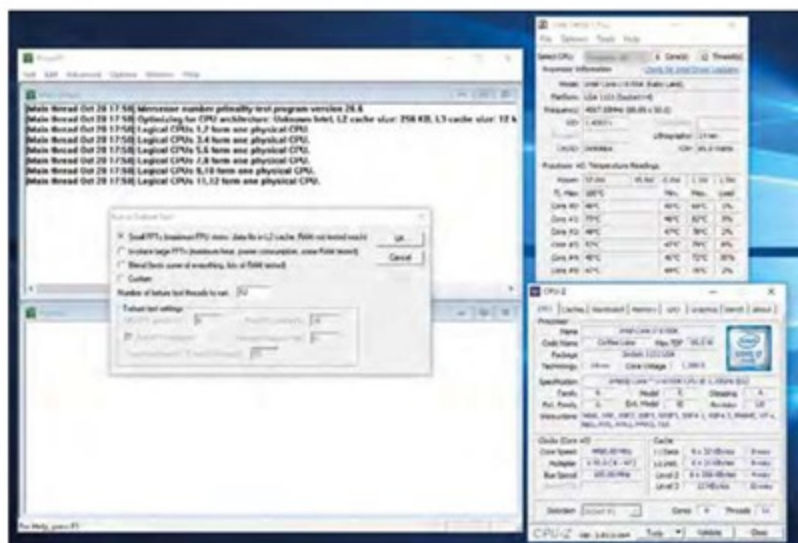
#### 7 / CONNECT FANS TO MOTHERBOARD

With radiator fans, it's best to use a splitter cable or hub to enable you to connect them all to a single fan header, which you can link to a thermal probe. The CPU fan header often can't switch to other temperature inputs, in which case you can use the CPU OPT or chassis fan headers instead.



#### 8 / SWITCH FROM CPU FAN

To switch from the CPU temperature being the input for fan speed, head to your EFI and locate the temperature input option if the board has one. On our board, the CPU OPT and chassis fan header controls could choose from a range of inputs, including our thermal probe.



#### 9 / STRESS-TEST SYSTEM

Once your system is set up and connected, work out the upper and lower limits of the coolant temperature, and when it starts to impact on CPU temperature. Start by running a stress test, such as Prime95, and leave it running for 20 minutes to see how the fans and coolant temperature react.





### 10 / LET EFI TUNE FANS

Allow your motherboard to identify and assess your fans to see what settings you can use in the EFI. Most manufacturers have fan-tuning software or EFI features that check what PWM or voltage settings are required to meet certain speeds.



### 11 / IDENTIFY PUMP SPEEDS

Many motherboards allow you to link a PWM-controlled pump to your coolant temperature as well. Our Gigabyte board also had the option to view data in terms of flow rate as well as the pump speed.



### 12 / USE A PWM HUB

You'll likely have a number of fans you want to control, but linking each one individually via single fan headers will take ages. Instead, use a PWM hub to split a control signal from a single fan header across multiple fans. These splitters are cheap, but you'll need to use identical models of fans.



### 13 / USE A MOLEX TO 3-PIN ADAPTOR

If your pump lacks a 3-pin connector or PWM control input, all is not lost. Many motherboards offer a high-amp header that can dish out 24W or more of power, so you can then use a 4-pin Molex/SATA to 3-pin adaptor to power and control the pump from your motherboard.



### 14 / SET FAN RESPONSE CURVES

Set your fans to spin up only when necessary in order to keep the coolant temperature in check without making too much noise. In addition, if you're using PETG rigid tubing, make sure the coolant stays well away from the manufacturer's suggested temperatures, in order to prevent it from becoming malleable.



### 15 / SET PUMP SPEEDS

Modern powerful pumps offer limited benefits above certain speeds, so you can cut noise and vibration by slowing them down. To find the lower limit, put your system under load again and find the point at which the flow rate has an impact on temperature, then raise it to keep the coolant temperature in check. **GPC**



# Readers' Drives

## Krait – Cold-Blooded

Inspired by MSI's monochromatic Krait motherboard designs, Ricky Kemp built his first PC with a custom water-cooling loop, fabricating several custom aluminium parts for the interior



**CPC:** What made you want to build a PC based around MSI's Krait theme?

**Ricky:** I had been frustrated with a previous motherboard, which didn't

have the best BIOS support and also had some hardware quirks, so I decided to swap it out. After browsing the usual sites, I stumbled across the MSI Krait series, which I thought was great-looking and had an understated look in contrast to the RGB trend. Black and white is a classic combination, and it inspired me to have my first go at a themed water-cooled build.

**CPC:** How did you go about making the custom motherboard tray, drive bay cover and PSU shroud?

**Ricky:** I wanted to focus the bulk of the costs on the cooling hardware rather

than the case, so I gutted my trusty Corsair 650D, removing the drive cages and various brackets. I got hold of some 3mm aluminium, as I'm not great at working with acrylic, and fabricated the motherboard tray, reservoir plate and PSU shroud – they're held in place with bolts, so I can remove them with hardware, such as the pump and reservoir, still in place. I made my own very simple plate-bender for the shroud, using flat steel bars and hinges, which allowed me to get a nice uniform radius along the length of the aluminium sheet.

**CPC:** We like the way you've made the soft tubing look like rigid tubing in places, using angled fittings and straight lines. Why did you decide to use soft tubing over rigid tubing?

**Ricky:** I absolutely love the look of hard tubing but at the time that I was planning this build, it was only just starting to take off. This project was my first go at a custom loop, so I wanted to stick with tried and tested products. I wanted to make sure that the loop was as efficient

as possible too, with no excess bends or stress on the fittings, and with a couple of curves as a nod to the 'snake/Krait' theme.

**CPC:** How did you go about planning the cable and tubing routing, and cutting the holes in the custom parts for the cables, tubing and reservoir?

**Ricky:** The 650D was one of Corsair's earlier cases, which is lovely to look at but isn't the best for cable management. To keep it simple, the majority of cables were routed under the PSU shroud – the only cables going above it were the 24-pin ATX, PCI-E and fan cables, which were routed to a controller in the front of the case. I drew up a load of paper templates and did lots of test fitting before using a power drill and various hole cutters to cut into the aluminium sheet.

**CPC:** How did you get the Krait snake logo on the PSU shroud?

**Ricky:** The shroud itself is covered with a vinyl wrap. I laid out a design in image editing software, and sent the file over to a local company that printed it onto the vinyl.



### /MEET THY MAKER

**Name** Ricky Kemp

**Age** 32

**Occupation** Civil servant

**Location** Essex

**Main uses for PC**

Gaming and movies

**Likes** Homemade

pizza, guitar playing

and overclocking

**Dislikes** Pineapple on

pizza and bad cable

management





## SYSTEM SPECS

**CPU** Intel Core i5-4690K  
overclocked to 4.7GHz

**GPU** MSI GeForce GTX 1070  
Founders Edition (2126MHz  
core, 9.6GHz memory)

**Case** Corsair Obsidian 650D

**Storage** 500GB Samsung 960 Evo  
SSD, 1TB Toshiba P300 hard disk

**Memory** 16GB (4 x 4GB) Corsair  
Vengeance 2400MHz DDR3

**Motherboard** MSI Krait Z97S SLI

**PSU** Corsair CX600

**Cooling** 240mm and 120mm  
radiators, with 120mm Yate  
Loon fans as intakes

The reservoir is probably where I went a bit over the top, and I ended up with a glass XSPC Photon



**CPC:** Talk us through the water-cooling system – what parts did you use and why?

**Ricky:** I spent a lot of time planning and researching my build, making sure that – where possible – I wasn't mixing copper and nickel in the loop. I had seen some horror stories about coloured coolants gunking up blocks and, as it was my first loop, I played it safe with distilled water and a couple of drops of biocide and inhibitor. Originally, I was planning on using a top 360mm radiator along, with a 120mm radiator, but the 650D has a SATA dock in the roof which would foul the fitting.

I worked out the TDP and decided to go for some nice thick rads instead to maximise the cooling headroom – I settled on using Alphacool NexXxos Full Copper radiators, as they have a great balance of price and cooling

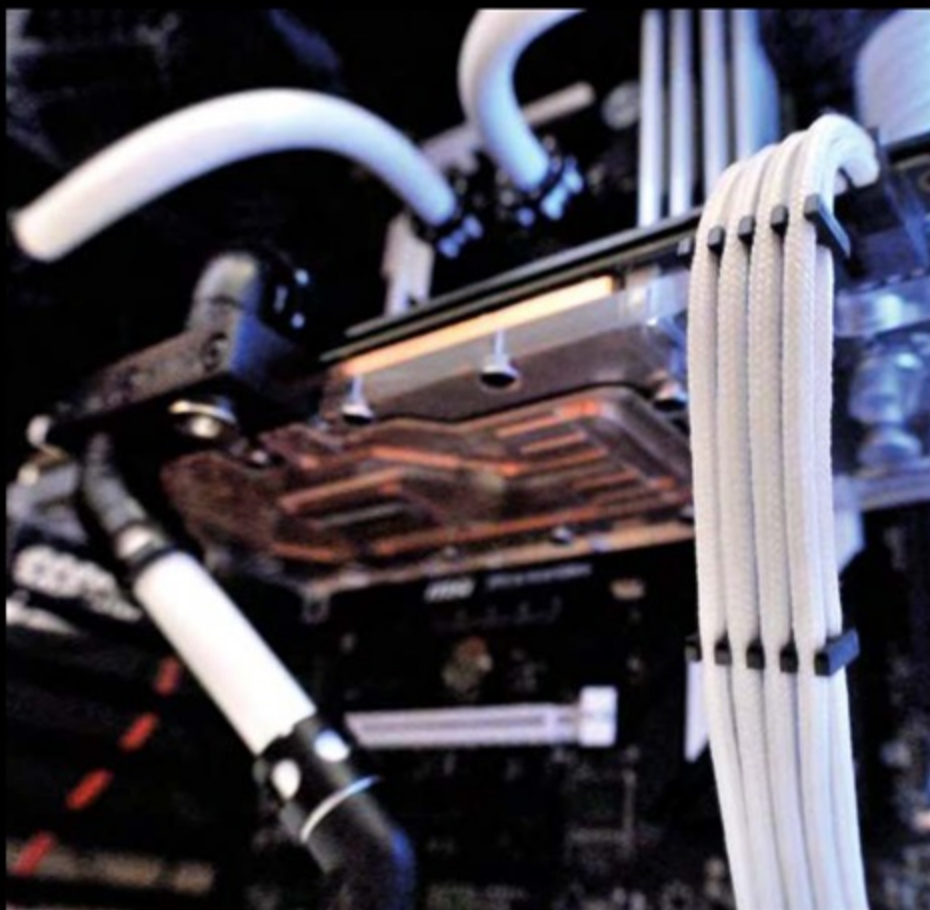
capacity. For the GPU, I just had to go with the copper and plexi full cover block from EK, as it's a stunning-looking block. The CPU block is from Aquacomputer, as I was won over by that company's attention to detail and precise machining.

The reservoir is probably where I went a bit over the top, and I ended up with a glass XSPC Photon. It holds over a pint of water, but it's beautiful and I had planned it as the main source of light in the build, so I really wanted to show it off. It feeds directly into the top of an EK SPC pump just beneath the PSU shroud. The fittings are a mix of Monsoon Chaingun and free-centre compression fittings, with the chain guns really suiting the black and white theme.

**CPC:** Where does the tubing from the GPU go once it enters the hole in the PSU shroud, and how is the fitting secured to the acrylic?

**Ricky:** I wanted a modular design to make maintenance easier. The EK SPC pump is attached under the shroud, with a drain loop. I used bulkhead fittings as pass-throughs





for the GPU block's tubing, and just below the reservoir, directly into the top of the pump. I wanted to be able to just pop the back of the case off and easily get access to the drain when needed.

**GPG: What specs did you choose and why?**

**Ricky:** I was essentially rebuilding my rig around the new motherboard, so I had the parts already. It's an Intel Core i5-4690K in an MSI Z97S Krait motherboard, along with 16GB of 2400MHz Corsair Vengeance DDR3 memory, an MSI GeForce GTX 1070 graphics card and a 600W Corsair power supply. It boots from a Samsung 960 500GB SSD and has a 1TB storage disk.

**GPG: What overlocks can you achieve with that cooling system?**

**Ricky:** I've managed to squeeze 4.7GHz from the Core i5-4690K at 1.37V. My GTX 1070 really impressed me once it was water-cooled too, hitting 2126GHz on the core and 9.6GHz (effective) on the memory, with the PC

sitting at around 65°C after a few hours running at full load.

**GPG: How long did it take you to complete this build, from start to finish?**

**Ricky:** I spent most of my time planning, which makes a change for me! Altogether it took around three months to get it to a point where I was happy.

**GPG: Did you come across any difficulties?**

**Ricky:** The only real difficulty was fabricating the parts on a workbench in my garden – the British weather is unpredictable and rain stopped play more than once!

**GPG: Are you completely happy with the end result, or do you wish you'd done some of it differently in retrospect?**

**Ricky:** For my first custom loop, I'm really happy with the result. I wish I'd worked more on the external appearance of the case, but I felt it trod a fine line between understated and ostentatious. **GPG**

## BE A WINNER

To enter your machine 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 [editor@custompcmag.org.uk](mailto:editor@custompcmag.org.uk). Fame isn't the only prize; you'll also get your hands on some fabulous prizes.

## Corsair K70 RGB MK.2 SE – Cherry MX Speed



The Corsair K70 RGB MK.2 SE is a premium mechanical gaming keyboard that's built to last. It has a silver anodised brushed aluminium frame, as well as stunning white precision-moulded, double-shot keycaps. It's built to turn heads and withstand a lifetime of gaming. There's a detachable, soft-touch wrist rest too.

Meanwhile, its Cherry MX Speed mechanical keyswitches provide the reliability and accuracy you demand, with blisteringly fast 1.2mm actuation. There's also stunning per-key RGB dynamic backlighting, 100 per cent anti-ghosting with full-key rollover, 8MB of on-board memory, plus dedicated media controls.

## Alphacool water-cooling gear

Water-cooling hardware manufacturer Alphacool is offering a choice of £150 worth of gear to every featured Readers' Drives winner. For your prize, you can select from DIY water-cooling kits, the Eiswolf and Eisbaer all-in-one CPU and GPU liquid coolers, as well as a vast range of individual components, including waterblocks (pictured), fittings, reservoirs, pumps



and radiators. Alphacool also makes coolant, tubing and fans, as well as modding and water cooling-related tools.





ANTONY LEATHER'S

# Customised PC

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

## Don't set your pump and radiator fans to respond to CPU temperature

If you own a water-cooling system or an all-in-one liquid cooler, then you'll want to fine-tune it to get the best balance of noise and cooling performance possible. However, if you have your radiator fans and pump responding to your CPU temperature, then you may be surprised to know that you're doing it wrong. In fact, setting them up this way will make your PC much louder than necessary, and could even mean your hardware runs hotter. Here's why.

Let's start with the example of an air-cooled PC that uses heatsinks where the transfer of heat from the CPU core to the contact plate on the heatsink occurs over a fairly short distance. From there, the heat is often transferred to a cluster of heatpipes sitting around the contact plate, and some coolers even have direct-contact heatpipes, which sit straight on top of your CPU's heatspreader.

It's a close-knit arrangement, and the time it takes for the waste heat

**Even relatively large heatsinks require their fans to spin up soon after a CPU is under load**

from your CPU core to make its way through the heatspreader, thermal paste and into the heatsink fins via those heatpipes is usually very quick. In a matter of seconds, you can feel those heatpipes getting warm and that heat will then immediately fan out into the fins to be dissipated by the cooler's fan.



As a result, the impact on the heatsink's ability to dissipate that heat, and in turn cool your CPU, will be huge and this behaviour is easily demonstrable too. Simply put your CPU under load, unplug your CPU fan and see how quickly the temperature rises. This is in part due to the fan being a critical component – you can buy fanless heatsinks, but they're invariably enormous – but also thanks to the heatsink's limited heat capacity.

It will quickly heat up, as the metals involved are good conductors, but they aren't able to absorb a large amount of heat and will quickly get very hot without a fan. This is why fanless CPU coolers are so large – they need to boost this heat capacity, so the cooler can absorb and dissipate enough heat to stop your CPU overheating.

With an actively cooled heatsink, though, the fan plays an important and rapid role. If you put your CPU under load and the fan spins up to cool the heatsink, the results are almost instantaneous. The effect is increased



due to the way heatpipes work too. The cooler the heatsink and upper parts of the heatpipes are, the more effectively heat will be transferred via the evaporation that occurs inside them.

So what does this have to do with water cooling and coolant temperatures? Well, quite a lot, in fact, as the two cooling systems work in the same way, just with different materials. While a heatsink uses heatpipes and evaporation to move heat from the CPU to the heatsink fins, a water-cooling system uses coolant and tubing to transfer its heat from your CPU through the waterblock that sits on top of it and then to the system's cooling component – the radiator and fans.

The key difference here is that the thermal capacity (called the specific heat capacity) of the coolant, which is often water-based, is very high – water can absorb a lot of heat before it too starts to heat up. Given that most water-cooling systems use a litre of coolant or more, you end up with a considerable heat storage medium that has far more thermal capacity than a typical heatsink.

The result of this in a PC water-cooling system is that, even with overclocked water-cooled components, it can take several minutes for the coolant to warm up once those components are under load. As such, if your CPU is suddenly put under heavy load for a few minutes, it will take quite a while for the coolant to warm up and for the fans on your radiator to actually have an impact.

Having your heatsink's fans spin up immediately provides a benefit, as the heatsink gets warm very quickly,

**If you have a GPU in the same loop as the CPU, setting the fans and pump to respond to coolant temperature will prevent it from overheating when the GPU is loaded, but the CPU isn't**

**Corsair and NZXT's latest all-in-one liquid coolers are already set up to respond to coolant temperature**



so the fan needs to be able to cool it and in turn your CPU. However, in a water-cooled PC, having your fans spin up the instant the CPU temperature spikes won't lead to cooler CPU temperatures. That's because, for the first few minutes, the coolant is absorbing that extra heat energy and the temperature delta between the coolant and the air passing through the radiator remains largely static.

This is why setting your radiator fans to respond to your CPU temperature is a bad idea. You'll be needlessly forcing them to spin up instantly, creating noise and for no benefit. There's another reason too. If you have both a CPU and GPU waterblock in your loop, and you run GPU-intensive applications, including games, that don't fully load the CPU, the coolant will continue to heat up unless your CPU reaches a certain lofty temperature, and your radiator fans will stay put, potentially resulting in higher GPU temperatures.

There are two very good reasons, then, to set your water-cooling system to respond to coolant temperature, rather than CPU temperature. Firstly, it will mean your PC is quieter, as the coolant will absorb a lot of heat before it warms sufficiently for your fans to have an impact. Setting your fans to spin up as soon as the CPU temperature spikes under load is pointless.

Secondly, it will mean that, if your CPU isn't under load, but other components in the same loop, such as the GPU, are loaded, then the other components won't suffer. If the coolant temperature rises, your fans will spin up, irrespective of what hardware is actually dishing out the heat. Thankfully, some AIO coolers, such as the models from Corsair and NZXT, already use coolant temperature rather than CPU temperature to control their fans. If you own a custom water-cooling system and want to know how to set up the pump and radiator fans to respond to coolant temperature, then turn to p106, where we walk you through the necessary steps. **GPU**





JAMES GORBOLD / HARDWARE ACCELERATED

# MISSING IN ACTION

This year's CES was a missed opportunity for the PC industry, argues James Gorbald

Once upon a time, the big trade shows such as Computex and CES were the places to watch what was going to be happening within the PC industry. Manufacturers used to stack up an exciting range of technology announcements and product launches for these shows, but they now seem to be much more spread out over the year, including manufacturers' own events, such as Intel's Extreme Masters game tournament and Nvidia's GPU Technology Conference.

This year's CES is a case in point. While there were apparently over 4,500 exhibitors and dozens of press releases issued, I struggled to spot a single truly innovative product or interesting announcement from the PC industry. I appreciate that, to some extent, this is down to my age – the older I get, the more jaded I become, but the shortage of vision on display was still very disappointing.

Probably the singular most important product announcement was for the new Radeon 5600 and 5600 XT GPUs (see p49), providing some much-needed competition in the mid-range graphics card market. In contrast, Intel merely gave out some more general waffle about its forthcoming 10th-gen processors, and managed to confuse people about whether Comet Lake or Ice Lake CPUs will be superior.

What could, and should have been really exciting – the first public demos of Intel's forthcoming GPUs – also got off to a shaky start. To be fair, Intel did point out that the DG1 graphics cards are for software developers, and aren't representative of the final product. But nonetheless, performance was so poor, with the cards struggling to run Warframe smoothly at 1080p; it was a thoroughly underwhelming demo. While it's easy and risk-free to me to second-guess other people's decisions, with such high

expectations for Intel entering the graphics market, I do think the DG1 unveiling was very badly handled. It would have been better seen in context demonstrated at the GDC show in March instead.

In contrast to 2020, last year's CES laid the groundwork for a great year for PCs, with major announcements coming thick and fast from the likes of AMD and Nvidia. For instance, CES 2019 was the first time that AMD publicly demonstrated its Ryzen 3000-series CPUs, which have since turned the desktop PC market on its head, promoting AMD from underdog to market leader in less than year – a truly amazing transformation.

Also on show for the first time last year was AMD's next-gen EPYC server CPUs, codenamed Rome, which have also begun to have a significant impact on the enterprise market. And last but not least, AMD also announced Radeon VII. While this graphics card may have ended up being underwhelming in terms of performance and sales, as the world's first 7nm GPU it laid the groundwork for

the much more successful Radeon 5000-series that would follow later. Nvidia was also busy at CES 2019, launching GeForce RTX for laptops and the GeForce RTX 2060, one of the most successful graphics cards of the year.

Moreover, the industry followed up these great teasers and announcements from CES 2019 with a flurry of exciting products throughout the year. In contrast, based on CES 2020, I'm struggling to get enthused by anything. Sure, there are roadmaps to which I'm privy, showing that there are a potentially some great products to come later this year, but it seems like a missed opportunity to not make more of a noise about them at CES, especially after such a great year for the PC in 2019. **GPG**

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James Gorbald has been building, tweaking and overclocking PCs ever since the 1980s. He now helps Scan Computers to develop new systems.



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