NEW OLEDs TESTED PG.74,78

TOP **MECHANICAL KEYBOARDS** PG.44

NEW LAPTOP REVIEWS PG.80, 84

MAXIMUM PC

MINIMUM BS • AUGUST 2024 • www.maximumpc.com

BUILD A $999 GAMING PC

Spend less and game more!

- Pick AMD's best value CPU & GPU
- Play at 1080p Ultra settings
- PLUS The best upgrades under $250

STEP-BY-STEP GUIDE PG. 22

GPUs vs CPUs WHICH SHOULD YOU UPGRADE? PG.32

FUTURE
VOL 29, NO 8

NETGEAR WIFI 7 MESH REVIEW PG.76

We build the world's most advanced PCs.

Experience a new level of performance with an award-winning Digital Storm PC. Built with the latest technology, highest quality components and backed by lifetime support. Visit our website and build your dream PC today.

DIGITALSTORM

LEARN MORE: WWW.DIGITALSTORM.COM

Digital Storm PCs featuring Intel® Core™ i7 processors.

intel CORE i7 inside

The Electronic Frontier Foundation is the leading nonprofit organization defending civil liberties in the digital world. Founded in 1990, EFF champions user privacy, free expression, and innovation through impact litigation, policy analysis, grassroots activism, and technology development. We work to ensure that rights and freedoms are enhanced and protected as our use of technology grows.

EFF.ORG

ELECTRONIC FRONTIER FOUNDATION

Protecting Rights and Promoting Freedom on the Electronic Frontier

inside

AUGUST 2024

SCAN TO GET THE TOM'S HARDWARE WEEKLY NEWSLETTER

QUICKSTART

16 BUILD A $999 GAMING PC

© LUCA GALANTE, LUCA GALANTE BANDAI NAMCO ENTERTAINMENT

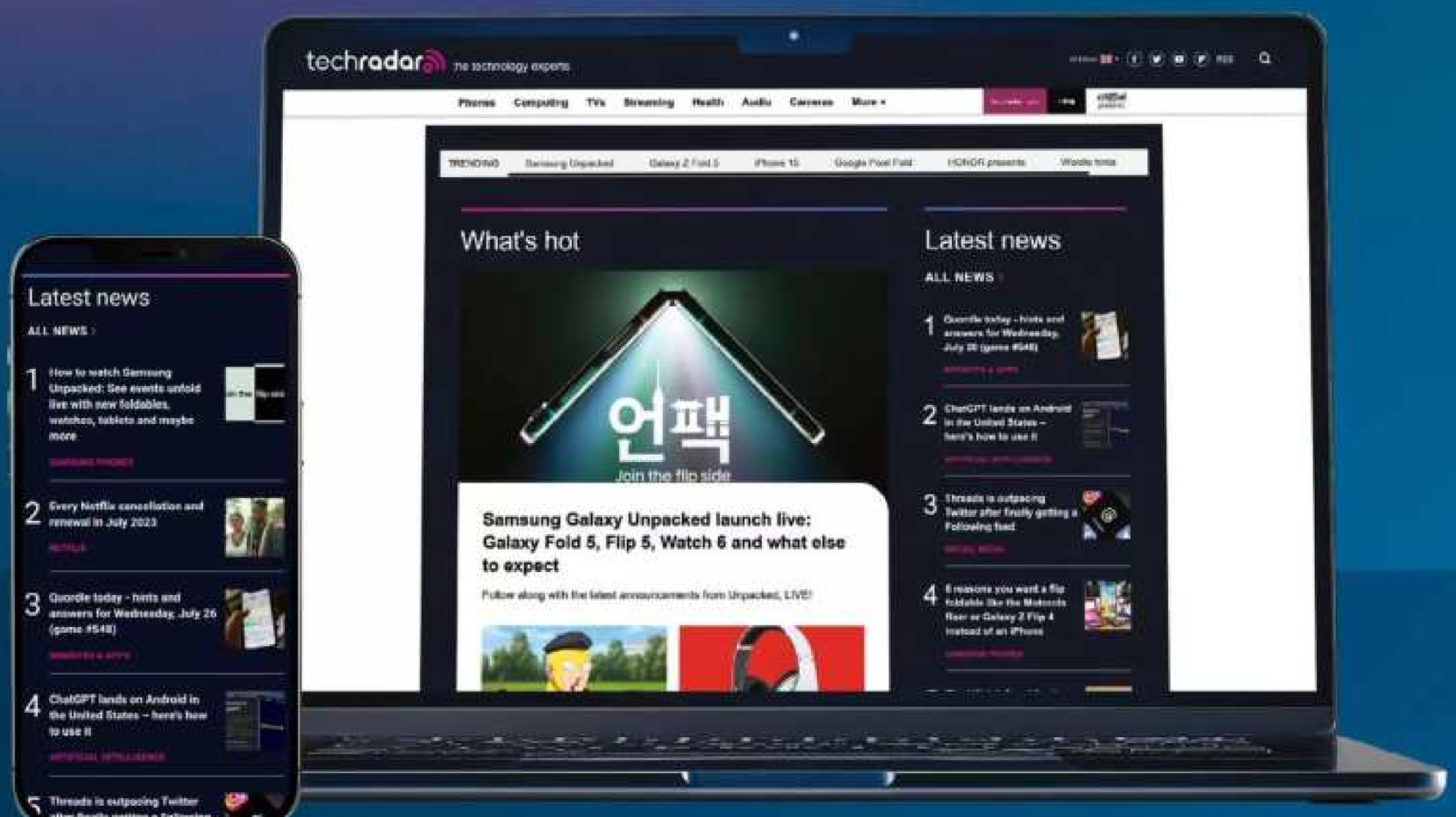
IN THE LAB

AMAZING
SUBSCRIPTION OFFERS

SUBSCRIBE TO ANY OF OUR **BEST-SELLING** MAGAZINES

SHOP THE FULL RANGE
WWW.MAGAZINESDIRECT.COM/SUBSCRIBE

Meet the technology experts



- The world's **most** comprehensive technology website
- An **unrivalled** mix of news, opinions, reviews and features
- **All-new design**, new homepage, new features and special reports
- Backed by **over 300 years** of editorial experience

techradar
the technology experts

www.techradar.com

MAXIMUMPC

EDITORIAL
Editor-in-Chief: Guy Cocker
Contributing Writers: Tyler Colp, Nate Drake, Ian Evenden, Cliff Joseph, Jeremy Laird, Chris Lloyd, Nick Peers, Nik Rawlinson, Jacob Ridley, Zak Storey, Jarred Walton
Production Editor: Steve Wright
Editor Emeritus: Andrew Sanchez

ART
Art Editor: Fraser McDermott
Photography: Neil Godwin, Olly Curtis, Phil Barker
Cover Photo Credits: Future PLC

BUSINESS
US Marketing & Strategic Partnerships: Stacy Gaines, stacy.gaines@futurenet.com
US Chief Revenue Officer: Mike Peralta, mike.peralta@futurenet.com
East Coast Account Director: Brandie Rushing, brandie.rushing@futurenet.com
East Coast Account Director: Michael Plump, michael.plump@futurenet.com
East Coast Account Director: Victoria Sanders, victoria.sanders@futurenet.com
East Coast Account Director: Melissa Planty, melissa.planty@futurenet.com
East Coast Account Director: Elizabeth Fleischman, elizabeth.fleischman@futurenet.com
West Coast Account Director: Austin Park, austin.park@futurenet.com
West Coast Account Director: Jack McAuliffe, jack.mcauliffe@futurenet.com
Director, Client Services: Tracy Lam, tracy.lam@futurenet.com

MANAGEMENT
CEO: Jon Steinberg
MD Tech: Paul Newman
Group Editor-in-Chief: Graham Barlow
Group Art Director: Warren Brown

PRODUCTION
Head of Production: Mark Constance
Senior Production Manager: Matthew Eglinton
Production Manager: Vivienne Calvert
Production Assistant: Emily Wood

Future US LLC, 130 West 42nd Street, 7th Floor, New York, NY 10036, USA. www.futureus.com

INTERNATIONAL LICENSING & SYNDICATION
Maximum PC is available for licensing and syndication. To find out more, contact us at licensing@futurenet.com or view our available content at www.futurecontenthub.com.
Head of Print Licensing: Rachel Shaw, licensing@futurenet.com

SUBSCRIBER CUSTOMER SERVICE
Website: www.magazinesdirect.com
Tel: 844-779-2822
New Orders: help@magazinesdirect.com
Customer Service: help@mymagazine.co.uk

BACK ISSUES
Website: https://bit.ly/mpcsingleissue

Next Issue On Sale August 13, 2024

EXTRA DIGITAL FEATURES

AUDIO FILE | PHOTO GALLERY | VIDEO FILE

Guy Cocker

SUMMER SALES

THIS ISSUE of *Maximum PC* is filled with glimpses into the future—next-generation Zen 5 chips from AMD (page 8), the future of gaming keyboards with 8,000Hz polling rates (page 49), as well as the first ARM-based Snapdragon X laptops and their amazing battery life (page 72). But as any bargain hunter will know, the release of the next big thing often results in great discounts on last season's model. And we really are seeing some excellent bargains at the moment, particularly on items like graphics cards, RAM, and SSDs.

This is why we've chosen to build a $999 gaming PC this issue to take advantage of all the great value PC tech that's out there. The last time we attempted such a budget build was in May 2023, when it felt like we were building a machine of compromises, thanks to a mini-ITX motherboard that lacked PCIe ports, already outdated DDR4 memory, and an Intel Arc A750 graphics card when I'd prefer an AMD or Nvidia alternative. This year's attempt features no such concessions—this is a machine that boasts a full-size ATX motherboard, fast DDR5 RAM, and an AMD GPU that's capable of 1080p gaming at Ultra settings. It's also housed in what our builder Zak has described as "the best budget case of all time" from Phanteks (also reviewed on page 82), which means that this is a machine that's all killer and no filler.

It's also a PC that answers our reader B. Duggan's question from last issue about the perfect PC to take to college, which is something a lot of students will be thinking about as they gear up for the new academic year. If your budget (or let's be honest, parents or guardians) can stretch a bit further, then Zak has also detailed the best upgrades you can make for $250, $500, and $1,000, and how much of an impact those spends will have on performance. He also helps you avoid any pitfalls with potential bottlenecks, so you don't waste money where you don't have to. It all starts on page 16.

In our reviews section, the march of the OLEDs continues as we give our verdict on two new models from Samsung and Philips—two titans of the display industry. While I use a 34-inch ultrawide OLED, I admit to having my head turned by a 4K model, perhaps just not the one featured this issue. We also take a look at a couple of excellent cases, a couple of new laptops, and Netgear's first (very expensive!) WiFi 7 mesh system. It begins on page 74.

We also have a couple of features that are exactly the sort of classic deep dives that you tell me you love when you write in to our letters section (editor@maximumpc.com). The first is a data-led investigation (page 32) by Jarred Walton on whether it's better to upgrade your CPU or GPU when chasing better gaming performance, plus whether AMD's much-loved Ryzen 7 7800X3D is still the best chip to buy for higher frames. Then Zak looks at gaming keyboards (page 44), what features are important to have, and whether polling rates are really that crucial.

Don't worry though, we have plenty of tutorials as well, including how to turn a discarded USB stick into an emergency rescue disk, recover deleted files without having to pay a specialist, clean and optimize your PC for free, and how to edit a podcast in Audacity 3.5.

Enjoy the issue!

Guy Cocker

Guy is Maximum PC's *editor-in-chief. He built his first gaming PC in 1997 to play* Tomb Raider *on 3dfx, and has been obsessed with all things PC ever since.*

↘ submit your questions to: editor@maximumpc.com

THE NEWS

First Zen 5 Chips

New desktop and mobile chips put AMD back in charge

TECH COMPANIES love launching new products at trade shows, and at this year's Computex, AMD treated us to a major chip announcement: the first Zen 5 processors. There are six new Zen 5 processors, four desktop versions, and two mobile, codenamed Granite Ridge and Strix Point. Zen 5 architecture offers, according to AMD, an IPC (Instructions Per Clock) gain of 16 percent over Zen 4, which, as generational IPC bumps go, is about average for a change of Zen architecture.

There had been some speculative rumors about a higher IPC than this, with 30 percent touted. This would have been amazing, but proved spurious. As it is, the bump is enough to allow AMD to offers "the fastest consumer desktop performance in the world", as CEO Lisa Su proclaimed from the main stage. They aren't the best gaming chips, however—that honor still falls to the Ryzen 9 7950X3D with its 144MB of cache. We expect a V-Cache Zen 5 chip this fall.

Top dog of the new Zen 5s is the Ryzen 9 9950X, a 16-core chip with a base clock of 4.3GHz, a top boost of 5.7GHz, and a TDP of 170W. Below this sits the Ryzen 9 9900X, a 120W, 12-core version with a 4.4GHz base clock and 5.6GHz boost. Next is the 65W Ryzen 7 9700X with eight cores, a 3.8GHz clock, and a 5.5GHz boost. Last is the 65W, six-core Ryzen 5 9600X, with a 3.9GHz base, and a 5.4GHz boost. Core counts haven't changed over the Zen 4 chips, and base clocks have dropped against Zen 4, from 200MHz on the top chip, and 300Mhz for the 12-core. The two 65W chips get more significant drops of 700MHz and 800Mhz. Apart from the top chip, all have power consumption reductions of about 30-40 percent, largely thanks to the new 4nm process and reduced base clocks. All use the AM5 socket, which AMD promises to support until at least 2027. This implies that Zen 6 chips will see some AM5 use, since they're expected in 2026. We also have two new AM5 motherboard chipsets: X870 and X870E. Both offer DDR5 memory and PCIe 4.0 and 5.0 support. You'll also be able to drop your new Zen 5 chip into a 600-series board after a BIOS upgrade.

As with all AMD chip launches, we got a set of bar charts that show how wonderful they are. Obviously, AMD is biased on this. The slide for the Ryzen 9 9950X matches it against the Core i9-14900K on a selection of productivity and gaming benchmarks. The best result is a whopping 56 percent lead in Blender, while Cinebench R24 is 21 percent ahead. Gaming results are less dramatic, ranging from four percent running *Borderlands 4*, to 23 percent with *Horizon Zero Dawn*. AMD also claims a 20 percent lead in AI processing. It estimates that Zen 5 has an 11 percent lead in gaming, and 21 percent in productivity. All this is against Intel's Raptor Lake refresh, but the real rival will be Arrow Lake, due this fall.

Alongside these desktop chips come two mobile Zen 5 chips, the Ryzen AI 300 Series, a name designed to highlight the AI features ready for Microsoft's Copilot+ PC. The more powerful is the Ryzen AI 9 HX 390, a 12-core chip with a base clock of 2.0GHz and maximum boost of 5.1GHz. It has four full Zen 5 cores and eight compact 5c cores. The integrated Radeon RDNA 3+ graphics has 16 compute units. The 10-core Ryzen AI 9 365 drops the boost to 5.0GHz, and loses two compact cores. Both boast a 50 TOPS NPU, exceeding the 40 TOPS needed to join the AI PC club, and topping Qualcomm's best. TDP is between 15 and 54W. A host of systems have been announced, including from Asus and MSI. Early benchmarks are promising, appearing to trounce Intel's Core Ultra 185H. They are "simply the best mobile CPU", although we await Intel's Lunar Lake, as well as the Strix Halo chips. Although there's nothing official from AMD, rumors are rife that they aren't far behind. Strix Halo features a multi-chip design with up to 16 cores and 40 compute units in the integrated graphics, and an NPU boasting 70 TOPS.

We won't get a clear view of the state of play until Intel's rival architectures appear, but until then, AMD appears to be top banana right across the spectrum, claiming the fastest gaming chip, productivity chip, mobile chip, and integrated AI. The new CPUs will be available any moment now. **–CL**

© AMD

> "The Zen 5's launch gives AMD pretty much a clean sweep of the CPU crowns

APPLE WORKING ON BUDGET VISION PRO

VISION PRO is an undoubtedly impressive piece of VR kit, with a equally impressive price: it starts at $3,499. Apple has reportedly hit pause on the development of the Vision Pro 2 in order to concentrate on a 'budget' version. Staff have been reassigned to the project, codename N109, which was started in 2022. Apparently, the idea is to price it next to premium iPhones at around $1,600. The new version was originally slated for this year, but is now expected late next year. Going for a cheaper model first over another high-end one is probably a good call. The Vision Pro was expected to sell over 700,000 units, but it'll be lucky to shift much over 400,000 this year. The expense is a big factor, although it isn't without other issues (heavy battery pack, fragile visor, and lack of software). Apple has a history of making something special and waiting until the market catches up. The first year of the iPhone didn't actually go that well. Despite its flaws, the Vision Pro undoubtedly does have that touch of Apple magic. **–CL**

FTC SUES ADOBE

THE FEDERAL TRADE COMMISSION has its eyes on Adobe for breaches of ROSCA (the Restore Online Shoppers' Confidence Act). This was enacted in 2010 to protect consumers from online fees that weren't made clear beforehand. Adobe has been pushing people toward an annual subscription billed monthly, at $59.99 a month for the Creative Cloud All Apps package. What isn't clear is what happens if you cancel the account, because that information is buried in tiny text that mentions a "early termination fee". You only get full details when you try to cancel, and that fee is half of any remaining months. Also, the FTC alleges that Adobe makes subscription cancellation difficult, incorporating "resistance and delay" tactics. Some customers are left thinking they've canceled their package, only to be billed. This is exactly what ROSCA was designed to stop. Subscription services are everywhere, and companies have no incentive to make cancellation easy. Allegedly, Adobe is aware of this, and chose to wait for legal action before sorting it. Not cool, guys. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

CLOTHES THAT DISSOLVE
Researchers have found a way to spin gelatin into clothes fibers that can be dissolved in water.

MASSIVE CPU BOOST
Flow Computing has plans for a Parallel Processing Unit (PPU) that accelerates CPU speeds by doing simple jobs in parallel.

SMALLER AND SMALLER
After its first High-Numerical Aperture EUV lithography machine for Intel, ASML is making an even more advanced Hyper-NA system.

TRAGEDIES

AI OVERVIEWS BROKEN
Google's attempt to fix its AI search hasn't worked, delivering mistakes and wrong answers.

MINECRAFT ACCOUNTS
Players that didn't migrate their Mojang account to Microsoft have had them deleted, and have to buy a new license.

MICROSOFT MANDATORY
Win11 setup will no longer accept a fake email. Microsoft increasingly sees Windows as a data-gathering and sales tool.

© COMPUTEX SHOW, FTC/WIKIPEDIA, APPLE CORP

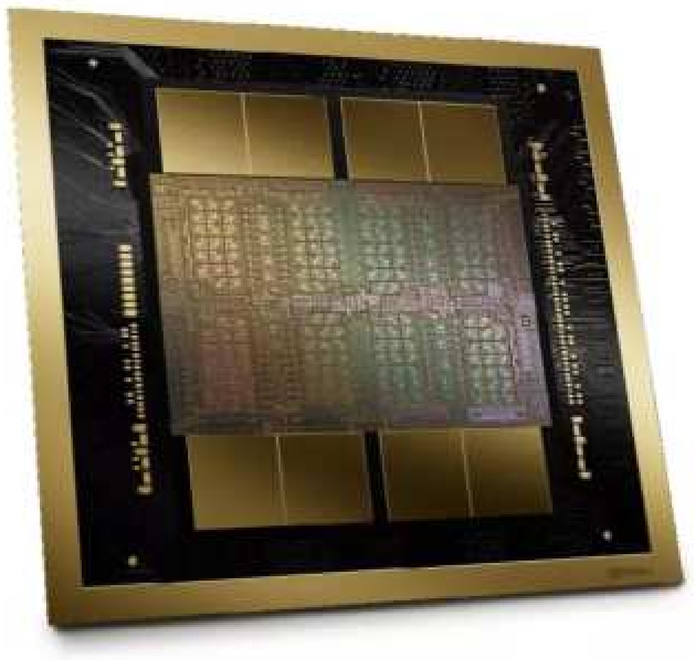
COMPUTEX 2024

Cool cases, wacky mods, and more

THE THEME of this year's Computex was AI, two letters that are already getting tired pretty quickly. This year saw 1,500 companies with over 4,500 booths, and alongside the usual array of new monitors, laptops, and other kit, it also attracted myriad oddities, innovations, and more.

MSI's MEG Vision X AI drew the attention of Intel CEO Pat Gelsinger, who signed it and added 'awesome'. The front of the case is a 1080 by 1920 touchscreen. You can run MSI's system software-monitoring temperatures, frequencies, lighting effects, and so forth, or use it as a second Windows screen. It's an experimental model so far. Ducky, the mechanical keyboard people, had their new One X, the first to use Cherry's innovative MX Multipoint system to adjust the actuation points, which is cheaper, and uses less power than Hall Effect switches. It will be available later this year for between $140 and $170. We saw another stab at adding extra screens to laptops, as Acemagic brought its X1 Dual-Screen model along, with a traditional 14-inch screen, and a second that folds to the side or behind, allowing you to sit opposite somebody for a presentation. Two screens means battery drain is sharp at four hours, and it's heavy. It's set to ship next year. Cooler Master had a prototype miniature arcade machine, the Retro Machine, complete with joystick and four buttons. No plans for production yet though. Asus ROG also had a UPS called Mjolnir, shaped like Thor's hammer.

There were a lot of cases: folding, open frame, and a lot with glass panels. Corsair had its 9000D, a bit of a beast designed to accept two full systems in one. At the other end of the scale, Fractal brought an experimental Raspberry Pi case. There were also a lot of customized cases—we had ones in the shape of a gas pump, coffee machine, beer pump, a claw machine, ED-209 (think RoboCop), a turtle, and one with a goat's head breaking open a globe of Earth (your guess as good as ours). All the fun of the fair... **–CL**



NVIDIA WORLD'S MOST VALUABLE COMPANY

AI has earned the green team a fortune

THE LIST of most valuable companies has been topped by big tech for years. Apple has generally been in prime place, with Microsoft and Alphabet occasionally usurping it. Now, we have a new winner: Nvidia. In mid-June, it became the world's most valuable company by market capitalization at $3.34 trillion. No prizes for guessing why. The growth of AI has led to every other big tech company beating a path to buy its high-end accelerators.

Last year, Nvidia sold 3.76 million data center GPUs—98 percent of the market. On March 18, Nvidia announced its Blackwell family, which it promised would power "a new era of computing". The 208 billion transistor B200 chips are built into GB200 systems that are 30 times faster and use less power than the previous generation. A tour by CEO Jensen Huang promoted Nvidia's new hardware and future plans. The stock price responded, briefly making Nvidia the world's most valuable company.

Elon Musk wants his X platform to be at the forefront of AI, and plans to add 300,000 Blackwell B200 chips to his servers. These will replace the 100,000 H100 GPUs the firm already runs. Apparently, the power consumption of these, at 1 gigawatt, is a concern (enough to run about 700,000 houses). Nvidia says that each B200 'might' cost between $30,000 and $40,000.

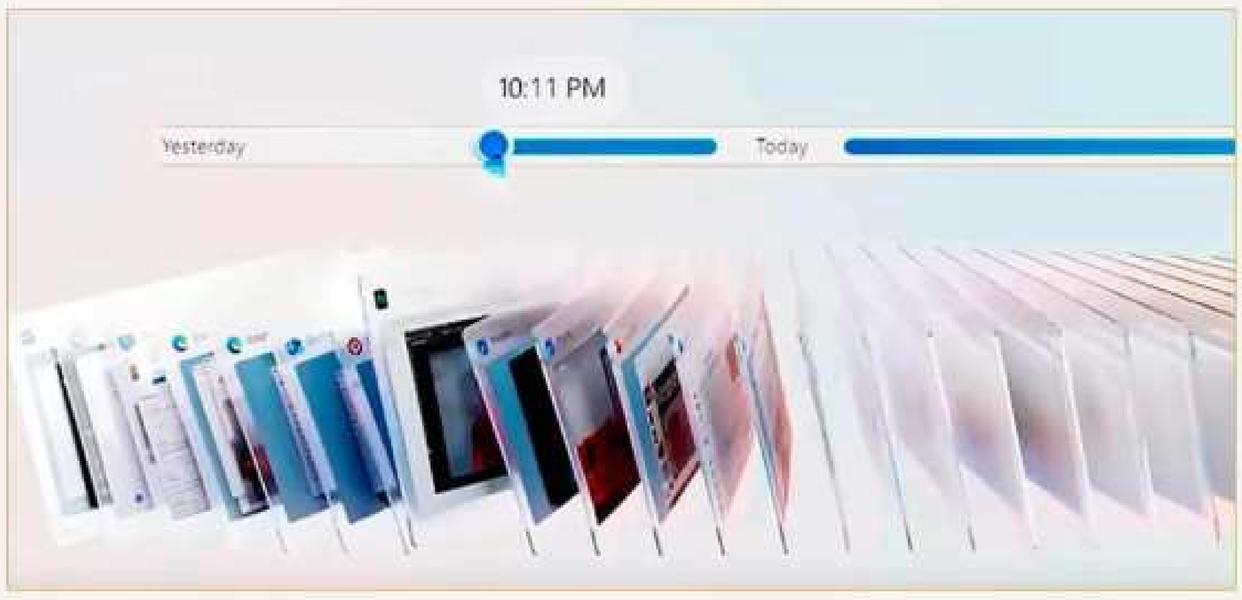
Market capitalization is a volatile metric, however. One dodgy announcement can knock billions off the price. Nvidia's stock took a small tumble after its high, and slid off the top spot. Pundits think we're not far away from the first $4 trillion company, with top contenders being Apple, Microsoft, and now Nvidia. **–CL**

Microsoft cans Recall

PART OF MICROSOFT'S PLANS for the AI PC, or 'Copilot+', was Recall. This AI-powered system takes snapshots of your screen and uses OCR to produce a searchable database of text. Sounds useful, but not everybody was happy. The system is unselective, so bank details, private correspondence, and more is logged, creating a treasure trove of data for hackers and the curious. Anybody using your account has full access, itself something of a concern, but it was discovered that physical access to your system wasn't even required. Those text files can be accessed by anyone with a Windows profile on that system, a process that can be actioned remotely.

As pressure grew, Microsoft made a few tweaks, making it an opt-in feature, and adding some encryption. Then it limited it to its Windows Insiders program. As the head of the Windows team, Pavan Davuluri, put it; "We are adjusting the release model for Recall to leverage the expertise of the Windows Insider community to ensure the experience meets our high standards for quality and security." That didn't last long—Recall was stripped out of the beta program, and is currently unavailable. What Windows saw as a useful tool to browse your past actions, others viewed an insecure piece of spyware. Its future is unclear, but in its present form it won't fly.

Having your PC record everything you do turned out to be an unpopular idea. Who didn't see that coming? **–CL**



AMD gets hacked

A forum had a post from a group called IntelBroker that claimed to have AMD data for sale, including product, employee, and customer details. AMD investigated, and did not confirm any losses, although there was a data breach. This was followed by a report that damage was limited in scope. It also said it was working with law enforcement and a third-party hosting partner. It transpires that the data was from a vendor's system. AMD has been suitably tight-lipped about what has been stolen, and says it is unlikely to have any significant effect on business or operations. IntelBroker has managed some high-profile breaches in the past, including one at Los Angeles International Airport. **-CL**

Audio AI watermark

Meta has an AI watermarking system called AudioSeal that can add and then detect watermarks in audio data. The digital tell-tales are distributed across the data, too small to be noticed by the human ear, but easy for an AI system to detect. Early tests show 90 percent accuracy. However, Meta has no plans to use watermarks in its AudioBox or VoiceBox tools. Why not? Online disinformation is a real and growing problem. A universal standard would be ideal—until then, something is better than nothing. At least Meta has new a policy of labeling AI content. It's a start, but more robust embedded watermarks for AI content are needed. AudioSeal is available on GitHub if you want a peek. **-CL**

Jarred Walton

TECH TALK

Intel Taps TSMC for its Lunar Lake CPUs

INTEL WAS THE LEADER in microprocessor manufacturing technology for decades, but the soon to be released Lunar Lake processors will primarily be produced using technology from TSMC. It's not the first time Intel has used another company's process technology, but it's the latest CPU cores being produced elsewhere. And that's only the start of the changes.

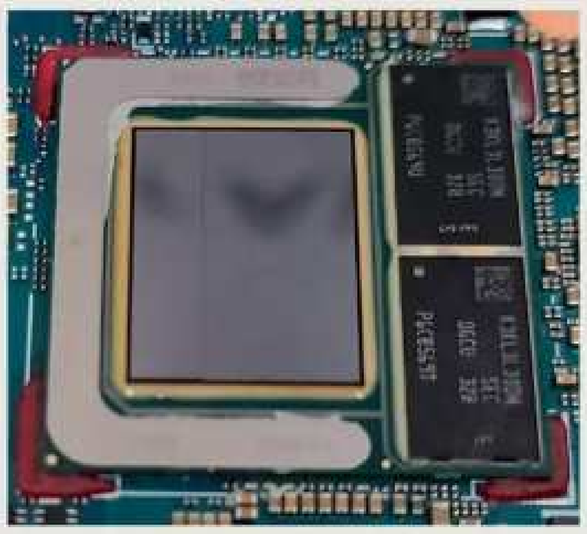
The simple explanation for the use of TSMC's N3B node for the main compute tile is it was better than what Intel had in the design phase of Lunar Lake. Intel stalled on 14nm process technology for what seemed like ages—it was first used in the 4th Gen Haswell chips in 2014, and extended to the 11th Gen Rocket Lake CPUs in 2021. TSMC passed Intel, and is now considered the leading foundry for semiconductor manufacturing. To prevent similar issues, Intel has altered how it creates new chips.

Intel has an initiative to release five nodes in four years. It started with Intel 7 in 2021 with the 12th Gen Alder Lake. Meteor Lake chips are the first to leverage the Intel 4 node, and the dense core Sierra Forest Xeon CPUs recently launched using Intel 3. That leaves Arrow Lake CPUs as the first to use Intel 20A. Next year, Intel plans to launch Panther Lake and Clearwater Forest on its Intel 18A node. But what about Lunar Lake?

One of the major design changes Intel has made is to switch from proprietary tools for designing its processors to industry standard. Previous chips often used manually designed circuits, with functional blocks containing tens of thousands of cells. The new tools can contain blocks of up to millions of cells, and will improve design times, increase die utilization, and reduce die area.

The new tools also make the processor designs more portable so that Intel can port an architecture between TSMC N3B and Intel 20A without a ton of rework. The design methodology apparently makes 99 percent of the design transferable from one process node to another, which is key to getting newer processors out more quickly, avoiding the stumbles of the 14nm era.

> Intel has an initiative underway to release five nodes in four years



Lunar Lake consists of a compute and platform controller tile by TSMC.

These design tools relate to Lunar Lake and Arrow Lake, which will both use the new Lion Cove P-cores and Skymont E-cores. Lunar Lake uses TSMC's 3NB for the compute tile, Arrow Lake should be the first to use Intel 20A for the same core architectures, though with other differences in core counts. Which process node is superior? That's hard to say, as process node names are more about marketing than transistor sizes, but clearly Intel expects to be competitive with TSMC.

Besides the compute tile, Lunar Lake has a platform controller tile that will use TSMC's N6 node. This houses all the external I/O functions for the chip, including the memory controllers, PCIe 4.0 and 5.0 interfaces, Wi-Fi and Bluetooth, and Thunderbolt, plus USB controllers. External interfaces don't scale as well with smaller manufacturing nodes, so putting this on an older and less expensive node makes sense. You can see the platform controller and compute tiles in the photo, with the narrow rectangle on the left being the platform controller.

There are some interesting changes when comparing Lunar Lake to Meteor Lake. MTL had four primary tiles, plus the Foveros tile, while ARL cuts that to two. All the CPU, GPU, and NPU processing is in the compute tile this time, while MTL separated these into three: compute, IO, and SoC. As Intel becomes more comfortable with mixing and matching technologies, we can expect to see differing approaches based on what's best for a particular design.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

THE BEST STEAM DECK GAMES

THE STEAM DECK AND ITS SHINY NEW OLED VARIANT are our favorite additions to PC gaming in years. They're perfect for those who don't want to play PC games in bed or on the sofa, and with Verified Playable support for more than 10,000 games now, there are almost too many options to choose from. More games are getting verified for the Steam Deck every day, but here's our pick of the best.

DAVE THE DIVER

Charming, deep, and constantly surprising, *Dave the Diver* is packed with activities. An adventure RPG featuring deep-sea exploration and fishing during the day and sushi restaurant management at night, it sounds pretty pedestrian—until you clock the stunning pixel art and characters. Even the credits sequence gives you a new game to learn and play.
$19.99, https://store.steampowered.com/app/1868140/DAVE_THE_DIVER

SLAY THE SPIRE

A roguelike single-player deckbuilder, it's one of the most elegantly designed games ever, even spawning its own subgenre. It's the essence of a great card game: the joy of building a machine and optimizing it as much as you can. If that isn't enough, moddability opens up whole new decks, enemies, and cards to tinker with. Truly a genre-bending achievement.
$24.99, https://store.steampowered.com/app/646570/Slay_the_Spire

DEAD CELLS

This action platformer debuted in 2018, but its presentation and combat are perfect for the Deck. Sure, the punishing structure can cause grief, but with experience comes knowledge of which routes to take, and how to get back to those tricky boss battles.
$24.99, https://store.steampowered.com/app/588650/Dead_Cells

STARDEW VALLEY

This farm life sim has built quite a following. Its escapism is a bit rough around the edges, but that hardly matters when you're fishing on a pier, or befriending a homeless person in a tent.
$14.99, https://store.steampowered.com/app/413150/Stardew_Valley

VAMPIRE SURVIVORS

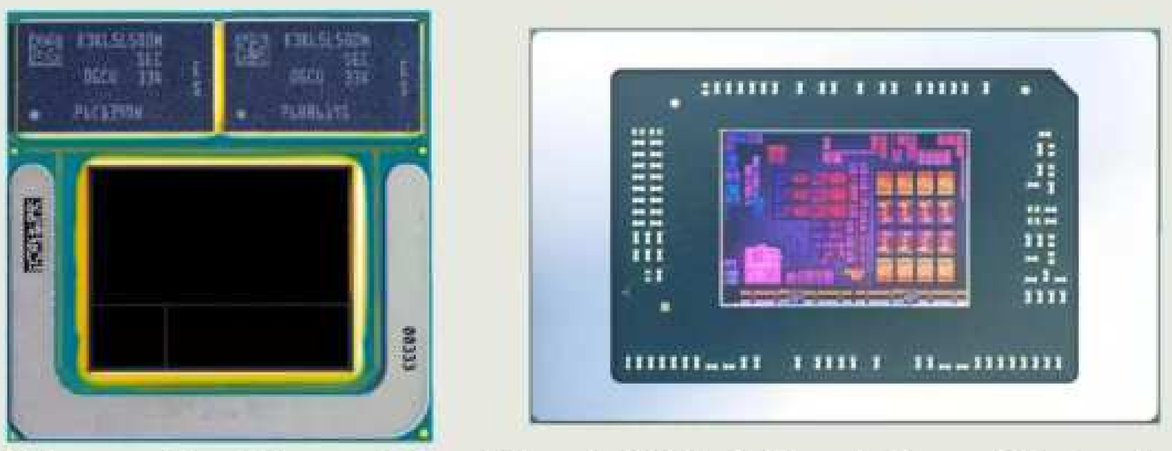
Untethered from a desktop-grade CPU, this starts to chug a bit in those late run steamroll sequences, but it doesn't really demand twitch reflexes. More to the point, it is a fun roguelike that absolutely sucks you in. It'll also only kill your free time, not your wallet.
$4.99, https://store.steampowered.com/app/1794680/Vampire_Survivors

Jeremy Laird

TRADE CHAT

The battle for next-gen laptops and handhelds

THE DUST has settled on the orgy of silicon, sweat-shop capitalism, and silly AI marketing straplines that was the 2024 Computex show in Taiwan. All that's left bar the cocktail of air-travel contracted pathogens currently laying waste to the post-Computex attendees is to decide which was the best new laptop chip announced at the show. AMD's or Intel's?



Chip wars: Intel's Lunar Lake will battle AMD's Strix point for mobile dominance.

I know what you're thinking. What about Qualcomm's new Arm chip, the Snapdragon X? It may well be a turning point for Arm on the PC, but there's a long way to go, and much to prove, not least the efficacy of its x86 emulation. In reality, the vast majority of laptops are still going to use AMD and Intel x86 chips for several years to come.

In some ways, Intel's Lunar Lake and AMD's Strix Point APUs are a bit of a mismatch. The latter has 12 CPU cores to Intel's eight. It's not quite a direct comparison, as both chips are hybrid designs with two types of CPU core. But in raw processing terms, you'd think AMD has the clear edge.

On the other hand, CPU grunt isn't critical in a laptop or handheld gaming context. You want enough CPU power without murdering the battery, so efficiency is where Intel scores its first on-paper points. Lunar Lake has on-package memory, which is a clear efficiency move, even if it makes post-purchase memory upgrades impossible.

Intel has also wound back on its chiplet approach with Lunar Lake. It only has two active chiplets, where its existing Meteor Lake chip has four. All the important bits are in the main compute tile. For sure, AMD's APU is a single-chip monolithic design, which is best for efficiency, but Intel seems to have minimized its disadvantage there.

Perhaps most importantly, that big compute tile in Lunar Lake is built on TSMC's N3B node, while AMD's Strix Point uses the same TSMC N4 node as its predecessor. Intel has a clear node advantage, and that bodes well for power consumption.

Intel's Lunar Lake also has what you might call a full-on hybrid CPU architecture. Intel's Performance and Efficient cores are of quite different designs, with the latter optimized for low power consumption. By contrast, the Zen 5 and Zen 5C cores in AMD's Strix Point are functionally identical.

If efficiency looks like advantage AMD, what about graphics grunt? This is much harder to judge. In some ways, we have a better idea of what AMD is bringing. Strix Point will top out with 16 graphics compute units, up from 12 in its old Hawk Point APU. The iGPU in Strix point runs faster, up to 2.9 GHz to Hawk Point's 2.7 GHz maximum.

The iGPU in Strix Point has also been upgraded from AMD RDNA 3 spec to RDNA 3.5. We don't have many details as to what RDNA 3.5 means versus the existing RDNA 3 graphics architecture, but it may boost ray tracing performance.

As for Intel's Lunar Lake iGPU, that's more of an unknown. It has eight graphics execution units—the same number as the existing Meteor Lake mobile chip. But that's eight of Intel's new Battlemage spec EUs, where Meteor Lake leverages the Alchemist graphics architecture. The caveat is Intel's patchy graphics driver quality. You have to give AMD the clear advantage when it comes to performance consistency.

Circling back to efficiency, 16 RDNA 3.5 cores on TSMC N4 silicon is a bit of a worry when it comes to power consumption. It's not like existing gaming handhelds with 12 RDNA 3 cores offer great battery life. Intel may have the edge for battery life, while AMD will have the faster chip. Either way, I reckon there are going to be some fantastic laptops and game-changing handheld PCs when these new chips hit the market.

Six raw 4K panels for breakfast, laced with extract of x86... Jeremy Laird eats and breathes PC technology.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> Fix server problems
> Extend movie files
> OEM license

Server teething troubles

I followed your feature on building a new server, but decided to install Ubuntu 24.04 LTS instead of Debian, as I know it better, and the new LTS supports Podman 4.9.3. So far, so good, but I've run into two annoying problems. The major one is that if I leave the server unattended for a short period, my Nextcloud client reports that the server is disconnected. If I log on to the server through cockpit, the connection is restored, but as soon as I leave the server to its own devices, it disconnects again.

The second problem is that I cannot get the server to shut down on a schedule. I've edited both user and root instances of crontab, but however I phrase the command, it's ignored. Can you suggest what to do?

—Charles S Currier

THE DOCTOR RESPONDS:
The answer to the first of Charles' problems was buried in the system logs. We directed him to the Logs section of cockpit, where he immediately saw a series of warnings that containers were closing and going to sleep after a period of inactivity. By widening the filter to show events with a priority of 'Info and above', Charles was able to trace the precise point at which the containers started to shut themselves down with the following message:

```
pam_unix(cron:session): session closed for user Charles
```

This confirmed that Charles hadn't set his user account to 'linger', which ensures that rootless Podman containers continue to run in the background even when the user has logged out or after the server has been left idle. The fix is a single command:

```
sudo loginctl enable-linger
```

When it came to resolving Charles' other problem, the Doc found himself going around in circles trying to find the precise syntax required for scheduling a shutdown. The crucial bit of missing information was the exact path to the shutdown utility, which has to be included in the crontab script. Once we'd identified the path was /sbin as opposed to /usr/sbin, Charles' problem was solved. To schedule a shutdown for every day at 1am, then issue the following command:

```
sudo crontab -e
```

If necessary, press 1 to edit using nano, then add the following line:

```
0 1 * * * /sbin/shutdown -h now
```

Press X, followed by Y, to exit back to the Terminal. You should be notified that changes have been made with a 'crontab: installing new crontab' message.

Self-hosted VPN

After following your WireGuard VPN server feature in the June 2024 issue, I can now dial in securely to my home network. Now, I'd like to remove public access to some of my more sensitive services, like my password manager. What steps should I follow, and are there drawbacks? **—Gary L Robins**

THE DOCTOR RESPONDS: If you've been following our tutorials to hosting your own services, chances are they've been set up using Docker or Podman. It's also likely that you configured remote access with the help of Nginx Proxy Manager, in which case it's quite simple to make the switch.

Start by logging into your Nginx Proxy Manager setup and select Proxies. This gives you the local IP address (and port number) you'll need to access your services. It's also where you can flick the switch off to disable remote access from outside your VPN.

The drawbacks relate mainly to connecting locally over https, where you'll see warnings about untrusted certificates, which can be ignored. However, there may be other side effects. For example, Vaultwarden is configured to connect internally via the insecure http protocol (http://192.168.x.y:8080). This won't stop you connecting through a browser add-on or desktop or mobile app, but you can't access the web vault directly through your web browser.

The other consideration is that you'll only be able to log on remotely through devices that connect through your VPN. This might require you to leave the VPN permanently connected on those devices, which means all apps and services will be channeled through your home network. To counter this, you'll need to configure

↘ submit your questions to: doctor@maximumpc.com

the WireGuard client app on each of your devices accordingly—tap to expand your home connection, then tap the edit (pencil) icon, followed by 'All Applications' to set up include-only filters restricting the connection to specific apps only.

VirtualBox missing files

I've downloaded an update to VirtualBox, but when I come to install, I'm told about missing dependencies (Python Core and win32api). Rather than download and install them, the installer appears willing to proceed without them. Do I need these files, and if so, where do I get them from?

—Leslie Shuster

THE DOCTOR RESPONDS:
If you've skipped this step on older versions of VirtualBox with no ill-effects, then you can probably do the same here, but adding these components gives you more options, particularly when using VirtualBox on the command line.

To add them, download the latest version of Python (www.python.org/downloads), clicking the link for the latest stable version—3.12.3 at time of writing. Double-click the installer, checking both options ('Use admin privileges...' and 'Add python.exe to PATH') before clicking 'Install Now'. Once the installation is complete, simply click Close.

One final step: right-click the Start button and choose Command Prompt (Admin) or Terminal (Admin), then issue the following command:

```
py -m pip install pywin32
```

Once installation is complete, reboot your PC, and everything should be configured for VirtualBox.

Time-shifting tricks

I'd like to take a commentary track from one MKV file and add it to another, plus add a subtitle track I've downloaded from the internet. The problem is that neither audio nor subtitles sync up correctly. I basically need to trim eight seconds from the beginning of both to align them correctly with the video. What tools do I need and how do I go about it?

—Jared T Maxwell

THE DOCTOR RESPONDS:
Originally, we looked at trimming eight seconds from the beginning of both audio and subtitle tracks. You can do this using MKVToolNixGUI, which we featured in the October 2023 issue. Use the 'Splitting' section under the Output tab to split the extracted audio track into two, which lets you slice away the first eight seconds. You can achieve something similar with subtitles using Subtitle Edit (www.nikse.dk/subtitleedit/help) by importing the subtitle file and choosing 'Synchronization > Adjust all times (show earlier/later)' to bring the subtitles forward.

However, this assumes that no one is talking in the first five seconds on the commentary track. If they are, you must either lose some of the commentary or try a different approach: add eight seconds of video to the start. This is tricky, because the blank file must have the same video and audio tracks as your main file.

To do this, use the ffmpeg command-line tool, which is included with apps like Handbrake (if it's missing, you can download the binaries from https://ffmpeg.org/download.html). After ffmpeg adds the extra seconds, you can use MKVToolNixGUI's multiplexer to combine it with your commentary and subtitle tracks.

To ensure the blank file's video and audio tracks match those in your main file, open the file in VLC Media Player and choose 'Tools > Codec Information'. Make a note of 'Video resolution' and 'Frame rate' (round this latter number to the nearest whole number) under Stream 0, and the 'Codec type', 'Channels', and 'Sample rate' under Stream 1 for the audio track. Once noted, right-click inside the folder containing your main MKV file, and choose 'Open in Terminal' or 'Open in Command Prompt'.

Now, enter the following command, adapting the 'color' filter to match your video resolution (s=1920x1080), frame rate (r=24) and duration (d=8):

```
ffmpeg -f lavfi -i color=c=black:s=1920x1080:r=24:d=8 black.mkv
```

Next, add an audio track that matches the one in your main file. Adapt the 'anullsrc' to your audio track's channel layout (such as c=stereo or c=5.1) and sample rate (r=48000), plus change -c:a aac to -c:a ac3 if necessary:

```
ffmpeg -i black.mkv -f lavfi -i anullsrc=r=48000:cl=stereo -c:v copy -c:a aac -shortest black-with-audio.mkv
```

Open your text editor and insert these two lines:

```
file 'black-with-audio.mkv'
file 'main.mkv'
```

Change main.mkv to your main MKV file's name, then save the file as 'input.txt' into the same folder as the two named files.

Now, enter the following command to stitch the two files together into a single file called output.mkv:

```
ffmpeg -f concat -i input.txt -c copy output.mkv
```

Double-click the output.mkv file to confirm there's eight seconds of black and silence at the start before the main file's video and audio feeds begin. Use MKVToolNixGUI to add audio and subtitle tracks from your other file to output.mkv.

Reusing OEM licenses

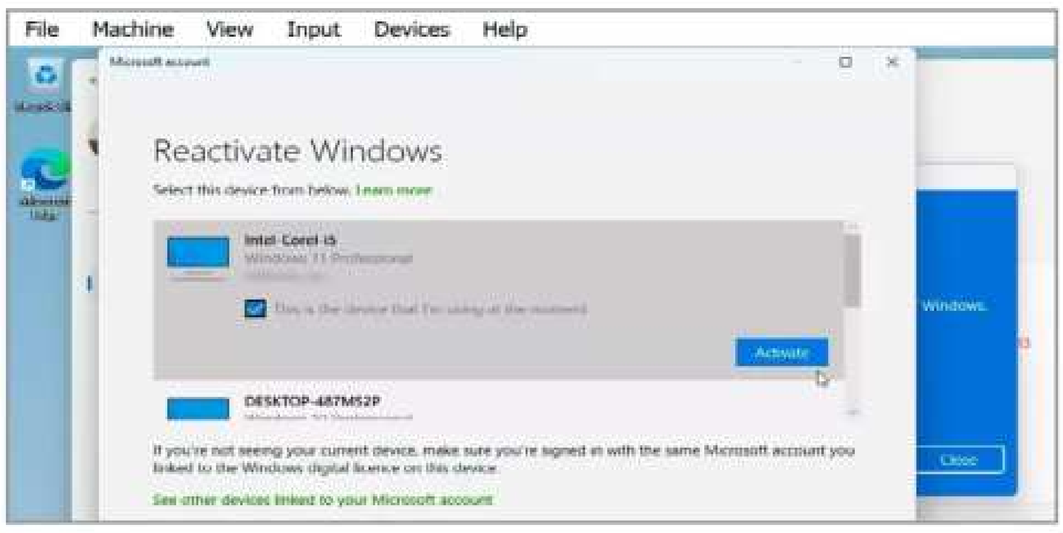
I'm looking at a Windows 11 OEM license to run on a virtual machine, as it's cheaper than a regular one. I've heard it's possible to reuse this license on another virtual machine—is that true?

—John Matheson

THE DOCTOR RESPONDS:
Yes, as long as that virtual machine is running on the same PC. Because the underlying hardware is the same, you can transfer your license from one VM to another. Log into the VM using a Microsoft account, so the license can be registered digitally (go to Settings > System > Activation and expand 'Activation state').

Transferring the license is done by skipping the prompt to enter the product key when you're installing Windows. Once installed, go to Settings > System > Activation, and click the Troubleshoot button. When the 'Troubleshooting has completed' dialog appears, click 'I recently changed hardware on this device'.

If prompted, sign into your Microsoft account. A window will appear listing your registered devices. Identify your old VM, check 'This is the device that I'm using at the moment', and click Activate to transfer the license across.



You can transfer OEM licenses between virtual machines.

The Best Sub-$1,000 Gaming PC pushing the envelope on value

With Ryzen 9000 right around the corner, is now the perfect time to buy? Zak Storey finds out

LET'S FACE IT, PCs are too expensive. Over the last ten years, graphics card prices have soared ever upward. Regardless of whether you support team green or team red, the trend has been the same. CPUs likewise have ballooned in price, and building an entry-level gaming PC for sub-$400 is a thing of the past.

That's a sad fact, but it's true. At launch, the humble Nvidia GeForce GTX 780 cost just $600. 10 years later, the RTX 4080 is now double that to $1,200. No matter how you split it, that cost increase tumbles down the range as well. Heck, even the 16GB 4060 Ti landed at $499. That's half the price of our entire build here for what should be a mid-range card.

After much discussion in the *Maximum PC* office, it got us thinking. With college and the next semester right around the corner, if you wanted to invest in a decent gaming PC, ready to while away the tiny amount of time that you've got spare on gaming instead of studying, what exactly could you get for under $1,000?

We've given ourselves some caveats to this build challenge. You could easily produce a super budget rig and save money by using 16GB of RAM, 500GB of hard drive storage, an Intel GPU, and/or second-hand or older components. But $1,000 feels like a good sweet spot.

So then, first criterion, 32GB of DRAM minimum. Second, the GPU must be AMD or Nvidia. Third, 1TB of modern-day PCIe storage is a must. Finally, it needs to look good, and have enough future-proofing to handle upgrades later down the line. This should give us an epic PC that not only keeps up with its far pricier counterparts, but also gives it enough legs to get some serious hardware upgrades in the future, too.

BENCHMARKS

Part		Price
CPU	AMD Ryzen 5 7600	$185
Mobo	Asus Prime X670-P ATX AM5 Motherboard	$144
RAM	32GB (2x16GB) Lexar Thor OC DDR5 @ 6000 C32	$100
SSD	1TB Adata Legend 960 Max	$90
GPU	Acer Predator BiFrost OC Radeon RX 7600 8GB	$260
Case	Phanteks XT View ATX Mid Tower	$80
PSU	1000W NZXT C1000 2022 80+ Gold	$140
Total		$999

PRICES CORRECT AT THE TIME OF PUBLISHING

https://content.jwplatform.com/videos/4XtwSWiq-u2lN49He.mp4
Please type this URL into your browser if the link is broken

999 dollars on the wall

CPU

AMD RYZEN 5 7600

WWW.AMD.COM

Don't be fooled by its understated demeanor compared to its X sibling; the Ryzen 5 7600 is no slouch when it comes to CPU prowess. Both chips feature the same core counts, the same cache, the same CCD setup, and more impressively, similar clock speeds as well, at least at stock.

For your money, you get six cores, with multithreading for 12 threads, along with a base clock of 3.8 GHz and a turbo of 5.1 GHz. There's all the hardware support you'd expect for a Ryzen 7000 series chip, including PCIe 5.0 and DDR5, but it's the differences in clock speed that blew us away. The Ryzen 5 7600X is only 200 MHz faster on its boost clock, and although it has 900 MHz on the base clock, given how workloads function on Windows resource allocation, we're not too bothered by that fact.

That said, one thing you do get with the 7600 that you don't with the 7600X (apart from a lower 65W vs 105W TDP) is an included cooler. Yep, the 7600 comes as standard with the Wraith Stealth CPU cooler. It's easy to install, and you don't have to worry about bringing your own or buying a second-hand Wraith off eBay or elsewhere. ***• $185***

MOBO

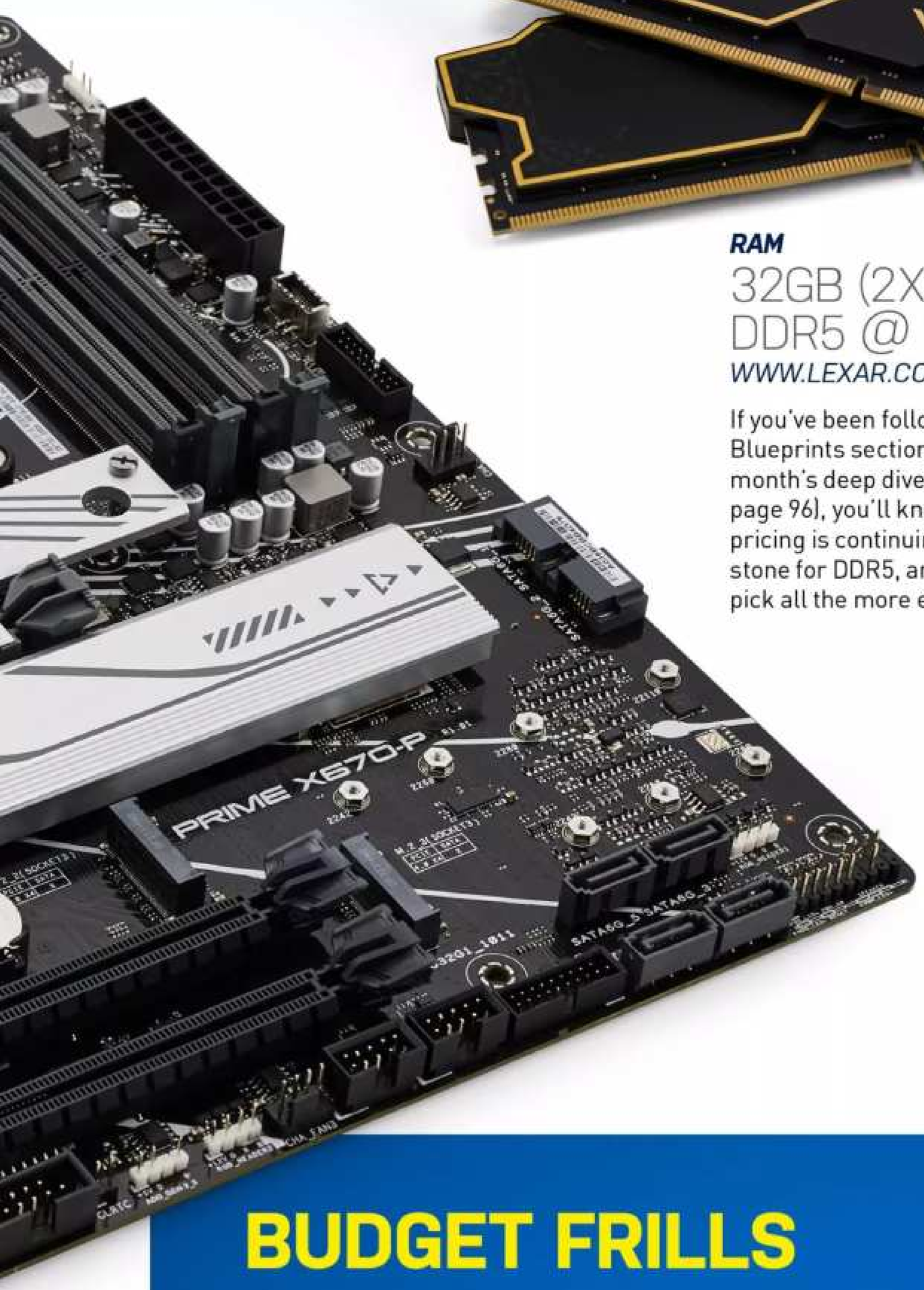
ASUS PRIME X670-P

WWW.ASUS.COM

Asus's Prime series of motherboards have been a staple for those looking to save cash on their system without stripping back to the bare bones. The X670-P likewise encapsulates that ethos, with a crisp black PCB and beautiful aluminum heatsinks. It not only looks the part, it also comes with some serious clout to back it up.

As standard, it includes that AM5 socket (which AMD has confirmed will be supported officially up to 2027), and features a 12+2 power stage design and support for PCIe 5.0 M.2 drives, DDR5 support up to 192GB/7600 MHz, and a serious amount of I/O.

Speaking of, there are seven USB 3.2 Type As, one USB Type C, two USB 2.0 ports, an HDMI port, DisplayPort, three audio outs, a PS/2 combi port, and, more impressively, a 2.5G Ethernet port. On top of that, the motherboard can house up to three M.2 drives, two in PCIe 4.0, and one at PCIe 5.0. The downside? No official PCIe 5.0 support for the top PCIe slot for GPUs, although that's not exactly the end of the world. *• $144*



STEP-BY-STEP GUIDE
PG. 22

RAM

32GB (2X16GB) LEXAR THOR OC DDR5 @ 6000 C32

WWW.LEXAR.COM

If you've been following our Blueprints section (you can find this month's deep dive into pricing on page 96), you'll know that memory pricing is continuing to fall like a stone for DDR5, and that's made this pick all the more easy to make.

For RAM, we've gone with Lexar's Thor OC 32GB kit @ 6000 MT/s. That's impressive enough, but couple that with a super-low CAS latency of 32, and it brings this kit down to an impressive 10.667 ns real-world latency. Not too shabby. Right now, though, 6000 MT/s is perfect for Ryzen's 7000 series, and Lexar's kit comes in super clutch at this price point.

Its gold and black heatsink design can be a touch intense, but honestly, it looks far better in person than in photos, and the performance is top-notch, too. Still, there are a number of kits out there at this price point, so if you want to swap this out for something a little more stylish, then it shouldn't be too challenging. ***• $100***

BUDGET FRILLS

Let's be honest, this chassis is fairly epic when it comes to the looks department, but if you want to amp up its appearance on the cheap, there are a few ways you can do that.

Added accessories in the PC world don't have to cost an arm and a leg, that chassis supports a ton of cooling, adding three 4.7-inch fans to the PSU shroud would work a treat, Phantek's M25-120 fans would be a great pick there, without breaking the bank, and add a little extra illumination in there.

Likewise, a good fan controller can make the world of difference. Corsair's Commander Core is a good pick, but pricier than we'd like. Thermalright sells a super cheap four-channel fan controller for just $7.59, or you could go with Arctic's Case Fan Hub—a 10-fold PWM fan controller with SATA power—for just $10 on Amazon. Just bear in mind that as this will plug directly into a single header, you won't be able to control individual fans—just set them to one speed.

SSD

1TB ADATA LEGEND 960 MAX

WWW.ADATA.COM

How much is enough storage? 250GB? 500GB? 1TB? The honest answer is simple: not 500GB. That's a fact. If you're looking at housing anything more than an OS and a few games on a single drive, then you're going to need way more than that. Interestingly, the most cost-effective way of doing that is through a singular PCIe 4.0 SSD.

Our drive of choice here is the Adata Legend 960 Max at 1TB of capacity. That's a solid chunk that should give you more than enough for a healthy gaming PC with plenty of cloud saves. That said, this might be one of the few areas where you can save a coin or two. Dropping down on the spec a touch, the Legend 960 Max is a fairly effective drive for the price, in the middle of the pack for PCIe 4.0, but in reality, real-world performance drops by moving to a cheaper drive won't impact you that severely. Something like WD's Blue SN580 or Lexar's NM790 would also fit the bill perfectly. ***• $90***

STEP-BY-STEP GUIDE
PG. 22

PSU

1000W NZXT C1000 2022 80+ GOLD

WWW.NZXT.COM

It's a classic, and we've used it before, and that's why it's back because to be quite frank, this is one solid power supply unit for the money. Two years on, it's still selling like hotcakes.

Gold-rated, modular, 1000W, and a super-quiet design give it a definitive edge over the competition. Combine that with a very quiet fan (plus the option to enable or disable 0rpm fan mode), and this is a default pick for our build.

If you want to save some money, and don't fancy upgrading, then downgrading the spec to 750 or 850W would save you $20-$30, and still leave you with an ample power supply. We're expecting this to draw around 340W at full tilt, so bear that in mind, and give yourself 20 percent more than that at least, and you'll be golden. *• $140*

GPU

ACER PREDATOR BIFROST OC RADEON RX 7600 8GB

WWW.ACER.COM

Acer may be relatively new to the graphics card game, but its got plenty of clout when it comes to design experience. Pairing its tech with the latest AMD Radeon RX 7600 has led to a quiet and efficient GPU that's perfect for 1080p gaming without breaking the bank.

It doesn't have reems of RGB, or an oversized cooler, but it delivers on performance. The stock RX 7600 8GB should have a max boost clock of around 2,655 MHz. In our testing, the Predator manages to slam that all the way up to 2,966 MHz under load. That's a 12 percent performance boost on stock cards for less cost. Not only is the Acer Predator often cooler than the majority of cards we've tested, it clocks higher too, albeit at the cost of higher power draw.

Still, at 1080p Ultra, 90 fps on average is more than a given, with 60 fps regularly seen at 1440p, even with that limited 8GB VRAM capacity. *• $260*

CASE

PHANTEKS XT VIEW ATX MID TOWER

WWW.PHANTEKS.COM

Meet possibly the best budget case of all time. We reviewed its more stock-looking XT cousin last issue, and enjoyed that too, but this takes that dial and cranks it all the way up over 9,000. Okay, it can't quite go Super Saiyan, but the XT View comes complete with an expansive internal layout, awesome cooling potential, some seriously slick RGB fans as standard, an RGB light bar, RGB controller, support for up to 14.2-inch rads, nine fans and glass panels as well. It's even got a mesh PSU floor area as well for better under-carriage airflow. Seriously, a budget case has no right being this good.

Here's the kicker, though: it's $80. That's insanely cheap for what you're getting. Couple that with the fact that it's available in black or white as well, and honestly, there aren't enough words for us to just describe how phenomenally good value this thing is. Expect this in Blueprints soon—that's a fact.***• $80***

Build Mastery

LENGTH OF TIME: One hour
DIFFICULTY: Easy

COMPARED TO LAST ISSUE'S BUILD, this month's was a cake-walk. It's nice to pivot from one complex system, with an incredibly intricate process required for even basic cable management, to a chassis that allows you to be super flexible in how you operate within it. In fact, arguably both builds are good builds—they're just for different people, and that's okay. They both look fantastic: one with a minimalist heart, and the other with ponderous thought and decision by every process.

That is to say that the XT View is phenomenally easy to build in. This build in general, given its lack of AIO or liquid-cooling of any capacity, effectively makes it a very easy build. You strip the case as much as necessary (although to be quite frank, you could leave the bulk of it in there, bar the obvious side panels). You prep your motherboard, installing CPU, SSD, and RAM. You insert that into the machine. Pop in a power supply, route some cables, install your GPU, and you're done. The beauty of the View is that unlike other cases, the RGB fans are pre-installed, they look good, and perform well. You don't need to replace them, add your own, or cable-manage anything, because it's already done.

That cuts out a large amount of time in your build process, and makes the whole procedure incredibly rapid. We've always argued that building PCs is like very expensive adult Lego, but if we're honest, there's still always a level of complexity to it. In this case, the opposite is true; this might be the easiest build we've ever done. Let's dive in and see why.

Whip the panels off

Like every *Maximum PC* build, first and foremost (after, of course, hunting around for all of our components in the store-room), we need to take those panels off, and everything that might cause issues later down the line.

It's an easy process: the tempered glass side panel is held on with two thumb screws at the rear of the case. Unscrew them, then slide the glass back out of the chassis. It's secured with notches built into the case itself. Then place that into the cardboard box the case came in. As for the rear panel, it's a similar procedure: unscrew two thumb screws and slide out. There's no removable top panel, just a magnetic dust filter, which you can put to one side for later. The front glass panel, however, is held in place with screws. You can theoretically remove this—however, unless you're very accident-prone, we'd advise against it, as you're more likely to damage that in the process, and it is providing some impeccable structural rigidity while you build in the case.

Also, as you're not actually installing any cooling directly in the front, it's unlikely that you'll be interacting near there anyway, certainly not if you're keeping those stock fans installed.

On the rear of the case, now you've removed the side panel, you'll spot an SSD tray mounted to the back of the motherboard tray. That slots into position, held in place with a single thumbscrew on the bottom. Remove that if you're not using any 2.5-inch drives, or need access to the rear of your motherboard.

Lastly, you've got the 3.5-inch hard drive caddy located at the bottom front of the case. A single thumb screw holds this in place, and similarly to the other panels, it's just a case of loosening that and sliding it out. You'll also find your accessories box, complete with all the screws you'll need, plus a whole heap of cable ties. Once all that's done, you should be left with a case that looks a little like this **(Step 1)**.

Going off-piste

We've decided to go a little leftfield, and not follow our typical build order here. The primary reason for this is that there's not a lot of reason to. It's hard even to justify testing your hardware outside of a case before installing it all in the machine; the build process is that simple.

We're going a little old-school and directly installing the motherboard first, with nothing on it. Radical, right? Well, because all we have is a stock cooler that mounts to the front, and an M.2 SSD and DRAM, there's not a lot for us to do.

Brazenly, we grabbed the motherboard and, with the case now resting carefully on its side, placed it into the machine, and began to secure it in position with the included screws. This, however, after installing our sixth screw, was when we noticed a problem. **(Step 2)** And that problem was that actually the motherboard, for the first time in what feels like an eternity, doesn't have an

01

02

03

STEP-BY-STEP GUIDE

04

05

integrated rear I/O shield. No, you have to install this by hand.

It looks like Asus did cut one corner, keeping the price of this X670 mobo so low, and that was with that rear I/O. Fish around in the motherboard box, and you'll find the bracket, then carefully line it up with the rear I/O and push it into position. After that, it's simply a case of putting the motherboard into the chassis, and carefully lining it up with the rear I/O plate and the stand-offs on the case itself. Make sure when you install your I/O shield that you pay attention to which orientation is correct. The last thing you want is to install it upside down **(Step 3)**.

CPU orientation 101

Once your motherboard's in, it's time to move onto the danger square (that's what we're calling CPUs now). This is still theoretically the most dangerous element of the build, but super-easy to do right.

To install your AMD CPU (or Intel as well, for that matter), push the retention arm down and move it out the way to the right, and it'll pop up. At this point, you can grab the CPU bracket and lift it up, revealing the shiny socket underneath, complete with all of its pins **(Step 4)**. Don't touch the pins—if you bend them even slightly, they won't correctly touch the contacts on the chip, and you'll likely end up with a dead motherboard. You can bend them back if you're extra careful by using a credit card or tweezers, but it's such delicate work, you can easily damage others, or snap off a pin entirely. Once that's done, manufacturers (retailers and AIB partners alike) consider that a user error, rather than a warranty thing, so you'll be left out of pocket, and with no motherboard to show for it.

With the CPU bracket up, take your CPU and identify the triangle on the top-left corner of the chip. If you look at the socket, you'll see a little triangle etched on the top left of the socket, just next to the LOTES engraving. This is to help you orient the chip. Line it up with the socket, and carefully place it into position until it fits snugly in the socket, give it a slight wiggle with your index finger to make sure it's secure, then push the CPU bracket back down, and lower the retention arm into place. When you've re-secured the arm, the little black cover will pop off, and you're good to go **(Step 5)**.

Motherboard management

With our CPU in, it's time to install the remainder of our components. First up is the CPU cooler. AMD should have pre-applied some thermal paste to the bottom of this. With your chassis on its side, locate the four screws holding the CPU cooler retention brackets in place. These are above and below your CPU socket. Remove the screws holding them in place. These are attached to the motherboard's backplate. The one brilliant element about AMD motherboards, since AM4 and the launch of Ryzen, is that every motherboard has its own dedicated full-size backplate, so you don't have to worry about any flimsy aftermarket solutions that cooler manufacturers might provide.

Nonetheless, remove the two brackets, and you'll be left with four mounting points. Then, take your Wraith Stealth cooler, and position it over the top. Push it down slightly, and in a diagonal pattern, secure each screw into position, tightening slightly as you go, until all four threads are bound. We like to ensure our AMD logo is on the left-hand side of the motherboard so everything lines up **(Step 6)**. After that, run the CPU cooler fan cable to the CPU fan header on the motherboard. This is usually situated to the top right of the VRM heatsink, at the top of the motherboard.

With all that wrapped up, it's time to move on to memory. Regardless of whether you're installing DDR5, or DDR4, or even DDR3 and 2, inserting DRAM has been pretty much the same for years. Locate the two slots you're going to be installing your memory into (usually these are alternating slots), lift up the latch on either end, then carefully place your memory sticks into position, making sure to align the notch on the stick with the notch on the DIMM slot itself. Push that down equally and firmly, and it'll click into position. Repeat the process, and you'll be good to go **(Step 7)**.

Next up is our M.2 SSD, that powerful Adata Legend M.2 drive. Adata provides a heatsink for this as standard, but you can assemble it yourself, which is a really nice touch. It gives you the option to add your own later if the AIB motherboard one isn't up to scratch, or if you move it into another rig without one, you've always got that dedicated one as a backup. Regardless, you'll be able to spot the M.2 heatsink below the CPU on your motherboard. You always want to use the top-most PCIe slot, as this will likely be the highest-spec slot, as it's closest to the CPU, and helps reduce latency, as it doesn't go through a controller or chipset **(Step 8)**.

To remove ours, we loosened the two Phillips head screws, then lifted off the heatsink. We removed the plastic film from the thermal pad underneath, and lay it aside. Then, carefully we slid the M.2 drive into position, paying attention to the notch in the drive and slot. Push it down all the way until it makes contact with

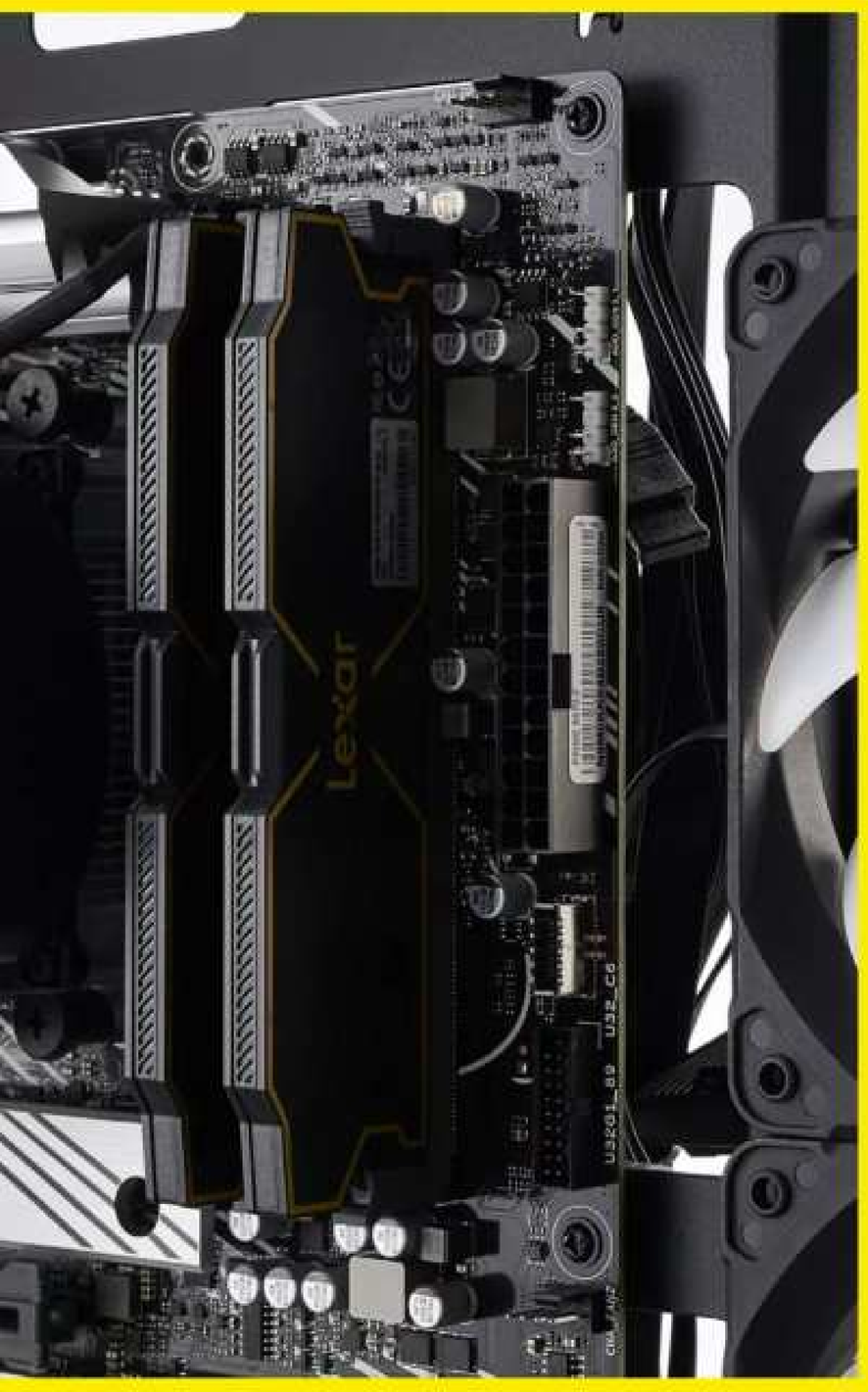
06

07

08

09

10



STEP-BY-STEP GUIDE

Asus's Q-latch, then rotate it clockwise to lock it in position. Then, it's simply a case of reattaching the heatsink you removed earlier **(Step 9)**.

Sleek cabling

We don't often install all of the USB cables from our cases into the motherboard, as usually they're quite chunky and inflexible. Not so with the XT View—these are both ribboned, super slick, and bendy, making installation a breeze. For those who haven't dabbled in the world of motherboard USB headers, the USB C header is reversible, while USB 3.0 Type A isn't. You'll have to identify the notch on that one, then push into position **(Step 10)**.

These are notoriously difficult to get out if you ever need to remove a motherboard, so we recommend wiggling them to give you extra leverage. We've also installed the front power button and LEDs. Phanteks is using a singular block for that, similar to NZXT and a number of case manufacturers now, which is great to see. Find your front power headers on your motherboard marked JFP, and push your front header cable in on the left-hand side. We've even gone so far as to install the HD audio passthrough. We don't suggest using it—quality is often poor. However, it can be good in a pinch.

At this point, we began to work on the cabling in the back, and oh boy is it a mess. This is the hardest part of the build, identifying where all the cables need to go and how you can tidy it up. The RGB controller is pretty much all plumbed in already—it just requires SATA power, and that's it. You can, however, connect it to your motherboard instead, and let the mobo control your RGB. It's also possible to expand your RGB componentry here, too. For the time being, we're going to leave this mess **(Step 11)** as it is while we work on the power supply.

Speaking of, grab your trusty PSU and pre-install the cables you're going to need. As we've got so much space, we highly recommend that if you do plan on adding better hardware in the future, you actually also attach any additional cables you think you might need, such as extra PCIe power, or EPS power specifically, then tucking that out of the way **(Step 12)**.

With the cables plugged in, you can then slide the PSU into the case. You have two options here: install the PSU with the fan facing downward, acting as an isolated unit, and keeping the temperature of the PSU well within parameters, or rotate the unit the other way, so the fan draws air in from the chassis, and exhausts it out the rear. This gives you an additional exhaust fan, but may increase the heat inside of your PSU. It's likely fine for this build, and why we've chosen that orientation (given the limited heat and power generated), but it's worth bearing in mind.

With the PSU now slid in the case (you can see the small cutout Phanteks has included on the bottom of the case in **Step 13**), you'll then need to secure it with the slightly larger screws Phanteks included in the case accessories box.

The finishing touches

With the PSU in, we need to install the remaining cables. The 24-pin can go up through the top-most side grommet, and pushed into position (don't panic about which orientation to plug this in—it can only be installed one way. A quick way to check is to spot the latch on the 24-pin and the raised 'lip' bump on the socket).

Then, our CPU power can go through the top-most cable hole (in this case, the Z670-P requires an 8-pin EPS and a 4-pin, split one of the two EPS pins in half, as they're designed to come apart for this).

With that out of the way, we've also gone ahead and ran the PCIe power cable through the cable hole in the middle of the PSU cover in preparation for our GPU, and finally, installed the fan cables, too. There's two to worry about (the two on the right are daisy-chained)—we've run the twin fans to the chassis fan header, and the rear fan to the CPU optional fan header at the top of the board **(Step 14)**.

With our build now mostly complete, it's the perfect time to do a little cable management in the rear. Remember, you don't need to do anything too fancy here. We're utilizing the bulk of the cables heading down and the 24-pin, plus a couple of tie-off points on the back of the case to do that. Simply grab as many cables as you can and bunch them together, then tie them up with a cable tie using one of the mounting points on the case, or a sturdier cable (such as the 24-pin one). Then snip off the ends of the cable ties, making sure to give yourself a little wiggle room, and you're done **(Step 15)**.

Lastly, we have our GPU. Again, with the case lying down on its side, grab your GPU and identify how many PCIe slot covers you'll need to remove. In our case, that's going to be two. Look at your top-most PCIe slot on the motherboard, and remove the two downwards-facing slots. Then, carefully slide your graphics card into the slot until it clicks into position. With that complete, you can then secure your GPU using the screws from those PCIe slot covers from earlier. Once that's finished, pop the case back onto its feet, install that PCIe power we left hanging earlier, and you're all done **(Step 16)**.

STEP-BY-STEP GUIDE

Minimalism is the Ultimate Sophistication

A BUILD DOESN'T need to be complicated to be brilliant. It doesn't need to be $5,000, liquid-cooled to the hilt, or modded to the nines to really be exceptional. Sometimes, a build just needs to *be*. Our most memorable systems aren't necessarily the fanciest, or the most complex, but the ones that mean the most to us; ones that we got through hard work, or ones that were there during a major life moment. Yes, Dream Machines are nice, and systems like that are aspirational and fantastic things to see, but do they hold the same weight as something like this? A PC built with purpose? That's elegant and simple, yet powerful and impressively good value? We think not.

That's exactly what this is. To be blunt, building in the XT View was awesome. It was super quick and insanely easy. The most complicated element of the whole affair was figuring out that we'd accidentally plugged the RGB components together incorrectly, and then unplugging one cable to make them work. That was it. Installing the motherboard was a doddle (once we got past that I/O shield), the GPU, even the cable management was super smooth. In fact there's very little we'd change, particularly at this price point.

The bulk of any recommendations along those lines, we'll cover in the following pages, but from an aesthetic standpoint there's very little to say. You could go with a few more fans—a $40 set of M25s goes a long way these days, and they're the fans you see on display in the case as standard, looking stellar. Chucking a triple pack of those in the roof alone would make this machine pop even more.

Additionally, one thing that is mildly annoying is the lack of intake air. As standard, those side 4.7-inches are configured to act as an exhaust, meaning the case doesn't have an intake. In reality and for the best performance, you'd be far better off swapping the orientation on those or installing three 4.7-inches in the floor as well. But honestly, that's it, a minor foible in an otherwise perfect build.

1 These side vent fans may look pretty, but really, they need to be oriented the other way around to act as intakes if you're not running any additional fans in this build.

2 It doesn't matter what graphics card you have; GPU sag is always going to be there in some form or another. You can get a small GPU holder for a very small amount of cash on Amazon to help alleviate this.

3 The bottom PSU shroud/cover area is actually perforated, giving it access to cool air, which is ideal if you want to install those three fans just above the PSU cover to act as intakes instead.

4 AMD's stock Wraith Stealth CPU cooler is more than enough for the Ryzen 5 7600, but if you want better performance, you might want to upgrade to an AIO and stick it in the roof.

BENCHMARKS

	ZERO-POINT	
Cinebench R23 Single-Core (Index)	2,031	1,802 (-11%)
Cinebench R23 Multi-Core (Index)	14,545	13,818 (-5%)
CrystalDisk QD32 Sequential Read (MB/s)	6,987	6,993 (0%)
CrystalDisk QD32 Sequential Write (MB/s)	6,755	6,591 (-2.4%)
3DMark Fire Strike Ultra (Index)	11,135	6,782 (-39%)
Cyberpunk 2077 (fps)	29	16 (-44%)
Cyberpunk 2077 RTX (fps)	20	3 (-85%)
Metro Exodus (fps)	46	22 (-52%)
Metro Exodus RTX (fps)	34	15 (-55%)
Total War: Three Kingdoms (fps)	48	21 (-56%)
Core Price ($)	$1,368	$779 (-43%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of the Hyte Y40 build from our March 2024 issue. Featuring an AMD Ryzen 5 7600X, Nvidia GeForce RTX 4070 Super, Gigabyte X670 Elite AC motherboard, 32GB of Corsair Vengeance DDR5 @ 5600 MT/s, and a 2TB Crucial T500 PCIe 4.0 M.2 SSD. All games tested at 4K "Ultra" graphics presets with DLSS and V-sync turned off and XMP for RAM speed turned on. No manual CPU overclocking. "Core Price" refers to the key components generating performance (CPU, GPU, Mobo, OS SSD, RAM), not accessories.

$999 Performance

WE ALWAYS KNEW a $1,000 build was going to be a little rough around the edges, so let's preface this benchmark chat with a little caveat. We are very much comparing this build to a system that costs $589 more on the core componentry alone. That doesn't sound like much, but if you took this build and poured all that extra cash into the GPU, you'd end up with a rig with an RTX 4070 Ti Super in it or better, and we're comparing it to an RTX 4070 Super at that. Additionally, all of our testing, for better or worse, is performed at 4K to really test the limits of our GPU in question, so when you see 3 fps in *Cyberpunk* with ray tracing enabled, that's definitely not a fair comparison.

The fact is, this system performs quite admirably across the board, CPU performance was solid, particularly in the multi-core realm, and single-core was no slouch either. SSD sequential throughput was also decent, particularly for an OS drive on its own, and likewise, those synthetic Fire Strike numbers definitely helped pick things up as well.

Now, onto gaming. As you can see, we don't have a single benchmark that went above 30 fps, well below a good gaming experience. However, this is at 4K, and a minor limitation of our system-building shenanigans. To give better clarity on how the RX 7600 performs, at 1080p we were getting frame rates of around 122 for *Total War: Warhammer III*, 105 for *Borderlands*, 115 for *Horizon Zero Dawn*, and 11 for *Cyberpunk*, although admittedly that was still with ray tracing on and FSR off.

Interestingly, if you do take the RX 7600 out in *Cyberpunk* for a spin, and disable ray tracing, but enable FSR at 4K, frame rates actually sit at a balmy 44 fps on average, up from 21 with no ray tracing and no FSR. That's not bad at all really. That alone goes to show how much of an impact FSR and techniques like it can have at improving frame rate performance.

Without a doubt, then, this machine is an absolute killer when it comes to 1080p gaming. Average frame rates sit comfortably in the 90-100 range, and at 4K, although it gets a bit of a bloody nose, it can perform well with FSR behind it and ray tracing disabled. But then, here's the thing: at its core it's a $779 machine, sub $1,000 with everything included, and when you're left with a beautiful rig, that dominates at 1080p, and is as versatile as it is awesome—well, you've got to be happy with that result.

Upgrade Paths

Lexar's NM790 is a fantastic budget PCIe 4.0 drive, particularly in its 1TB capacity.

THIS MONTH'S BUILD has arguably been all about upgrade paths, and saving cash wherever possible to drop that overall price below $1,000. The thing with our builds is that we often look at them as a one-off. The reality, however, is vastly different. Even our very own systems here at the *Maximum PC* labs go through iteration after iteration and change after change as hardware becomes available or budgets accessible, and it's no different out there in the real world.

Our $1,000 rig is a fantastic starting point, and if you're heading into a new semester, or looking for a clean complete rebuild after six or seven years, it's a solid choice. But later down the line, when more funds become available, what's the best way to upgrade this rig?

There are a number of avenues you can go down, all dependent on how much your budget's going to be. We're going to list a few of our favorite recommendations for how to spruce up this build, depending on how much cash you have to hand.

Less than $250

To get the most out of your upgrades here, you're going to be thinking less about the core performance and more about accentuating what you have. We're talking cooling and storage here.

Having 1TB of PCIe storage is certainly a solid start, but that's definitely an area we can expand and gain some significant convenience. Additionally, amping up the cooling is a solid step up as well. Adding to the complement of fans we have, with a few extra, or improving our CPU cooling solution and adding a slight overclock to the Ryzen 5 7600 would seriously improve our processor's performance, while simultaneously giving the overall look of the build a bit more pep in its step.

Part		Price
CPU Cooler	be quiet! Pure Loop 2 360mm AIO	$105
SSD	1TB Lexar NM790 M.2 PCIe 4.0 SSD	$80
Fans	2x Phanteks M25-120 PWM D-RGB Triple Packs	$20
Total		$245

We're a big fan of Lexar's NM790 series of PCIe 4.0 SSDs, even with its somewhat unproven 232-layer TLC NAND flash at its heart. Regardless, performance is top-notch, and chucking an extra 1TB of storage in this rig will ensure all your games are well handled.

We've gone ahead and paired that with a 14.2-inch AIO from be quiet! in the form of the Pure Loop 2. There's no fanciful wizardry or outrageous LED displays, but it does come in at $105 and with some potent fans (that we're about to replace). Once again, because it's a 14.2-inch AIO, we're thinking of the future, and any chip upgrades we might fancy down the line.

To tie it all together, we've also picked up another two sets of Phanteks M25 4.7-inch fans, one set to stick on top of that PSU shroud and draw cool air up straight into the chassis, helping to keep the GPU and CPU chilled (which should give us more overclocking leverage for both), and the other to replace those stock black fans in the AIO. Technically, you don't need to do that last part, but it will tie the theme of the system together if you do.

$250 - $500

The $250 to $500 price area is a bit of a gray area when it comes to PC hardware upgrades right now, and it depends entirely on the weaknesses of the system in question as to how you proceed. Similarly to before, leaning on that cooling and storage could be a solid angle, but then the question at that point is 'How do you spend the extra cash?' as any serious/major component upgrade on the hardware you already have will be a five to 10 percent performance boost at best.

At this point, you could go down the peripherals route, opting to boost your gaming mice and keyboard in the process (NZXT's Function line of keyboards is a fantastic choice for a budget mid-range board with optical switches). Alternatively, you could change that motherboard out entirely for something a bit more potent with better connectivity.

All that said, we'd recommend going back to square one, and instead of upping the cooling, you push all of that cash into your graphics card and a touch more storage, leaving the cooling as it is in the stock build. This should lead to far greater performance, although the system might still look a little rough around the edges. But then, function over form, right?

WHEN IS THE BEST TIME TO UPGRADE?

The hard truth is that upgrading your PC is going to be great for around 9-12 months, then new hardware's going to launch that'll dwarf the performance. You can spend thousands on a new gaming PC, but when those Supers launch in six months time, and your GPU price falls by $400, it's going to leave a sour taste in your mouth.

That said, aside from some philosophical angles about appreciating what you have, and that the performance you have that was the best yesterday, is still darn awesome today after that RTX 5080 launch regardless, there are a few tips and tricks as to the 'when' to buy.

If you've got some cash set aside, and a solid PC puttering away in the background, then you want to be waiting for those holiday periods and special sales. Labor Day, Black Friday, New Year, Cyber Monday—the works. Across these periods, manufacturers will be slamming their prices as low as they can to shift stock that's sat in warehouses claiming valuable storage space, and boost margins for the end of the financial year.

Of course, you need to be wary of what's a deal. Tech journalists like ourselves and the good folk of Tom's Hardware, PC Gamer, and TechRadar do a fantastic job of collating lists of the best deals and sifting through the thousands of items that PRs and companies send. Additionally, you can use tools like PC Part Picker or CamelCamelCamel to check the average and lowest prices of these components to see if that Ryzen 5 7600X at its lowest ever price is actually its 'lowest' ever price, and make your move from there.

Phanteks' M25 fans are phenomenally good value at just $30 for a pack of three.

Part		Price
SSD	500GB MSI Spatium M450 M.2 PCIe 4.0 SSD	$40
GPU	Gigabyte Gaming OC Radeon RX 7700 XT 12GB	$400
Fans	2x Phanteks M25-120 PWM D-RGB Triple Packs	$60
Total		$500

We're actually doing something a little radical, and going with a slightly smaller PCIe 4.0 SSD, with the intention being able to move our OS onto the 500GB drive, and then house all of our secondary files, games, and programs on the Adata drive.

We're doing this so that it gives us a bit more wiggle room on the GPU here too, and instead of our RX 7600, we've opted for the 7700 XT 12GB instead. It punches far harder than the 7600 does—69 percent harder, in fact. At 1440p, you'll regularly see frame rates well above the 90 fps mark, versus the 7600's 58 or so, making it an easy pick. That extra VRAM makes it a serious contender at 4K as well, with the 7600 reporting just 20 fps on average there, and the 7700 XT equally leaning up at the 45-50 fps mark.

Similarly, we're taking advantage of those ridiculously cheap 4.7-inch RGB fans and improving the look of the entire system, as well as cooling.

At this price range, you can sneak in a smart GPU upgrade, plus some storage if you're careful.

The $1,000 mark

At $1,000, or akin to the entire system budget, you've got a lot more wiggle room to play with, and as a result, there are a few avenues you can go down dependent on some pretty unique variables. That said, our PSU, motherboard, case, and storage solution still have plenty of legs, so we can save some cash and expend it fairly comfortably elsewhere.

So then, what do we mean by that? Well, if it's within three months, and there's been no major chip launches or upgrades, your best bet is to spend the cash on your graphics card, ideally at a split of $800 on the GPU, then the rest on the SSD and some cooling.

There are a surprising number of good-value 14.2-inch AIOs out there if you deviate from the big names.

Part		Price
SSD	1TB Crucial T500 M.2 PCIe 4.0 SSD	$90
GPU	PNY Verto OC RTX 4070 Ti Super 16GB	$791
CPU Cooler	Cooler: Asus ROG Strix LC II - 360mm	$110
Total		$991

This should give you a pretty slick rig all around, and you'll be pushing 120 fps and beyond at 1440p and well above 70 fps at 4K with the RTX 4070 Ti Super at the helm, or something similar.

Combine that with a super-snappy PCIe 4.0 SSD in the form of Crucial's T500, and some expanded cooling (again with future-proofing in mind) thanks to the 14.2-inch AIO from Asus, and you're on to a winner. Similar to before, you could do with some additional intake fans, but that will take us over our budget.

On the flip side, if it's been a year or more, and there's a new generation of processors and graphics cards out there that revolutionize your gaming PC's performance (or any other task you might need to do), then at that point, it's better to pivot the other way, and look at spending $400 on your CPU, $500 on your GPU, and $100 on a suitable processor cooling solution. The last thing you want is to invest that $800 into a GPU, only for your aging CPU to become the bottleneck.

WHAT CAUSES BOTTLENECKS?

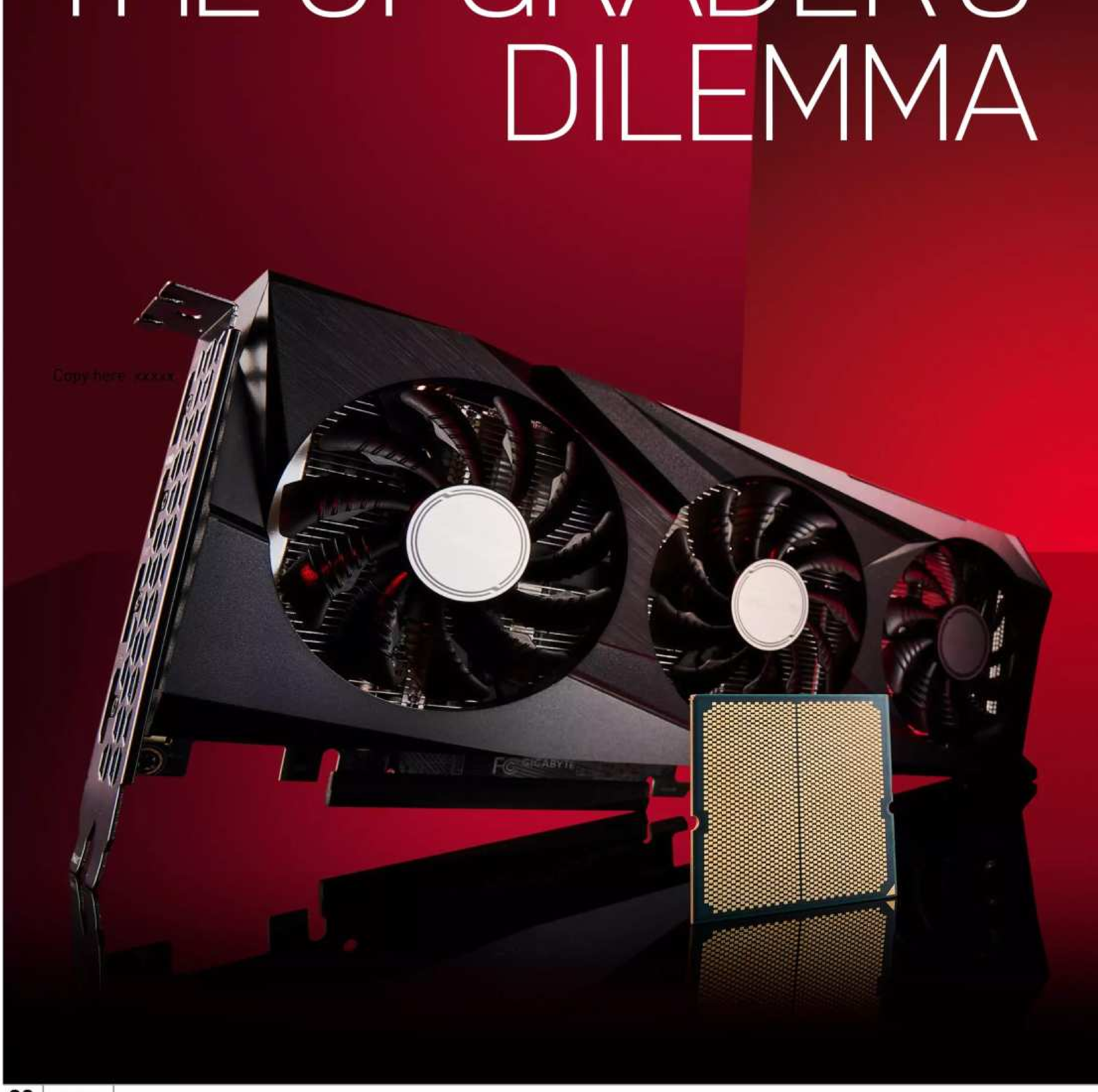
It's all about bandwidth. That's the long and the short of it. Let's take graphics cards as an example. You can have multiple bottlenecks with them, dependent on a variety of factors. The first and most obvious is the PCIe slot, namely, its overall available bandwidth. Each PCIe generation doubles the bandwidth capacity over the last, but equally so do the number of lanes. PCIe 5.0 x8 is the same as PCIe 4.0 x16, and so on. If you have a PCIe 5.0 graphics card that's saturating a x8 slot at 100 percent efficiency, then although installing it on a PCIe 4.0 x16 will be fine, chucking it in a PCIe 3.0 x16 should effectively half the number of operations that can occur over that interconnect, effectively halving your performance (although not necessarily halving frame-rate, but the amount of data being transferred between your GPU and your CPU).

Similarly, if your CPU's single-core performance isn't up to scratch, it may not be able to process the frames generated by your graphics card, and the inputs created by the game (via you) in a timely manner, leading to a reduction in frame-rates (you can spot this if your CPU load is constantly at 100 percent).

Similarly dependent on its configuration, a CPU may only support x8 PCIe lanes to the graphics slots, which as we mentioned, halves available bandwidth. Likewise, if you're installing a PCIe 5.0 SSD into a 4.0 slot, then yes, it will work, thanks to it being backward compatible, but you'll likely see a reduction in performance as that bandwidth limit becomes the bottleneck.

CPU vs GPU THE UPGRADER'S DILEMMA

Copy here xxxxx



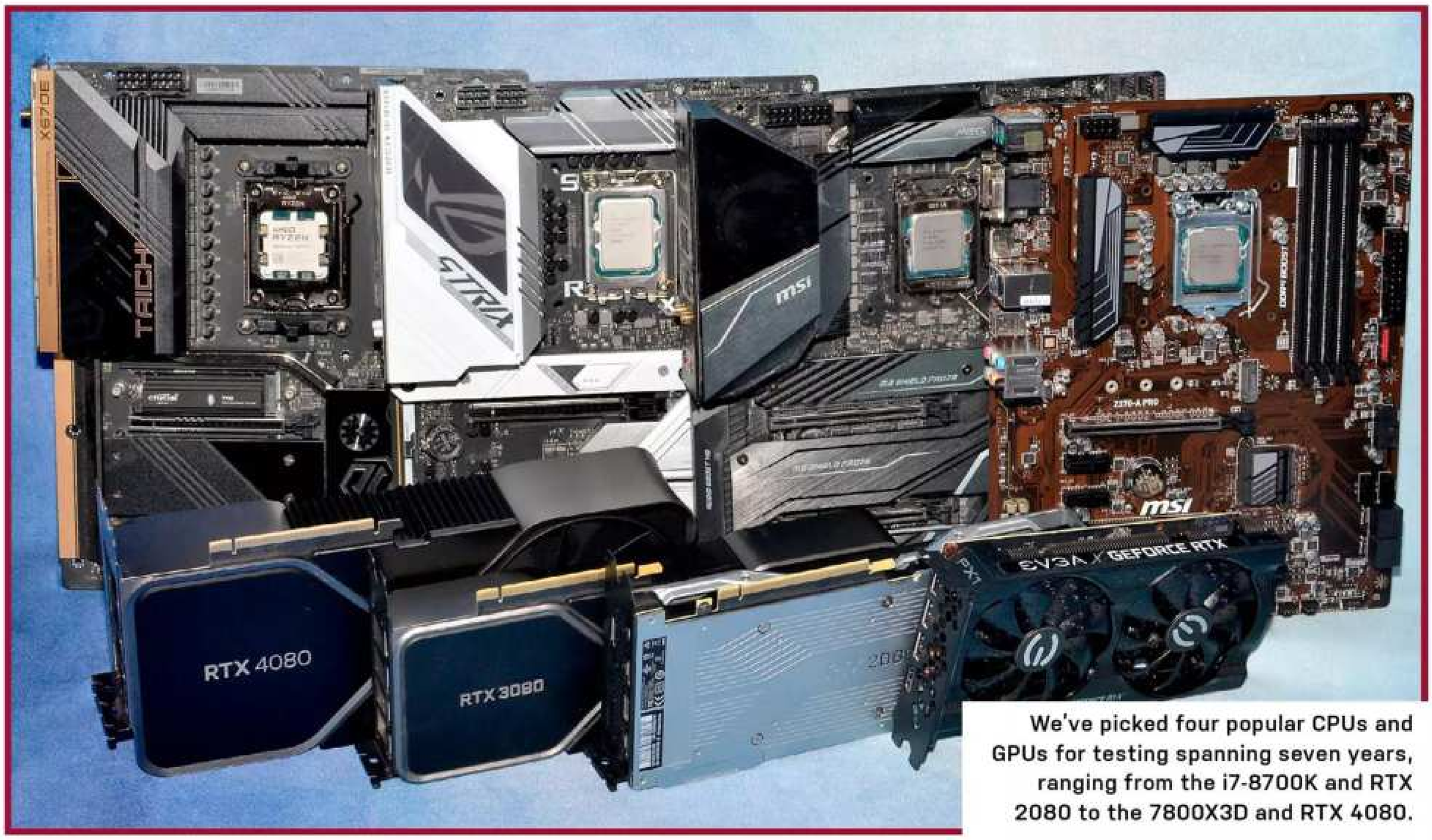
Jarred Walton investigates 16 combinations of graphics cards and processors

IF YOU'VE BEEN a PC enthusiast for long enough, you'll know the feeling: your once-proud system has started to feel a little long in the tooth. Back in the heyday of Moore's Law, that might only take a year or two, but things have slowed down quite a bit these days. Every generation of new hardware outperforms the previous generation, but sometimes the gap can be quite narrow.

Most of us don't have unlimited funds, and the question inevitably becomes one of stretching your existing hardware as far as possible and choosing the most beneficial upgrades. That's especially true with gaming PCs, where the usual advice tends to focus on replacing the GPU. It's the pixel-pumping heart of any gaming rig, after all—why bother with upgrading any other components?

It helps that swapping out a graphics card is simple, as far as upgrades go. At worst, you need to wipe existing GPU drivers from your system, power off, unplug the power connectors and monitor cables, then remove the old GPU. Reverse the process with your new card, and you should be in gaming nirvana.

But in the back of your mind, you wonder if sticking with an older CPU, mobo, or memory might be holding you back. To show just how much performance you may or may not be losing, we've gathered four different CPUs and GPUs from the past seven years, and run them through a modern gaming test suite.



We've picked four popular CPUs and GPUs for testing spanning seven years, ranging from the i7-8700K and RTX 2080 to the 7800X3D and RTX 4080.

MEET THE CONTENDERS

In a perfect world, you'd have access to loads of information showing every conceivable combination of PC hardware. Those who know combinatorial math will realize that this is a fool's errand. Even if we ignore things like motherboards, RAM, and SSDs—not to mention cases and power supplies—there have been more than enough different CPUs and GPUs to make our heads spin.

Even if we omit GPUs that don't support ray tracing, a rough count gives us 54 different AMD, Intel, and Nvidia GPUs since 2018—that's when the first RTX 20-series GPUs appeared. Add in cards that don't support ray tracing, and we'd have another 21 GPUs to consider—and that's the easier task.

Between Intel and AMD, there have been over 125 different desktop CPUs released since 2017, and that has eliminated quite a few extra options. That number doesn't include Intel's lower power T-series parts, graphics-less F-series parts, or any Pentium or Celeron models. It also doesn't count AMD's G-series APUs or newer F-series parts. Adding those in could get us to more than 200 different CPUs.

If we wanted to test each of those 75 GPUs with each of the... let's call it 150 CPUs, that's over 11,000 different possible configurations. There are myriad other possible builds using different motherboards, memory, etc.

The good news is that we don't need to test every potential configuration. Sure, we might not be able to say precisely how CPU X and GPU Y stack up, but there's plenty of overlap. Core i7-14700K and i9-13900K, for example, may differ in exact core counts, but for gaming, they deliver nearly identical performance. That goes for GPUs as well, with the RTX 4070 and RTX 3080 basically tied (as long as you discount DLSS 3 frame generation).

Our task, then, isn't to test everything, but to provide a reasonable sampling of options. To that end, we've picked Nvidia's last three RTX xx80 GPUs: the RTX 2080, RTX 3080 (the original 10GB version, not the later 12GB model), and RTX 4080. Then we tossed in the RTX 3050 8GB (not the newer and less performant 6GB variant) for good measure, as it's generally the slowest desktop RTX card available.

Seven years of CPU history, from the Core i7-8700K up to the Ryzen 7 7800X3D—all still fully compatible with Windows 11.

For the CPUs, we set our way-back machine to 2017 with the Core i7-8700K, the former king of Intel CPUs and the oldest generation CPU that can still run Windows 11 (without hacks or workarounds). We picked the Core i9-11900K as the final iteration of 14nm tech from Intel, plus the newer hybrid architecture Core i9-13900K that has P-cores and E-cores—14900K can be decently faster for multi-threaded workloads thanks to its extra efficiency cores, but for gaming, it's generally only a few percent faster.

That's three Intel CPUs, but unlike the graphics side of things, where we wanted to keep drivers and features like DLSS consistent, we wanted to add at least one AMD processor. We picked the Ryzen 7 7800X3D as the current fastest CPU for gaming. Yes, it's actually faster than the more expensive Ryzen 9 7900X3D and 7950X3D, which end up being hampered somewhat by their asymmetrical core and cache configurations (only one compute die gets the extra 64MB of L3 cache stacked on top).

Each CPU runs in a different motherboard, and the two older platforms only support DDR4 while AMD's socket AM5 requires DDR5—and the 13900K and socket LGA1700 straddle the line with potential support for either DDR4 or DDR5. We picked high-end motherboards from each generation (see Test Hardware boxout) with enthusiast grade memory and other components, installed Windows 11 23H2 with all the updates, and got ready for testing.

That's still only 16 combinations of hardware out of potentially millions of possibilities, depending on how you want to break things down. But it's at least a reasonable start, and will show where you should draw the line between upgrading your graphics card and when you'll want to consider a new CPU—and possibly motherboard and memory as well.

BREAKING DOWN PERFORMANCE

Not only do we have four CPUs and four GPUs, but we also have four different resolution/setting combinations for games. We wanted to show a range of performance, because not everyone plays games on a 4K monitor, and similarly not everyone is happy with 1080p gaming at medium settings. We're breaking things down into performance categorized by resolution and setting.

1080P MEDIUM AGGREGATE PERFORMANCE

	RTX 4080	RTX 3080	RTX 2080	RTX 3050
AMD Ryzen 7 7800X3D	**195.4**	145.8	95.3	64.3
Intel Core i9-13900K	185.6	**146.3**	**98.1**	**65.1**
Intel Core i9-11900K	148.7	127.4	94.5	63.0
Intel Core i7-8700K	119.4	108.7	87.6	60.8

Best scores are in bold.

1080P ULTRA AGGREGATE PERFORMANCE

	RTX 4080	RTX 3080	RTX 2080	RTX 3050
AMD Ryzen 7 7800X3D	**146.1**	101.6	64.0	40.4
Intel Core i9-13900K	144.4	**102.3**	**66.1**	**40.8**
Intel Core i9-11900K	120.2	93.7	64.6	40.3
Intel Core i7-8700K	97	83.7	61.5	39.3

Best scores are in bold.

Each performance table shows the GPUs across the top and the CPUs on the left, with the best score for each GPU bolded. That's going to be either the Ryzen 7 7800X3D or Core i9-13900K in every case, though it's interesting to see that the 'fastest' CPU doesn't always come out on top (see the 1080p Medium Aggregate Performance table).

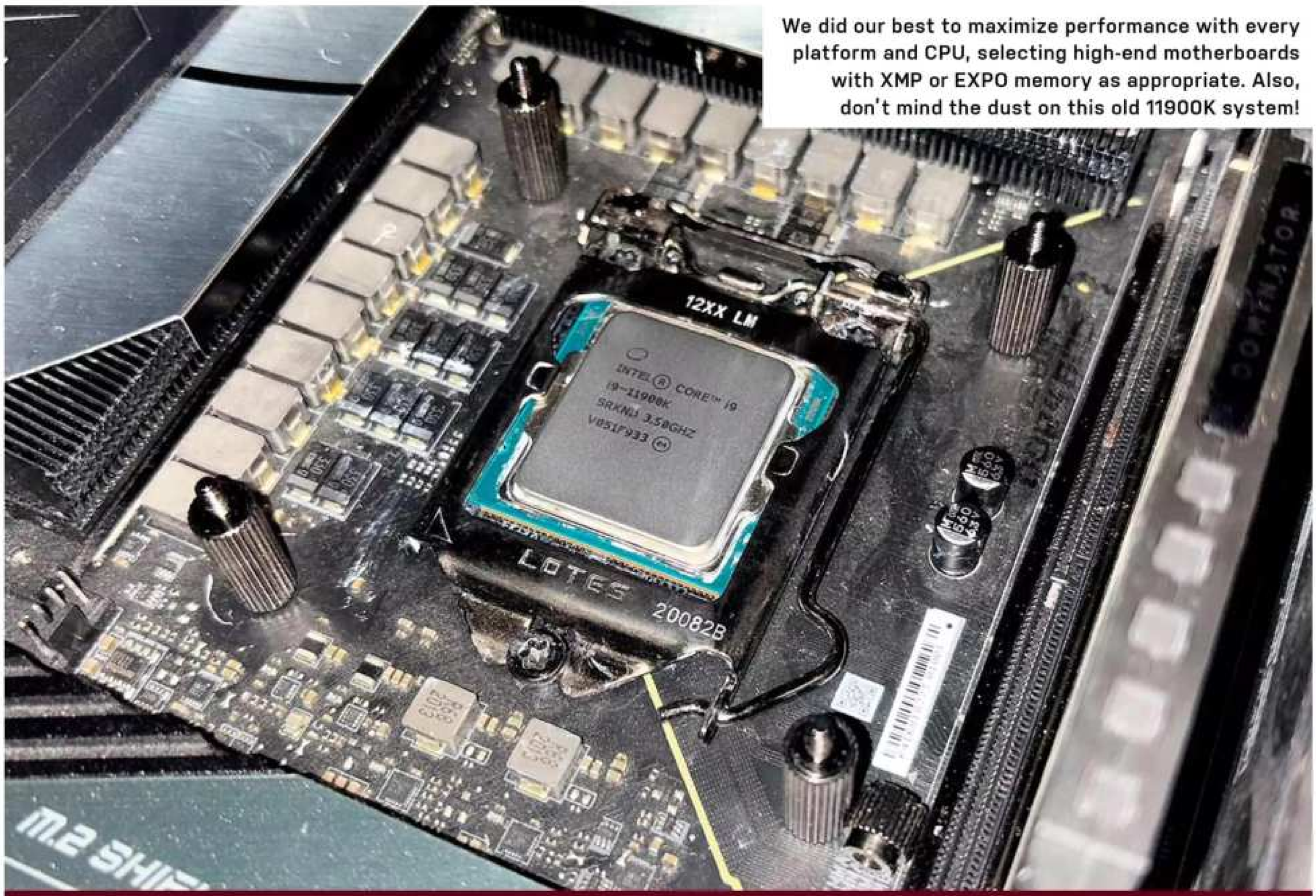
Starting with our 1080p medium results, the less demanding settings should show the biggest difference between the CPUs. Overall performance improves by over 60 percent when comparing the 8700K to the 7800X3D, at least when using the RTX 4080. But let's be real—most people buying a $1,000 graphics card are probably also willing to spend a similar amount of money on a new CPU and platform. There's also a five percent gap between the 7800X3D and the 13900K, and a 25 percent gap between the 13900K and 11900K.

There's still a sizable 35 percent difference between the 8700K and 7800X3D / 13900K at 1080p ultra when using the RTX 3080, which mostly matches the performance of the newer RTX 4070. However, the top two CPUs are now effectively tied—there are individual games that show a minor difference, but in general, you shouldn't expect to feel the difference between the fastest AMD and Intel CPUs at 1080p ultra on slightly less extreme GPUs. The gap between the 13900K and 11900K also shrinks to just 15 percent now, which is still noticeable, but perhaps not the end of the world.

Dropping down to the RTX 2080 sees the 13900K lead increase over the 'faster' 7800X3D (check the sidebar above for further details). But now the three fastest chips are close enough that outside of one particular game (*Diablo IV*), no one would really care. What's special about Diablo IV? Nothing much, other than an apparently quite poor implementation of ray tracing. Performance seems to be heavily limited by the throughput of one or two CPU cores, so the 13900K is nearly 50 percent faster than the 11900K. That's very much an outlier, as the largest gap otherwise is only six percent.

As expected, the RTX 3050 mostly delivers a similar gaming experience across all four processors. The 13900K does offer seven percent higher performance overall compared to the 8700K, but most gamers would definitely want a faster graphics card before worrying about a CPU upgrade. (see 1080p Ultra Aggregate Performance table)

> We wanted to show a range of performance, because not everyone plays games on a 4K monitor, and similarly not everyone is happy with 1080p gaming at medium settings



We did our best to maximize performance with every platform and CPU, selecting high-end motherboards with XMP or EXPO memory as appropriate. Also, don't mind the dust on this old 11900K system!

TEST HARDWARE

For gaming purposes, the difference between the fastest and slowest motherboard for a platform can be quite large. We wouldn't expect an $80 board with an H610 chipset to match a $400 board with a Z790 chipset on features or performance, and the same goes for a socket AM5 board using the A620 chipset compared to the X670E chipset. Memory support, power delivery, and other aspects can and will differ.

We've done our best to level the playing field as much as possible by selecting some of the best components for each platform. Some elements are even the same across all four systems, like the Crucial T700 4TB PCIe 5.0 SSD for storage and be quiet! Dark Power Pro 13 1600W power supply. The SSD won't run at PCIe 5.0 speeds on the older platforms that only support PCIe 3.0 and 4.0, but it certainly won't hurt performance.

For the motherboards, we used an MSI MEG Z390 ACE for the i7-8700K and LGA1151 socket. That's a late-cycle upgrade for that socket that was released for the 9th Gen Core processors like the i9-9900K, and critically it has ReBAR (resizable base address register) support with the latest BIOS revision. For LGA1200 and the 11900K, we used an MSI MEG Z490 Godlike motherboard. Technically there are newer Z590 chipset boards, but MSI's Godlike boards are no-holds-barred extreme enthusiast parts. Both the Z390 and Z490 boards use the same DDR4-3600 CL16 memory—not the absolute fastest RAM available, but our Corsair Vengeance RGB kit delivers good performance without impacting stability (and we've been using it for years).

For LGA1700 and the 13900K, we used an MSI MEG Z790 ACE, pretty much the fourth-generation descendant of the Z390 board. The AMD AM5 platform used an ASRock Z670E Taichi board, another top-tier offering. These two newer CPUs perform best with DDR5 memory, but AMD processors tend to work a bit better with RAM kits that support EXPO—the AMD alternative to Intel XMP 3.0. We selected a 32GB (2x16GB) G.Skill Trident Z5 DDR5-5600 CL28 kit for the 13900K, and a similar G.Skill Trident Z5 Neo 32GB DDR5-6000 CL30 kit for the 7800X3D.

CPU cooling consisted of either a 14.2-inch closed-loop liquid cooling radiator, or a 280mm radiator. We enabled XMP/EXPO in the BIOS but otherwise didn't conduct any low-level tweaking to attempt to further improve performance. The CPUs were not running overclocked, other than on the memory, and each board used the latest BIOS revision that was currently available.

The exact same graphics card was installed in each PC to eliminate variables, running Nvidia 555.83 drivers. We used the Founders Edition models for the RTX 2080, 3080, and 4080 cards. There's no official reference design for the RTX 3050, so in that case we opted for an EVGA RTX 3050 Black. (RIP, EVGA graphics cards, we miss you.)

Moving to higher-quality 'ultra' settings while sticking with a 1080p, the margins already start to shrink quite a bit. Even with our fastest tested GPU, the RTX 4080, the 7800X3D only beats the 13900K by less than two percent—not something you'd notice while gaming. Compared to the 11900K, you'd still get more than a 20 percent boost to framerates, however, so even a three-year-old CPU can hold back the fastest graphics cards. As for the 8700K, it drops performance of the 4080 by about a third. It's definitely time for a CPU upgrade if you're running a 4080 with that sort of CPU—at 1080p, anyway.

Things become a lot less dire for the older CPUs when we shift to 2020's RTX 3080. You can still improve performance by around 10 percent overall when going from the 11900K to one of the two latest generation processors, and there's a potential 20 percent increase available for the 8700K. But there are a lot of games in our test suite where the difference between the 7800X3D and 8700K is less than 10 percent—11 of them, to be precise.

Which games really don't like the 8700K? *Diablo* (again, because of DXR) shows the biggest delta of over 80 percent. *Flight Simulator*, *Far Cry 6*, and *Spider-Man* show more than a 50 percent improvement as well. *Horizon Zero Dawn* falls just below a 50 percent improvement, followed by *Watch Dogs* at 36 percent and *Total War* at 32 percent. Last is *Assassin's Creed*, with a 20 percent increase on the line.

The RTX 2080 ends up being almost completely GPU limited, with *Diablo* being the only serious outlier once again. You can potentially get 65 percent higher performance from the 2080 in that game by moving from the 8700K to a faster CPU like the 13900K or 7800X3D. The 13900K is also 27 percent faster than the 11900K, but that's the only game where the 11900K falls behind by more than a few percent. *Far Cry 6* and *Flight Simulator* can still benefit from a faster CPU than the 8700K, but nothing else really cares.

As for the 3050, *Diablo* showed a 12 percent difference, but overall there's nothing to suggest the 8700K can't handle such a GPU. The biggest potential problem with the 8700K in other games would be if the 3050 doesn't have enough VRAM for the chosen settings, in which case swapping data over a PCIe 3.0 x8 connection is slower than on PCIe 4.0. *Spider-Man* shows a 15 percent deficit with the 8700K, for example, with plenty of stuttering and generally a poor overall experience—performance drops into the low 20s at times, compared to maintaining 30fps or more on the 13900K. (See 1440p Ultra Aggregate Performance table.)

It used to be that 1440p ultra settings basically removed the CPU from being a bottleneck, but the fastest graphics cards can still get another 10–20 percent performance uplift if you're running them on an old processor. The RTX 4080 isn't as fast as the 4090, which would push the bottleneck more toward the CPU, but we wouldn't want to waste the performance potential by pairing it with an 8700K. That would be a bit like putting the cheapest tires and gasoline into an exotic sports car and then wondering why it seemed to be struggling to keep up.

The performance deltas with the RTX 3080 at 1440p now look pretty similar to what we saw with the RTX 2080 at 1080p ultra: Outside of games like *Diablo*, *Flight Simulator*, and *Far Cry 6*, you can still run most games at relatively close to the GPU's maximum performance. CPUs like the 11900K are certainly fast enough to keep the 3080 fed with data.

The 2080 likewise performs nearly the same with all four CPUs. *Diablo IV* remains a bad apple, though you can 'fix' that by just disabling ray tracing (which we would normally do, but we found the CPU bottleneck to be quite fascinating, as few other games behave this poorly on older CPUs). *Spider-Man* also has some performance issues with the 2080, which appear to stem from the 8GB VRAM and the Turing architectures' less sophisticated delta color compression.

There aren't any noteworthy CPU performance limitations for the RTX 3050, other than some VRAM thrashing in *Cyberpunk* on the 8700K—1440p ultra with ray tracing enabled on the 3050 simply isn't viable, averaging just over 10fps. Most of the demanding games would need DLSS enabled and/or lower settings to get acceptable performance out of the 3050. (See 4K Ultra Aggregate Performance table.)

Last, and certainly not least—unless you mean least interesting—4K ultra is the great equalizer for CPU bottlenecks. Our aggregate scores do show a few larger differences, like *Diablo IV* hating the 8700K when using the 4080, but only three of the games in our test suite show more than a 10 percent improvement

1440P ULTRA AGGREGATE PERFORMANCE

	RTX 4080	RTX 3080	RTX 2080	RTX 3050
AMD Ryzen 7 7800X3D	114.3	75.9	44.8	27.6
Intel Core i9-13900K	**114.5**	**76.2**	**46.6**	**28.1**
Intel Core i9-11900K	101.2	73.1	46.2	27.6
Intel Core i7-8700K	87.1	68.2	44.4	27.2

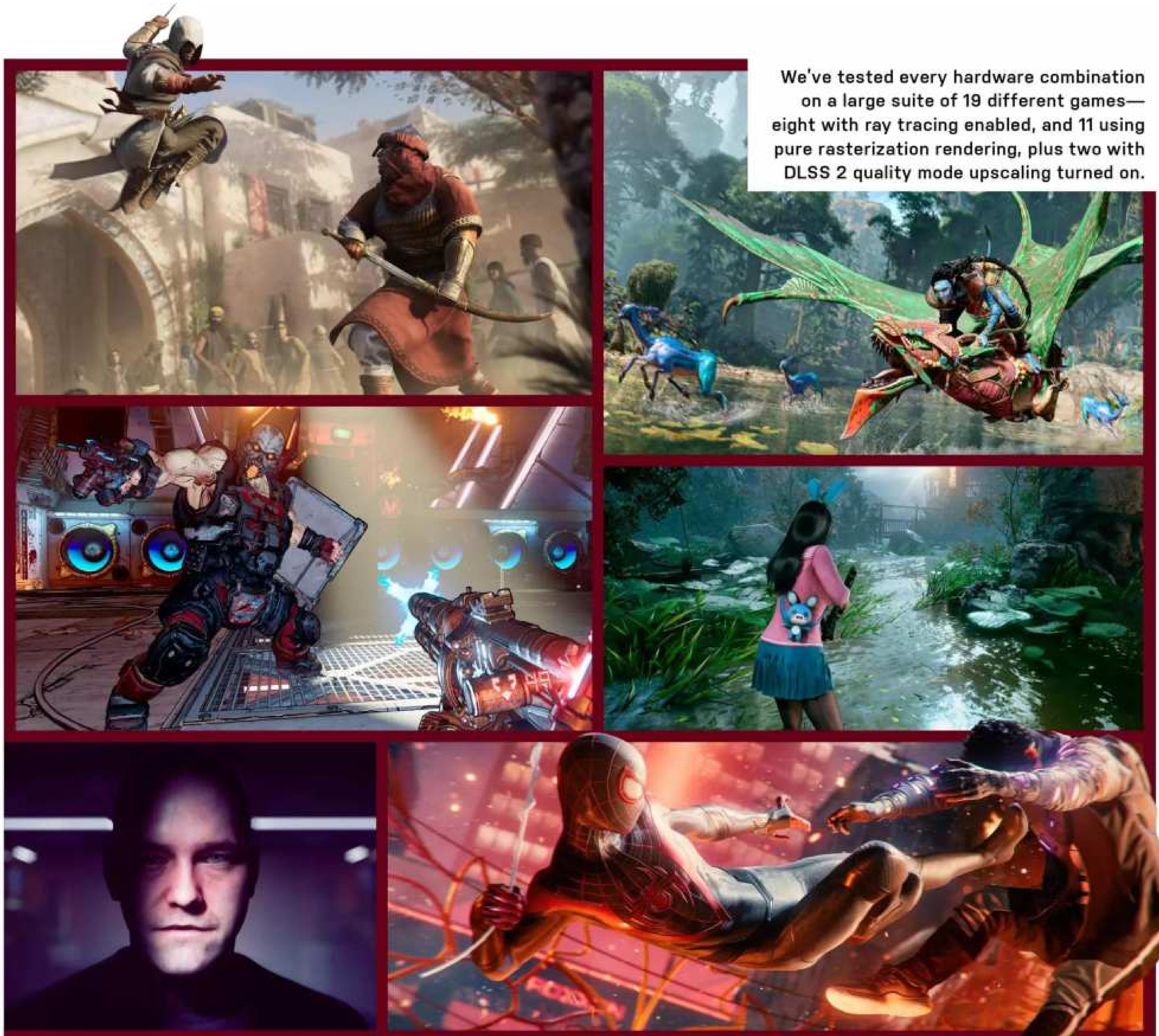
Best scores are in bold.

4K ULTRA AGGREGATE PERFORMANCE

	RTX 4080	RTX 3080	RTX 2080	RTX 3050
AMD Ryzen 7 7800X3D	67.7	**43.4**	22.9	14.3
Intel Core i9-13900K	**68.3**	**43.4**	**23.5**	**14.5**
Intel Core i9-11900K	66.3	43.1	23.2	14.2
Intel Core i7-8700K	61.8	41.7	21.0	13.4

Best scores are in bold.

> You can potentially get 65 percent higher performance from the 2080 in that game by moving from the 8700K to a faster CPU like the 13900K or 7800X3D



We've tested every hardware combination on a large suite of 19 different games—eight with ray tracing enabled, and 11 using pure rasterization rendering, plus two with DLSS 2 quality mode upscaling turned on.

THE GAMING SUITE

There's no single game or game engine that will universally represent every game. This is one of the drawbacks of tools like 3DMark, because while it does illustrate some aspects of GPU performance and matches up well with certain games, it's designed to focus on graphics performance. Some games end up being more dependent on the CPU, so we've tried to include a mix of engines and game types.

We don't have room on the pages of our magazine to show every score from every game for each GPU, unfortunately—you can see additional testing results at Tom's Hardware if you're interested (bit.ly/cpu-vs-gpu). For the performance tables here, we're using the geometric mean of the average fps across all 19 games, which gives equal weighting to each result.

We used more demanding games for testing from the past five years, as there's not much point in checking performance in lightweight games that can run on a potato. The games and APIs for each are: *Assassin's Creed Mirage* (DX12), *Avatar: Frontiers of Pandora* (DXR), *Borderlands 3* (DX12), *Bright Memory Infinite* (DXR), *Control Ultimate Edition* (DXR), *Cyberpunk 2077* (DXR), *Diablo IV* (DXR), *Far Cry 6* (DX12), *Flight Simulator* (DX11), *Forza Horizon 5* (DX12), *Horizon Zero Dawn* (DX12), *Metro Exodus Enhanced* (DXR), *Minecraft RTX* (DXR), *A Plague Tale: Requiem* (DX12), *Red Dead Redemption 2* (Vulkan), *Spider-Man: Miles Morales* (DXR), *The Last of Us Part 1* (DX12), *Total War: Warhammer 3* (DX11), and *Watch Dogs Legion* (DX12).

Several of the DX12 games also support ray tracing, but it was not enabled, except where we list DXR (DirectX Raytracing) as the API.

Most games have graphics presets for medium and ultra settings (or similar names). *Red Dead Redemption 2* does not, but we used the same 'medium' and 'ultra' settings on all four platforms. All the games were tested using native resolution rendering, with the exception of *Avatar* and *Diablo IV*. We used DLSS Quality upscaling on those two games (but left Frame Generation off in *Diablo*).

when moving from the 8700K to the fastest CPU.

Drop the GPU to an RTX 3080, and the overall gap between the fastest and slowest CPUs we tested shrinks to just four percent. Diablo still has a 25 percent improvement from the faster CPUs compared to the 8700K, with *Spider-Man* and *Bright Memory Infinite* showing just over a 10 percent gain. Everything else shows single percentage point improvements.

The RTX 2080 seems to show a larger 12 percent difference between the 13900K and 8700K, but this time it comes from something other than *Diablo IV*. *Far Cry 6* basically choked on the 8700K and RTX 2080, as it wants more than 8GB VRAM. We could occasionally get better performance out of the newer CPUs, but after dozens of benchmark attempts, the 8700K never got above 5fps—compared to 20fps on the 13900K. That's enough to create the additional seven percent gap in performance (when compared to the 3080's overall performance delta).

It's mostly the same story with the RTX 3050, though here the superior lossless delta color compression of the Ampere architecture comes into play. *Far Cry 6* managed 22fps on the 8700K compared to 28fps on the 13900K and 7800X3D. It's the only instance in all our testing where the 3050 offered higher performance than the 2080, thanks to the architectural improvements in Ampere.

KEEPING YOUR CPU & GPU BALANCED

Most of the results aren't particularly surprising. PC enthusiasts have long recommended a balanced approach to new builds, so if you're going to splurge on the fastest graphics card available, buying an equally fast CPU makes sense. For mainstream users, pairing a modest $300–$600 graphics card with a Core i5 or Ryzen 5 also makes sense.

The problem is that newer CPUs and GPUs constantly arrive, and while we've

AMD's fastest GPU right now is the RX 7900 XTX, which roughly matches the performance of Nvidia's RTX 4080, depending on the game and settings used.

WHAT ABOUT AMD GPUS?

We wanted to minimize variables and keep settings consistent for our testing, so we only used Nvidia RTX cards. AMD has competing GPUs for every generation, though it only has ray tracing hardware in the RX 6000- and 7000-series. We'd expect to see similar scaling overall if we were to test AMD Radeon GPUs, though some of the individual game results would vary quite a lot from the RTX hardware.

Generally speaking, AMD GPUs of the past several generations have performed slightly better than similarly priced Nvidia GPUs in games that use traditional rasterization rendering. Some AMD promoted games, like *Borderlands 3*, have favored Radeon cards quite heavily, and similarly, there are Nvidia-promoted games, like *Cyberpunk 2077*, that favor GeForce cards. Games with ray tracing also tend to favor Nvidia GPUs, especially for games that use multiple overlapping RT effects (eg. reflections, shadows, and ambient occlusion).

Just as we couldn't realistically test hundreds of CPU and GPU combinations, we can't exhaustively list how every AMD GPU compares to the Nvidia cards we've tested. However, we do have an online GPU hierarchy (https://bit.ly/gpu-hierarchy) that ranks most of the past decade's worth of GPUs by performance. That's a great place to start if you're trying to figure out where your particular GPU lands.

That's also why we have four clearly distinct levels of GPU performance. The RTX 3050 represents our slowest pick, with the RTX 2080 delivering 50–65 percent more performance, depending on the resolution and setting you look at. The RTX 3080 provides another 40–90 percent boost over the 2080, with the biggest gains coming at 4K. The RTX 4080 in turn beats the 3080 by 20–55 percent, again with the larger deltas at 4K.

Most GPUs (outside of substantially slower options like the RX 6500 XT and RX 6400) should be within 10 percent of one of the GPUs we tested, so you can approximate performance scaling with different CPUs that way.

> Drop the GPU to an RTX 3080 and the overall gap between the fastest and slowest CPUs we tested shrinks to just four percent

Not everyone needs or wants an exotic car, or an extreme gaming PC. Don't worry about keeping up with the Joneses.

seen a few significant bumps to CPU performance over time, rarely do they match the improvements we've seen on the graphics card front. Things are likely to get another kick in the pants this fall, as we're slated to see new Ryzen 9000 'Zen 5' CPUs from AMD, Intel second generation Core Ultra 'Arrow Lake' processors, and Nvidia Blackwell RTX 50-series GPUs.

Rumors point to potentially 15~20 percent more CPU performance from AMD and Intel, while the current hints of a future RTX 5090 sound like the stuff of fantasy. We could see up to 192 SMs and 24,576 CUDA cores, with a 512-bit GDDR7 memory interface offering more than double the bandwidth of the RTX 4090 and up to 32GB of VRAM capacity. On paper, it seems like to be at least 50 percent faster than the current king of the hill, but you'll need an even faster CPU to keep it occupied.

We expect some significant performance improvements to trickle down to the rest of the RTX 50-series product stack. So if you're currently thinking, "Yeah, I would never spend $1,000 on a graphics card and so the RTX 4080 results don't really worry me," don't be surprised if the next generation RTX 5070 (or whatever it's called) deliver similar performance on a card that's far more affordable. This means that even mainstream gamers who are looking to upgrade their rigs might need to consider more than just a GPU upgrade.

7800X3D: NOT ALWAYS THE WINNER

With the fastest GPU available, the RTX 4090, the Ryzen 7 7800X3D wins, but it's not always the fastest with older graphics cards.

When is the fastest processor not the fastest? When drivers, platforms, and architectures come into play. AMD's stacked 3D V-cache used in its Ryzen 5000 and 7000 series X3D chips can dramatically boost gaming performance, though it varies by game and other factors. That's actually not something we expected to see.

We started our testing of these processors with the RTX 4080, and everything lined up pretty much as expected. As we worked our way down to the RTX 3080, 2080, and eventually 3050, however, we started to see some curious results. The 7800X3D clearly wins at 1080p with the 4080, while the 1440p and 4K are basically GPU limited. Based on that, we expected to see very little difference between the 2080 and 3050, since those GPUs are substantially slower. That didn't quite happen.

The 13900K ended up as the fastest gaming CPU with all three of the older graphics cards. We suspect it comes down to driver and platform tuning that's focused more on the latest and greatest hardware. Prior to the X3D chips, which first arrived in April 2022 with the Ryzen 7 5800X3D, one of Intel's strong selling points was gaming performance. Sure, the 16-core Ryzen 9 3950X might have had the highest multi-threaded performance back in 2019, easily beating Intel's top Core i9-9900K, but Intel still held the gaming crown.

2022 marked an inflection point where suddenly there were AMD chips that could beat Intel at its own game. So when the RTX 40-series launched later that year, it made sense for Nvidia to put extra effort into ensuring its cards would take advantage of AMD's improved CPU performance. Similar effort likely wasn't put into older generation hardware, and so we end up with Intel still offering slight advantages on those GPUs. This is one area where we suspect AMD GPUs might show some differences.

On the other hand, it's important to consider exactly how you plan on using your PC. If you have a 4K monitor, then faster GPUs continue to be the most important upgrade you can make. Even when looking at the 8700K and 7800X3D, at 4K we only saw an eight percent overall performance improvement. Conversely, going from a 3080 to a 4080 while sticking with the 8700K improved 4K performance by 50 percent on average.

We've also focused primarily on gaming, but there are plenty of other tasks that can make use of newer PC hardware. Software developers might not care so much about a high-end gaming GPU, but more RAM and faster CPUs can help with compile times. AI researchers might not care about fps, but they'll want lots of VRAM and raw GPU compute. For typical SOHO tasks, a bleeding-edge PC likely isn't necessary—I do most of my work on a PC that's quite similar to the lowly 8700K used in these tests, and it's generally fast enough.

Before you drain your bank account or whip out your credit card, however, take a moment to consider whether you even need to upgrade. Sure, an RTX 4080 (Super) and a Zen 5 or Arrow Lake CPU might sound enticing, but if you're happily playing games at 1080p medium, you probably don't need to worry about investing in new hardware. The day will eventually come when it's time to take the plunge, and rest assured, there will be plenty of even faster and better parts around when you're ready.

> Before you drain your bank account or whip out your credit card, however, take a moment to consider whether you even need to upgrade

magazinesdirect.com

Over 100 brands to choose from

GIFT IDEA! Gifts that keep on giving

3 GREAT REASONS TO SHOP WITH US

- From tech and gaming titles to fashion and celebrity magazines there's something for everyone.
- Immerse yourself in our specialist one-off publications about your favorite hobby or interest.
- Exclusive Offer - Get 15% Off Guides and Specials - **MDMAG15**

VISIT OUR ONLINE STORE AT

www.magazinesdirect.com

✓ Convenient home delivery ✓ Save on shop price ✓ Never miss an issue ✓ 1.4m subscriptions sold

MAXIMUMPC

PREMIUM DIGITAL SUBSCRIPTION

As a premium subscriber you instantly get access to 100+ back issues

www.magazinesdirect.com/MPP

*Price in US $. Offer is valid on US orders only, visit us at www.magazinesdirect.com or call 1-844-779-2822 for other subscription options.
Offer valid until August 30 2024.

The Life & Times of Gaming Keyboards

Zak Storey takes a deep dive into the world of our favorite peripheral...

Today's gaming boards have come a long way since the early 2000s.

...looking at where they've been, where we're at, and where it's all heading

KEYBOARDS are one of the few devices that we often overlook as PC enthusiasts. Whenever we price up systems and specs, peripherals are mostly ignored outside of the occasional consideration to screen resolution. Yet the reality is that monitors, keyboards, and mice are all integral elements of any good build.

So why are keyboards so overlooked? For the majority, a keyboard is the primary method of interacting with the PC. Yet, the world of keyboards has changed dramatically since the PC scene first exploded. To get a good idea of where we've been, and where we're heading, we're going to jump into the noisy world of the humble keyswitch, giving you the lowdown on all the latest tech. Is it time to upgrade that aging K70? Or are you still trying to outlast Cherry's 50,000,000 key switch rating? Let's jump in, and see what it's all about.

Where it all began

The rise, fall, and rise again of mechanical keyswitches

FOR ANY LONG-TIME PC veteran, the mechanical keyswitch might seem like a bit of an oddity, arriving back into the PC market after so many years, and with good reason. The first keyboards produced by IBM back in the early '80s were actually based on a similar mechanical design.

In fact, if you took the stats and specs of a Model F, and placed them side by side with a similar mechanical keyboard today, you'd be hard pressed to tell them apart, at least outside of the realm of RGB.

The Model F launched with a 'buckling spring' style of keyswitch. Effectively, a long spring situated under the keycap would push down and bend when pressed, pushing force onto a metal plate that would make contact with the PCB below, completing the circuit, and generating the keyswitch. This design was simultaneously cheaper to manufacture and easier to service than earlier switch variants, and perhaps even more surprisingly, gave IBM the advantage of having a keyboard that not only had switches capable of over 100 million keypresses before failure, but also allowed for complete N-Key rollover, with no ghosting—a phenomenal achievement, without a doubt.

The Model F would be superseded by the Model M in 1985. This version was far more widespread and synonymous with getting closer to the original ANSI and ISO layouts that we know today. It did, however, differ significantly from the Model F in a number of key areas, including its external chassis no longer being painted, and the more important change being the shift away from a capacitive plate for its buckling spring switch, instead pivoting out to a plastic membrane (sadly leading to support for only two-key rollover). Additionally, a number of build quality elements were swapped out from metal to single-use plastic elements instead.

This helped IBM reduce the cost significantly, and saw widespread adoption of the Model M well into the early '90s. Despite the move to a plastic membrane, the overall design remained solid, and a number of enthusiasts still use the Model M to this day, thanks to its insane levels of durability

Similar in a lot of ways to a mechanical keyswitch, optical uses an IR laser instead of a contact to complete the 'circuit'.

THE RISE OF MEMBRANE

In the late '80s and early '90s, however, another star was rising: the membrane keyboard. Unlike the Model F and M counterparts, this didn't have individual switches as such, featuring a solid membrane on top of the contact plate, separated with rubber spacers, and featuring metal traces under the contact area. With each key press, the membrane would compress, completing the circuit and actuating the switch as a result.

Although nowhere near as dynamic, tactile, or enjoyable as the early mechanical switches, membrane had one key advantage over its mechanical competitor: cost. It was more affordable to manufacture, and as a result, the 'Dark Ages of cheap keyboard and input designs', as our friends over at Tom's Hardware call it, had arrived.

THE FIRST TRUE GAMING KEYBOARD

Depending on your perspective, nailing down when the first gaming keyboard arrived is a bit of a challenge. In our opinion, Logitech holds that crown with its now legendary G15 gaming keyboard.

Even so, it was still very much a membrane-based board. It was the first to include an LCD, along with dedicated media keys, macro keys and profiles, USB passthrough connectivity, blue backlighting, and more, all for an impressively low price. In fact, you could pick one up for just $70 (they now go second hand for around $450).

In fact, the G15, and boards like it from similarly placed manufacturers dominated the market well into the early 2010s. Mechanical keyswitches would eventually surpass them in the gaming ecosphere, but not for some time.

Interestingly, the first mechanical keyboard (that we could find in our investigative archives) was SteelSeries' 7G professional gaming keyboard, complete with 18K gold-plated mechanical switches. This board was first announced in November 2007, and was wildly underwhelming to the mass market, with many deriding its $150 price as far too expensive, given that all you got was a dull-looking office keyboard.

THE MODERN ERA

Brands like Razer, Corsair, and Logitech would eventually join the fray with the Black Widow, K70 Vengeance, and G Series respectively, finally cementing the mechanical keyboard's position in the market. These early boards typically used Cherry MX switches (still being one of the only manufacturers of true mechanical keyswitches on the market at the time).

From 2014 onward, we also started to see bespoke mechanical keyswitches

© WEDIPEDIA/RAYMANGOLD22, RAZER

The IBM Model F paved the way for keyboards, and then membrane took us completely in the wrong direction.

The Model M revolutionized not only keyboard design, but also form-factor as well

Magnetic keyswitches typically have a magnet in the middle of the switch, and a sensor below to detect it.

land in the market, particularly from the likes of Logitech, SteelSeries, and Razer, all touting their own brand's particular switch as being faster and more responsive. Corsair, however, stayed with Cherry as a major manufacturing partner until the early 2020s with its first optical switch in the form of OPX.

Other manufacturers, dedicated solely to keyswitches, also joined in on the action with the likes of Gateron, Kalih, Outemu, and Holy Panda, among others, providing a variety of mechanical keyswitch types at all manner of specifications for AIB partners and DIY enthusiasts.

THE ARRIVAL OF OPTICAL AND MAGNETIC

It wouldn't be long, however, until mechanical switches weren't enough, and in the pursuit of advancement, optical and magnetic switches were developed as similarly functioning replacements.

Optical switches were championed by Wooting in 2017, and provided near instantaneous reaction times compared to the 'slow' electrical traces of mechanical keyswitches. The keyswitch was near identical to a mechanical switch, complete with spring and tactile or linear feedback. However, the signal differed massively. As mechanical keyswitches rely on a contact trace to complete a circuit, an optical switch intersects an infrared beam below the keyswitch.

This does two things: first, it reduces the points of failure on the PCB itself, as there's no longer any physical contact between the switch and PCB; second, it allows the keyswitch a degree of analog control, as you can measure how much of the switch is intersecting the beam, and control the response.

Because of the elimination of traces, and a simpler overall design, with optical boards it's far easier to hot-swap out the switches depending on your preference, or replace faulty keyswitches as a result, which in turn are cheaper to manufacture as they lack any of the contact parts, instead typically just being a plastic switch with a spring in it.

MAGNETIC MASTERY

Magnetic switches operate in a similar manner to optical. Again, like their mechanical counterparts, the switch design is pretty much identical, with a spring and plastic components forming most of the keyswitch design. Again, linear and tactile variants are possible in all manner of force setups.

We first saw magnetic keyswitches at Computex 2019, with SteelSeries debuting them on its Apex Pro line of keyboards. Magnetic keyswitches have an extra element in the switch itself, namely a tiny magnet. Underneath each keyswitch location on the PCB is a sensor that can measure the distance each switch's magnet is located at. You can then tell the PCB to register the keyswitch as actuated once it reaches a certain distance away from the sensor. Similar to optical switches, there's no direct contact of metal plates to create that signal. Instead, it's handled via the PCB and its sensors.

This allows magnetic switches to then vary the height of the actuation point in a similar manner to an optical switch, which is particularly useful if you're after a lighter, faster keyboard.

Although optical switches came first in the battle for switch dominance, because magnetic switches operate off a sensor, rather than the intersection of a beam of light, the range of actuation adjustment is typically far higher on a magnetic keyboard than it is on an optical board.

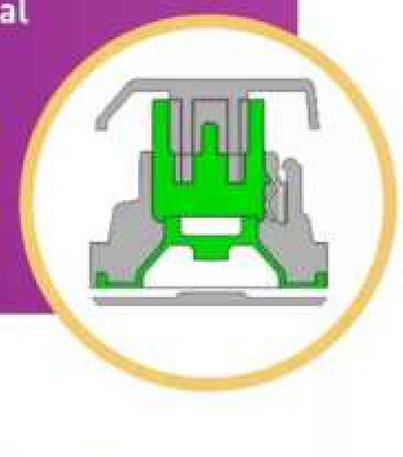
Chiclet & membrane

Down but not out, both rubberdome membrane and Chiclet keyboards still have a place in modern day gaming keyboards. The biggest detractor from modern day gaming keyboards is the cost. Even for the most budget of mechanical keyboards, you're still looking upwards of $80 for a single purchase, which can be a big investment, particularly if your budget only extends to $1,000 for a new rig.

There are a number of more budget oriented keyboards out there that feature chiclet or membrane style switches. One particular type that's becoming increasingly popular, however, is Mecha-Membrane switches, or Mechanical Membrane. These boards still feature the membrane-style contact PCB, with traces. However, each switch situated on top is now fully mechanical, making contact with a rubber dome, pushing down on the membrane itself. This allows manufacturers the opportunity to incorporate a similar feel of a mechanical switch, even including tactile clicks, but at a fraction of the cost of a fully integrated soldered PCB with switches, significantly reducing the cost.

Most notably, Razer has its Ornata series boards. If you find any boards featuring Cherry Violet switches (MX is reserved for its Mechanical switch range), then you're dealing with a mechanical membrane hybrid.

Razer's mechanical membrane is far superior to a traditional membrane board.



Not only was the Logitech G15 one of the first gaming keyboards, it's now almost impossible to buy one, or even find a picture of one

One of the first to break into the mainstream with optical keyswitches, Wooting's One keyboard was a phenomenal piece of kit.

Modders leading the way

Custom keyboards have radically developed the marketplace and its preferences, but why?

ONE OF THE BIGGEST developments we've seen over the last few years is the rise of custom keyboards among the PC enthusiast community. With a number of manufacturers out there from all over the globe specializing in the field, it's now possible to build your own keyboard from the ground up. We've written extensively in the past about building your own DIY keyboard, but the basic premise hasn't particularly changed.

At its core, you need a case to house all your components, a PCB that's going to handle all of your inputs and switches (you can now get these in optical or mechanical configs, with different pin/contact types), a plate, allowing you to mount your switches to the board for added rigidity, stabilizers for your switches, switches, and finally, key-caps. There are additional options and accessories, too, including custom cables and more, but that's pretty much the core of what you'll need to build your own.

Similar to building a PC, it's very much a plug-and-play activity these days. Switches will only fit in the correct slots, and the right form-factors support only certain plates and PCBs and so on.

A SOFTER, QUIETER, FASTER, FUTURE

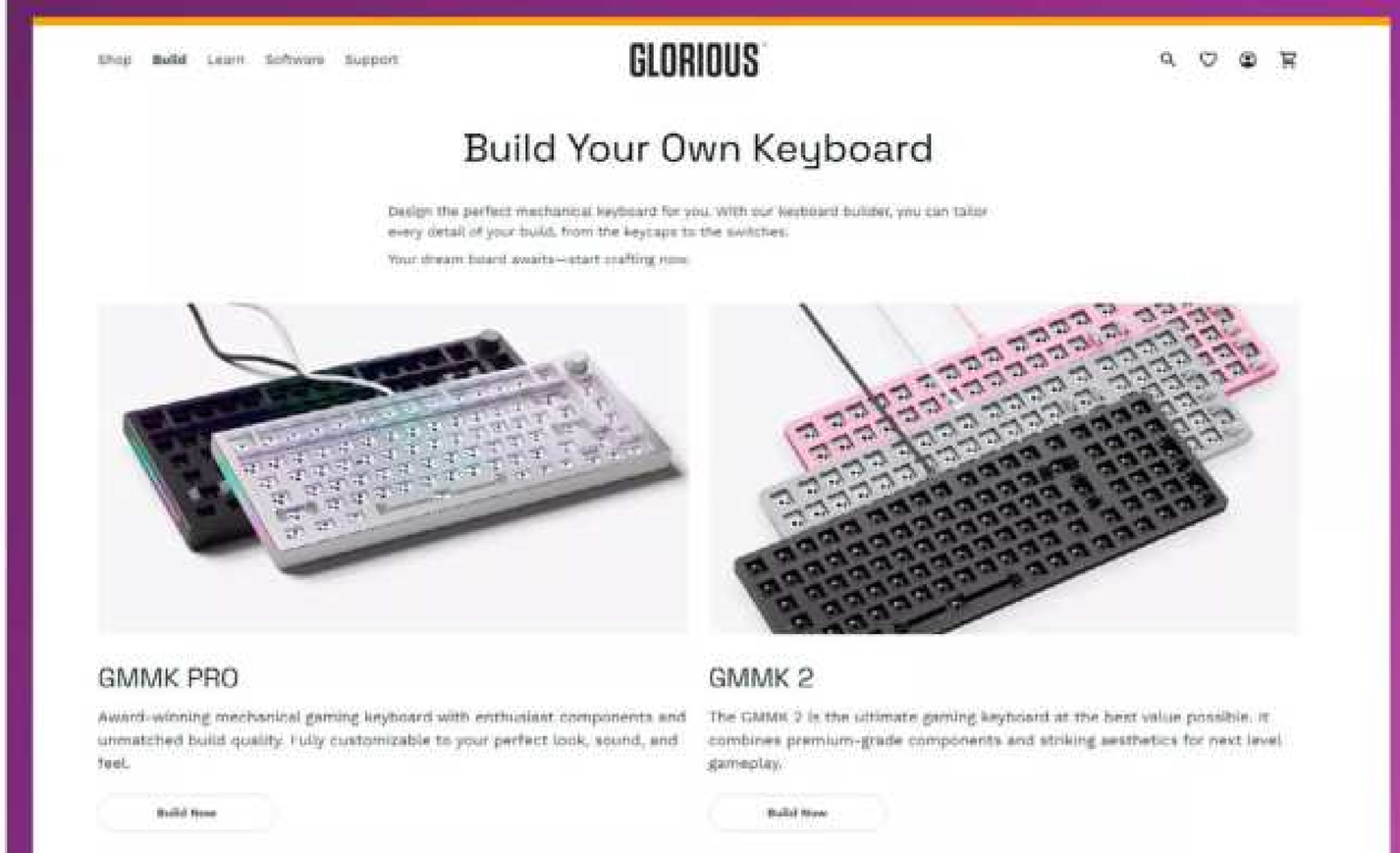
So, where are we at right now? Well, the big battles for custom gaming keyboards are happening in two key areas: keyswitch type, and optical versus magnetic. Magnetic is, although arguably the slightly superior tech, far more expensive than its optical counterpart. However, optical still touts a very similar feature set, and given that it's far more affordable, and durable to boot, it's probably the better solution for most.

We've also seen a rise in polling-rates recently as well, with a number of manufacturers pushing higher 8,000Hz polling rates as the norm. This allows your keyboard to report its inputs to your PC eight times faster than the standard 1,000Hz polling rate, theoretically reducing latency as it does so. Corsair was the first to market on this with its AXON controller. However, recently, manufacturers such as Razer, SteelSeries and even NZXT have followed suit with identical or similar speeds, along with a bevy of other manufacturers.

There's a bit of a caveat to that tech in the fact that it does have an impact on

1,000 Hz hyperpolling registers a keypress every 1ms.

The rise of Glorious

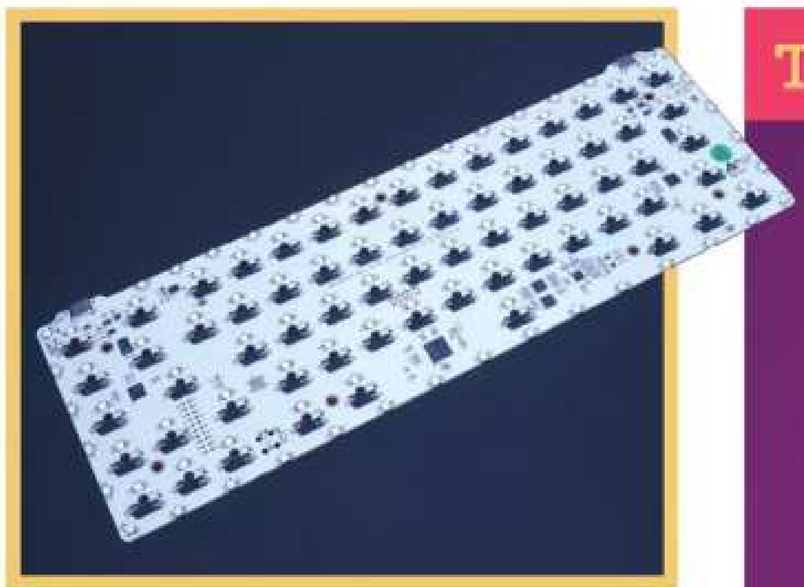


You've likely heard of Glorious. Founded in 2014, it started due to a frustration with gaming mouse mats being limited in size and scope, and set out to manufacturer its own larger solutions instead, building the first XXL mousepad.

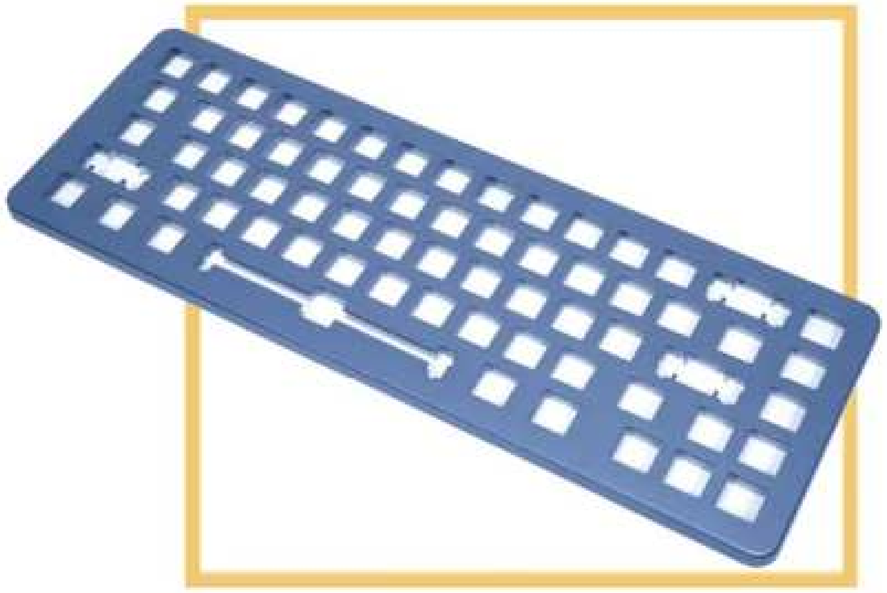
In 2016, it launched its first hot swappable keyboard, allowing you to change out switches on the fly. At the time, mechanical keyboards were still making their way into the marketplace proper, so it mostly flew under the radar.

Today, you can build your own custom board on its site, choosing everything from keyswitches and lubrication options to keycaps. Alternatively, you can buy a barebones kit and go elsewhere to get your keyswitches, too. We reviewed another custom kit, the Ducky ProjectD Outlaw 65, in our March 2024 issue.

The main part of the keyboard is the case or housing that will hold all the componentry.



The printed circuit board keeps everything tidy and lets switches be soldered to it easily.



Plates are not seen in all keyboards, but they exist in most, one way or another.

All the rage now, sound-dampening foam helps mitigate any errant pings.

overall system performance, and when it first launched, 8,000Hz hyperpolling did have a minimum system spec as well, particularly for your processor, as it ate up additional CPU cycles to process the extra data.

There's an argument to be had as to whether this is beneficial to the end user as well. The average human reaction time to a visual stimulus ranges between 100 and 475 ms, with the mean average sitting around 250-270 ms or so (you can test your own reaction time at https://humanbenchmark.com/tests/reactiontime—we managed 191ms on our best go). All, of course, is dependent on age, training, and physical condition at the time of testing. Bearing that in mind, 1000Hz is effectively 1,000 cycles per second. If you break that down, it's a cycle every ms, meaning your PC effectively registers the inputs from your keyboard 250 times by the time it's taken you to react once, and the input is recorded if not as you react, but within 1ms after. Multiply that by a factor of eight, and you get a response of 0.125 ms. We'd be curious to see the scientific data on that producing better results in-game.

Hyperpolling aside, the second major front we mentioned earlier is on the qualitative feel of these keyboards. Modders have been introducing sound-dampening foam to their custom boards for some time, and smaller, more agile manufacturers likewise have been picking this up and running with it as well. This has put more pressure on the larger manufacturers to radically change how they've produced their keyboards to incorporate it into the overall design.

Sound-dampening foam acts as a tertiary layer between the plate and the keys, reducing errant pings and clicks, and providing a smoother overall experience, at least from the auditory perspective. Additionally, this has been paired with keyswitch lubrication, to further enhance the smooth feel of each keyswitch, and also remove any additional sounds generated by the depression of the keyswitch itself. These minor elements have led to some impressive boards finally landing from the larger brands, as well as even more refinement from the likes of Glorious, Keychron, Mountain Everest, Wooting, and more.

To recap, in the modern era, experience when typing is everything, and as we spend more time in front of our PCs, working from home, or gaming late into the evening, how you interact with that tactile experience is everything.

The future?

So where do we go from here? The world of gaming keyboards has never been more competitive. As the competition heats up, we're seeing advances in fields across the board. One field in particular is in connectivity. There has been a big push recently in the world of wireless keyboards, particularly those looking to be competitive with them.

Over the years, wireless keyboards (and mice, for that matter) have had a reputation as being pretty awful when it comes to latency. Couple that with a low battery life, and usually a lackluster featureset compared to the likes of their wired brethren, and they're often disregarded.

At this year's Computex, a number of manufacturers debuted boards that re-envision that belief. Asus in particular showcased its latest Azoth Extreme keyboard, featuring an OLED display, pre-lubed ROG switches, sound-dampening, RGB, and more importantly, a wireless dongle that allows you to run the keyboard itself at 8,000Hz polling without a cable in sight. Regardless of whether you run at that rate, or believe in the hyperpolling hype, the fact that this is even possible is nothing if not impressive.

Likewise, manufacturer customization is making waves, too. Corsair recently purchased Drop for a tidy sum, and it displayed a large variety of custom keyboards, cases, and plates for its next line of keyboards too.

Asus's latest Azoth Extreme has a blisteringly quick polling rate for a wireless board.

CENTE

PERFORMANCE GEAR LA

1 DREAM STREAMER

The headphones support spatial audio with dynamic head tracking. Dolby Atmos and 360 Reality Audio tracks in Apple Music, Amazon Music, Tidal, and Deezer are supported, so you can get your spatial audio kicks.

2 GET CONNECTED

These are equipped with Bluetooth 5.4, and can play lossless audio thanks to Snapdragon Sound's aptX Lossless support. It doesn't support next-gen codecs such as Auracast and LE Audio, though Sonos says it is tracking how these codecs are developing and will adapt accordingly.

Sonos Ace

WHEN you're a company like Sonos, which has pretty much nailed the soundbar, wireless speaker, and multi-room markets, what do you do next? You set your sights on a whole new category and launch a brand new product, of course, in this case, the Sonos Ace wireless headphones.

Rumors and rumblings about a pair of cans to complement the rest of the Sonos family have been doing the rounds for a few years, and when you think about it, it's not a huge leap. If Sonos can introduce a couple of unique selling points for its customers while mastering the sound quality, then it could be quite the success story.

But Sonos is entering an area of the market that isn't for the faint-hearted. Some of the brands in the space are huge hitters, and were making headphones before Sonos was even born. The likes of Apple, Bose, Bowers & Wilkins, Sennheiser, and Sony all have sensational Bluetooth, over-ear noise-canceling headphones that we have tested and rate highly. They won't make life easy for the Sonos Ace.

Still, Sonos's strength is its ecosystem, combined with strong sound quality. The Sonos Ace can pair with your Sonos Arc (support for other soundbars is promised via update later this year) to instantly and seamlessly take the sound from your 'bar and pump it into your ears, using head-tracked 3D spatial audio. Will that be enough to make these new cans stand out in an awfully crowded market? It will be interesting to find out. –**MAXIMUM PC**

3 SLEEK DESIGN

We particularly like how the hinges and joints are concealed in the body. It offers an elevated look, and ensures that those with long hair won't get it caught when moving them. As is the trend, the earcups swivel flat, but don't fold up, while the replaceable earpads are attached to the frame by strong magnets.

BUILD THE ULTIMATE RESCUE DISC

Nick Peers on how to prepare for the worst

Everybody needs some form of rescue disc—the problem is there are so many to choose from. Keeping a drawer full of USB flash drives can be a pain, but did you know that you can keep all the recovery tools you need on a single USB flash drive? Splash out on a 64GB or 128GB drive, pair it with the right software, and it can house all your recovery discs, complete with boot menu, allowing you to switch as required.

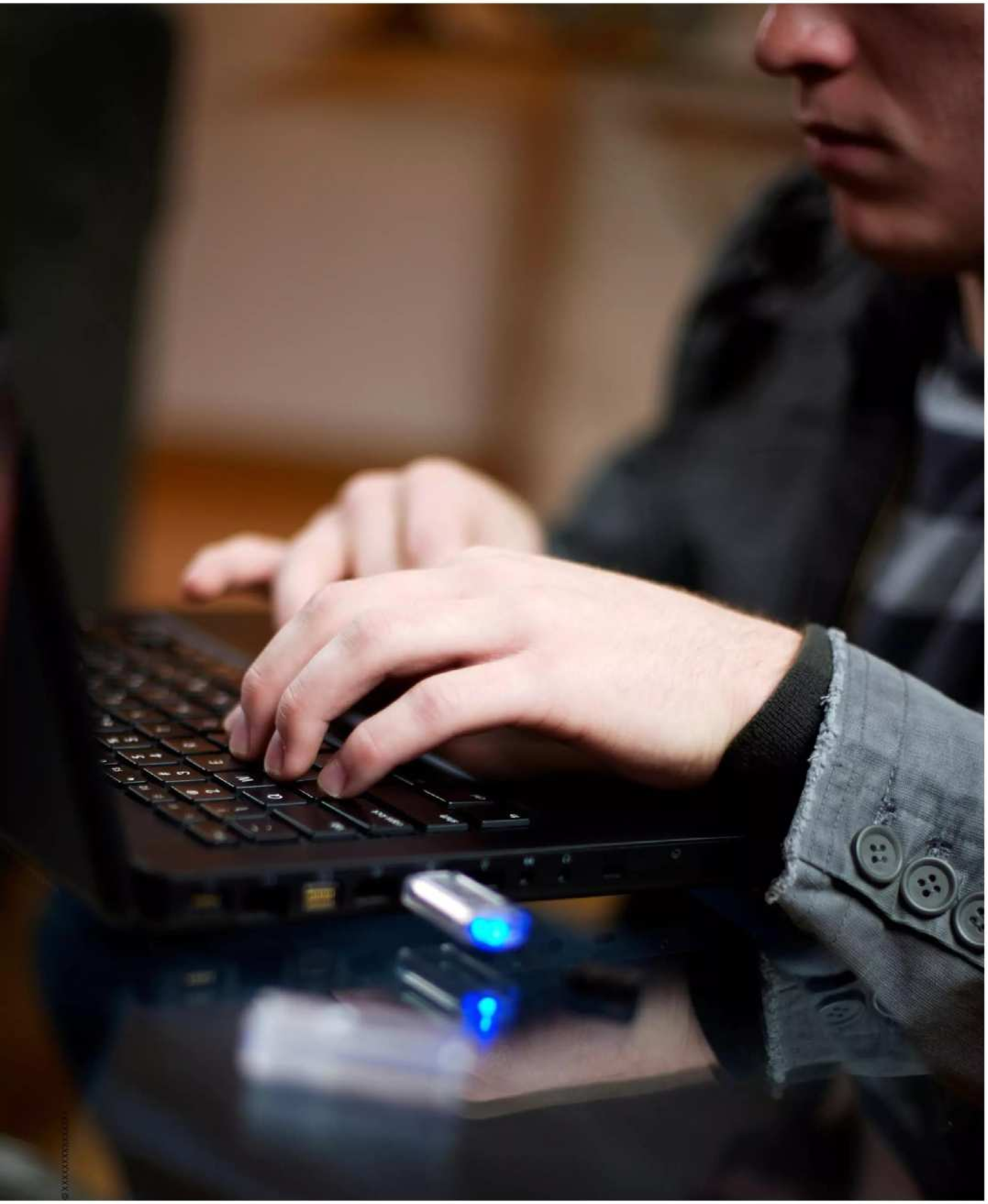
Fantastic news, but what recovery media do you need, where do you find it, and how do you add it to your all-encompassing recovery media? In this feature, we'll show you how to set up your recovery media to make the process of adding recovery tools a case of little more than copying ISO files to your flash drive. When new versions of your recovery media emerge, simply download the latest ISO file, and copy it over the original copy to update it.

We'll show you where to look for the best targeted recovery tools, from malware removal to Windows recovery, plus reveal how to build your own customized Windows 'live' environment, so you can use your favorite fix-it tools in an environment that you're familiar with. Without further ado, let's build the only rescue disc you'll ever need.

Let's start at the beginning. You'll need two items to get your ultimate recovery media up and running. One is a USB flash drive, the larger the better (although 64GB should suffice in most cases). The other is the tool required to transform your flash drive into a Swiss army knife by allowing you to store multiple rescue discs on a single drive. That tool is Ventoy (www.ventoy.net), and it's incredibly simple to set up and use. For the purposes of this feature, follow the instructions in the box to make your USB flash drive ready for use.

ADD SECURE BOOT SUPPORT

Once you've installed Ventoy, you need to make sure that you can use it on your PC. The biggest hurdle is if Secure Boot is enabled on your PC, as it will be in many cases. On booting from the drive, you'll likely be presented with a 'Verification failed (0x1A) Security Violation' message. Press Enter, followed by any key, to perform MOK management. Select 'Enroll key from disk', choose your drive (VTOYEFI in most cases), and then pick 'ENROLL_THIS_KEY_IN_MOKMANAGER.cer'. Choose Continue > Yes > Reboot.



You should now find yourself at the main Ventoy screen—there won't be any options to boot from, so press F4 for 'local boot' to return to Windows proper. Going forward, this enrolment means that you can use the Ventoy boot disk on your own PC—you must repeat the process for every other PC you use the disk on. If you're unable to get it to work with Secure Boot, recreate the disk with 'Secure Boot Support' disabled, then remember to disable Secure Boot on your PC whenever you need to use the disk.

All you need to do now is download any bootable media as an ISO file and copy it to your USB flash drive. ISO files can be copied directly to the root of the drive, or you can store them in folders—press F3 from the Ventoy menu to switch to 'TreeView' to allow you to view by folder instead of seeing them all in a single list.

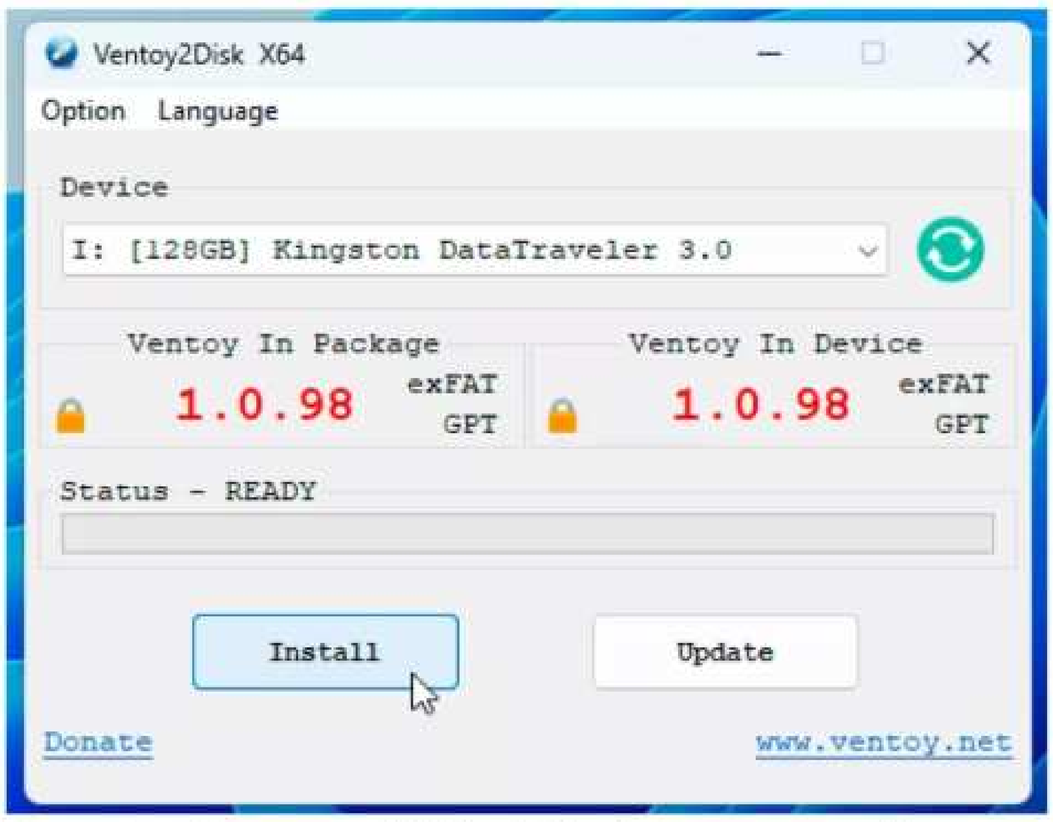
Once you've copied a couple of ISO files to your drive, it's time to test that they work correctly. Reboot your PC again, and this time you should see the filename of each ISO displayed. Use the cursor keys to select one, and press Enter. If all works as it should, the ISO should boot as if it were physical media, giving you access to whatever tools it contains.

BUILD YOUR ULTIMATE RESCUE DISK

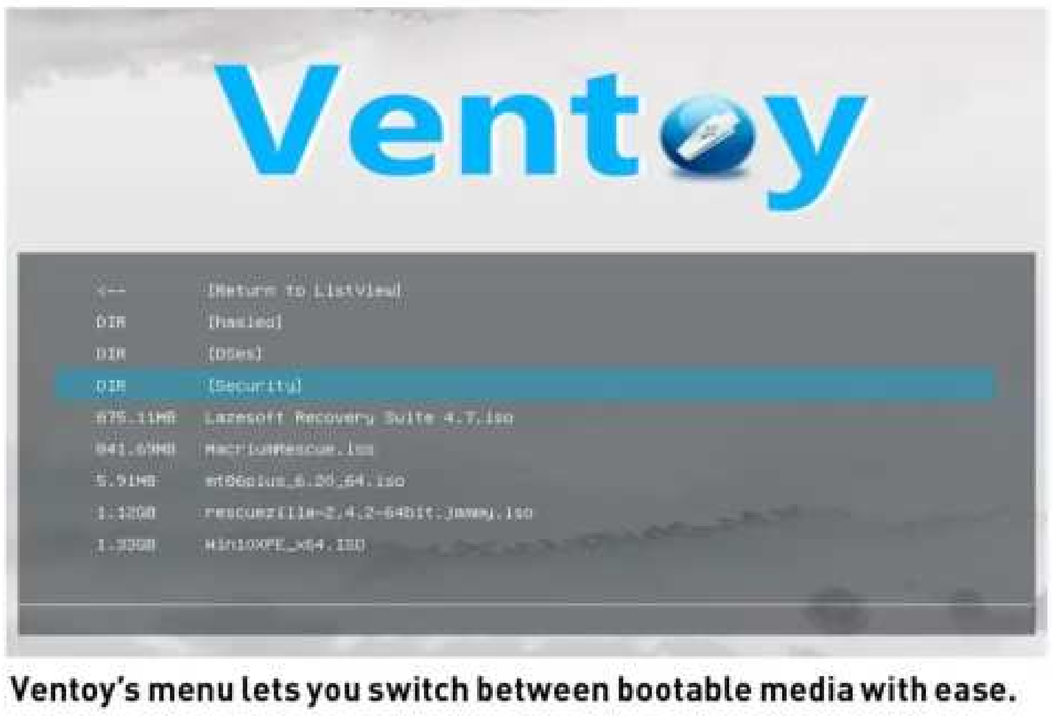
The first thing to do is add to your rescue disk as the installation media for your current version of Windows. Windows 11 users can download an ISO file directly from www.microsoft.com/software-download/windows11, but Windows 10 users should hold off for now—you'll be able to download the latest Windows 10 ISO directly using Win10XPE's Winbuilder tool later (spoilers!).

Our next recommendation is Lazesoft's Recovery Suite Home Edition (www.lazesoft.com). This contains four tools in one, all accessible via a user-friendly point-and-click interface that may feel a little dated, but is still straightforward to use. We include it for two of its four tools: Windows Recovery can automate many repairs that prevent Windows from starting, while Data Recovery can be used to both copy data from a crashed Windows boot drive and attempt to recover deleted files and other data from formatted or lost drives.

Lazesoft requires a working version of Windows, so build the rescue media now before disaster strikes. After downloading and launching the main program, click the 'Burn CD/USB Disk' option to create your recovery media in ISO form. Leave 'Same as this computer' selected, and click Next. Choose ISO image and select your USB flash drive as the destination, then click Start. When complete, an lsboot.iso file should be on your flash drive—consider renaming this to something more easily identifiable from the Ventoy boot menu, like Lazesoft Recovery Suite 4.7.iso.



Ventoy transforms your USB flash drive into recovery media.



Ventoy's menu lets you switch between bootable media with ease.

FIX PROBLEMS USING LAZESOFT

Should you ever need to use the Lazesoft tool, select it from the Ventoy menu, and hit Enter at the boot selection screen. You'll see the familiar Windows logo appear before it's replaced by the main screen, a facsimile of the main Windows interface with a pop-up window providing shortcuts to Lazesoft's four primary tools. Note the Start menu button—clicking this reveals various shortcuts, as well as access to Microsoft tools like Task Manager (you'll need this if the Recovery Suite home page vanishes).

If you're trying to fix a non-booting Windows installation, choose Windows Recovery. Make sure your Windows install is selected from the list, and click OK to access the full suite of recovery tools. The obvious first port of call is the 'One Click Fix Crash' solution—this is a relatively risk-free option, as it comes with an undo button should the fix fail, and you find yourself back in the Lazesoft tool.

Other tools are placed in specific categories such as BootCrash, LoadingCrash, and so on. Click a tool to read a description and access the all-important button for triggering it. Look out for the FinalSolution tab with instructions on how to reinstall Windows while minimizing data loss using Lazesoft's other tools.

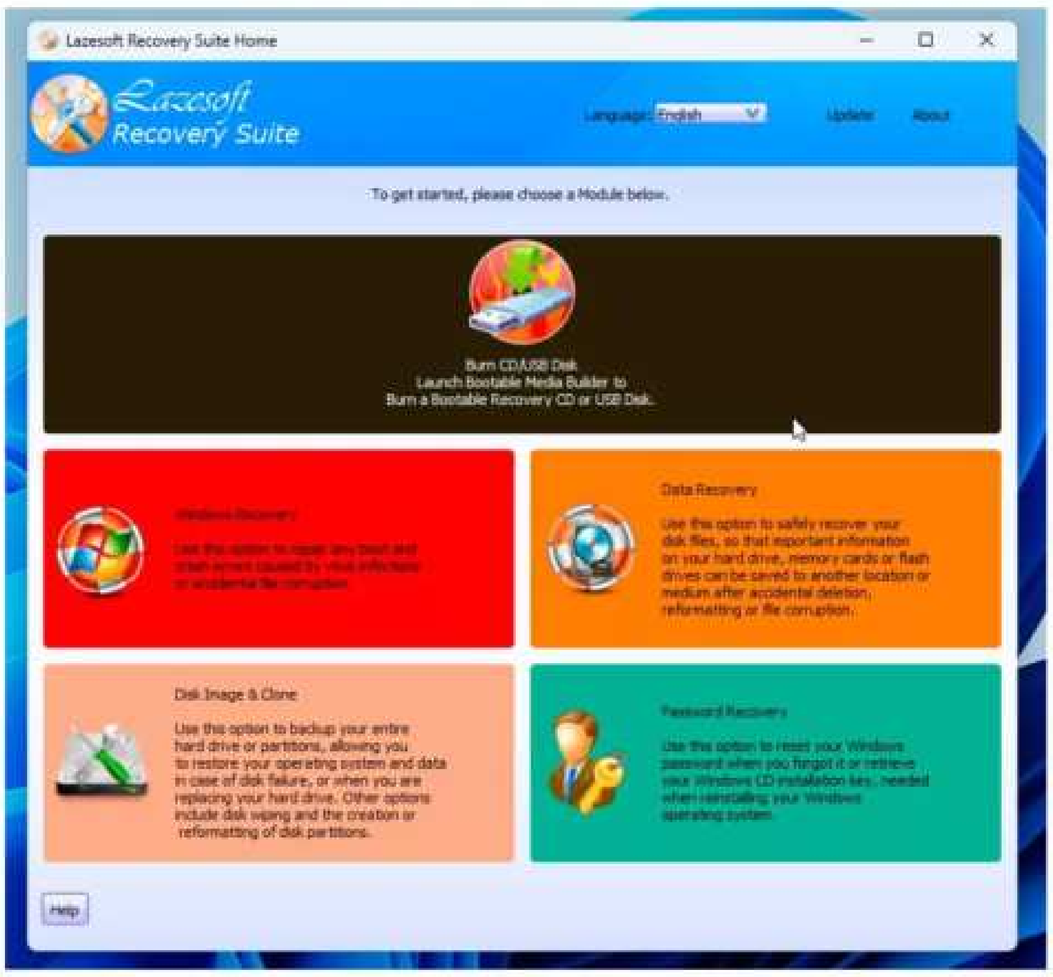
RECOVER LOST AND DELETED FILES

Lazesoft's Data Recovery Wizard provides four tools for recovering data from drives: Fast Scan is designed for recovering undamaged data from working drives, while Undelete allows you to search for deleted files from uncorrupt file systems. The final two tools—Unformat and Deep Scan—deal with problematic partitions. Unformat is a simple recovery tool from accidentally erased drives, while Deep Scan attempts to recover partitions before offering files for recovery.

The tools are all simple to use—select your target partition or drive, click Options for advanced settings (simple file recoveries have none to choose from) and then click Start Search. As with all data recovery options, never recover files to the same drive, so plug in a USB drive if you need somewhere to copy them to.

ONE RECOVERY ENVIRONMENT TO RULE THEM ALL

The 'More tools...' box reveals more specialized tools that you can add to your recovery media, from anti-malware tools for dealing with stubborn malware to an open-source memory testing tool. But what happens if these tools can't fix your problem? Lazesoft's data recovery tools are easy and simple to use, but they may not be as effective as a dedicated tool like DMDE (www.dmde.com), for example. Similarly, you might prefer to work with other familiar tools, in which case you'll want to build a single recovery environment to work in, one that lets you pick and choose which tools you use.

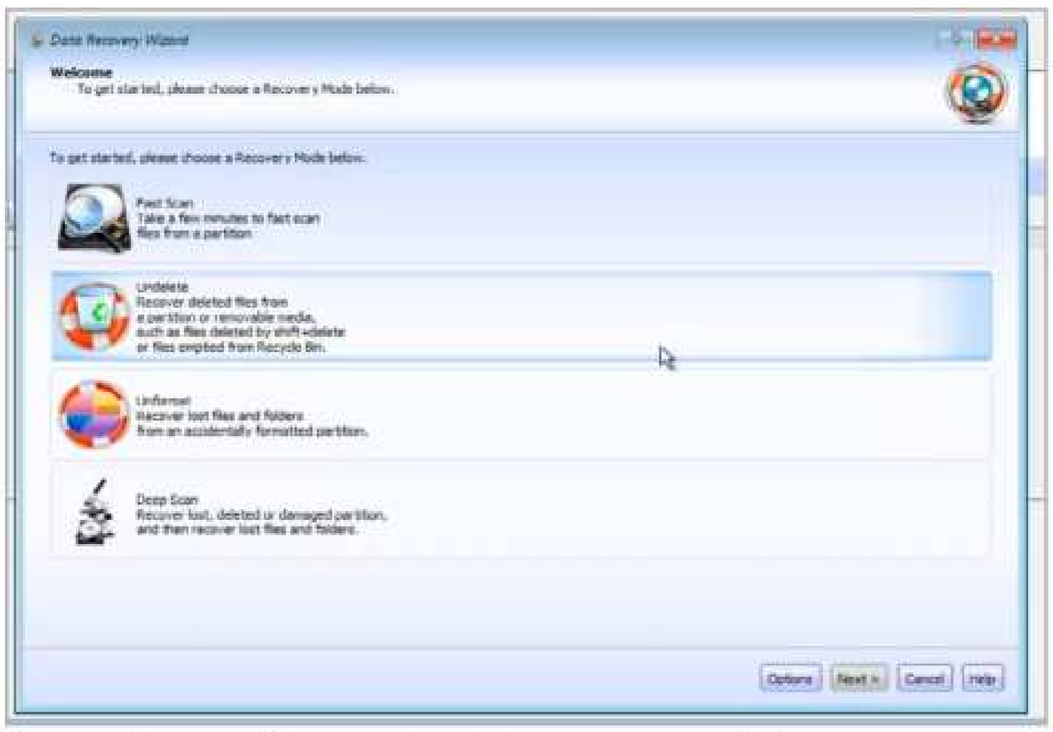


Install Lazesoft in Windows to create your rescue media.

What we're looking for is one built on Windows PE (Preinstallation Environment), which lets you run a live Windows install like you can with Linux installation media, and is the bedrock of tools like Lazesoft. The advantage of building your own WinPE environment is that you get access to a wider range of Windows tools, plus run portable applications from it, allowing you to place these in a separate folder on your Ventoy rescue disk.

The tool we're going to use is Win10XPE, which takes a Windows 10 or 11 ISO and allows you to customize it. Note that because the tool hasn't been updated in around a year, some of the optional modules will either fail to compile or prevent the recovery environment from loading successfully—we detail these in the box to leave you with a fully working version of Windows PE.

Start by visiting https://github.com/ChrisRfr/Win10XPE and downloading the source code (zip) file to your Downloads folder. Once done, extract the folder within, then open 7-Zip (www.7-zip.org) and navigate to the Win10XPE-Win10XPE_2023-08-23 folder in the left-hand pane. Right-click the first 7z.001 file and choose Combine Files. A new dialog should appear confirming all three 7z files have been selected. Click OK to combine them all into a single 7z archive. When it appears, select the file and click the Extract button and allow it to extract the contents into its own Win10XPE sub-folder.



Lazesoft can perform various data recovery techniques.

SET UP VENTOY ON YOUR BOOTABLE DRIVE

You can download a standalone version of Ventoy in zip format from https://ventoy.net/en/download.html, or add it to an existing PortableApps.com toolkit (choose 'Apps > Get More Apps > By Category'—it's under Utilities). Once installed or extracted, connect your flash drive and open Ventoy, clicking Yes when prompted to give it administrator access.

When the main screen appears, verify that your USB flash drive is selected under 'Device', then check the 'Ventoy in Package' settings, which lists the drive type (exFAT, which is fine) and partition table (MBR). Press Win + R, type msinfo32 and press Enter, then verify BIOS Mode from the System Summary screen—in most cases, this will be set to UEFI, in which case select 'Option > Partition Style > GPT' to change the partition table to match your PC setup. Also check to see if Secure Boot is enabled on your PC—again, you can do so from the msinfo32 System Summary screen. If it's switched off, select 'Option > Secure Boot Support' to uncheck it.

Now, click the Install button, read the warning, and click Yes twice. This is a destructive process—all data on the drive will be wiped. Unless you have a compelling reason to keep data on the drive (in which case, we'd suggest copying it off and back on after Ventoy is installed), this should be fine. If it's not, visit www.ventoy.net/en/doc_non_destructive.html for a potential workaround.

Ventoy will install itself to your USB flash drive—once complete, click OK, and verify that 'Ventoy in Device' matches 'Ventoy in Package'. If it does, your USB flash drive is bootable and ready for use. Going forward, Ventoy occasionally releases new versions. After updating Ventoy, launch the app and verify that 'Ventoy in Package' is a newer version. Click Update to update your flash drive without losing ISO files.

Make sure you set the correct partition type for your PC.

MORE TOOLS FOR YOUR RECOVERY DRIVE

Lazesoft's Recovery Suite is just one tool you can add to your Ventoy flash drive as an ISO file. If you'd rather run dedicated tools than rely on a single recovery environment, you'll find plenty online. If they can be downloaded in ISO format, they can be added to your recovery media.

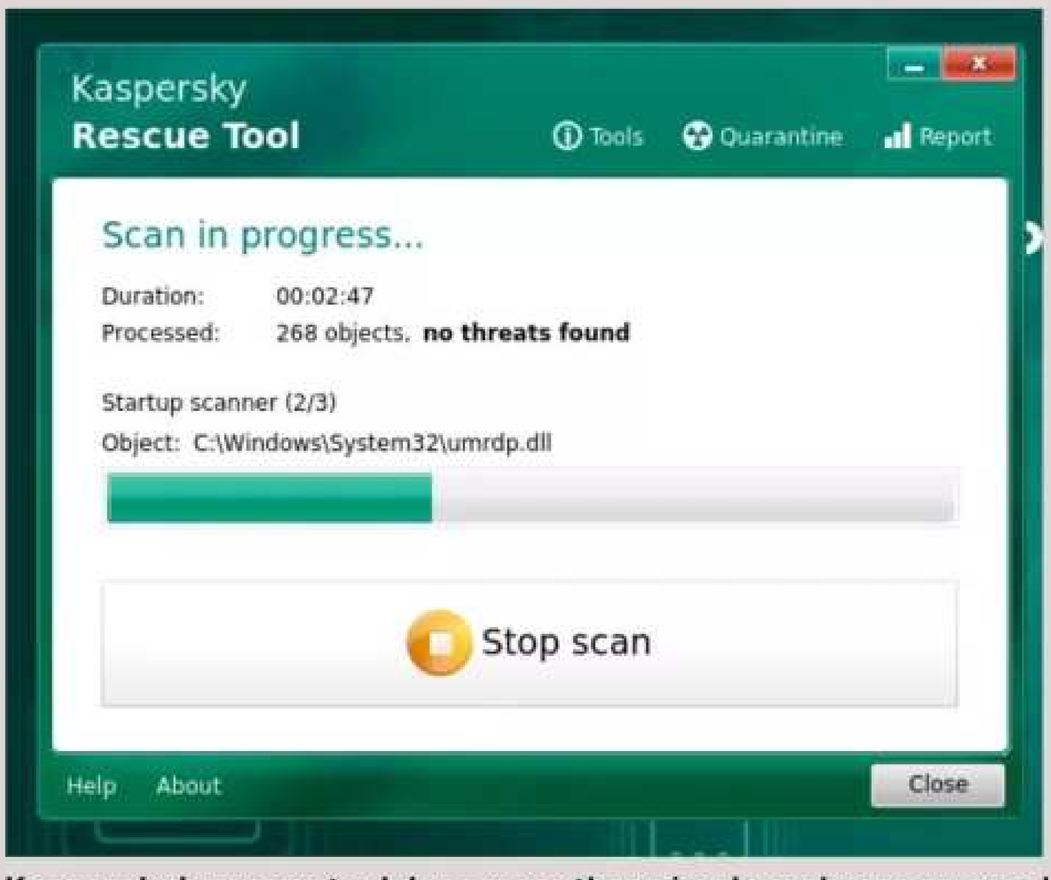
One major category is bootable security tools, which specialize in scanning hard drives for threats. They include Norton Bootable Recovery Tool (https://support.norton.com/sp/static/external/tools/nbrt.html), Kaspersky (www.kaspersky.com/downloads/free-rescue-disk), and Panda Cloud Cleaner (www.pandasecurity.com/en/support/card?id=1681). Choose the DVD or ISO version rather than the USB.

If you use Hasleo Backup Suite (www.hasleo.com) or Macrium Reflect (www.macrium.com) to take drive images of your system, make sure you create recovery media in these, too—again, choose the ISO file, and copy it to your Ventoy rescue disc.

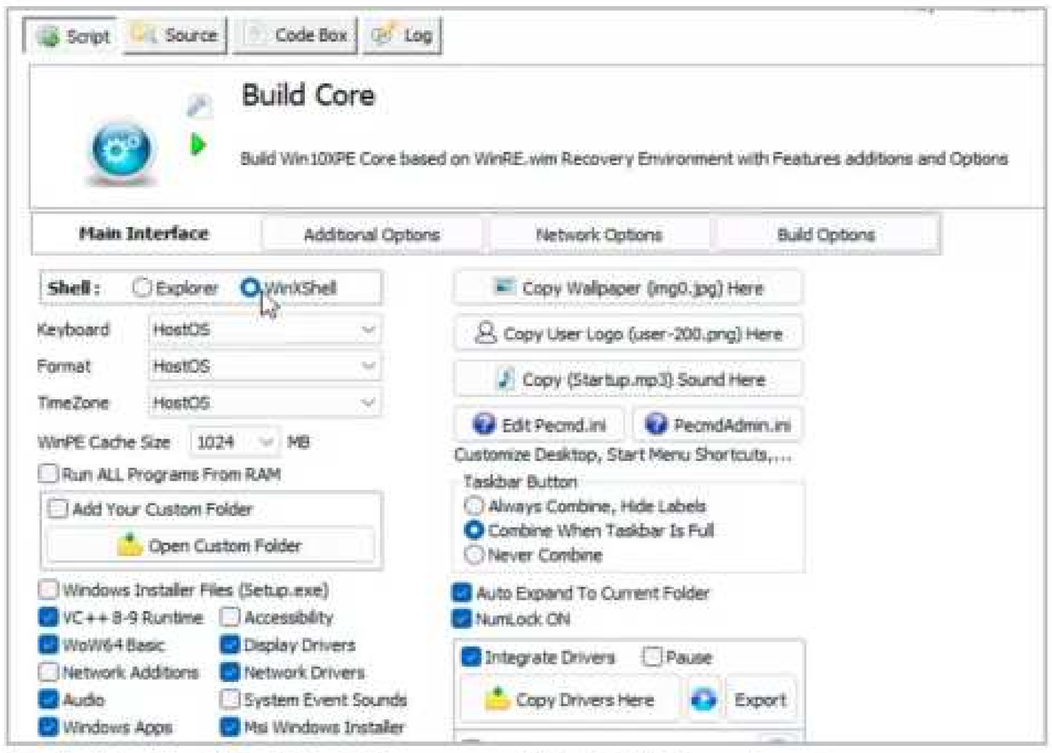
Another standalone bootable tool worth incorporating includes the open-source Memtest+ (https://memtest.org) for memory checks.

Also, consider your favourite flavor of Linux—the vast majority of Linux installation discs provide a 'live' environment for testing and recovery purposes, including Ubuntu (https://ubuntu.com) and Linux Mint (https://linuxmint.com). Linux users should add SystemRescue (www.system-rescue.org) for system repair and data recovery, and RescueZilla (https://rescuezilla.com) for creating and restoring drive images.

Last but not least, if you're struggling to get Win10XPE working, or want a no-fuss, zero-configuration Windows recovery environment, download the latest version of Hiren's BootCD (www.hirensbootcd.org). At over 3GB, it's one of the larger ISO files, so be prepared to wait for the download to complete.



Kaspersky's rescue tool does more than simple malware removal.



Switch to the WinXShell to ensure Win10XPE can boot.

BUILD YOUR WINDOWS PE DISC

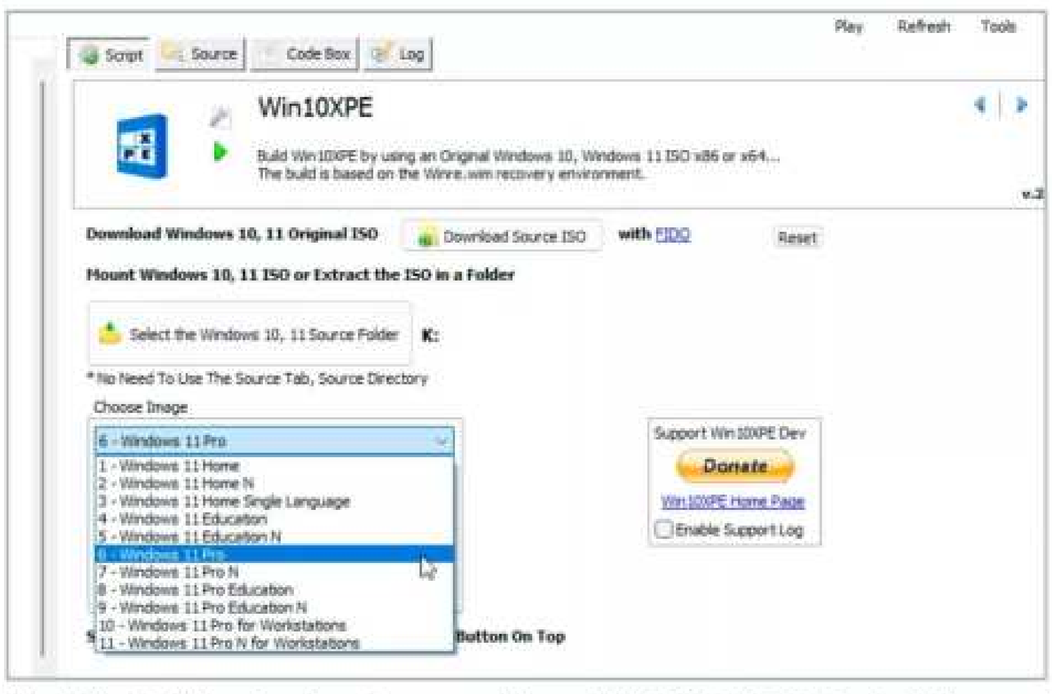
Once done, quit 7-Zip and manually navigate to the Win10XPE_2023-08-23\Win10PXE folder in File Explorer. Double-click Win10XPE.exe to launch the WinBuilder tool. If you've not yet downloaded a Windows ISO, click 'Download Source ISO' and wait for the Fido—Feature ISO Downloader—window to open. From here, go through the various options picking, your target Windows version (10 or 11), release, edition, language—be sure to switch to English (United States)—and finally, architecture (x64 in most cases) before clicking Download.

Once downloaded, double-click the ISO file to mount it in File Explorer, return to WinBuilder and click 'Select the Windows 10, 11 Source Folder' to select the virtual drive, and click OK. It'll be mounted, and you'll return to the WinBuilder screen, where you'll need to select your chosen edition (Pro is usually the best choice).

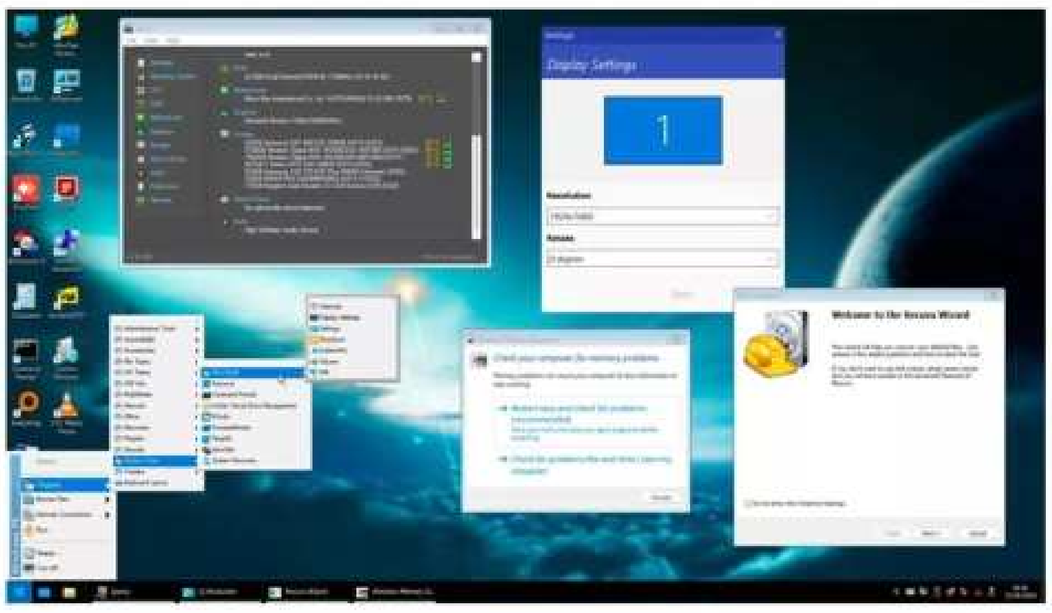
Once done, select 'Build Core' to set up your core preferences. The only setting that requires changing for Win10XPE to boot successfully is Shell—Explorer doesn't work with the latest Windows builds, so you'll need to select WinXShell. Feel free to explore other tweaks, but be prepared to undo them if you can't get Win10XPE to boot successfully after building the ISO.

ADD TOOLS TO YOUR DISC

Before proceeding, check out the 'Customize your WinPE build' box for some ideas on how to add key functionality to your Win10XPE environment through integrating additional apps or adding your own collection of trusted portable tools, such as the aforementioned DMDE data recovery tool and the Emsisoft



The WinBuilder tool makes creating a Win10XPE ISO straightforward.



Win10XPE provides a familiar environment to troubleshoot from.

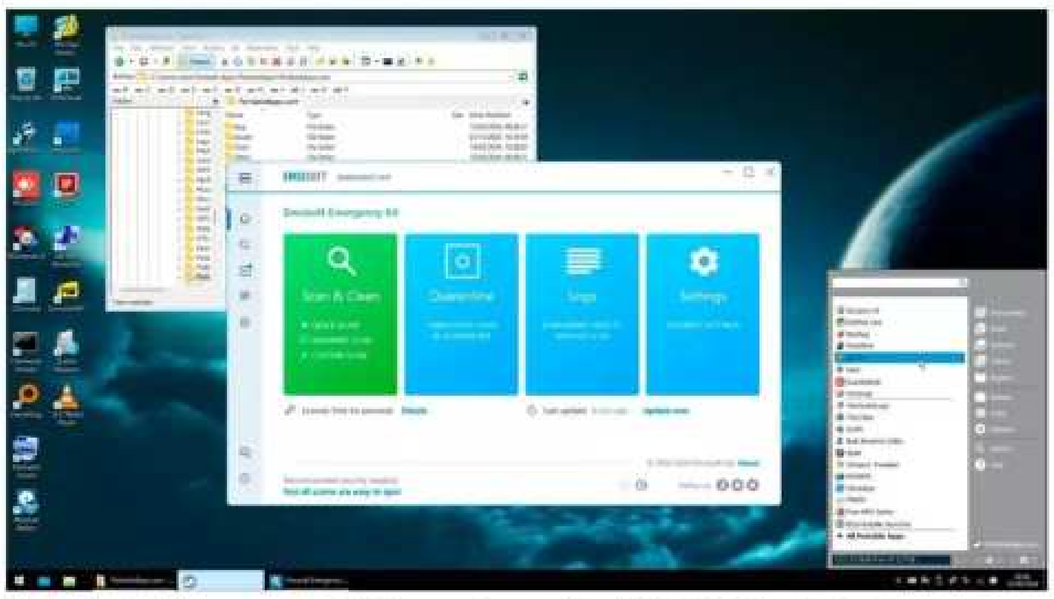
Emergency Kit malware remover tool (www.emsisoft.com/en/home/emergency-kit).

Once you're ready, click the blue Play button, follow any prompts, then wait for the custom ISO file to be created. If you run into errors, they're likely to refer to apps you've selected. Uncheck these, then re-run the script. On our Windows 11 machine, we had to uncheck Media Transfer Protocol (Components), AOMEI Partition Assistant (HD Tasks), Chrome (Network), and ProduKey (Security). We replaced the former with MiniTools Partition Wizard. If you're desperate to include them, or need other help, visit www.tenforums.com/software-apps and click the Win10XPE sticky thread to post your query or see if someone else has had similar problems. When the ISO file has been created, it'll be placed in the Win10PXE directory.

BOOT TO WIN10XPE

Restart your PC, select your USB flash drive as your boot device, then choose Win10XPE_x64.EXE. You'll see some familiar-looking screens, then the PE Network Manager will attempt to connect you to the internet by Wi-Fi or Ethernet cable. After this, the WinXShell desktop should boot—if you're left with a blank screen, press Ctrl + Alt + Del to bring up Task Manager, switch to the Processes tab, and end the WinXShell process.

You'll find yourself at a familiar-looking Windows desktop, which works in practically the same way as Windows itself. All incorporated tools can be accessed via its Start menu, and you can use the file manager to browse to the folder containing your portable apps. You can now proceed to attempt to fix whatever's ailing your PC—from running a selection of malware removal tools to recovering data, running repairs or—as a last resort—backing up your PC via a fail-safe drive image, then wiping the drive and reinstalling Windows from scratch, all from a single USB flash drive. Good luck, and don't forget to email the Doctor if you need help with this or any other PC-related problems.



Run virtually any portable app from the Win10XPE desktop.

CUSTOMIZE YOUR WINPE BUILD

When it comes to configuring WinBuilder to craft the perfect recovery environment, start by examining the left-hand pane to see what will make up your Windows PE environment. Leave 'Basic Build' unchecked, and expand 'Apps', followed by the categories to see what extra tools can be included. Click one for a description. You'll find plenty of familiar names, and it's worth exploring, as there are a choice of tools for some categories, such as two partition managers in HD Tasks.

We also recommend adding some others to improve your recovery environment's capabilities: HD Tune and WizTree (HW Info), VLC Media Player (MultiMedia), Avira PC Cleaner and McAfee Stinger (Security), and NSudo—Run As Trusted Installer (System Tools). Don't forget to leave out any tools mentioned in the main text—these led to errors that prevented us from successfully building our Win10XPE ISO file.

Finally, expand the Utilities section to find more tools you can download or configure. Work your way through them—the Mega Optional Application Download offers additional tools, including office suites, in case you need one. The tools are a little out of date, and there are no descriptions, so Google filenames to find out more (Comodo Cleaning Essentials is another malware remover tool, for example).

You can also run portable apps directly from the Win10XPE environment. If you already have a portable toolkit on a folder stored on your hard drive, then assuming the drive remains accessible, you'd be able to run tools directly from that. However, if this is the drive containing your Windows files or data you're looking to recover, we recommend not using them; instead, copy them to a dedicated folder on your Ventoy drive (another fringe benefit of this approach is that the tools could be used on any PC you run Win10XPE on).

WinBuilder can incorporate additional tools into Win10XPE.

SUBSCRIBE TODAY

Find your next great read

On iOS & Android!

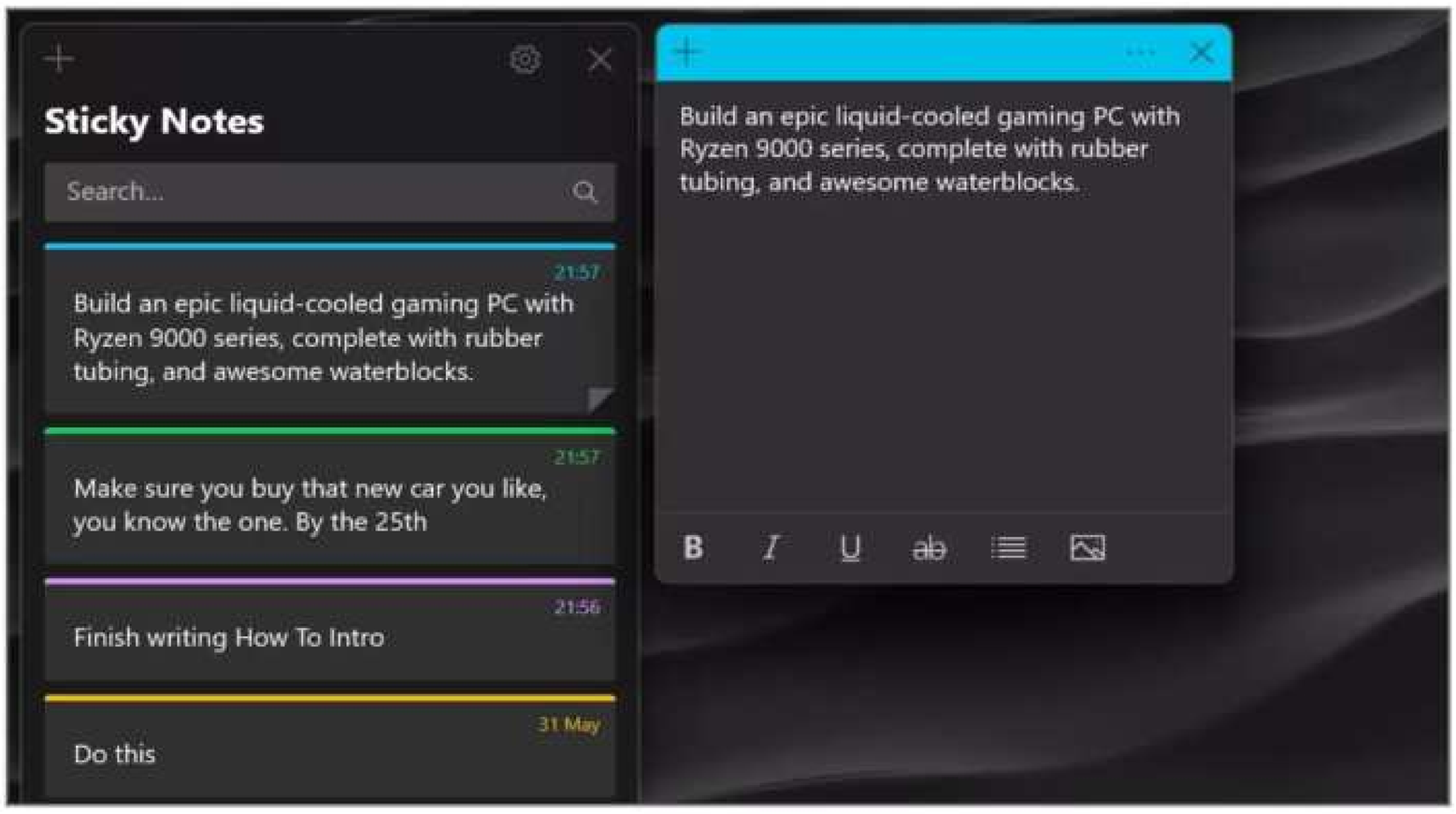
Subscribe today and get instant access on your iPad, iPhone or Android device.

www.magazinesdirect.com/B3XMPC

HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH

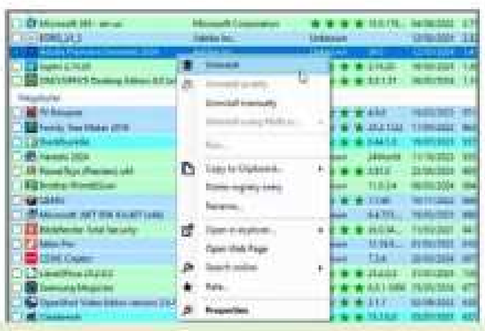


WINDOWS STICKY NOTE

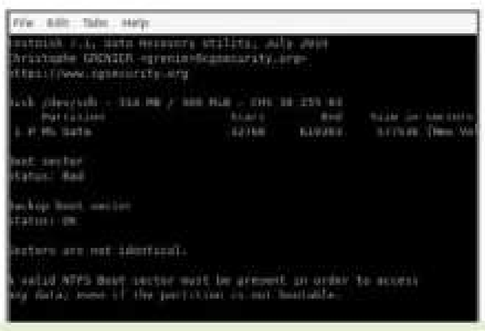
Are you an organizational mess, like this editor? Got too many things to keep track of, and not enough time in the day? Do you constantly stare at your PC monitor thinking, "I know I need to do something right now"? Why not try Sticky Notes? Hit the Start menu, type 'sticky notes', and open it up. You can create a complete to-do list or sticky notes, and slap them over your desktop, so you don't forget that important deadline.

MAKE – USE – CREATE

60
Audacity 3.5 masterclass



64
Clean and optimize your PC for free



68
Recover deleted files

© MICROSOFT, AUDACITY

ZAK STOREY
CONTRIBUTOR

SPINNING PLATES

Recently, I got massively distracted by *Baldur's Gate 3*. I tried it on PS5 first, and found it a bit tedious. However, a buddy came over, moaned at me for not playing it on PC where it belongs, and $70 and 60 hours later, I've finished my first (and hopefully last) playthrough.

I'm fully back now and firing, yet I've been finding it difficult to keep fully focused and organized. I've got spreadsheets on spreadsheets to manage my finances, training, and deadlines, but the hardest part is sitting at the PC and writing copy without getting distracted. There are emails to manage, clients to keep happy, invoices to send, and payments to chase, expenses to log, not to mention the benchmarking, building, and writing that I actually love doing.

I've tried to stay on top of it, using special work timer plugins for the Steam Deck, Chrome extensions, you name it. I even tried out a custom Rainmeter plugin with a note system so I could list my deadlines on my desktop. It's been somewhat successful, but I feel like I could be doing more. I've got a lot of projects that I need to stay on top of. Please, if you do have any advice, or plugins, or programs to help me stay focused, I'm all ears, send them my way.

↘ submit your How To project idea to: editor@maximumpc.com

Audacity 3.5 MasterClass

YOU'LL NEED THIS

AUDACITY 3.5X
www.audacityteam.org/download
80 MB disk space

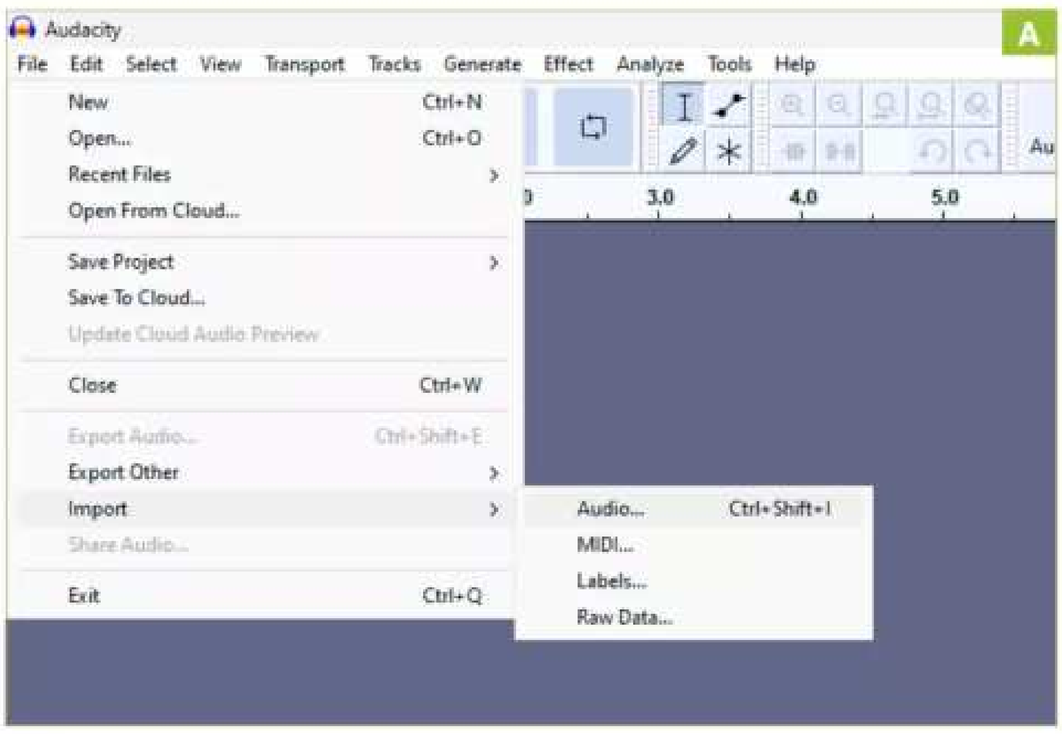
FFMPEG LIBRARY
(Optional)
27.5 MB disk space

FOR ALMOST 24 YEARS, Audacity has been one of the most popular open-source audio recording and editing apps. This is partly down to its extremely simple interface, which allows beginners to easily begin adding and mixing their own tracks.

In April 2024, the developers released Audacity 3.5 with some innovative new features. Chief among these was the ability to save projects to the cloud with an audio.com account. Users can even upload sound files to share with others. (Exporting files locally is still supported).

Audacity can also now automatically detect and adjust the tempo of imported clips, as well as non-destructively change their pitch. The software's functionality can be expanded through downloading plugins to add new themes and audio effects. In the latest version, however, the plugin manager has had an overhaul. The interface is far simpler, and it's easy to filter plugins.

In this tutorial, we'll cover the basics of setting up Audacity, as well as the FFmpeg library, to ensure the software supports importing/exporting a range of sound formats. You'll learn how to add multiple audio tracks, record vocals and even label sections for editing purposes. You'll also learn how to apply effects, as well as how to save and export projects. **–NATE DRAKE**



1 AUDACITY SETUP

Audacity is available for install via www.audacityteam.org/download. As you'll see, the software is available for both 32-bit and 64-bit systems, and there are no specific GPU/CPU requirements. While you're on the download page, you may want to download the offline manual for Audacity for reference later.

» Due to patent restrictions, Audacity doesn't ship with the FFmpeg library, meaning it can't import and export certain audio formats, like M4A and WMA. On the plus side, the latest version of Audacity does natively support the MP3 format.

» If you plan to use proprietary audio formats like M4A, visit https://lame.buanzo.org/ffmpeg.php and scroll down to the section marked 'FFmpeg Installer for Audacity 3.2 and later'.

» From here, you can click on the relevant installer link (most likely for '64-Bit Windows'). If Audacity is already open, make sure you restart before continuing.

» Upon launch, Audacity will automatically check for updates and prompt you if one is available. The most recent version also has a helpful video tutorial that explains the new features of Audacity 3.5.1 in detail.

» Before getting started, go to 'Edit' > 'Preferences' to view your default audio settings. Pay careful attention to both the 'Playback' and 'Recording' sections. You can use the drop-down menus here to change your input and output devices, e.g. to have Audacity choose a USB microphone over the one built into your laptop.

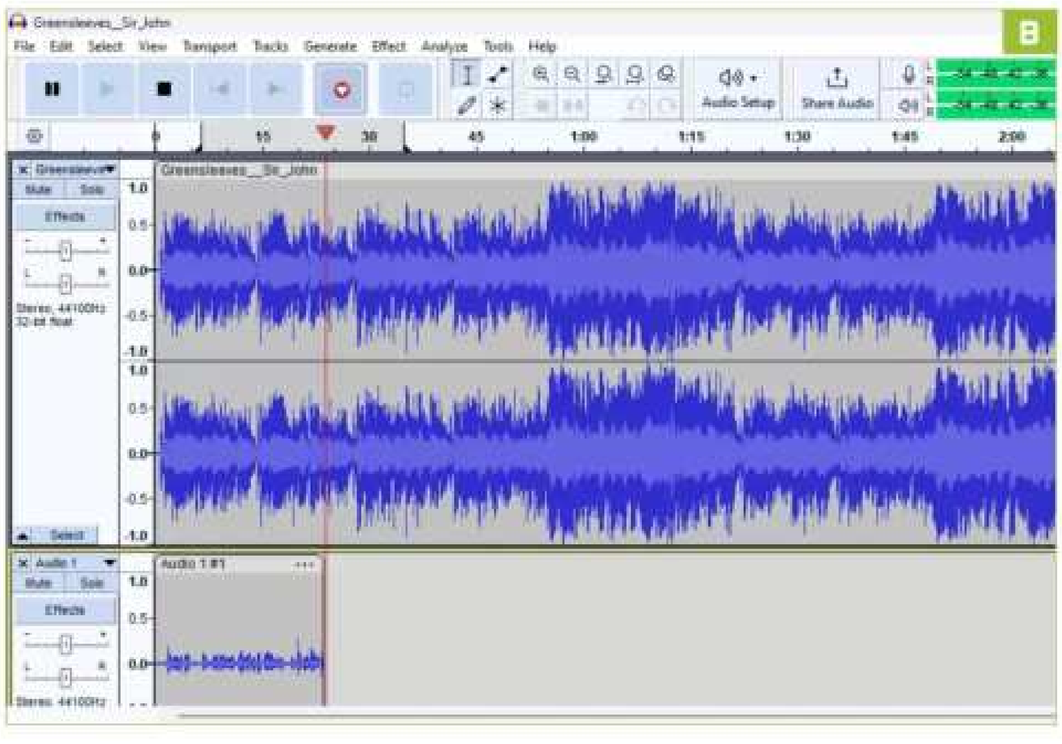
» Once these settings are confirmed, click into 'Interface' in the left-hand pane. Here, you can change the app language, as well as configure the theme. If you plan to work on large projects, we also recommend enabling 'Beep on completion of longer activities'.

2 IMPORT AND PLAY AUDIO

By default, Audacity supports importing audio files in AIFF, AU, FLAC, MP2, MP3, OGG Vorbis, and WAV format. If you chose to install the FFMpeg library in the previous step, then a great many more formats will be supported, provided they're not protected by DRM.

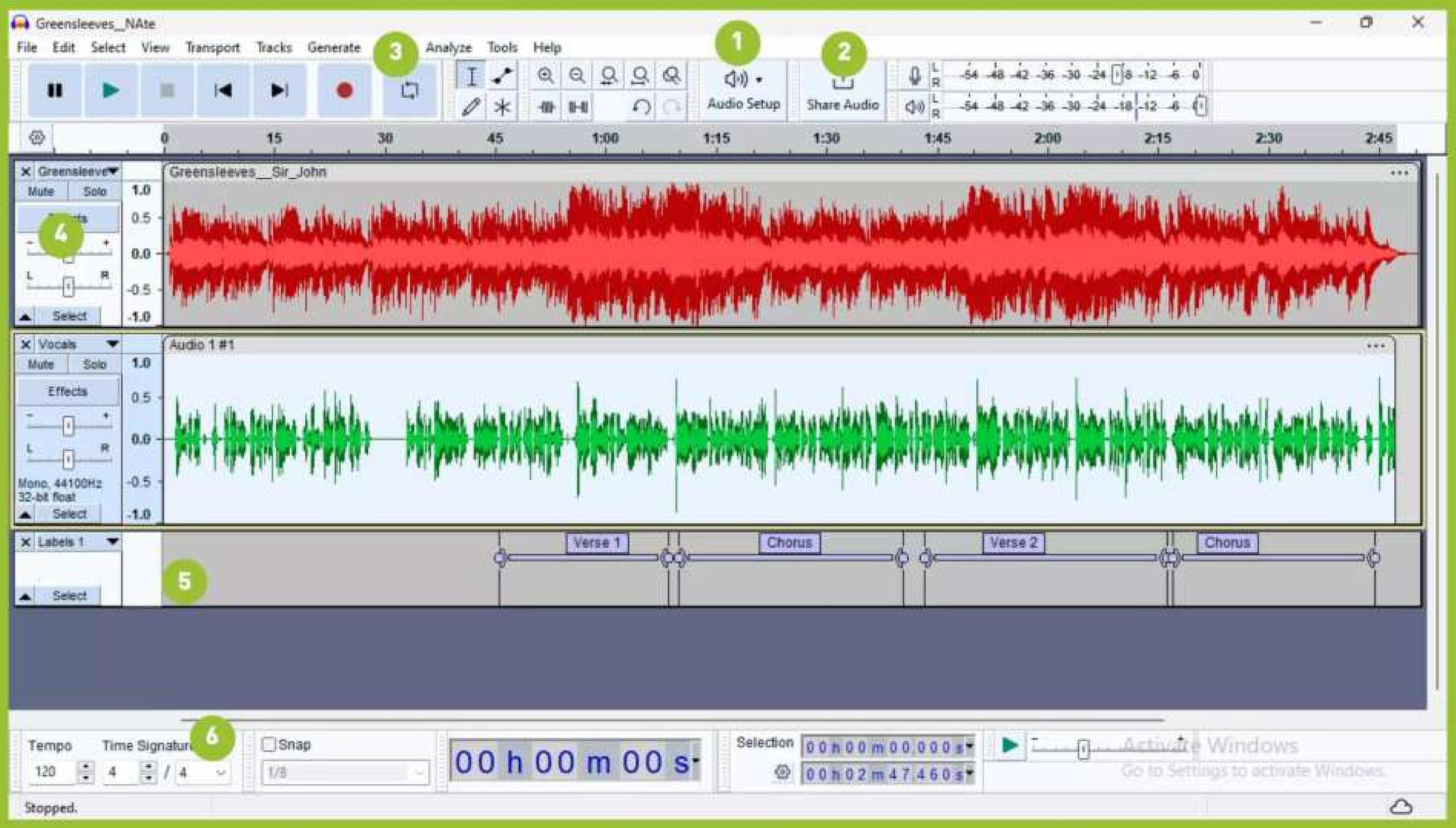
» Audacity supports dragging and dropping audio files into the project window. Alternatively, click 'File' > 'Import' > 'Audio', then navigate to your chosen media. [Image A]

» Once the file has been imported, you'll see various playback controls listed along the top pane. Audacity's documentation also states that you can use the spacebar to start and stop playback, though we



© AUDACITY

MASTERING AUDACITY



1. AUDIO SETUP
Before starting any project, click here to ensure that you have the correct audio input and output devices selected. From here, you can also switch between mono and stereo channels.

2. SHARE AUDIO
Audacity now comes with options to save and share files via the cloud with an audio.com account. This allows others to view your project and download in MP3/WAV format.

3. EFFECTS
This menu allows you to apply a number of audio effects to tracks and clips. If you download others, then you can also manage these via the dedicated plugin manager.

4. TRACK CONFIGURATION
Choose 'Select' to make changes to individual tracks. From here, you can alter amplification and panning, as well as mute the track, set a track name, and change the waveform color.

5. LABEL TRACK
These are a useful way to annotate certain portions of audio, like verses and choruses, or interview questions and answers. Label tracks can be edited, snipped, and exported like audio tracks.

6. AUTOMATIC TEMPO DETECTION
Audacity 3.5 now uses audio analysis and metadata checking to detect and adjust the tempo of imported loops. The current track tempo is displayed here in the Time Signature toolbar.

noticed in our tests that tapping space actually restarts playing the clip in question.

» You can, of course, click into the track and press space/Play to begin playback from there. You can also use click and drag to select a certain portion of the audio track, then press space/Play to hear only that section.

» If you want to play a section in a loop, select it using click and drag, then click 'Enable Looping' next to the Record button.

» You can also use the two buttons to the left of the Record button to skip to the start and the end of the track respectively.

» Certain tracks may need to be trimmed to your needs, as was the case with our test audio file, which has half a second of silence at the start. To do this, simply click and drag over the portion of audio you want to remove, then press delete.

» If you want to use only a specific portion of your imported audio, select it using the mouse then hold Ctrl + T to trim all audio outside your selection.

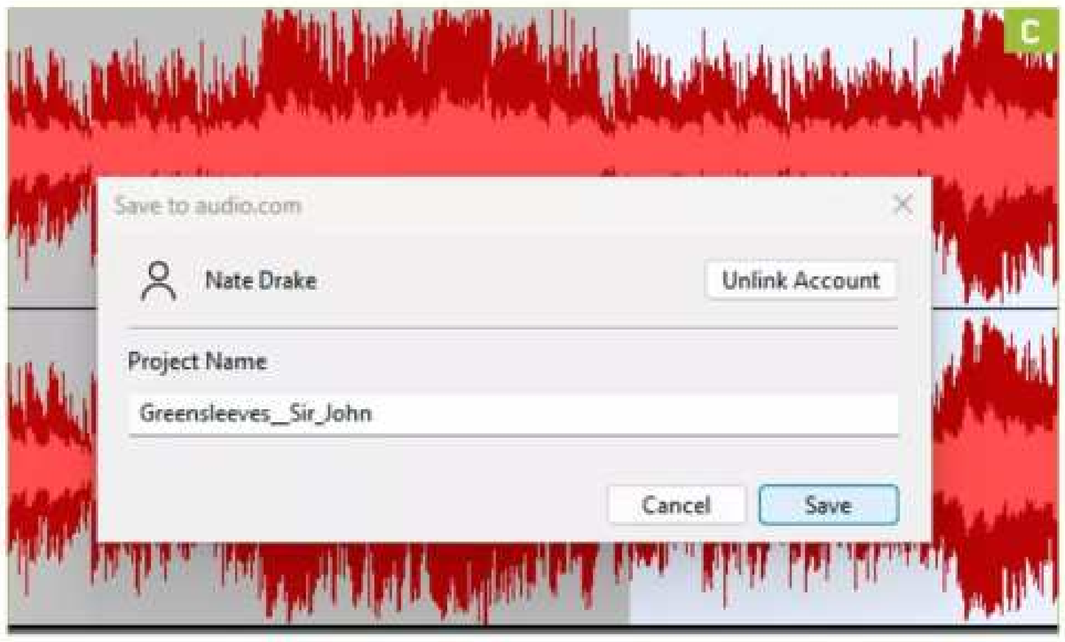
» The left-hand pane next to the track has two sliders to control gain and panning. By default, these are set to 0.0dB and center respectively, but click and drag with your mouse as you see fit. From here, you can also mute the track and add effects, which we'll explore later.

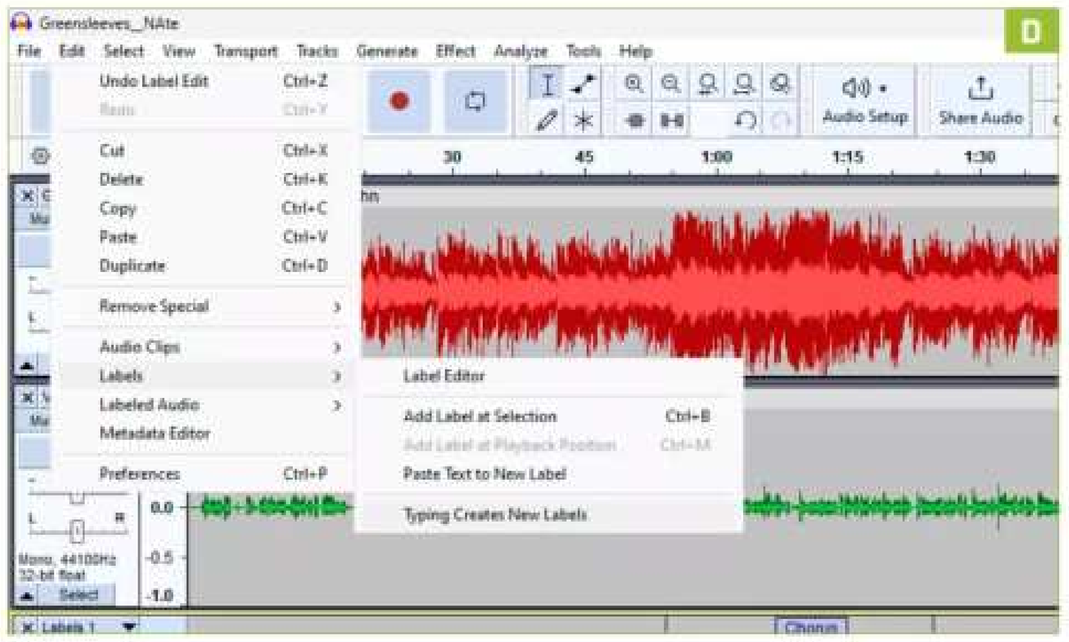
3 RECORD YOUR AUDIO

For the purposes of this tutorial, we're assuming that a user is importing background music, over which lyrics will be recorded. Although Audacity has impressive recording features, you can use a separate program to do this if you wish, then repeat the instructions in the previous step to import the audio as a file. If you do so, make sure the file is in a supported format.

» If you want to use Audacity and you've followed the instructions in Step 1, you should already have selected the correct recording device. Still, you can click 'Audio Setup' > 'Recording Device' to double check.

» Technically, you can record audio over your current track, but this is likely to make editing and adding effects





extremely difficult. Instead, hold Shift + R to begin recording a new track, then add your vocals.

» By default, Audacity will play all tracks as you record. This is excellent if you want to record a karaoke-style piece, but you can click 'Mute' next to the music track if you want to record the vocals alone.

» As you're now working with multiple tracks, make sure you look out for the 'Select' button at the bottom of the left-hand pane for each track. Clicking on these makes sure any edits or effects you add apply only to that track. [Image B]

» Once you've done this, it's helpful to have a way to distinguish between tracks. Click the black arrow in the left-hand pane and select 'Rename Track' to choose something more meaningful. If you're working with multiple instruments/vocals, this menu also offers a 'Wave Color' option to help you further.

» Once this is done, select the vocals track, then hold Ctrl + Shift + P to open the dialog to control pitch and speed via the dedicated spin boxes. From here, you can also check 'Optimize for Voice'.

4 SAVE YOUR PROJECT

Given that you've now imported multiple tracks, this is a good time to save your project.

» Holding Ctrl + S displays two options: 'Save to the Cloud' and 'On your computer'.

» If you want to save the project locally, choose the 'Save to Computer' button. Make sure you read the warning dialog carefully, as Audacity will only save in its own project format (.aup3), not as a playable audio file. Click 'OK' to confirm, then save to a suitable location on your hard disk.

» As of version 3.5, Audacity now offers the option to store project files remotely. In theory, this makes collaborating on audio projects easier. Audacity's developers caused privacy concerns in 2021 after making changes to how the program collects user data. Still, in this case, it's a third-party provider storing projects (audio.com), not Audacity themselves.

» To get started, choose 'Save to Cloud' in the save dialog. You'll next see a notification stating 'Account not linked'. Click 'Link account' to open audio.com in your default browser. From here, select 'Link Audacity' either to sign in with your audio.com, Google, or Facebook account, or to create a new one.

» Once sign in/registration is complete, your browser will prompt for permission to open Audacity. If you grant this, your account will automatically be linked, and you'll be able type a project name [Image C]. A dialog will appear informing you that syncing will continue as you work. Look to the bar at the bottom-right for a progress update.

» Once a project has been saved to the cloud, you can click 'View Online' to see it on audio.com. Choose 'Generate Audio Preview' to launch Audacity and export an MP3 file to share with others. You can also click 'Invite to View' to share the link with other audio.com users, which allows them to comment on your project.

5 WORKING WITH LABELS

This step is optional, but recommended if you plan to add multiple effects to tracks and/or you need to be able to identify specific sections of audio, such as interview questions and answers.

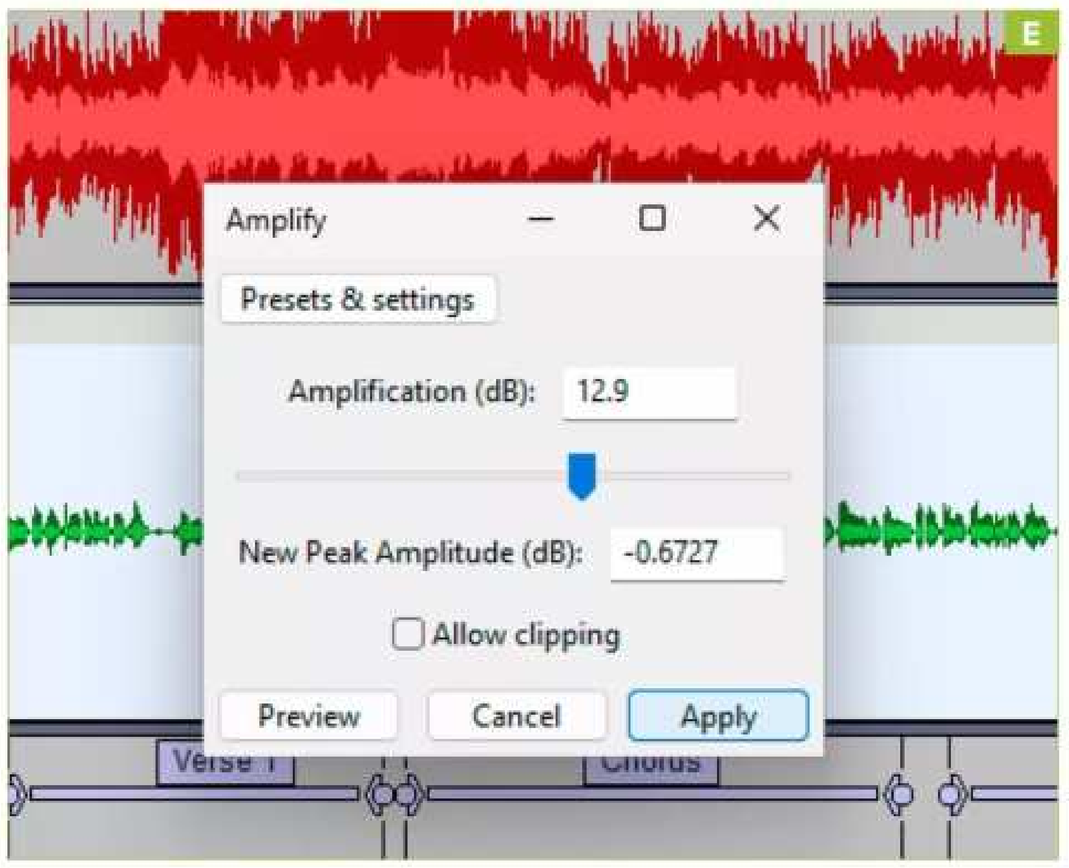
» This is where labels come in useful. In essence, they allow you to annotate the waveforms of sounds to easily identify sections. This is done through creating a separate 'label track'.

» To get started, click and drag with your mouse over a certain section of your audio, such as a question or the chorus of a song. Use the space bar as necessary to play audio clips to make sure you have the right area.

» You can now add a label for your selection either by clicking 'Edit' > 'Label' > 'Add Label at Selection' or by holding Ctrl + B. This will create a new label track with a blank label at the same time index. Click on the small white box to add text. [Image D]

» If you plan to use multiple labels, return to the 'Edit' Menu and choose 'Labels' > 'Typing Creates New Labels'. As the name suggests, this means that each time you highlight a section of audio and begin typing, Audacity will create a new corresponding label on the label track.

» Labels aren't static—simply hover your mouse over the central bar until you see the hand cursor, then click



and drag to move them forward or backward. You can also trim a label's length by hovering your mouse over the small white dot over the start or end.

» Audacity's documentation recommends using a maximum of 260 characters for labels. You can enter more than this, but you run the risk that the labels won't appear next time the project opens. The project website also warns that using too many labels can make the project 'sluggish' to open and edit.

6 EDITING AND EFFECTS

Audacity has a huge range of effects, all of which can be accessed via the dedicated menu. Naturally, we don't have the space here to examine what each of them do, but if you click on 'Effect', you'll notice that they are grouped by functionality by default.

» For instance, when recording tracks for this tutorial, Nate's vocals were extremely quiet. We accessed 'Effect' > 'Volume and Compression' to choose from options like 'Amplify'. [Image E]

» In most cases, when you select an effect, a dialog will open to allow you to configure it to your needs, such as setting the number of decibels by which to amplify the track.

» Most effects also have a dedicated 'Presets and Settings' button. From here, you can choose to save your configuration or export it for future use. This is very useful if you're applying the same effect to multiple tracks or clips. However, if you simply want to apply the same effect as before to a new track, you can also just hold Ctrl + R.

» The 'Preview' button will render a short sample of your audio with the new effect applied. Crucially, this won't make any permanent changes to your project. If you find the effect satisfactory, choose 'Apply' to save your changes.

» Further effects are available via plugins at https://plugins.audacityteam.org. In most cases, these can be installed as part of a collection, such as the MFreeFXBundle pack. Once installation is complete, go to 'Effect' > 'Plugin Manager' to ensure the corresponding checkbox is enabled.

» Certain plugins don't come with their own installer, in which case you'll need to load them manually. First, save your current project, then quit Audacity. These should be placed in various folders in your 'Common Files' folder.

» Access this by typing '%ProgramFiles%\Common Files' into the Windows search bar. Next, follow the steps at https://support.audacityteam.org/basics/customizing-audacity/installing-plugins to install your plugin to the relevant folder.

7 EXPORTING AUDIO

Once you've loaded all tracks and applied any effects, you can export your project to a playable sound file. To get started, go to 'File' > 'Export Audio', or simply hold Ctrl + Shift + E.

» As of Audacity 3.5, users have two main options for exporting projects. Take the time to read through these options in the dialog marked 'How would you like to export?' Assuming you set up an audio.com account earlier, clicking the relevant button will upload the project to the website, allowing others to play the sound file. The caveat here is that only MP3 and WAV formats are supported.

» If you choose 'Export to Computer' [Image F], you can create sound files in a far wider range of formats. Assuming you do this, a new dialog will appear that first allows you to set a meaningful name as well as location for the new audio file.

» The 'Format' drop-down menu will list all export formats natively supported by Audacity, as well as any you installed via the FFmpeg library and others.

» The 'Audio Options' section also supports making basic changes to your configuration, such as switching channels, as well as setting a sample rate and encoding. You can also click into 'Edit Metadata' to change the title, artist name, and so on. Click 'Export' to continue.

THE AUDACITY CONTROVERSY

In November 2022, the open-source website FOSSPost ran an article with the damning headline 'Audacity is Now a Possible Spyware, Remove it ASAP'.

The controversy touched on Audacity's acquisition by The Muse Group. The new owners made changes to the privacy policy that seemingly gave them the right to transfer European users' data to Russia.

It also reported on users' IP addresses being logged for 24 hours on Audacity's servers before being hashed and saved for a year. As Audacity had no cloud-saving features, there was no need for it to connect to the internet.

As open-source software, Audacity is also licensed under the GPL (GNU Public License), which allows users to freely distribute and use it. This seemed to be at odds with the new privacy policy, which banned people under 13 from using Audacity.

In response to the backlash, the new owners blamed 'poor wording' for people's interpretation of the policy, and quickly backed down.

The open-source community also responded with their own 'pre spyware' fork of Audacity, named Tenacity (https://tenacityaudio.org). At the time of writing, Audacity still

remains open-source. There's no requirement to allow the software internet access, except during updates. If you're still concerned, we recommend that you block Audacity connections via Windows Firewall and store projects locally.

Clean and optimize your PC for free

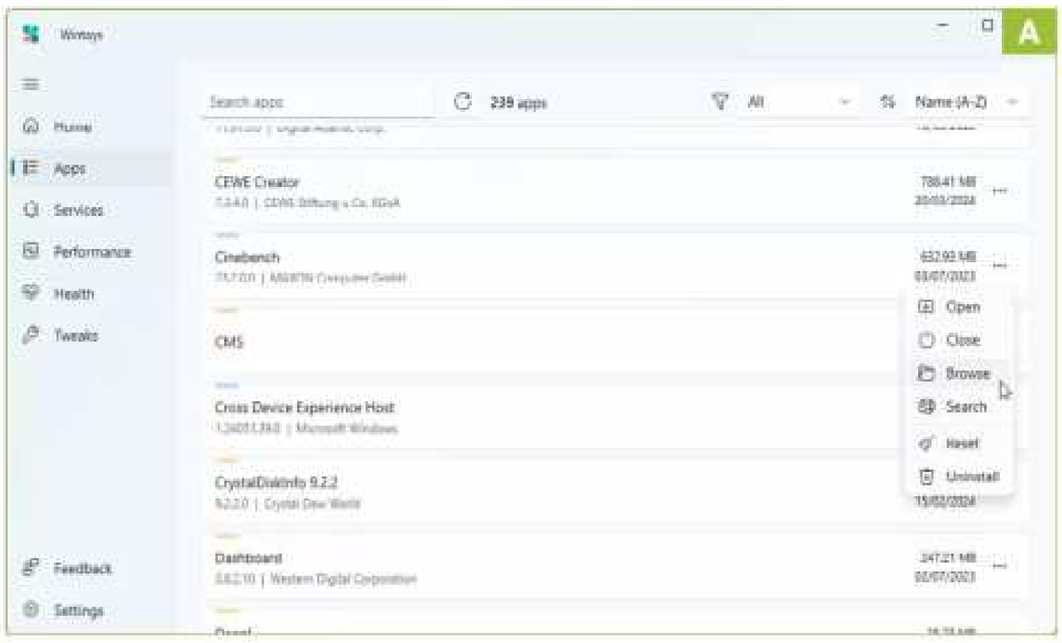
YOU'LL NEED THIS

WINTOYS
(free from the Microsoft Store), Windows 10 or 11

IF YOU'RE LOOKING TO KEEP YOUR PC PURRING, then Wintoys is worth taking for a spin. It's a beautifully designed tool that provides a host of tuning, tweaking, and managing options, from cleaning and optimization to maintenance and repairs. The app echoes other parts of Windows, in particular its Settings app, and you'll find plenty of options that already exist there. But what sets Wintoys apart is that it attempts to make these options more visible and easier to access.

In this guide, we're going to give you the complete tour—you'll discover how to use it to manage your app installs, Services, and startup items, plus clear out redundant files. You'll also find out how it brings together related switches that Microsoft would prefer to keep hidden and separate, specifically in the realms of privacy, and how to use Wintoys to perform various maintenance and repair tasks, as well as maximize performance.

Best of all, Wintoys is currently completely free to download and install—go on, add it to your PC's toolkit today, and discover how it can keep your PC in tip-top condition. **–NICK PEERS**



1 FIRST STEPS

Wintoys is installed through the Microsoft Store—a simple search should suffice, but you can also access it via its own web page (https://bogdan-patraucean.github.io/about/wintoys). Once installed, simply search for 'Wintoys' to find and open it. The program will ask for administrative privileges—verify that the publisher is Bogdan Pătrăucean, and click Yes.

» You'll be shown the main Wintoys screen, which opens to its home page. Here, you'll see a quick summary of your system—motherboard, processor graphics, RAM, Windows version, and Performance score. This comes from Windows' own WEI benchmark, and if you've recently upgraded your system, click the 'Run benchmark (WEI)' button to update it.

» Roll your mouse over any of these elements, and a pop-up will display additional information about the component in question—for example, the System pop-up tells you your current BIOS version and date, while the graphics card confirms how much RAM it has and its current driver version and date.

» Below the hardware summary are real-time indicators for how many apps, processes, and services are running, how much space you've cleaned using Wintoys' own tools, plus CPU, GPU, RAM, and network usage.

2 MANAGE APPS

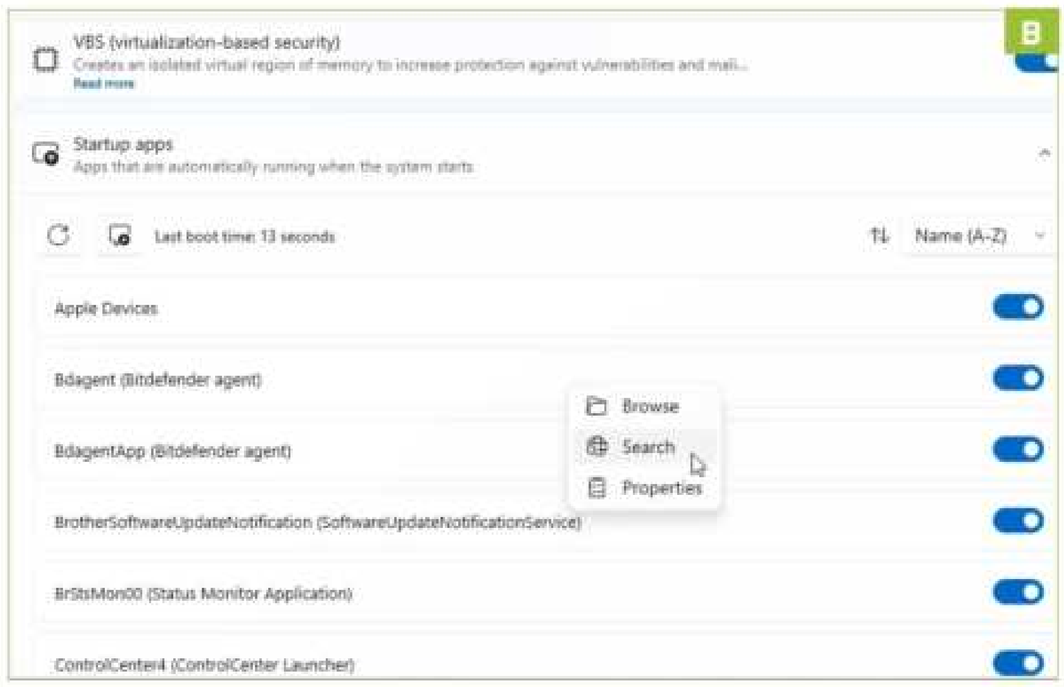
The Apps section provides you with a list of all installed programs and apps on your PC. At first glance, there's little to differentiate this from Windows' own Apps component under Settings, but there are subtle differences. On our test system, Wintoys detected more apps (239 versus 225) than the 'Settings > App' component. On closer inspection, you'll see that it includes Microsoft tools like App Installer and Cross Device Experience Host, which Windows would prefer you didn't remove.

» One advantage of Wintoys' own Apps tool is that it color-codes entries according to whether they're Microsoft Store apps (blue) or installed through traditional means (yellow). You can also filter the view to show only one or other type by clicking the All filter and choosing Store or Win32 respectively.

» When it comes to sorting the installed apps list, Wintoys' 'Sort by' drop-down is marginally better again than Windows thanks to the fact you can view apps in the order they were installed with oldest at the top (Windows only allows you to view them in order of newest first).

» Like the Settings' App component, each entry is accompanied with a more (...) menu, as shown in [Image A]. Again, there are differences, but here, the advantages are less clear cut. Wintoys does score points for providing options to open, close, and reset apps to their defaults, but these only apply to those installed through the Microsoft Store.

» What is genuinely useful is a Browse button, which takes you to the program's parent folder, and a



Search option that basically provides a Google web search for the program, along with its version number. The final option—Uninstall—does what you expect it to.

» There's one area where the Settings tool retains key advantages: in the management of Store-installed apps. Not only can you move these to another drive to free up space, but you also gain access to an 'Advanced Options' dialog, which gives you access to more tools, such as disk permissions and whether the app is allowed to run in the background or not.

3 TWEAK SERVICES

Windows hides its service management tools in Task Manager, as well as its own dedicated Services console. Wintoys places these tools front and center in their own dedicated Services section, and it has sensibly been designed to closely resemble Wintoy's Apps section.

» By default, Wintoys sets its filter to show only running services—clicking the filter drop-down reveals a range of options above and beyond simply displaying services by their current status (running or stopped) and startup mode (automatic, manual, disabled). You can filter the list to show either Microsoft or third-party services only, view all services together (thus echoing what's shown in Task Manager), and—of most interest—select a 'Useless' filter.

» This filter displays services that Wintoys believes could be safely stopped or disabled. Use this filter in conjunction with the information icon to the left of the more options (...) button to find out more about an individual service. Alongside some general information, you may see a description of the service in question, helping you to determine if it's essential or not.

» When it comes to managing individual settings, click ... to access all the tools you need to start, stop, restart, and switch modes, plus you can click Browse to jump to the service's parent folder or Search to set up a Google Search for the service name.

» Wintoys also allows you to select multiple services at once by clicking on each one in turn. Once selected, you'll see buttons appear at the top of the screen that allow you to start, stop, and restart services, plus change their startup mode en masse.

4 RAMP UP PERFORMANCE

The Performance tab contains an array of tweaks designed to boost performance. We've highlighted six boosts on the annotated screenshot, but a particular standout is the Startup apps section—click it to expand its contents and reveal a comprehensive list of items set to start with Windows.

» At the top, you'll also see a figure showing you your last boot time. It's a little misleading, as it refers to the time it takes for your PC to power up and run BIOS/UEFI checks before handing over to the Windows bootloader, as opposed to the complete boot process. If it's more than 10 seconds, check your fast start settings.

» Beneath this is a list of apps set to start with Windows. It's similar to the one shown under Settings > Apps > Startup, with the same flickable switch to enable or disable individual items. Rolling your mouse over one also reveals two additional buttons: copy and delete. These only apply to apps that start up through the Registry, and the latter basically allows you to remove that item by deleting its Registry key. Use the copy button with Registry Editor if you want to investigate further.

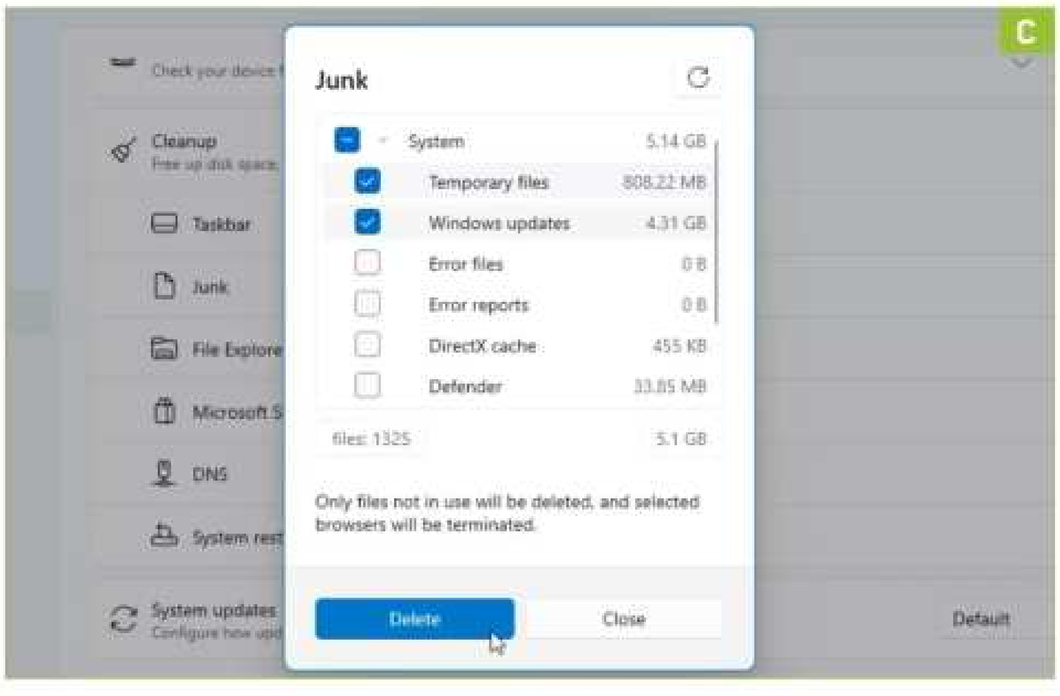
» If the buttons are grayed out, it means the app in question is launched from elsewhere. Try right-clicking it, as shown in [Image B], to reveal a pop-up with three options: Search again allows you to search Google for more information about the item, while Browse and Properties take you to the program's own parent folder or reveal information about its executable. If these are grayed out, it's usually because they're associated with launching a Microsoft Store app.

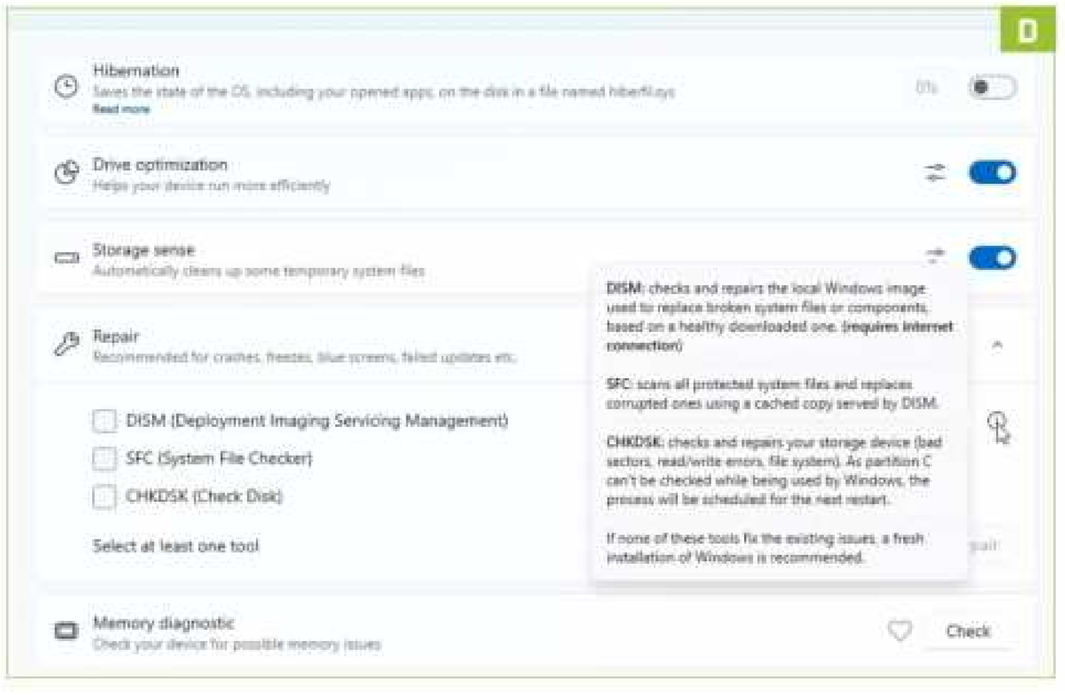
CUSTOMIZE WINTOYS SETTINGS

Wintoys is as customizable as it is comprehensive—simply click the Settings button in the bottom left-hand corner to get started. You can start by switching theme from auto (which follows your system) to either permanent light or dark. You can also toggle the backdrop between light blue (Mica) and a darker shade (Mica alt).

Of more practical benefit is the ability to open Wintoys to a specific section, selected under the landing page. Below this is a slightly cryptic option for 'persistent' sorting and filtering. Flicking this switch on basically remembers your chosen filters and sort orders in relevant sections like Apps, Services, and the Startup apps section of Performance, instead of reverting to whatever defaults Wintoys has set.

Moving on, the Shortcut makes it easy to place a shortcut to Wintoys on your desktop, while you can disable error reporting if you don't want to share any data with the developer. Rounding things off is a quick version number (keep checking back to the website for any updates), accompanied by links to the app's terms and conditions, privacy policy, and a shortcut to the Microsoft Store app, where you can rate Wintoys if you wish.





BEYOND WINTOYS

While Wintoys provides a convenient one-stop shop for many system tools and tweaks, it's more of an everyman utility than best-in-class. If you find that its tools fall short of what you need, consider augmenting it with the following free apps, all focused on excellence in one specific area.

When it comes to uninstalling software from your PC, consider Bulk Crap Uninstaller (pictured above) (**www.bcuninstaller.com**) should you want to remove applications thoroughly from your system—including leftover files and Registry entries. Looking to see what impact start-up items have your PC before deciding if to remove them or not? Try the free version of Bootracer (**https://greatis.com/bootracer/index.html**)—check out the January 2023 issue for our guide. Also consider Autoruns (**https://learn.microsoft.com/en-us/sysinternals/downloads/autoruns**) for a more comprehensive start-up manager in general.

Wintoys' cleanup tools will free up space on your PC, but if you want to go the extra mile and comb through individual apps for potential files to remove, then the portable free version of CCleaner (**https://portableapps.com/apps/utilities/ccportable**) remains hard to beat. Finally, looking for a more comprehensive repair tool? Try the free version of Windows Repair All In One (**www.tweaking.com**), which offers targeted repairs in addition to general scan-and-repair methods.

5 FURTHER TWEAKS

The Performance tab is also home to other useful settings—the VBS (virtualization-based security) setting is used to harden your RAM against certain attacks. It utilizes your PC's 64-bit AMD or Intel processor's hardware virtualization capabilities, along with its TPM 2.0 chip. Any Windows 11 PC should be able to use this feature, but you may need to enable hardware virtualization in the BIOS. Use the 'Read more' link to find out its explicit requirements.

» Beneath this is a 'Relaunch apps' slider, which applies to any app that can reopen itself to its previous state if you leave it open prior to rebooting your PC. The 'Activity history' setting tells you if Microsoft is tracking all or part of your Windows activity (see https://account.microsoft.com/privacy for a summary of what it has tracked so far). This mirrors what's shown under 'Settings > Privacy & Security > Activity History', where you'll also find an option to clear what's already been stored.

» If you flick the switch to off, you'll notice a Reboot prompt appear above the Feedback button—a reminder that some tweaks will require a reboot to take effect.

6 CLEAN YOUR DRIVE

The Health section provides a range of tools concerned with the maintenance of your PC. Let's start by tapping into Wintoys' clean-up tools for reclaiming disk space. There are two primary sections here: Storage sense and Cleanup. Storage sense is a simple on/off switch for Windows' own disk cleaning tool, with a handy shortcut that takes you directly to the relevant section of the Settings app.

» Wintoys' main Cleanup tool comprises six separate categories, of which Junk is the most effective. Click its trash can icon, and a separate window will appear, as shown in [Image C] to provide you with a wider range of junk file categories than you'll find in Windows' own cleanup tools. They're split into two sections: System covers Windows, of which Windows Update is likely to be the most effective option to check, while Browsers handles the big three web browsers: Edge, Chrome, and Firefox. Make your selection and click Delete to clean out the files in double-quick time compared to Windows' somewhat laborious cleanup tool.

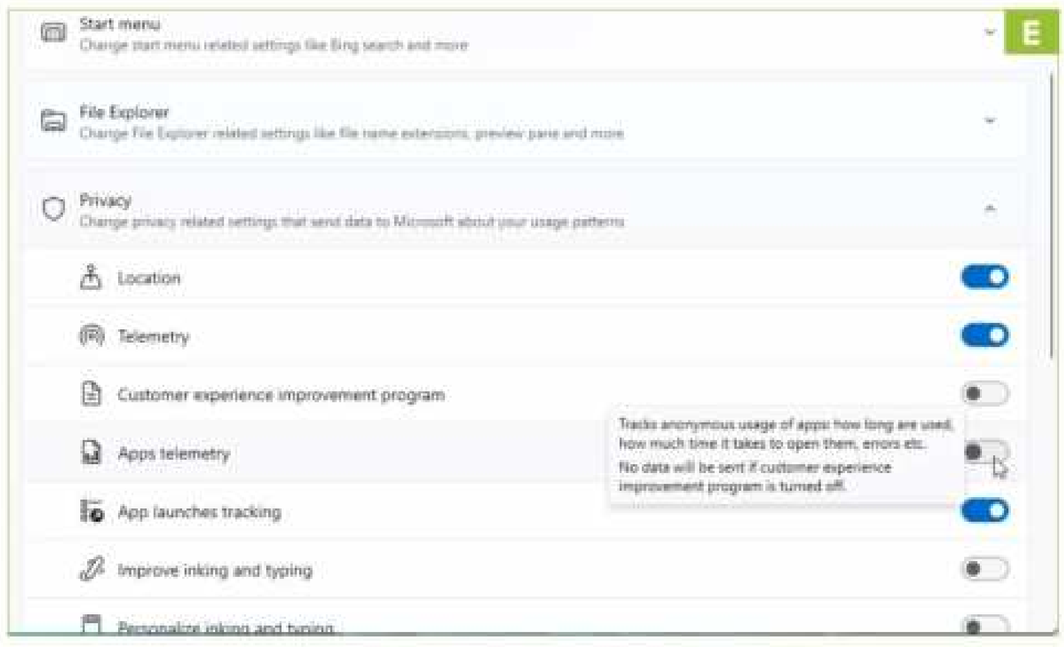
» Other options allow you to quickly remove (by unpinning) all items from the Taskbar, clear the Microsoft Store cache, flush the DNS cache for internet-related problems, and clear all System Restore points. There's also a File Explorer option for cleaning out the unpinned items from the Quick Access folder, Favorite bar items, jump list history and more (hover your mouse over its button for a complete list).

7 PERFORM SYSTEM MAINTENANCE

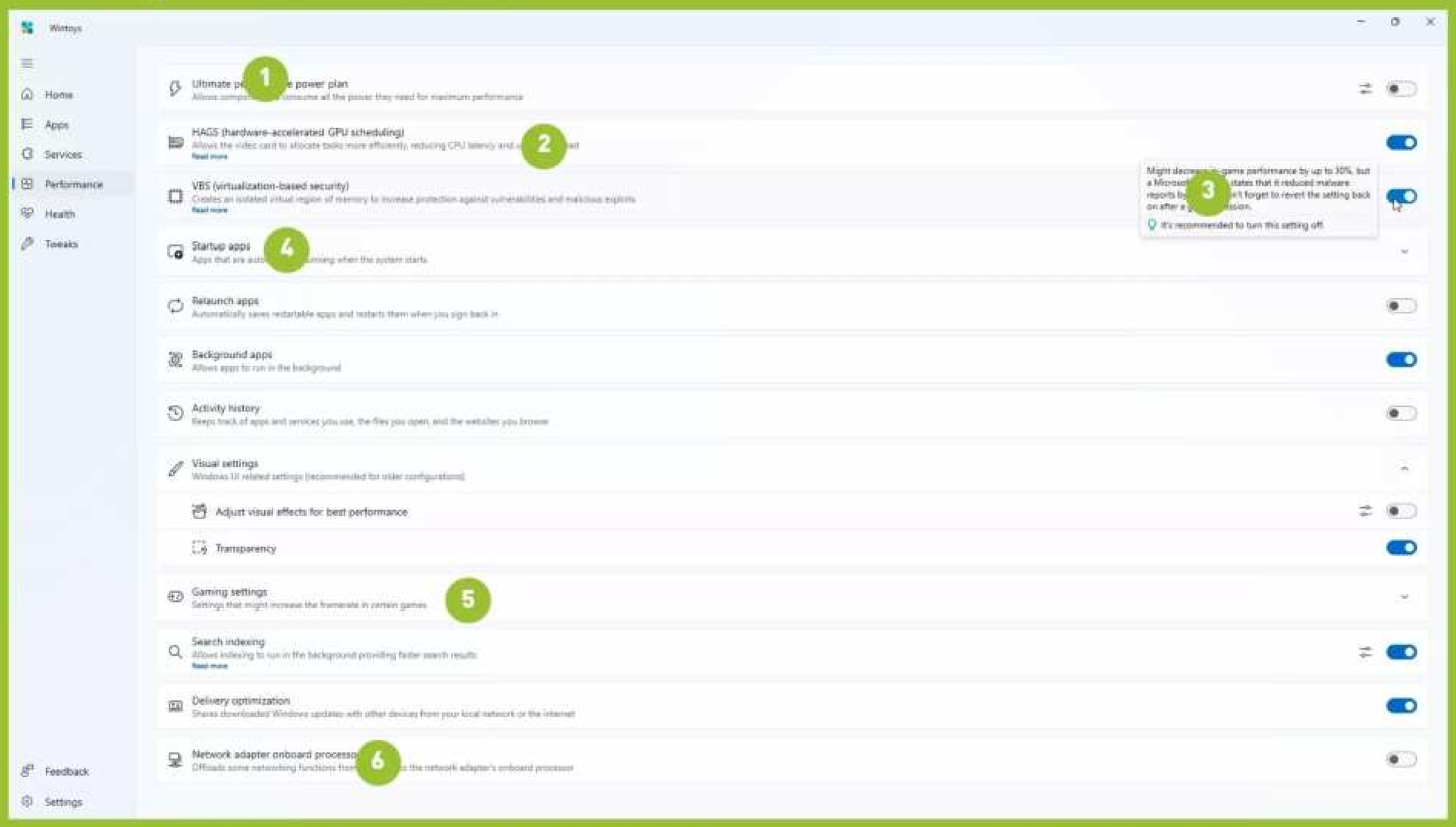
Most other tools in the Health section provide shortcuts to Windows tools like Windows Memory Diagnostic and Optimize Drives, or offer quickfire ways of enabling or disabling features like fast startup and hibernation. One of the most useful of these is Repair, as shown in [Image D]—expand this, and you'll see options to run SFC, CHKDSK and DISM in scan-only or repair mode, either individually or all together.

» Look out too for System updates, which lets you quickly configure Windows Update to either receive only security updates, switch it to manual, or disable it altogether (not usually recommended). There's also the obligatory shortcut to Windows Update itself, which triggers a check. Below this is App Updates, which allows you to disable automatic updates for apps installed through the Microsoft Store if you so wish.

» The final three tools could prove particularly handy: Sleeping pill can be used to find and disable scheduled tasks that prevent your PC from remaining



SIX QUICK BOOSTS



1. ULTIMATE PERFORMANCE POWER PLAN
Provides a way to enable the 'high performance' power plan hidden under Power Options. Click the settings to jump to the Power Options control panel.

2. HAGS (HARDWARE-ACCELERATED GPU SCHEDULING)
Another shortcut to a feature in Settings > System > Display > Graphics > Default graphics settings. Click the link to learn about how it reduces latency to improve performance.

3. STARTUP APPS
Click here in order to expand the section and see how long your last boot time took, plus view and manage all of the startup entries.

4. BACKGROUND APPS
Windows 11 removed the universal setting that disabled all of the background apps. Wintoys restores this setting, enabling you to free up system resources and RAM, in addition to extending battery life with the flick of a switch.

5. GAMING SETTINGS
Provides a convenient location to apply four different performance-related tweaks for gamers, including a simple switch to enable and disable Superfetch as required.

6. NETWORK ADAPTER ONBOARD PROCESSOR
This is extremely unlikely to have any effect on performance, but it does allow you to offload networking from your CPU to your network adapter.

asleep. Graphics driver restarts your driver to attempt to resolve certain problems—after clicking Restart, the screen will blank momentarily, so don't panic. Finally, the Rebuild button under Icons cache can resolve problems with desktop or File Explorer icons.

8 FURTHER TWEAKS

The final section provides even more handy time-saving shortcuts. Expand each in turn to reveal various options related to the category in question, from the Desktop and Start menu to File Explorer. They're all largely self-explanatory, and repeat options found elsewhere, but again provide you with handy access to a scattered collection of tools in one place.

» Below these is a Privacy section, which brings together all those features that Windows scatters around the system in the hopes you won't notice what's being recorded. As always, roll your mouse over each switch in turn to reveal a popup explaining what that setting refers to as shown in [Image E]. The Ads section offers similar functionality, bringing together all those settings that lets Microsoft show potentially annoying (or 'personally tailored') content in Windows.

» The System section can be viewed somewhat as a miscellaneous basket for settings that don't fit neatly elsewhere. You can enable features like the clipboard history, mouse acceleration, and even God mode, which creates an icon on your desktop. Double-click this, and dozens of old-style Control Panel items appear in a File Explorer window, sorted by category. Annoyingly you can't rename the icon and you can't pin it to the Taskbar, but you can pin it to the Quick Access toolbar in File Explorer if you find it handy.

» The final option—Spotlight images—is for those who've set 'Windows spotlight' as their lock screen. If you come across a picture that you like the look of, you can extract it to your hard drive from here. Start by clicking the folder icon to choose where to save your photos, then click Extract to save all currently downloaded pictures to the location you chose.

Recover deleted files

YOU'LL NEED THIS

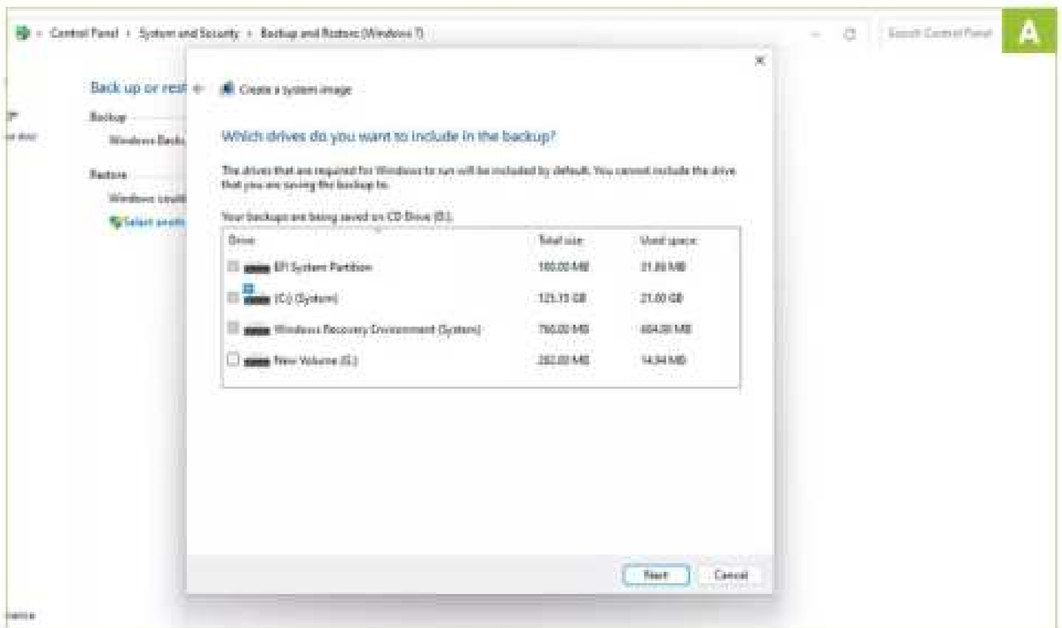
EXTERNAL HARD DRIVE
To store disk image/ Windows backup

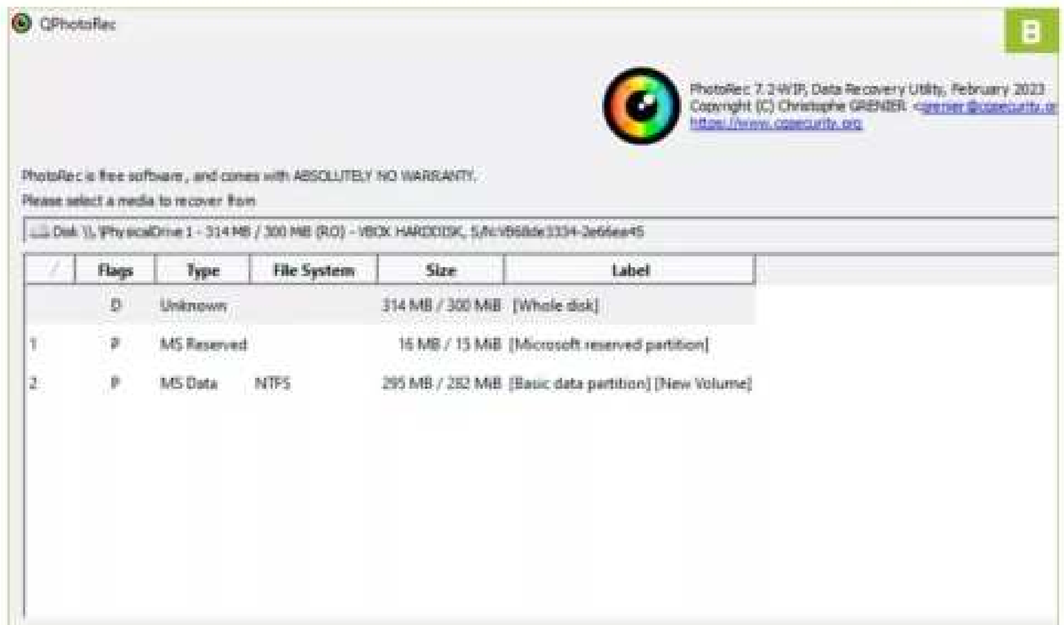
USB STICK
For bootable OS (System drives only)

WITH THE RISE OF ONLINE APP suites and cloud storage, horrific data loss scenarios are becoming rarer. Still, as anyone who's worked in IT knows, people don't always engage in best practices when it comes to data storage. The subreddit 'Tales from Tech Support' even contains a number of stories of customers storing important documents in their Recycle Bin!

In this scenario, if files are accidentally deleted from Trash, there's no automatic way to retrieve them. Even expert PC users can fall victim to this if a failed update or malware corrupts a drive, or if they accidentally delete the wrong partition. There are many data recovery programs, but TestDisk and PhotoRec stand out. Firstly, they're both free and open-source. Secondly, in our tests simulating accidentally deleted files, a formatted drive, and a corrupted partition, both utilities retrieved files with flying colors.

In this guide, you'll learn how to create a backup image of your drives before attempting recovery. You'll also learn how to use PhotoRec to safely recover files, as well as configure TestDisk to restore lost or damaged partitions. Both utilities come with a warning that they're provided without any guarantee whatsoever, advice that we echo for this tutorial. If you feel uncertain, then there are forensic specialists who can attempt recovery for you. **–NATE DRAKE**





1 BACKUP WINDOWS DRIVES

The PhotoRec utility doesn't write to affected disks, so at the very least, using it shouldn't make it harder to retrieve deleted files. Still, each time you mount a drive, there's also the possibility that data can be corrupted, particularly if it's damaged. TestDisk also writes to partitions.

» This is why it's important to create an image of the drive you want to recover, so the original won't be affected by your attempts to recover deleted data. Most importantly, if you're unsuccessful, you can provide a copy of the image to a data forensics specialist to work on with more advanced tools.

» To get started, you'll need to connect an external hard disk to your machine with enough capacity to store an image of your hard drive, as well as any other connected disks. Make sure you save and close any open files, as well as exit any running programs first.

» Next, open the Windows 11 Control Panel via the Windows search bar. Find the 'System and Security' section, then choose 'Backup and restore'. Next, click 'Create a system image' in the left-hand pane.

» Windows will now prompt you to choose where you want to save the backup. Select 'On a hard disk' [**Image A**], then choose your external drive from the dropdown menu.

» On the next step, you can choose which drives to image. By default, the utility will include all system partitions, but you can also choose other drives if they contain data you want to recover.

» Click 'Next' then 'Start Backup' to continue. If your system drive is encrypted, e.g. via Bitlocker, then you'll see a warning that the backup image won't be, so be sure to store it in a safe place.

2 SET UP TESTDISK/PHOTOREC

When a file is deleted in Windows via emptying the Recycle bin, only its header and metadata are removed. The file data itself remains until it's overwritten.

» This means that if you're trying to use recovery tools on the same system with deleted data, each time you make any changes you risk overwriting the files you want to recover.

» Luckily, both TestDisk and PhotoRec are available as portable applications. In theory, this means you can just open your browser—head to www.cgsecurity.org/wiki/TestDisk_Download and download the utilities in a ZIP archive. If you then right-click to extract onto the USB stick, this shouldn't affect your target system. Still, we recommend performing the download/extraction on a separate system, then inserting the USB into the device from which you want to recover your files.

» For peace of mind, you can even boot another OS from your USB stick such as GParted, which comes with both PhotoRec and TestDisk preinstalled.

» If you do choose to run the apps from the ZIP archive, begin with 'qphotorec_win.exe'. This is the graphical version of the tool, so is the simplest to use.

» Upon loading, the utility will ask you to select a drive to recover. This defaults to your main system drive, so if the deleted files are elsewhere, use the drop-down menu to specify the correct disk. The main window will

display all disk partitions. This offers you the choice to search the whole disk or just specific areas, such as the data partition, for the files you need.

» PhotoRec works using 'file carving'. In other words, it analyzes files based on their raw data to determine their type. If you only want to recover files of a specific type, choose 'File Formats', then 'Reset' [Image B]. You can now check only certain formats.

» PhotoRec also prompts you to select 'Browse' to choose a destination for the recovered files. Make sure the location is a different drive to the one from which you're trying to recover the deleted data.

3 SEARCH YOUR DRIVES

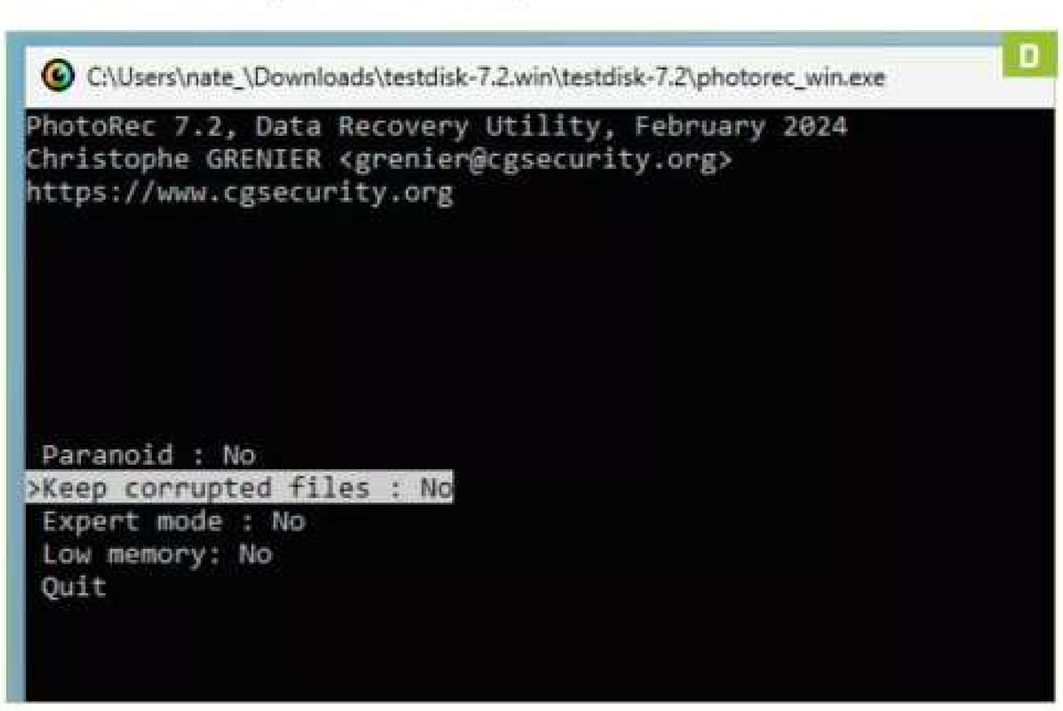
Once you've successfully determined the target drive, file formats to recover, and destination, choose 'Search' to begin file recovery.

» In the new window you'll see a progress bar as each sector is being scanned. The pane below specifies the 'file family', ie. format of files being recovered, along with the number of such files [Image C].

» Once recovery is complete, there's no automatic way to display the recovered files, but you can choose to 'Quit' the utility.

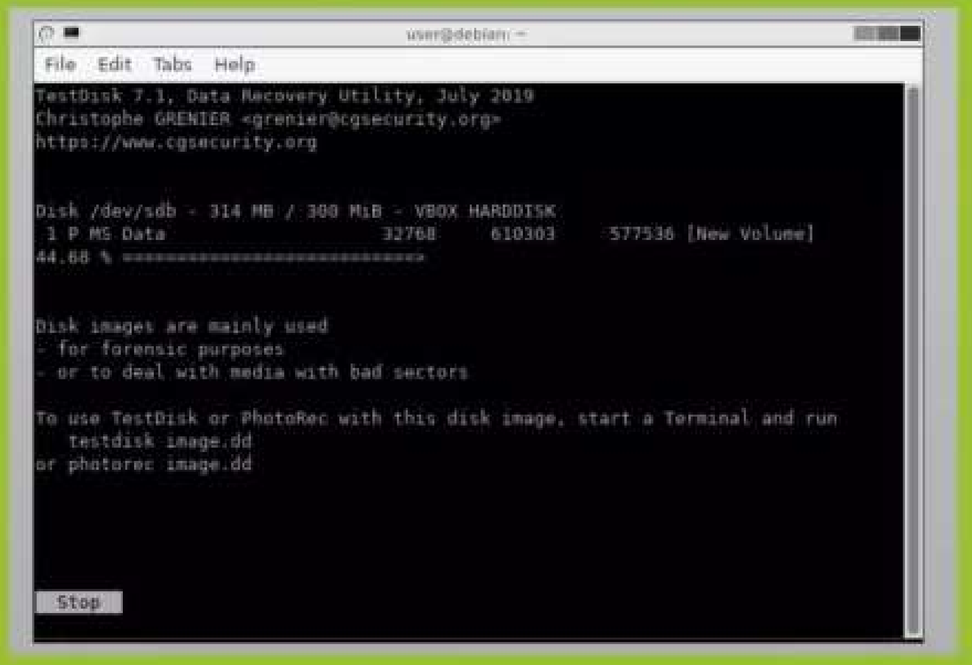
» In the interests of preserving data, it's a bad idea to try to view the recovered files on the target system on which you lost them originally. Instead, safely dismount your external drive, and connect it to a different device.

» Due to the way in which Windows deletes files, it's likely that the filenames won't be present. Still, take the time to open each one to check they load correctly.



© GPARTED DEVELOPERS/NATE

IMAGING YOUR DRIVE



In the first step, we discussed creating an image of all drives before recovering your data. This involves using Windows' own tools via the Control Panel.Obviously, this won't work if the Windows system won't boot. Fortunately, TestDisk supports creating a disk drive image.

To get started, you'll need to use another device to create a bootable USB of a Linux OS that comes with TestDisk pre-installed, such as GParted. Once you've done this, open Terminal and run 'sudo testdisk'.

From here, you can select your system partition and partition table using the arrow and enter keys. Next, choose 'Advanced' in the 'Filesystem Utils' section. From here, use the arrow keys to select 'Image Creation'.

TestDisk will ask you to confirm the location where to store the image. In Gparted, this is '/home/user/', but you can change this to an external drive. Once you've chosen the right location, press 'C' to start copying the image.

Once this is done, use Ctrl + C to exit TestDisk. You can use 'cd' to move to the folder where the image is located, eg. 'cd /home/user'. If you want to try and recover files, you can now do so by running 'sudo photorec image.dd'.

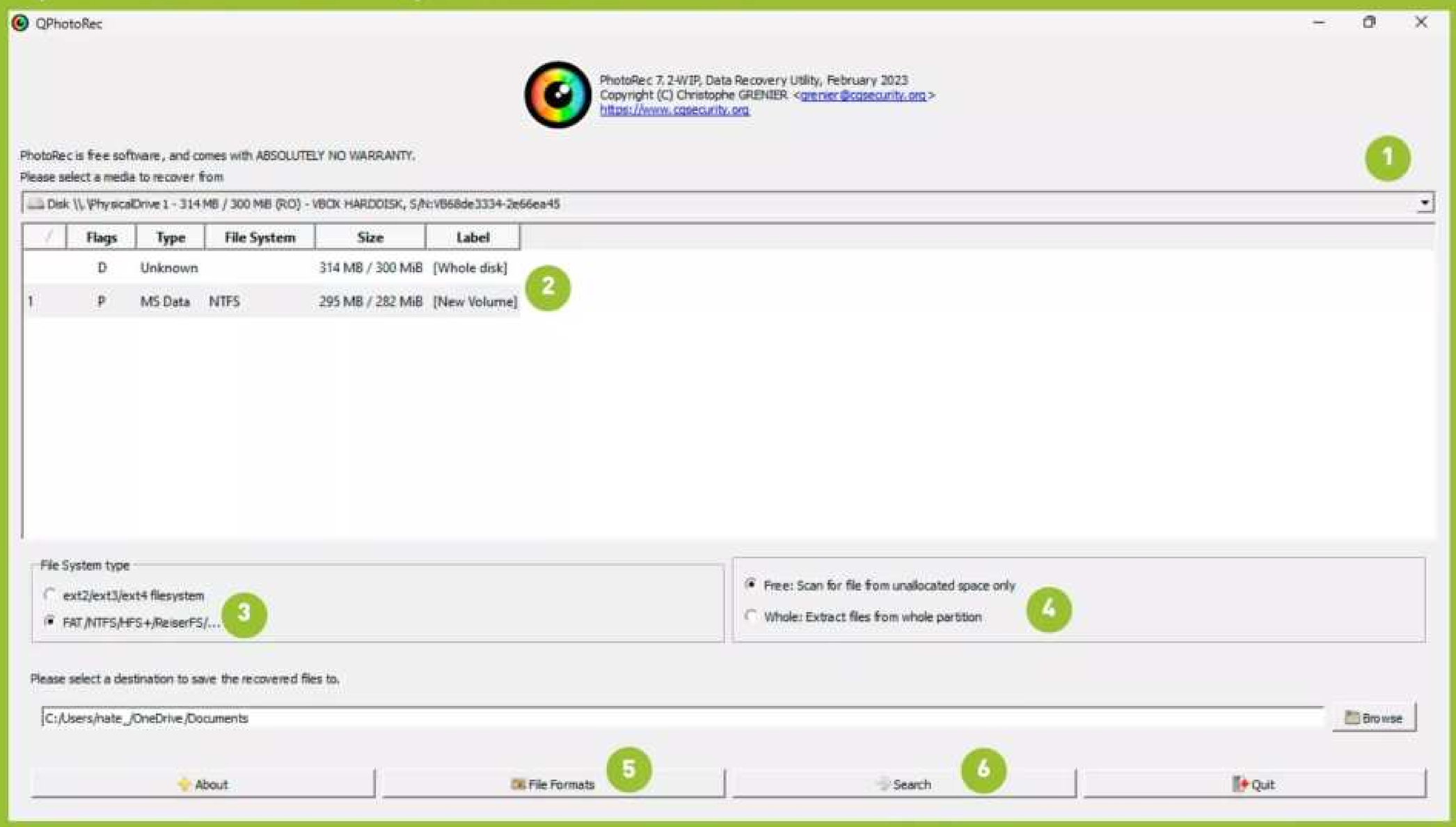
» The developer Wiki actually has a dedicated page on common problems that you may encounter after running PhotoRec (www.cgsecurity.org/wiki/After_Using_PhotoRec)—chief among these is large amount of duplicate files.

» In Windows, the easiest way to find these is by using the command-line utility fc (File Compare). The CG Security Wiki contains the text for a batch file, which you can execute to list duplicates automatically.

» Setting this up is as simple as pasting the text into Windows notepad then saving it as a batch file with a suitable name and extension, eg. 'list-duplicates.bat'. You can also download a functioning example of this batch script from Nate's Github page (https://github.com/azuregate/mpc-recoverdeletedfiles/blob/main/list-duplicates.bat).

» Once you've dealt with any duplicates, if you're still having trouble navigating multiple files, the project Wiki also contains a link to a Powershell Script (https://github.com/lconte/Copy-PhotoRecFilesbyExtension.ps1), which can take your folder of recovered data and neatly copy the files into directories, grouped by extension.

QPHOTOREC QUANTIFIED



1. SELECT MEDIA DEVICE
Use this drop-down menu to select the drive with the files you want to recover. This can be the system drive, external drive, or a disk image.

2. DRIVE PARTITIONS
QPhotoRec can search an entire drive, but searches are faster if you target specific partitions. If your partition isn't listed, you may be able to restore it using TestDisk.

3. FILE SYSTEM TYPE
The utility will automatically try to detect the file system type on your chosen partition. If you're uncertain, leave the default option checked. Most Windows drives use FAT or NTFS.

4. FILE EXTRACTION METHOD
By default, QPhotoRec extracts files from unallocated space. This is the most common scenario where files have been deleted. The utility also supports extracting files from whole partitions, but this takes longer.

5. FILE FORMATS
By default, QPhotoRec searches for files in a huge variety of formats. Click here, then 'reset' to manually specify only certain types, like Microsoft Word documents, by ticking the corresponding check box.

6. SEARCH
Click here to begin 'file carving', ie. identifying files by their data rather than deleted metadata. QPhotoRec will display the number and type of files recovered, and copy to the destination folder.

4 PHOTOREC CLI

Even after sifting through recovered files, you may find that some are missing due to the graphical version of PhotoRec's default settings. This is where the command-line version comes into play, as it offers more configuration options.

» To get started, navigate to the 'testdisk' folder once again, but this time run 'photorec_win.exe'. On first launch, you'll be asked to choose the drive from which you want to recover your files. Use the arrow keys to do this, then press enter.

» Once your drive has been selected, just as with the graphical version, PhotoRec will list the target disk's partitions.

» If the graphical version of PhotoRec failed to find all your files, use the right arrow key and enter to choose 'Options'.

» By default, the utility deploys 'Paranoid' mode. In other words, all recovered files must be verified as valid.

» Use the left arrow key to change this to 'no' to enable 'bruteforce' mode. This will recover more fragmented files, but will place a larger strain on system resources.

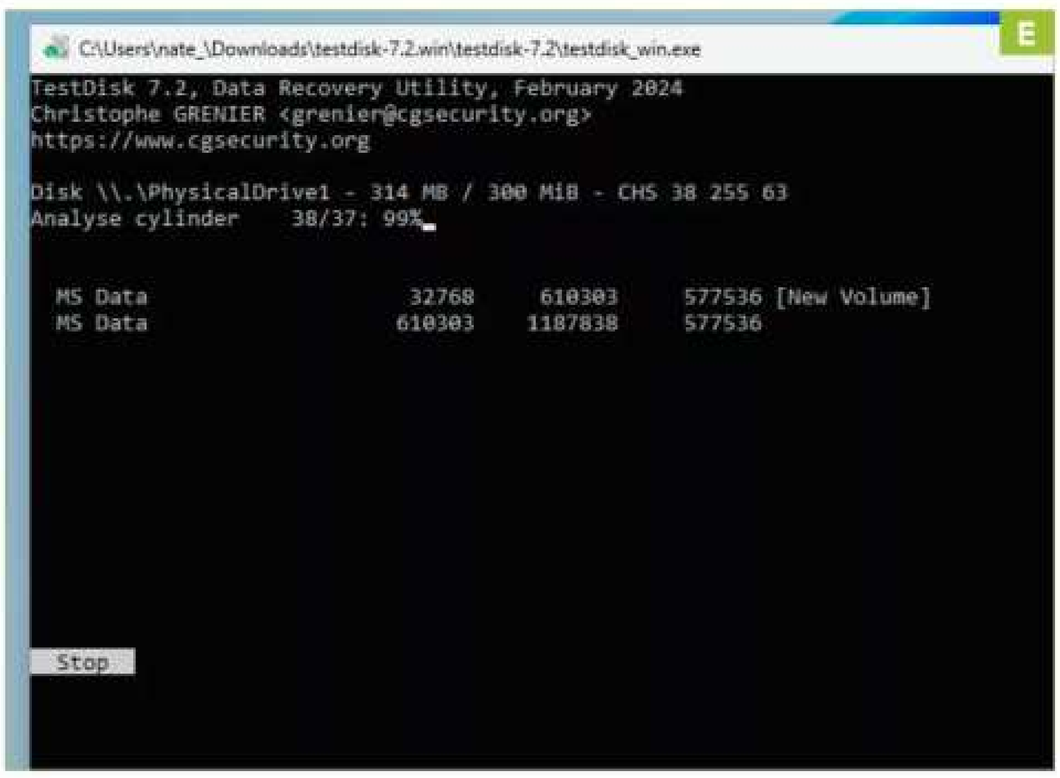
» While you're here, you can also change 'Keep corrupted files' to 'Yes' if you wish [Image D]. While such recovered files probably won't open correctly in their default application, it may be possible to extract some data with other specialist tools.

» The 'expert mode' option allows you to set the file system block size and the offset. This can sometimes be useful when you're working with an entire system drive or a formatted partition. If files are missing, then the project Wiki recommends trying the smallest sector size value that PhotoRec lets you select.

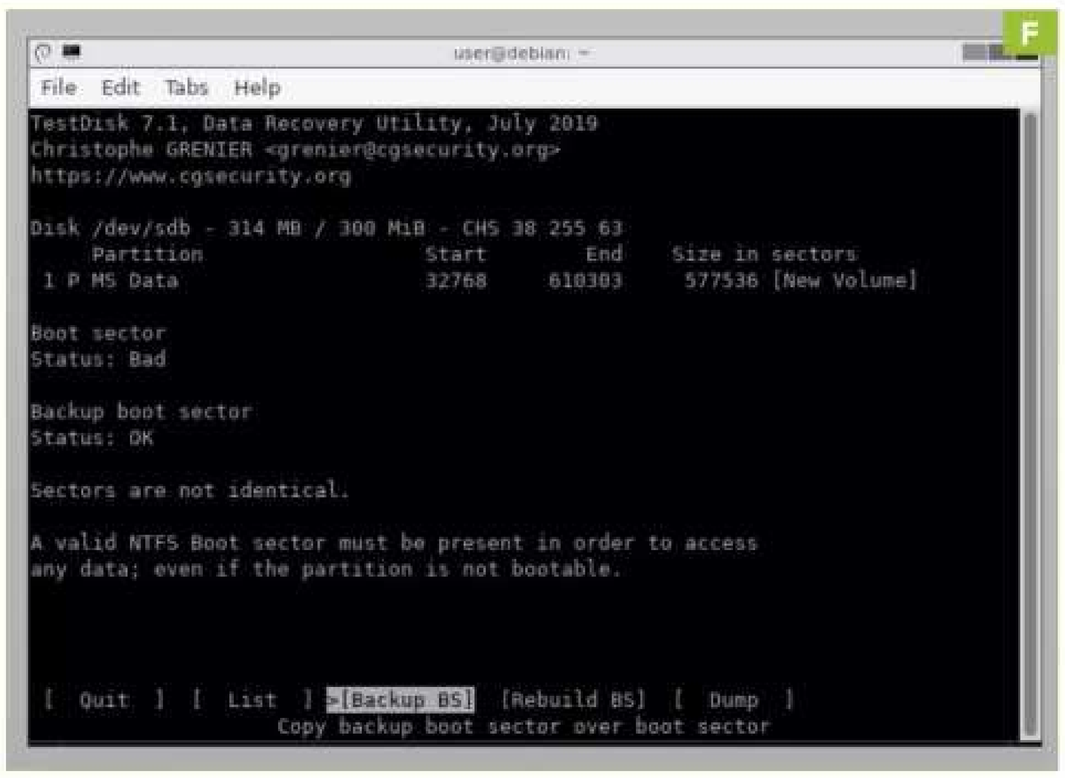
» 'Low Memory' should only be used on systems that crash during recovery.

» Choose 'Quit' to return to the main menu. At this stage, you can also select 'File Opt' to search only for files of a specific format. Select 'Search' to specify the filesystem type, as well as the destination directory.

© PHOTOREC



E



F

5 ANALYZE PARTITIONS

PhotoRec is a useful tool when you've deleted files or accidentally formatted a partition. It's less so in situations where the partition has been deleted or the drive corrupted.

» This is where PhotRec's companion utility, TestDisk, comes into play. According to the official documentation, its primary purpose is to recover lost partitions, as well as make non-booting disks bootable. It can also easily recover lost partition tables.

» One of the best indicators of this is if you access a disk via File Explorer, and Windows says the drive needs to be formatted.

» To get started, open the main 'testdisk' folder. From here, you can access the full documentation 'testdisk.pdf', which lists all the utility's features. You can also launch 'testdisk_win.exe'.

» TestDisk is a command line utility, but is easy to navigate via the arrow and enter keys. On first launch, you'll be prompted to configure logging options. Hit enter to create a new log file [Image E].

» You'll next be asked to select the drive that contains the missing/damaged partitions. TestDisk will display various partition table types, along with a helpful description. The utility will attempt to detect this automatically, so if you're unsure, choose the default option.

» Once this is done, choose 'Analyze' to check your current partition structure. What you see here will vary depending on the nature of your disk and its partitions.

» Our virtual disk had a damaged partition header, so TestDisk couldn't automatically detect the filesystem type. However, the first partition was listed twice, showing it was corrupted.

» Press enter to run a 'Quick Search' to examine the drive and find any lost or missing partitions. If nothing is found, press enter again to run a 'Deeper Search'.

6 REPAIR PARTITIONS/MBR

Assuming that TestDisk is able to find your missing/damaged partitions, these will be listed in the main utility window. Use the arrow keys to move between them and tap 'p' to list any detected files to make sure you have the right partition. You can also use 'q' to return to the previous menu.

Once you've confirmed your file location, press enter. You'll now see a list of your chosen partitions. Use the arrow keys to move to 'Write' and hit enter again. Press 'Y' to confirm that you wish to write the partition structure.

» If you need to use TestDisk to recover a system drive, using 'Write' won't automatically fix the boot sector.

» If you need to do this, firstly you'll need to have a way to access the bootable drive. You can accomplish this by connecting it to another PC so it can be mounted as an external disk.

» Alternatively, you can boot a live USB of an OS like 'GParted' (https://gparted.org), which comes with TestDisk preinstalled.

» Whichever method you use, after using 'Write' to fix the partition structure, select 'Backup BS', and hit enter. Press 'Y' to confirm that you want to copy the backup boot sector over the existing boot sector.

» TestDisk will prompt you to restart your device. Press enter, and hopefully start your device using the fixed boot sector. If you're using GParted, you can also choose 'Local operating system' from the boot menu.

» If the system still fails to boot, there's another way to recover your data. Start TestDisk again, then choose the system drive and partition table, as you did before. In the next menu, choose 'Advanced', then scroll down to the partition that contains your files, eg. 'MS Data'.

» Choose 'List' from the menu to view files in the partition. Use 'C' to select and copy files to a new drive. [Image F]

7 CALLING IN THE SPECIALISTS

If you've been unsuccessful in recovering your files, it may be because the data has been overwritten or that there's a hardware fault in your disk.

» Fortunately, there are companies that specialize in data recovery. The good news is that they have a range of methods far beyond what either TestDisk or PhotoRec can do. This includes advanced techniques like disassembling drives in a forensic environment.

» The downside is that such recovery methods are usually quite expensive. If you're going down this route, the more information with which you can provide the recovery specialist, the better. Make a note of the specific files you're trying to retrieve, eg. Word documents, as well as any other useful information, like filenames or creation dates.

» Even if you've already followed the first step in this tutorial to back up your Windows system and any external drives, use TestDisk to create an image of the affected drive. The file format used (.dd) is universal, so it'll be easier to share.

» When you contact the recovery specialist, they may ask you to ship them the original device right away. Still, we recommend sending them the image you created first. Not only is this faster, but recovery is likely to be less expensive if the specialist only has to use software tools.

LAB NOTES

ZAK STOREY, CONTRIBUTING EDITOR

AMD's 9000 is coming

Yes, AI was on the agenda

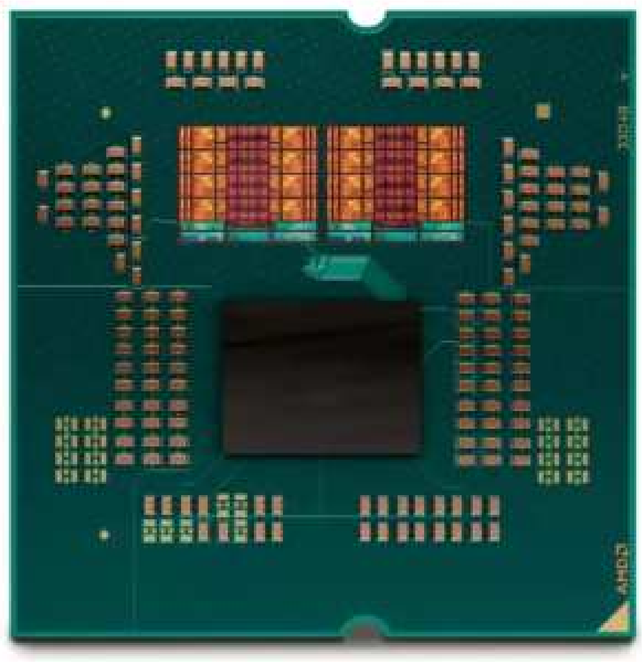
COMPUTEX 2024 has happened, and we've had a few announcements, first and foremost being AMD's 9000 Ryzen series presentation. The top-line facts are straightforward: spec generally stays the same across the majority. However, it's moving to TSMC's N4 4nm (maybe 5nm) process, and combining that with lowering latency, TDP, and increasing the bandwidth between the L1 and L2 memory cache, the CCD, and other pipelines.

That's impressive, as it's given AMD a 16 percent IPC performance boost, without increasing voltages or CCDs. Interestingly, that means we haven't seen an expanded core count on the mainstream chips this generation, either, making this the fourth one in a row where core count has been somewhat stagnant. No doubt this is to retain Threadripper's workstation and big data dominance, but given how efficient these chips are, it's a shame we've not seen an extra eight cores. Ryzen 9 9990X with 24 cores and 48 threads at 5.5 GHz, anyone?

It wouldn't be Computex 2024 without every brand sliding the word 'AI' into their presentations, and the 9000 series is no exception, generating 20 percent more in AI Acceleration. It'll also deliver twice as much bandwidth via PCIe 5.0 when GPUs and SSDs of that caliber are used in tandem, although those workloads aren't what we expect to see on desktop processors.

With such dominant performance available for high-end desktops, is there room for a Xeon or Threadripper outside of pure CPU performance? If so, would you be better off running multiple systems instead of one giant multi-core high-latency rig?

Regardless of theoretical build conundrums, AMD's 9000 series looks exciting. Combine that with AMD supporting AM4 until 2027, and a bevy of new 5000 series processors, and the next few months should be interesting indeed.



AMD is still using CCD, but there's no sign of X3D merging into the main branch just yet.

JEREMY LAIRD

contributing editor

Is gaming on Arm a goer? Qualcomm's new Arm chip, the Snapdragon X, looks promising. It's going to shake things up in the laptop market with its excellent battery life, and the new Prism layer for legacy x86 looks better than previous emulation attempts for Windows on Arm.

But the biggest test is going to be gaming, which is where the Qualcomm-Arm-Windows alliance begins to falter. Early indications are that x86 games generally work, and the superficial frames rates look tolerable. But you likely wouldn't want to game on a Snapdragon X.

For starters, some games seem to suffer from stuttering. The most likely cause is software. Some games, including *Diablo 4*, can cause the Prism emulation layer to crash. Others seem to have odd resolution limitations or default to aggressive upscaling. A few titles, including *Fortnite*, won't start up at all.

Depending on how you look at it, this is or isn't a big deal. Most laptop users will appreciate the excellent battery life and the relatively cool and quiet running, and won't notice that whatever legacy x86 app they're using is taking a 10 to 15 percent performance hit.

However, Qualcomm has decided to big up gaming on the Snap' X, and that's probably a mistake. Gaming is the one thing this chip doesn't really deliver on.

It might be slow, but it does come in some lovely colorways.

Editor's Pick:

WD Passport 6TB

A seriously chunky backup drive

I'LL CONFESS, my attitude to backing up information is fairly Spartan. I've been flattening my PC and reinstalling Windows at the slightest inconvenience for the last 14 years or so. It's the simplest solution for me. Graphics driver issue? Flatten it. Game not loading correctly? Flatten it. Weird hardware bug that doesn't make any sense? Flatten it. Given how easy it is to reinstall Windows, and the amount of bugs and registry mishaps it clears away, I advocate that everyone does a hard reset every six months or so.

The thing is, this has also helped me develop a blasé attitude when it comes to backing up. I don't keep anything valuable locally. All my music is streamed, and my personal files are either physical or backed up on the cloud behind layers of encryption. Videos, photos, and that ilk is archived and stored away on the old interweb. The bulk of what I'd consider my 'mission critical' info is safely stored away whenever I need it. Each time I get a new phone, I chuck the old one into a USB port, move all the files to my desktop, archive the lot, and chuck it into Google Drive.

Whenever I suggest that the easiest course of action for their PC problems is to just flatten the machine and start over, I get a repertoire of excuses. They need this file, that and the other, it's just too much work, or "Oh I've fixed it", only for it to become an issue shortly after, and then me query why they still haven't done a reinstall. That's particularly frustrating for me, when I consider it a 20-minute job.

That's where something like WD's My Passport comes in, at least to help less storage-adverse folk reset their PC. Not your average review product, admittedly, I knew I had to get one in for testing because I was curious. A 6TB drive? For $180, surely that's not going to be good, right?

Let's be clear—this isn't exactly a super-snappy M.2 SSD blistering along at 10GB/s sequentials, but for $180, 6TB isn't to be sniffed at. You're getting 33.33 GB per $. It is, however, a spinning platter hard drive at its core, I suspect with a smidge of SSD cache to boost its sequentials. From my digging, I found out that it's a SATA 3 device, tapping out at 6 Gbps max throughput (while the USB cable it comes with is limited to 5 Gbps, there is a USB Type C version), and it runs at a fairly reasonable 4,800 RPM. It's tiny too, weighing 0.46lb, and clocking in at a paltry 4.22 x 2.95 x 0.81 inches, or thereabouts.

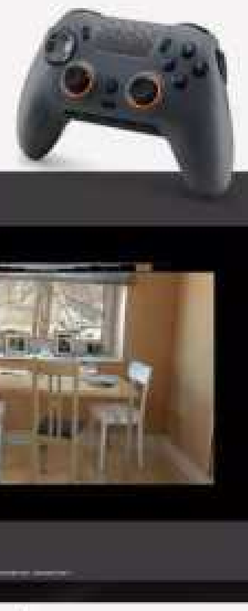
Performance is probably what you'd expect for a spinning platter running over a 5Gbps USB cable. Crystal Disk regularly reported figures at 120 MB/s for sequential read and write, and random 4K performance was just 0.42 MB/s read and 12.15 MB/s write. Equally, *Final Fantasy XIV*'s benchmark total load time was 36 seconds or thereabouts.

It's slow, and just goes to show how far we've come from a storage perspective. If you're just transferring documents to and from it, it's a solid pick. But anything even mildly large, and you're going to have a bad time. Transferring a copy of *Red Dead Redemption 2* took 20 minutes and topped out at 120 MB/s. Copying that transferred file on the drive again took 80 minutes, and capped out at 30 MB/s.

Something like Crucial's X10 Pro comes in at a similar price for one third of the storage, but with 20 times the speed. Do you really need 6TB of slow external storage in 2024? I'm not so sure. **–ZS**

$180, www.westerndigital.com

Reviewed...



The Samsung Odyssey G8 uses familiar QD-OLED tech, but the implementation? Sheesh...

Samsung Odyssey G8 OLED G80SD

Another monitor miss from Samsung

SAMSUNG IS a tricky company to gauge. On the one hand, it's a tech colossus, striding from advanced chip manufacturing to OLED panels, laptops, cell phones, and more. On the other, it is capable of some remarkable slip-ups and oversights.

So where does the new Samsung Odyssey G8 OLED G80SD fit into the triumph-or-tragedy spectrum? Frankly, it's too close to the wrong end for comfort. That's a surprise, because in many ways, this monitor is a known quantity.

It's a 4K OLED panel with up to a 240Hz refresh rate. Several monitors matching that specification have been announced this year, and of the ones you can actually buy, they all have essentially the same QD-OLED panel used here. By the time you read these words, it's possible that a few LG-based alternatives will be on sale. But the point is that we've seen the core technology before, and loved it.

What's not to like about Samsung's uber-zingy, ultra-quick QD-OLED panel tech combined with crispy 4K pixel density? Well, the first sign that something's up is that Samsung has opted for a matte anti-glare panel coating, where all the other 4K OLEDs have been glossy. There's a debate to be had over glossy versus matte, but this panel has been packed with Samsung SmartTV features and pitched for gaming, and that combo certainly leans heavily glossy.

In practice, the matte coating only slightly detracts from the usual contrasty OLED experience. Were it our only reservation, it wouldn't be a deal breaker. But speaking of the SmartTV functionality, that is this monitor's downfall. From a PC user's perspective, the SmartTV interface dominates procedures, and is infuriating and bewildering.

It all starts with initial power-up. You can't just plug in a PC and go; you have to go through a SmartTV setup procedure, which even involves identifying what device type you're plugging. Okay, that's a one-time deal, you say. If only.

The problem is that the SmartTV interface is supposedly designed to make things simple for general consumers rather than PC users, so it doesn't conform to any PC monitor norms. It was hours before we fully understood how to select HDMI or Displayport inputs reliably. Indeed, it got to the point where we were terrified of touching the bundled remote for fear that it would kick us back into the SmartTV interface, which it does at every possible opportunity.

Then there are the baffling settings menus, all of which are accessed in separate, counterintuitive ways. Working out if the panel had any OLED care features took about 20 minutes, while we still don't know if we got to grips with setting this panel up correctly for HDR.

Anyway, somewhere buried in those menus might be a fantastic OLED monitor, but we could never get the SDR or HDR colour balance to look right. This is a very nice monitor with incredible performance potential, and still looks incredible in games in HDR mode, even if the calibration is a little off in all of the modes I could uncover. But as a PC user, there's no way you'd choose this monitor over the alternatives using essentially the same OLED panel, only actually optimized for PC use.–**JEREMY LAIRD**

VERDICT
6

Samsung Odyssey G8 OLED G80SD

EXPERT PANEL Samsung's QD-OLED tech rocks; Crispy 4K visuals.

PAROLE BOARD SmartTV interface is an absolute nightmare; Very expensive.

$1,299, www.samsung.com

SPECIFICATIONS

Screen size	32 inches
Resolution	3,840 x 2,160
Brightness	250 nits full screen, 1,000 nits max HDR
Color coverage	99% DCI-P3
Response time	0.03ms
Refresh rate	240Hz
HDR	HDR10
Features	Samsung QD-OLED 3rd Gen panel, Adaptive Sync, 1x DisplayPort 1.4, 2x HDMI 2.1, Samsung SmartTV

© UNSPLASH

Need to connect 200 devices at 27Gbps? Then the Netgear Orbi 970 is for you, albeit at a price.

Netgear Orbi 970

Mega speed for a mega price

NETGEAR WAS QUICK off the mark with its RS700S, one of the first routers we've seen supporting the new Wi-Fi 7 standard. This Orbi 970 mesh system was announced around the same time, and promised to be one of the best mesh Wi-Fi systems on the market, but faced delays, and has only just become available here.

However, the Orbi 970 goes even further and faster than the standalone RS700, offering a three-piece 'whole home' mesh system with a top speed of 27Gbps and is capable of covering areas of up to 10,000 square feet. It's also phenomenally expensive, with the three-piece system here costing $2,299, and that's before you add the cost of the extra subscription services that Netgear tries really hard to sell you. Ouch.

On cost, the Orbi 970 will probably rule itself out for most home users on domestic broadband services running at 150Mbps. However, Wi-Fi 7 isn't just about speed. It also brings improved capacity and reliability, and the Orbi 970 claims to provide fast, reliable connections for up to 200 devices on your network. It also includes new Wi-Fi 7 features, such as 'preamble puncturing', which helps to reduce outside interference and improve the reliability of your Wi-Fi connections.

ON THE SURFACE

The upright rectangular design of the Orbi range is a familiar sight in many homes and offices, but the Orbi 970 has had a bit of a facelift. The speed of Wi-Fi 7 requires a lot more power than previous models, so the new Orbi units have a taller, more cylindrical design that stands at 11.6 inches high and 5.7 inches deep, and houses no less than 12 internal antennae. The larger design means that each Orbi unit weighs 4lb, so you'll need a sturdy shelf or table to support them, preferably with plenty of free space.

Reflecting the state-of-the-art performance of Wi-Fi 7, the main router has a 10Gb main Ethernet port, with a second 10Gb port to provide a high-speed wired connection (LAN) for a device such as a gaming PC or console that needs maximum performance.

The router also includes four additional ports with 2.5G Ethernet for additional wired connections. The two satellite units also have a 10Gb Ethernet port, plus two 2.5Gb connections. You can't fault the Orbi 970 for its high-speed connectivity, but it's a little disappointing that there are no USB ports, which would allow you to connect a shared hard drive or other storage device to your network.

As for the Orbi app, it's easy to use, though a bit lightweight when it comes to extra features. The app combines the different frequency bands—2.4GHz, 5.0GHz, and 6.0GHz—into a single network, then automatically connects your devices to the fastest band. That keeps things simple for newcomers, but more advanced users might want more precise control over the network settings.

As for performance, we have an office at the back of our building that normally struggles with weak Wi-Fi, forcing us to rely on some PowerLine adaptors to provide a wired network connection. To test the Orbi 970, we connected the Orbi's main router to our existing office router, then positioned one Orbi satellite in a hallway roughly halfway between the main router and back office. The second Orbi satellite was set up in the office.

Unsurprisingly, the Orbi effortlessly cruised along at the maximum 150Mbps provided by our office broadband connection. So, it may be wildly expensive. But this is one of the best routers out there. If you're looking for state-of-the-art performance for a larger home or office, and you don't need too much in the way of parental controls, then the Orbi 970 really is state of the art. **–CLIFF JOSEPH**

VERDICT **8**

Netgear Orbi 970

+ ESCAPE VELOCITY Ultra-fast speeds; Huge device count capacity.

– LOST ON RE-ENTRY Insanely expensive; No USB connectivity.

$2,299, www.netgear.com

SPECIFICATIONS

Wi-Fi	Quad-band Wi-Fi 7 (2.4GHz/5.0GHz/5.0GHz/6.0GHz)
Speed	27Gbps
Router	1x 10 Gigabit Ethernet (WAN), 1x 10 Gigabit Ethernet (LAN), 4x 2.5 Gigabit Ethernet (LAN)
Satellites	1x 10 Gigabit Ethernet (LAN), 2x 2.5 Gigabit Ethernet (LAN)
Processor	Broadcom quad-core CPU, 2.2GHz
Memory	2GB
Storage	4GB
Dimensions	11.6 x 5.7 x 5.2 in, 4lb

Philips Evnia 49M2C8900

Philips gets in on the uberwide OLED action

49 INCHES? Check. QD-OLED panel? Present. 240Hz? Affirmative. We've seen this before, surely? Certainly, the new Philips Evnia 49M2C8900 is not a new concept. There have been several gaming monitors using the 49-inch 32:9 aspect QD-OLED panel, not least panel manufacturer Samsung.

The question is how well Philips has implemented this panel and where it fits in the price hierarchy. Features-wise, it's at the better-specified end. Connectivity is comprehensive thanks to dual HDMI 2.1 ports, Displayport 1.4, USB-C with 90W power delivery, a USB hub, and audio out.

You also get a KVM switch, which combined with that USB-C interface, makes this perfect for sharing between a laptop and gaming desktop. Further niceties include Phlilips' Ambiglow RGB lighting on the rear and a stand with height, tilt, and swivel adjustment. You will, of course, need a large desk to accommodate a monitor of this scale.

The rest of the specs are as you'd expect. That includes low 0.03ms pixel response, 5,120 by 1,440 native resolution, and 250 nits full-screen brightness. Peak brightness is quoted at 1,000 nits on a three percent window. Those figures are near identical to other monitors using this QD-OLED panel.

As for broader image quality, there are no surprises. Philips has set this up in SDR mode to deliver constant brightness, and it's as punchy as it gets for OLED gaming monitors. The color calibration is decent, with the caveat that the signature pink tint of QD-OLED tech is present.

It's not a huge issue, but it is visible most obviously in flesh tones, which don't look terribly natural. As for HDR performance, again it's very much in line with similar monitors. Philips offers a range of HDR presets. Most of them have

Philips has taken Samsung's QD-OLED panel and given it the Evnia Gaming treatment.

little if any obvious benefits compared to the default VESA HDR True Black option.

If that sounds rather clinical, be in no doubt that this monitor is absolutely staggering. The combination of the huge scale with the contrast, black levels, speed, and vibrancy of QD-OLED is incredible. The ultrawide aspect ratio doesn't suit all games, but where it works, the wraparound experience, combined with the massive panel size and OLED visual zing, is something else.

The catch is that this panel is not unique, and can be mostly matched for less money—the Gigabyte Arous C049DQ can be had for $899. It's the same QD-OLED panel, the one major spec difference being 144Hz refresh rather than 240Hz. It also only offers 18W of power delivery for laptops over its USB-C port.

Given the 5,120 by 1,440 resolution, 240Hz versus 144Hz will be academic in the most demanding games—you're not going to be hitting 240Hz, and the ultrawide aspect makes this monitor suboptimal for eSports. All you'd be giving up would be a USB-C interface that can keep more powerful laptops charged.

All of this means this is an excellent monitor, but doesn't stand out. Should you be in the market for a 49-inch OLED, and want the USB-C with the full 90W, put this on your shortlist and pull the trigger if you can get a discount. **–JEREMY LAIRD**

VERDICT **8**

Philips Evnia 49M2C8900

PEAK PERFORMANCE Gorgeous QD-OLED panel; Strong feature set.

FEELING PEAKY Doesn't do anything novel; There are cheaper options.

$1,349, usa.philips.com

SPECIFICATIONS

Screen size	49 inches
Resolution	5,120 x 1,440
Brightness	250 nits full screen, 1,000 nits max HDR
Color coverage	99% DCI-P3
Response time	0.03ms
Refresh rate	240Hz
HDR	VESA DisplayHDR True Black 400
Features	Samsung QD-OLED 3rd Gen panel, Adaptive Sync, 1x DisplayPort 1.4, 2x HDMI 2.1, USB-C with 90W power delivery

© UNSPLASH

Microsoft's new Copilot button takes its place near the space bar.

Lenovo LOQ 15IRX9

A well-specced gaming machine that's just a little bit unexciting

LOQ IS LENOVO'S new budget gaming brand, and it takes a lot of design cues from the older IdeaPad 3 Gaming machines, though gains an extra cooling vent on the side. It's well-priced, though definitely worth paying the extra few hundred bucks for the uprated model we're reviewing here. With an RTX 4060 and 13th-gen Core i7 CPU, it's still not going to be competing for a place at the top of the pile when it comes to gaming framerates, but it does a good enough job considering the price point.

As a fairly standard 15-inch laptop, there's one thing that stands out about the LOQ 15, and that's the keyboard. Seriously. It's extremely comfortable to type on, and Lenovo has resisted the urge to do anything silly like replace the WASD keys with see-through caps. There's RGB lighting behind it, because that's a law or something, but otherwise, it's very comfortable to use, the round-edged keys sinking into their beds with enough resistance that you're never left wondering if a keypress has connected. The trackpad isn't bad, too, although an external gaming mouse will probably make it redundant.

Elsewhere, it's all business as usual. The i7/4060 combo delivers the performance you'd expect, dishing out 123fps in *Horizon Zero Dawn Complete Edition* at 1080p Ultimate Quality settings and with DLSS on.

The chassis is largely uninteresting, though some attempt at making it less boring has been made in the way the webcam cluster rises above the top edge of the screen itself, creating a lip that you can use to open the machine from its folded position. There are no ports on the left-hand side of the LOQ 15, and instead some have taken up residence at the rear, including the Lenovo charging connector, which we're big fans of—it slips in easily, and doesn't care what way up you have it. With three USB-A ports, two USB-C (not Thunderbolt) connectors, gigabit Ethernet, a full-size HDMI 2.1 that's asking for some external monitor action, and (perhaps in a nod to Lenovo's business heritage) a switch to disable the webcam, there's a lot to choose from.

Wireless connectivity tops out at Wi-Fi 6, which is fine, as most of us don't have Wi-Fi 7 or the means to use all of its capabilities, but this and the 1080p screen can make it look like it's trapped in the past. The display is generally fine—an IPS panel with a maximum refresh rate of 240Hz and a peak brightness of just over 300 nits—but when pitted against the high-res OLEDs of other laptops, it feels dull. This is, of course, a budget machine, so we're not expecting miracles, but it's remarkable how your appreciation of features can shift once you've been exposed to the next step up in quality.

Although not one of the new breed of Copilot+ AI laptops, there's a Lenovo LA1 AI chip onboard, and its job is to monitor your usage and adjust settings in an attempt to extend the battery life. This is desperately needed, as the battery ran dry in only 2.5 hours in our tests, and if you push it hard while gaming, it's going to be less. This is the price you pay for this kind of portable power, however, and there's clearly a lot of internal heat being generated here, as the fans repeatedly pulse on and off, even when it's not doing much, and makes a lot of noise when it's being stressed.

Gaming laptops are often expensive monsters, and it's nice to see Lenovo produce something well specced but reasonably priced. The LOQ 15 suffers from being unexciting, but then, sometimes that's what you need.

–IAN EVENDEN

VERDICT **7**

Lenovo LOQ 15IRX9

LOCK, STOCK Good specs; Decent price; Lots of connectivity.

BARREL A bit dull, but there's plenty of excitement on-screen.

From $1080, www.lenovo.com

SPECIFICATIONS

CPU	Intel Core i7-13650HX
Graphics	Nvidia GeForce RTX 4060
Memory	16GB
Screen size	15.6 in
Resolution	1080p
Refresh rate	144Hz
Colour coverage (stated)	100% sRGB
Storage	500GB SSD
Connectivity	Wi-Fi 6, Bluetooth 5.1, 3x USB 3.2 Gen 1 Type-A, 1x USB 3.2 Gen 2 Type-C (DisplayPort 1.4), 1x HDMI 2.1, Ethernet, 3.5mm headset jack
Dimensions	0.94 x 14.17 x 10.2 in
Weight	5.25 lbs

© UNSPLASH

The best budget case, period.

Phanteks XT View

Flawless, purely flawless

TALKING ABOUT a case like this is simultaneously incredibly nice and exceptionally frustrating. It's so good that conversely, there's not a lot to complain about. The XT View is nothing if not spectacular. Not only does it provide some exceptional features, aesthetics, and build convenience, it manages to do that all while keeping the price below $80. You get a full fish-bowl case, complete with tempered glass, three RGB fans, and an RGB light strip, plus an RGB controller built in to the front I/O, with room for expansion as well. On top of that, there's support for all manner of cooling solutions, all of which are well-ventilated, in a relatively small compact ATX tower. There's no corners cut here at all, which for the price, is honestly insane.

We've had the pleasure of building in the XT View this very issue—you can take a look at our build on page 16 for our full thoughts on that process—but the lowdown is that it's just phenomenally well designed.

The View is available in two colorways: you've got the Satin Black version that's on display here, along with a Matte White variant, both for the same price. Both support full-length GPUs up to 16.33 inches, along with housing E-ATX boards up to 11 inches, too. CPU clearance is also incredibly healthy, with a maximum height tapping out at 7.24 inches.

Dimensions aside, there's also ample room for cooling. Despite lacking any form of mounting on the front panel like in a traditional chassis, you can install up to a 14.2-inch rad in the roof, plus 9.4 inches in the side (as long as you have a vertical GPU adapter), and a further 4.7 inches in the rear. The midplate does support fan mounting, but sadly lacks capacity for a full-blown radiator. You can house up to a total of nine 4.7-inch fans throughout, all in the usual places, along with those three on the midplate. Or you could swap four 14.2-inches out instead and pop two 5.5-inches in the roof, and one 5.5-inch in the rear instead if you want something with a little more punch.

Front I/O is hardly lacking, either. There's USB Type C, USB 3.0, power reset, and a headphone jack, plus an integrated RGB controller as well. You can install the fans and the RGB strip directly into it, or have them plumbed into your motherboard instead, although to be honest, the amount of control you have via the RGB controller is phenomenal, with a mixture of patterns and color presets available across all of them.

The only minor flaw this chassis has is that it's not entirely intuitive on how you're meant to configure the RGB cabling across all the included devices, and the instruction manual isn't that helpful either, as it mostly tells you that you have RGB cables that need adding, and that's it. Still, with a little tinkering, it's easy to get it done and dusted.

Honestly, the View is phenomenal. It's hard to understate just how impressive a case this thing is. Not only is it super-easy to build in, what Phanteks has managed to pack into this absolutely stunning chassis is, well, simply put, outstanding, particularly at this price. If you'd turned around to us and said, "Here's the XT View, it's $140", we'd probably have given it a 9/10 and praised it for all the above all the same, but at just under $80? Well, just wow. We don't give things a 10/10 at *Maximum PC*, but honestly, the XT View deserves it. **–ZAK STOREY**

VERDICT
9
KICK ASS!

Phanteks XT View

+ 20:20 VISION Beautiful chassis design; Exemplary compatibility; Solid cooling support throughout; Awesome RGB accessories included as standard; Multiple color options; Super-easy to build in.

– BLIND LEADING THE BLIND It could do with rubber grommets.

$80, www.phanteks.com

SPECIFICATIONS

Motherboard Support	ITX, Micro-ATX, ATX, E-ATX (12x11-inches)
2.5-inch / 3.5-inch Support	Up to 5 x 2.5-inch, or 2x 3.5-inch and 3x 2.5-inch
Max Radiator Support	120mm Rear, 360mm Roof, 240mm side
Fan Support	1x 120/140mm Rear, 3x120/2x140mm Roof, 3x120mm floor, 2x120mm Side
Dimensions	17.32 x 9.05 x 19.68 inches
Graphics Card Clearance	16.33 in
CPU Tower Clearance	7.24 in
Warranty	5 years limited

HP Spectre X360 14 (2024)

A sleek two-in-one that's bright, fast... but uses integrated graphics

BUYING A 2-IN-1 laptop often incurs an additional expense—a stylus—so it's good to see that HP has included one in the box with this 2024 edition of the Spectre X360. It's an up-to-date package all round, with the Core Ultra 7 155H (Meteor Lake) CPU powering it along. From a gaming point of view, the integrated Arc graphics are sub-optimal, but this is still a very attractive package if you only want to do the occasional bit of alien blasting.

The OLED touchscreen is the Spectre's window on the world, and it's a lovely place to do things. No only do you get those marvellous OLED colors and blacks, but with an 1800p resolution and 120Hz max refresh rate, it was clear and bright before HP covered it in Gorilla Glass and made it touch sensitive. It's attached to the body of the laptop with two hinges, and these are smooth to operate and broad, so that they don't create too much of a weak point in the laptop's design.

The shape of the Spectre is slightly unusual, as rather than leave it as a rectangle, HP has chosen to shave off the rear corners to create flat surfaces. This has two effects: there are ports on these extra edges, a Thunderbolt on the right that can be used for charging, and the 3.5mm headset port on the left. With the same corners shaved on the screen half, it adds a design flourish that makes the Spectre look modern, though the memory of the octagonal pieces of paper used in the *Battlestar Galactica* reboot did resurface when we first saw it.

The 14-inch laptop is an attempt to merge the useful size of the 15-inch with the extra portability of the 13-inch, and for the most part HP has succeeded. The keyboard is tenkeyless, yet retains full-size keys and speakers either side, and the compromises that have been made in the name of keeping things compact—note the USB-A port that uses a slimline design that needs to be opened up before use—are mostly wise ones. That angled Thunderbolt port, for example, means your charging or video cable can run off to the back of your desk without getting in the way, yet is easy to find when you want to leave. The headset port is smaller, so may be harder to insert, especially on the first attempt.

Performance is generally excellent, though the Arc graphics make themselves known by being incompatible with the demanding Cinebench 2024 benchmark test. In 3D Mark's Night Raid, a gaming test made with integrated graphics in mind, the integrated solution scores less than an RTX 2060 laptop GPU, but in Time Spy (which is really for discrete GPUs), it scored better than the Steam Deck. So gaming is absolutely possible on the Spectre, and thanks to its hardware advantages (mainly the screen), it does a good enough job of it as long as you keep the settings down.

Gaming is not really the 2-in-1's forte, though. In reality, it's a fantastic all-rounder that can be used for natural pen input (though it's a little heavy to use as a tablet all the time, and artists may like to rest it on something) and will power through office work, image editing, content creation, and much more. It has good battery life (eight and a half hours in our tests), an excellent keyboard, and the screen locks your eyes to it. There is so much to like about this evolution of the Spectre, it seems unfair to complain about that GPU. **–IAN EVENDEN**

VERDICT **9**

HP Spectre X360 14 (2024)

+ SPECTRE Excellent 2-in-1; Plenty of RAM; A gorgeous screen.

– OBJECTER Only Arc integrated graphics, which will cause gamers to flinch.

$1,850, www.hp.com

SPECIFICATIONS

CPU	Intel Core Ultra 7 155H
Graphics	Intel Arc integrated
Memory	32GB
Screen size	14in HDR OLED
Resolution	2880 x 1800
Refresh rate	120Hz
Colour coverage (stated)	100% P3
Storage	2TB SSD
Connectivity	Wi-Fi 7, Bluetooth 5.4, 1x USB Type-A 10Gbps, 2x Thunderbolt 4, 1x 3.5mm headset port
Dimensions	12.35 x 8.68 x 0.67 in
Weight	3.19 lb

© UNSPLASH

The maximum wattage of the CPU is 115W, but it can draw as little as 28.

Bag a software bargin

Don't pay full price for software when we can offer you huge reductions on everything from security software to Windows 11 Pro

Norton 360 Premium for $29.99

WE'VE NEGOTIATED a killer deal with Norton. No subscriptions, just a one-off bargain price of $29.99 compared to the regular $109 charge. That buys you fifteen months of cover from the Norton Security suite across ten devices.

Because it's the Premium version, you get a host of extra tools. There's 75GB of cloud storage for secure backups, plus the full version of Norton Secure VPN, both to protect your identity and provide a way of watching TV from home while abroad.

Norton Parental Control provides tools to see exactly what your kids are up to on their various devices, and you also get GPS location monitoring for Android and iOS.

To round things off, Norton Password Manager generates and stores passwords across all your devices, while SafeCam for PC stops cybercriminals taking photos on your webcam without your knowledge.

ALSO CONSIDER Avast Ultimate Suite 2024 for $29.99 (10 devices for two years) SAVE 87%

Windows 11 Pro for $79.99

WANT TO UPGRADE from Windows 11 Home to Windows 11 Pro? Or perhaps you're building a new PC from scratch, or looking to move up from Windows 10? Maybe you want to run Windows on your Mac? Whatever your motives, a Windows 11 Professional OEM licence is a great choice.

The first reason is simple: price. Microsoft charges $119.99 for a retail licence of Windows 11 Home, and a staggering $219.99 for Windows 11 Professional. By choosing an OEM licence—and avoiding the many dubious sources of licences you may find online—you cut that price substantially.

ALSO CONSIDER Windows 11 Home for $49.99 SAVE 64%

Avast Ultimate 2024 for $29.99

WE'VE SECURED AN 87% discount for Maximum PC readers on this excellent security suite. $29.99 buys you protection, a VPN, and a range of handy utilities and tools for two years across ten devices. That includes PCs, Android devices, iPhones, and Macs. Along with a powerful antivirus engine, Avast can help you shop and bank safely, spot fake websites and ransomware, and stop hackers from remotely taking over your device.

You also receive Avast SecureLine VPN, which offers a secure tunnel to the internet, changing your location, hiding your IP address and adding an extra layer of protection. It usually costs $45 a year alone.

The $29.99 cost includes a two-year subscription for ten devices, compared to $194.99 if you bought the products individually, and for a limited time we're offering readers an extra 10 percent off by using the code MPCAUG10 at checkout.

ALSO CONSIDER Adobe Photoshop Elements 2023 for $70 SAVE 30%

software.maximumpc.com

Geometric Future Model 4 Caliburn

Challenging build, beautiful finish

THIS IS THE SECOND CASE from Geometric Future that we've absolutely fallen in love with recently. When it comes to outlandish design, the company is certainly not pulling its punches. The Model 4 is without question a super-small chassis. Geometric labels this thing as a Compact 35L ATX case, and they're not kidding on that front.

We spoke about it last issue in our feature build for that month, but for reference, this thing clocks in at just 15.6 x 8.5 x 16.1 inches in its smallest configuration. It does that while retaining support for up to nine 4.7-inch fans, GPUs up to 15.9 inches in length, plus full-size PSUs and E-ATX motherboards, plus you can still stick two radiators in there. In contrast, the NZXT Manta, one of our all-time favorite ITX cases, is bigger than this thing.

But it's not all about size or lack thereof; the Model 4, comes packing incredible build quality, too, with L-shaped tempered glass windows, mirrored finishes, and plenty of pristine metal all around as it does so. Ventilation is solid, and cable management is much improved over the Model 8 that we tested just a few months prior. Front I/O is decent as well.

The real versatility, though, comes in how you can configure this thing. The Model 4 has four separate variations that you can install hardware in, depending on if you want more radiator support, a top-mounted PSU, vertical GPUs, or even just more SSDs. The chassis itself is predominantly held together with Phillips screws, and there are a number of sliding thumbscrews and panels that can be moved around and rearranged to provide you with extra clearances and facilitate whatever it is you have in mind. It's not the most intuitive of cases to work with, definitely requiring the instruction manual, but once you've got that PSU installed, and the cables carefully managed, it becomes far more manageable.

It's also worth noting that, like many ITX cases, the Model 4 actually does require you to think a little bit more out of the box when building. There's not a huge amount of clearance available here, certainly when you have additional components installed. Chuck a 14.2-inch radiator in the floor, and immediately you're going to lose access to those bottom motherboard connectors. Install the radiator without the fans on, and the PSU in all ready, and you'll need a super small screwdriver to get access to those fan screws on top. It's not exactly a bad thing—everything you want to do, you can do—but it just requires a touch more thought than your standard ATX build.

There are some minor tolerances that could do with tweaking, however. During our time building it, the rear I/O ports, and PCIe slots in particular, felt slightly offset. In some cases, that made it difficult to install and secure the motherboard, or get the GPU display cables plugged in correctly, but that doesn't require much tweaking to get to work. It also doesn't come with any fans as standard, so you will need to provide your own there, too.

The biggest selling point? You get all this brilliance, and a stunning chassis, with a tiny footprint and tons of power, without compromising on hardware, and a mirrored and beautiful box for just $109. That is incredible, and it's well worth the consideration if you're looking at downsizing your current build. **–ZAK STOREY**

VERDICT **9** KICK ASS!

Geometric Future Model 4 Caliburn

MODEL T Insane flexibility; Stupidly small; Crazy amount of compatibility; Solid price point; Beautiful materials.

CYBERTRUCK Clearances can be tight; No fans included.

$109, www.geometricfuture.com

SPECIFICATIONS

Motherboard Support	ITX, Micro-ATX, ATX, E-ATX (12 x 11 in)
2.5-inch / 3.5-inch Support	2 x 2.5 in + 2 x 2.5 / 3.5 in
Max Radiator Support	4.7-in Rear, 9.5-in Roof, 14.2-in Floor
Fan Support	2 x 4.7/5.5-in Roof, 1 x 4.7-in Rear, 3 x 4.7-in / 2 x 5.5-in Floor, 3 x 4.7 in / 2 x 5.5-in Underside
Dimensions	15.6 - 16.9 x 8.5 x 16.1 in
Graphics Card Clearance	15.9 in
CPU Tower Clearance	6.46 in
Warranty	1 year limited

Glorious Model D 2 Pro 4K/8KHz Edition

8,000Hz polling is wasted on me

OUTRAGEOUS SPEED in a featherweight chassis. That's what Glorious is bringing to the table with the Model D 2 Pro 4KHz/8KHz Edition. This gaming mouse delivers a painfully quick 8,000Hz polling rate over a wired connection, and maintains half of that even over wireless. In other words, it's communicating its position with your PC eight times faster than most gaming mice.

Superficially, the 4K/8KHz Edition appears to be your run-of-the-mill black plastic mouse, and hardly screams quality from the outset, though this is the trade-off you have to make to shed weight. It has to be pretty simple to keep weight down, which is paramount to competitive gaming aspirations, and comes in at just 62 grams. Don't confuse the 4K/8KHz Edition with the 1KHz version, either. The latter is $30 cheaper and weighs a couple grams less.

However, the 4K/8KHz Edition's strongest feature is its refined shape. It has a gentle curve which slopes more aggressively downwards from the inner edge of mouse button two but levels out again. Obviously, hand shapes and sizes vary, but we found it to be an excellent fit for both fingers and thumb with all the buttons within comfortable reach. There's also a DPI switch in the center of the mouse that's sufficiently out of the way to not be accidentally pressed.

As for complaints, a more distinctive and tactile click to the main mouse buttons would be nice, and the scroll wheel is pretty average. It's not very tactile, but you can at least make out each individual notch in the movement. That's important if you plan to use the scroll wheel for any shortcut shenanigans, such as scroll jump.

Anyway, the core features of the 4K/8KHz Edition are pretty good for a lightweight gaming mouse, but the BAMF 2.0 sensor is something else. It produces smooth and highly consistent updates in our mouse testing graph. Even with rapid mouse movements, you won't get the sensor to buckle under the pressure.

That's all running at 1,000Hz. With higher polling rates, greater discrepancies between each count inevitably creep in. At 8KHz, you see that writ large, so you can't help but wonder about the real-world utility in an 8KHz, or even 4KHz, polling rate. The same applies to the subjective experience. The 1,000Hz polling rate seems more than sufficient. The headline feature for this gaming mouse feels entirely wasted on me—I'm unable to tell the difference between 4,000Hz, 8,000Hz, and 1,000Hz polling rates while playing a game. There's also the issue of which games actually allow you to use really high polling rates. Some do, like *Valorant*, while others don't.

All that aside, we also noticed some connection dropouts—both wireless and wired—requiring the mouse to be reconnected. The battery also runs out with little warning, and the general sense is of a mouse that has to be charged more often than other wireless rodents. Notably, using the 4K/8KHz Edition at 4,000 Hz polling rate wirelessly chews through the battery at over twice the rate compared to 1,000 Hz, which is only more reason to go for the cheaper and slightly lighter still 1KHz model.

The software suite is basic in appearance, too, but at least contains all the key functionality you could reasonably expect. There are quite a few options for changing various performance parameters, such as lift-off distance, debounce settings, DPI, and remapping any of the buttons as you see fit.

Overall, the 4K/8KHz Edition delivers what it sets out to, namely an extreme polling rate. But to what end? That's the question. If you're going to invest in a Glorious Model D 2 Pro, our advice is to stick to the 1KHz model. But now that this review is wrapped up, however, I'm going back to my time-proven favorite: the Logitech G Superlight. That, ultimately, says it all. –JACOB RIDLEY

VERDICT **6**

Glorious Model D 2 Pro 4K/8KHz Edition

➕ **LIGHT, SPEED** Ultra-fast 8KHz polling; Very light; Good ergonomics.

➖ **LIGHT WEIGHT** Questionable benefits from the 8K polling; Poor battery life.

$130, www.gloriousgaming.com

SPECIFICATIONS

Buttons	6
Feet	PTFE
Connectivity	Wired (USB-C), Wireless (USB-C dongle)
Sensor	BAMF 2.0
Max DPI	26,000
Max acceleration	50g
Max speed	650 IPS
Polling rate	Up to 8,000 Hz wired, 4,000 Hz wireless
Battery life	80 hrs (1,000 Hz), 35 hrs (4,000 Hz)
RGB lighting	None
Warranty	2 years

Scuf Envision Pro

A high-end controller actually designed for PC gaming

A CONTROLLER built for PC gaming? Imagine that—a whole controller just for us. We've become so accustomed to borrowing pads from the best consoles that it actually seems like a novel idea. The thing is, Microsoft and Sony spend big money on designing their controllers, so what can Corsair-owned Scuf bring to the table?

For starters, a software package exclusive to Windows. The Envision Pro relies heavily on the Corsair iCUE application to deliver a range of functionality. Most notable are the five programmable macro G-keys running beneath the twin sticks and configurable via the application. With iCUE, they can be programmed for pretty much any function.

There are also a few additional buttons, too. Each shoulder has programmable buttons, known as SAX buttons, which you activate with the lower half of your index finger, while the rear of the controller offers four more shortcuts to add any macros or inputs desired. Even the standard D-pad, thumbsticks, triggers, bumpers, and X and Y buttons are programmable from within iCUE.

The process of adding, removing, or modifying macros is simple. iCUE offers a modular approach built around recording and reconfiguring each 'event', which is a key press, wait time, or action. It's definitely one of the smoother macro experiences around, and something iCUE does well. Many of the buttons on the Envision Pro are of the clicky variety. Courtesy of Omron switches, like those often employed in the best gaming mice, this controller offers a snappy, tactile response to rival the best of the best.

Following in the footsteps of Sony's PlayStation pads, the Envision Pro offers a symmetrical twin-stick layout. This controller has a particularly comfortable symmetrical stick design, too. It's chunky and bulbous in all the right places, so offers a firm grip and pushes comfortably into your palms. Add in the soft-touch finish on the front and textured grips on the rear, and the Envision Pro feels great to hold. At 289 grams, it's also only a touch heavier than Sony's DualSense at 277 grams, and near enough the same as the Xbox Wireless Controller at 288 grams.

ROOM FOR IMPROVEMENT

While all that sounds great, there's a snag. Having Corsair's iCUE software running at all times isn't obligatory, as it has its own onboard memory to save profiles. But you will have to go through the initial setup in iCUE at least once. Pretty much any other controller would work out of the box once plugged in via USB. The Envision Pro doesn't, and this feels like a big miss for a PC-first pad.

Another failing is the lack of Hall effect sticks. We consider these a must-have for any modern high-end controller due to their inherent resistance to stick drift, unlike more traditional potentiometer sticks. We didn't detect any drift during testing, but then these issues tend to crop up after extended use and once the potentiometer is worn down. Given the $180 price tag, which is four times the price of an Xbox Wireless Controller, it's quite an omission.

Suffice to say, then, the Scuf Envision Pro is a mixed bag. It feels great to use, and perfectly comfortable for longer sessions. The Slipstream Wireless connection was likewise flawless throughout our review.

But the Envision Pro is also expensive, and not the slam dunk you'd want it to be for the money. The lack of Hall effect sticks, clunky connectivity sans iCUE, and high price take the shine off an otherwise appealing controller. A controller designed from the ground up for PC is definitely a great concept. With a few tweaks, Scuf could have a PC controller that's as unbeatable as it should be for the money. As it is, we can't give it an unqualified nod. –JACOB RIDLEY

VERDICT **7**

Scuf Envision Pro

ALL UNDER CONTROL Highly configurable; Comfortable and well made; Made for PC.

CONTROL FREAK Initial setup required; No Hall Effect sticks; Very pricey.

$180, www.scufgaming.com

SPECIFICATIONS

Connectivity	Wireless (USB Type-A + Type-C dongle), Wired (USB Type-A to Type C)
Layout	Symmetrical
Ports	USB Type-C, 0.14-in jack
Dimensions	6.5 x 4.23 x 2.5 in
Warranty	One year

ACTION ROLE-PLAYING GAME

Elden Ring: Shadow of the Erdtree

Captivating battles meet impeccable storytelling

ELDEN RING: *Shadow of the Erdtree* is a staggering expansion, not only for its massive size—it's about as big as half of the original map—but for the ways it challenges the assumptions we had about the nature of its world, coming from the main campaign, and the limits of an open-world narrative.

SotE rivals *Dark Souls* with a corkscrew world design layered with wondrous and horrific secrets to discover. FromSoftware has perfected its command over creating a dark fantasy world layered with history and details that cement *Elden Ring* as one of the most creative and satisfying action RPGs ever made. Old enemies return in new contexts, weapons, and spell types stretch your approach to combat with acrobatic animations and potent synergies with existing items, and new characters come to blur the morality of major figures we've spent hundreds of hours learning about. *Shadow of the Erdtree*'s storytelling is so masterfully embedded into the fabric of everything you see and do that it's practically elemental.

Bosses aren't just a test of your skill and ability to react in *SotE*; they're short narrative arcs that can embolden the thrill of victory or hollow it out. FromSoft revitalizes its boss encounters with creative counters to habits formed from playing *Elden Ring*, nudging you to either invest in your chosen play style, or mold your build around these dramatic new fights. Fans of the Meteorite spell, for example, will need to account for bosses who can't be knocked out of dangerous attacks. We found ourselves too sluggish with the two-handed mace, but saying goodbye led to us falling in love with the new weapons, like the throwing daggers that magically rematerialize. In a flexible spellcaster build, they complemented faster (but weaker) spells.

You'll need to adapt because combat encounters constantly deny old tricks, like a catacomb dungeon that brings back *Bloodborne*'s dreaded frenzy debuff to force you to run straight into the unknown or risk instant death. FromSoft has also invented a new, somehow worse type of bird that will pester you everywhere you go, like horse-sized mosquitos on a camping trip. Even the hand spiders return after nobody asked them to—get ready for the dread of running through a field full of them lying in wait. Almost everything you hated having to deal with in *Elden Ring* is back in a way that feels like a middle finger from FromSoft, followed by a confident handshake signaling that you willingly signed up for this and will actually enjoy every minute of it.

Weapons like the new great katanas—which also feel like a middle finger to anyone who was tired of seeing the Rivers of Blood—push *Elden Ring*'s rhythmic combat into new directions. Upgrade materials are abundant enough that it's not a chore to give them, and the many other new weapons, a shot. I never thought FromSoft would let me leap into the air and spin-kick a giant scorpion to death at a speed that could work in faster action games like *Devil May Cry*, but it does with the new martial arts weapons.

These weapons, and some of the newer movement-based spells, show that FromSoft has the chops to innovate on a combat style it made synonymous with the soulslike and shift it into a gear that competes with the best action games out there. The backhand blades were my favorite: they supercharge the age-old trick of circling around gigantic enemies with a skill that lets you dash behind them at the same speed as a regular dodge roll.

The heightened difficulty allows *SotE*'s new leveling system, which requires finding two new upgrade items scattered in the Land of Shadow, to lure you through the maze-like design of the new map.

SotE is as dense and vertically aligned as Lordran in *Dark Souls*, with forking paths to distract you from your destination.

Most of the map can be accessed from multiple directions, intensifying the DLC's dreamlike quality. It feels like there are entire realms to explore lurking right outside your field of view. Turn your head, and suddenly, there they are. *SotE*'s smaller map doesn't limit the expansiveness you'd expect from *Elden Ring*—it reorients it in another direction, where ladders send you to hidden ruins and elevators take you into forests grown on stone pillars reaching into the sky.

The payoff for your occasionally grueling path through *SotE* are dozens of secrets and gorgeous views. I once got lost trying to avoid hand spiders, and fled to the nearest site of grace that happened to be overlooking a field of massive stone structures—which are instantly recognizable to anyone who played *Elden Ring*—sprouting out of the ground. It was like taking the elevator down into Siofra River for the first time again, but heightened with the gut-punch of those familiar shapes. SotE does this again and again, teasing you with a captivating view of the corpse of a dragon lying in a pool of blood-red flowers or the fading silhouette of a tower piercing through a golden sky. If *Elden Ring* was like exploring a pristine painting, *SotE* is like exploring that same painting after it's been dunked in alcohol; the colors are smeared and fleeting, but its beauty endures.

SotE's new characters also call back to the original campaign, widening your perspective of figures lost to history, and are as idiosyncratic as you'd expect from a FromSoft game. Freyja fought alongside Radahn, and daydreams about gladiatorial combat. Her love of battle and admiration for you is surprisingly charming in a DLC that is otherwise extremely dour. One initially heroic character asks you to lend a hand in a series of betrayals that make Lautrec in *Dark Souls* look like a level-headed guy. After the first murder, they have an epiphany about their actions: "I've come to a realization... There's ample evidence... I'm quite mistrustful of others." You don't say!

Elden Ring already contained FromSoft's most ambitious challenges and themes, and *SotE* is obviously essential for fans who want more of it. But the ways the DLC deliberately mimics the original game elevate it from a simple epilogue to a clear thesis on what *Elden Ring* has always been about, no matter how much dialogue you skipped or item descriptions you left unread. It wields these familiar things to satisfy all the sickos they've created since *Demon's Souls*. Then, in a few late-game moments, pushes it all aside to look you in the eyes and make it clear what it's getting at.

It's a stunning achievement that reminds me why I fell in love with FromSoft's games in the first place, and why this studio remains unparalleled in creating eclectic, unforgettable worlds time and time again. –TYLER COLP

VERDICT
9
KICK ASS!

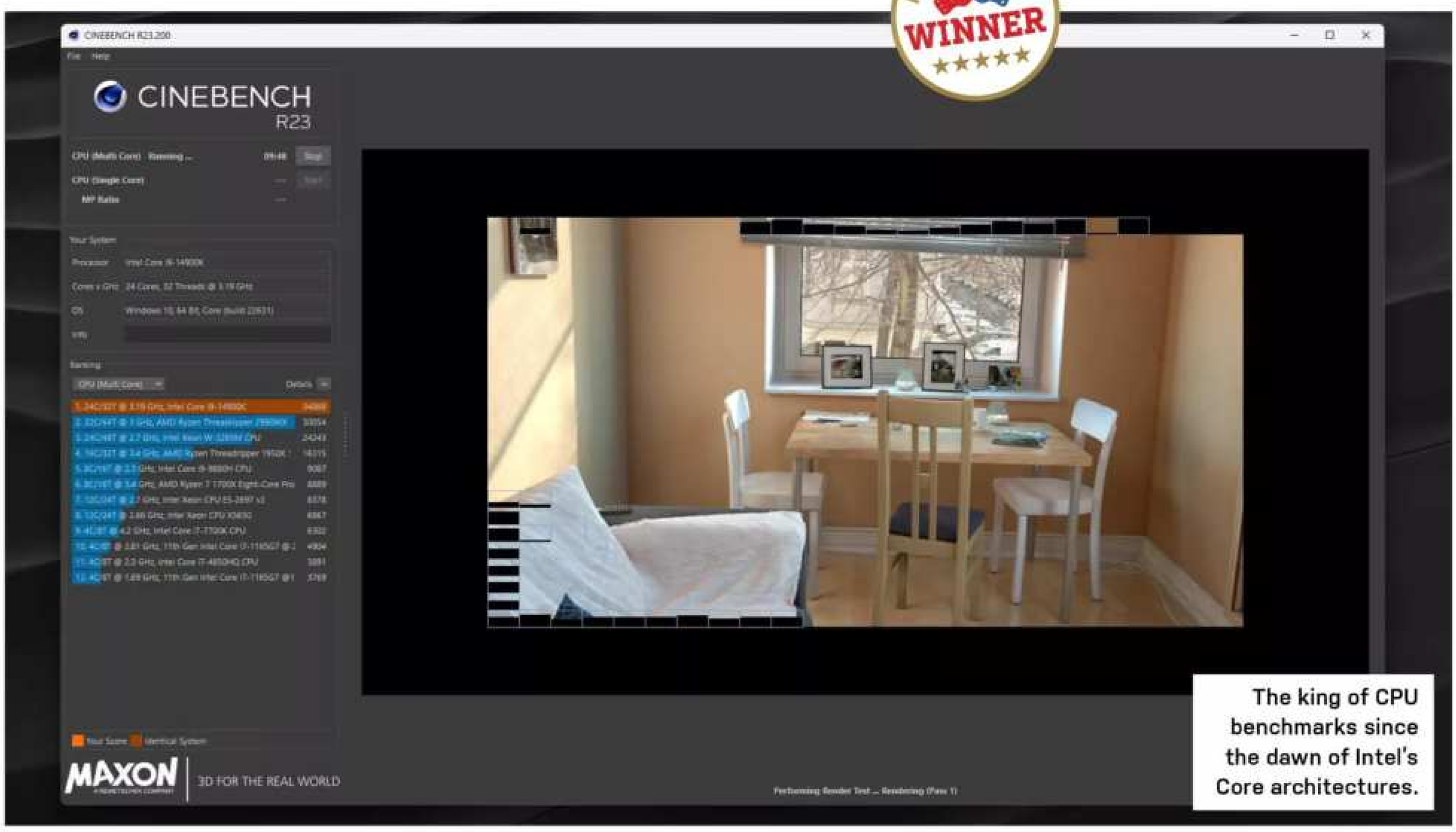
Elden Ring: Shadow of the Erdtree

RING THE CHANGES Gorgeous landscapes; Game-changing gear and spells; Top-notch bosses and enemies; Enigmatic storytelling.

RING OF FIRE Challenge and direction sometimes feel unreasonable; Experimentation with mechanics doesn't always land right.

RECOMMENDED SPECS CPU, Intel Core i7-8700K or AMD Ryzen 5 3600X. GPU, GTX 1070 or RX Vega 56 or Intel Arc A750. RAM, 16GB.

$40, www.eldenring.com. ESRB: M-rated



Cinebench R23/24 vs Geekbench 6.2.1

Battle of the benches

WE SPEND A LOT of our time benchmarking. It's a core part of the job. In fact, no matter where you work as a tech journalist, it's fair to say that your career very much hinges on your ability to benchmark. And not only being able to benchmark successfully (which can be as complex or as simple as you'd like to make it), but also in being able to analyze the data that those tests spit out.

In a similar vein, picking the right benchmarks for your own test set is of pivotal importance. Finding ones that stress whatever it is you're testing to the max, or providing unique workloads that are relevant both to your audience and to the product itself, is incredibly important.

To that end, this month, we decided to take a bit of a deeper look at both Cinebench and Geekbench, how they operate, what these benchmarks produce, how we can interpret that data, and which is better for you to use at home on your own machine.

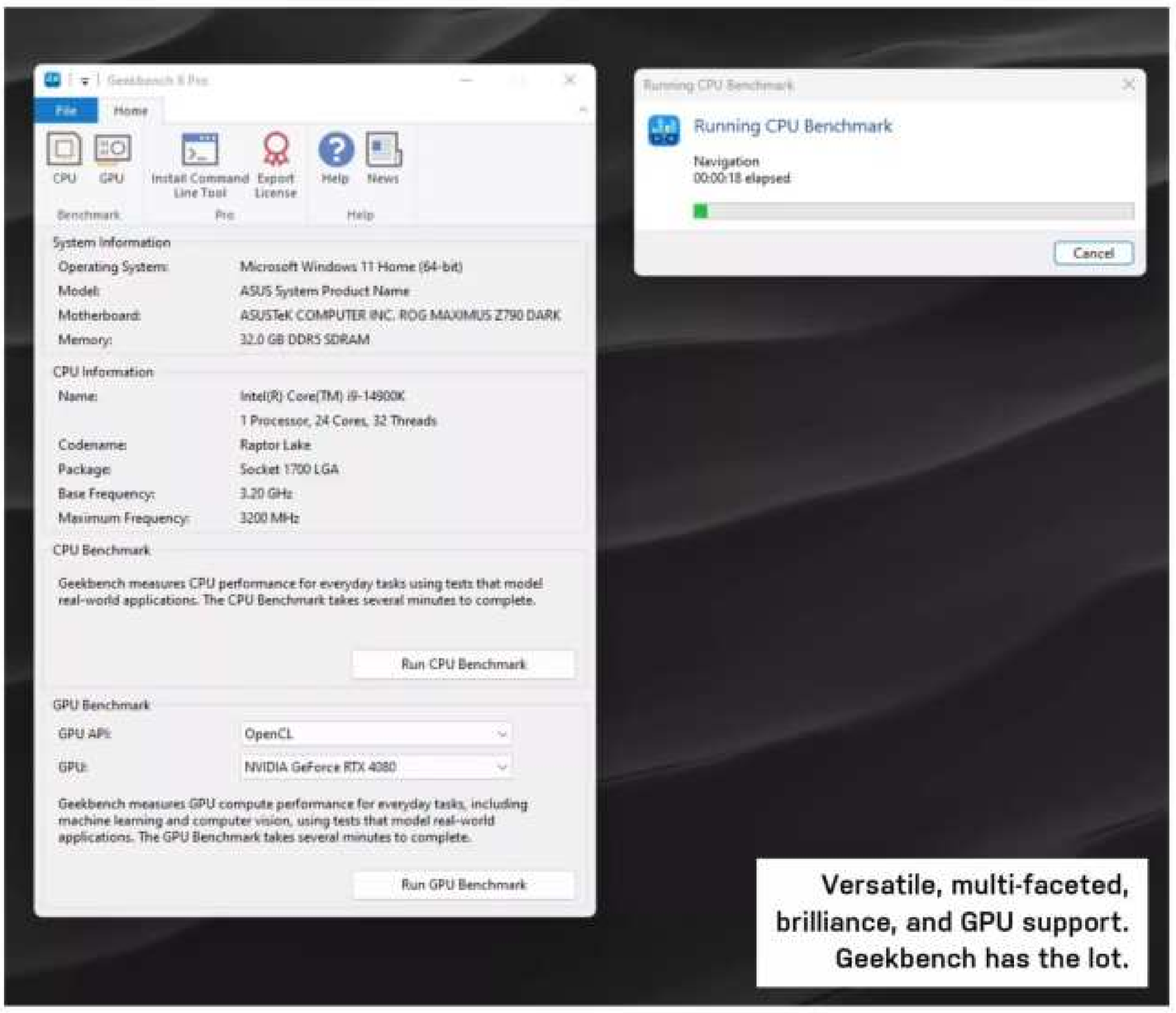
CINEBENCH

Without a doubt, Cinebench has long been a staple piece of software for anyone looking to benchmark their CPU. It's been quite unique in its prevalence over the years. We've seen a huge array of versions come and go in that time, particularly as processors have advanced and developed as rapidly as they have.

Cinebench operates by simulating a 3D rendering application. It does this with Cinema4D, which is commonly used in the movie industry as a CGI simulation, 3D modeling, and rendering tool, and then creates a 3D scene that your processor will then attempt to render with the correct resources at hand. There are two effective tests on the modern variants of Cinebench (although you can find GPU tests in the older Cinebench R15, which utilizes OpenGL as well): the multi-core test, and the single-core test. As the names imply, the multi-cores maximize the load across all available cores and threads on your processor. Similarly, single-core will use only one core instead. These are represented on the 3D render by a single square; the more threads you have, the more squares will be on display at any given time, as each square/thread renders part of the scene. In Cinebench R23, each test sequence is run for 10 minutes (older variants used just three passes of the entire scene). If the scene is still being rendered after the 10-minute timer has finished, it will finish rendering the scene before the final index score is given.

Although its multi-core test is pretty thorough in how accurate it is, correctly loading all cores and threads simultaneously, leading to some significant power draw (oftentimes greater than Prime95 in its base scenario), it does struggle with its single-core test. This is less to do with Cinebench itself and more with how Windows allocates resources, dependent on the priority of the application. As such, if you ever watch Task Manager or HWMonitor while

© CINEBENCH



Versatile, multi-faceted, brilliance, and GPU support. Geekbench has the lot.

Cinebench's single-core test is running, you'll spot CPU utilization bouncing around rather sporadically.

Cinebench, even today, is an incredibly useful tool to measure CPU performance, particularly for multi-core tasks, and when either improving cooling, applying your own overclocks, or even just tweaking BIOS settings to get a more stable PC. Having a baseline figure, that you can continually go back to and check, whether a relatively short test time, makes it a fantastic solution in that regard.

GEEKBENCH

Geekbench however is vastly different from Cinebench, although it does spit out similar results (i.e. an indexed figure) for both single-core and multi-core respectively. Like its benchy brother, Geekbench has been around for some time as well, however, it differs massively in how it approaches its test. Think of it much in a similar vein to PC Mark from ULBenchmark (of 3D Mark Fire Strike fame). Whereas Cinebench only tests CPUs and how effective they are from a purely raw throughput mode, Geekbench runs a series of tests designed to mimic everyday workloads. Generally, this covers everything from file compression to machine learning, to productivity application load times, image editing, and more.

What's great about it is that it's actually a cross-platform benchmark. It works not only on Windows but also on smartphones, Linux, MacOS, Android, and everything else with an operating system on it. If you can install an app or program, Geekbench is probably supported. Not only does it support CPU testing, it runs GPU testing as well (as long as you have a license).

At the end of its CPU benchmark run, similarly to Cinebench, it'll spit out an index of its overall performance. That's typically weighted on how well the CPU did at tests relevant to select functions, such as floating point calculations (which are scored at 35 percent) and your more common integer calculations (65 percent).

HEAD TO HEAD

The advantage of this, of course, is that these tests are more relevant than a single brute force test like Cinebench. However, this does mean that CPU utilization may be lower as a result throughout the test. That's important, because a test like Cinebench actually gives you some additional information and data points that Geekbench otherwise can't provide. As we know, Cinebench's multi-core test hits 100 percent utilization, we can simultaneously use that to measure power-draw (with either a power meter, or HWMonitor), maximum CPU temperature, and maximum clock speed as well. That can give us some incredible insight into how these processors operate.

In fact, traditionally when overclocking, you may find that although your overclock is stable when running something like Prime95's Mersenne number stress test, it may very well crash during Cinebench's multi-core run.

Geekbench, however, also has a Pro version with some expanded feature sets, including automated benchmark testing, standalone config modes, offline results (useful if you're working with NDA'd hardware), and of course, a license for commercial use.

So then, which bench comes out on top? Well, both stress-test the CPU. However, maximum utilization generally tends to fall more on Cinebench, particularly as its modern runs operate for 10 minutes, while Geekbench typically finishes up in half that, with a variety of different workloads. Geekbench, however, wins out on flexibility and system comparison. If you're looking to compare an ARM laptop or an Apple iPhone to your Intel PC, Geekbench can give you an easy index to see exactly what that performance delta is, in a wide variety of tasks. Combine that with its ability to test GPUs as well, all for free, and it makes it an ideal pick for anyone looking for a quick and easy benchmark to evaluate their system.

Still, although Cinebench lacks the breadth of tests, the data you can pull from it actually makes it the far more appealing tool, and although it does only test one scenario, and isn't available on multiple devices, it's that specialization that, at least in our eyes, really gives it the edge. If you're looking for the best CPU benchmark for overclock stress testing, Cinebench is it. If you're looking to compare apples to oranges, Geekbench is the one to work with. –ZAK STOREY

VERDICT 9 KICK ASS!

Cinebench R23/24

A KUROSAWA MASTERPIECE Fantastic high CPU utilization; Beautiful to watch; Great for stress testing; Easy to run and use.

GODZILLA X KONG One-dimensional testing; No cross-platform compatibility.

Free www.maxon.net

VERDICT 9

Geekbench 6.2.1

CAN BENCH PRESS A PLANET Multiple device/OS support; Multiple different workloads; Quick testing; GPU support as well.

GETTING BENCHED Utilization could be higher; Online uploads; No visual indicator of workload.

Free / Starting from $99 www.geekbench.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Back to the future

> Thermal issues

> AI, AI, oh

Benefit of hindsight

I recently re-read Jeremy Laird's Trade Chat column from the February 2023 edition on page 13 titled: 'This cannot go on. It will not go on'. He wrote about $700 GPUs becoming the new price for a mid-market model: "It's an incredibly short-sighted way to go about things...[AMD and Nvidia] are not just ripping off gamers, they're hurting their own businesses. The longer they stick at this nonsense, the smaller the remaining market of PC gamers is going to be when they come back to their senses."

I don't believe that much has changed, and Jeremy's conclusion may not be accurate. AMD and particularly Nvidia make vast amounts of money from enterprise/AI supercomputer-market GPUs. The consumer graphics card market pales in comparison, particularly for Nvidia now that it's valued at $3 trillion. As a result, I'm not sure Nvidia has any incentive to 'properly' price its 5000-series cards. AMD isn't in the same boat, of course, and how it will price its 8900 XT or 8900 XTX cards is hard to determine. **–M. McCullough**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thanks very much for your letter—it's always interesting to go back into the archives and see how accurate some of our predictions are with the benefit of hindsight!

Obviously, AMD and Nvidia have become stock market darlings in the 18 months since Jeremy wrote his column, with a 100 percent and 520 percent increase in share price for the two companies respectively over that time. Obviously, the majority of that growth has come from the rise in enterprise sales, particularly for the latter, whose Hopper chips are being bought up well into next year, and have captured over 90 percent of the AI market.

I put this concern to Nvidia's consumer PR reps at CES in Las Vegas in January regarding the fact that have transformed into a business-to-business, rather than business-to-consumer company, but they of course claimed to be as focused on gamers as they've ever been. While I don't completely buy that, it has to be said that they are dominating the consumer market as well, with an 88 percent market share. True, the research and development of their cloud technology helps feed the consumer products that come later, so the growth in business applications for its technology isn't necessarily at the cost of its GPU division, but I don't personally buy that the company's internal focus won't have shifted—it's now the biggest company in the world at the time of writing, and that's not happened off the back of it shifting RTX 4070s to gamers.

What has changed in the last year is that GPU prices have settled down a bit, and you can now get an RTX 4060Ti for $365, or a 4070 for $530. Okay, I appreciate that those aren't the bargains of the century, but it's much better to see a mid-range card come down toward the $500 level. Same for AMD's 7900 GRE, which is also around the $530 mark now. I expect more bargains will be able to be had as we enter the second half of the year and next-gen cards get announced and released. Granted, RTX 5000-series cards will be the star attractions, but a $450 4070 would be a decent buy, and still be good for a few years yet.

On AMD's side, all rumors indicate that it will continue to compete at the upper-mid tier (think $900 or RTX 40/5080 level) but leave the top-end to Nvidia. The company's market share isn't huge, but I for one hope they continue to compete with Nvidia in at least some of the market, which is good for consumers overall.

How big a blob?

In his feature on building 'The Ultimate Gaming PC' (May 2024), Zak Storey recommends "placing a small blob" of thermal paste on the CPU.

Okay, but how small of a blob? Over the years, I've seen recommendations varying widely, from a grain of rice to the size of a pea. Some say to put the whole blob in the center of the CPU, others to spread it around in an X pattern.

↘ submit your questions to: editor@maximumpc.com

Experts erring on the small side say it would be dangerous if the paste spilled over the edges, while those on the big side say that applying too little would fry the CPU.

This vagueness has been maddening—I don't know if I would end up burning the CPU from too little paste or too much of it! Can Zak, or another one of *MPC*'s master builders, give us an exact amount for us amateurs to work with?

–J. Amador

CONTRIBUTING EDITOR, ZAK STOREY, RESPONDS: Thermal paste is, if I'm honest, one of the most overthought elements when it comes to building PCs, and I totally get why. That said, I'm a bit laissez-faire about the whole thing these days because it's all a bit too subjective. A grain of rice, or a pea-sized blob, is generally the usual advice most tech journos give, but even that is down to interpretation by the end user. It's also typically a phrase that was around with the LGA 115X chips and so forth, which are markedly smaller and less power-hungry than today's beasts.

It also very much depends on the CPU, how it's designed, and where that heat is coming from directly. For instance, a Threadripper chip is large and rectangular, and it also has multiple core complexes, generating heat, with cooler channels around each side. So you'll often see PC builders do strips of paste down the middle or four dots. There are numerous application methods out there. Our friends over at Gamer's Nexus did a fantastic deep-dive video on just what difference the various styles make (well worth checking out at youtube.com/watch?v=EUWVVTY63hc). But the TL;DR of that is, as long as you've got "enough" paste, it doesn't really matter how you apply it.

Our master builder Zak Storey says to use a thin strip of thermal paste down the middle of the CPU.

And the thing is, you can't actually have too much thermal paste on your chip, there's no detrimental effects outside of clean-up if you do so. As long as your paste doesn't conduct electricity, you can stick on as much as you'd like. The pressure from your CPU block will happily distribute that nicely into the gaps regardless. If you ever watch extreme overclocking comps or pro builders, many of them even empty entire tubes onto their chips with abandon. Similarly, in my own rigs, I tend to place a blob the size of a Tylenol on my chips, certainly for Ryzen and Intel processors, or multiple dots of that on larger chips like Threadripper or Xeon.

If you find that thermal paste is squeezed out of the edges of your CPU and onto the motherboard, then grab some 90% isopropyl alcohol or above and wipe it off. Try to avoid getting paste in the CPU socket itself. It can be ok, but if you need to clean it off, you can risk bending pins.

Artificial Intelligence laptops

I see that the first batch of AI-certified laptops are now available. ARM-based CPUs from Snapdragon seem to be attracting the most attention for now, and I've seen a couple of columns on them in your fine publication (July 2024 on page 13, this issue on page 72). I'm a gamer myself, so I wouldn't really go for a Qualcomm-powered machine, even if they promise they're gaming-ready and have amazing battery life. However, even the new Gen 9 2024 Legion gaming laptops have an AI chip in them, and a Windows Copilot button on the keyboard.

Are these new AI features worth anything, or just a gimmick? As they're presumably the first generation of AI laptops, should I hold off buying until the technology's a bit more mature? And is there anything else I should know about AI PCs?

–E. Partridge

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Ah yes, as we note on our lead news story this issue, it's now impossible to attend a tech conference without having the letters 'A' and 'I' rammed down your throat by every manufacturer in PC land.

That said, there are some really cool AI features available on the PC, and I'd direct you towards the May 2024 issue for the best Copilot-powered applications in Microsoft's Windows and Office suite, as well as our June 2024 issue where we give you the full lowdown on AI-powered PCs and the best laptops that are currently available.

Your question on whether to get into AI PCs now or wait is an interesting one. That's because the specifications required for an 'AI PC' are still being worked out—it's presumed that the Neural Processing Unit inside the PC needs to be capable of 45 TOPS (trillion operations per second), but Microsoft hasn't officially confirmed that. The current high-end CPUs from AMD and Intel come in at around 30-40 TOPS, while Qualcomm's Snapdragon X Elite boasts 75 TOPS, which is why there's so much excitement about the latter.

On the subject of the Legion laptops, they boast an AI chip, but it's Lenovo's own, and based on my look at this year's CES, it's cool, but much more basic than what you'd expect from an AI PC. It does things like analyze the content on its display, and if it thinks you're playing a game, it will automatically kick itself into 'Performance' mode and divert more power to the GPU. Neat, but I always do this manually on my gaming laptop ahead of launching into a game.

I hope that helps explain where we're at, but keep an eye on more coverage of AI PCs in future editions of *Maximum PC*.

THE BUILDS

THIS MONTH'S STREET PRICES...

THIS MONTH has been a little weird. In some segments of the market, the entry-level stuff has held fast. Yet, on the top end, once more we've had massive swings as manufacturers vie to one-up each other on volume sold, without compromising too heavily on their margins. Not one key area has gone up consistently, either. Some CPU pricing has dropped on AMD's side (not surprising, given the announcement of the Ryzen 9000 series), and PSUs have crept up, but that's about it.

We've actually made some sizable changes to both our Intel and AMD rigs this month, with each receiving a new SSD in the form of the 1TB Kingston NV2, replacing the Crucial P3. Not only is the NV2 slightly cheaper at $56 versus $61, it also packs better stats, thanks in no small part to its PCIe 4.0 pedigree.

For our AMD system, we've swapped out the motherboard, shifting from ASRock's B650 PG Lightning to Gigabyte's Eagle AX, and we've ditched the TeamGroup T-Create Classic kit for the Patriot Viper Venom setup. It's slightly more money than last time, but it's got far better performance stats, clocking in at 6,000 MT/s and a CAS latency of 36, versus last month's 5600 and CAS latency of 46. That's a big difference that should translate to far better in-game and general CPU performance too.

For Intel, we've had a few price tweaks, but the big change comes in the form of the GPU, swapping from an ASRock model to XFX, saving $10. Admittedly, we're not entirely happy with the memory kit, as it's considerably lower spec than the AMD variant, but it's a sacrifice we're willing to make to accommodate that extra $50 on the GPU. The one saving grace is that Intel's processors aren't as reliant on memory specs as AMD's.

All said and done, that's allowed us to save $9 for our AMD system and $12 for the Intel build, all while improving performance via memory or SSDs respectively. Nice.

AMD INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	600W Thermaltake Toughpower GX2 80+ Gold	$60
Mobo	Gigabyte B650 EAGLE AX ATX NEW	$140
CPU	AMD Ryzen 5 7600	$189
GPU	ASRock Challenger D Arc A750 8GB	$200
RAM	32GB (2x16GB) Patriot Viper Venom @ 6000 C36 NEW	$90
SSD 1	512GB ADATA Legend 840 PCIe 4.0 M.2	$45
SSD 2	1TB Kingston NV2 PCIe 4.0 M.2 NEW	$56
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$907**

INTEL INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	600W Thermaltake Toughpower GX2 80+ Gold	$60
Mobo	ASRock B760M-HDV/M.2 Micro-ATX	$98
CPU	Intel Core i5-14400F	$200
GPU	XFX Speedster SWFT 210 Core RX 7600 8GB NEW	$250
RAM	32GB (2x16GB) Silicon Power DDR5 @ 5600 C46	$76
SSD 1	512GB ADATA Legend 840 PCIe 4.0 M.2	$45
SSD 2	1TB Kingston NV2 PCIe 4.0 M.2 NEW	$56
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$912**

MOVING ON to the middle of the pack, we've seen some hefty changes here, too. For our AMD rig, we saw some serious price drops both on the motherboard and CPU combos, with a little extra on the chassis. Unfortunately, the Asus's Dual OC Radeon RX 7800 XT had a $20 price bump, and our secondary SSD went out of stock. That's forced us to make a harsh choice (as all 7800 XT's are now at $480). We've dropped the 7800 XT and gone for one of the better-value RX 7700 XT's instead. This will impact performance, but you'll still be able to game at 1440p at well over 90 fps, and 4K will sit happily at around 40-50 fps, too.

That said, dropping the GPU by $100 has given us more wiggle room, particularly as we've managed to find a secondary SSD with the same specs for the same price. With that in mind, we pumped the extra cash into the CPU, opting for a more gaming-oriented CPU in the form of the Ryzen 9 7900X3D. That's going to give us four more cores than we had with the 7700X, some buff cache, and better latencies for gaming. We're expecting frame rates to spike as a result of that across a number of titles. Why the 7900X3D and not the 7800X3D? It was cheaper. We're not sure why, but it's best not to look a gift horse in the mouth.

As for Intel, the price flux also mostly revolved around our GPU and cooling, so we've downgraded things a touch to keep pricing steady. It's not as dramatic a shift as we saw with the AMD build, as we've swapped from the RTX 4070 Super to the standard 4070, but similarly, GPU prices are climbing at the moment in the mid-range, and it was necessary to alleviate that pressure while retaining that aim for $1,500. We've also tweaked the cooler to save $4, and the rig gets the same SSD as AMD.

With all that, though, prices have remained fairly resilient here, with the Intel rig dropping by just $23 last month, and AMD's build saving $44 overall.

AMD INGREDIENTS

PART		PRICE
Case	NZXT H7 Flow	$90
PSU	850W Thermaltake Toughpower GF1 2024 80+ Gold	$95
Mobo	Gigabyte X670 Gaming X AX V2 - AM5	$195
CPU	AMD Ryzen 7 7900X3D NEW	$330
Cooler	Noctua NH-D12L Chromax.Black	$100
GPU	Acer Nitro OC Radeon RX 7700 XT 12GB NEW	$380
RAM	32GB (2x16GB) Silicon Power Xpower Zenith Gaming @ 6000 C30	$95
SSD 1	1TB Lexar NM790 w/Heatsink M.2 PCIe 4.0 SSD	$85
SSD 2	2TB Silicon Power UD90 M.2 PCIe 4.0 SSD NEW	$105
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$1,507**

INTEL INGREDIENTS

PART		PRICE
Case	NZXT H7 Flow	$90
PSU	850W Thermaltake Toughpower GF1 2024 80+ Gold	$95
Mobo	MSI Z790-S Wifi ATX	$170
CPU	Intel Core i5-14600K	$306
Cooler	Cooler Master MasterLiquid 360L Core ARGB 360mm AIO NEW	$86
GPU	MSI Ventus 2X OC RTX 4070 12GB NEW	$543
RAM	32GB (2x16GB) Silicon Power Xpower Zenith Gaming @ 6000 C30	$95
SSD 1	1TB Lexar NM790 w/Heatsink M.2 PCIe 4.0	$85
SSD 2	2TB Silicon Power UD90 M.2 PCIe 4.0 SSD NEW	$105
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$1,607**

INTERESTINGLY, with all of the drama happening with our top-tier products, only a few changes have been required for both rigs, revolving around storage, cooling, and power supplies.

SSDs across both systems went up by $15, with the T500 creeping up as well. We've swapped the T700 for MSI's Spatium M570 HS. It's not as potent as the T700, but still delivers impressive sequentials and random 4K. To back that up, our secondary drive has, again, become the Lexar NM790. It's impossible to deny how much value is on offer. Similarly, the T500 is superior, but it's received a $20 price bump, and we're trying to offset that. Our second favorite budget drive, Kingston's Fury Renegade, is well into the $170 region, too, so no joy there.

We've also seen power supplies rise. Whether that's due to enthusiasts buying up stock in prep for new Ryzen builds is hard to discern, but it's our only theory. It's a challenge to find a 1000W PSU with an 80+ Platinum rating at this price point—to circumnavigate that, we've grabbed the white variant on last month's Lead Platinum, which has retained its price. Genuinely though, if you're after a piece of hardware, and see it skyrocket, check different colorways of it—you might just get lucky.

With joint picks tweaked, our AMD build has also shifted its cooler from the Asus ROG Ryou III to NZXT's Kraken 360. It's a simple LED display cooler, but cheaper than the $210 that the Asus unit was at. Similarly, our Ryzen 9 7950X and motherboard picks fell, too, giving us some much-needed savings.

Similarly with our Intel rig, not a lot has changed. The Gigabyte Z790 Aorus Elite nabbed a $45 price drop, but that's it. We switched out the cooler, too, opting for Corsair's 360mm H150i Elite. It doesn't have a display, but it does feature RGB, and clocks in at $35 cheaper than the Glacier One D360 we had last month. One thing worth mentioning is power draw. The Intel rig currently sits at around 750W of power draw under peak load, which is starting to eat into our headroom on that 1000W PSU.

Otherwise, both rigs saw savings, with AMD's total price falling by $39, and Intel's $45.

AMD INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$150
PSU	Super Flower Leadex Platinum SE 1000W - 80+ Platinum White NEW	$145
Mobo	Asus Prime X670E Pro WiFi - AM5	$289
CPU	AMD Ryzen 9 7950X	$487
Cooler	NZXT Kraken 360 - 360mm AIO NEW	$180
GPU	ASRock Phantom Gaming OC Radeon RX 7900 XTX 24GB	$900
RAM	64GB (2x32GB) TeamGroup T-Create Expert @ 6000 C34	$180
SSD 1	2TB MSI Spatium M570 HS PCIe 5.0 M.2 NEW	$239
SSD 2	2TB Lexar NM790 PCIe 4.0 M.2 NEW	$135
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$2,737**

INTEL INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$150
PSU	Super Flower Leadex Platinum SE 1000W - 80+ Platinum White NEW	$145
Mobo	Gigabyte Z790 Aorus Elite AX-W ATX	$321
CPU	Intel Core i9-14900KF	$529
Cooler	Corsair iCUE H150i RGB Elite - 360mm AIO NEW	$155
GPU	PNY Verto Overclocked RTX 4080 Super 16GB	$965
RAM	48GB (2x 24GB) G.Skill Ripjaws DDR5 @ 6400 CL36	$150
SSD 1	2TB MSI Spatium M570 HS PCIe 5.0 M.2 NEW	$239
SSD 2	2TB Lexar NM790 PCIe 4.0 M.2 NEW	$135
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$2,821**

Maximum PC (ISSN 1522-4279) is published 13 times a year, monthly plus a Holiday issue following the December issue, by Future US LLC, 130 West 42nd Street, 7th Floor, New York, NY 10036. USA. Website: www.futureus.com. Future US LLC also publishes *MacLife*, and *PC Gamer*.

UNEARTH THE FULL STORY BEHIND THE LEGEND OF ZELDA

Explore every game in the series and what makes each one so great. If you're a fan, you'll enjoy the trip through time. If you're a newcomer, we offer you this sage advice: "It's dangerous to go alone, take this!"

ON SALE NOW

We build the world's most advanced PCs.

Experience a new level of performance with an award-winning Digital Storm PC. Built with the latest technology, highest quality components and backed by lifetime support. Visit our website and build your dream PC today.

DIGITALSTORM

LEARN MORE: WWW.DIGITALSTORM.COM

Digital Storm PCs featuring Intel® Core™ i7 processors.

intel CORE i7 inside

9000