Raspberry Pi 5 : The new Raspberry Pi family with more computation power and AI integration

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Introduction :

In this draft we present the new Raspberry Pi 5, coming at the end of October. Priced at $60 for the 4GB variant, and $80 for its 8GB sibling (plus your local taxes), virtually every aspect of the platform has been upgraded, delivering a no-compromises user experience. Raspberry Pi 5 comes with new features, it’s over twice as fast as its predecessor, and it’s the first Raspberry Pi computer to feature silicon designed in-house here in Cambridge, UK.

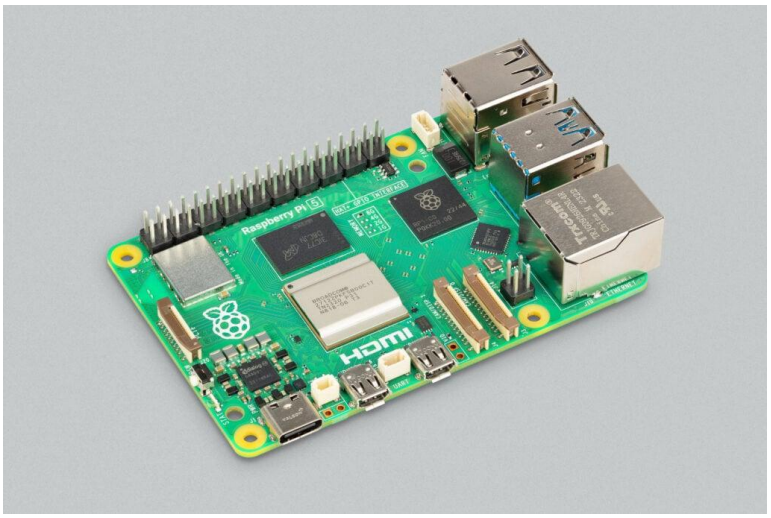


Figure1 : Raspberry Pi 5

Raspberry Pi 5 Technical Features, at a glance:

- The Raspberry Pi 5 is the latest model of everyone's favourite single-board computer.
- Pi 5 sees significant upgrades and speed increases (2-3x in CPU performance) over its predecessor, the Raspberry Pi 4 Model B. A full feature comparison can be found here.
- The board is available in both 4GB and 8GB versions.
- A pocket-sized, dual-display, desktop computer, robot brain, smart home hub, media centre, networked AI core, factory controller, NAS, and much more.
- It offers performance that rivals entry-level PCs at a fraction of the cost.
- Drop it straight into your old projects, it's the same general size and shape as its predecessors and it features the same backwards-compatible GPIO interface as its predecessors.
- The fanless, energy-efficient Raspberry Pi runs silently and uses far less power than other computers.
- It offers the perfect platform for learning/teaching; coding, Linux, IoT systems, streaming media, playing games, automated domestic and industrial applications, or your complete desktop solution and much much more.
- It is the first time the flagship product has features Raspberry Pi silicon, the RP1 I/O controller chip has been designed in-house at Raspberry Pi HQ.
- Raspberry Pi 5 builds on the phenomenal success of Raspberry Pi 4. In comparison with its predecessor, it delivers a 2-3x increase in CPU performance, and a significant uplift in GPU performance, alongside improvements to camera, display, and USB interfacing.
- Each board will include a marking on the upper side of the PCB to identify what memory density is fitted to a specific board.
- All boards now carry a unique serial number on the PCB.

- Raspberry Pi 5 will remain in production until at least January 2035.

The Raspberry Pi 5 Key features include:

- **CPU:** 2.4GHz quad-core, 64-bit Arm Cortex-A76, with 512KB L2 cache and a 2MB shared L3 cache.
- **GPU:** 800MHz VideoCore VII GPU supporting OpenGL ES 3.1, Vulkan 1.2.
- **RAM:** LPDDR4X-4267 SDRAM (4GB or 8GB).
- **WiFi:** Dual band 2.4 GHz and 5.0 GHz 802.11ac Wi-Fi.
- **Bluetooth:** Bluetooth 5.0 / Bluetooth Low Energy (BLE).
- **Storage:** Micro SD card slot, with support for high-speed SDR104 mode.
- **USB 3.0:** 2 x USB 3.0 ports, supporting simultaneous 5Gbps operation.
- **USB 2.0:** 2 x USB 3.0 ports.
- **Ethernet:** Gigabit Ethernet, with PoE+ support (requires PoE+ HAT).
- **HDMI:** 2 x micro-HDMI® ports (up to 4kp60 supported) HEVC decoder and HDR support.
- **DSI/CSI:** 2 × 4 lane MIPI camera/display transceivers (3x bandwidth improvement).
- **PCIe:** PCIe 2.0 x1 interface for fast peripherals (requires separate M.2 HAT or other adapter).
- **Power:** 5V/5A DC power via USB-C, with Power Delivery support.
- **GPIO:** Raspberry Pi standard 40-pin header (Backwards compatible).
- **RTC:** Real-Time Clock (RTC), powered by an external battery.
- **On/Off Switch:** On-board power button!!

As we can see, that is an impressive array of features that can easily deliver your day to day desktop needs and power your industrial applications.

In a break from recent tradition, we are announcing Raspberry Pi 5 before the product arrives on shelves. Units are available to pre-order today from many of our Approved Reseller partners, and we expect the first units to ship by the end of October.

We’re incredibly grateful to the community of makers and hackers who make Raspberry Pi what it is; you’ve been extraordinarily patient throughout the supply chain issues that have made our work so challenging over the last couple of years. We’d like to thank you: we’re going to ringfence all of the Raspberry Pi 5s we sell until at least the end of the year for single-unit sales to individuals, so you get the first bite of the cherry.

The magazines The MagPi and HackSpace contains more details on this new raspberry pi 5.

Click those links to learn more about our Priority Boarding programme

Figure 2 : two magazines with more details on RPI-5

Between now and the end of October, we'll be running a series of regular articles and videos, focusing on different aspects of the platform. Keep checking in here.

A little history

After 4 years waiting, way back in June 2019, they launched Raspberry Pi 4, the first true PC-class Raspberry Pi computer. With a quad-core Arm Cortex-A72 processor clocked at 1.5GHz, it was roughly forty times faster than the original Raspberry Pi model from 2012. In many ways the timing was perfect: in March the following year, schools closed, and millions of schoolchildren around the world were sent to study from home. Tens of thousands of them were able to rely on a Raspberry Pi 4 as their primary PC.

In the four years since then, Raspberry Pi 4, and its derivatives Raspberry Pi 400 and Compute Module 4, have become firm favourites of enthusiasts, educators, and professional design engineers worldwide. Modern Raspberry Pi 4 computers run 20% faster than the launch variant, with a core clock speed of 1.8GHz. And, despite the well publicised challenges that have affected the electronics supply chain over the last two years, we've made and sold over 14 million units of Raspberry Pi 4 in that time.

But time doesn't stand still, and neither does our community's appetite for performance. And since 2016 — the era of Raspberry Pi 3 — we've been quietly working on a much more radical overhaul of the Raspberry Pi platform. Today, that effort bears fruit, with the launch of Raspberry Pi 5: compared to Raspberry Pi 4, we have between two and three times the CPU and GPU performance; roughly twice the memory and I/O bandwidth; and for the first time we have Raspberry Pi silicon on a flagship Raspberry Pi device.

New platform, new chipset

Three new chips, each designed specifically for the Raspberry Pi 5 program, come together to deliver a step change in performance.

a) BCM2712 power full SoC

Figure 3 : the main SoC on RPI-5, Broadcom 2712

BCM2712 is a new 16-nanometer application processor (AP) from Broadcom, derived from the 28-nanometer BCM2711 AP which powers Raspberry Pi 4, with numerous architectural enhancements. At its heart is a quad-core 64-bit Arm Cortex-A76 processor, clocked at 2.4GHz, with 512KB per-core L2 caches, and a 2MB shared L3 cache. Cortex-A76 is three micro-architectural generations beyond Cortex-A72, and offers both more instructions per clock (IPC) and lower energy per instruction. The combination of a newer core, a higher clock speed, and a smaller process geometry yields a much faster Raspberry Pi, and one that consumes much less power for a given workload.

Our newer, faster CPU is complemented by a newer, faster GPU: Broadcom's VideoCore VII, developed here in Cambridge, with fully open source Mesa drivers from our friends at Igalia. An updated VideoCore hardware video scaler (HVS) is capable of driving two simultaneous 4Kp60 HDMI displays, up from single 4Kp60 or dual 4Kp30 on Raspberry Pi 4. A 4Kp60 HEVC decoder and a new Image Sensor Pipeline (ISP), both developed at Raspberry Pi, round out the multimedia subsystem. To keep the system supplied with memory bandwidth, we have a 32-bit LPDDR4X SDRAM subsystem, running at 4267MT/s, up from an effective 2000MT/s on Raspberry Pi 4.

b) RP1: the I/O controller for Raspberry Pi 5

Previous Raspberry Pi generations were built on a *monolithic* AP architecture: while some peripheral functions were provided by an external device (the Via Labs VL805 USB controller and hub on Raspberry Pi 4, and the Microchip LAN951x and LAN7515 USB hub and Ethernet controller chips on earlier products), substantially all of the I/O functions were integrated into the AP itself. Fairly early in the history of Raspberry Pi, we realised that as we migrated the AP to progressively newer process nodes, this approach would eventually become both technically and economically unsustainable.

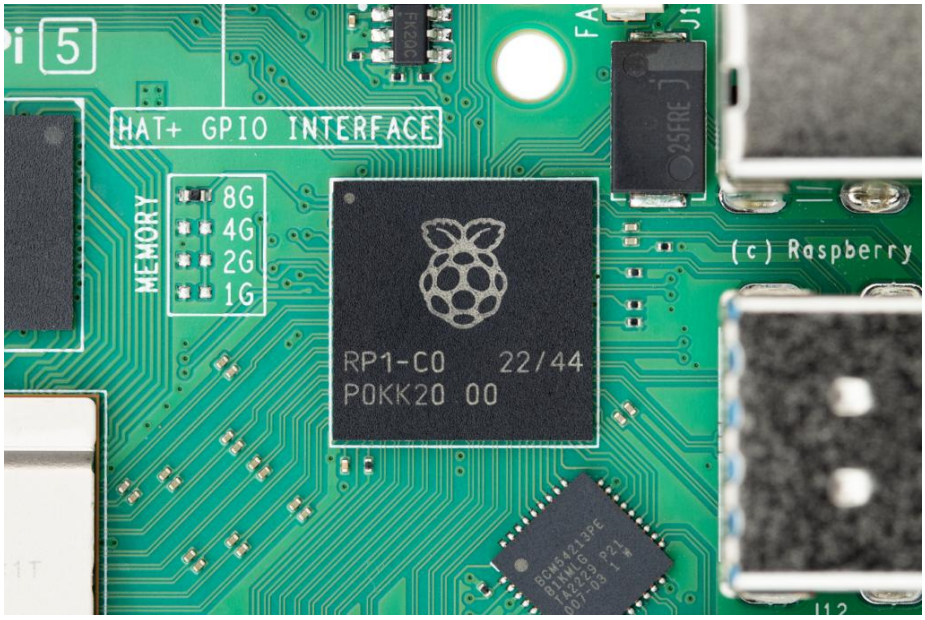


Figure 4 : I/O controller for Raspberry Pi 5, the RP1

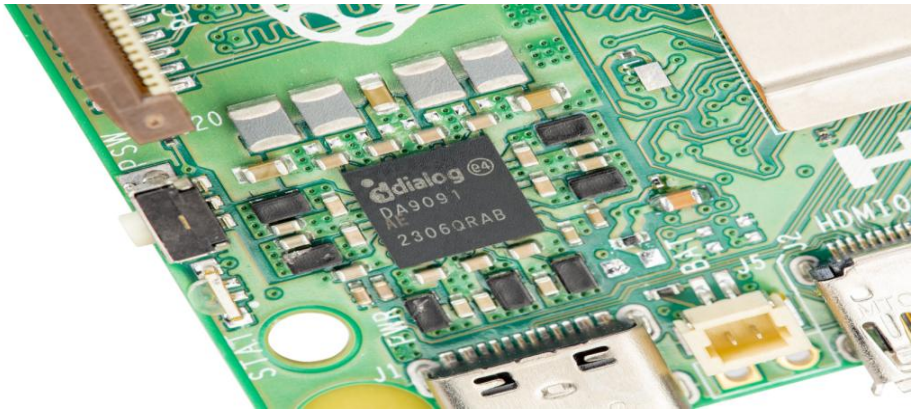
Raspberry Pi 5, in contrast, is built on a disaggregated *chiplet* architecture. Here, only the major fast digital functions, the SD card interface (for board layout reasons), and the very fastest interfaces (SDRAM, HDMI, and PCI Express) are provided by the AP. All other I/O functions are offloaded to a separate I/O controller, implemented on an older, cheaper process node, and connected to the AP via PCI Express.

RP1 is our I/O controller for Raspberry Pi 5, designed by the same team at Raspberry Pi that delivered the RP2040 microcontroller, and implemented, like RP2040, on TSMC's mature 40LP process. It provides two USB 3.0 and two USB 2.0 interfaces; a Gigabit Ethernet controller; two four-lane MIPI transceivers for camera and display; analogue video output; 3.3V general-purpose I/O (GPIO); and the usual collection of GPIO-multiplexed low-speed interfaces (UART, SPI, I2C, I2S, and PWM). A four-lane PCI Express 2.0 interface provides a 16Gb/s link back to BCM2712.

Under development since 2016, RP1 is by a good margin the longest-running, most complex, and (at $15 million) most expensive program we've ever undertaken here at Raspberry Pi. It has undergone substantial evolution over the years, as our projected requirements have changed: the C0 step used on Raspberry Pi 5 is the third major revision of the silicon. And while its interfaces differ in fine detail from those of BCM2711, they have been designed to be very similar from a functional perspective, ensuring a high degree of compatibility with earlier Raspberry Pi devices.

c) DA9091 for power management

BCM2712 and RP1 are supported by the third new component of the chipset, the Renesas DA9091 "Gilmour" power-management IC (PMIC). This integrates eight separate switch-mode power supplies to generate the various voltages required by the board, including a quad-phase core supply, capable of providing 20 amps of current to power the Cortex-A76 cores and other digital logic in BCM2712.



Like BCM2712, DA9091 is the product of a multi-year co-development effort. Working closely with the Renesas team in Edinburgh allowed us to produce a PMIC which is precisely tuned for our needs. And we were able to squeeze in two frequently requested features: a real-time clock (RTC), which can be powered by an external supercapacitor or a rechargeable lithium-manganese cell; and a PC-style power button, supporting hard and soft power-off and power-on events.

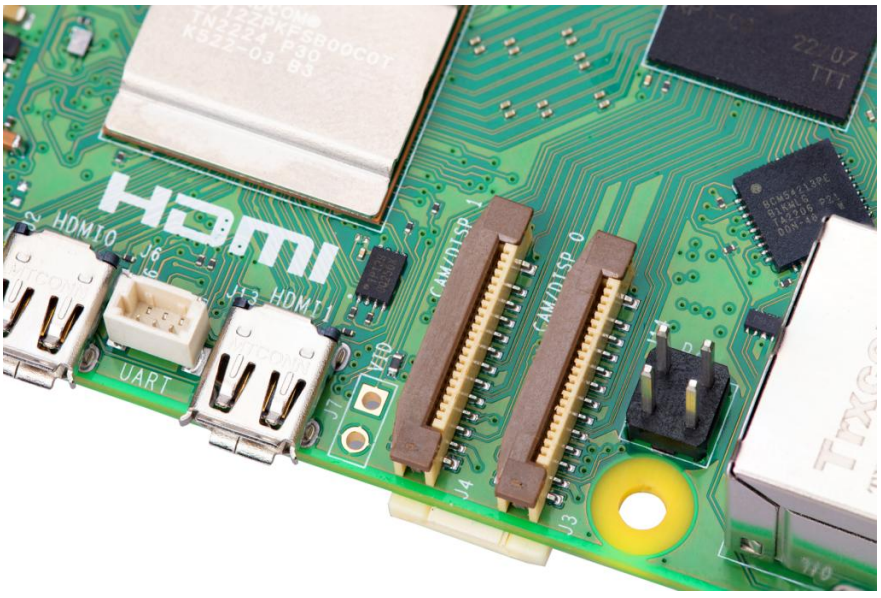
Two other elements of the chipset have been retained from Raspberry Pi 4. The Infineon CYW43455 combo chip provides dual-band 802.11ac Wi-Fi and Bluetooth 5.0 with Bluetooth Low-Energy (BLE); while the chip itself is unchanged, it is provided with a dedicated switched power supply rail for lower power consumption, and is connected to BCM2712 by an upgraded SDIO interface which supports DDR50 mode for higher potential throughput. As before, Ethernet connectivity is provided by a Broadcom BCM54213 Gigabit Ethernet PHY; this now sits at a jaunty 45-degree angle, a first for Raspberry Pi, and a source of enduring disappointment for orthogonal-layout enthusiast and CTO (Software) Gordon Hollingworth.

Form-factor evolution

On the outside, Raspberry Pi 5 closely resembles its predecessors. But, while retaining the overall credit-card-sized footprint, we've taken the opportunity to update some elements of the design, to align with the capabilities of the new chipset.

We've removed the four-pole composite video and analogue audio jack from the board. Composite video, now generated by RP1, is still available from a pair of 0.1"-spaced pads on the bottom edge of the board.

We now sport a pair of FPC connectors, in the space formerly occupied by the four-pole jack and camera connector. These are four-lane MIPI interfaces, using the same higher-density pinout found on various generations of Compute Module I/O board; and they are bi-directional (transceiver) interfaces, meaning that each one can connect either to a CSI-2 camera or to a DSI display. The space on the left of the board formerly occupied by the display connector now contains a smaller FPC connector which provides a single lane of PCI Express 2.0 connectivity for high-speed peripherals.



The Gigabit Ethernet jack has returned to its classic position in the bottom right corner of the board, after a brief sojourn in the top right on Raspberry Pi 4. And it's brought with it the four-pin PoE connector, simplifying the board layout at the cost of a compatibility break with our existing PoE and PoE+ HATs.

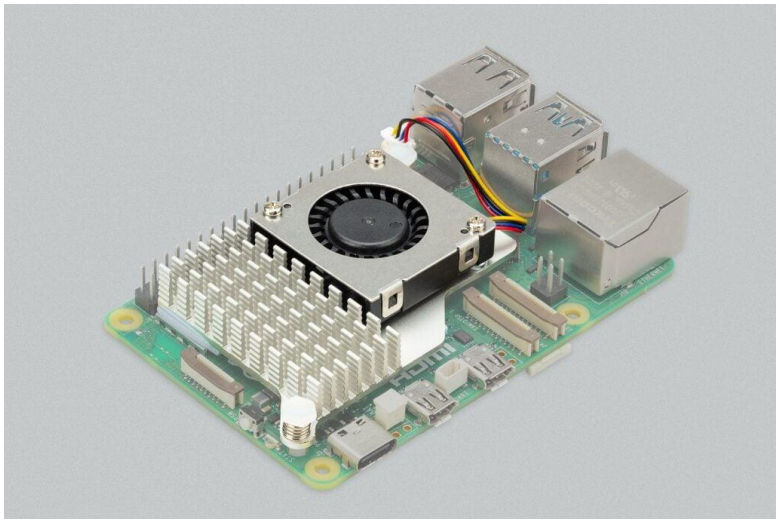
Finally, we've grown a pair of mounting holes for a heatsink, as well as JST connectors for the RTC battery (two pins), Arm debug and UART (three pins), and fan with PWM control and tacho feedback (four pins).

Accessories, accessories, accessories

Every new flagship Raspberry Pi product is accompanied by new accessories, and Raspberry Pi 5 is no exception. Layout changes, new interfaces, and much higher peak performance (and a smaller increase in peak power consumption) have led us to redesign some existing accessories, and to develop some entirely new ones.

a) Active Cooler

Raspberry Pi 5 has been designed to handle typical client workloads, uncased, with no active cooling. Users who wish to use the board uncased under continuous heavy load, without throttling, have the option of adding a $5 Active Cooler. This attaches to the board via two new mounting holes, and connects to the same four-pin JST connector as the case fan.



A radial blower, again selected for low noise and extended operating lifetime, pushes air through an extruded and milled aluminium heatsink. Both the case and the Active Cooler are able to keep Raspberry Pi 5 well below the thermal throttle point for typical ambient temperatures and worst-case loads. The cooling performance of the Active Cooler is somewhat superior, making it particularly suitable for overclockers

b) 27W USB-C Power Supply

Raspberry Pi 5 consumes significantly less power, and runs significantly cooler, than Raspberry Pi 4 when running an identical workload. However, the much higher performance ceiling means that for the most intensive workloads, and in particular for pathological “power virus” workloads, peak power consumption increases to around 12W, versus 8W for Raspberry Pi 4.

When using a standard 5V, 3A (15W) USB-C power adapter with Raspberry Pi 5, by default we must limit downstream USB current to 600mA to ensure that we have sufficient margin to support these workloads. This is lower than the 1.2A limit on Raspberry Pi 4, though generally still sufficient to drive mice, keyboards, and other low-power peripherals.

For users who wish to drive high-power peripherals like hard drives and SSDs while retaining margin for peak workloads, we are offering a $12 USB-C power adapter which supports a 5V, 5A (25W) operating mode. If the Raspberry Pi 5 firmware detects this supply, it increases the USB current limit to 1.6A, providing 5W of extra power for downstream USB devices and 5W of extra on-board power budget: a boon for those of you who want to experiment with overclocking your Raspberry Pi 5.

It should be noted that users have the option to override the current limit, specifying the higher value even when using a 3A adapter. In our testing, we have found that in this mode Raspberry Pi 5 functions perfectly well with typical configurations of higher-power USB devices, and all but the most pathological workloads.

c) Camera and display cables

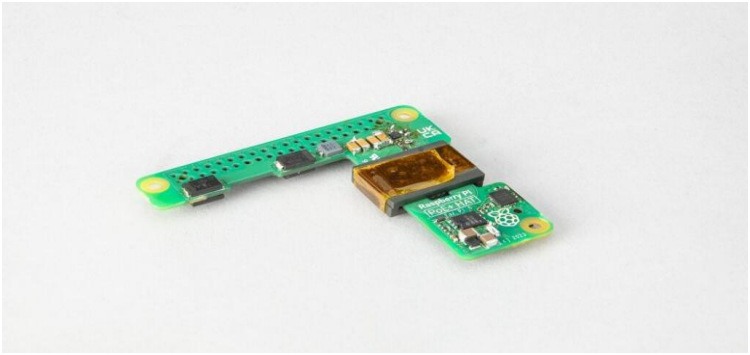
The new, higher-density pinout of the MIPI connectors means that an adapter is required to connect our own cameras and displays, and third-party products, to Raspberry Pi 5.

To support existing camera and display owners, we are offering FPC camera and display cables, which convert from the higher-density format (now referred to as “mini”) to the older lower-density format (now referred to as “standard”). These cables are available in 200mm, 300mm, and 500mm lengths, priced at $1, $2, and $3 respectively.

Camera Module 3, the High-Quality Camera, the Global Shutter Camera, and the Touchscreen Display will all ship with both a standard-to-standard and a 200mm mini-to-standard cable.

d) PoE+ HAT

From early 2024, we will be offering a new PoE+ HAT. This supports the new location for the four-pin PoE header, and has an L-shaped form factor which allows it to sit inside the Raspberry Pi 5 case without interfering mechanically or disrupting airflow.



Prototype PoE+ HAT. We don’t know yet what the production version will look like, but we do know that it won’t look like this. The new PoE+ HAT integrates a planar transformer into the PCB layout, and utilises an optimised flyback converter architecture to sustain high efficiency across the whole zero to 25W range of output powers.

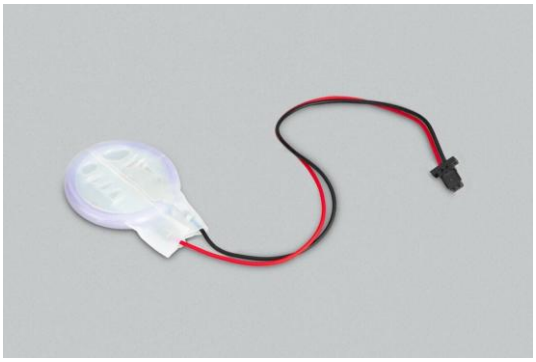
e) M.2 HATs

One of the most exciting additions to the Raspberry Pi 5 feature set is the single-lane PCI Express 2.0 interface. Intended to support fast peripherals, it is exposed on a 16-pin, 0.5mm pitch FPC connector on the left-hand side of the board.

From early 2024, we will be offering a pair of mechanical adapter boards which convert between this connector and a subset of the M.2 standard, allowing users to attach NVMe SSDs and other M.2-format accessories. The first, which conforms to the standard HAT form factor, is intended for mounting larger devices. The second, which shares the L-shaped form factor of the new PoE+ HAT, supports mounting 2230- and 2242-format devices inside the Raspberry Pi 5 case.

Prototype M.2 HAT. Final hardware will not look like this.

f) RTC battery



We have sourced a Panasonic lithium manganese rechargeable coin cell, with a pre-fitted two-pin JST plug and an adhesive mounting pad. This is priced at $5, and is suitable for powering the Raspberry Pi 5 real-time clock (RTC) when the main power supply is disconnected

g) Case

Last, but very much not least, the updated case for Raspberry Pi 5, priced at $10, builds on the aesthetic of its Raspberry Pi 4 predecessor, but adds a host of new usability and thermal-management features.

An integrated 2.79 (max) CFM fan, with fluid dynamic bearings selected for low noise and an extended operating lifetime, connects to the four-pin JST connector on Raspberry Pi 5 to provide

temperature-controlled cooling. Air is drawn in through a 360-degree slot under the lid, blown over a heatsink attached to the BCM2712 AP, and exhausted through connector apertures and vents in the base.

We've lengthened the case, and tweaked the retention features, to make it possible to insert the Raspberry Pi 5 board without removing the SD card. And by removing the top of the case, it is now possible to stack multiple cases, as well as to mount HATs on top of the fan, using spacers and GPIO header extensions.

Like all our plastic products, the new case is manufactured by our friends at T-Zero, in the West Midlands, UK.

. Overclocking computer systems is a fun way to extract some free performance, or at least see how far you can push the hardware before you run into practical limitations. The newly released Raspberry Pi 5 with BCM2712 SoC is no exception here, with Tom's Hardware having a go at seeing how far both the CPU and GPU in the SoC can be pushed. The BCM2712's quad Cortex-A76 CPU is normally clocked at 2.4 GHz and the VideoCore VII GPU at 800 MHz. By modifying some settings in the `/boot/config.txt` configuration file these values can be adjusted.
In order to verify that an overclock was stable, the Stressberry application was used, which fully loads the CPU cores. Here something like a combination of stress-ng and glxgears could also be used, to stress both the CPU and GPU. With the official actively cooled heatsink the CPU reached a temperature of 74°C with a whole board power usage of about 10 Watts. At idle this dropped to 3 Watts at 46°C. At these speeds, the multiple Raspberry Pi 5 units OCed by Tom's Hardware were mostly stable, though one of the team's boards experienced a few crashes. This suggests that this level of OCing could still be subject to luck of the draw, and long-term stability would have to be investigated as well.

As for the practical use cases of OCing your Raspberry Pi 5, benchmarks showed a marked uplift in compression and Sysbench benchmark scores, but OCing the GPU had no real positive impact on YouTube or 3D performance, leading even to a massive increase in dropped frames with video playback. This probably means that increasing the CPU clock may be beneficial, but OCing the GPU could be futile without also OCing the RAM frequency, if at all possible.

Realistically, the Raspberry Pi SoCs never were speed monsters, with even the Raspberry Pi 4B's SoC being beaten handily in 2020 by a budget dual-core Intel CPU. The current Intel Alder-Lake-N-based N100 SoC has a 6 Watt TDP and boosts up to 3.4 GHz while its Xe-LP-based iGPU (with AV1 decoding support) makes for a decent gaming experience within a ~16 Watt power envelope. Clearly, any OCing of the Raspberry Pi boards is more for the challenge of it, but then so is running the latest Intel CPU at 10 GHz with liquid nitrogen cooling.

Raspberry Pi Beginner's Guide, 5th Edition

Sporting a brand-new look and feel, and priced at RRP £19.99 ($24.99), this new edition of our bestselling Raspberry Pi Beginner's Guide is the definitive manual for Raspberry Pi computers and accessories. It has been comprehensively updated to cover Raspberry Pi 5, and the upcoming release of Raspberry Pi OS based on Debian Bookworm.

A newer, better Raspberry Pi OS

In parallel with the final stages of the Raspberry Pi 5 programme, our software team has been busy developing a new version of Raspberry Pi OS, the official first-party operating system for Raspberry Pi devices. This is based on the most recent release of Debian (and its derivative Raspbian), codenamed "Bookworm", and incorporates numerous enhancements, notably the transition from X11 to the Wayfire Wayland compositor on Raspberry Pi 4 and 5.

Raspberry Pi OS will launch in mid-October, and will be the sole supported first-party operating system for Raspberry Pi 5. Keep checking back here: we'll be telling you some more about the new OS, and you'll be able to download it shortly before Raspberry Pi 5 arrives on the shelves in late October.

References

1) https://www.raspberrypi.com/news/introducing-raspberry-pi-5/
2) https://kitronik.co.uk/blogs/resources/raspberry-pi-5-launch-today
3) https://hackaday.com/2023/10/01/overclocking-raspberry-pi-5s-soc-to-3-ghz-and-1-ghz-gpu/